The influence of sensory and behavioral factors on whole grain bread consumption among a convenience sample of adults

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Sara A. Sjoberg

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Leonard Marquart, PhD, RD, Advisor

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Abstract

Substantial research has shown that whole grain foods are associated with reducing the risk of coronary heart disease, type 2 diabetes, and obesity. However, Americans are consuming far below the recommended 3 servings of whole grains per day. Several barriers to consuming whole grains include unfamiliarity with the health benefits of whole grain foods, inability to identify whole grain foods, limited availability, preparation time and costs. Many studies have identified factors that influence whole grain food consumption; however there is little research that focuses on examining factors that influence consumption of a specific whole grain food such as bread. The fact that yeast breads are a major source of whole grains consumed by Americans and consumption of whole grains is low indicates a need to examine factors that influence whole grain bread consumption. A simple substitution of whole grain bread for refined grain bread could result in a significant increase in whole grain intake. In addition to behavioral factors influencing whole grain consumption, sensory factors (taste, color and texture) have been cited as being influential. Some sensory characteristics of whole grain bread, such as bitterness, may be preventing consumption of whole grain bread by some consumers. While many studies described the sensory quality of breads using various ingredients, processing and shelf-life conditions, the breads that were evaluated were made in the laboratory. There is no published research on the sensory quality of American commercial whole grain breads that are available to the consumer. Perception of sensory quality of foods differs among people such as the ability to detect the bitterness of whole grain bread. The differences could be dependent upon the ability to detect a bitter tasting compound 6-*n*-propylthiouracil (PROP). There is little research that examined the ability to detect PROP and liking of whole grain breads. Examining PROP intensity ratings and liking differences among whole grain breads may provide reasons why some people like whole grain breads and consume whole grain breads. Examining both sensory and behavioral factors will give a comprehensive explanation for liking and consumption of whole grain breads. Comparing the sensory characteristics of whole grain breads to the consumer liking of whole grain breads will allow for an understanding of which sensory attributes contribute to consumer acceptability.

This current research study included four phases that were interrelated and included both quantitative and qualitative methodologies. In phase 1, through the use of descriptive analysis, a lexicon was developed and used to describe the taste, flavor, aroma, appearance, aftertaste and oral texture of 100% whole grain commercial breads. A convenience sample of nine University students received 20 hours of training to develop the lexicon. Multivariate principal component analysis was used to reduce the set of sensory attributes that described the breads and to determine five breads that offered the greatest diversity in sensory qualities for use in a subsequent bread liking study.

Phase 2, part 1 included development and testing of a questionnaire associated with consumption of whole grain bread. The questionnaire, which was based upon the theory of planned behavior, assessed psychosocial beliefs related to whole grain bread consumption. Subjects also provided their whole grain versus refined grain bread preference, provided a bread bag of the bread typically consumed and completed a food frequency questionnaire (FFQ) that measured bread intake. The theory-based questionnaire and FFQ were tested and re-tested with 30 grocery store consumers to develop a reliable questionnaire.

In phase 2, part 2 the theory-based questionnaire was used to determine factors that influence whole grain bread consumption among 270 bread consumers that were recruited at a local grocery store. Sensory factors (overall bread liking, whole grain versus refined grain bread preference, and PROP rating), usual whole grain bread consumption pattern, exercise frequency and demographics were added to the theoretical model to examine if these variables increased the predictive power of the model for intention to consume whole grain breads and whole grain bread intake.

The objectives of phase 3 were to examine if there were differences in liking ratings among five commercial whole grain breads and if liking ratings were influenced by different consumer groups (whole grain versus refined grain bread preference, type of bread bag returned and PROP taster groups). In addition, cluster analysis was used to examine if there were differences in liking of breads, psychosocial beliefs, and whole grain bread intake for each cluster based on centered overall liking ratings of the breads.

The secondary objective of phase 3 was to determine which descriptive analysis sensory attributes had an effect on bread consumer liking ratings.

Results are reported as follows for each phase of this project. In phase 1 descriptive analysis was used to characterize 12 commercial whole grain breads. Use of multivariate PCA reduced the number of attributes that described the breads and principal components one to five explained 76% of the total variance. Visual assessment of the score plot of the first two principal components showed that Cub Foods, Country Hearth, Natural Ovens, Pepperidge Farms, and Sara Lee breads were representative of the range of different breads, so these were chosen to be used in a subsequent bread liking study.

Next, in phase 2 part 1 focus groups were conducted to develop a questionnaire based on the TPB that assessed predictors of intention to consume whole grain bread and whole grain bread intake. Theoretical statements within the questionnaire included 11 attitudinal beliefs, six normative beliefs, 16 control beliefs and two intentional statements.

For phase 2 part 2 the majority of consumers that completed the TPB questionnaire and FFQ were highly educated, white women. The mean daily whole grain bread intake was 1.3 servings. Liking, whole grain versus refined grain bread preference, and usual whole grain bread consumption pattern were significant predictors of intention to consume whole grain bread and significantly increased the variance explained by the model compared to the standard model. Intention, whole grain versus refined grain bread preference, and usual whole grain bread consumption pattern were significant predictors of whole grain bread intake and significantly increased the variance explained by the model.

Results from phase 3 (bread liking study) showed that Cub Foods and Country Hearth breads were most liked and Natural Ovens bread was least liked. Consumers' characteristics (whole grain versus refined grain bread preference, type of bread bag returned, and PROP taster status) had no effect on liking ratings. Using cluster analysis, three cluster groupings were determined based on centered overall liking ratings. Attitudes and usual whole grain bread consumption pattern were significantly different between each clustered group.

When comparing descriptive analysis sensory attributes and liking ratings, several sensory attributes had a significant effect on bread liking ratings. Bitter taste and flavor of the crust had a significant effect on flavor liking of the breads. Along with Sara Lee bread, the least liked bread (Natural Ovens bread) was scored highest for bitter taste and flavor and supports the hypothesis that the least liked bread would be the most bitter. Unexpectedly the effect of saltiness (taste, flavor and aftertaste) was significant on liking ratings and flavor and overall liking was significantly greater for the Cub Foods bread compared to the other four whole grain breads. This result may explain why this particular whole grain bread was liked the most.

Overall the behavioral and sensory studies provide a more comprehensive investigation of factors that influence intention and behavior related to whole grain bread consumption. Consumption of whole grain bread can be dependent upon one’s bread preference, liking of bread, the length of time consuming whole grain bread and whether one has control over their behavior related to consuming whole grain breads. Most of these factors are dependent upon whether the whole grain bread is appealing which is dependent upon many sensory characteristics of whole grain breads. Consumption of whole grain bread is multifaceted.

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Chapter 1. Introduction

Sara A. Sjoberg, MS

As described in the review of literature (Chapter 2), considerable evidence supports the health benefits associated with intake of whole grain foods; however, dietary intake of whole grains remains far below recommended levels for U.S. consumers. Yeast breads are commonly consumed grain foods that may serve as a vehicle to increase whole grain intake among consumers by substituting whole grain for refined grain flour. There is little research addressing behavioral and sensory barriers related to consuming a specific whole grain food product, such as bread. Only one study used a theoretical model to determine psychosocial predictors of consumption of a specific whole grain food (whole meal bread). However there are no studies that used the Theory of Planned Behavior (TPB) to measure the extent that TPB constructs predicted intention to consume whole grain bread and whole grain bread intake along with the additive effect of additional sensory variables. No studies have examined the liking differences of commercial whole grain breads and if consumers' sensory characteristics are related to liking ratings. There are many studies that have characterized breads with the use of descriptive analysis; however, there are no published studies that used descriptive analysis to characterize commercial whole grain breads. Determining which sensory attributes have an effect on liking will provide additional information about sensory attributes that influence the liking of these whole grain breads. Chapter 4 includes the descriptive analysis study where 12 commercial whole grain breads were characterized. Development of the theory based questionnaire and food frequency questions related to whole grain bread intake is described in Chapter 5 part 1. Use of the TPB and the expanded model with liking ratings of breads, whole grain versus refined grain bread preference, usual whole grain bread consumption pattern and demographic characteristics are also described in chapter 5 part 2. Differences in liking among the whole grain breads and by consumers' sensory characteristics, and the effect of sensory attributes on liking ratings of five commercial whole grain breads are further explained in chapter 6.

Chapter 2. Literature review

Sara A. Sjoberg, MS

Literature Review

Definition of Whole Grains

Whole grains are defined as an ingredient or as a food product. According to the American Association of Cereal Chemists (AACC), a *whole grain ingredient* is defined as "the intact, ground, cracked or flaked caryopsis, whose anatomical components, the starchy endosperm, germ and bran, are present in substantially the same relative proportions as they exist in the intact caryopsis" (AACC 2000). A more consumer friendly whole grain ingredient definition has been adopted by the Whole Grains Council: "Whole grains or foods made from them contain all the essential parts and naturally-occurring nutrients of the entire grain seed" (Whole Grains Council 2005). A *whole grain* has also been defined as consisting of the "intact, ground, cracked or flaked fruit of the grains whose principal components—the starchy endosperm, germ and bran are present in the same relative proportions as they exist in the intact grain" (USDA-FDA 2006).

A *whole grain food* can be labeled with a health claim if the food items contain at least 51% whole grain per reference amount and contain approximately 1.7 grams of fiber (FDA 1999). This whole grain health claim was approved by the FDA in July 1999. In addition, the U.S. Department of Agriculture and Agricultural Research Service (1997) claimed that one serving of a whole grain food contains 16 grams of whole grain flour, based on Pyramid Servings data. A universal and concrete definition of a whole grain food is yet to be determined and remains a point of confusion for consumers and health professionals. Establishment of a whole grain food definition may increase awareness and enhance communication about whole grain foods which may in turn lead to an increase in the availability, selection and dietary intake by consumers.

Whole grains and health

Whole grains are rich sources of biologically active constituents that may contribute to reduced risk for chronic disease. The three primary components of a whole grain include: the bran (B-vitamins, minerals, dietary fiber, protein and phyto-chemicals); the endosperm (carbohydrate, protein and small quantities of vitamins and minerals); and the germ (B-vitamins, vitamin E, minerals, protein and phyto-chemicals). Other important constituents found in whole grains include complex carbohydrates, resistant starch, oligosaccharides, omega-3 fatty acids, phytic acid, phenolic acids, sphingolipids, phytates, lignans, phytoesterols, tocotrienol, tocopherols and tannins (Miller et al. 2000; Slavin 2004; Pascoe and Fulcher 2007). Current evidence suggests that grains and their constituents work as a single component, additively and/or synergistically to reduce the risk of chronic diseases (Jacobs and Steffen 2003). The individual constituents in a whole grain act synergistically when consumed. Studies have shown that when whole grain foods, which contains all parts of the grain, are consumed the risk of chronic disease is reduced. Numerous epidemiological studies provide support for the efficacy of whole grain foods in reducing risk of weight gain, obesity, heart disease, and type 2 diabetes.

Obesity

According to the National Health and Examination Survey (NHANES) 2007-2008, 68% of U.S. adults are overweight and obese (body mass index (BMI) > 25) (Flegal et al. 2010). Although the causes of obesity and over-weight are multi-factorial, epidemiological studies indicate that whole grains are associated with reduced risk of obesity and less weight gain (Liu et al. 2003; Koh-Banerjee et al. 2004; Lutsey et al. 2007; Rose et al. 2007; Good et al. 2008; Harland and Garton 2008; McKeown et al. 2009; Thane et al. 2009; Van de Vijver et al. 2009; Brownlee et al. 2010; McKeown et al. 2010).

In a prospective cohort study, dietary intake was assessed among 74,091 US female nurses, aged 38-63 years, free of known cancer, cardiovascular disease, and diabetes at baseline (Liu et al. 2003). Dietary intakes were assessed in 1984, 1986, 1990, and 1994 with validated food-frequency questionnaires (FFQ) and were followed from 1984 to 1996. High whole grain consumption was associated with less weight gain (mean weight gain of 1.58 kg in 2-4 y in the lowest quintile and 1.07 kg in the highest quintile; *P* for trend < 0.0001). After adjusting for covariates, subjects whole consumer more refined grains gained more weight (from 0.99 kg to 1.65 kg; P for trend < 0.0001).

Koh-Banerjee et al. (2004) conducted an 8-year prospective cohort study to examine healthy men (n = 27,082) aged 40-75 years from the Health Professional Follow-up Study (HPFS). Whole grain, bran and cereal fiber intakes were measured by a FFQ to examine the association between whole grain intake and 8-year weight gain among these men. There was an inverse association between whole grain intake and weight gain (P<0.0001). For every increase in whole grain (40 grams per day) there was a reduction in weight (0.49 kg). The addition of bran or cereal fiber along with whole grains was associated with less weight gain.

Two smaller cross-sectional studies investigated the effect of whole grains on BMI (Lutsey et al. 2007; Rose et al. 2007). Lutsey et al. (2007) examined the association of obesity with whole grain intake using baseline data from the Multi-Ethnic Study of Atherosclerosis (MESA). Men and women (n = 5,496) between the ages of 45 and 84 years completed a 127-item FFQ that included measurement of whole grain intake (cereal, oatmeal, dark bread, bran muffins, brown or wild rice). Although whole grain intake was inversely associated with BMI, the mean difference between the extreme quintiles of whole grain intake was 0.6 kg/m^2 (P<0.0001). Rose et al. (2007) investigated the association of whole grain intake (whole wheat flour, whole oat flour, whole grain corn, and brown rice listed as the first ingredient on the food label) and BMI among 159 college students who consumed on average 0.7 daily servings of whole grains as part of 5.4 total grain servings per day. Consumption of whole grain foods was significantly higher (P<0.05) in the normal weight students compared to students who were overweight or obese. Estimation whole grain intake for both of these cross-sectional studies may have been overestimated due to the use of a single FFQ (Lutsey et al. 2007) and confusion between refined and whole grain food products (Rose et al. 2007).

Good et al. (2008) used dietary intake data from the NHANES (1999-2000) to examine the association between whole grain intake and body mass index (BMI) in a sample of adult American women (n = 2,092). Women who consumed at least one serving of whole grain per day had a significantly lower mean BMI and waist circumference than women with no whole grain intake (p<0.05). An inverse relationship between BMI and whole grain consumption was observed (p = 0.004) after adjusting for covariates (age, energy intake, dietary fiber and alcohol intake). This study provides further evidence that high whole grain consumption is inversely associated with healthy body weight in adult women.

A recent study calculated the whole grain content of foods based on recipes and manufacturer ingredient lists and applied it to a survey among British adults (Thane et al. 2009). The data were based on the U.K. National Diet and Nutrition Survey of Adults from 1986-1987 and 2000-2001. Whole grain intake was determined by a 7-day food record and included foods that contained >10% whole grains. Whole grain intake was inversely associated with BMI for obese men according to the 1986-1987 data independent of covariates (socio-demographic, lifestyle factors and season). However, no association was found between whole grain intake and BMI for obese women. For both genders whole grain intake was not associated with body weight, BMI, or waist circumference according to the 2000-2001 survey.

A cross-sectional study also found that whole grain intake was inversely associated with BMI and the risk of obesity and being overweight among men (n = 2,078) and women (n = 2,159) aged 55-69 years (Van de Vijver et al. 2009). The risk of being obese for men and women was 10% and 4% lower compared to normal weight men and women for each additional gram of dry grain consumed.

Brownlee et al. (2010) conducted a controlled dietary intervention to study the effects of whole grain intake in the diet of non-whole grain consumers. Subjects (n = 316) were randomly assigned to one of three dietary groups: 1) typical diet-no diet change (control); 2) 60g whole grains per day for 16 weeks; and 3) 60g whole grains per day for eight weeks and 120g whole grains per day for eight weeks. There were no significant differences in BMI or percent body fat between the three dietary groups after 16 weeks.

A review (Harland and Garton 2008) and two cross-sectional studies examined the effect of whole grains on abdominal fat distribution (McKeown et al. 2009; McKeown et al. 2010). Harland and Garton (2008) conducted a systemic review and analysis of observational studies on the effect of whole grain intake on body weight and adiposity. The review of 15 studies included data from 119,829 men and women 13 years and over and showed that a higher intake of whole grains was related to lower BMI and central adiposity (waist to hip ratio). Subjects who were among the 20 different treatment groups and who consumed more whole grains had a healthier lifestyle (frequent exercise, lower fat and higher fiber intake).

McKeown et al. (2009) examined the association between grain intake (whole and refined) and body fat distribution among older adults between 60 and 80 years of age (177 men and 257 women). Subjects completed a FFQ that measured whole grain intake (cooked and cold breakfast cereal, dark bread, brown rice, popcorn, and other grains). Percent fat mass (body and trunk) was measured by whole body dual-energy x-ray absorptiometry. Whole grain intake was inversely associated with percentage body and trunk fat mass and BMI. Subjects who consumed more cereal fiber from whole grain foods had a lower total percent body fat and percent trunk fat mass.

A recent study examined the influence of whole grain intake on abdominal fat distribution (McKeown et al. 2010). This cross-sectional study examined associations between whole grain and refined grain intakes, waist circumference size, and abdominal subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT) volumes among 2,834 Framingham Heart Study subjects. After adjustment for covariates (age, sex, current smoking status, total energy and alcohol intake) and comparing the lowest to the highest quintile category, whole grain intake was inversely associated with SAT and VAT volumes. The VAT volume was 10% lower in subjects consuming greater than three servings of whole grains per day compared with subjects consuming no whole grains. Higher refined grain intake was associated with higher SAT and VAT volumes. This was the first study to examine a potential mechanism that demonstrates the association between whole grain intake and body fat distribution. Subjects consuming $\geq$3 servings of whole grains per day significantly lowered SAT and VAT compared to subjects rarely consuming whole grain foods.

Although numerous epidemiological studies have examined associations between whole grain intake, obesity and less weight gain, and abdominal fat distribution, few clinical studies have assessed whether the inclusion of whole grains while on a hypocaloric diet promotes weight loss or prevents weight gain. A randomized clinical study was conducted to assess diet quality on three weight-management programs: 1) exercise only (control); 2) hypocaloric diet plus exercise; or 3) hypocaloric diet with fiber-rich whole grain cereals plus exercise (Melanson et al. 2006). Subjects included 134 nonsmoking, sedentary overweight and obese adults with an average BMI of 31 kg/m^2

who participated in the study for 12 weeks during phase one (weekly counseling) and for another 12 weeks during phase 2 (monitoring only). Results showed that the hypocaloric diet with fiber-rich whole-grain cereals plus exercise decreased energy intake more than exercise only (P = 0.032). However, weight loss was similar for subjects on the hypocaloric diet with fiber-rich whole-grain cereals plus exercise and the hypocaloric diet plus exercise. The authors concluded that a hypocaloric whole grain cereal diet enhanced dietary quality (lower fat intake, higher fiber, magnesium and vitamin B-6) compared to the hypocaloric diet without whole grain cereals.

A more recent clinical study examined the effect of a hypocaloric diet (-500 kcal per day) and whole grains, on weight loss among obese adults with metabolic syndrome (Katcher et al. 2008). Subjects (25 males / 25 females) were randomly assigned for 12-weeks to a hypocaloric diet with dietary advice to obtain all of their grain servings from whole grains or the hypocaloric diet with dietary advice to avoid whole-grain foods. Both hypocaloric diets (whole grains or refined grain) caused moderate weight loss. However, subjects in the whole grain food group lost a greater percentage of body fat in the abdominal region.

Limitations of some studies that investigated whole grain intake and body weight relied upon self-reported body weights. In addition, there are no large clinical/feeding studies that further elucidated the impact of whole grain foods on body weight or composition.

Whole grains and obesity - mechanisms

The relationship between whole grain intake and lower body weight may be attributed to several innate characteristics of these nutrient-rich foods which provide more volume, higher fiber and lower energy density. It is hypothesized that whole grains may enhance satiety and promote satiation with a lower overall energy intake via relatively unexplored potential mechanisms. The mechanisms by which whole grains may support weight management include increased insulin sensitivity and lower insulin demand (Koh-Banerjee and Rimm 2003; Slavin 2004); prolonged gastric emptying by viscous soluble fibers, such as oats and barley (Leclere et al. 1994; Tomlin, 1995; Rigaud et al. 1998); and secretion of gut hormones such as cholecystokinin, which increase in concentration after consumption of high-fiber foods, and correlate with greater feelings of satiety in women (Bourdon et al. 1999; Burton-Freeman, Davis, and Schneeman 2002). Although preliminary evidence supports a role for whole grain intake and healthy body weight, additional clinical and experimental studies are needed to directly link consumption of whole grains to changes in weight over time and to further elucidate the mechanisms associated with weight management. Being overweight or obese also contributes to the risk for other diseases such as heart disease. Therefore, consuming whole grains can be multifaceted in relation to reducing the risk of chronic diseases.

Heart disease

Many epidemiological and cohort studies have shown that whole grain intake reduces the risk of CVD (Seal and Brownlee 2010). A number of observational studies have shown that consumption of whole grains is associated with reduced risk of heart disease (Jensen et al., 2004; Djousse and Gaziano 2007; Mellen et al. 2008). Jensen et al. (2004) evaluated the association between whole grain intake and incidence of coronary heart disease (CHD) among 42,850 males aged 40-75 years free of cardiovascular disease (CVD), diabetes and cancer at baseline. After 14 years and adjusting for CVD, the hazard ratio was 0.82 ($p = 0.01$) for men in the top quintile for whole grain consumption in comparison to men in the lowest quintile for whole grain consumption. Subjects reduced their risk of CHD by 6% for each 20 gram increase in whole grain intake. Whole grains and bran were protective against CVD while the addition of germ was not protective.

A 19.6 year prospective study examined the risk of heart failure among 21,376 male subjects from the Physicians' Health Study I (Djousse and Gaziano 2007). After adjusting for age, smoking history, alcohol consumption, vegetable intake, multi-vitamin use, exercise, history of atrial fibrillation, valvular heart disease and atrial fibrillation, the hazard ratios for heart failure were 1 for 0 servings of whole grain cereal per week; 0.92 for up to 1 serving per week, 0.79 for 2-6 servings, and 0.71 for 7 or more servings per week ($P<0.001$). There was an inverse association between intake of whole grain cereals and the risk of heart failure ($P<0.001$), however there was no significant association between the intake of refined cereals and heart failure ($P=0.70$). A higher intake of whole grain breakfast cereals was associated with reduced risk of heart failure.

Mellen et al. (2008) examined seven prospective cohort studies that measured whole grain intake along with clinical cardiovascular outcomes. After adjusting for cardiovascular risk factors, greater whole grain intake (pooled average 2.5 servings per day vs. 0.2 servings per day) was associated with a 21% lower risk of cardiovascular disease events [OR 0.79 (95% CI: 0.73–0.85)]. There was no association between intake of refined grains and incident CVD events [1.07 (0.94–1.22)].

A cross-sectional study examined the association of whole grain, bran and germ intake with the risk of ischemic heart disease among 938 healthy men and women in a sub-sample of the Health Professionals Follow-up study and Nurses Health Study II (Jensen et al. 2006). Whole grain intake was inversely associated with TC (P=0.02) and HDL-C (P=0.05). Subjects in the highest quintile had 3%, 5%, and 2% lower mean values for TC, HDL-C and LDL-C compared to subjects in the lowest quintile. Whole grain intake was not associated with markers of inflammation (C-reactive protein, fibrinogen and interleukin 6).

Several intervention studies were conducted to investigate the effect of whole grains intake on biomarkers of cardiovascular disease (Andersson et al. 2007; Katcher et al. 2008; Brownlee et al. 2010). Katcher et al. (2008) investigated the effect of a hypocaloric diet (either refined or whole grain products) on CVD risk factors (C-reactive protein, total cholesterol, LDL and HDL cholesterol) among obese adults (25 females, 25 males) with metabolic syndrome. Both hypocaloric diets reduced CVD risk factors. Subjects that consumed the whole grain hypocaloric diet had a greater reduction in C-reactive protein and abdominal body fat compared to refined grain consumers.

Two intervention studies (Andersson et al. 2007; Brownlee et al. 2010) found that whole grain intake did not reduce several risk factors (biomarkers) for CVD events. Andersson et al. (2007) compared the effects of a whole grain-rich diet versus a refined grains diet on markers of lipid peroxidation and inflammation. The researchers used a randomized crossover study design, as the healthy, moderately overweight subjects (22 women and 8 men) were given either whole-grain or refined-grain products (3 bread slices, 2 crisp bread slices, 1 portion muesli, and 1 portion pasta) to consume with their habitual daily diet during the two 6-week periods. Results showed that whole-grain products did not affect markers of lipid peroxidation (8-iso-PGF (2alpha) in urine), inflammation (IL-6 and C-reactive protein in plasma), blood pressure, or serum lipid concentrations. The lack of effect could be dependent upon the simultaneous lack of effect on insulin sensitivity, the length of the intervention and the use of milled flour food products in the form of bread and pasta.

A recent controlled dietary intervention study examined the effects of substituting whole grain for refined grains in the diet of non-whole grain consumers on markers of CVD risk factors (Brownlee et al. 2010). Subjects (n = 316) were randomly assigned to consume one of three diets: 1) typical diet- no dietary change (control); 2) 60g whole grains per day for 16 weeks; or 3) 60g whole grains for eight weeks, and then 120g whole grains per day for eight weeks. Although the intervention groups were compliant with the increased whole grain diet, there was no significant difference in CVD markers (BMI, percentage body fat, waist circumference, fasting plasma lipid profile, glucose and insulin, and indicators of inflammation, coagulation, and endothelial function) among the three dietary groups. No significant differences in markers of CVD between groups may be a result of the intervention dietary group including whole grains as an addition rather than a dietary substitution. The researchers stated that some of subjects may not have habitually consumed refined grain products, which explains the lack of substitution of whole grain for refined grain food products.

There are few studies that examined the relation between whole grain intake and progression of coronary artery diseases, such as atherosclerosis. Erkkila et al. (2005) conducted a small cohort study that examined the association between whole grain and cereal fiber intake among postmenopausal women (n = 229) with established coronary artery disease (CAD). Women who consumed more than six servings of whole grains per week reduced the decline in minimum coronary artery diameter, after adjustment for age, cardiovascular risk factors, dietary fat, cholesterol, and alcohol intake compared to women consuming less whole grains. The results suggest that consumption of whole-grains is inversely associated with progression of atherosclerosis in postmenopausal women with established CAD. Another cohort study examined the effects of whole grain intake (dark breads, cooked cereals, and high-fiber cereals) on carotid artery atherosclerosis among ethnically diverse individuals (n = 1,178) using a semi-quantitative FFQ (Mellen et al. 2007). Atherosclerosis was defined by the common carotid artery intimal medial thickness (CCA IMT) and IMT progression is associated with CVD events. The mean whole grain intake was 0.79 servings per day. Consumption of whole grain was inversely associated with the CCA IMT progression (P = 0.005).

The development of cardiovascular disease may be attributable to changes in blood pressure. Wang et al. (2007) conducted a prospective cohort study among 28,926 women 45 years and older to determine if baseline grain consumption (whole and refined) was associated with hypertension during a 10-year follow-up. Compared with subjects who consumed less than 0.5 servings of whole grains per day, the relative risk of hypertension and 95% CIs was 0.93 (0.87, 1.00) for subjects consuming less than 1 serving of whole grains per day; 0.93 (0.87, 0.99) for 1-2 serving per day, 0.92 (0.85, 0.99) for 2-4 servings per day, and 0.77 (0.66, 0.89) for four or more servings per day ($P<0.001$). Intake of refined grains was not related to the risk of hypertension. The relative risk of hypertension decreased with increasing intake of whole grains, which may help prevent development of hypertension and its cardiovascular complications. After adjustment for fiber the inverse association between whole grain intake and risk of hypertension was weakened and suggests that the fibrous parts of the whole grain may help protect against hypertension.

The association of whole grain intake and incidence of hypertension was examined among 51,529 male health professionals in the Health Professional follow-up study (Flint et al. 2009). When comparing subjects in the highest quintile to subjects in the lowest quintile, whole grain intake was inversely related to the incidence of hypertension with a relative risk of 0.81 ($p<0.0001$) and total bran intake was also inversely related to the incidence of hypertension with a relative risk of 0.85 ($p = 0.002$).

Two clinical studies also found that whole grains are associated with lower blood pressure (Behall et al. 2006; Tighe et al. 2010). Behall et al. (2006) examined the effects of a whole grain diet on blood pressure in seven men, nine pre-menopausal, and nine post-menopausal women who were hypercholesterolemic. For the first two weeks non-hypertensive subjects consumed a controlled Step I diet followed by five weeks on a diet that replaced 20% of energy with whole wheat/brown rice, barley, or half wheat-rice/half barley. Systolic pressure was reduced after consuming the whole wheat/brown rice and half wheat-rice/half barley. Consumption of the whole-grain diets reduced the diastolic and mean arterial pressures.

A similar study examined the effects of consuming three daily portions of whole-grain foods (wheat or a mixture of wheat and oats) on cardiovascular disease risk factors (lipid and inflammatory marker concentration, and blood pressure) among relatively high-risk individuals (n = 206) (Tighe et al. 2010). Subjects consumed a refined grain diet for 4 weeks, and then for 12 weeks consumed the refined grain diet, the wheat diet or the wheat and oats diet. The systolic blood pressure and pulse pressure were significantly reduced by 6 and 3 mm Hg for the whole-grain food diet compared to the refined grain diet (control group). However, there were no changes in the systemic markers of cardiovascular disease risk, such as lipids (triglycerides, HDL and apolipoprotein A1 concentration) and inflammatory markers (high-sensitivity C-reactive protein, and interleukin-6).

Consumption of beta-glucan, a constituent of whole grain oats and barley, can reduce cholesterol levels in hyperlipidemic subjects. Behall et al. (2004) examined the effects of beta-glucan on lipid levels. For 5 weeks subjects with mild hypercholesterolemia (9 postmenopausal and 9 premenopausal women, and 7 men) consumed whole-grain foods containing 0, 3, or 6 grams of beta-glucan per day from barley as part of a Step 1 diet. Total and LDL cholesterols in both men and women were lowered among those who consumed beta-glucan.

Keenan et al. (2007) found that TC and LDL-cholesterol were reduced when dyslipidaemic subjects (n = 155) consumed a diet with a dose of 3 grams or 5 grams of either high molecular weight (HMW) or low molecular weight (LMW) concentrated beta-glucan extract for 10 weeks. Another study found that total cholesterol and LDL-C were reduced from baseline, and LDL-C was reduced significantly more than in the control group (p = 0.03) when hypercholesterolemic men and women (n = 75) were fed 6 grams of concentrated oat β-glucan for 6 weeks (Queenan et al. 2007).

Shimizu et al. (2008) examined the effect of replacing rice with high-β-glucan barley on serum LDL-C, TC and visceral fat area among 44 hypercholesterolemic Japanese men (BMI>22 kg/m^2). For 12 weeks subjects were randomly assigned to consume rice (placebo group) or a mixture of rice and pearl barley with a high β-glucan content (7.0 g β-glucan per day) (intervention group). The high beta-glucan barley diet significantly reduced serum concentrations of LDL-C (P = 0.041) and TC (P = 0.037). In addition, there were significant differences between the intervention and placebo groups for visceral fat (P = 0.039), BMI (P = 0.015), and waist circumference (P = 0.011).

In contrast to the previously mentioned studies associated with beta-glucan, Biorklund et al. (2008) conducted a clinical trial to determine if a nutrient-balanced meal containing four grams of oat beta-glucan would lower TC and LDL-C. For 3 weeks all subjects consumed a daily ready-meal soup low in energy and fat and high in fiber and containing no oat beta-glucan. During the 5-week intervention, the 43 hyperlipidemic subjects were randomly assigned to either the control soup or a soup supplemented with beta-glucan. There were no significant differences in TC or LDL-C concentrations between the control and intervention groups. No differences between groups in the reduction of cholesterol could be a result of only administering the beta-glucan once per day and servings a healthy food (soup) to both the control and intervention groups.

Whole grains and heart disease - mechanisms

The effects of whole grain intake on the prevention of CVD are attributable to protective constituents that include magnesium, vitamin E, and phytonutrients (Slavin 2003). The protective effects of whole grains on systemic inflammation may be explained, in part, by improving CVD factors such as adiposity, dyslipidemia, and hypertension (Schulze et al. 2004; Jensen et al. 2006; Qi and Hu 2007; Katcher et al. 2008). It is well documented that blood cholesterol levels may be reduced via soluble fiber found in oats (Van Horn et al. 2001; Davy et al. 2002; Karmally et al. 2005; Queenan et al. 2007); by increasing intestinal viscocity (Gallaher et al. 1999; Naumann et al. 2006; Poppitt et al. 2007); fecal bile acid excretion (Lia et al. 1995); bile acid production (Marlett et al. 1994; Naumann et al. 2006; Ellegayrd et al. 2007); and LDL-C uptake from the blood (Anderson 1985). Cholesterol can also be reduced by beta-glucan rich soluble fibers found in barley (Newman et al. 1989a; Newman et al. 1989b), rye (Leinonen et al. 2000) and oats (Behall et al. 2006). In addition, it is difficult to fully understand the protective effects because of the various types and forms of whole grains. Potential mechanisms that contribute to the inverse relationship between whole grain intake and heart disease may also be mediated through the positive effects of whole grains on LDL-cholesterol (Slavin, Jacobs and Marquart 1997), vascular reactivity caused by lignans (Newman et al. 1989a, Mendelsohn and Karas 1999), coagulation and fibrinolysis (Marckmann et al. 1993; Pereira et al. 2000), insulin sensitivity (Pereira et al. 2002) and homocyteine levels (Liu et al. 1999). Further studies are needed to examine the effects of various types of whole grains on mechanisms related to heart disease. The role of whole grains in reducing the pathogenesis of heart disease is also related to the prevention of type 2 diabetes.

Type 2 diabetes

Type 2 diabetes is a major worldwide health epidemic (James et al. 2001; Wild et al. 2004) and preventative strategies are strongly needed. It has been proposed that type 2 diabetes risk could be reduced by the type of carbohydrate-rich food consumed such as whole grains (Van Dam et al. 2002). Prospective cohort and clinical studies, and epidemiological data indicate that whole grain intake is inversely associated with type 2 diabetes (McKeown et al. 2002; Montonenn et al. 2003; Jensen et al. 2006; Qi et al. 2006; Van Dam et al. 2006; De Munter et al. 2007; Schulze et al. 2007; Priebe et al. 2008; Brownlee et al. 2010; Hopping et al. 2010; Sun et al. 2010; Rosen, Ostman, and Bjork 2011).

Investigating the association between whole grain intake and the risk of type 2 diabetes is one research effort to explore potential dietary factors that may help contribute to the attempt to prevent this chronic disease. Montonenn et al. (2003) examined the effect of whole grain and fiber intake and the incidence of type 2 diabetes among a cohort of men (n = 2,286) and women (n = 2,030) who were initially free of diabetes. Consumption of whole grain was inversely associated with the risk of type 2 diabetes. The relative risk between high and low quartiles of whole grain consumption was 0.65 (95% CI: 0.36, 1.18; P = 0.02) after adjusting for covariates. Cereal fiber also was inversely associated with the risk of type 2 diabetes. The reduced risk of type 2 diabetes associated with whole grains may be attributed to the intake of cereal fiber.

In another prospective cohort study including 41,186 Black women, the hazard ratio of type 2 diabetes was 0.69 for dietary magnesium when comparing highest quintile of whole grain intake to the lowest quintile (Van Dam et al. 2006). This is supported by previous studies indicating that high intake of magnesium and whole grain reduced the risk of type 2 diabetes (McCarty 2005; Larsson and Wolk 2007; Kirii et al. 2010; Dong et al. 2011).

De Munter et al. (2007) evaluated prospective cohort studies (Nurses' Health Studies I and II (NHS)) to examine whole grain intake and risk of type 2 diabetes among 161,737 healthy women. The relative risk (RR) for subjects in the highest quintile of whole grain intake compared to subjects in the lowest quintile was 0.63 for NHSI and 0.68 for NHSII. Further adjustment for BMI resulted in a RR of 0.75 and 0.86. After adjustment for potential confounders and BMI, women consuming two-servings of whole grains per day reduced their risk of type 2 diabetes by 21%.

Priebe et al. (2008) assessed the associations between whole grain food intake and the incidence of type 2 diabetes among 11 cohort studies lasting longer than five years, and one randomized control trial that was longer than six weeks. Three of prospective studies that examined whole grain intake found that the risk of diabetes was reduced by 27-30% with higher whole grain intake. Two studies showed that higher intake of cereal fiber intake reduced the risk of developing of type 2 diabetes by 28-37%. Schulze et al. (2007) conducted a prospective cohort study to assess the incidence of diabetes over 11 years among 176,117 men and women in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Potsdam study. The researchers also conducted a meta-analysis of existing prospective studies in PubMed. A FFQ was used to measure dietary fiber and magnesium intake. In the EPIC prospective study, high cereal fiber consumption was associated with reduced risk of type 2 diabetes (RR = 0.72). The meta-analysis study also showed reduced risk of type 2 diabetes (RR = 0.67) with high cereal fiber intake.

Hopping et al. (2010) conducted a cohort study as a component of the Hawaii multiethnic cohort study. The subjects (n = 75,512) included Caucasian, Japanese Hawaiian and Native Hawaiians aged 45-75 years. Subjects completed a baseline FFQ and were observed at the 14-year follow-up. The risk of diabetes was reduced by 10% in men and women, especially among Caucasians and to a lesser extent for the Native Hawaiians, with a high intake of grain fiber.

Sun et al. (2010) conducted a prospective study to assess the associations between white or brown rice consumption and risk of type 2 diabetes among Health Professionals (39,765 men and 157,463 women) who participated in the Nurses' Health Study I and II. After adjustment for covariates, subjects consuming at least 2 servings of brown rice per week compared to subjects consuming less than one serving per month was related to lower risk of type 2 diabetes (pooled RR = 0.89 (95% CI, 0.81-0.97)). The pooled RR for white rice consumption was 1.17 (95% CI, 1.02-1.36). Replacing 50 grams white rice per day with brown rice was estimated to decrease risk of type 2 diabetes by 16%. Researchers also estimated that if the white rice was replaced by other whole grains, type 2 diabetes would decrease by 36%.

Several observational studies have shown that whole grains cause lower post-prandial insulin responses and can counteract the development of diabetes. McKeown et al. (2002) examined the association between whole grain and refined grain intake and type 2 diabetes in the Framingham Offspring Study cohort that consisted of 1,338 men and 1,603 women. There was a significant inverse association between whole grain intake and fasting insulin concentration, especially among the overweight participants. However, there was no significant association between refined grain intake and fasting insulin concentration.

Jensen et al. (2006) conducted a cross-sectional study to examine the influence of whole grain, bran and germ intakes on markers of glycemic control among 938 healthy men and women (sub-sample Health Professionals Follow-Up Study and Nurses' Health Study II). Whole grain intake was inversely associated with plasma insulin, hemoglobin A1-C, (c)-peptide and leptin. Subjects in the highest versus lowest quintile of whole grain intake had a 14% lower concentration of insulin which suggests lower risk of diabetes.

In a randomized dietary intervention, the effects of whole grains on markers of CVD risk were measured in subjects (n = 316) aged 18-65 years with a BMI >25kg/m^2 who previously consumed no whole grains (Brownlee et al. 2010). Subjects (n = 316) were assigned to consume 1) typical diet-no diet change (control); 2) 60g whole grains per day for 16 weeks; and 3) 60g whole grains for eight weeks and consume 120g whole grains per day for eight weeks. There were no differences in serum glucose or insulin levels for the whole grain diet versus the control diet.

In a recent randomized cross-over design, the effects of various rye breakfast products on postprandial insulin and satiety were examined (Rosen, Ostman and Bjork 2011). Factors measured included glucose, insulin, appetite regulating hormones and hydrogen excretion. Subjects (n = 10) with normal BMI randomly consumed the test and reference products on seven different occasions separated by one week. The foods included: four rye breads (endosperm rye bread; endosperm rye bread + lactic acid; whole grain rye bread; whole grain rye bread + lactic acid); boiled rye (RK) and wheat kernels (WK), with white wheat bread (WWB) as the reference. Insulin indices were lowered for all rye products and WK. Compared to the WWB and WK the RK product caused a higher glucose response which reduced the desire to eat before lunch. Consumption of the RK product resulted in a 16% reduction in energy intake at the lunch meal, a high prolonged blood glucose response and high hydrogen excretion. A high hydrogen excretion at 120-270 minutes was associated with a high glucose response and resulted in a lower energy intake at lunch. Rye products contributed to the regulation of glucose and appetite.

Several recent clinical studies investigated the relationship between whole grains and insulin sensitivity (Ostman et al. 2006; Poppitt et al. 2007; Rave et al. 2007). Ostman et al. (2006) evaluated the effects of low glycemic index (GI)/high dietary fiber (DF) or high GI/low DF bread products on glucose tolerance and insulin sensitivity among seven women with impaired glucose tolerance and a history of gestational diabetes. Subjects consumed either the low GI/high DF or high GI/low DF bread products during two consecutive 3-week periods with a 3-week washout period. The researchers concluded that consumption of a lower GI/high DF bread could help regulate insulin levels among women who are at risk of type 2 diabetes.

Poppitt et al. (2007) investigated the postprandial effects of an enriched barley β-glucan fiber product on blood glucose and insulin among 18 lean healthy men. The intervention included consumption of a 10 gram dose of a barley β-glucan fiber supplement for each of the following treatments: 1) high-carbohydrate (food control), 2) high-carbohydrate (food + fiber), 3) high-carbohydrate (drink control), and 4) high-carbohydrate (drink + fiber). All four treatments increased glucose and insulin responses. The β-glucan supplement in food form significantly reduced the glycemic and insulinemic responses ($p<0.05$) when compared to control. The increased gastro-intestinal viscosity that occurred with the food helped improve glucose control.

Rave et al. (2007) used a randomized two-way crossover design to determine if hypo-energetic diets improved insulin resistance among obese individuals with elevated fasting blood glucose. Subjects (n = 31) consumed two daily meals with 200 grams of either the whole grain reduced starch product (WG) derived from double-fermented wheat or a nutrient dense meal replacement product (MR) for four weeks, with a 2-week wash out period, followed by another 4-week treatment. Both treatment groups similarly reduced body weight, fasting blood glucose, total cholesterol, triaclyglycerol, and homeostasis model assessment insulin resistance (Homa-IR) scores. After adjusting for weight loss, the WG diet compared to the MR diet improved the fasting serum insulin ($P = 0.031$) and Homa-IR score ($P = 0.049$).

In summary, epidemiological and clinical studies found that whole grain intake reduces risk of diabetes. Additional randomized clinical trials are needed that focus on diets rich in whole grains in the prevention and management of diabetes.

Whole grains and diabetes - mechanisms

Research indicates that consumption of whole grains can improve carbohydrate metabolism. Whole grains can reduce postprandial blood glucose responses (Jenkins et al. 1986; 1988; Bjork et al. 1994), reduce insulin resistance (Pereira et al. 2002), fasting insulin levels (Pereira et al. 1998, 2002), and improved insulin sensitivity (Liese et al. 2003).

The influence of whole grains on diabetes appears to depend upon the physical properties and structural characteristics of the grain. Mechanisms of whole grains on type 2 diabetes can also be additive where several physical and structural components can work synergistically (Miller 2001; Jacobs & Steffen 2003). Grains can vary by the type of glucose chains present in the grain (amylase versus amylopectin); amount of soluble fiber, presence of beta-glucan, and level of nutrients such as magnesium, vitamin E, selenium, and other potential bioactive components such as phenolics, and phytic acid (Bjorck et al. 1994; Slavin et al. 1997). Grains with higher levels of amylase (Liljeberg et al.1996), soluble fibers (Tappy et al. 1996; Lu et al. 2000), higher viscosity (Braaten et al. 1994; Gallaher et al. 1999), beta-glucans (Poppitt et al. 2007), and nutrients such as magnesium, vitamin E, selenium, phenolics, and phytic acid (Liu et al. 2000) can reduce responses to glucose. The structural characteristics of grains can also be affected by the level of processing, form and method of cooking (boiling versus baking) which can have an effect on glucose metabolism. Some studies suggest that the more processing of grains and smaller particle size of the grain can lead to higher glucose and insulin responses (O'Donnell et al. 1989; Liljeberg et al. 1992). While there are several mechanisms that may reduce type 2 diabetes additional research is needed to more fully understand the mechanisms associated with whole grains and risk of type 2 diabetes.

There are limitations in the scientific data linking whole grains to reduced risk of chronic disease. Large clinical trials have yet to be conducted to explore any cause and effect relationship between whole grain intake and chronic disease. Confounding variables associated with demographics, dietary intake and physical activity are only a few of the lifestyle factors that interfere with the "true" relationship between whole grain intake and risk of chronic disease. Additional evidence is needed to elucidate the role of whole grains and the synergistic effects of a healthy diet. Despite these shortcomings, whole grain intake has been recommended to help reduce risk of certain chronic diseases (USDA Dietary Guidelines 2010). Epidemiological evidence shows that the incidence of weight maintenance, heart disease, diabetes and insulin sensitivity is inversely associated with whole grain consumption. Additional research is needed to examine the hierarchal structure of dietary patterns, foods and nutrients along with the interaction of whole grain foods on health and chronic disease. This may enhance our understanding of the potential contribution of whole grain foods and their influence on health and well-being within the scope of the overall diet.

Dietary intake of whole grain foods

Recommendations

The 2010 Dietary Guidelines for Americans recommend that half of total grains should be consumed as whole grains and to replace refined grains with whole grains (USDA 2010). The 2005 Dietary Guidelines and MyPyramid first recommended daily consumption of three or more ounce-equivalents of whole grain products (e.g. one slice of bread) or at least half of the grains as whole grains (USDA Dietary Guidelines 2005). One serving of a grain food could include one slice of bread, one cup of cereal or ½ cup of cooked cereal. Based on considerable scientific evidence, government and health related organizations have recommended daily consumption of whole grain foods for disease prevention, such as the American Heart Association (Lloyd-Jones et al. 2010). The Healthy People 2010 initiative proposed that persons aged two years and older should consume at least six servings of grain products per day and of those three servings should be whole grains (Healthy People 2010). In addition, Healthy People 2010 initiative recommends choosing a variety of whole and enriched grain foods since grain foods vary considerably in the amount of fiber, nutrients, and phytochemicals.

Intake of whole grains

Despite significant support for increased whole grain consumption and related health benefits, most American adults do not obtain the recommended daily servings of whole grains (Healthy People 2010). Data from the Continuing Survey of Food Intake by Individuals (CSFII) (1994-1996) showed that of the American adults who consumed 6.7 servings of grain foods per day, only one serving was contributed through whole grains. Only 8% of the adults consumed at least three servings of whole grains and 36% consumed less than one serving of whole grains per day (Cleveland et al. 2000; Kantor et al. 2001). More recent data from the NHANES (1999-2000) indicate that the mean whole grain intake per day was 0.76 servings (Good et al. 2008). About 30% of the women consumed no whole grains, 70% consumed less than one serving per day, and only 6%

consumed three or more servings per day. According to NHANES (2001-2002) data only 10% of total grains consumed consisted of whole grains (Cook and Friday 2004; Bachman et al. 2008). Another assessment of the NHANES data (1999-2004) was completed by O'Neil et al. (2010) using the new whole grain definition that was applied to the MyPyramid Equivalents Database (MPED) (USDA Pyramid Servings Database 2009). The new definition excludes bran and pearled barley. According to this secondary analysis the mean intake of whole grains per day was 0.63 for adults aged 19-50 years and 0.77 servings for adults 51 years and older (O'Neil et al. 2010). Approximately 5% of adults aged 19-50 years and 7% of adults 51 years and older consumed three or more servings of whole grains daily. Despite some variation in quantifying whole grain consumption, based on varying dietary assessment instruments, it remains clear that most Americans are not meeting the recommendation intake for three servings per day.

The average American who is meeting the recommendations for whole grain intake are likely to be older, more educated, have a lower body mass index, higher socioeconomic status, exercise regularly, consume more fruits and vegetables, is a non-smoker, and have a better diet quality and nutrient intake (Adams and Engstrom 2000b; Cleveland et al. 2000; Lang and Jebb 2003; Lin and Yen 2007; O'Neil et al. 2010). Overall intake of whole grains is directly associated with a healthier lifestyle.

Given that most Americans fail to meet the whole grains recommendation, more research is needed to examine factors that influence whole grain intake. According to the CSFII (1994-1996) data, yeast breads provided about one-third of total whole grain servings (Cleveland et al. 2000). A more recent cross-sectional study based on NHANES (2001-2002) data estimated that yeast breads represented 25% of all whole grains consumed and yeast breads also contributed 26% of non-whole grains consumed (Bachman et al. 2008). A simple substitution of whole grain bread for refined grain bread could result in a significant increase in whole grain consumption which may have a positive influence on health.

Barriers associated with intake of whole grain foods

Numerous barriers may prevent consumers from meeting the recommended daily intake of whole grain foods including: limited availability (Adams and Engstrom 2000b;

Kantor et al. 2001); difficulty identifying whole grain foods (Adams and Engstrom 2000b; Kennedy and Davis 2000; Chase et al. 2003; Burgess-Champoux et al. 2006); dislike of taste, color and texture of whole grain foods (Adams and Engstrom 2000b; Ellis et al. 2005); lack of knowledge about the health benefits of whole grain foods (Chase, Reicks, & Jones 2003; Croy and Marquart, 2005; Burgess-Champoux et al. 2006; Marquart et al. 2006); costs associated with production and distribution (Adams and Engstrom 2000b; Kantor et al. 2001; Ellis et al. 2005) and preparation time (Adams and Engstrom 2000b). No studies have examined barriers associated with the intake of a specific whole grain food such as bread.

Several studies used theoretical models to examine behavioral factors related to whole grain food consumption (Marquart et al. 2004; Croy & Marquart 2005; Ellis et al. 2005; Larson et al. 2010). One study measured consumers' attitudes toward specific whole grain foods (Arvola et al. 2007).

Marquart et al. (2004) used the Social Cognitive Theory (SCT) to assess beliefs about whole grain foods among three groups (food and nutrition professionals (n = 103); health club members (n = 103); and the general population (n = 68)). Questionnaires measured perception, classification and knowledge of whole grains (ability to identify a whole grain food and recommended servings); and environmental and social influences on whole grain consumption. Bread was identified as a whole grain food when subjects were asked to name foods that contain whole grains. Results from the questionnaire indicated that most participants had limited knowledge of whole grains and perceived that the best method for identifying a whole grain food was by reading the food label.

A 4-week long educational program was conducted to introduce whole grain foods into the daily diet of health club members (n = 21) (Croy and Marquart 2005). The SCT was used as a basis for developing focus group questions to measure whole grain knowledge, environmental and behavioral influences on whole grain intake. At the beginning of the study subjects were familiar with whole grains and claimed to consume on average 1.91 servings/day. Survey data indicated that barriers to whole grain consumption included daily incorporation of whole grains into one's lifestyle, identification, purchase, and preparation of whole grains. In addition, there was a lack of knowledge of whole grains, such as the potential health benefits, means of identification, and experience with different whole-grain foods.

Ellis et al. (2005) used the health belief model for the development of a questionnaire and an intervention to increase whole grain consumption among 84 older adults (mean age of 77 years). Subjects provided their health beliefs related to chronic disease, knowledge, and attitudes toward whole grain foods, and barriers to consuming whole grains. A FFQ was also used to measure consumption of whole grain and refined grain foods. The intervention included information related to perceived benefits and barriers to consumption of whole grains (e.g., health benefits, information on labeling whole grain foods; including whole grains in meals). The intervention resulted in an increase in consumption of whole grain food (whole grain bread, cereal and crackers) from 5.8 times per week to 6.9 times per week and improved participants' ability to correctly identify a whole grain food (45% to 62%).

Larson et al. (2010) used the SCT to assess factors with respect to whole grain intake among 1,686 young adults with a mean age of 21 years. The data for this cross-sectional analysis came from the Project EAT-II (Eating Among Teens) study. Subjects completed a survey that measured personal, socio-environmental, behavioral and socio-demographic factors and a FFQ that measured usual intake over the past year for whole grains (dark bread, kasha/couscous/bulgur, popcorn, hot cereal, and cold cereal). The mean intake of whole grains was 0.68 servings for males and 0.58 servings for females. Factors with a positive association with whole grain intake included availability of whole grain bread at home, preference for taste of whole grain breads and self-efficacy to consume at least three servings of whole grains/day. The researchers suggest that all three factors should be addressed in interventions to promote whole grain intake.

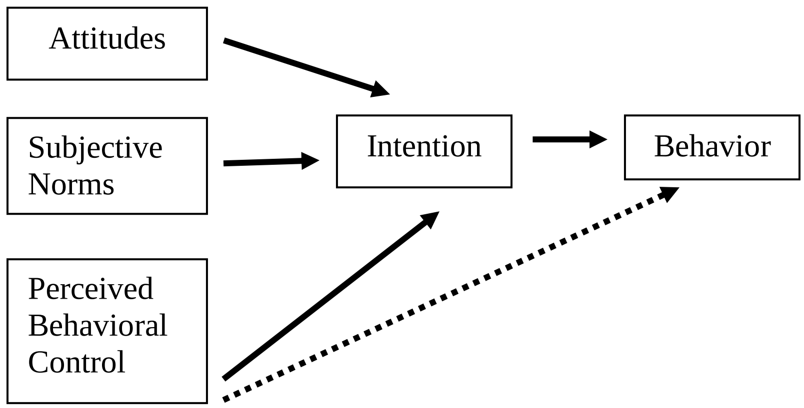
Arvola et al. (2007) examined consumer beliefs about whole grain and refined grain bread products in the UK (n = 552), Italy (n = 504) and Finland (n = 513). The beliefs were selected from focus group discussions comparing whole grain and refined grain products. Consumers rated their beliefs on bipolar semantic differential scales for both whole grain and refined grain products. In comparison to refined grain products all consumers thought that whole grain products were nutritionally balanced, healthier, more natural, more filling and released energy more slowly. However, whole grain products were rated less desirable for price and taste compared to refined grain products. Consumers from Italy and the UK found few differences in health benefits between whole grain and refined grain products while consumers from Finland noted differences. Italians felt that refined grains tasted better than whole grains. The researchers suggest that promoting whole grains based on health benefits may not be useful because of the lack of awareness by some consumers.

These studies suggest that more education about whole grains is necessary for the general population. Additional studies are needed to confirm the usefulness of theoretical models to predict intake of whole grain foods, especially with respect to specific whole grain foods, such as whole grain bread.

Overview of the theory of planned behavior

The theory of planned behavior (TPB) offers a structural foundation for predicting and explaining behavior (Ajzen and Madden 1986) based on cognitive and affective factors (Fishbein & Ajzen 1975). It is an extension of the Theory of Reasoned Action (TRA) to include the concept of perceived behavioral control (PBC) (Ajzen 1980, 1988, 1991). PBC was added to account for behaviors that are not under complete volitional control (e.g., physical inability to perform a behavior) (Ajzen 1988). The TPB model has been widely used in social psychology (Ajzen & Fishbein 1980) and studies to predict intake of specific foods or groups of foods (Cook, Kerr and Moore 2002; Kim, Reicks and Sjoberg. 2003; Bogers et al. 2004; Kassem and Lee 2004; Rah et al. 2004; Verbeke and Vackier 2004; Fila and Smith 2006; Brug et al. 2006; Arvola et al. 2008; De Bruijn et al. 2008; Blanchard et al. 2009; White et al. 2010).

The standard TPB uses attitude toward the behavior (positive or negative evaluation of the behavior), whether others approve or disapprove of engaging in the behavior (normative), and perceptions of control over the behavior (perceived behavioral control) to predict intention to engage in a behavior or the likelihood to change a behavior. As applied to intention to eat whole grain bread, examples of the three standard TPB constructs include: attitude (whole grain breads taste good), subjective norms (SN) (My spouse thinks that I should eat whole grain bread), and PBC (it is hard to understand whole grain bread packaging and labeling/ingredient lists). Attitudes, SN, and PBC influence the intention of an individual to perform the behavior and this predicts the likelihood that the behavior will occur (see figure below) (Ajzen 1991). Again, applying the model to whole grain bread consumption, the stronger the intention (intending to consume three servings of whole grain bread per day) the more likely the individual will perform the behavior (consuming whole grain breads on a regular basis).



Behavioral intention and apparent behavior are related but depend upon strength of the other constructs (Fishbein & Ajzen 1975; Shepherd 1989). Intention and behaviors associated with consumption of whole grain breads can be explained by attitudinal, normative and control beliefs.

Constructs

Attitudes

Attitude is the extent to which an individual has a favorable or unfavorable evaluation of the behavior. Attitude is predicted by the sum of the products of the salient behavioral beliefs about the behavior multiplied by the evaluations of those outcomes (Towler and Shepherd 1991-1992; Eagly & Chaiken 1993). The assessment of outcome evaluation is not always included as part of the attitudinal belief construct because others have found that people similarly evaluate the outcomes of the behavior making it unnecessary (Ureda 1993). Attitude consists of three components 1) affective (emotions and feelings associated with the behavior), 2) cognitive (related to the attributes and beliefs about the behavior), and 3) conative (tendency to behave in a certain way based on feelings and beliefs) (Fishbein and Ajzen 1975). Applied to food intake as the behavior of interest, these three attitudinal components may include emotions or feelings about consumption of a food, attributes or beliefs about consuming a food and the tendency to behave in a certain manner regarding the food based on feelings and beliefs.

Subjective norms (SN)

SN is the perceived social pressure to perform or not perform a certain behavior (normative beliefs) and is moderated by the individual’s motivation to comply with the individual or group exerting the pressure (Conner and Sparks 1995). SN is measured by multiplying the normative beliefs by the individual’s motivation to comply with the expectations of others. Social pressures may affect some individuals while others may follow their own beliefs. According to Godin and Kok (1996) SN was less influential for eating behaviors than automobile-related behaviors.

Perceived behavioral control (PBC)

PBC is the perception of the ease or difficultly in performing a behavior under the control of the individual. This construct also takes into account factors that are not under an individual’s volitional control or factors that facilitate or prevent the performance of the behavior (Ajzen and Madden 1986). PBC refers to two components: first, the availability of resources needed to perform the behavior (control beliefs) and second, the individual’s self-confidence in the ability to perform the behavior (perceived power) (Chiou 1998). Control beliefs in regard to behaviors may include internal and external factors (Ajzen 1991). Applied to dietary behavior, internal factors may include values, attitudes, and beliefs toward foods based on personal experience, and taste preference, while external factors include demographic, environmental (price and availability) and socioeconomic status factors. PBC has a direct effect on behavior and an indirect effect on behavior through intentions. PBC provides information as to why intentions may not always predict behavior (Armitage and Conner 2001) including non-volitional behaviors. Some non-volitional behaviors may require “skills, resources or opportunities that are not freely available” (Conner and Sparks 1995) thus limiting control. In this case PBC can influence behavior directly. In situations where the individual is in complete control of the behavior, PBC can influence behavior indirectly through intention. Depending upon the presence or absence of obstacles, PBC is a measure of control. The addition of the

PBC construct has enhanced the power to predict intention and behavior in many studies (Ajzen 1991; Godin and Kok 1996; Armitage and Conner 2001).

Intention

Intention to perform a behavior depends upon the conscious plan to perform the behavior and the motivation to perform it. According to Ajzen (1991), behavioral intention is predictive of one's behavior while attitudes, SN, and PBC are independent determinants of intention. Intention to perform a behavior may occur if the individual has a positive attitude, perceived social pressure from others to do the behavior, and the perception they are in control of the behavior (Conner et al. 2001). Intention is based on an action that the individual intends or plans to perform. According to Fishbein and Ajzen (1975), intention should be operationalized to refer to action (e.g., consumption of food), target of action (e.g., increasing whole grains), context (e.g., at home or away from home), and time (e.g., when the behavior can be changed such as next week, month or year). The correlation between intention and behavior is strong when both were measured with the same action, target, context, and time period. Low prediction of intention may occur because of other variables that predict the behavior such as taste of a food. Sometimes intention may not directly translate into a behavioral change especially when intention only represents a desire to behave differently (Cox et al. 1998). Individuals may have good intentions (e.g. to eat whole grain breads) but fail to act upon this intention (e.g., actual consumption of whole grain breads). Intention to perform a behavior can be described in terms of implementation intentions (Gollwitzer 1999). Implementation intentions are plans that involve specifying when, where and how the person will perform the behavior. Implementation intentions can successfully enhance the likelihood of reaching the goal.

Behavior

In the public health arena, behavior represents a desired action to improve health. Behaviors of interest include actions such as improving dietary intake, smoking cessation or increasing physical activity. Behavior is strongly influenced by behavioral intention and PBC (Ajzen and Fishbein 1980; Fishbein and Ajzen 1975). PBC can influence whether a behavior is performed if the person perceives that they have control over the behavior, which is the case with volitional behaviors. Positive attitudes, perceived social pressure to do the behavior, and positive perceived behavioral control tend to lead to intention to preform the behavior and then to the actual performance of the behavior.

Use of the theory of planned behavior to predict intention and behavior

Several studies found the TPB model is highly predictive of intention and food consumption among various food categories. The TPB has been used to predict the likelihood that many behaviors will occur ranging from alcohol consumption to eating behavior with good predictive power (Godin and Kok 1996; Armitage and Conner 2001; Kim, Reicks, and Sjoberg 2003; Kassem and Lee 2004; Rah et al. 2004; Verbecke and Vackier 2005). A review by Godin and Kok (1996) indicated that the mean proportion of variance explained in intention was 41% among many health-related behaviors whereas the mean proportion of variance explained for behavior was 34%. A meta-analysis of 185 studies that applied the TPB to improve health behaviors showed that across 154 tests, the constructs of attitudes, SN and PBC accounted for 39% of the variance in intention; and across 63 applications, intention and PBC accounted for 27% of the variance in the behavior (Armitage and Conner 2001). A fairly large percentage of variance was explained when predicting intention to consume foods such as starchy foods (21%) (Stubenitsky and Mela 2000); dairy products (42%) (Kim, Reicks and Sjoberg 2003), soy products (48%) (Rah et al. 2004), soft drinks (61%) (Kassem and Lee 2004); fruit (44%) and vegetables (51%) (Bogers et al. 2004); omega-3 fatty acids (73%) (Patch et al. 2005); fish (31%) (Verbecke and Vackier 2005), fruits and vegetables (50%) (Blanchard et al. 2009); and foods low in saturated fats (29%) (White et al. 2010). A relatively smaller but still fairly large percentage of variance was explained when predicting consumption of dairy products (39%) (Kim, Reicks and Sjoberg 2003), soy products (49%) (Rah et al. 2004), soft drinks (15%) (Kassem and Lee 2004); fruit (37%) and vegetables (10%) (Bogers et al. 2004); fish (42%) (Verbecke and Vackier 2005), fruits and vegetables (11%) (Blanchard et al. 2009); and fruit (26%) (De Bruijn 2010).

Most of these studies reported a fairly large proportion of variance explained in intention and behavior which supports the usefulness of the TPB in predicting intention and behavior for food consumption.

Theory of planned behavior and whole grain consumption

Several studies have applied the TPB to whole grain consumption among adults (Sparks et al. 1992; Kvaavik et al. 2005). The first study used the general structure of the TRA and TPB to examine whole meal bread consumption among 173 British members of a consumer panel (Sparks et al. 1992). The purpose of the study was to examine the association between attitude variability (feelings being favorable or unfavorable and varying with each situation), perceived control and behavior. Additional constructs that were examined included attitudes, influence of others' attitudes, intake expectations and desire to eat. Approximately 25% of the variance was explained in intention to consume whole meal bread tomorrow. Those who intended to consume more whole meal bread had more positive attitudes toward consumption than subjects who did not intend to consume whole meal bread. PBC and others' attitudes did not significantly improve the prediction of intention, expectations to eat tomorrow or next week, and desire to eat tomorrow. Attitude variability was inversely related to perceived control. As attitude variability increased, the associations between components of the TRA became weaker.

Kvaavik et al. (2005) used the TPB to investigate factors that influenced consumption of a group of whole grain foods (bread and cereals) at baseline and eight years later. The subjects (240 men and 279 women) completed a questionnaire and a FFQ that measured whole grain intake (whole wheat bread and breakfast cereals) during the past year. For each TPB construct, beliefs addressed eating healthy foods such as foods low in fat, sugar and salt. Variance explained for consumption of whole grains for men and women ranged from 0% to 5% for the baseline model (attitudes, SN, PBC and intention); 5% to 12% for an extended model (baseline model + demographics); and 7% to 17% for a second extended model (baseline model + demographics + baseline eating behavior). SNs, PBC and education were associated with whole grain intake. For men, education and past eating behavior were predictive of whole grain intake, and for women, SNs, education and past eating behavior were predictive of whole grain intake.

These two studies found that the variance explained in relation to whole grain consumption was moderate (Sparks et al. 1992; Kvaavik et al. 2005). Studies that examined barriers to consuming whole grains indicated that more research is required to understand the role that consumers play with respect to purchasing and consuming whole grains. Many dietary-intake studies found that measuring consumption of more specific foods rather than a group of foods resulted in the prediction of a fairly large proportion of the variance in consumption (24% to 49%). Examples include studies based on intake of milk (Park and Ureda 1999); biscuits and whole meal bread (Sparks et al. 1992); organic vegetables (Sparks and Shepherd 1992), and fish (Verbeke and Vackier 2004). Baranowski et al. (1999) suggested that the predictive power of the TPB can be improved by examining intake of a specific food (e.g., milk) rather than a group of foods (e.g., dairy products). The predictive power may be improved because individuals may find it easier to form opinions about specific foods (e.g., whole grain bread) rather than a food category (e.g, whole grains). Therefore, using the TPB to examine consumption of a specific whole grain food product such as bread may improve predictiveness of the model. Bread is also one of the most commonly consumed whole grain foods by Americans (Bachman et al. 2008) making it an important focus for further study. No studies were found that examined factors that influenced whole grain bread consumption among US consumers using the TPB.

Expanded TPB model including overall liking rating, bread preference and PROP rating

Researchers have argued that the TPB is an incomplete model and have modified it by including additional variables to increase the predictiveness (Conner and Armitage 2002). The expanded TPB models have addressed types of attitudes or feelings (affective attitude, instrumental attitude, anticipated affective reaction, and attitude ambivalence), different ways of conceptualizing behaviors (past behavior, habit strength, self-efficacy towards the behavior) and various personal factors (or individual difference variables) (moral norms, self-identity, planning index, perceived need, and food neophobia) to further understand and predict behaviors. Table 2.1 provides detailed information on the variety of behaviors involved and reported change in variance explained when additional variables were added to the standard TPB model.

Some studies differentiated types of attitudes when predicting intention and behavior (Paisley and Sparks 1998; Verbeke and Vackier 2005; Arvola et al. 2008; De Bruijn 2008; Blanchard et al. 2009; De Bruijn 2010). A two-part attitudinal component consisted of instrumental and affective evaluations of the behavior. Instrumental attitude (cognitive component or evaluative component) is defined by thoughts and beliefs people have about the attitude object, and the risk and benefits of performing the behavior (Ajzen 1991). The affective component of attitudes refers to "feelings or emotions that people have in relation to the attitude object" (Eagly and Chaiken 1993). Researchers have used one attitude component where attitudes were measured by both instrumental and affective evaluations to predict intention and behavior in relation to consuming a low-fat diet and five servings of fruit and vegetables (Povey et al. 2000), fish (Verbeke and Vackier 2005) and organic food (Arvola et al. 2008). Other studies have used two separate attitudinal components to predict intention and behavior in relation to consuming reduced-fat foods (Paisley and Sparks 1998), low saturated-fat (De Bruijn 2008), five servings of fruit and vegetables (Blanchard et al. 2009) and fruit (De Bruijn et al. 2010). Instrumental attitude was a significant predictor of intention for reducing fat intake (Paisley and Sparks 1998) and consumption of fruit (De Bruijn 2010). Affective attitude was a significant predictor of intention to consume fruit and vegetables (Blanchard et al. 2009), consumption of reduced fat foods (Paisley and Sparks 1998) and consumption of fruit (De Bruijn 2010).

Richard et al. (1996) expanded the TPB to predict intake of less desirable foods or junk foods. Anticipated affective reaction (anticipate feelings of regret after performing the behavior) was added to the TPB and was a significant predictor for eating junk foods. Inclusion of anticipated affective reactions in the TPB was supportive across some behaviors (using soft drugs, alcohol) and extends the understanding of beliefs underlying attitudes.

Attitude ambivalence refers to having positive and negative attitudes simultaneously. Stronger intentions were associated with having less ambivalence towards consuming a meat diet, but not for consuming a vegetarian or vegan diet (Povey, Wellens and Conner 2001), or meat and chocolate (Sparks et al. 2001).

Past behavior, has been shown to be the strongest predictor of future behavior and sometimes more predictive than intention and other constructs (Sparks and Shepherd 1992; Ouellette and Wood 1998; Conner, Norman and Bell 2002). Past behavior significantly increased prediction of intention to consume breakfast and was the strongest predictor of future breakfast intake (Wong and Mullan 2009). Inclusion of past behavior increased the level of variance explained in consumption of low-fat foods (Paisley and Sparks 1998) and foods low in saturated fats (White et al. 2010).

Past behavior has been considered a separate construct from "habit" since the two constructs may contribute differently to explaining intention or behavior (Conner and Armitage 1998). However, in the case when behavior is infrequently performed (nonhabitual), then past behavior and habit are assumed to be related. Past behavior does not necessarily lead to future behavior. When a frequently performed behavior occurs, the future behavior can become a habitual process. According to Ajzen (1991), when habit is defined independently of past behavior it can be added to the TPB model. Habit or the unawareness of performing the behavior, has increased the predictive power of the model for intention to consume chips (Towler and Shepherd 1991/1992), milk (Saba et al. 1998), ready made and takeaway meals (Mahon et al. 2006); and fish (Verbeke and Vackier 2004); and for consumption of chips (Towler and Shepherd 1991/1992), fish (Verbeke and Vackier 2004), fruit (Brug et al. 2006; De Bruijn et al. 2010) and saturated fat (De Bruijn et al. 2008). When habit strength is strong the intention and behavior relationship is weak (De Bruijn et al. 2007).

Researchers applying the TPB have had different ideas about how to assess control beliefs which resulted in inclusion of several different constructs with respect to PBC in an expanded TPB (Gummerson et al. 1997; Armitage and Conner 1999; Povey et al. 2000). Ajzen (1991) claimed that PBC and self-efficacy are synonymous; however, several researchers have included self-efficacy as an independent variable. Control beliefs have been divided into two components when predicting intention and behavior. The two-part control component consisted of perceived difficulty (self-efficacy) and whether the behavior is under the person's control (perceived control). Self-efficacy was a significant predictor of intention to consume a low-fat diet and to consume five portions of fruit and vegetables (Povey et al. 2000); consumption of a low-fat diet (Armitage and Conner 1999; Povey et al. 2000), and consumption of milk, cultured milk and yogurt (Gummerson et al. 1997). However, self-efficacy was not significantly associated with fruit consumption (Brug et al. 2006). According to Schwarzer and Renner (2000), there are two types of self-efficacy: action (anticipating successful situations when thinking about certain actions) and coping (positive beliefs about being able to cope with barriers that appear when the action is being performed). Only one food-related study included coping self-efficacy in the model and found that it was a significant correlate of intention to eat two or more servings of fruit per day (Brug et al. 2006).

Personal characteristics have also been used to expand the TPB to explain variance in intention and intake of certain foods. A characteristic known as moral norms, personal responsibility or moral obligation, refers to the personal beliefs about right and wrong (Ajzen 1991). Moral norms are a useful additional variable when the behavior is explained in moral terms. Moral norms significantly influenced intention to consume skim milk (Raats et al. 1995), to purchase organic pizza (Arvola et al. 2008), to consume organic foods (Bissonnette and Contento 2001), and to use genetically modified foods (Sparks and Shepherd 2002). In situations when moral norms are not applicable, researchers have used the concept “personal norm” which refers to the person’s own values related to the behavior.

Another personal characteristic that has been included in an expanded TPB is self-identity which is the individual’s perception that he or she has the ability to perform the behavior (Conner and Armitage 1998). Self-identity has also been described as the “salient part of an actor’s self which is related to a particular behavior and reflects the extent to which an actor sees him or herself as fulfilling the criteria for any societal role” (Conner and Armitage 1998). Self-identity independently predicted intention to consume organic vegetables during the following week (Sparks and Shepherd 1992), intention to consume and buy organic foods (Bissonnette and Contento 2001), and to eat a low-fat diet (Armitage and Conner 1999). However self-identity was not an independent predictor of intention to eat a meat, vegetarian or vegan diet (Povey, Wellens and Conner 2001) or to consume chocolate or meat (Sparks et al. 2001).

Intention is translated to behavior when planning occurs to implement the intention. This concept was defined as a planning index by Norman and Conner (2005) where the index was based on specifying where, when, and how an intended behavior is to be performed, similar to the concept of implementations intention which was previously described. Including this concept in the TPB increased variance explained to consume foods low in saturated fats (White et al. 2010) and was an independent predictor of consuming breakfast (Wong and Mullan 2009).

Other concepts that have been applied in an expanded TPB include personal issues such as perceived need (the extent to which one perceives the need to engage in a behavior) and food neophobia (the tendency to avoid novel foods). Including perceived need in the TPB increased the prediction for intention to consume a low fat diet and eating five portions of fruit and vegetables (Povey et al. 2000), and to reduce fat intake (Paisley and Sparks 1998). Inclusion of food neophobia in an expanded TPB increased the predictiveness of the model for intention to consume cheeses (Arvola et al. 1999).

The evidence provided has clearly shown that the inclusion of additional variables to expand the model beyond attitudes, norms and perceived behavior control and to consider personal characteristics has been beneficial in improving the predictiveness of the theory. Decisions regarding which additional variables to include in the TPB depend upon the nature of the behavior being examined and if the variables would be a logical expansion of the theory to improve predictiveness.

A logical expansion of the TRA and TPB to predict food intake would involve the addition of another category of personal characteristics based on liking or preference. Researchers have found that including liking in the TPB increased the predictive power for intakes of bread, milk and cheese (Tuorila-Ollikainen et al. 1986; Tuorila 1987; Shepherd et al. 1991-1992; Saba et al. 1998; Arvola et al. 1999).

Tuorila-Ollikainen et al. (1986) included liking ratings in the TRA model to identify factors that influenced intention to consume low-salt breads (white, wheat, rye and sour rye). Sixty-one subjects completed a theory-based questionnaire and consumed the self-selected low-salt breads with two levels of sodium at home 15 times over 7-weeks. The TRA model explained 38% of variance in intention and 21% of the variance in behavior (bread selection). Inclusion of the hedonic response into the model increased prediction of intention to 52% and behavior to 32%.

Tuorila (1987) also used the TRA model to examine buying intention and selection of milks (skim, low-fat and regular fat). Subjects (n = 236) completed a questionnaire that measured attitudes, norms, buying intention, milk selection and overall liking (sensory hedonic responses; and responses to milk names in a survey). The TRA model predicted 18-36% of the variation for intention and 28-47% for behavior (selection of milk). Inclusion of hedonic responses in the model increased the percentage of variance explained in intention negligibly for skim milk (1%); however when response to milk names was included the percentage of variance explained in intention increased to 25-45%. Response to milk names also improved the predictive power of behavior to 32-48%.

Saba et al. (1998) evaluated attitude, milk consumption habits, liking and milk consumption based upon the TRA. Subjects (n = 160) were recruited at a grocery store and subsequently completed two questionnaires at home related to milk consumption (usual or habitual frequency; and frequency over the past week). Multiple regression results showed that behavioral intention was mainly explained by habit and then attitudes. Liking was a second predictor for intention to drink whole milk and improved the predictive power of intention by 3%. Liking was the best predictor for behavior (drinking skimmed milk and whole fat milk) based on usual consumption frequency and consumption frequency of the past week, but not for consumption of semi-skimmed milk. The addition of liking in the TRA only improved the predictive power of behavior (usual frequency; frequency over the past week) for semi-skimmed milk by 5% and 8%, respectively.

Shepherd et al. (1991-1992) included liking rating of milks in the TRA model while examining the role of attitudes and beliefs (weight control, health benefits, having a nice texture and having a nice taste) in the selection of flavored full-fat and low-fat milks. Subjects (n = 80) completed a TRA questionnaire and rated the liking of flavored milk. Intention accounted for 34% of the variance in intake of full-fat milk and 41% in intake of low-fat milk. Liking increased the extent that intention accounted for intake of full-fat milk by 5% and of low-fat milk intake by 5%.

Arvola et al. (1999) also used the TRA to examine intent to purchase novel and familiar cheeses and included expected pleasantness of taste (liking) and actual taste pleasantness as additional predictors. College-age and adult females (n = 106) completed a questionnaire that measured attitudes, subjective norms, liking and purchase intent for each cheese. Expected liking (measured before tasting the cheeses) improved the predictiveness of the model for intention by 2-5% for the familiar cheeses and by 25% for a novel cheese. Attitudes and subjective norms were good predictors of purchase intent. Since attitudes and subjective norms were measured only before tasting the cheeses, the effect of including actual liking (pleasantness) in the TRA model could not be measured.

Results from the studies that included liking ratings of foods to extend the TPB or TRA provide evidence that liking will increase the proportion of variance explained in intention and behavior for various types of foods. These studies demonstrated that hedonic responses can be an independent predictor of food consumption. Therefore, including additional variables based on liking and preference in the TPB may allow for a more precise prediction of intention and behavior related to consumption of whole grains.

Liking of breads

While a theoretical behavioral model may explain more of the cognitive basis for food consumption, sensory studies may help elucidate the affective basis for liking and consumption of food such as whole grain bread. Given that yeast breads constitute a large part of the American diet, enhancing the taste characteristics of whole grain breads is a logical approach to increase whole grain consumption in the U.S. population. The decision to consume a food such as whole grain bread can also be dependent upon one's taste preference and liking. Two studies measured preferences of whole grain breads (Peryam et al. 1960; Vickers et al. 1981) and three studies measured liking responses to actual food (whole grain bread) (Lang and Walker 1990; Mialon et al. 2002; and Bakke and Vickers 2007).

Peryam and others (1960) surveyed food preferences of men (n = 4,000) in the US armed forces. Liking ratings of breads were measured on a nine-point hedonic scale ranging from 1= dislike extremely and 9 = like extremely. Refined grain bread was preferred more than whole wheat bread with scores of 7.7 and 6.8. Refined grain bread was preferred to 89% of the foods surveyed, while whole grain breads were preferred to 59% of the foods surveyed. These results cannot be extrapolated to the general population as all subjects were service men.

Vickers et al. (1981) examined food preferences of older cancer patients and age-matched control subjects. The age-matched control subjects (n = 205) rated their preference for 89 food-items on a nine-point hedonic scale that ranged from 1 = like extremely to 9 = dislike extremely. The control subjects significantly preferred the whole wheat bread (score of 2.5) over refined white bread (score of 3.0). These results conflict with the previously mentioned study which may be attributed to population differences. Peryam and others (1960) and Vickers et al. (1981) examined the preferences of bread products, but these studies did not measure actual tasting of the foods.

There are four studies that measured hedonic sensory responses to actual food (whole grain bread) (Lang and Walker 1990; Mialon et al. 2002; Bakke and Vickers 2007). Lang and Walker (1990) examined whether there were differences in liking of breads made with hard white wheat and hard red wheat with various fibers and whole grain additions (cracked wheat, flaked wheat, bran, and whole wheat) to develop a high-fiber hamburger bun. Approximately 328 subjects completed a triangle difference test that asked "Which is the different sample?", and a hedonic sensory test that measured liking using a nine-point scale that was anchored with "dislike extremely" and "like extremely". Results from the triangle test showed there was a significant taste difference between the two types of whole wheat breads (red and white whole wheat flour). However, results from the preference test showed no preference for buns made from red over white flour.

Mialon et al. (2002) examined hedonic responses to commercial available pre-packed refined grain and whole meal breads (3 types of breads and 3 types of English muffins). Subjects consisted of 79 Chinese Malaysians and 82 Australians. Liking ratings were measured by expected liking (appearance) and actual liking (based on tasting). For both groups of subjects, the expected liking and actual liking of refined white bread was greater than liking of whole meal bread. These results cannot be generalized to consumers within the U.S., but show that refined grain bread was liked more than whole meal bread.

Bakke and Vickers (2007) examined if refined wheat bread was liked more than whole wheat bread. Subjects (n = 89) tasted and rated the liking of nine different breads (five laboratory made breads (refined and whole wheat); 2 commercial breads (refined and whole wheat); and 2 artisan breads (refined and whole wheat). Participants were also classified into subgroups according to bread preference (whole wheat or refined). When comparing across the same bread ingredients and procedures, the laboratory-prepared refined wheat breads were liked more than the whole wheat breads. However there were no differences in liking between the refined and whole wheat commercial and artisan breads. The laboratory-prepared refined wheat breads were liked more than the whole wheat breads by participants who preferred refined wheat bread. Participants who preferred whole wheat breads liked the appearance of the red whole wheat laboratory-prepared breads more than the red refined wheat laboratory-prepared bread; however, they liked the flavor of the white refined wheat laboratory-prepared breads more than the white whole wheat laboratory-prepared breads. These participants also significantly liked the appearance of the whole wheat commercial breads more than the refined wheat commercial breads and liked the flavor and appearance of the whole wheat artisan breads more than the refined wheat artisan breads.

Of the previously mentioned studies that examined liking of whole grain breads one study found liking differences among different whole grain breads (Bakke and Vickers 2007) and another study found no liking differences among the different whole grain breads (Lang and Walker 1990). Results of the previously mentioned bread studies provide evidence that whole grain breads are liked less than refined grain breads. However, no studies examined liking differences among commercial whole grain breads and identified reasons for the differences in liking.

Bitter taste of foods and 6-n-propylthouracil (PROP) taster status and the liking of bitter foods

Liking of foods has also been hindered by specific taste attributes, such as bitter taste. Humans are innately born to dislike bitter taste (Rozin and Vollmecke 1986) and prefer sweet tastes (Cowart 1981). This is further supported by studies suggesting that bitterness is a primary factor for rejecting some foods (Rozin and Vollmecke 1986; Drewnowski and Rock 1995; Drewnowski 1997; Drewnowski et al. 2000). Whole grain breads have been described as being bitter (Chang and Chambers 1992; Challacombe et al. 2011) and the bitter taste may be a barrier to liking whole grain breads.

Differences in perception of bitterness may be influenced by genetic variation in taste perception. A genetic factor allows some individuals to taste the bitterness of 6-n-propylthiouracil (Bartoshuk 1979). Sensitivity to PROP was first determined in 1931 as a genetic trait (Fox 1931). Kalmus (1971) was the first to classify the bimodal distribution of PROP tasters or PROP nontasters. Approximately 70% of the American population can taste PROP while the other 30% are nontasters (Blakeslee and Fox 1932; Bartoshuk, Duffy, and Miller 1994). Bartoshuk (1993) further classified a subgroup of highly sensitive tasters called “supertasters.” Currently, PROP taster status is distributed tri-modally into nontasters (30%), medium tasters (50%) and supertasters (20%) (Bartoshuk and Beauchamp 1994). Supertasters perceive PROP as extremely bitter while medium tasters perceive it as moderately bitter and nontasters perceive nothing (Bartoshuk and Beauchamp 1994; Prutkin et al. 2000). Nontasters have two recessive alleles (tt) while medium and supertasters have at least one dominant allele (Tt or TT) (Kalmus 1958 and Bartoshuk and Beauchamp 1994). The PROP taster status is dependent upon the presence or absence of the TAS2R38 receptor (Kim et al. 2003).

The genetic factor associated with PROP can affect an individuals’ taste response. PROP tasters tend to experience a higher intensity from a wide range of oral stimuli than nontasters (Duffy et al. 2004). Consumers with higher taste sensitivity, bitterness sensitivity, and perceived PROP sensitivity may like bitter tasting foods such as whole grain breads less than nontasters. Several researchers demonstrated that higher PROP bitter sensitivity and liking of bitter tasting foods are inversely related (Intranuovo and

Powers 1998; Kaminski et al. 2000; Lanier et al. 2005; Dinehart et al. 2006; Bakke and Vickers 2007; 2011).

Intranuovo and Powers (1998) studied the relationship between PROP taster status, liking of beers (Pilsner Urquell and Budweiser), and beer consumption. Forty-seven males and fifty-three female subjects rated the bitterness of the beer on a labeled magnitude scale, and their degree of liking on a nine-point Likert scale. Subjects also provided their degree of alcoholic beverage consumption and rated the bitterness of PROP impregnated paper. The Pilsner beer was rated as more bitter than Budweiser. Supertasters found the Pilsner to be more bitter than medium and nontasters. Male nontasters liked the Pilsner beer more than the male supertasters when the Budweiser beer was consumed before the Pilsner beer. Beverage bitterness was negatively related with degree of liking for taste, and supertasters consumed less beer than nontasters when they first started drinking beer. Overall PROP taster status influenced the liking of beer.

Kaminski et al. (2000) conducted a study whereby 63 women (25 PROP tasters, and 25 PROP nontasters) rated the bitterness intensity of seven PROP solutions and six foods (Brussels sprouts, broccoli, spinach, black coffee, soy milk, and soybean tofu). Subjects used a nine-point category scale to rate the sensory intensity for bitterness, pleasantness of taste, odor, and texture, and overall food acceptability. Subjects also completed a food frequency questionnaire and a food-preference checklist for 22 bitter-tasting foods. PROP tasters rated Brussels sprouts, broccoli, and spinach as more bitter than nontasters. Lower acceptability and pleasant scores were given for foods that were perceived as more bitter. PROP taster status was not related to frequency of consumption for the 22 food items.

Lanier et al. (2005) examined the relationship between PROP taster status, bitter tastes and liking of alcoholic (beer and scotch) and non-alcoholic beverages (instant espresso and unsweetened grapefruit juice). Forty-nine undergraduate students rated the bitterness intensity and liking of the four beverages on a general labeled magnitude scale, and rated the intensity of PROP solutions. Increased PROP intensity ratings were associated with increased bitterness ratings for all four beverages and less preference for the beverages.

Dinehart et al. (2006) examined whether subjects who tasted PROP as least bitter also reported little bitterness when tasting bitter vegetables (asparagus, Brussels sprouts, and kale). Subjects (71 females, 39 males) rated their perceived bitter intensity and liking of the traditional bitter vegetables, completed a food frequency questionnaire that measured vegetable intake, and rated various concentrations of PROP. The PROP tasters detected the most bitter from vegetables and consumed the least amount of vegetables. As the vegetables (Brussels sprouts, and kale) became more bitter the vegetables were liked less.

Bakke and Vickers (2007) examined consumers liking of refined wheat bread to whole wheat bread. Nine breads (five laboratory made breads (refined and whole wheat); 2 commercial breads (refined and whole wheat); and two artisan breads (refined and whole wheat)) were tasted and rated on a labeled affective magnitude scale by 89 subjects. Subjects also rated the intensity of PROP and were classified into subgroups according to bread preference (whole wheat and refined wheat) and PROP taster status. Nontasters liked the refined red wheat bread and whole red wheat breads equally. PROP supertasters and medium tasters liked the laboratory made refined red wheat bread more than the two whole red wheat breads. Similar results were found when comparing refined white wheat bread to whole white wheat bread.

The same authors conducted another study that examined the effect of PROP taster status on liking of breads with varying levels of darkness (addition caramel color), bitterness (additional wheat germ extract), and roughness (additional bleached bran) (Bakke and Vickers 2011). The prepared breads contained low, medium and high levels of caramel color, wheat germ extract and bleached bran. The additional caramel color and wheat germ extract on liking was not influenced by PROP taster status. The additional bran caused the greatest effect on overall and texture liking for nontasters. However, nontasters and supertasters liked the breads that contained the added bran significantly more for overall and texture liking compared to the bread with no added bran. The researchers concluded that the bitterness of bread had no influence on liking and was not dependent upon PROP taster status.

Results from the previously mentioned bread studies are conflicting. Bakke and Vickers (2007) found that PROP taster status caused liking differences between refined and whole grain breads. While these authors found in the other study that PROP taster status had no influence on liking of breads (Bakke and Vickers 2011). Whole grain breads have been described as being more bitter than refined grain bread (Challacombe et al. 2011). This discrepancy between the two bread studies could be attributed to the wheat germ extract added to the breads. The authors mentioned that perhaps the amount of wheat germ extract added to the breads caused higher levels of bitterness which could be detected by all PROP tasters (Bakke and Vickers 2011). Similarly to other food studies previously mentioned, the more bitter food was liked less by PROP tasters. Most of these studies found that the bitterness intensity was negatively related to the liking of the foods. Some results indicated that liking alone was affected by PROP taster status. However, there are no studies that examined the effect of PROP taster status on the liking of commercial whole grain breads. The effect of PROP taster status on liking of a group of U.S. commercial whole grain breads is unpublished. Based upon the many food-related studies and one bread study, it is hypothesized that PROP tasters will like the whole grain breads less than nontasters.

Descriptive analysis of breads

The obvious differences in sensory attributes among breads are brought to our attention particularly when these sensory differences have an effect on consumer liking of breads. To more fully understand the sensory perception (taste, flavor, appearance, and texture) of bread it is necessary to determine important bread attributes that describe the ideal whole grain bread. Taste is a major determinant in food selection and it refers to the perception of salty, sweet, sour, bitter, and umami (Moskowitz 1978; Glanz et al. 1998). Descriptive analysis (DA) is a method used to describe the perception of the foods (Lawless and Heymann 1999). There are many bread studies that used DA to measure attribute intensities of breads and to establish a general profile (Caul & Vaden 1972; Johnson and Sanchez 1973; Hellemann et al. 1987; Hellemann 1988; Johnson & Vickers 1991; Chang & Chambers 1992; Huang et al. 1995; Haglund 1998; Carson et al. 2000; Lotong et al. 2000; Gambaro et al. 2002; Murray et al. 2002; Heinio et al. 2003; Shogren et al. 2003; Kihlberg et al. 2004; Salmenkallio-Marttila et al. 2004; Hersleth et al. 2005; Kihlberg et al. 2005; Battochio et al. 2006; Flander et al. 2006; Katina et al. 2006; Kihlberg et al. 2006; Annett et al. 2007; Curic et al. 2008; Heenan et al. 2008; Lassoued et al. 2008; Hayakawa et al. 2010; Jensen et al. 2010; Elia 2011). Most of these studies were recently mentioned in a review of descriptive sensory analysis of breads in developing a standard method for sensory analysis of bread (Callejo 2011). These DA bread studies described the bread using some or all of the following sensory characteristics: flavor (sensations perceived by tongue, mouth, throat, and nose when food is consumed); taste (sensation perceived by taste buds as sweet, sour, bitter, or salty); aroma (sum of odors and feelings perceived through sniffing food); aftertaste (flavor factors perceived in the mouth and nose after food has been swallowed); and texture (geometric and surface attributes of the product perceived by mechanical, tactile, visual and auditory receptors) (International Organization for standardization 1981).

Based on the aforementioned studies, there are numerous bread studies in the literature that characterized whole grain/whole meal breads using DA (Hellemann 1987; Hellemann 1988; Johnson & Vickers 1991; Chang & Chambers 1992; Haglund 1998; Murray et al. 2002; Shogren et al. 2003; Kihlberg et al. 2004; Hersleth et al. 2005; Battochio et al. 2006; Flander et al. 2006; Annett et al. 2007; Jensen et al. 2010; Challacombe et al. 2011). Of the whole grain bread studies, seven studies included panelists who developed a sensory lexicon to profile the breads (Hellemann 1987; Chang & Chambers 1992; Haglund 1998; Murray et al. 2002; Kihlberg et al. 2004, 2005; Hersleth et al. 2005; Jensen et al. 2010; Elia 2011) while the other studies used a previously developed lexicon (Shogren et al. 2003; Flander et al. 2006; Annett et al. 2007). Important attributes from some of these studies were used and adapted for DA of the whole grain breads in the proposed research studies (Caul and Vaden 1972; Hellemann 1987; Hellemann 1988; Chang & Chambers 1992; Lotong et al. 2000; Murray et al. 2002; Kihlberg et al. 2004). Most of the DA whole grain bread studies examined specific laboratory made breads using specific techniques. Three studies examined commercially made breads: to determine differences in sensory, nutrition and usage features (Johnson & Vickers 1991); to compare the perceptions of bread by consumers to a trained panel (Hersleth et al. 2005); and to understand sensory characteristics of popular breads in Australia (Murray et al. 2002).

Hellemann et al. (1987) used DA and direct similarity assessment (degree of similarity between samples) to evaluate 32 types of rye breads that included whole meal rye breads. Panelists (n = 20) developed a lexicon to describe the appearance, texture (by appearance and touch), odor, taste, and oral texture of the crumb and crust of rye breads. Texture was the most discriminative attribute between the samples and the intensity of sour for the crust was the largest difference between subjects. The most important discriminatory dimensions were the following attributes: pleasant rye-like to unpleasant flour-like; sweet to bitter; and the presence or absence of a characteristic flavor caused by specific baking conditions. This study established a method for quality control of rye breads.

The same researchers used flavor profiling to describe five different whole meal (sour) rye breads with varying levels of sourness (Hellemann et al. 1988). Fourteen men rated the intensity of odor (sweet, sour, rye-like, overall intensity), taste (sweet, salty, sour, bitterness, flour-like, rye-like, overall intensity), and overall desirability based on an unstructured scale. The researchers examined and compared the sensory sourness to the chemically analyzed acidity (acetic and lactic acid) among the whole meal sour rye breads. The most significant difference in variation among the rye breads was with sourness in taste and odor which is related to the addition of acetic acid. While sweetness of odor showed the smallest variation among the whole meal sour rye breads.

Johnson and Vickers (1991) had 20 subjects rate the intensity of 42 different attributes (e.g. overall flavor, sour flavor, moist, freshness) for 26 different commercial bread products (bagels, cornbread, pita bread, rolls, 100% whole wheat breads, etc.). The top two principal components were characterized as having richness and a nutrition/fiber dimension. The whole wheat breads represented a high nutrition/fiber bread that was low in richness (flavor, fat content, and moistness), and refined grain bread was low in nutrition, fiber and richness.

Chang and Chambers (1992) established flavor profiles of 100% refined grain pan breads and 100% whole wheat pan breads made with hard red wheat (HRW) and hard white wheat (HWW). Flavor differences were made between the two breads. Attributes were rated on a four-point intensity scale for aroma, flavor, and aftertaste of the crumb and crust. The hard red wheat and hard white whole wheat breads had similar flavor characteristics: (crumb) burnt, toasted, brown, grain-like, sour, salty, bitter; (crust) grain like. However, there were differences in the appearance and intensity of the flavors.

Haglund et al. (1998) used DA to determine differences in taste between whole meal bread samples in regards to kneading intensity (low and high) and farming systems (ecological and conventional). After development of the lexicon, four subjects rated the attributes (appearance, flavor, texture, aroma, and mouth feel) for each bread sample on a continuous scale. There were many differences between the kneading intensity and farming systems used among the bread samples. The first principal component for the sensory attributes included elasticity, color and dryness and the second principal component had an aromatic dimension.

Murray et al. (2002) had 15 Australian assessors develop a lexicon to describe the appearance, aroma, flavor, texture and aftertaste of eight commercial breads (white sandwich breads, whole meal breads and rye breads). Principal components were used to characterize breads. There were significant differences between the breads for 17 attributes except for the salty flavor. PCA results showed that the whole grain bread sample scored higher for flavor and aroma attributes than the refined bread. This study established a sensory lexicon for describing commercial breads in Australia.

Shogren et al. (2003) used DA to analyze the effects of ingredient level on the sensory properties (flavor and texture) of 10 whole wheat/soy flour breads using a 15-point scale. The 10 trained panelists rated the bread samples in replicate with varying amounts of whole wheat flour and soy flour (0-40%). The whole grain bread was described as having the highest grainy flavor. Substitution of whole wheat flour for white flour resulted in less bitter tasting bread. Bread containing up to 30% soy flour can yield a similar beany and bitter flavor rating as the control whole wheat bread. The reduced beany flavor could have been influenced by the amount of sugar and ascorbic acid.

Kihlberg et al. (2004) used a descriptive sensory analysis to investigate the influences of farming systems (organic and conventional), milling and formulations on the sensory qualities of 48 whole wheat pan breads. There were six bread samples with two milling techniques (roller- and stone-milled), two flour levels (organic and conventional), and two kneading levels for each. Once the lexicon was developed, eight subjects rated the intensity of 19 sensory attributes on a continuous scale that described the appearance, flavor and texture. Principal component analysis showed that milling techniques resulted in the greatest difference between attributes intensity ratings. There were more sensory qualities reported for the organic breads compared to the conventional bread samples. Whole meal breads from the roller-milled wheat were described as sweet, juicy and compact, while the stone-milled whole meal bread was described as being salty and deformed, and having roasted-cereal attributes. The organic breads were reported to have large sensory attribute variation compared to the conventional bread.

Hersleth et al. (2005) compared untrained consumers' perception of seven commercially available Norwegian breads (white rolls, focaccia, whole grain bread, French bread, dark-rye bread, ciabatta and whole grain rolls) by the repertory grid method (RGM) to the descriptive attributes provided by a trained panel. The RGM involves presentation of a triad of samples and the consumer describes the similarities and differences between the samples. Descriptive sensory profiling of the appearance, flavor, texture and odor was described for the crumb and crust of the breads using a continuous, non-structured scale. For the untrained consumers PC1 was related to the texture (hard, crispy, dry, airy versus compact); and PC2 was related to the salty and sweet flavor. Appearance of the breads was not very important. For the trained panel PC1 related to flavor and odor (wheat flour flavor/odor by rye flour flavor/odor), while PC2 was related to the juiciness and stickiness of the crust, spicy flavor and odor. Overall, the consumers' perceptions of the breads were similar to the trained panel. Both panels used similar description of texture.

Quantitative descriptive analysis was conducted to describe sensory properties of three commercial whole wheat breads (labeled A, B, C), two of which were whole wheat breads (Battochio et al 2006). The panelists (n = 11) described the breads using 18 attributes. Principal component 1 and 2 made up 81.6% of the variance. Given the tables and figures in the paper are reported in Portuguese the results described will be limited.

Each sample had a unique characterization. Sample C was described to have a burned skin aroma, fermented flavor, and the second bread was described to have a residual fermented flavor and moisture.

Flander et al. (2006) examined the effects of gluten and water content, dough mixing time, proofing temperature and time, and baking conditions on loaf volume for whole meal oat bread with good quality, high whole meal and beta-glucan content. Five panelists rated the attributes intensities of flavor, texture and mouth-feel on a verbally anchored intensity scale. Response variables included instrumental crumb hardness, sensory texture, mouth feel and flavor. Partial least squared regression showed that water content, gluten, and proofing conditions affected the volume and hardness of the oat bread. Ingredients (gluten and water) had an effect on the sensory crumb properties and processing conditions (baking temperature) affected the crust properties and richness of crumb flavor.

Annett et al. (2007) used DA to compare the attributes of color, texture, taste and aroma for bread baked with organic and conventionally produced wheat grain (60% whole wheat breads). A commercial whole wheat bread was included as an experimental comparison to 60% whole wheat breads that are available in the Canadian market. Nine panelists used 14 descriptive attributes to describe the breads. There were no differences in flavor, aroma or color attributes among the commercial and conventional breads ($P>0.05$), however the visual surface texture and density was greater for the organic bread compared to the conventional and commercial breads.

A recent study used DA to examine the effect of prolonged shelf life on the sensory profile of wheat and whole wheat breads (Jensen, Oestdal and Thybo 2010). Study objectives explored the effect of the extended storage time (four months apart) on the sensory profile of breads and evaluate the reliability of the results (variation between assessors and with different batches of wheat flour). Whole wheat breads had a larger variation in sensory profiles with the change in storage time as compared to wheat breads, especially for the aroma-related attributes. The change in storage time had no effect on the sensory panel's ability to discriminate samples of breads. Extended shelf life affected aroma and flavor of both breads. Given large differences in the sensory profile of both breads with respect to the storage time this would imply more research is needed to help prevent these differences since manufacturers best before due dates should last two weeks without noticeable changes.

Use of various ingredients, types of bread products, milling and baking techniques, and attributes intensity rating scales all contribute to differences in the characterization of breads. Currently there are no published American studies that characterized 100% whole grain breads that are available to the U.S. general population. Therefore it would seem prudent to undertake DA of currently available commercialized whole grain breads in the U.S. marketplace. The proposed study will provide a descriptive profile of commercial 100% whole grain breads.

Descriptive analysis and liking of breads

Examining descriptive attributes and liking ratings of whole grain bread could provide a basis for selecting sensory characteristics that help optimize whole grain bread products. Several bread studies examined descriptive attributes and liking ratings of breads (Heinio et al. 1997; Carson et al. 2000; Kihlberg et al. 2005; Challacombe et al. 2011). Only one of these studies examined associations between descriptive attributes and liking ratings to understand which sensory characteristics contribute to consumers' liking of breads (Challacombe et al. 2011).

Heinio et al. (1997) examined the impact of four sour rye bread recipe variables (wheat to rye flour ratio, bread acidity, ash content (rye flour and sodium chloride), and bread type) and sensory attributes on overall acceptance. The two types of breads included in the study were sour-soft rye bread and sour-crisp rye bread. Subjects rated the attributes intensities (sour, salty, rye-like flavor) on a nine-point scale; general expectations of rye corresponding to color, appearance, odor, taste and texture; pleasantness ratings and purchase intention (acceptance) were rated on 9-point hedonic scale. Expectations of rye bread were highly dependent upon the acidity and ash content. The sodium chloride content had no impact on consumer expectations. Acceptance was affected by ash content, the interaction of sodium chloride content x acidity and wheat: rye ratio x ash content. Rye-like and sourness increased with expectations. The content (ash or acidity) influenced identity but not acceptability. Sodium chloride content had no influence on acceptability when bread acidity was high. There was no comparison between acceptance ratings and sensory attributes.

Carson et al. (2000) had six trained panelists profile the flavor, aroma, and texture of 50% sorghum composite bread and a commercial rye bread for comparison using an unstructured line scale. Untrained panelists (N = 37) also rated the acceptability of the breads (crumb and crust) on a 9-point hedonic scale. Results from the descriptive panel analysis showed that sorghum bread was described as having a toasted grain and hay-like aroma and the crumb and top crust flavors were described as having slight sourness and astringency. Textures were different between the sorghum and rye breads. Breads containing up to 50% sorghum flour was acceptable in taste, however breads made with 30% sorghum flour or less were liked less. The results for descriptive testing and acceptance tests were not correlated for analysis.

Kihlberg et al. (2005) examined sensory characteristics and liking ratings of four different wheat breads in combination with product information (flour, health effects, and with neophobic information). The four breads consisted of conventional, organic, organic amaranth, and conventional amaranth. Six assessors rated the intensity of 12 attributes (appearance, aroma, texture by finger, mouth feel and flavor) from low to high on an unstructured line scale. The acceptance test (overall liking) was completed by 480 consumers. The first principal component described the aroma and flavor attributes (wheat and cereal aromas; wheat, cereal, earthy and astringent flavors, and earthy aroma). The second principal component described the texture attribute (juiciness). Breads with amaranth had an earthy aroma and earth and astringent flavors. White conventional and organic breads had wheat and cereal flavors. There were significant differences in liking of the four breads. When information on organic production was provided liking ratings were highest. Organic production had a greater effect on liking than other types of information. This study did not examine correlations between sensory attributes and liking of the breads.

A recent study examined the sensory characteristics of 100% whole grain breads made from commercial whole red and white wheat flours- with fine or coarse bran partical sizes (red fine bran, red coarse bran, white fine bran, and white coarse bran)

(Challacombe et al. 2011). The whole wheat breads and a control refined wheat bread were characterized using descriptive analysis for crumb and crust by a trained panel (N = 13). Consumer acceptance tests were conducted with 73 untrained participants who rated overall liking, appearance liking, flavor liking, texture liking, and the strength of aftertaste. The control bread was perceived to have a more yeasty flavor intensity than the four whole grain breads and sweeter than the white coarse crumb. There were sensory differences in the whole grain breads with small or large bran particle sizes. Results from the acceptability test showed that the red wheat breads were liked more for appearance, flavor, texture and overall liking compared to the white wheat breads. Liking of the breads was not affected by the bran particle size. The descriptive analysis liking data were correlated with the liking data by partial least square regression to determine which attributes influenced liking of the breads. The first cluster of subjects who liked whole grain products was associated with wheat, malt, molasses and astringent characteristics of the breads. The second cluster preferred refined bread and were associated with yeasty and salty flavor of the crust.

Three of the previously mentioned studies did not examine correlations between the sensory attributes and liking ratings of breads. However these studies identified attributes that contributed most to subjects' expectations. Only one study determined sensory attributes that described well-accepted whole grain bread that was also liked by consumers (Challacombe et al. 2011). There were no studies that examined if bitter taste of whole grain breads affect liking. Thus, the question remains as to whether the bitter tasting breads are liked less. Based upon previously mentioned food-related studies that found bitter foods to be liked less, we hypothesize that the bitter tasting whole grain breads will be liked less. Examining both sensory attributes along with liking ratings can allow for better understanding of positive and negative attributes of bread. This can ultimately lead to improvement in liking of whole grain breads.

Table 2.1 Expanding the TRA* and TPB model to predict intention and behavior.

Author/Year	Foods	% Variance Intention	Additional Variable	% Variance Intention Extended	% Variance Behavior	% Variance Behavior Extended
White et al. 2010	Foods low in saturated fats	29	Planning Past behavior	- 33		
De Bruijn 2010	Fruit & vegetable intake	-	Affective attitude Cognitive attitude Habit strength	-	26	27 27 30
Wong et al. 2009	Breakfast consumption	53	Past behavior	76	-	-
De Bruijn 2008	Saturated fat	-	Affective attitude Cognitive attitude Habit strength	-	8	8 8 9
Brug et al.2006	Fruit consumption	44	Pros, cons, self-efficacy & habit	49	36	39
Mahon et al. 2006	Ready meals and takeaway meals	0.6 0.6	Habit strength	26 27	43 15	46 16
Kvaavik et al. 2005	(For men, women) Whole grains Fruit & vegetables Fat Sugar	-	Demographics/ Baseline Eating behavior	-	0, 5.4 1.6, 8.4 2, 6.6 2.2, 1.5	1.3, 8.7/6.6, 17.1 0.8, 11.2/9.3, 20.1 2.9, 7.1/3.9,7.1 3.2, 1.2/ 13.9,7.1
Verbeke & Vackier 2005	Fish consumption	31	Habit	52	42	44
Povey & Conner 2000	Low-fat diet Eat 5 portions of fruit and vegetables	64 57	Perceived need	70 68	19 32	-

Author/Year	Foods	% Variance Intention	Additional Variable	% Variance Intention Extended	% Variance Behavior	% Variance Behavior Extended
Arvola et al. 1999 (before tasting cheeses)	Novel cheese 1 Novel cheese 2 Familiar cheese 1 Familiar cheese 2	24 35 58 54	Neophobia/ Expected pleasantness	25/50 39/42 59/61 54/58	-	-
Saba et al. 1998	Skim, 1%, whole milk	50, 62, -	Survey liking Habit	-, -, 53 46, 50, 50	12, 35, 41	9, 45, 29
Sparks and Shepherd 1992	Organic produced vegetables	23	Self-identity Past behavior	27	-	-
Shepherd et al. 1991/1992*	1% flavored milk 2% flavored milk	41 34	Liking	46 39	-	-
Tuorila 1987*	Skim 1% 2% milk	35 18 36	Survey/ Liking	45/36 25/18 41/36	44 28 47	44/48 32/28 48/48
Tuorila-Ollikainen 1986 *	Low-salt bread (Beginning/ End)	19 38	Liking ratings	22 52	12 21	28 32

Chapter 3. Summary, objectives and hypotheses

Sara A. Sjoberg, MS

Summary, objectives and hypotheses

The review of literature demonstrates that consumption of whole grains is far below the recommended levels established by dietary guidance. Based upon observational and clinical research, consumption of whole grains may reduce the risk of some chronic diseases. Several studies identified behavioral and sensory barriers to consumption of whole grain foods. However, few studies have examined barriers to consuming a specific whole grain food such as bread. Research focusing on a specific whole grain food will provide a more comprehensive understanding of barriers. The following studies will identify factors that influence whole grain bread intake by examining behavioral and sensory factors that influence consumption.

Overview

This research project includes studies based on qualitative and quantitative methods. Chapter 4 describes the results of the first phase of this project. The purpose was to characterize commercial whole grain breads using descriptive analysis. Through multivariate principal component analysis, the numbers of attributes that describe the breads were reduced to obtain a subset of bread samples to be used in a subsequent study to determine liking of whole grain breads. Chapter 5 describes the results of the second phase of this project. The purpose of Part 1 was to develop and test a questionnaire based on the TPB that measures predictors of whole grain bread intake. In Chapter 5, Part 2 results of multiple regression analysis to determine the predictiveness of the TPB to explain whole grain bread intake were described. Finally in the last phase of this project, associating the bread consumer liking ratings with descriptive analysis sensory attributes allowed for determining which sensory attributes have an effect on bread liking. These results are described in Chapter 6.

The study objectives and hypotheses for each part of the project include:

Phase 1 (Chapter 4): Descriptive analysis of breads

Objective 1. To develop a lexicon that describes the taste, flavor, texture, appearance, aroma and aftertaste of 12 commercial 100% whole grain breads.

Objective 2. To reduce the data to a smaller data set using principal component analysis.

Objective 3. To characterize a range of commercial 100% whole grain breads.

Objective 4. To determine the most diverse breads described by principal component analysis that will be used in the bread liking study.

Chapter 5: Application of the Theory of Planned Behavior to intention to consume whole grain bread and estimated consumption

Phase 2 (Chapter 5, Part 1): Development and testing of the TPB questionaire

Objective 1. To develop a questionnaire based on the standard TPB constructs: attitude, subjective norms, perceived behavioral control and intention scales.

Objective 2. To determine re-retest reliability and internal consistency properties for the TPB scales.

Phase 2 (Chapter 5, Part 2): Application of an expanded TPB model to intention to consume whole grain bread and estimated consumption

Objective 1. Identify predictors of intention and consumption with respect to whole grain bread using the standard TPB constructs.

Objective 2. To assess the effect of including additional variables to expand the TPB to explain the variance in intention and consumption with respect to whole grain bread. Additional variables included mean liking rating of whole grain bread samples, whole grain versus refined grain bread preference, PROP rating, usual whole grain bread consumption pattern, demographic and personal characteristics.

Hypothesis: The additional variables will improve the predictive power of the TPB for intention and behavior.

Phase 3 (Chapter 6): Descriptive analysis and liking associations

Objective 1: To examine liking differences among the five 100% whole grain bread samples.

Objective 2. To determine if liking ratings of the whole grain breads were different by bread consumer group (whole grain versus refined grain bread preference), type of bread bag returned (whole grain bread or refined grain bread), and PROP taster status (nontaster, medium taster and supertaster) among the five whole grain bread samples.

Hypothesis: PROP tasters will like the breads less than PROP nontasters.

Objective 3: Determine cluster groups based upon mean liking ratings of bread and to examine if the clustered groups differed by liking of breads, psychosocial beliefs and whole grain bread intake.

Hypothesis: Differences will exist by cluster groups for liking and TPB variables.

Secondary Objectives

Objective 1. Examine which sensory attributes have an effect on liking of the five whole grain breads.

Hypothesis: The bitter tasting breads will be liked the least.

Chapter 4- Descriptive analysis of commercial 100% whole grain breads

Sara A. Sjoberg, MS

Despite the health benefits associated with whole grain foods, dietary intake remains far below the recommendation of at least 3 daily servings. Low intake could be related to the taste, flavor and texture of whole grains. The objective of this study was to determine sensory attributes of 12 commercial whole grain breads through the use of descriptive analysis (DA) that was conducted with nine trained panelists. A general linear model was used to examine significant differences of the sensory attributes among the bread samples and to examine the effects of sample, panelists, and replication on attribute ratings. Multivariate principal component analysis (PCA) was performed to further reduce the DA data and to identify a diverse subset of whole grain breads for use in a subsequent bread liking study. Panelists developed a lexicon consisting of 165 attributes that described the crumb and crust of the breads. Breads were significantly different for 126 of the 165 sensory attributes. In the PCA results of the DA data, 11 principal components were retained to describe 100% of the variance. The total amount of variance explained by the first two principal components was 42%. The biplot of the first two principal components demonstrated that Cub Foods and Natural Oven breads were the most diverse breads. Cub Foods bread was characterized by salty taste and aftertaste, uncooked flavor and aftertaste, and gummy and squishy oral texture. Natural Ovens bread was characterized by wheat germ aftertaste, cardboard flavor, brown aroma, moist appearance, and soft oral texture. Breads that showed the most variation, based on the score plot of principal component one and two included Cub Foods, Country Hearth, Natural Ovens, Pepperidge Farms, and Sara Lee breads.

Introduction

Consumption of whole grain foods is associated with reduced risk of chronic diseases (Jensen et al. 2004; De Munter et al. 2007; Mellen et al. 2007; Sun et al. 2010). Despite scientific, policy and regulatory support to consume more whole grains, dietary intake of whole grain foods remains far below recommended levels (O'Neil et al. 2010). Various factors influence consumers' decisions to consume whole grains such as limited availability in the marketplace and higher cost (Kantor et al. 2001); personal factors include difficulty in identifying a whole grain food product, limited knowledge of health benefits and preparation methods, and additional time and effort required to read food labels (Britten et al. 2006; Larson et al. 2010). Cited sensory barriers to consuming whole grain foods among adults include the dislike of taste, color, and texture (Adams and Engstrom 2000; Bakke and Vickers 2007). Whole grain breads are one of the most frequently consumed whole grain food products among Americans (Cleveland et al. 2000; Lang et al. 2003; Bachman et al. 2008). There is plenty of opportunity for refined grain bread consumers to gradually shift to breads with higher whole grain content (Keast et al. 2011). Thus, there is a need to identify sensory profiles of whole grain breads that more closely meet consumer expectations. Characterizing commercial whole grain breads and determining what attributes differentiate these breads may be a first step in developing a more palatable whole grain bread for the general adult population. This is reinforced by the fact that there are no known published studies to address these analyses in commercial whole grain breads.

Descriptive analysis (DA) is a method used to describe the sensory attributes of foods (Lawless and Heyman 1999). Several studies included DA to characterize whole grain/whole meal breads (Hellemann 1987; Hellemann 1988; Johnson & Vickers 1991; Chang & Chambers 1992; Haglund 1998; Murray et al. 2002; Shogren et al. 2003; Kihlberg et al. 2004; Hersleth et al. 2005; Battochio et al. 2006; Flander et al. 2006; Annett et al. 2007; Jensen et al. 2010; Challacombe et al. 2011); refined grain breads (Caul & Vaden 1972; Huang et al. 1995; Gambaro et al. 2002; Salmenkallio-Marttila et al. 2004; Kihlberg et al. 2005; Kihlberg et al. 2006; Curic et al. 2008; Heenan et al. 2008; Lassoued et al. 2008; Hayakawa et al. 2010; Elia 2011); sorghum bread (Carson et al.

2000); sour dough breads (Lotong et al. 2000; Katina et al. 2006); specialty breads (Heenan et al. 2008); and rye breads (Hellemann et al. 1987; Hellemann 1988; Murray 2002). Based on these studies whole grain breads were characterized through the use of DA with the following attributes: ***flavors***- bitter, grainy, sour, yeasty, sweetness, molasses, malt, juiciness, saltiness, roasted cereals, cereal, rancid, and sickly sweet; ***aromas***- yeasty, toasted, brown burnt crust, wheat, burnt, cereal, chemical acid, cocoa, and sourdough; ***aftertaste***- burnt, and bitterness of crust; ***texture***- dense, deformity, crispness, hard, elasticity, and dryness; and ***appearance***- compactness, and color intensity. Most of these bread studies established general sensory attributes and definitions that are appropriate for describing bread, however the various methods, types of bread, vocabulary, and taste references makes it difficult to compare the descriptive sensory results to other bread studies. Many studies were limited by the use of various ingredients, processing conditions, and shelf-life of breads. A recent review by Callejo (2011) reported a lack of a standard method for sensory evaluation of bread in comparison to other foods (e.g., wine) that have a standard method. Since data is limited on descriptive analysis of commercial whole grain breads there is a need to expand the sensory profile of bread products to commercial whole grain breads that are available to consumers in the U.S. Determining the sensory attributes of whole grain breads will allow for the characterization of breads and the ability to compare and contrast bread samples based on important attributes such as bitter taste.

The objectives of the study were to 1) characterize the sensory attributes of 12 commercial whole grain breads and 2) select a diverse subset of these breads for use in a subsequent bread liking study.

Materials and methods

Products

During the fall of 2006, 12 whole grain breads were selected from a Midwestern grocery chain to serve as a representative sample of whole grain breads available within the Minneapolis/St. Paul metropolitan suburban area (Table 4.1). These breads were representative of the available commercial 100% whole grain breads. The bread samples were purchased within 48 hours of consumption, and were prepared less than 24 hours before tasting. End pieces and any bread slice containing large air pockets were discarded. Each bread slice was vertically sliced in half. A half slice of bread was placed and sealed in a Ziploc® sandwich bag, and coded with a three-digit random number.

Panelists

A total of nine University of Minnesota undergraduate and graduate students (4 females and 5 males) between the ages of 18 - 40 years were recruited based upon availability to participate as panelists in the 4-month DA study. All panelists completed on average 20 hours of training and received monetary compensation for participating. This study was approved by the University of Minnesota Institution Review Board.

Sensory panel training

During orientation and training, panelists were provided with a vocabulary list based upon lexicons developed from previous bread studies in order to become more familiar with sensory attributes that describe bread. The procedures used for the development of attributes, definitions and a final lexicon were adapted from previous bread studies that used DA to characterize breads (Caul & Vaden 1957; Hellemann et al. 1987; Chang & Chambers 1992; Lotong et al. 2000; Murray et al. 2002). Panelists wrote down words (attributes) that described each of the 12 breads including: taste, flavor, aroma, appearance, aftertaste, and oral texture. Panelists then described each of the breads as a group and all attributes were recorded by the investigator. During this vocabulary refinement phase panelists discussed new attributes not found on the vocabulary list. Panelists eventually decided as a group to examine the top and bottom crust separately as in other bread DA studies (Caul & Vaden 1972; Johnson and Sanchez 1973; Hellemann et al. 1987; Chang & Chambers 1992; Lotong et al. 2000; Hersleth et al. 2005; Flander et al. 2006; Heenan et al. 2008). Reference standards were presented during practice sessions to familiarize panelists with terms and to calibrate the panelists with the use of each attribute (not available).

Development of sensory lexicon

Panelists compared attributes among all 12 bread samples to learn how to differentiate among some of the more difficult attributes, such as sour taste. Several attribute names were eliminated in this phase due to redundancies. Training-sessions were conducted until the group unanimously decided upon a final lexicon for each of the attribute categories (taste, flavor, aroma, appearance, aftertaste, and oral texture) that described all 12 breads for both crumb and crust (top and bottom).

Trial sessions

During the next phase, panelists were trained to understand and examine all 12 whole grain breads for each of the attribute categories (taste, flavor, aroma, appearance, aftertaste, and oral texture) for both the crumb and crust (top and bottom). Panelists used the lexicon to initially help with familiarization of terms and definitions while rating the attributes. The trial sessions were completed in sensory laboratory booths. Filtered water was provided for rinsing between the tasting of bread samples. The intensity of the attributes for all 12 bread samples was rated randomly in duplicate by placing a vertical line on the score sheet. The line scale was 15 cm in length and the end points were labeled "none" to "extreme" for most attributes. The exceptions included some aroma, appearance and oral texture attributes. Scales for these attributes were labeled, for example, by level of toasted aroma- "toasted" ….to…."burnt". Panelists who had similar mean attribute ratings for all the breads or had mean differences greater than five for each attribute between the replicated ratings received additional feedback and training. These training sessions were conducted until all panelists were able to discriminate each attribute among all samples, and give similar replicated ratings for each attribute.

Descriptive analysis of bread samples:

During the final DA sessions, panelists assessed the bread samples in replicate on different days similar to the methods used in the training sessions for all of the attribute categories (taste, flavor, aroma, appearance, aftertaste, and oral texture). Randomization of bread samples for each panelist was generated by a random numbers table. Approximately 18 sessions were held to examine the 12 whole grain breads for all attribute categories and replicated ratings. Panelists first rated the crumb and then the crust of the bread sample before moving onto the next bread sample. In session 1, panelists rated the aroma and appearances for samples 1-4; for session 2 samples 5-8, for session 3 samples 9-12. In session 4 taste, flavor and oral texture were rated for samples 1-4; session 5 samples 5-8; and session 6 samples 9-12. In session 7, panelists rated the aftertaste for samples 1-4, for session 8 samples 5-8, session 9 samples 9-12. These methods were repeated for the replicate ratings of the same bread samples 1-12 for session 10-18. After a break of 30 minutes panelists could return to evaluate four more bread samples.

Data analysis

Data were compiled using SIMS 2000 (Sensory Computer Systems, Morristown, N.J., USA) and analyzed using Statistical Analysis System (SAS, version 9.1, Cary N.C). Attribute intensity ratings were determined by measuring the distance of the scored vertical line from the left end of the line in units of 0.1 cm. Descriptive statistical measures (means and standard deviations) were determined for all attributes. Analysis of variance using a general linear model (GLM) procedure was used to examine significant differences for each attribute among all 12 bread samples. Tukey's honest significant difference post-hoc multiple comparison tests were run, while using the lines option, for displaying the multiple comparison results of the attributes among the bread samples ($p \leq 0.05$). To determine which attributes were significantly different across breads samples, "bread sample" was the predictor variable and was a fixed factor and attribute ratings were the response variable. A general linear model (GLM) (PROC GLM attribute rating = bread sample + panelist + replication + bread sample x panelist + bread sample x replication + panelist x replication) was used to determine if there were significant differences in attributes ratings with bread sample, panelist, replication and its interactions. Panelists were a fixed factor rather than a random factor since the panelists were considered to be a well trained instrument. Consistency of the panelists was measured by including "panelist" in model. To determine if replication was a source of variation, "replication" was included in model. Replication was also included as a random factor in the model to determine if replication accounted for variance for each attribute. To examine the consistent use of the attributes by panelists and sample "bread sample x panelist" interaction was included in model. Significant differences indicated that the attributes for the bread sample were not rated similarly by all panelists. To examine if the attributes for each bread sample were not rated the similarly for the replicated ratings, "bread sample x replication" was included in model. Including the interaction “panelist x replication” in model allowed for examination of whether the attributes rated by each panelist were rated the same for each replicated rating.

Multivariate principal component analysis (PCA) (PROC PRINCOMP) was applied to the mean attribute scores (taste, flavor, aroma, appearance, aftertaste, and oral texture) to assess relationships (sources of variation) among the average attribute ratings of the breads (Piggott and Sharman 1986). PCA allowed for classification of 12 whole grain breads based upon the sensory characteristics. Information from PCA allowed for describing the breads that were similar or different in a summary form. PCA was applied to the 12 bread samples by 126 bread attributes. Principal components (PCs) represented the scores for the bread samples and of the loadings (distribution of the attributes), and allowed for summarization of the attributes. The important PCs were determined by the Scree test (Cattell 1966) and by the Kaiser criterion (eigenvalue > 1) (Massart et al. 1988).

Results

A sensory lexicon was developed for the description of commercial 100% whole grain breads. Of the 165 attributes used to describe the bread, 65 attributes described the crumb and 100 attributes described the crust. The following attributes were identified for each category of the crumb: (4 taste), (12 flavor), (14 aroma), (8 appearance), (4 taste aftertaste), (12 aftertaste), and (11 oral texture); and of the top crust: (4 taste), (10 flavor), (9 aroma), (7 appearance), (4 taste aftertaste), (10 aftertaste) and (9 oral texture); and of the bottom crust: (4 taste), (8 flavor), (9 aroma), (4 appearance), (4 taste aftertaste), (9 aftertaste) and (9 oral texture).

The mean values, standard deviations and ANOVA p-values for all attributes are shown in table 4.2. A total of 36 of the 165 attributes that described the 12 whole grain breads were not significantly different across the breads; and three attributes were missing data and were not included in the PCA (Table 4.2). The three attributes with missing values (graintopshapstap, graintopszstap, and oattopszstap) was a result of some breads not having grains or oats on the top crust. Panelist was significantly different ($p \leq 0.05$) for all but four attributes (Table 4.3). Replication was a source of variation for 38 attributes ($p \leq 0.05$). The interaction of bread sample by panelist ($p \leq 0.05$) was significant for 86 attributes ($p \leq 0.05$). A significant bread sample x replication interaction was found for 14 attributes. A significant panelist x replication interaction was found for 82 attributes.

Principal component analysis

According to the scree plot, the data were reduced down to 11 PCs that accounted for 100% of the total variance. The bread scores that were determined from PCA explained which bread samples differentiated from one another according to the sensory attributes for each PC (Table 4.4). The eigenvector loading scores represent the key sensory attribtes for describing each PC (Table 4.5). Table 4.6 summarizes the data that are displayed in tables 4.4 and 4.5 and displays the most positive and negative loading correlations of the attributes and bread sample scores for PC 1-11.

PC1 and PC2 accounted for 42% of the total variation of the original variables. PC1 describes the greatest amount of variance and PC2 accounted for the next largest part of variance. The highly positive and negative attributes for PC 1 and 2 will be first discussed for the crumb and then the crust (top and bottom) (Table 4.6). The loading correlations for PC1 and PC2, which represented the linear combinations of the set of sensory attributes that explain the distribution of the eigenvectors, ranged from 0.2-0.9. For the crumb, the first PC correlated highly positive with cardboard flavor, brown aroma, moist appearance, wheat germ aftertaste, cardboard aftertaste, and soft texture; fermented aroma, fermented aftertaste, squishy texture, and moist texture correlated highly negative with this component (Tables 4.5 and 4.6). For the crust, PC1 correlated highly positive with aroma intensity of bottom crust, thick appearance of top and bottom crusts, light and soft texture of top and bottom crusts and leathery texture of bottom crust; salty taste of top and bottom crusts, salty aftertaste of top and bottom crusts, and grain topping of appearance correlated highly negatively with this component. The first PC correlated highly positively with Natural Ovens bread and Cub Foods bread correlated highly negatively with this component.

For the crumb, the second PC correlated highly positive with air cell evenness and air cell size, salty aftertaste, grainy aftertaste, uncooked aftertaste; fermented flavor and sour aftertaste correlated highly negative with this component (Tables 4.5 and 4.6). For the crust, PC2 correlated highly positive with salty taste, flavor, and aftertaste of top and bottom crusts, grainy aroma and aftertaste of bottom crust, appearance of bottom crust (dull-shiny), and appearance of bottom crust surface (smooth-rough); toasted flavor of top crust, bitter aftertaste of top crust, sour aftertaste of bottom crust and springy texture of top crust correlated highly negative with this component. PC2 correlated highly positive with Cub Foods bread; and EarthGrains and Sara Lee breads correlated highly negative with this component.

Of the 12 commercial whole grain breads that were examined in the DA study, five of those whole grain breads were selected for a subsequent bread liking study based upon differences from PCA of the descriptive attributes of PC 1 and PC 2 (Figure 4.1). Based upon the diverse scores that were calculated from PCA of the DA data, the following five breads were selected: (Cub, Country Hearth, Natural Ovens, Pepperidge Farms, and Sara Lee). For PC 1 Natural Ovens bread had the most positive score and Cub Foods bread had the most negative score. For PC2 Cub Foods bread had the most positive score and Sara Lee bread had the most negative score. These three breads were located within top quadrants and bottom-left quadrant of the graph displaying PC 1 and PC 2 (Figure 4.1). Country Hearth bread was located in the middle of the PCA graph and had very low scores for PC 1 and PC 2. Pepperidge Farms bread was the last bread selected as a result of being in the top right quadrant and having a low positive score for PC 1 and a high positive score for PC 2. These five breads represented combinations of high and low scores on PC 1 and PC 2. The decision to limit the number of bread samples to five was to allow subjects in the next study to successfully taste and rate breads without causing carryover effects.

The data were analyzed to identify relationships between the bread samples and attributes using a biplot (Figures 4.2 and 4.3). Natural Ovens bread (crumb) was characterized by wheat germ aftertaste, cardboard flavor and aftertaste, brown aroma, moist appearance, soft texture, and oily flavor (Figure 4.2). Pepperidge Farms bread (crumb), which was in the same quadrant as Natural Ovens bread, was characterized by air cell size and distribution, grainy aftertaste and texture, and having large grain pieces. Cub Foods bread (crumb) was characterized as having a salty taste and aftertaste, moist, squishy, gummy and tooth packing texture, uncooked taste and aftertaste. Wonder bread was located in the same quadrant as Cub Foods bread. Wonder bread (crumb) was characterized as having a chewy texture, buttery and doughy aroma. Dutch, EarthGrains and Sara Lee breads were clustered together in the bottom left quadrant. These breads (crumb) were characterized as having a sour aftertaste, fermented flavor and aftertaste, bitter taste and aftertaste, and yeasty aftertaste. Country Hearth, Brown Berry Hearty and Natural breads, Healthy Choice and Bakers Inn breads were clustered together in the upper part of the bottom right quadrant and were characterized (crumb) as having musty flavor, honey flavor, sweet taste, sweet aftertaste, honey aroma, and spongy texture.

For the crust Natural Ovens bread was characterized by wheat germ aftertaste, light and soft texture, grainy, oily and nutty flavors (Figure 4.3). Pepperidge Farms bread (crust), which was in the same quadrant as Natural Ovens bread, was characterized by grainy flavor, aroma and aftertaste, color appearance of top (uniform-variable), surface appearance (smooth-rough) and crust appearance of bottom crust (dull-shiny). Cub Foods bread (crust) was characterized as having a salty taste, flavor and aftertaste. Wonder bread was located in the same quadrant as Cub Foods bread. Wonder bread (crust) was characterized as having a grainy aftertaste, moist and gummy texture. Dutch, EarthGrains and Sara Lee breads were clustered together in the bottom left quadrant. These breads (crust) were characterized as having a bitter flavor and aftertaste, moist and springy texture of bottom crust. Country Hearth, Brown Berry Hearty and Natural breads, Healthy Choice and Bakers Inn breads were clustered together in the bottom right quadrant and were characterized (crust) as having baked aroma and aftertaste, sweet and flavor, sweet, honey and caramel aftertaste, color appearance of top crust and gritty texture.

Discussion

The DA results demonstrate the complexity and wide range of sensory characteristics among the 12 commercial whole grain breads indicated by 165 attributes. The biplot of the breads and attributes demonstrate the diversity of the whole grain breads chosen for this descriptive analysis study. When examining the loading plot of PC 1 and 2, Cub Foods and Natural Ovens bread, which were on positive and negative ends of the

PC1 scale, differentiated the most and thus appeared to be the most diverse breads. The large differences between these two breads could be related to the different types of grains used. Cub Foods contained whole wheat flour while Natural Ovens contained a mix of whole grains (whole wheat and oats). Cub Foods bread was characterized by saltiness (taste, flavor and aftertaste), uncooked flavor and squishy texture, and Natural Ovens was characterized by nutty flavor and a high level of toast aroma in the crumb. Similar to results from a study that used DA to describe breads with added oats (Salmenkallio-Marttila et al. 2003), the Natural Ovens bread was described as having a springy, moist texture with a nutty flavor. These attributes also differed greatly between Natural Ovens and Cub Foods as seen in the biplot. Pepperidge Farms bread, which had oats on the top crust, was in the same positive loading plot quadrant as Natural Ovens bread and was described as having a nutty flavor, spongy and gummy texture. The addition of oats to Natural Ovens and Pepperidge Farms breads may explain why these breads were similar and differentiated from the other breads.

There were four breads (Healthy Choice, Country Hearth, BB Natural and Bakers Inn) that were clustered in the center of the biplot, are similar and were described as having a spongy texture. Clustering of these breads could be a result of the variation or contrasting attributes of the other breads and the low variation of attributes among these breads.

The PCA of attribute data described 42% of the variance for the first two PCs. The low level of variance could be a result of the panelists' inability to differentiate among the bread samples or their lack of motivation when rating the bread products (Lawless and Heymann 1999).

Attributes that were not significantly different among the bread samples were not included in PCA as no differences were observed between samples. Some of these attributes that did not discriminate between breads should be reassessed before use in future studies. Some of these terms may have been subjective rather than objective and had different meaning to each panelist (Lawyless and Heymann 1999). Significant sample by panelist interactions for some attributes could have resulted from redundancy and confusion between attributes such as cardboard flavor, nutty flavor, and brown aroma and if the bread samples had similar ratings for some attributes. Similarly in another study that used DA (Cliff et al. 1996), when comparing the bread sample x panelist interactions magnitude of difference (f-values) to the differences in attributes ratings among the samples the magnitude is small. Panelist and sample interaction is common even with trained panelists (Naes and Langsrud 1998). According to Chambers et al. (2004), a longer descriptive training period (120 hours) would be necessary to increase the ability to differentiate complicated attributes between samples. Perhaps in the present study training of panelists for more than 20 hours would have improved panelist ability to discriminate among less discernible attributes.

Conclusion

A lexicon was developed to describe the taste, flavor, aroma, appearance, aftertaste and oral texture of a wide range of commercial 100% whole grain breads. This enabled the ability to characterize these whole grain breads. PCA performed on the DA data allowed for reduction in the number of attributes used to characterize whole grain breads and for the selection of diverse breads that were used in a follow-up bread liking study. The biplot allowed for visual examination of the relationship between the bread samples and attributes for the first two principal components. Cub Foods bread was described as salty and Natural Ovens bread had a brown aroma and a wheat germ aftertaste. Researchers may be able to use the sensory attributes of these commercial whole grain breads and relate them to other whole grain breads available in the market. Future work is needed to further reduce the highly correlated attributes as this would simplify the training needed to accurately describe whole grain breads. Since the completion of data collection for this DA study, many 100% whole grain breads have been introduced into the marketplace. Future research should identify the sensory attributes that describe these newer breads, which include whole grain bread using white whole wheat flour; and other 100% whole grain breads that contain a variety of whole grains compared to breads made only with whole wheat flour. Use of descriptive analysis on these diverse commercial whole grain breads allowed for the sensory characterization that could identify important attributes for development of well-accepted and innovative whole grain bread products.

Table 4.1 Breads name, abbreviation, type, manufacturers name and address of the 12 100% whole grain breads used in the descriptive analysis study.

Breads*	**Bread Abbreviation**	**Bread type (100%)**	**Manufacturers Name**	**Address**
Bakers Inn	Bakers	Whole wheat	Bakers Inn	Kansas City, MO
Brown Berry Natural	BBnat	Whole wheat	Bimbo Bakeries	Horsham, PA
Brown Berry Hearty	BBHeart	Whole wheat	Bimbo Bakeries	Horsham, PA
Country Hearth	CH	Whole wheat	Supervalu	Eden Prairie, MN
Cub Foods	Cub	Whole wheat	Supervalu	Eden Prairie, MN
Dutch	Dutch	Whole wheat	Arnold Bread Bimbo Bakeries	Horsham, PA
EarthGrains	EG	Whole wheat	Sara Lee Inc.	Peoria, IL
Healthy Choice*	HC	Whole grain	Con Agra Foods	Omaha, NE
Natural Ovens*	NO	Whole grain	Natural Ovens Bakery	Manitowoc, WI
Pepperidge Farms	Pepp	Whole wheat	Pepperidge Farm Inc.	Norwalk, CT
Sara Lee	Sara Lee	Whole wheat	Sara Lee Inc.	Downers Grove, IL
Wonder	Wonder	Whole wheat	Interstate Bakeries	Kansas City, MO

Table 4.2 Descriptive analysis results from analysis of variance on 12 whole grain breads

CRUMB Attributes	**Cub Foods**	**BB hearthy**	**HC**	**Wonder**	**BB Natural**	**CH**	**Bakers Inn**	**Dutch**	**EG**	**NO**	**Pepp**	**Sara Lee**	**p-value**
TASTE													
Tbitter	1.72abc	0.80c	1.91abc	1.35abc	1.13bc	2.59a	2.12ab	2.46a	2.49a	0.67c	0.96bc	2.22ab	<0.0001
Tsalty	3.12a	0.35d	1.59bc	0.77cd	0.27d	1.88b	0.82cd	1.09bcd	0.58d	0.77cd	0.85cd	0.51d	<0.0001
Tsweet	0.61b	4.91a	0.53b	0.67bc	6.67a	1.01b	2.30b	0.98b	2.28b	0.63b	2.05b	0.88b	<0.0001
Tsour*	0.26a	0.22a	0.49a	0.34a	0.27a	0.24a	0.53a	0.34a	0.39a	0.33a	0.24a	0.58a	0.36
FLAVOR													
Fermented	1.06abc	1.28abc	1.06abc	1.21abc	1.48abc	1.27abc	1.39abc	2.22abc	2.71a	0.44c	0.69bc	2.46ab	0.001
Bitter	2.01abc	0.57d	2.06abc	1.32bcd	1.13cd	2.67a	2.12abc	2.52ab	2.69a	0.64d	1.07cd	2.49ab	<0.0001
Cardboard	0.47b	0.41b	0.89b	0.52b	0.60b	0.43b	0.33b	0.36bc	0.37b	2.21a	0.47b	0.24b	<0.0001
Coffee*	0.18a	0.21a	0.19a	0.20a	0.22ab	0.12a	0.12a	0.28a	0.30a	0.16a	0.12a	0.14a	0.84
Grainy	2.96cd	3.65bc	4.18ab	2.79cd	3.86abc	4.86a	3.52bc	2.81cd	2.72cd	3.07bcd	5.01a	2.27d	<0.0001
Honey	0.25f	4.12b	0.63ef	0.51ef	5.38a	0.99ef	2.53c	0.48ef	2.13cd	0.33f	1.49cde	1.12def	<0.0001
Molasses*	0.24a	0.62a	0.32a	0.23a	1.11a	0.41a	0.46a	0.22a	0.20a	0.35a	0.25a	0.26a	0.13
Musty	0.33b	0.26b	0.38b	0.36b	0.41bc	0.46b	0.31b	0.43b	1.19a	0.73ab	0.49b	0.43	<0.0001
Nutty	0.28cd	0.82bcd	0.72bcd	0.29cd	1.30ab	0.97bc	0.61bcd	0.23cd	0.44cd	0.91bc	1.97a	0.14d	<0.0001
Oily	0.48ab	0.37ab	0.71ab	0.31ab	0.75ab	0.61ab	0.39ab	0.26b	0.46ab	0.92a	0.56ab	0.31ab	0.0221
Uncooked	2.81a	0.49b	1.20b	0.41b	0.38b	1.38b	0.79b	0.94b	0.57b	0.31b	0.62b	0.56b	<0.0001
Oxidized	0.48ab	0.26a	0.36a	0.25a	0.52a	0.51a	0.30a	0.44a	0.42a	0.69a	0.69a	0.45a	0.01
AROMA													
Brown	1.18ab	1.28ab	1.69ab	1.49ab	1.33ab	1.23ab	1.31ab	0.84b	0.86b	2.58a	2.00ab	0.71b	0.005
Butter	1.16ab	1.52a	0.86ab	1.25ab	0.61b	0.94ab	0.86ab	1.12ab	1.17ab	0.60b	0.84ab	0.69ab	0.0072
Caramel	0.21ab	0.14a	0.32a	0.13a	0.16a	0.19a	0.13a	0.47a	0.34a	0.17a	0.29a	0.14a	0.45
Xfermented	5.00a	0.43c	1.04bc	3.18abc	3.63ab	2.71abc	1.41bc	4.74a	3.56ab	0.69c	1.34bc	2.43abc	<0.0001
Xgrainy	3.03abc	4.11ab	3.66abc	3.88abc	2.59bc	2.82abc	3.22abc	3.17abc	2.66bc	4.53a	4.45a	2.32c	<0.0001
Hay	1.40a	1.12a	1.42a	0.62a	1.92a	1.33a	1.18a	1.12a	1.44a	1.73a	2.07a	1.42a	0.12
Xhoney	1.05b	0.86b	2.73a	0.60b	0.32b	0.71b	1.82ab	1.54ab	1.88ab	1.06b	1.21ab	0.76b	0.0001
Xmolasses	0.35a	0.49a	0.64a	0.76a	0.52a	0.46a	0.27a	0.53a	1.23a	0.63a	0.46a	0.43a	0.55
Xoily	0.70ab	0.58ab	0.25b	0.45ab	0.66ab	1.14ab	0.46ab	0.51ab	0.48ab	1.41ab	1.53a	0.52ab	0.056
Sourdo	0.42a	0.14a	0.47a	0.47a	0.13a	0.71ab	0.39a	0.14a	0.43a	0.28a	0.14a	0.69ab	0.6
Levelar	1.83ab	2.60a	2.19ab	1.79ab	1.19b	1.92ab	1.53ab	2.11ab	1.22b	2.67a	2.47ab	1.19b	0.0003
Leveltoasted	0.44a	0.94a	0.77a	0.76a	0.68a	0.76a	0.68a	0.68a	0,62a	0.83a	0.97a	0.49a	0.13
Doughy	0.95ab	1.08ab	0.35b	1.33a	0.84ab	0.61ab	0.51b	0.74ab	0.43b	0.42b	0.31b	0.83ab	0.0003
Yeasty	0.56a	0.49a	0.44a	0.51a	0.45a	0.51a	0.38a	0.48a	0.40a	0.29a	0.23a	0.83a	0.28

CRUMB Attributes	Cub Foods	BB hearthy	HC	Wonder	BB Natural	CH	Bakers Inn	Dutch	EG	NO	Pepp	Sara Lee	p-value
APPEARANCE													
Moist	3.50c	5.40c	8.99b	4.25c	5.43c	5.28c	4.99c	4.51c	4.52c	12.78a	5.09c	5.88c	<0.0001
Grainpi	1.72de	3.17cd	1.51de	11.91a	7.15b	1.37de	3.86c	1.13e	1.63de	1.63de	13.03a	0.74e	<0.0001
Aircell	8.76bc	6.02cd	5.92cd	11.32ab	9.66ab	2.62e	3.00de	4.45de	4.69de	8.88abc	11.96a	3.18de	<0.0001
Grapiece	1.83bc	3.02b	2.29bc	6.39a	5.33a	1.13c	1.66bc	1.37bc	1.71bc	1.82bc	6.67a	0.90c	<0.0001
Texture	6.59bcd	4.68de	11.59a	8.69b	7.92b	2.08f	7.16bc	4.05ef	5.33cde	11.89a	7.29bc	1.80f	<0.0001
Overcol	2.89bc	2.63bc	3.46bc	6.02a	2.77bc	1.72c	3.32bc	1.54c	1.63c	2.87bc	4.17ab	1.49c	<0.0001
Aircellsz	7.96bc	5.04de	4.62def	9.00ab	9.18ab	2.93efg	3.91efg	2.89fg	4.23ef	6.47cd	10.35a	1.89g	<0.0001
Color	6.14de	3.21fg	11.48a	9.02bc	9.53b	3.93f	7.52cd	4.72ef	5.04ef	8.47bc	9.74ab	2.02g	<0.0001
TASTE AFTERTASTE													
Tbitteraf	1.37abc	0.70bc	0.62bc	1.73ab	2.04a	1.97a	1.69ab	1.82ab	2.05a	0.44c	0.72bc	1.84ab	<0.0001
Tsaltyaf	3.56a	0.45c	0.22c	1.88b	0.39c	0.62c	0.85bc	0.55c	0.28c	0.36c	0.94bc	0.39c	<0.0001
Tsweetaf	0.53bc	4.16a	5.23a	0.64bc	0.63bc	0.48c	1.31bc	0.44c	1.96b	0.24c	1.22bc	1.23bc	<0.0001
Tsouraf	0.21b	0.17b	0.28ab	0.17b	0.37ab	0.33ab	0.43ab	0.27ab	0.63a	0.18b	0.16b	0.38ab	0.002
AFTERTASTE													
Bitteraf	1.31abcd	0.62cd	0.86bcd	2.20a	1.78ab	2.16a	1.53abc	2.19a	2.29a	0.38d	0.76cd	1.94a	<0.0001
Saltyaf	3.53a	0.41c	0.28c	1.80b	0.54c	0.84bc	0.77c	0.58c	0.25c	0.33c	0.66c	0.48c	<0.0001
Sweetaf	0.64b	4.40a	5.42a	0.72bc	0.81b	0.64b	1.76b	0.46b	1.76b	0.23b	1.49b	1.33b	<0.0001
Souraf	0.17b	0.17b	0.24ab	0.24ab	0.21ab	0.31ab	0.44ab	0.23ab	0.53a	0.29abc	0.15b	0.36ab	0.01
Cardboardaf	0.45b	0.24b	0.29b	0.49b	0.74b	0.82b	0.52b	0.36bc	0.42b	2.23a	0.41bc	0.24b	<0.0001
Fermentedaf	1.48ab	0.44de	0.56bcde	0.84abcde	0.69abcde	0.52cde	0.49cde	1.42abc	1.53a	0.10e	0.38de	1.23abcd	<0.0001
Oxidizedaf	0.65a	0.28a	0.32a	0.47a	0.37ab	0.41a	0.51d	0.34a	0.26a	0.55a	0.52a	0.30a	0.35
Grainyaf	2.25cde	2.52bcd	2.49bcd	3.85a	2.79abc	1.97cde	2.17cde	1.52cde	1.23de	1.61cde	3.56ab	1.12e	<0.0001
Toastedaf	0.41a	0.44a	0.44a	0.34a	0.38a	0.41a	0.37a	0.36a	0.29a	0.45a	0.53a	0.33a	0.97
Uncookedaf	2.52a	0.57b	0.39b	2.36a	0.91b	0.63bc	0.65b	0.40b	0.52b	0.38b	0.74b	0.40b	<0.0001
Wheatgermaf	0.17b	0.48b	0.64ab	0.57ab	0.28b	0.51b	0.31b	0.16b	0.25b	1.19a	0.59ab	0.19b	<0.0001
Yeastyaf	0.39a	0.15a	0.11a	0.16a	0.21a	0.18a	0.47a	0.43a	0.60a	0.11a	0.22a	0.29a	0.04
ORAL TEXTURE													
Chewy	5.01abc	5.06abc	5.57abc	5.01abc	4.39bc	6.37ab	6.60a	4.49abc	4.15c	3.74c	6.33ab	4.24bc	<0.0001
Density	5.79cdef	4.56efg	6.43bcde	3.46fg	9.59a	8.73ab	7.77abcd	4.03efg	5.41def	9.84a	8.17abc	2.69g	<0.0001
Squishy	7.92a	4.36bcd	4.01bcde	4.34bcd	1.93de	6.43ab	5.43abc	5.01bc	3.46cde	1.42e	3.77bcde	4.09bcde	<0.0001
Moisture	10.28a	7.48b	8.26ab	7.22b	4.31c	8.88ab	8.12ab	8.48ab	7.39b	2.36c	7.36b	7.46b	<0.0001
Elastic	3.19bc	5.40ab	3.26bc	6.69a	2.29c	4.96ab	5.62ab	6.23a	4.11abc	2.31c	5.52ab	4.77abc	<0.0001
Gritty	0.49c	1.56c	4.13b	0.47c	1.62c	8.64a	4.78b	0.64c	0.82c	1.57c	9.03a	0.51c	<0.0001

CRUMB Attributes	Cub Foods	BB hearthy	HC	Wonder	BB Natural	CH	Bakers Inn	Dutch	EG	NO	Pepp	Sara Lee	p-value
ORAL TEXTURE													
Gummi	4.52a	1.64b	2.14b	1.72b	0.78b	2.45ab	2.81ab	1.55b	1.87b	0.68b	2.04b	1.63b	<0.0001
Softness	2.47ef	2.32ef	4.50bcd	1.94f	5.95bc	4.18cde	4.73bcd	2.28ef	3.43def	8.28a	6.28b	1.54f	<0.0001
Smooth	2.29f	2.63ef	5.72cd	1.80f	4.21de	8.09ab	6.74bc	1.68f	3.01ef	7.83ab	8.83a	1.65f	<0.0001
Spongy	1.94f	5.50abcd	3.79def	7.13ab	4.81bcde	2.58ef	4.41cdef	6.11abcd	5.83abcd	5.09bcde	7.02abc	7.82a	<0.0001
Tpacking	2.81a	1.42abc	1.49abc	1.19bc	1.02c	2.63ab	1.26bc	1.47abc	1.04c	0.71c	1.80abc	1.37abc	0.0001
CRUST Attributes													
TASTE TOP													
Tbitterstfl	2.82de	3.22cde	3.68bcde	5.98a	2.83de	3.65bcde	4.72abc	4.41abcd	4.37abcd	5.03ab	2.61e	4.92ab	<0.0001
Tsaltystfl	2.59a	0.32c	0.88bc	0.48bc	0.27c	1.33b	0.50bc	0.61bc	0.40c	0.28c	0.67bc	0.33c	<0.0001
Tsweetstfl	0.35c	1.94b	0.28c	0.22c	3.21a	0.38c	0.87bc	0.21c	0.97bc	0.33c	0.79bc	0.39c	<0.0001
Tsourstfl	0.13a	0.14a	0.25a	0.14a	0.31a	0.19a	0.22a	0.45a	0.26a	0.22a	0.16a	0.20a	0.45
FLAVOR TOP													
Bitterstfl	2.94cd	3.64bcd	4.02abcd	5.59a	3.15bcd	3.57bcd	4.82ab	3.90abcd	4.47abc	5.44a	2.33d	5.48a	<0.0001
Burntstfl	1.33f	4.00bcde	4.39abcd	6.45ab	3.19cdef	2.88def	5.26abcd	4.51abcd	3.52cdef	6.77a	1.89ef	5.63abc	<0.0001
Coffeestfl	0.34a	0.75a	1.29a	2.12a	1.05a	1.10a	2.08a	1.28a	1.21a	2.05a	1.01a	1.41a	0.05
Grainystfl	2.80abc	3.33abc	2.95abc	1.85bc	2.67abc	3.59a	3.14abc	2.42abc	2.12abc	2.00abc	3.46ab	1.72c	0.001
Molassesstfl	0.13a	1.03a	0.34a	0.75a	0.99a	0.39a	1.00a	0.17a	0.94a	0.34a	0.56a	0.48a	0.02
Oilsstfl	0.14a	0.15a	0.32a	0.22a	0.16a	0.34a	0.16a	0.28a	0.14a	0.48a	0.34a	0.27a	0.04
Oxidizedstfl	0.30ab	0.23b	0.35ab	0.21b	0.29ab	0.62a	0.41ab	0.50ab	0.37ab	0.30ab	0.26b	0.31ab	0.01
Saltystfl	2.66a	0.46bc	0.58bc	0.72bc	0.15c	1.21b	0.36bc	0.64bc	0.20bc	0.22bc	0.63bc	0.34bc	<0.0001
Toastedstfl	2.16b	4.38ab	2.63ab	3.48ab	3.92ab	3.50ab	4.57a	3.97ab	3.95ab	4.45ab	2.99ab	3.48ab	0.02
Uncookedstfl	0.15a	0.41a	0.11a	0.12a	0.12a	0.24a	0.14a	0.11a	0.13a	0.14a	0.10a	0.11a	0.53
TASTE BOTTOM													
Btbitterstfl	2.67abcd	1.20cd	3.27ab	2.69abc	2.93ab	1.98abcd	3.46a	2.71abc	3.20ab	0.98d	1.61bcd	2.58abcd	<0.0001
Btsaltystfl	2.37a	0.28c	0.99bc	0.67bc	0.41bc	1.38ab	0.59bc	1.07bc	0.61bc	0.41bc	0.81bc	0.66bc	<0.0001
Btsweetstfl	0.27d	2.91a	0.30d	0.56bcd	2.93ab	0.67bcd	1.44bc	0.61bcd	1.46b	0.32cd	1.10bcd	1.24bcd	<0.0001
Btsourstfl	0.13a	0.14a	0.57a	0.37a	0.21a	0.24a	0.38a	0.36a	0.26a	0.27a	0.23a	0.43a	0.06
FLAVOR BOTTOM													
Bbitterstfl	2.66ab	1.15cd	3.27ab	2.48abcd	2.57abc	2.36abcd	3.32a	2.63abc	3.16a	1.01d	1.24bcd	2.87ab	<0.0001
Bsweetstfl	0.27d	3.38ab	0.43d	0.69d	4.07a	0.89d	1.19cd	0.82d	2.27bc	0.51d	1.43cd	1.23cd	<0.0001
Btoastedstfl	2.11b	2.33b	3.53ab	3.84ab	4.83a	2.85b	4.80a	2.28b	3.74ab	3.04ab	2.56b	3.40ab	<0.0001
Bgrainystfl	2.46bc	2.82abc	2.98abc	2.43bc	2.99abc	3.14abc	3.27ab	2.14c	2.45bc	2.73abc	3.62a	2.27bc	<0.0001
Bsaltystfl	2.48a	0.28c	0.92bc	0.74bc	0.14c	1.43b	0.45bc	0.91bc	0.48bc	0.89bc	0.71bc	0.62bc	<0.0001

CRUMB Attributes	Cub Foods	BB hearthy	HC	Wonder	BB Natural	CH	Bakers Inn	Dutch	EG	NO	Pepp	Sara Lee	p-value
FLAVOR BOTTOM													
Bstarchystfl	0.37a	0.23a	0.18a	0.31a	0.27a	0.43a	0.33a	0.42a	0.35a	0.27a	0.27a	0.29a	0.83
Bdairystfl	0.21ab	0.19ab	0.16ab	0.14ab	0.13b	0.22ab	0.13b	0.16ab	0.32ab	0.40ab	0.21ab	0.18ab	0.04
Bnuttystfl	0.14b	0.33b	0.27b	0.18b	0.44b	0.71ab	0.40b	0.16b	0.32b	0.59b	1.36a	0.31b	<0.0001
AROMA TOP													
Intensitystar	4.53c	7.03a	5.39abc	5.02bc	6.02abc	6.64ab	5.88abc	5.97abc	4.81c	6.92a	5.44abc	5.83abc	<0.0001
Butterstar	0.81ab	1.76a	0.68ab	0.84ab	1.24ab	0.98ab	0.52b	1.01ab	1.05ab	0.70ab	1.03ab	1.02ab	0.05
Caramelstar	0.14a	0.82a	0.51a	0.26a	0.47a	1.06a	0.64a	0.26a	0.34a	1.05a	0.51a	0.88a	0.01
Grainystar	2.84a	2.97a	2.48a	3.09a	2.86a	2.29a	2.94a	2.92a	2.38a	3.08a	3.01a	2.37a	0.29
Sourdostar	0.19a	0.13a	0.21a	0.30a	0.16a	0.12a	0.20a	0.14a	0.23a	0.16a	0.14a	0.24a	0.72
Sweetstar	0.88a	0.81a	1.39a	0.83a	0.59a	0.50a	1.39a	0.76a	0.74a	1.01a	0.77a	0.88a	0.24
Doughystar	0.54a	0.14a	0.16ab	0.14a	0.17a	0.21a	0.14a	0.15a	0.11a	0.44a	0.24a	0.24a	0.11
Leveltoastedstar	2.69a	5.29a	4.65a	3.22a	4.21a	5.42a	4.02abc	3.38bc	3.33bc	4.40ab	4.06abc	4.12abc	<0.0001
Levelbakedstar	1.78e	6.67ab	4.94abc	2.13e	3.20cde	7.14a	4.55bcd	3.48cde	2.47de	4.57cde	2.04e	3.49cde	<0.0001
AROMA BOTTOM													
Bintensitystar	3.28b	3.92ab	4.95a	3.48ab	4.51ab	4.15ab	4.47ab	3.44ab	4.15ab	4.78ab	4.27ab	4.29ab	0.01
Bbutterstar	0.55a	0.91a	0.79a	0.49a	0.66a	0.60a	0.63a	0.79a	0.62a	0.56a	0.72a	0.64a	0.48
Bcaramelstar	0.17a	0.24a	0.18a	0.14a	0.47a	0.41a	0.18a	0.17a	0.26a	0.22a	0.16a	0.38a	0.34
Bgrainystar	2.23abc	2.39abc	2.32abc	2.52abc	2.04abc	1.83bc	2.03bc	1.83bc	1.62c	2.94a	2.64ab	1.81bc	0.0004
Bsourdostar	0.21ab	0.21a	0.25a	0.31a	0.14a	0.20a	0.18a	0.14a	0.30a	0.23a	0.15a	0.23a	0.87
Bsweetstar	0.66a	0.84a	1.34a	0.84ab	0.73a	0.76a	1.13a	0.83a	0.78a	0.75a	1.02a	0.67a	0.69
Bdoughystar	0.65a	0.39a	0.19a	0.72a	0.45a	0.27a	0.31a	0.48a	0.54ab	0.34a	0.29a	0.57a	0.28
Bleveltoastedstar	2.18ab	2.88ab	3.38a	2.43ab	2.44ab	2.87ab	2.50ab	1.67b	2.03ab	2.63ab	2.94ab	2.37ab	0.05
Blevelbakedstar	0.78b	1.31b	3.11a	0.69b	1.21b	1.96ab	1.81ab	0.77b	1.86ab	1.37b	1.18b	1.15b	<0.0001
APPEARANCE TOP													
Graintopstap	9.84bc	9.58bcd	6.95cde	10.98ab	6.61de	0.51f	13.16a	7.14cde	6.57e	.	0.59f	5.75e	<0.0001
Oattopstap	0.27b	0.25b	0.05b	0.17b	0.02b	0.01b	0.06b	0.01b	0.14b	0.02b	4.39a	0.01b	<0.0001
Graintopshapestap	5.56a	7.97a	7.95a	7.12a	5.08a	0.10b	5.88abc	7.67a	5.88a	.	1.82b	8.63a	<0.0001
Graintopszstap	1.82de	8.98a	7.96a	3.05cd	8.12a	0.11e	9.20a	5.53b	7.39ab	.	2.83d	5.29bc	<0.0001
Oattopszstap	2.06b	0.21c	.	0.45c	0.43c	.	.	.	0.65c	.	11.00a	.	<0.0001
Thicktopstap	3.42d	6.86b	5.74bc	4.98bcd	6.16bc	7.02ab	4.96bcd	4.45cd	5.78bc	9.16a	6.29bc	6.90b	<0.0001
Colortopstap	2.11bc	2.04bc	2.11bc	2.24bc	3.29ab	1.26c	2.08bc	1.91bc	3.82a	1.84bc	2.93ab	2.54abc	<0.0001
APPEARANCE BOTTOM													
Crustbottomstap	9.94a	7.45abc	7.83ab	3.31f	6.86f	7.19f	6.18bcde	3.41f	3.55ef	4.86cdef	6.37bcd	4.22def	<0.0001

CRUST Attributes	Cub Foods	BB hearthy	HC	Wonder	BB Natural	CH	Bakers Inn	Dutch	EG	NO	Pepp	Sara Lee	p-value
APPEARANCE BOTTOM													
Surfacebstap	7.38a	7.87a	6.39ab	7.18a	7.51a	7.95a	6.98a	4.87ab	3.36b	6.80a	6.44ab	5.55ab	0.0002
Thicknessbotstap	4.72bc	6.29abc	6.46ab	5.11bc	6.27abc	6.01abc	5.60abc	4.32c	6.11abc	7.17a	6.31abc	5.56abc	0.0004
Colorbotstap	3.27c	3.99bc	3.31bc	6.21ab	7.84a	4.89bc	5.06abc	4.29bc	2.97c	5.09abc	5.57abc	4.98abc	<0.0001
TASTE AFTERTASTE TOP													
Tbitterstaf	1.66d	3.68bc	2.74bcd	2.86bcd	3.56bc	5.71a	3.31bcd	3.52bc	3.43bcd	2.27cd	2.06cd	4.47ab	<0.0001
Tsaltystaf	2.08a	0.22c	0.24c	1.18b	0.28c	0.38c	0.31c	0.44bc	0.35c	0.21c	0.41bc	0.27c	<0.0001
Tsweetstaf	0.70c	1.69b	2.88a	0.45c	0.24c	0.29c	0.36c	0.21c	0.94bc	0.14c	0.62c	0.50c	<0.0001
TSourstaf	0.14a	0.12a	0.17a	0.17a	0.18a	0.11a	0.12a	0.14a	0.15a	0.15a	0.08a	0.19a	0.5608
AFTERTASTE TOP													
Bitterstaf	1.89d	3.59bc	2.81bcd	2.94bcd	4.01b	6.18a	3.79bc	3.54bcd	3.69bc	2.77bcd	2.20cd	4.34b	<0.0001
Saltystaf	2.57a	0.25c	0.23c	1.36b	0.36c	0.62bc	0.43c	0.29c	0.36c	0.24c	0.46c	0.28c	<0.0001
Sweetstaf	0.29a	1.58a	3.09a	0.41a	0.28a	0.28a	0.39a	0.28a	1.27a	0.20a	6.41a	0.37a	0.35
Sourstaf	0.12a	0.12a	0.19a	0.16a	0.28a	0.09a	0.19a	0.22a	0.29a	0.17a	0.16a	0.21a	0.54
Burntstaf	1.02e	4.13b	2.91bcde	1.86cde	3.77bc	6.25a	2.41bcde	2.69bcde	2.11bcde	3.21bcd	1.24de	2.83bcde	<0.0001
Cardboardstaf	0.29ab	0.16ab	0.13ab	0.16ab	0.22ab	0.13ab	0.24ab	0.18ab	0.24ab	0.43a	0.28ab	0.12b	0.04
Caramelstaf	0.18c	0.74ab	0.84a	0.12c	0.33abc	0.57abc	0.22bc	0.21bc	0.18c	0.29abc	0.12c	0.42abc	<0.0001
Grainystaf	1.78ab	1.59abc	1.58abc	2.51a	1.83ab	1.12bc	2.12ab	1.17bc	1.35bc	0.64c	1.98ab	1.07bc	<0.0001
Honeystaf	0.09b	0.32b	0.93a	0.11b	0.09b	0.11b	0.16b	0.10b	0.12b	0.18b	0.23b	0.13b	<0.0001
Wheatgermstaf	0.19a	0.14a	0.31a	0.21a	0.16a	0.11a	0.09a	0.12a	1.12a	0.33a	0.31a	0.15a	0.07
TASTE AFTERTASTE BOTTOM													
Btbitterstaf	1.59abc	0.77bc	1.58abc	1.73abc	1.42abc	1.94ab	2.38a	1.63abc	2.51a	0.58c	1.01bc	1.92ab	<0.0001
Btsaltystaf	2.16a	0.31c	0.16c	1.10b	0.38c	0.59bc	0.30c	0.45bc	0.41c	0.28c	0.36c	0.34c	<0.0001
Btsweetstaf	0.25b	2.91a	3.33a	0.52b	0.18b	0.26b	0.27b	0.26b	0.82b	0.19b	0.39b	0.76b	<0.0001
Btsourstaf	0.11a	0.18a	0.18a	0.10a	0.27a	0.17a	0.36a	0.36a	0.16a	0.14a	0.18a	0.25a	0.09
AFTERTASTE BOTTOM													
Bbitterstaf	2.08ab	0.73c	1.73abc	1.53abc	1.61abc	2.24ab	2.52a	1.74abc	2.45a	0.68c	1.05bc	1.94abc	<0.0001
Bsaltystaf	2.61a	0.38c	0.13c	1.28b	0.38c	0.63bc	0.26c	0.61bc	0.32c	0.39c	0.38c	0.31c	<0.0001
Bsweetstaf	0.26c	3.10a	3.45a	0.68bc	0.34bc	0.27c	0.38bc	0.36bc	1.12b	0.23c	0.61bc	0.97bc	<0.0001
Bsourstaf	0.12b	0.16b	0.19ab	0.12b	0.25ab	0.11b	0.39a	0.21ab	0.16b	0.18b	0.16b	0.27ab	0.0007
Bburntstaf	0.43b	0.54b	1.33ab	0.39b	1.12ab	1.21ab	1.68a	0.59ab	0.98ab	0.35bc	0.33b	0.53b	0.0002
Bfermentedstaf	0.17a	0.26a	0.29a	0.37a	0.28a	0.21a	0.39a	0.43a	0.31a	0.12a	0.19a	0.36a	0.07
Bgrainystaf	1.74abc	1.82abc	1.54abc	2.44a	1.76abc	1.45abc	1.71abc	1.41bc	1.30c	1.40bc	2.33ab	1.12c	0.0004
Btoastedstaf	1.46a	1.41a	1.72a	0.88a	1.44a	1.38a	1.08a	0.77a	1.02a	1.18a	1.66a	1.48a	0.09

CRUST Attributes	Cub Foods	BB hearthy	HC	Wonder	BB Natural	CH	Bakers Inn	Dutch	EG	NO	Pepp	Sara Lee	p-value
AFTERTASTE BOTTOM													
Bwheatgermstaf	0.18b	0.19b	0.39b	0.38b	0.22b	0.18b	0.34b	0.32b	0.14b	1.13a	0.27b	0.16b	<0.0001
ORAL TEXTURE TOP													
Chewystot	3.03b	4.49ab	5.66a	6.33a	4.56ab	4.98ab	6.29a	5.22a	4.50ab	5.29a	5.77a	5.57a	<0.0001
Lightnessstot	4.16d	6.29bcd	7.68ab	6.66abc	6.08bcd	6.19bcd	7.36abc	5.17cd	5.06cd	8.90a	6.02bcd	5.77bcd	<0.0001
Moisturestot	4.88ab	4.65ab	4.54ab	3.80b	4.17ab	5.14ab	4.37ab	4.17ab	4.46ab	1.92c	5.76a	4.34ab	<0.0001
Grittystot	2.89cd	2.84cd	3.77bc	1.12d	5.11ab	6.80a	6.87a	1.97cd	3.28bc	1.68cd	6.98a	2.46cd	<0.0001
Gummistot	0.52abc	0.23c	0.28c	0.22c	0.19c	0.93ab	0.32bc	0.26c	0.25c	0.35bc	1.05a	0.60abc	<0.0001
Softnessstot	3.28d	4.97cd	7.07abc	6.99abc	6.00bc	6.19c	7.29ab	5.99bc	5.91bc	8.61a	5.97bc	5.67bc	<0.0001
Leatherystot	2.08d	5.36bc	5.30bc	7.72a	4.87c	5.23bc	7.08ab	4.63c	5.12bc	7.26ab	4.32c	6.40abc	<0.0001
Paperystot	1.62ab	2.63ab	1.49ab	3.56a	3.12ab	2.32ab	2.49ab	1.85ab	1.24b	3.45a	2.17ab	3.14ab	0.002
Springystot	2.46b	3.09ab	4.00a	2.74ab	2.80ab	2.90ab	3.48ab	3.42ab	2.81ab	3.28ab	2.63ab	3.67ab	0.02
ORAL TEXTURE BOTTOM													
Bchewystot	2.35c	4.27ab	5.07a	4.44ab	3.10bc	4.65ab	4.08ab	3.63abc	3.58abc	4.15ab	5.13a	3.97abc	<0.0001
Blightnessstot	2.51e	3.78cde	5.78bc	3.74cde	5.75bc	5.32bc	5.93b	4.38bcde	3.80bcde	8.23a	4.75bcd	2.99de	<0.0001
Bmoisturestot	5.66ab	6.94a	5.47ab	5.93ab	4.19bc	6.85a	5.82ab	7.40a	5.81ab	2.80c	6.23ab	6.26ab	<0.0001
Bgrittystot	1.16cd	0.76d	2.88bc	0.48d	1.83cd	4.87a	4.29ab	0.41d	0.91d	1.45cd	5.06a	0.64d	<0.0001
bgummistot	0.80ab	0.47b	0.63ab	0.32b	0.23b	0.64ab	0.41b	1.09a	0.54ab	0.44b	0.71ab	0.75ab	0.0006
Bsoftnessstot	2.23g	3.32cdefg	4.72bc	3.14defg	5.06b	4.10bcde	4.72bc	2.46fg	3.67bcdef	7.13a	4.52bcd	3.01efg	<0.0001
Bleatherystot	0.60b	1.27ab	2.28a	1.24ab	1.20ab	1.22ab	2.21a	0.66b	1.12ab	2.45a	1.25ab	1.09ab	0.0002
Bpaperystot	0.46a	1.11a	0.67a	0.94a	1.01a	0.99a	1.21a	0.52a	0.67a	1.36a	1.20a	0.79a	0.1
Bspringystot	3.63c	6.24a	5.31abc	6.64a	3.71c	4.78abc	4.26bc	5.34abc	5.74ab	3.41c	3.92bc	5.25abc	<0.0001

Ratings were made on a 15-point scale with 1.0 increments, where 0 =None and 15=Extreme.

Means in the same row with the same letter are not significantly different at the 95% confidence level.

*Of the165 attributes, 36 attributes were not significantly different between samples and 3 attributes contained blanks and were not used in PCA.

Table 4.3 Analysis of variance (GLM) of attribute ratings: f-ratios, mean rating, and standard deviations

Attribute	Sample	Panelist (n=9)	Replication (2)	Sample X panelist	Sample X replication	Panelist X replication	Mean	Std. dev.
CRUMB								
TASTE								
Tbitter	6.64***	37.65***	0.92	2.85***	0.71	1.46	1.70	0.70
Tsalty	14.72***	13.00***	1.09	3.22***	0.85	1.37	1.05	0.81
Tsweet	25.98***	6.43***	0.03	2.21***	0.62	1.25	1.96	1.94
Tsour	1.11	12.69***	0.85	1.07	0.79	0.61	0.35	0.12
FLAVOR								
Fermented	3.24***	10.16***	1.19	1.14	0.65	0.73	1.44	0.69
Bitter	8.11***	36.49***	5.19*	2.44***	0.65	3.21**	1.78	0.79
Cardboard	6.27***	5.00***	0.81	1.21	0.45	0.4	0.61	0.53
Coffee	0.58	15.14***	0.32	0.6	0.91	0.71	0.19	0.06
Grainy	12.45***	56.38***	0.11	3.41***	0.77	2.33*	3.47	0.87
Honey	49.63***	35.76***	0.04	6.38***	0.6	3.94***	1.66	1.63
Molasses	1.55	4.70***	6.20*	1.1	1.15	2.82**	0.39	0.26
Musty	5.19***	39.86***	0.95	2.30***	1.03	0.65	0.48	0.25
Nutty	11.40***	25.14***	10.19*	4.08***	0.8	1.27	0.72	0.53
Oily	2.19*	18.27***	4.96*	1.60**	0.88	2.91**	0.51	0.20
Uncooked	6.78***	12.71***	1.52	1.53	1.03	0.78	0.87	0.69
Oxidized	2.38*	69.14***	0.2	1.34	0.98	3.37**	0.45	0.15
AROMA								
Brown	2.70**	21.16***	9.13*	1.5*	1.34	1.82	1.38	0.52
Butter	2.57**	47.11***	10.40**	1.45*	1.61	3.69***	0.97	0.28
Caramel	1.00	5.77***	2.45	1.15	1.09	0.36	0.22	0.11
Xfermented	6.80***	7.24***	0.03	1.2	0.48	1.49	2.51	1.55
Xgrainy	4.08***	24.95***	0	1.39	0.66	1.3	3.37	0.75
Hay	1.56	35.23***	6.61**	3.14***	0.69	1.44	1.40	0.39
Xhoney	3.87***	9.05***	2.29	1.87*	1.05	1.88	1.21	0.68
Xmolasses	0.90	4.49***	0.98	0.96	1.26	1.59	0.56	0.25
Xoily	2.65	12.65***	2.12	1.04	1.21	1.6	0.72	0.41
Sourdo	0.84	4.40***	0.65	1.1	0.75	1.69	0.37	0.20
Levelar	3.59***	27.64***	2.07	1.54*	0.93	0.87	1.89	0.53
Leveltoasted	1.53	42.47***	0.49	1.45*	1.13	1.83	0.72	0.16
Doughy	3.66***	31.14***	2.95	1.05	1.2	1.79	0.70	0.32
Yeasty	1.22	6.45***	0.73	1.02	0.86	1.09	0.47	0.16
APPEARANCE								
Moist	21.76***	7.06***	0.29	1.14	1.04	0.73	5.89	2.55
Grainpi	101.98***	11.51***	0.99	1.96**	0.48	0.6	4.07	4.30
Aircell	25.45***	10.58***	0.64	1.2	1.66	0.99	6.70	3.30
Grapiece	29.92***	29.75***	0.15	3.86***	1.23	2.05	2.84	2.08
Texture	45.79***	7.46***	2.23	2.49***	0.68	1.38	6.59	3.23
Overcol	8.42***	25.30***	3.24	1.85*	1.31	1.21	2.88	1.31
Aircellsz	39.28***	9.98***	0.05	1.51*	2.29	2.82**	5.71	2.82
Color	55.91***	20.87***	18.61***	1.49*	1.69	4.81**	6.74	2.99
TASTE AFTERTASTE								
Tbitteraf	5.75***	36.48***	3.19	1.76*	0.77	1.04	1.42	0.62
Tsaltyaf	14.86***	3.65**	0.29	1.25	0.93	2.51*	0.88	0.96
Tsweetaf	25.87***	5.88***	2.62	1.78*	1.58	0.49	1.51	1.58
Tsouraf	3.01*	19.15***	3.51	1.24	1	7.64***	0.30	0.14
AFTERTASTE								
Bitteraf	11.24***	74.47***	3.79	3.54***	0.64	3.76**	1.50	0.70

AFTERTASTE	Sample	Panelist	Replication	Sample X panelist	Sample X replication	Panelist X replication	Mean	Std. dev.
Saltyaf	19.26***	3.77***	2.32	1.52*	0.72	2.38*	0.87	0.93
Sweetaf	24.13***	5.20***	0.71	1.68*	1.12	0.45	1.64	1.62
Souraf	2.46**	15.69***	3.26	1.33	0.59	6.83***	0.28	0.12
Cardboardaf	10.52***	2.85**	0.04	1.43	1.25	1.08	0.60	0.54
Fermentedaf	6.04***	13.03***	3.92	2.13***	1.81	2.52*	0.81	0.49
Oxidizedaf	1.13	29.99***	0.08	0.94	0.37	0.98	0.42	0.12
Grainyaf	9.84***	29.91***	0.96	1.92	0.98	2.58**	2.26	0.86
Toastedaf	0.36	16.31***	20.98***	0.71	1.55	6.56***	0.39	0.07
Uncookedaf	8.57***	6.38***	11.11**	1.63**	1.92*	2.24*	0.87	0.75
Wheatgermaf	4.65***	9.87***	6.46**	1.19	0.99	3.49**	0.44	0.29
Yeastyaf	1.97*	11.32***	0.01	1.37	1.17	3.11*	0.28	0.16
ORAL TEXTURE								
Chewy	4.37***	21.27***	1.8	1.3	1.03	2.29*	5.08	0.95
Density	19.84***	4.68***	0.01	1.68**	1.49	2.55**	6.37	2.44
Squishy	8.61***	15.00***	41.3*	1.28	0.77	0.56	4.35	1.77
Moisture	20.96***	8.87***	3.56	2.22***	1.59	2.76**	7.30	2.09
Elastic	7.43***	15.75***	0.13	1.46*	0.74	1.62	4.53	1.48
Gritty	53.02***	8.77***	2.89	1.53*	0.97	1.79	2.86	3.13
Gummi	4.89***	8.28***	4.12	1.48*	0.47	2.49*	1.99	1.00
Softness	25.03***	16.70***	1.96	1.88**	1.48	2.48*	3.99	2.06
Smooth	55.83***	20.46***	1.78	3.25***	2.34**	3.53**	4.54	2.75
Spongy	10.02***	25.17***	0.16	2.46***	0.64	0.61	5.17	1.80
Tpacking	3.95***	15.07***	5.75*	1.39	1.37	5.54***	1.52	0.63
CRUST								
TASTE TOP								
Tbitterstfl	8.68***	36.20***	0.45	2.19***	0.71	8.31***	2.00	1.05
Tsaltystfl	11.90***	5.29***	3.51	2.33***	3.18**	0.45	0.72	0.66
Tsweetstfl	11.37***	4.68***	0.16	0.84	0.31	1.03	0.83	0.90
Tsourstfl	1.00	8.13***	0	0.68	0.51	1.11	0.22	0.09
FLAVOR TOP								
Bitterstfl	8.04***	26.45***	0.2	1.87**	0.94	6.37***	4.11	1.07
Burntstfl	10.43***	17.61***	12.56**	1	2.16**	2.43*	4.15	1.70
Coffeestfl	1.87*	23.92***	1.87	0.87	1.33	2.24*	1.31	0.55
Grainystfl	3.44**	27.97***	0.8	1	0.95	0.45	2.67	0.65
Molassesstfl	2.20*	8.50***	0.04	0.91	0.96	1.47	0.59	0.34
Oilsstfl	1.98*	24.94***	7.56*	1.91**	0.91	2.44*	0.25	0.11
Oxidizedstfl	2.61**	69.77***	1.830	1.81	0.8	1.04	0.34	0.12
Saltystfl	9.47***	3.36**	0.78	1.26	1.55	1.05	0.68	0.69
Toastedstfl	2.30*	38.46***	0.06	1.28	1.11	3.50**	3.62	0.74
Uncookedstfl	0.91	2.36*	0.81	1.03	1.03	1	0.16	0.09
TASTE BOTTOM								
Btbitterstfl	5.15***	16.38***	0.06	1.69**	0.85	3.23**	2.44	0.81
Btsaltystfl	6.33***	8.34***	0.05	1.62**	1.85	0.68	0.85	0.57
Btsweetstfl	15.34***	9.14***	0.48	1.41	0.62	1.49	1.15	0.93
Btsourstfl	1.85	10.51***	0.85	0.97	0.75	1.07	0.30	0.13
FLAVOR BOTTOM								
Bbitterstfl	6.88***	16.66***	0.39	2.17***	0.75	5.28***	2.39	0.82
Bsweetstfl	20.64***	10.52***	4.90*	1.63**	1.08	2.44*	1.43	1.20
Btoastedstfl	5.27***	48.35***	0.65	1.49*	1.04	3.65***	3.28	0.92
Bgrainystfl	4.20***	67.88***	3.45	2.51***	1.03	4.24***	2.78	0.45
Bsaltystfl	8.53***	7.57***	0.12	2.44***	0.66	0.89	0.84	0.62
Bstarchystfl	0.59	31.22***	6.01*	0.76	0.98	4.83***	0.31	0.07

Attribute	Sample	Panelist	Replication	Sample X panelist	Sample X replication	Panelist X replication	Mean	Std. dev.
FLAVOR BOTTOM								
Bdairystfl	2.03*	30.12***	10.92**	1.93***	1.34	7.93***	0.20	0.08
Bnuttystfl	4.80***	10.84***	0.27	2.74***	0.68	1.88	0.43	0.34
AROMA TOP								
Intensitystar	25.36***	25.36***	1.49	1.55*	0.51	15.49***	5.79	0.80
Butterstar	1.88*	10.02***	0.59	0.87	0.63	0.89	0.97	0.32
Caramelstar	2.40**	11.61***	3.01	0.93	1.02	1.79	0.58	0.31
Grainystar	1.21	81.80***	0.2	1.54*	0.38	4.97***	2.77	0.30
Sourdostar	0.72	14.04***	0.01	1.03	0.98	3.21	0.18	0.05
Sweetstar	1.29	14.42***	0.31	1.65*	0.81	0.58	0.88	0.27
Doughystar	1.61	6.91***	0.02	1.04	0.93	0.99	0.22	0.13
Leveltoastedstar	5.65***	34.60***	11.56***	1.50*	1.73	8.61***	4.07	0.82
Levelbakedstar	13.02***	13.18***	3.25	1.35	1.31	5.28***	3.87	1.76
AROMA BOTTOM								
Bintensitystar	2.41**	16.68***	12.22***	1.15	0.99	9.22***	4.14	0.53
Bbutterstar	0.97	30.29***	4.54*	1.81**	1	3.25**	0.66	0.12
Bcaramelstar	1.13	5.20***	0.09	1.13	0.97	0.07	0.25	0.11
Bgrainystar	3.52***	64.65***	8.39**	1.60**	1.05	1.17	2.18	0.39
Bsourdostar	0.55	10.59***	0.71	1.06	0.9	3.34**	0.21	0.06
Bsweetstar	0.75	12.41***	0.08	1.43	0.49	0.25	0.86	0.20
Bdoughystar	1.23	21.96***	5.10*	0.88	1.05	2.80**	0.43	0.16
Bleveltoastedstar	1.92	25.41***	1.29	1.26	0.31	10.12***	2.53	0.46
Blevelbakedstar	4.30***	16.46***	0.18	1.12	1.87*	1.67	1.43	0.68
APPEARANCE TOP								
Graintopstap	45.92***	3.77***	2.29	2.00***	0.76	0.66	6.48	4.25
Oattopstap	45.33***	1.59	3.57	1.09	2.19*	0.83	0.45	1.25
Graintopshapestap	17.18***	5.62***	0.23	1.09***	2.37**	2.64***	5.37	3.05
Graintopszstap	46.80***	5.43***	2.59	1.49*	2.29**	0.7	5.02	3.38
Oattopszstap	126.88***	2.84**	0.02	2.68***	0.82	1.17	1.23	3.13
Thicktopstap	10.03***	19.46***	0.26	1.35	1.15	2.35*	5.98	1.48
Colortopstap	5.08***	33.18***	14.26***	1.86**	1.32	0.88	2.35	0.70
APPEARANCE BOTTOM								
Crustbottomstap	14.01***	21.09***	0.01	1.29	1.45	2.98**	5.93	2.08
Surfacebstap	3.80***	15.27***	9.97**	0.89	2.03*	1.65	6.52	1.35
Thicknessbotstap	3.49***	18.72***	1.92	1.92***	0.61	4.32***	5.83	0.80
Colorbotstap	9.98***	25.89***	1.83	1.23	2.81**	1.23	4.79	1.38
TASTE AFTERTASTE TOP								
Tbitterstaf	8.03***	32.07***	2.72	1.62**	1.73	0.89	3.27	1.10
Tsaltystaf	10.85***	3.97***	1.43	1.41	1.2	1.56	0.53	0.55
Tsweetstaf	16.62***	11.49***	4.47*	2.87***	2.25**	0.62	0.75	0.79
TSourstaf	0.88	26.81***	10.340	1.26	0.82	4.62***	0.14	0.03
AFTERTASTE TOP								
Bitterstaf	9.85***	29.24***	3.87	1.83**	1.09	2.85**	3.48	1.12
Saltystaf	18.13***	4.33***	2.31	1.78***	1.69	1	0.62	0.69
Sweetstaf	1.13	1.47	1.51	1	1.03	0.9	1.24	1.84
Sourstaf	0.91	15.90***	2.12	1.38	1.05	1.62	0.18	0.06
Burntstaf	10.77***	21.93	0.6	1.18	1.63	2.02*	2.87	1.41
Cardboardstaf	2.01*	19.95	0	1.42	1.52	3.46**	0.21	0.09
Caramelstaf	4.37***	20.68***	0.85	1.65**	0.78	2.58**	0.35	0.24
Grainystaf	5.39***	45.04***	1.71	1.54*	1.45	7.21***	1.56	0.52
Honeystaf	11.41***	8.63***	2.93	4.97***	1.31	1.62	0.21	0.23
Wheatgermstaf	1.80	22.60***	0.63	1.25	0.19	2.02*	0.19	0.08

Attribute	Sample	Panelist	Replication	Sample X panelist	Sample X replication	Panelist X replication	Mean	Std. dev.
TASTE AFTERTASTE BOTTOM								
Btbitterstaf	5.32***	19.60***	13.07***	1.24	0.59	2.37*	1.59	0.59
Btsaltystaf	14.94***	5.28***	0.42	1.32	3.00**	1.65	0.57	0.55
Btsweetstaf	63.27***	11.20***	16.96***	3.51***	4.15***	1.87	0.84	1.09
Btsourstaf	1.69	17.15***	15.35***	0.88	0.37	3.71***	0.22	0.09
AFTERTASTE BOTTOM								
Bbitterstaf	5.16***	15.46***	17.07***	0.97	0.33	3.22**	1.69	0.62
Bsaltystaf	21.92***	6.10***	3.3	1.49*	1.49	2.89**	0.64	0.69
Bsweetstaf	42.30***	9.94***	1.07	2.27***	3.06	2.63**	0.98	1.11
Bsourstaf	3.33***	23.73***	23.91***	2.76***	0.49	6.15***	0.19	0.08
Bburntstaf	3.69***	22.43***	10.93**	1.42*	0.57	1.15	0.79	0.45
Bfermentedstaf	1.75	35.90***	13.29***	2.18***	1.79	7.74***	0.28	0.10
Bgrainystaf	3.56***	34.61***	11.91**	1.47*	0.77	9.96***	1.67	0.40
Btoastedstaf	1.69	34.99***	34.14***	1.06	1.57	13.73***	1.29	0.30
Bwheatgermstaf	5.58***	20.99***	0.15	1.94**	1.98	0.71	0.33	0.27
ORAL TEXTURE TOP								
Chewystot	4.35***	37.28***	2.19	1.2	1.12	4.55***	5.14	0.92
Lightnessstot	6.22***	12.42***	3.12	1.29	0.79	4.66***	6.28	1.27
Moisturestot	5.13***	22.03***	0.55	1.41	0.66	2.92**	4.35	0.92
Grittystot	21.95***	21.53***	7.91	2.12***	2.20*	3.88***	3.81	2.11
Gummistot	4.80***	4.17***	1.34	1.50*	0.73	1.73	0.43	0.29
Softnessstot	8.10***	29.75***	10.76**	1.95**	0.95	4.34***	6.16	1.31
Leatherystot	11.24***	37.59***	13.58***	1.69**	1.48	7.89***	5.45	1.53
Paperystot	2.94**	64.62***	9.60**	1.42*	0.9	4.74	2.42	0.78
Springystot	2.15*	227.19***	1.4	1.90*	1.37	1.89	3.11	0.47
ORAL TEXTURE BOTTOM								
Bchewystot	4.93***	29.54***	0.04	1.38	0.75	5.38***	4.04	0.80
Blightnessstot	12.06***	17.64***	0.23	1.44	1.17	3.26**	4.75	1.57
Bmoisturestot	7.40***	7.10***	1.98	1.35	0.87	2.03	5.78	1.25
Bgrittystot	21.44***	18.17***	0.36	2.13***	1.21	3.89***	2.06	1.76
bgummistot	3.41***	9.10***	6.87**	2.00***	1.42	4.10***	0.59	0.24
Bsoftnessstot	20.21***	62.38***	0.15	2.71***	1.32	4.58***	4.01	1.35
Bleatherystot	3.81***	24.88***	0.17	1.25	1.86	2.12*	1.38	0.61
Bpaperystot	1.66	65.50***	0.11	1.52*	1.33	2.11*	0.91	0.29
Bspringystot	6.75	99.17***	0.03	1.43	0.68	0.95	4.85	1.07

Significant sample x judge interactions indicate confusion of attributes by panelists.
165 attributes. 36 attributes were not significantly different between samples.
*p<0.05, **p<0.01, ***p<0.001

Table 4.4 Principal component analysis on attributes of the 12 whole grain breads: scores and percentage variance for the first 11 principal components (PC)

Breads	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**	**PC9**	**PC10**	**PC11**
Cub	**-10.94**	**8.86**	-0.02	-3.04	0.20	0.34	-3.21	1.31	0.60	-0.28	-0.79
BBHeart	2.24	-0.50	0.92	5.06	-4.98	**-5.62**	-2.51	0.32	2.17	0.29	-0.06
HC	3.29	-0.15	5.36	-0.91	**-6.30**	**4.50**	-1.59	-0.21	-2.30	-0.14	0.36
Wonder	-2.13	2.11	**-7.39**	2.38	-3.02	1.14	**4.56**	1.96	-0.95	1.95	0.50
BBnat	2.84	-0.85	-2.42	**5.11**	**5.10**	0.34	**-4.11**	2.37	**-2.37**	-0.86	0.71
CH	-0.57	-0.30	**7.51**	-1.86	3.38	-3.26	2.97	2.51	-0.82	**2.13**	0.64
Bakers	0.53	-3.32	1.75	1.55	1.28	4.46	2.16	**3.27**	**3.31**	-1.72	-0.56
Dutch	-5.13	-2.96	-1.12	-2.50	-0.47	-1.98	1.57	-2.18	-0.17	-2.82	**2.84**
EG	-3.51	**-6.11**	-1.16	-0.69	1.89	2.49	-2.69	-3.73	1.33	**3.03**	0.38
NO	**11.92**	2.17	-3.86	**-7.39**	0.64	-0.92	-0.98	0.52	0.87	0.09	0.00
Pepp	4.05	7.13	1.79	3.91	2.54	0.67	2.68	**-5.27**	0.13	-0.56	-0.65
Sara Lee	-2.59	**-6.06**	-1.35	-1.62	-0.25	-2.16	1.14	-0.87	-1.80	-1.09	**-3.35**
% Variance	25	17	12	11	9	7	6	6	3	2	2

* Bolded bread scores are the most important bread samples for each PC.

Table 4.5 Principal component analysis on sensory attributes of 12 whole grain breads showing the loadings for principal components (PC) 1-11.

Attributes	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
CRUMB											
Taste											
tbitter	-0.598	-0.539	0.390	-0.284	0.132	0.180	0.221	-0.021	-0.079	0.055	0.100
tsalty	-0.519	0.567	0.399	-0.440	-0.053	0.103	-0.055	0.185	-0.049	0.039	0.036
tsweet	0.204	-0.158	-0.069	**0.727**	0.279	-0.192	-0.496	0.135	0.059	-0.084	0.105
FLAVOR											
fermented	-0.532	**-0.782**	-0.107	0.021	0.104	-0.044	-0.077	-0.267	-0.064	0.014	-0.020
bitter	-0.629	-0.471	0.377	-0.327	0.155	0.223	0.183	-0.077	-0.134	0.050	0.019
cardboard	**0.718**	0.244	-0.225	-0.562	-0.056	0.040	-0.186	0.096	-0.004	0.049	0.090
grainy	0.383	0.383	0.690	0.360	0.193	0.017	0.137	-0.023	-0.099	0.084	0.168
honey	0.204	-0.267	-0.013	**0.737**	0.260	-0.132	-0.460	0.178	0.102	-0.060	0.020
musty	0.107	-0.324	-0.161	-0.344	0.323	0.192	-0.223	-0.505	0.129	0.519	0.091
nutty	0.599	0.411	0.292	0.416	0.390	-0.008	-0.010	-0.240	-0.051	0.004	0.046
oily	0.687	0.290	0.175	-0.270	0.250	0.163	-0.391	0.135	-0.236	0.141	0.073
uncooked	-0.645	0.496	0.398	-0.321	-0.033	0.074	-0.188	0.179	0.010	-0.049	-0.027
oxidized	0.387	0.376	0.052	-0.376	0.595	-0.104	-0.082	-0.379	-0.178	-0.114	-0.068
AROMA											
brown	**0.791**	0.550	-0.076	-0.172	-0.046	0.156	0.050	0.012	0.058	0.049	0.043
butter	-0.487	0.077	-0.038	0.277	-0.497	-0.289	0.004	-0.080	0.404	0.319	0.279
xfermented	**-0.798**	0.032	-0.246	-0.138	0.348	0.014	-0.094	0.006	-0.243	-0.035	0.302
xgrainy	0.596	0.544	-0.129	0.029	-0.388	-0.039	0.195	-0.190	0.288	0.006	0.150
xhoney	0.016	-0.192	0.402	-0.226	-0.413	**0.636**	-0.094	-0.311	0.174	-0.097	0.172
levelar	0.476	0.521	0.164	-0.155	-0.423	-0.316	0.105	-0.188	0.234	-0.087	0.251
doughy	-0.432	0.080	-0.513	0.310	-0.266	-0.421	0.055	0.425	-0.099	0.077	-0.005
APPEARANCE											
moist	**0.807**	0.004	-0.014	-0.518	-0.189	0.051	-0.160	0.044	-0.104	-0.036	-0.048
grainpi	0.180	0.449	-0.344	**0.634**	0.137	0.180	0.394	-0.143	-0.101	0.092	0.022
aircell	0.230	**0.730**	-0.506	0.267	0.035	0.116	-0.049	-0.155	-0.189	0.080	0.062
grapiece	0.228	0.466	-0.371	**0.671**	0.067	0.133	0.181	-0.135	-0.221	0.111	0.095
texture	0.547	0.389	-0.249	-0.110	-0.259	0.570	-0.203	0.104	-0.050	-0.004	0.170
overcol	0.184	0.528	-0.366	0.364	-0.290	0.387	0.369	0.165	-0.038	0.151	0.012
aircellsz	0.178	**0.746**	-0.390	0.394	0.178	0.194	-0.094	-0.053	-0.109	0.097	0.054
color	0.433	0.440	-0.091	0.152	-0.053	**0.683**	-0.023	0.042	-0.247	-0.047	0.230

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
TASTE AFTERTASTE											
tbitteraf	-0.585	-0.499	-0.124	0.116	0.509	0.035	0.145	0.214	-0.167	0.114	0.107
tsaltyaf	-0.616	0.694	-0.200	-0.083	-0.016	0.087	0.015	0.229	0.120	0.037	-0.126
tsweetaf	0.173	-0.167	0.411	0.294	**-0.729**	0.143	-0.322	-0.143	-0.007	0.085	-0.057
tsouraf	-0.240	**-0.730**	0.129	-0.020	0.375	0.360	-0.228	-0.071	0.098	0.227	-0.064
AFTERTASTE											
bitteraf	-0.620	-0.496	-0.146	0.038	0.328	0.045	0.298	0.092	-0.239	0.204	0.204
saltyaf	-0.648	0.652	-0.169	-0.117	0.001	0.053	-0.015	0.304	0.054	0.047	-0.112
sweetaf	0.186	-0.141	0.441	0.337	**-0.716**	0.150	-0.290	-0.100	0.013	0.039	-0.078
souraf	-0.055	**-0.722**	0.010	-0.246	0.231	0.385	0.053	-0.007	0.305	0.306	-0.155
cardboardaf	0.643	0.179	-0.241	-0.566	0.290	-0.079	-0.070	0.227	0.096	0.102	0.098
fermentedaf	**-0.870**	-0.240	-0.211	-0.166	0.050	0.043	-0.178	-0.260	-0.099	0.001	0.028
grainyaf	0.143	0.606	-0.146	**0.638**	-0.138	0.175	0.277	0.107	-0.144	0.106	0.119
uncookedaf	-0.533	0.608	-0.395	0.100	-0.056	0.122	0.061	0.324	-0.041	0.222	-0.044
wheatgermaf	**0.833**	0.308	-0.078	-0.309	-0.181	-0.009	0.117	0.043	0.022	0.240	0.051
yeastyaf	-0.605	-0.371	-0.064	-0.094	0.322	0.300	-0.096	-0.256	0.455	-0.072	0.058
ORAL TEXTURE											
chewy	-0.031	0.266	0.662	0.364	0.032	0.231	0.482	0.160	0.207	-0.031	-0.026
density	0.599	0.300	0.293	-0.063	0.563	0.183	-0.184	0.218	0.051	0.018	0.165
squishy	**-0.767**	0.268	0.422	-0.087	-0.098	-0.065	0.216	0.223	0.206	-0.016	-0.042
moisture	**-0.796**	0.095	0.484	0.086	-0.239	0.056	0.209	-0.046	0.096	-0.006	-0.025
elastic	-0.309	-0.147	-0.043	0.330	-0.225	-0.165	**0.767**	-0.148	0.258	-0.040	0.126
gritty	0.312	0.264	**0.715**	0.187	0.291	0.082	0.423	-0.103	0.020	0.080	-0.007
gummi	-0.682	0.432	0.380	-0.105	-0.057	0.227	0.002	0.151	0.270	0.020	-0.205
softness	**0.796**	0.265	0.087	-0.147	0.414	0.249	-0.139	-0.017	0.048	-0.048	0.099
smooth	0.656	0.287	0.501	-0.089	0.347	0.200	0.220	-0.004	0.125	0.062	-0.003
spongy	0.178	-0.337	-0.553	0.271	-0.095	-0.111	0.366	-0.510	-0.096	-0.103	-0.201
tpacking	-0.566	0.504	0.575	-0.095	0.093	-0.203	0.103	0.105	-0.055	0.075	-0.070
CRUST											
TASTE TOP											
tbitterstfl	0.060	-0.447	-0.529	-0.358	-0.236	0.144	0.501	0.186	0.067	0.149	-0.029
tsaltystfl	-0.601	0.611	0.351	-0.297	0.027	0.040	-0.124	0.175	-0.011	0.056	-0.041
tsweetstfl	0.214	-0.127	-0.091	0.677	0.320	-0.141	-0.557	0.172	-0.030	-0.066	0.071
FLAVOR TOP											
bitterstfl	0.167	-0.519	-0.491	-0.383	-0.277	0.114	0.295	0.259	0.054	0.143	-0.221
burntstfl	0.412	-0.455	-0.499	-0.270	-0.349	0.052	0.326	0.254	0.018	-0.053	-0.051

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
FLAVOR TOP											
grainystfl	0.083	0.342	**0.785**	0.388	0.086	-0.089	0.015	0.082	0.239	-0.062	0.160
molassesstfl	0.212	-0.386	-0.187	**0.728**	0.107	0.106	-0.135	0.150	0.336	0.242	-0.080
oilsstfl	0.621	0.172	0.126	-0.561	-0.003	-0.130	0.355	-0.196	-0.264	-0.043	0.041
oxidizedstfl	-0.199	-0.340	0.599	-0.386	0.322	-0.079	0.252	0.126	-0.015	-0.015	0.384
saltystfl	-0.642	0.655	0.215	-0.246	-0.020	-0.079	-0.056	0.192	0.018	0.048	-0.052
toastedstfl	0.452	-0.578	-0.262	0.086	0.158	-0.222	0.053	0.169	0.484	-0.078	0.197
TASTE BOTTOM											
btbitterstfl	-0.513	-0.388	0.039	0.117	0.025	**0.706**	-0.048	0.154	-0.177	-0.098	0.072
btsaltystfl	-0.674	0.526	0.327	-0.372	0.051	0.047	-0.030	0.087	-0.100	-0.013	0.020
btsweetstfl	0.153	-0.320	-0.068	**0.743**	0.180	-0.287	-0.410	0.081	0.142	-0.058	-0.063
FLAVOR BOTTOM											
bbitterstfl	-0.554	-0.474	0.148	-0.042	-0.007	0.600	-0.017	0.205	-0.203	-0.038	-0.005
bsweetstfl	0.170	-0.296	-0.103	**0.704**	0.254	-0.264	-0.488	-0.002	0.032	0.046	0.053
btoastedstfl	0.229	-0.455	-0.197	0.315	0.264	0.588	-0.016	0.407	-0.106	0.041	-0.090
bgrainystfl	0.516	0.325	0.529	0.418	0.268	0.233	0.137	0.040	0.142	0.005	-0.075
bsaltystfl	-0.509	0.601	0.232	-0.547	-0.005	-0.029	-0.015	0.136	-0.042	0.064	-0.031
bdairystfl	0.377	0.050	-0.111	-0.620	0.184	-0.128	-0.220	-0.313	0.283	0.420	-0.064
bnuttystfl	0.505	0.359	0.312	0.207	0.452	-0.054	0.288	-0.403	0.039	0.049	-0.143
AROMA TOP											
intensitystar	0.632	-0.221	0.190	-0.035	0.016	**-0.623**	0.028	0.259	0.141	-0.170	0.100
caramelstar	0.628	-0.241	0.329	-0.219	0.086	-0.442	0.137	0.217	0.061	0.090	-0.333
leveltoastedstar	0.607	-0.197	0.573	0.168	-0.104	-0.410	0.019	0.201	-0.061	0.102	-0.050
levelbakedstar	0.381	-0.291	0.590	-0.039	-0.215	-0.432	0.020	0.389	0.130	0.080	0.111
AROMA BOTTOM											
bintensitystar	**0.776**	-0.262	0.310	-0.057	0.063	0.341	-0.180	0.019	-0.156	-0.028	-0.225
bgrainystar	0.612	0.671	-0.272	-0.044	-0.287	0.003	0.067	0.019	0.091	-0.023	-0.055
blevelbakedstar	0.333	-0.279	0.677	-0.077	-0.247	0.444	-0.165	0.036	-0.105	0.221	0.008
APPEARANCE TOP											
graintopstap	-0.503	-0.171	-0.254	0.356	-0.392	0.303	-0.091	0.390	0.302	-0.176	0.005
oattopstap	0.193	0.520	0.128	0.349	0.209	0.062	0.274	**-0.631**	0.055	-0.080	-0.153
thicktopstap	**0.827**	-0.173	0.024	-0.204	0.105	-0.370	-0.024	-0.045	-0.056	0.209	-0.216
colortopstap	-0.059	-0.214	-0.335	0.398	0.318	0.351	-0.393	-0.494	-0.081	0.177	-0.139
APPEARANCE BOTTOM											
crustbottomstap	-0.092	0.570	0.567	0.125	-0.051	-0.004	-0.435	0.322	0.022	-0.083	-0.160
surfacebstap	0.228	0.522	0.178	0.263	-0.045	-0.272	0.061	**0.697**	-0.031	-0.038	-0.082

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
APPEARANCE BOTTOM											
thicknessbotstap	**0.862**	-0.016	0.184	0.029	0.056	0.036	-0.284	-0.062	-0.001	0.312	-0.188
colorbotstap	0.360	0.062	-0.378	0.428	0.472	-0.064	0.236	0.326	-0.348	-0.175	0.012
TASTE AFTERTASTE TOP											
tbitterstaf	-0.068	-0.651	0.375	0.077	0.201	-0.440	0.241	0.250	-0.189	0.186	0.008
tsaltystaf	-0.676	0.631	-0.245	-0.139	-0.056	0.088	-0.034	0.195	0.021	0.107	-0.057
tsweetstaf	0.079	-0.008	0.418	0.170	**-0.749**	0.232	-0.342	-0.149	-0.134	0.133	-0.031
AFTERTASTE TOP											
bitterstaf	-0.002	-0.613	0.389	0.031	0.331	-0.367	0.219	0.333	-0.144	0.215	0.049
saltystaf	-0.643	0.648	-0.178	-0.127	-0.002	0.082	-0.044	0.270	0.040	0.154	-0.108
burntstaf	0.306	-0.347	0.460	-0.012	0.122	-0.521	0.010	0.420	-0.173	0.205	0.197
cardboardstaf	0.376	0.421	-0.331	-0.397	0.364	0.164	-0.263	-0.120	0.409	-0.058	-0.003
caramelstaf	0.271	-0.209	0.588	0.067	-0.536	-0.247	-0.276	0.216	-0.237	0.057	-0.044
grainystaf	-0.252	0.319	-0.185	**0.709**	-0.109	0.438	0.225	0.191	0.073	0.034	0.007
honeystaf	0.313	0.029	0.454	0.031	-0.677	0.354	-0.184	-0.088	-0.261	-0.034	0.024
TASTE AFTERTASTE BOTTOM											
btbitterstaf	-0.579	-0.535	0.150	-0.009	0.212	0.468	0.194	0.105	0.044	0.197	-0.055
btsaltystaf	-0.685	0.609	-0.204	-0.169	0.024	-0.006	-0.081	0.241	0.029	0.138	-0.067
btsweetstaf	0.175	-0.126	0.346	0.241	**-0.811**	-0.008	-0.308	-0.087	-0.071	0.099	-0.032
AFTERTASTE BOTTOM											
bbitterstaf	-0.634	-0.393	0.289	-0.107	0.292	0.449	0.089	0.194	0.022	0.112	-0.049
bsaltystaf	-0.656	0.638	-0.216	-0.196	-0.007	-0.053	-0.081	0.240	0.036	0.089	-0.029
bsweetstaf	0.171	-0.159	0.317	0.278	**-0.797**	0.002	-0.309	-0.132	-0.071	0.112	-0.048
bsourstaf	0.158	-0.507	-0.023	0.133	0.161	0.376	0.025	0.234	0.230	**-0.606**	-0.240
bburntstaf	0.040	-0.460	0.544	0.158	0.134	0.501	-0.067	0.415	0.057	-0.015	0.134
bgrainystaf	0.059	0.628	-0.253	**0.607**	-0.096	0.140	0.336	0.021	0.055	0.104	0.117
bwheatgermstaf	0.697	0.180	-0.316	-0.566	-0.092	0.080	0.038	0.113	0.117	-0.079	0.116
ORAL TEXTURE TOP											
chewystot	0.435	-0.286	-0.094	0.144	-0.169	0.318	**0.740**	-0.005	-0.061	-0.126	-0.038
lightnessstot	**0.867**	-0.061	-0.014	-0.173	-0.237	0.206	0.172	0.290	0.042	-0.016	-0.011
moisturestot	-0.472	0.170	0.594	0.529	0.092	0.000	0.119	-0.278	-0.048	0.030	-0.114
grittystot	0.147	0.087	0.674	0.377	0.521	0.222	0.165	0.052	0.127	-0.055	-0.074
gummistot	0.009	0.388	0.503	-0.054	0.389	-0.205	0.428	-0.290	-0.093	0.073	-0.344
softnessstot	**0.754**	-0.271	-0.147	-0.237	-0.029	0.322	0.358	0.125	-0.017	0.033	0.173
leatherystot	0.530	-0.455	-0.360	-0.028	-0.176	0.105	0.474	0.283	0.078	0.130	-0.110
paperystot	0.458	-0.010	-0.557	0.106	0.085	-0.305	0.290	0.442	-0.145	-0.059	-0.253

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
ORAL TEXTURE TOP											
springystot	0.287	-0.556	0.249	-0.262	-0.484	0.169	0.065	0.055	-0.151	-0.418	-0.095
ORAL TEXTURE BOTTOM											
bchewystot	0.568	-0.037	0.356	0.165	-0.330	0.059	0.566	-0.223	-0.101	0.170	-0.019
blightnessstot	**0.843**	-0.020	0.096	-0.263	0.182	0.210	0.002	0.219	0.039	-0.107	0.268
bmoisturestot	-0.590	-0.182	0.370	0.310	-0.226	-0.309	0.399	-0.233	0.099	-0.053	0.116
bgrittystot	0.301	0.244	**0.696**	0.169	0.360	0.268	0.350	0.039	0.089	0.001	-0.061
bgummistot	-0.483	0.050	0.301	-0.423	-0.098	-0.220	0.154	-0.490	-0.076	-0.393	0.113
bsoftnessstot	**0.909**	0.037	0.023	-0.177	0.229	0.236	-0.107	0.131	0.031	0.041	0.007
bleatherystot	**0.773**	-0.096	0.138	-0.187	-0.221	0.436	0.033	0.254	0.159	-0.009	-0.099
bspringystot	-0.255	-0.441	-0.140	0.286	**-0.612**	-0.164	0.262	-0.103	-0.032	0.369	0.145

Table 4.6 Principal component analysis on attributes of 12 whole grain breads: summary of 11 principal components (PC) for the positive and negative ends of the axis.

PC	Variance (%)	Whole grain breads	CRUMB Attributes	CRUST Attributes
1	25	Natural Ovens	+ cardboard flavor brown aroma moist appearance wheat germ aftertaste, soft texture	+ intensity of aroma bottom thick appearance of top and bottom light, soft texture of top and bottom leathery texture of bottom
		Cub Foods	-fermented aroma/aftertaste, moist squishy texture	-salty taste of top and bottom salty aftertaste top and bottom grain topping appearance
2	17	Cub Foods	+ air cell evenness and size salty, grainy, uncooked aftertaste	+ salty taste/flavor/aftertaste top and bottom grainy aroma and aftertaste bottom bottom appearance (dull-shiny),bottom surface (smooth-rough)
		Earth grains Sara Lee	- fermented flavor sour aftertaste	- toasted flavor of top, bitter aftertaste of top sour aftertaste of bottom springy texture of top
3	13	Country Hearth Healthy Choice	+ grainy flavor chewy, gritty texture smooth and tooth packing texture	+ grainy flavor top and bottom oxidized flavor top crust level of toasted aroma top level of baked aroma of top & bottom bottom appearance (dull-shiny), caramel aftertaste top ;burnt aftertaste of bottom gritty texture of top and bottom moist texture top
		Wonder Bread	- doughy aroma air cell evenness, spongy texture	- bitter taste of top, papery texture of top

4	11	BB Hearty BB Natural	+ sweet taste, honey flavor, grainy aftertaste grain piece size and distribution	+ sweet taste of top and bottom sweet flavor bottom, molasses flavor top grainy aftertaste of top and bottom moist texture of top
		Natural Ovens	- cardboard flavor/aftertaste moist appearance	- salty flavor bottom oily flavor top crust, dairy flavor of bottom wheat germ aftertaste bottom
5	9	BB Natural	+ taste bitter aftertaste dense texture	+ nutty flavor of bottom gritty texture top
		Healthy Choice	- butter aroma sweet aftertaste	- sweet taste aftertaste top and bottom sweet aftertaste bottom honey aftertaste of top springy texture bottom
6	7	Healthy Choice	+ Honey aroma overall color uniformity, texture of appearance	+ Bitter taste bottom bitter and toasted flavor of bottom
		BB Hearty	- doughy aroma	- butter aroma top, aroma intensity top burnt aftertaste top,
7	6	Wonder	+ chewy, elastic, gritty texture	+ bitter taste top chewy texture of top & bottom
		BB natural	- sweet taste, honey flavor	- sweet taste top
8	5	Bakers Inn	+ doughy aroma salty aftertaste uncooked aftertaste	+ toasted flavor bottom surface bottom appearance, burnt aftertaste top and bottom papery texture top
		Pepperidge Farms	- musty flavor, nutty flavor spongy texture	- nutty flavor bottom oats on top, color top gummy texture bottom

9	2	Bakers Inn	+ Butter aroma Yeasty aftertaste	+ Toasted flavor top molasses flavor of top, grain on top crust cardboard aftertaste top
		BB Natural	- oily flavor, fermented aroma, color appearance grain shape (uniform-not uniform)	- color of bottom,
10	2	Earthgrains Country Hearth	+ Musty flavor Butter aroma, sour aftertaste	+ dairy flavor of top crust thickness bottom appearance springy texture of bottom
		Dutch	- oxidized aroma	- sour aftertaste bottom springy texture of top gummy texture bottom
11	2	Dutch	+ Butter aroma fermented aroma	+ oxidized flavor top light texture bottom
		Sara Lee	-gummy texture	- sweet taste top, caramel aroma top, intensity aroma of bottom, thick appearance of top sour aftertaste bottom, gummy texture top, papery texture of top

*Breads full name and brand:
BB Natural and BB Hearty (Brown Berry Natural; Brown Berry Hearty.

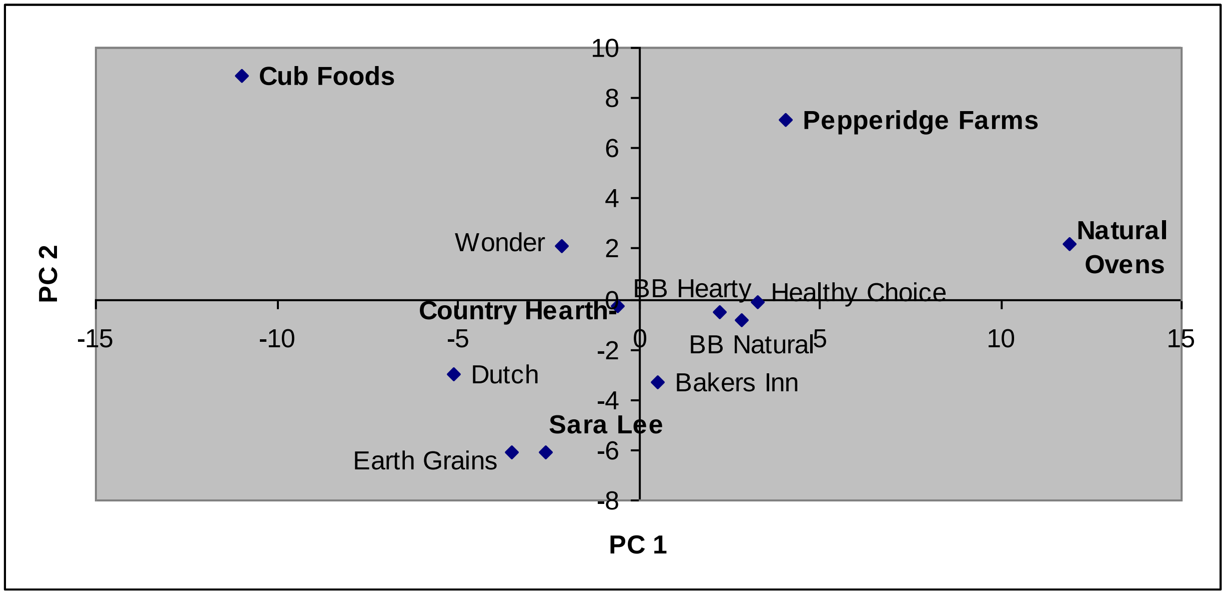


Figure 4.1 Score plot of the first two PC obtained from PCA of the sensory attributes for whole grain breads. Bread samples in bold were used in a subsequent bread liking study.

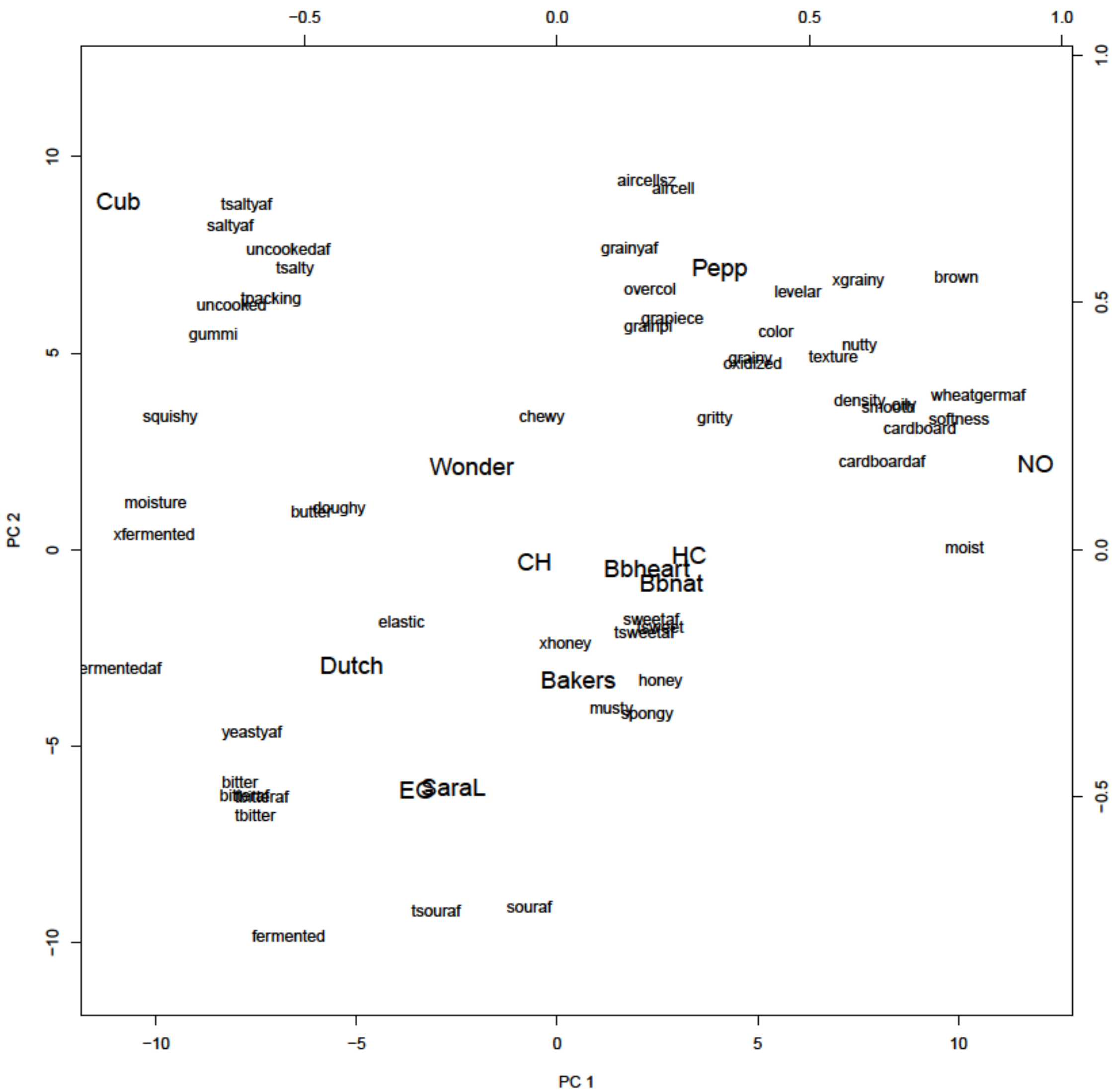


Figure 4.2 Crumb biplot of the first two PC obtained from PCA of the sensory attributes for 12 whole grain breads

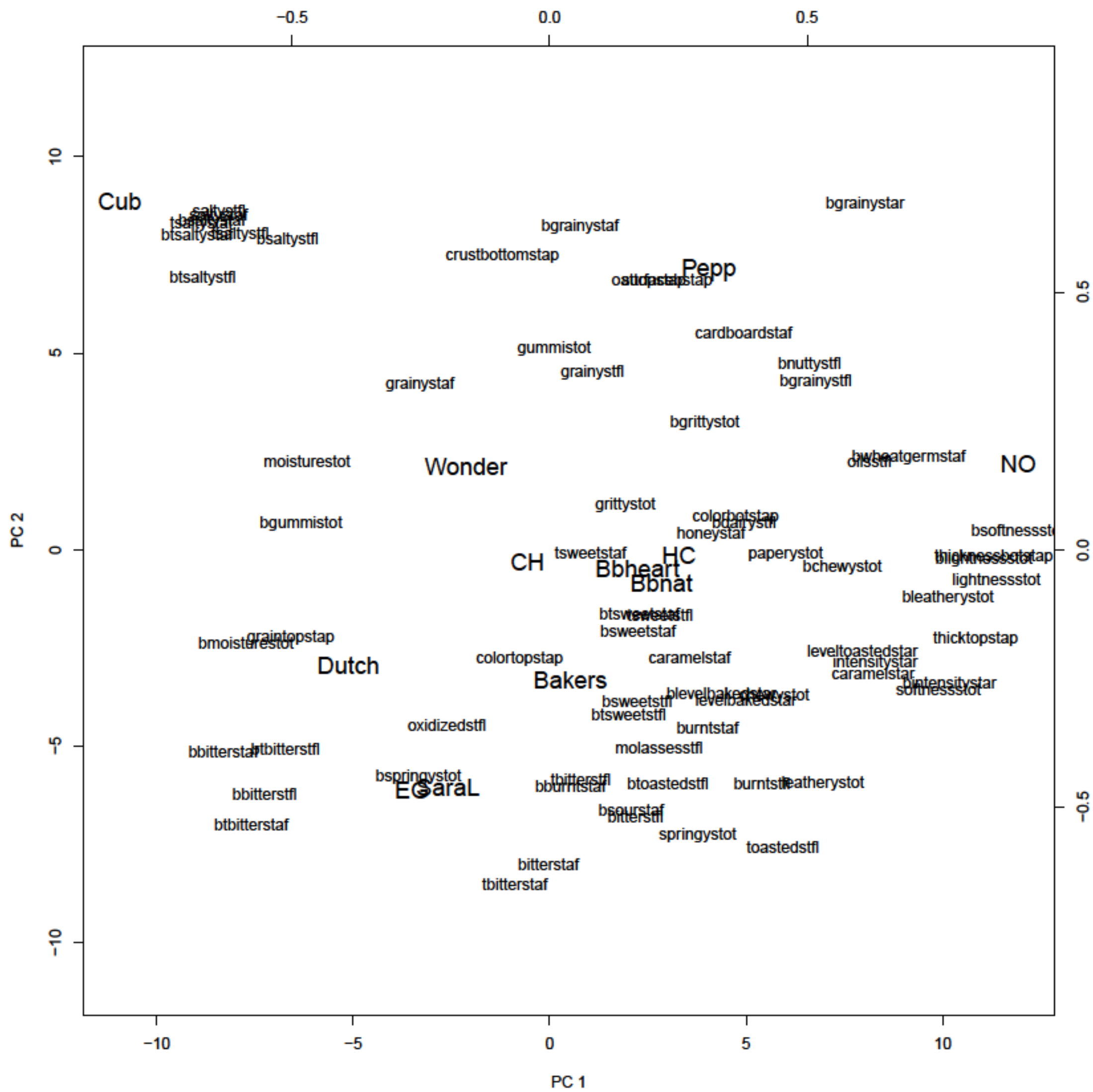


Figure 4.3 Crust biplot of the first two PC obtained from PCA of the sensory attributes for 12 whole grain breads

Chapter 5, Part 1. - Development and testing of the TPB questionnaire

Sara A. Sjoberg, MS

The purpose of this study was to develop and test a questionnaire based on the TPB to measure attitudes, subjective norms, perceived behavioral control, intention and consumption with respect to whole grain bread. A convenience sample of 47 participants (21 identified as typically consuming whole grain bread and 26 as typically consuming refined grain bread) was recruited on the University of Minnesota, Twin Cities campus to participate in focus group interviews. Participants were asked to answer questions based on the TPB to identify salient beliefs (attitudinal, normative and control beliefs) about whole grain bread consumption. Consumers also completed food frequency questions to estimate whole grain bread intake. Focus group discussions were audio taped and transcribed. The majority of participants were women and White. After construction of the questionnaire based on focus group results, another convenience sample of 30 participants completed the questionnaire one or two times to establish internal consistency and test retest reliability of the scales. The final version of the questionnaire contained 11 items to measure attitudinal beliefs (α = 0.78); 6 for subjective norms (α = 0.43), 16 for control beliefs (α = 0.86); 2 items measuring intention (α = 0.96); and 2 food frequency questions to estimate whole grain bread intake. Test retest reliability of all scales was acceptable with correlation coefficients >0.5.

Overview

The objective of this phase of the overall research project was to develop and test a questionnaire based on the TPB (Ajzen and Fishbein 1980) to predict intention and consumption with respect to whole grain bread. Focus group interviews were conducted on the University of Minnesota campus to provide information to create questionnaire statements or items regarding attitudes, subjective norms, perceived behavioral control and intention to consume whole grain bread. Questions were also included to estimate usual whole grain bread consumption based on frequency of intake and portion size. The results were used to construct a questionnaire to measure attitudinal, normative and control beliefs, intention and whole grain bread intake. Another group of consumers completed the questionnaire once at a local grocery store to establish internal consistency reliability and again via the mail to establish test-retest reliability of the various scales based on the TPB.

Subjects

A convenience sample of 47 adult participants were recruited to participate in focus group interviews to identify salient beliefs associated with whole grain bread intake that would be used to construct questionnaire items. Recruitment fliers were posted on the University of Minnesota-Twin Cities campus asking interested participants to contact researchers via email. Interested participants were sent a form that asked them to report their age, the type of bread they typically consumed (whole wheat/whole grain or white bread), and times available to meet for a focus group session. Those indicating they consumed whole grain bread and refined grain bread were classified as whole grain ($n = 21$) and refined grain ($n = 26$) bread consumers, respectively. Inclusion criteria included participants who were between 18-60 years of age and consumed bread. Participants who indicated they typically consumed whole grain bread were mostly women (90%), White (85%), with a mean age of 37 years. About 95% had attended some college or were college graduates with 5% having a high school education only. Participants who indicated they typically consumed refined grain bread were primarily women (58%), 58% White, 23% Asian, and 15% Hispanic with a mean age of 32 years. About 88% had a college education and 12% had attended college but did not have a college degree.

A convenience sample of adult consumers was also recruited to test the questionnaire to establish adequate psychometric properties. The investigator approached about 48 consumers in the bakery area of a grocery chain store in the Minneapolis/St. Paul metropolitan area during the day and asked if they would complete a questionnaire about bread consumption. Consumers who did not eat bread or were older than 60 years of age were excluded. A total of 30 bread consumers agreed to complete the questionnaires. Participants were mostly women (80%), White (93%), with a mean age of 37 years. About 94% had attended some college or were college graduates with 6% having a high school education only. This study was approved by the University of Minnesota Institution Review Board with informed consent obtained prior to data collection.

Methods for questionnaire development – focus group interviews

Focus group interviews were conducted in classrooms on the University of Minnesota-Twin Cities campus. A total of nine focus groups were conducted including four focus groups with whole grain bread consumers and five with refined grain bread consumers. Each focus group included 4-6 participants and lasted 1 to 1 ½ hours. To confirm that participants were whole grain or refined grain bread consumers, they were asked to select one of two unlabeled breads as the one they most preferred and mark the form that asked “Which bread do you prefer? (whole wheat or white). Additionally, they were asked to bring two bags from home for breads they typically consumed. Bread labels that had a refined flour listed on the ingredient list were defined as refined grain bread, while 100% whole grain bread contained only whole grain ingredients. Of those participants in the whole grain bread consumer groups, about 76% brought in a 100% whole grain bread bag which represented the bread they typically consume at home, whereas 24% brought in a refined grain bread bag. Of those who participated in the refined grain bread consumer groups, all participants brought in a refined grain bread bag. About 73% indicated they preferred refined grain bread and 27% whole wheat bread.

The focus group interview questions were based on the TPB and were the same for groups including whole grain and refined grain bread consumers (Ajzen and Fishbein

1980) (Table 5.1). Open-ended questions explored attitudinal, normative, and control beliefs about whole grain bread consumption. Attitude was assessed by asking participants to list reasons why they eat or do not eat whole wheat or whole grain breads. This question allowed participants to provide positive and negative judgments about whole grain breads. Questions related to perceived behavioral control were based on what makes it difficult or what situations make it difficult for participants to eat whole grain bread. Normative beliefs were explored by asking participants to identify sources of influence with respect to whole grain bread consumption.

Focus group discussions were audio taped and transcribed. First, the investigator organized the responses into meaningful thematic categories and sub-categories that related to the questions consistent with the TPB constructs. Second, the number of responses for each thematic category was tallied. Those with the highest number of responses were used to develop the set of statements that made up the attitudinal, normative and control belief scales in the questionnaire.

Themes were only identified by the investigator and then were discussed with the advisor. This process did not allow for multiple perspectives when identifying themes from the focus group interviews. Not educating participants about the differences between whole grain and refined grain breads may have limited the discussion of beliefs and barriers.

Methods for questionnaire development – food frequency questions

After the focus group discussion was concluded, participants in the whole grain focus group completed food frequency questions created to measure bread consumption. Questions measuring intake frequency and portion size were adapted from the National Cancer Institute (NCI) Dietary History Questionnaire (DHQ) (DHQ 2002). Participants answered a question to assess the frequency of bread consumption based on the following responses: never, 1-6 times per year, 7-11 times per year, 1 time per month, 2-3 times per month, 1 time per week, 2 times per week, 3-4 times per week, 5-6 times per week, 1 time per day, and 2 or more times per day. Another question asked about portion size of bread consumed quantified as 1 slice or 1 dinner roll, 2 slices or 2 dinner rolls, and more than 2 slices or dinner rolls. An additional question asked “How often are the bread, toast or dinner rolls, you eat dark bread such as whole wheat, cracked wheat, rye, or multi-grain?" with the following response options: almost never, or never; about ¼ of the time; about ½ of the time; about ¾ of the time; almost always or always; and don't know. Participants in the refined grain bread focus groups completed modified food frequency questions. Participants answered a question to assess the frequency of bread (whole grain sandwich bread, refined white sandwich bread and other whole grain or refined white breads (English muffins, bagels, dinner rolls, pita bread, hamburger or hot dog buns)) consumption based on the following responses: never, 1-6 times per year, 7-11 times per year, 1 time per month, 2-3 times per month, 1 time per week, 2 times per week, 3-4 times per week, 5-6 times per week, 1 time per day, and 2 or more times per day. The questions also contained a box for the subjects to total the frequency of consumption according to the days of the week. Another question asked about portion size of bread consumed quantified as 1 slice or 1 dinner roll, 2 slices or 2 dinner rolls, and more than 2 slices or dinner rolls. An additional question asked "Are most of these other breads whole grain or refined?" Consumption frequency of bread (behavior) was measured as the summation of the consumption frequency of whole grain sandwich bread, and other breads (whole grain). Frequency responses were standardized to times per day by taking the midpoint of frequency category and dividing it by a factor. The frequency per day was then multiplied by the sum total amount of bread (whole grain) that was consumed/day to give the consumption frequency of bread consumed per day. The frequency and serving size questions were used in previous analysis of whole grain bread consumption (DHQ 2002).

Questionnaire development

The questionnaire based on the TPB model as described by Fishbein and Ajzen (1980) was constructed to measure the following: attitudinal beliefs; normative beliefs and the individual's motivation to comply; control beliefs; behavioral intention and behavior (Ajzen and Fishbein 1980). The questionnaire was based on focus group results and results based on responses to the bread food frequency questions that participants completed after the focus group discussions.

Attitudes

Attitudinal beliefs were measured with 11 statements prefaced with "I believe that whole grain breads…". Five response options were coded for data analysis as follows: very unlikely (-2), unlikely (-1), neither unlikely nor likely (0), likely (1) and very likely (2). The statements were based on focus group interview responses to a question regarding reasons why participants eat whole grain bread. Statements were related to health, taste, appearance, smell, satiety, and texture characteristics of bread.

Subjective Norms (normative beliefs x motivation to comply)

Normative beliefs were measured with six statements prefaced with the following question: "How likely do the following think you should eat whole grains?" If the source of influence wasn't applicable, the subject was given the option to select a Not applicable response. For data analysis, responses were coded to assign values for responses as follows: not applicable (0) very unlikely (-2), unlikely (-1), neither unlikely nor likely (0), likely (1) and very likely (2). The statements asked about the influence of family members, roommates, spouse, boyfriend/girlfriend, magazines/newspaper advertisements, food companies, and health claims. Possible sources of influence were identified in the focus group interviews by asking participants about other people or information sources that influence whole grain bread consumption.

Motivation to comply with normative beliefs or the opinions of others was measured with six statements based on the normative belief sources of influence (family members, roommates, etc). The following question preceded the statements: "How much do the following influence your decision to eat whole grain bread?" If the source of influence wasn't applicable, the participant was given the option to select a Not applicable response. For data analysis, responses were coded to assign values for responses as follows: not applicable (0), not at all (0), a little bit (1), a fair amount (2), much (3) and very much (4). Subjective norms were calculated as the product of the normative beliefs value and motivation to comply value for each source of influence (e.g., normative belief that family members encourage whole grain bread consumption x motivation to comply with family members) and were summed to obtain a total SN score.

Perceived Behavioral Control

Control beliefs were measured with three statements prefaced with "How hard is it for you…?" Five response options were coded for data analysis as follows: very hard (-2), hard (-1), neither hard nor easy (0), easy (1), and very easy (2). The statements were based on focus group interview responses to a question regarding what makes it difficult or what situations make it difficult to eat whole grain bread. Statements were related to eating away from home, when restaurants don't provide ingredient content, and the ability to understand labels.

Control beliefs were also measured with another 13 statements prefaced with "I think eating whole grain bread is hard because…?" Five response options were coded for data analysis as follows: disagree a lot (-2), disagree a little (-1), neither disagree nor agree (0), agree a little (1) and agree a lot (2). The statements were based on focus group interview responses to a question regarding what makes it difficult or what situations make it difficult to eat whole grain bread. Statements were related to whole grain bread being expensive, using whole grain bread for toast and a sandwich, not liking to read labels, everyone else in household eats white bread, availability, texture, taste, familiarity of white bread, whole grain bread not good for sandwiches, preference of white bread for Italian and French bread. Control beliefs were assessed by summation of the responses to the 16 statements.

Intention

Behavioral intention was measured by two items. The first intention item ("How likely is it that you will eat 3 servings of whole grain breads per day?") had five response options coded for data analysis as follows: very unlikely (-2), unlikely (-1), neither unlikely nor likely (0), likely (1) and very likely (2). The second intention item ("How many servings of whole grain breads do you plan to eat for the next month?") had seven response options coded for data analysis as follows: none (-2), 1 month (-2), 1 slice/week (-1), 2-4 slices/week (-1), 5-7 slices/week (0), 2-3 slices/day (+1) and > 4 slices/day (+2). Behavioral intention was measured as the summation of the two statements regarding intention to consume whole grain breads.

Behavior – whole grain bread intake

A number of items were slightly modified based on responses to the food frequency questions completed by focus group participants. The questions for the frequency and portion size were obtained from the NCI DHQ (DHQ 2002). The food frequency questions measured frequency of whole grain sandwich bread consumption and refined white sandwich bread, and other whole wheat and refined white breads (English muffins, bagels, dinner rolls, pita bread, hamburger or hot dog buns). For data analysis, frequency responses were coded to assign values for responses as follows: never (0); 1-6 times per year (1); 7-11 times per year (2), 1 time per month (3); 2-3 times per month (4); 1 time per week (5); 2 times per week (6), 3-4 times per week (7); 5-6 times per week (8); 1 time per day (9); and 2 or more times per day (10).

The portion size of whole grain and refined grain sandwich bread and other whole grain and refined grain breads (English muffins, bagels, dinner rolls, pita bread or buns with hamburger or hot dogs) consumed at breakfast, lunch, dinner and snack was quantified as 1 slice, 2 slices or more than 2 slices. For data analysis, serving size responses were coded as follows: 1 slice (1), 2 slices (2) or more than 2 slices (3). Frequency responses were standardized to times per day by taking the midpoint of the frequency category and dividing it by a factor. The frequency per day was then multiplied by the sum total amount of bread (whole grain or refined grain bread) that was consumed in a day to give the consumption frequency of bread consumed per day. Behavior (whole grain bread intake) was measured as the summation of the consumption frequency of whole grain sandwich bread and other whole grain breads.

The food frequency questions for the test questionnaire included more specific questions about the type of whole grain bread consumed (e.g. sandwich versus other) than the food frequency questions used after the focus group discussion. The tool box for frequency consumption according to the days of the week was confusing for the subjects and was not included in the final food frequency questions.

Methods for questionnaire testing

Participants (n=30) completed the TPB questionnaire and food frequency questions in the grocery store. The same TPB questionnaire and food frequency questions were sent in the mail along with a self-addressed stamped envelope with a test-retest period of 10-14 days (80% response, N=24). Cronbach alpha correlation coefficients were determined to assess internal consistency (Nunnally 1967) and test retest reliability was determined using Pearson's correlation analysis.

The test-retest correlation coefficients were adequate for the questionnaire scales as follows: attitudes = 0.54, subjective norms = 0.51, perceived behavioral control = 0.64, and intention = 0.79, demonstrating reproducibility between the measurements. The Cronbach alpha coefficients were 0.78, 0.43, 0.86, and 0.96 for the attitudes, subjective norms, control beliefs and intention, respectively and were considered acceptable except for the subjective norms scale which was below the level considered acceptable. To improve internal consistency, two sources of influence (roommates and boyfriend/girlfriend) were thought to be similar and were combined into one category "friends" for the final questionnaire. The final TPB questionnaire included 11 attitudinal statements, 6 normative beliefs, 16 control beliefs, and 2 intentional beliefs.

Table 5.1 Focus group questions about whole wheat/grain bread

What kind of whole wheat/grain breads do you eat?
Please list reasons why you eat whole wheat/grain breads
Please list reasons why you do not eat whole wheat grain breads
What makes it difficult for you to eat whole wheat/grain bread regularly?
Please mention situations that make it difficult to eat whole wheat/grain breads (e.g., when it is not available)?
Can you tell us about other people that help you eat more whole wheat/grain bread?
How do other people help you eat more whole wheat/grain breads?
Is there anyone who keeps you from eating more whole wheat/grain bread?
How do people keep you from eating more whole wheat/grain breads? Please list all of the ways.

Chapter 5. Part 2. Expanding the Theory of Planned Behavior to explain intention to consume whole grain bread and consumption

Sara A. Sjoberg, MS

Many barriers to whole grain consumption have been identified; however few studies have examined factors that influence consumption of a specific whole grain food such as bread. Expanding the Theory of Planned Behavior (TPB) to include barriers such as liking and usual whole grain bread consumption pattern may improve the ability to predict intention to consume whole grain bread and estimated intake. Therefore, the objective of this study was to expand the standard TPB to predict intention and whole grain bread consumption with the added variables of liking rating, whole grain versus refined grain bread preference, responsiveness to bitter taste (measured by rating the bitterness of 6-*n*-propylthiouracil - PROP), typical whole grain bread consumption pattern and demographic characteristics. Questionnaire data were used from 258 participants regarding attitudinal, control, and normative beliefs, intention and whole grain bread consumption, demographic characteristics, preferences and intake patterns. Participants also tasted and rated their liking of five whole grain breads, and provided their intensity rating of PROP. Multiple regression analysis was used to determine the associations between model components and intention and intake of whole grain bread. Perceived behavioral control was more important than subjective norms in the standard model in predicting intention and explained 13% of its variance. Inclusion of liking rating only slightly improved the predictive power (14%). In a further expansion of the standard model to predict intention, perceived behavioral control, whole grain bread liking rating, and usual whole grain bread consumption pattern were significantly associated with intention and together explained 17% of the variance. Intention and perceived behavioral control were positively associated with whole grain bread intake. Inclusion of liking rating in the standard model did not further increase the predictive power for intake (46%). In the expanded model that included liking rating, response to bitter taste and demographic characteristics, significant predictors of intake included perceived behavioral control, liking rating and whole grain bread consumption patterns with 53% of the variance in intake explained by the expanded model. Nutrition education aimed at increasing whole grain bread consumption should address barriers including liking to foster habitual intake.

Introduction

Consumption of whole grain foods is associated with reduced risk of obesity/weight gain (Liu et al. 2003; Good et al. 2008; McKeown et al. 2010) and chronic diseases, including heart disease (Jensen et al. 2004; Mellen et al. 2007) and type 2 diabetes (De Munter et al. 2007; Sun et al. 2010). Based on this protective relationship, the 2010 Dietary Guidelines recommends that Americans consume half of total grains as whole grain and replace refined grains with whole grains (USDA 2010). Despite considerable scientific, policy and regulatory support, dietary intake of whole grain foods remains far below recommended levels. NHANES (1999-2004) data showed that the mean intake of whole grains for adults aged 19-50 and ≥ 51 years was 0.63 and 0.77 daily servings, respectively (O’Neil et al. 2010). Only 5% of adults aged 19-50 years and 7% of adults ≥ 51 years consumed three or more daily servings of whole grains. Low intake among the majority of Americans supports the need for research to examine factors that affect whole grain consumption.

Frequently cited barriers to consuming whole grain foods among adults include limited availability in the marketplace and higher cost (Kantor et al. 2001). Personal factors include difficulty in identifying a whole grain food product, dislike of taste, color, and texture, limited knowledge of health benefits and preparation methods, and additional time and effort required to read food labels (Britten et al. 2006; Bakke and Vickers 2007; Larson et al. 2010).

The Theory of Planned Behavior (TPB) is a well-established theoretical model used to predict the likelihood that individuals will perform selected behaviors (Fishbein & Ajzen 1975). The standard model proposes that intention to perform a behavior is influenced by attitudinal beliefs (positive or negative evaluation of performing the behavior), perceptions of whether others approve of performing the behavior (normative beliefs), and perceptions of whether the individual has control over the behavior (perceived behavioral control) (Ajzen 1991). Intention to perform a behavior is based on implementation planning and is therefore thought to be an important direct predictor of behavior (Gollwitzer 1999). When applied to food-related behaviors, the theory has been fairly effective in explaining a significant proportion of the variance in intention and dietary behavior (Godin and Kok 1996; Armitage and Conner 2001). The predictiveness of the standard TPB model in explaining food-related behavior has been improved when additional variables related to dietary behavior and food choice were included (Conner and Armitage 1998). Past behavior, habit strength, and liking ratings have been shown to be independent contributors to intention and behavior and increased the predictiveness of the theory by 4-23% when applied to consumption of starchy foods, fish, breakfast and foods low in saturated fats (Stubenitsky and Mela 2000; Verbeke and Vackier 2004; Wong and Mullan 2009; White et al. 2010). Food choice studies that modified the TPB and the theory of reasoned action to include sensory hedonic responses were based on actual tasting of foods or liking rating in surveys and showed improvement in the ability to predict consumption of low-salt bread, and milk (Tuorila-Ollikainen et al. 1986; Tuorila 1987).

The TPB has been used in two previous studies to examine the relationship between psychosocial factors and consumption of whole grain foods (Sparks et al. 1992; Kvaavik et al. 2005). Sparks et al. (1992) found that TPB constructs explained 25% of the variance in intention to consume whole meal bread among a consumer panel. Kvaavik et al. (2005) applied the TPB to intake of a group of whole grain foods including wheat bread, unsweetened breakfast cereal, and oat porridge at baseline and eight years later among adults. When intakes of whole grain foods were the dependent variable the theory explained between 0 to 5% of the variance at baseline and between 5-12% of the variance eight years later. Other studies using the TPB constructs to predict the intake of specific foods found that the theory predicted a fairly large proportion of the variance in intake. For example, the TPB constructs explained 42% of the variance in fish consumption (Verbeke and Vackier 2004) and 49% of the variance in milk intake (Park and Ureda 1999). As suggested by Baranowski et al. (1999) using the TPB to examine consumption of a specific food product may improve predictiveness of the model. Bread is also one of the most commonly consumed whole grain foods by Americans (Bachman et al. 2008) making it an important focus for further study. In addition, limited studies have examined factors that influence whole grain bread consumption among US consumers using the TPB.

Several studies have examined liking of whole grain breads (Lang and Walker 1990; Mialon et al. 2002; Bakke and Vickers 2007). Lang and Walker (1990) compared the liking of laboratory-prepared whole wheat hamburger buns made with red and white wheat flour and found that consumers did not prefer one type over the other. Mialon et al. (2002) compared the liking of commercial whole meal bread to other refined grain breads when different dietary information was provided. Bakke and Vickers (2007) compared the liking of laboratory-prepared, commercial and artisan whole wheat bread to their refined counterparts. Both studies found that consumers liked the commercial and laboratory-prepared refined grain breads more than the whole grain breads. However, consumers liked the commercial and artisan whole wheat breads as much as their refined counterparts (Bakke and Vickers 2007).

Whole grain food products have been described as tasting bitter (Chang and Chambers 1992; Murray et al. 2002) which may contribute to a dislike for whole grain bread (Bakke and Vickers 2007; Challacombe et al. 2011). Sensitivity to bitter tastes has been related to a genetic trait (Drewnowski, Henderson, and Shore 1997) to detect bitter taste as measured with the reaction to 6-n-propylthiouracil (PROP) (Dinehart et al. 2006). Those who perceived PROP as extremely or moderately bitter had a greater dislike (overall, flavor and texture) for whole wheat bread compared to refined grain wheat bread (Bakke and Vickers 2007). Therefore incorporating the response to PROP in the application of the TPB to explain intention to consume whole grain bread and consumption may improve predictiveness.

Objectives

The objective of this study was to apply an expanded TPB model to intention and behavior with respect to consumption of whole grain breads. The expanded model included liking, preference for whole grain versus refined grain bread, PROP rating, demographic characteristics and typical whole grain bread consumption pattern. The hypothesis was that inclusion of these additional factors would improve the predictive power of the standard TPB model for intention to consume whole grain bread and consumption.

Methods

Participants

Participants were recruited from seven grocery stores from one Midwestern-national grocery chain in the Minneapolis/St. Paul metropolitan suburbs. Each store was separated by at least 12 miles from another store. A researcher consecutively approached all grocery store shoppers who walked by the bakery area of the store. Efforts were made to ensure that data collection was completed across a variety of times during the day and week, in line with preferences of store managers. A total of 428 consumers were approached during January and February 2007 and 270 (215 female and 54 male) who met inclusion criteria agreed to participate. Inclusion criteria were an indication of usual bread consumption, being between the ages of 18-60 years and conditions that may place one at risk while tasting PROP including being pregnant or in poor health, reported history of thyroid disease, dry mouth, nasal disorders, severe respiratory infections, and ear infections (Bartoshuk et al. 1996). Others meeting inclusion criteria (n = 158) declined to participate indicating that lack of time and or the presence of young children prohibited participation. This study was approved by the University of Minnesota Institution Review Board with informed consent obtained prior to data collection. Participants were given a grocery store gift card in return for participation.

Procedures

Figure 5.1 depicts the basic steps involved in data collection. Prior to completion of a questionnaire, participants were asked “Which bread do you prefer? Whole grain or refined white bread?” as a measure of preference for whole grain or refined grain bread. This question was followed by a 5-minute scripted lesson that described differences between whole grain bread and refined grain bread to ensure that participants could differentiate between whole grain and refined grain bread prior to completing the questionnaire that focused on factors influencing consumption. The lesson was included because previous focus group discussions (Chapter 5, Part 1) indicated that consumers were confused about the differences between these breads. Participants then completed the questionnaire, rated their liking for several bread samples and measured their reaction to PROP.

Questionnaire

The questionnaire contained items that made up several subscales based on the standard TPB including attitudinal beliefs; normative beliefs and the person's motivation to comply; perceived behavioral control beliefs and intention to consume whole grain bread (Ajzen and Fishbein 1980). The statements were developed from previous focus group interviews (Chapter 5, Part 1) following the procedures suggested by Ajzen and Fishbein (1980).

Attitudes

Attitudinal beliefs were measured with 11 statements prefaced with "I believe that whole grain breads…" with five response options coded for data analysis as follows: very unlikely (-2), unlikely (-1), neither unlikely nor likely (0), likely (1), and very likely (2). The statements were related to reasons why whole grain bread may be consumed including health, taste, appearance, smell, satiety, and texture characteristics of bread. One attitudinal belief ("will make me gain weight") was reverse coded so a positive response was reflected from higher values for all items.

Subjective Norms (normative beliefs x motivation to comply)

Normative beliefs were measured with six statements prefaced with the following question: "How likely do the following think you should eat whole grains?" with six response options coded for data analysis as follows: not applicable (left blank), very unlikely (-2), unlikely (-1), neither unlikely nor likely (0), likely (1), and very likely (2). The statements examined the possible influence of others or information sources on whole grain bread consumption including family members, spouse, friends, magazines/newspaper advertisements, food companies, and health claims. Motivation to comply with normative beliefs was measured with a question about the possible normative sources of influence (family members, spouse, etc) as follows: "How much do the following influence your decision to eat whole grain bread?" The six response options were coded for data analysis as not applicable (left blank), very unlikely (1), unlikely (2), neither unlikely nor likely (3), likely (4), and very likely (5). While the responses options allowed a participant to respond in an incremental matter, the response options did not exactly match the question. Subjective norms were calculated as the product of the normative beliefs and motivation to comply for each source of influence (e.g., normative belief that family members encourage whole grain bread consumption multiplied by motivation to comply with family members) and then were summed to obtain a total subjective norm score.

Subjective norms were calculated as the product of the normative beliefs and motivation to comply for each source of influence (e.g., normative belief that family members encourage whole grain bread consumption multiplied by motivation to comply with family members) and then were summed to obtain a total subjective norm score.

Perceived Behavioral Control

Control beliefs were measured as the sum of scores from two series of statements. The first included three statements prefaced with "How hard is it for you…? with five response options coded for data analysis as very hard (-2), hard (-1), neither hard nor easy (0), easy (1), and very easy (2). The statements were based on issues or situations that may make it difficult to eat whole grain bread including eating away from home, when restaurants do not provide ingredient content, and the inability to understand food labels. The second included 13 statements prefaced with "I think eating whole grain bread is hard because…? with five response options coded for data analysis as disagree a lot (-2), disagree a little (-1), neither disagree nor agree (0), agree a little (1) and agree a lot (2). These statements were related to cost, preferences for use, need to read labels, household norms, availability, texture, taste, and familiarity. Control beliefs were reverse coded so that higher values represented a positive value where applicable.

Intention

Behavioral intention was measured by two items. The first ("How likely is it that you will eat 3 servings of whole grain breads per day?") had five response options coded for data analysis as very unlikely (-2), unlikely (-1), neither unlikely nor likely (0), likely (1), and very likely (2). The second ("How many servings of whole grain breads do you plan to eat for the next month?") had seven response options coded for data analysis as none (0), 1-2 slice/month (1), 1 slice/week (2), 2-4 slices/week (3), 5-7 slices/week (4), 2-3 slices/day (5), and >4 slices/day (6). Behavioral intention was measured as the summation of values for these two statements.

Internal consistency for the various subscales was previously established with 30 participants with similar demographic characteristics as those in the current study (Chapter 5, Part 1) (Cronbach alpha coefficient for attitudes = 0.78, subjective norms = 0.43, perceived behavioral control = 0.86, and intention = 0.96). Internal consistency was acceptable for all subscales (Nunnally 1967) except subjective norms which was somewhat less than acceptable. Test-retest reliability was also established previously with the same 30 participants who provided data to test internal consistency. The same questionnaire was completed 10-14 days apart and correlations between results were determined as follows: attitudes = 0.54, subjective norms = 0.51, perceived behavioral control = 0.64 and intention = 0.79.

Whole grain bread intake

Consumption of whole grain bread was quantified by multiplying the reported frequency of whole grain sandwich bread and other whole grain bread intakes (including English muffins, bagels, dinner rolls, pita bread, hamburger or hot dog buns) by the estimated portion size. Questions assessing intake frequency and portion size were adapted from the National Cancer Institute Dietary History Questionnaire 2002 (DHQ 2002) by separating questions related to intake of whole grain sandwich bread and other whole grain breads into two separate questions. The two questions measured frequency of 1) whole grain sandwich bread consumption; and 2) other whole grain bread consumption on an 11-point scale: never (coded as 0 times per day); 1-6 times per year (0.0096); 7-11 times per year (0.025), 1 time per month (0.033); 2-3 times per month (0.0822); 1 time per week (0.143); 2 times per week (0.286) ; 3-4 times per week (0.5); 5-6 times per week (0.785); 1 time per day (1.0); and 2 or more times per day (2) (Appendix 2). Usual portion size was determined by asking respondents to indicate if they usually ate one, two or more than two slices of whole grain sandwich bread and other whole grain breads at breakfast, lunch, dinner and snack. Coded frequency responses were multiplied by usual portion sizes: 1 slice (coded as 1 portion), 2 slices (2 portions) or more than 2 slices (3 portions). Total servings of whole grain bread were quantified by summing intake across the day (breakfast, lunch, dinner and snack) for both whole grain sandwich bread and other whole grain bread. Intake data from participants who reported consuming whole grain servings greater than 2 standard deviations from the total mean intake were excluded from further analysis (n = 12) (Grubbs 1950).

Other questionnaire items

Participants also provided information about age, gender, race, education, marital status and household composition. An additional question assessed exercise frequency as (Do you exercise regularly - at least 5 times a week, 30 minutes each time? (yes, no)). Lastly, participants were asked about their usual whole grain bread consumption pattern with the following question: “How long have you consumed whole grain breads as a part of your typical diet?” Eight response options included 0 month, 0 – 6 months, 6 – 12 months, 12 – 24 months, 24 – 36 months, 3 – 5 years, 5 – 10 years, and > 10 years.

Whole grain bread liking rating

Participants were asked to rate liking of five commercial 100% whole grain bread samples (Table 5.1). The five whole grain breads that were selected for this study offered the greatest diversity in sensory qualities as determined from a previous descriptive analysis study (Chapter 4). The bread samples were purchased from the grocery store 1-2 days prior to tasting and prepared by vertically slicing the bread samples in half and placing each bread sample in a Ziploc® plastic sandwich bag, labeled with a three-digit code, and served within 24 hours at room temperature.

Liking ratings of appearance, flavor, overall liking and texture of the five 100% whole grain breads were measured using a 120 point labeled affective magnitude scale (LAM) ranging from 0 = greatest imaginable disliking, 60 = neutral, and 120 = greatest imaginable liking (Schutz and Cardello 2001). The order of presentation of the bread samples was randomized. While the participants were standing at the counter height table, they were asked to open the plastic sandwich bag and remove the bread slice. Participants first rated their liking of the appearance of the bread sample. Next, the subject took a bite of the crumb and crust of the bread sample. Participants rated their liking of flavor, overall liking and liking of the texture of the five breads. They were instructed to place a mark anywhere on the line (LAM scale) corresponding to their response. The order of presentation of the breads was balanced across participants using a William’s Latin Square design (Macfie et al. 1989). The liking rating data were obtained by measuring the distance in millimeters from the left (“greatest imaginable disliking”) to the right (“greatest imaginable liking”). The mean liking rating was determined from the top three ratings for each person.

PROP score

Participants also rated the bitterness intensity of PROP to identify participants as supertasters, medium tasters and nontasters (Bartoshuk et al. 2002). PROP papers were prepared by dipping filter paper into a saturated PROP solution heated to near boiling (Bartoshuk et al. 2004). The papers were air dried, cut into 1.3 cm squares and individually placed in a Ziploc® plastic bag. Each paper contained approximately 1.6 mg (0.0032mmol/l) PROP. As a therapeutic medication for hyperthyroid patients a daily dose typically contains on average of 300 mg of PROP. Therefore the amount of PROP on each paper was minimal.

Participants rated the bitterness intensity of PROP using a general labeled magnitude scale (gLMS) (Bartoshuk et al. 2002). The gLMS was a semantically labeled line scale (Dinehart et al. 2006). The descriptors on the gLMS ranged from the left with “no sensation”, “barely detectable”, “weak”, “moderate”, “strong”, “very strong” to the far right with the “strongest imaginable sensation of any kind”. First, participants became acclimated to the gLMS by rating a variety of remembered visual and auditory sensations varying in intensities (e.g., “loudness of a whisper”; “saltiness of potato chips”; “brightness of this room”) using the gLMS. This exercise allowed participants to compare the intensity of other sensations to the bitter intensity of PROP. Before tasting the PROP paper participants were informed of the bitter taste of PROP. Participants placed the PROP paper disk on the tip of their tongue until it was moistened with saliva and rated the intensity of the bitterness of PROP by placing a vertical line on the gLMS. The ratings were measured in millimeters from the base of the scale (“no sensation”) to the far right (“strongest imaginable sensation of any kind”) ranging from 0 to 90. The PROP taster status was classified according to methods used by Bakke and Vickers (2011). A PROP nontaster score was defined as < 13, a PROP medium taster score was between 13 and 73.2 and a PROP supertaster was > 73.2.

The average time for completion of a questionnaire, tasting and rating liking of bread samples and PROP paper was 30 minutes. Incentives (gift-cards and baking spoon) were provided for completion of the questionnaires.

Data analysis

Data were analyzed using Statistical Analysis System (SAS, version 9.2, Cary N.C). Descriptive statistics (means, standard deviations, ranges and frequencies) were calculated for each of the TPB constructs, demographic characteristics, whole grain bread intake, bread liking rating, whole grain bread consumption pattern, and PROP intensity rating.

Student t-tests and mixed analysis of variance (ANOVA) were conducted to determine if there were differences in whole grain bread intake, according to demographic categories, whole grain versus refined grain bread preference, and PROP taster status.

Regression analysis

Pearson correlation coefficients were determined to examine associations among TPB constructs and whole grain bread consumption pattern, PROP rating, mean whole grain bread liking rating and whole grain versus refined grain bread preference. To test the hypothesis that the expanded TPB model will improve the predictiveness of intention to consume and intake of whole grain bread, nine multiple regression models were used. The first model with intention as the dependent variable included the traditional TPB constructs: (Model 1: PROC REG (intention to consume whole grain bread = attitude + SN + PBC). The second model with intention as the dependent variable was expanded to include mean liking of whole grain bread (Model 2: PROC REG (intention to consume whole grain bread = attitude + SN + PBC + mean liking rating). The third model with intention as the dependent variable expanded the model further to include whole grain versus refined grain bread preference (whole grain bread preference = 1, refined grain bread preference = 2) (Model 3: PROC REG (intention to consume whole grain bread = attitude + SN + PBC + bread preference).

The final model with intention as the dependent variable included mean liking rating, PROP intensity rating, whole grain versus refined grain bread preference and demographic characteristics (Model 4 PROC REG: (intention to consume whole grain bread = attitude + SN + PBC + mean liking rating + PROP rating + bread preference + demographics). Race (Caucasian = 1, other = 2), sex (female = 1, male = 2), marital status (married = 1, not married =2), exercise frequency (no = 1, yes = 2), and household composition variables (living alone = 1, living with others = 2) were included in the models as dichotomous variables. Age was included in the models as a five category variable (1 = ages 10-19 years, 2 = 20-30, 3 = 31-40, 4 = 41-50, 5 = 5-60) and bread consumption pattern was included in the models as a six category variable (1 = 0 months, 2 = 0-6 months, 3 = 6-12 months, 4 = 12-24 months, 5 = 24-36 months, 6 = 3-5 years, 7 = 5-10 years, and 8 = greater than 10 years). To measure if the increase in the proportion of variance in intention explained as a result of expanding the model increased significantly above the standard model, rsdelta was calculated by using the formula F(Change) = [SSError (standard model) – SSError (expanded model)] / [df(standard model) - df(expanded model)] / SSE(expanded model) / df(expanded model). If F(Change) > F(0.05, df(standard model)-df(expanded model), df(expanded model)) that indicates a significant improvement in variance explained.

Predictors of reported whole grain bread intake were determined using log-linear Poisson regression analysis (Allison 1999). The Poisson regression was used to predict whole grain bread consumption as intake data were non-normally distributed and negatively skewed (6% of participants indicated they consumed no whole grain bread, and the mean and variance of whole grain bread consumption were approximately equal). Other studies used Poisson regression for similar reasons (Hutchinson et al. 2003; Hutchinson and Holtman 2005). The Poisson regression null model 5 with whole grain intake as the dependent variable (PROC GENMOD) = /Dist = poisson link = log type 1 type 3) was used to conduct the likelihood ratio test of goodness of fit to calculate R^2 value from full log likelihood values since R^2 values cannot directly be calculated in SAS using PROC GENMOD (Shtatland et al. 2000). According to Shtatland et al. (2000) R^2 can be calculated with the following equation: $R^2SAS = 1 – \exp\{-2[\log L(M) – \log L(0)] / n\}$ where logL(M) and logL(0) are the maximized log likelihood for the fitted model and the null model that contains only an intercept term, and n is the sample size. To measure if the increase in the proportion of variance in behavior explained was a result of expanding the model increased significantly above the standard model; a chi-squared test was conducted within the Poisson regression analysis.

The Poisson regression model used for examining TPB constructs as predictors of whole grain bread consumption was model 6: (Proc Genmod (whole grain bread intake) = attitude + SN + PBC + intention). The expanded model 7 included the mean liking rating of whole grain bread (Proc Genmod) (whole grain bread intake) = attitude + SN + PBC + intention + mean liking rating). The expanded model 8 included whole grain versus refined grain bread preference (Proc Genmod) (whole grain intake) = attitude + SN + PBC + intention + bread preference). The final expanded model 9 with whole grain bread intake as the dependent variable included mean liking rating, PROP rating, whole grain versus refined grain bread preference and demographic characteristics (Proc Genmod) (whole grain bread intake) = attitude + SN + PBC + intention + mean liking rating + PROP rating + bread preference + demographic characteristics).

Results

Demographic characteristics

Participants were mostly Caucasian (92%) women (81%) with a mean age of 41 years (range of 18 – 60 years) (Table 5.2). About 86% of the participants lived with another person and 58% were married. Most participants had some college education (87%) and about 43% reported that they exercised at least 5 days/week for 30 minutes each session. Over 79% of the participants claimed to consume whole grain breads for at least one year.

Consumption of whole grain bread

The mean daily intake of whole grain bread (sandwich and other) was 1.3 servings (SD 1.49). A small proportion of participants (6%) reported consuming zero servings of whole grain bread/day, while 48% reported >0 and < 1 serving per day, 21% reported 1-2 servings per day, 11% reported 2-3 servings/day, and 14% reported >3 servings per day.

There were no significant differences in consumption of whole grain breads with age ($F = 1.15$, $p = 0.33$), gender ($t = -0.72$, $p = 0.47$), race ($t = -1.06$, $p = 0.30$), education

(F = 0.80, p =0.53), marital status (t = 0.16, p = 0.88), household composition (t = -0.82, p = 0.42) and exercise frequency (t = -1.24, p = 0.22). Participants consuming whole grain bread for 0-6 months reported consuming significantly less whole grain bread (0.2 servings per day) compared to those reporting consumption for greater than six months (1.6 servings per day) (F = 4.39, p = 0.0001).

Approximately 62% of the participants indicated they preferred to consume whole grain bread and 38% refined grain bread. Participants who preferred to consume whole grain bread (n = 161) reported consuming significantly more whole grain bread (1.8 servings per day) than participants who reported that they preferred to consume refined grain bread (n = 97) (0.6 servings per day) (t = 7.3, Pr>t <0.0001). There was no significant difference in reported intake of whole grain breads by PROP taster status (F = 2.48, p = 0.09).

Table 5.3 shows the means and standard deviations for the individual items and scales based on the standard TPB constructs. Attitudinal beliefs with the highest scores included the beliefs that whole grain breads are healthy, taste good, are high in fiber, contribute to satiety, and are hearty and robust. The highest scores for normative beliefs included magazine/newspaper advertisements and health claims on food packages and then were followed with personal sources of influence such as family members. The highest scores for motivation to comply were health claims on food packages and a spouse. For control beliefs, the highest scores for barriers were not liking to use whole grain bread for toast, finding it hard to find whole grain bread in the store where the participant buys bread, and having to go to a certain grocery store/bakery to buy a type/brand of whole grain bread. Understanding whole grain labels on packages was also an important concern. The mean score on the first question assessing intention indicated that most participants did not intend to eat 3 servings of whole grain bread per day. The mean response for the second intention question indicated that participants only planned to eat 2-4 slices of whole grain bread per week over the next month.

The mean response regarding the length of time that participants have consumed whole grain bread as part of their typical diet was equivalent to 24-36 months, indicating a pattern of usual whole grain bread consumption covering the past two to three years.

The mean liking rating of whole grain bread was determined from the mean of the top three ratings of the five samples tasted for each person (81.83). This value was somewhat higher than a neutral rating (60) but far from the greatest imaginable liking rating (120). The mean PROP rating was 36 (range 0 = no sensation to 90 = strongest imaginable sensation of any kind) indicating a PROP medium taster score. Lastly, a mean value of 1.4 was obtained in response to the question about bread preference (whole grain (coded as 1) versus refined grain bread (coded as 2)) indicating a stronger overall preference for whole grain rather than refined grain bread.

Correlations between TPB constructs and additional variables

In Table 5.4, correlation coefficients are presented for the traditional TPB constructs and the additional explanatory variables. Intention was moderately correlated with estimated whole grain intake ($r = 0.58$, $p<0.0001$) and weakly correlated with PBC ($r = 0.31$), usual whole grain bread consumption pattern ($r = 0.29$) and liking of whole grain bread ($r = 0.22$). Intention was also negatively correlated with bread preference (whole or refined grain) ($r = -0.36$). Whole grain intake was correlated with each of the standard TPB constructs (PBC ($r = 0.35$), subjective norms ($r= 0.18$) attitudinal beliefs ($r = 0.19$)) and with usual whole grain bread consumption pattern ($r = 0.28$). Intake was negatively correlated with bread preference ($r =-0.38$). The strength of the correlations between TPB constructs and additional variables was generally weak (0.18 to 0.31) but statistically significant.

Predictors of intention

Multiple regression analysis showed that the standard constructs of the TPB (Attitude, SN, PBC) explained 13% of the variance in intention to consume whole grain bread (Model 1: [$F = 12.50$, $p<0.0001$]) (Table 5.5). PBC and SN were significant predictors of intention.

When mean liking rating was included in the regression model (model 2), PBC and liking were significant predictors of intention and the variance explained in intention to consume whole grain breads was improved to 16% [$F = 11.87$, $p = <.0001$] (Table 5.5). Including bread preference in the regression model (model 3), further improved the percentage of variance explained to 17% [$F = 12.92$, $p = <.0001$] with PBC and bread preference identified as significant predictors of intention (Table 5.5). In the last model with intention as the dependent variable, mean liking rating, PROP rating, bread preference and demographics were all included in the regression model (model 4). The variance in intention explained by the model was increased to 24% [F = 5.47, p = <.0001] (Table 5.5). Mean liking rating of whole grain bread, bread preference and usual whole grain bread consumption pattern significantly influenced intention to consume whole grain breads.

Predictors of whole grain bread intake

Table 5.6 shows the results of the Poisson regression models with whole grain bread intake as the dependent variable and the standard constructs of the TPB as explanatory variables (PBC, SN, attitudes and intention) along with additional explanatory variables. In Model 6, PBC and intention were significant predictors of behavior with 45% of the variance in intake of whole grain bread explained by the model. For every one point increase in intention, consumption increases by an average of 31%, for example, from one serving per day to 1.31 servings per day (Allison 1999). In Model 7, mean whole grain bread liking rating was included in the model but had no significant independent effect. In Model 8, inclusion of bread preference improved the percentage of variance explained in intake of whole grain bread to 49% (Table 5.6). When mean whole grain bread liking rating, PROP rating, bread preference and demographic characteristics were added to the regression model (model 9), the percentage of variance in intake explained by the model increased slightly (53%). Intention, bread preference and the usual whole grain consumption pattern were significant predictors of whole grain bread intake (Table 5.6).

Discussion

Expanding the standard TPB model to include additional variables related to sensory properties (mean whole grain bread liking rating, and bread preference – whole or refined grain) and usual whole grain bread consumption pattern improved the proportion of the variance explained in intention from 13% to 24%. The addition of bread preference and usual whole grain bread consumption pattern slightly improved the proportion of variance explained in whole grain bread intake (45% – 53%). The increase in the proportion of variance in intention explained by the expanded model was expected as the mean liking rating of whole grain bread was in a range indicating that participants slightly to moderately liked whole grain bread and there was a stronger overall preference for whole grain rather than refined grain bread. Liking rating was only an important factor in predicting intention but not for intake in the expanded model. However, inclusion of bread preference increased the predictive power of the standard model for both intention and behavior. Bread preference may be more important than liking rating because it reflects a longer term experience while the liking rating were done at a single time point based on a short term evaluation of five whole grain bread samples. Similar findings were reported by Tuorila (1987) where the predictive power of the TPB for milk consumption was improved by including rating of milk liking based on survey results (longer-term evaluation) and not by results obtained from actual tasting of the milk (short term evaluation).

A higher PROP rating (supertaster status) is related to lower liking of whole grain bread (Bakke and Vickers 2007), therefore including PROP rating in the model was expected to result in an increase in the predictive power for intention and behavior. The mean PROP rating indicated a medium taster score which might explain why PROP rating had no significant correlation with whole grain bread intake, intention or with liking rating of bread samples. No other studies were found for comparison that included PROP rating as an additional variable to explain intention to consume or consumption of whole grain bread or other foods based on the TPB.

The usual whole grain bread consumption pattern was equivalent to typically consuming whole grain bread for the past 24-36 months. Participants consuming whole grain breads for a longer period of time consumed more whole grain bread than those who consumed whole grain bread for a shorter period of time supporting the concept that the usual whole grain bread consumption pattern would be related to intention and intake. In fact including the usual whole grain bread consumption pattern in the model was significantly associated with both intention and behavior. These findings are similar to other studies where a construct defined as habit was included to expand the TPB and was shown to be a significant predictor of intention and behavior in relation to consumption of fish (Verbeke and Vackier 2004), two daily servings of fruit (Brug et al. 2006), and fat intake scores (De Bruijn et al. 2008). Typical intake patterns over time imply a long term familiarity which could lead to habitual consumption and greater preference as suggested by the results of the current study.

Overall preference for whole grain bread, a mean intake pattern of 24-36 months and mean intake of 1.3 servings/day among participants in the current study may not be consistent with preferences and intake of the general population of US adults. The mean intake of whole grain bread was 1.3 servings/day while the mean intake of all whole grain foods for Americans determined from a cross-sectional analysis of NHANES data was between 0.63 and 0.77 servings per day for adults aged 19-50 years and > 51 years, respectively (O'Neil et al. 2010). The high level of intake may be related to the demographic profile of participants which consisted of highly educated females in households with spouses or children. The relatively high intake of whole grain bread is consistent with findings related to bread preference, liking rating and usual whole grain bread consumption pattern, although responses to the intention questions were less positive. Women subjects were overrepresented in the current study, however women from family households tend to make the purchasing decisions as the 'food gatekeeper' and the gatekeeper has indirect and direct influences on what other family members eat (Lewin 1943; Wansink 2003; 2006). Several studies indicated that females, particularly those who are older and more educated, believed that healthy eating is important (Hunt et al. 1997; Nestle et al. 1998; Kearney et al. 1999). Consumers who also live a healthier lifestyle consume more whole grains (Lang et al. 2003; Kyro et al. 2011). A recent data analysis of whole grain consumption among young adults showed that health was positively related to whole grain intake (Larson et al. 2010) and two other studies found that individuals who consumed more whole grains had an overall healthier diet (O'Neil et al. 2010; Kyro et al. 2011). Participants in the current study who were highly educated and exercised more may have believed that healthy eating was important which may explain why the mean consumption of whole grain breads was higher than the average intake of whole grains for Americans. Therefore, the positive results regarding the predictiveness of the TPB toward whole grain bread consumption behavior may be partially related to the positive attitudes and behaviors of the participants in the current study. Replicating this study with other population groups may therefore produce less positive results.

The overall predictiveness of intention in the standard model was lower than the range (29-51%) exhibited among other studies that used the TPB to predict intention with respect to food intake (Bogers et al. 2004; Rah et al. 2004; Blanchard et al. 2009). The expanded model in the current study also explained less of the variance in intention compared to other studies that used an expanded model (26-76%) (Verbeke and Vackier 2004; Mahon et al. 2006; White et al. 2010; Wong et al. 2010). The proportion of variance in whole grain bread intake explained by the standard model in the current study was comparable to that explained in other studies that used the TPB to predict food intake (10-49%) (Bogers et al. 2004; Rah et al. 2004; De Bruijn et al. 2010). The variance for predicting behavior in the expanded model was also comparable to the range in other studies (10-78%). These studies included habit to explain intake of fish, saturated-fat and fruit (Verbeke and Vackier 2004; De Bruijn 2008; De Bruin 2010). In the current study the measurement of usual whole grain consumption pattern was very similar to how habit was previously measured (Verbeke and Vackier 2004). Habit regarding consumption of fish was measured by an item that asked if eating fish is part of one's eating habits. Two previously mentioned studies that assessed habit strength used a validated self-reported habit index survey (Verplanken and Orbell 2003). The use of the reported habit index was a more comprehensive measure of habit than the measure used in the current study and may therefore have been a better component of the TPB to explain intake.

Several limitations should be noted. Use of food frequency questions was a convenient method for estimating whole grain bread intake in a grocery store setting; however, this estimation may be less accurate compared to a 24-hour recall or food diary. Caution must be taken regarding the accuracy of reported whole grain bread intake because consumers typically have some difficulty differentiating whole grain bread from refined grain bread that contains mixed grains (Adams 2000; Slavin, Marquart and Jacobs 2000; Kantor et al. 2001; Mancino et al. 2008). These issues may have resulted in an overestimation of whole grain bread intake which was not consistent with responses to intention to consume three servings of whole grain breads. Another limitation of this study was use of response options that did not exactly match the motivation to comply questions which may have been confusing to participants making interpretation of the SN results more difficult. White women and participants who preferred whole grain breads were overrepresented in this study which may explain the high mean whole grain bread intake and provide for more positive results. Participants in the present study were self-selected consumers who volunteered to be in the study. Despite these limitations, expanding the TPB model with additional factors (sensory and demographics) allowed for a comprehensive investigation of factors that influence whole grain bread consumption.

Implications for research and practice

Future research should aim to identify additional important factors that influence whole grain bread consumption to explain more variability in intention. Given that intention to consume whole grain bread and control beliefs were directly related to whole grain bread intake, interventions to increase whole grain bread intake should address barriers found to be important such as availability and preferences for use of refined bread in some situations (for toast or sandwiches). The importance of usual whole grain bread consumption suggests that interventions need to acknowledge that environmental cues can help develop healthier eating habits. One method to provide environmental cues and to address control barriers would be to increase availability of whole grain breads away from home. Additional research is needed to examine influences on whole grain bread consumption at home and away from home since consuming whole grains away from home was a barrier in the current study and has been cited as a barrier in other studies related to whole grain intake (Adams and Engstrom 2000; Kantor et al. 2001; Marquart et al. 2003). Improved availability of whole grain breads when away from home can increase exposure to whole grain breads leading to a preference for whole grain over refined grain breads and improve the usual whole grain bread consumption patterns, thus resulting in increased consumption of whole grain bread. Further research is also needed to examine factors affecting whole grain bread consumption among populations including males, low income, lesser educated, and more ethnically diverse.

Table 5.1 Breads, type, and bread manufacturer information for the 5 whole grain breads included in liking study

Breads	Bread Type (100%)	Manufacturer Name	Address
Cub Food	Whole wheat	Supervalu	Eden Prairie, MN
Country Hearth	Whole wheat	Pan O Gold Baking Company	St. Cloud, MN
Natural Ovens	Whole grain	Natural Ovens Bakery	Manitowoc, WI
Pepperidge Farms	Whole wheat	Pepperidge Farm Inc.	Norwalk, CT
Sara Lee	Whole wheat	Sara Lee Inc.	Downers Grove, IL

Table 5.2 Participant demographic and lifestyle/dietary characteristics (n = 258)

Characteristic	Categories	% (n)
Age	10-20 years	4.7(12)
	20-30 years	19.0 (49)
	30-40 years	14.7 (38)
	40-50 years	33.7(87)
	50-60 years	27.9 (72)
Gender	Female	80.6 (208)
	Male	19.4 (50)
Race/ethnicity	White	91.9 (237)
	African American	3.1 (8)
	Asian	1.2 (3)
	Hispanic	1.2 (3)
	Other	2.7 (7)
Education	Up to 8th grade	0.4 (1)
	Some high school	1.6 (4)
	High school or GED	11.6 (30)
	Some college/technical school	34.1 (88)
	College graduate	52.3 (135)
Marital status	Married	58.5 (151)
	Single	31.0 (80)
	Divorced	8.5 (22)
	Separated	1.9 (5)
Household composition	Spouse	27.5 (71)
	Boyfriend/girlfriend	10.1 (26)
	Sisters/brothers	1.2 (3)
	Daughters/sons	6.6 (17)
	Alone	14.3 (37)
	Others (____)	5.8 (14)
Exercise frequency (at least 5 times a week, 30 minutes each time)?	No	56.6 (146)
	Yes	43.4 (112)
Whole grain bread consumption pattern (consumed whole grain breads as part of a typical diet?)	0 months	10.1 (26)
	0-6 months	8.5 (22)
	6-12 months	3.1 (8)
	12-24 months	6.6 (17)
	24-36 months	3.5 (9)
	3-5 years	16.7 (43)
	5-10 years	16.7 (43)
	>10 years	34.9 (90)

Frequencies may not add up to 100 due to rounding.

Table 5.3 Means and standard deviations for attitudinal, normative and control beliefs and intentions.

Construct	Belief Items	Mean	Standard Deviation
Behavioral Beliefs (I believe that whole grain breads….) (very unlikely=-2 to very likely = +2)	Are healthy	1.51	0.68
	Taste good	1.19	0.90
	Are high in fiber	1.14	0.80
	Make me feel full	1.05	0.81
	Are hearty and robust	1.03	0.78
	Make me feel satisfied	1.00	0.83
	Have a dense/heavy texture	0.89	0.83
	Are dark in color	0.86	0.77
	Smell good	0.81	0.88
	Prevent me from eating as much	0.49	0.96
	Will make gain weight	0.47	0.91
	Overall scale – behavioral beliefs	10.4	5.5
Normative Beliefs (How likely do the following think you should eat whole grain bread?) (very unlikely = -2 to very likely = +2, not applicable = blank)	Magazine/newspaper advertisements	0.76	0.99
	Health claims on food packages	0.73	1.02
	Family members	0.29	1.16
	Spouse	0.25	1.21
	Food companies	0.22	1.07
	Friends	0.08	1.04
	Overall scale – Normative beliefs	2.2	3.7
Motivation to Comply (How likely is it that the following encourage you to eat whole grain breads?) (very unlikely = 1 to very likely = 5, not applicable = blank)	Health claims on food packages	3.24	1.12
	Spouse	3.18	1.21
	Family members	3.02	1.17
	Magazine/newspaper advertisements	2.80	1.17
	Food companies	2.76	1.08
	Friends	2.74	1.09
	Overall scale – Motivation to comply	17.8	4.5
	Overall scale – Subjective norms	9.7	11.6
Control Beliefs (How hard is it for you to…?) (very hard = -2 to very easy = +2)	Understand WG bread packaging and labeling/ingredient list	0.36	0.94
	Eat WG breads when restaurants do not provide ingredient content information on breads served	-0.36	1.03
	Eat WG breads when eating away from home (at restaurants, parties, and family functions)	-0.01	1.10
Control Beliefs (I think eating whole grain bread is hard because…) (disagree a	I do not like to use WG bread for toast	1.16	1.16
	It is hard to find WG bread in the store where I/we usually buy bread	1.15	1.06
	I have to go to a certain grocery store/bakery	1.00	1.16

lot = +2 to agree a lot = -2)	to buy my type/brand of WG bread		
	I do not like to use WG bread for sandwiches	0.97	1.26
	It takes over the taste of the ingredients inside or on top of the sandwich or bread (meat, cheese, peanut butter, jelly etc.)	0.88	1.20
	There are pieces of grains in WG breads that are hard to bite and chew	0.79	1.22
	White bread is wheat I have always eaten	0.74	1.44
	Everyone else in the household eats white bread	0.61	1.42
	I do not like to read bread labels	0.39	1.30
	White bread goes better with some foods (peanut butter and jelly, grilled cheese) than WG bread	0.39	1.43
	WG breads are expensive	0.14	1.21
	It is not soft as white bread	0.12	1.33
	White Italian and French bread go better with some foods	-0.85	1.09
	Overall Scale - Perceived Behavioral Control	7.5	10.1
Intention 1	How likely is it that you will eat 3 servings of whole grain bread per day? 1 serving = 1 slice of bread (very unlikely = -2 to very likely = +2)	-0.55	1.15
Intention 2	How many servings of whole grain bread do you plan to eat for the next month? (none (0), 1 -2 slices/month (1), 1 slice/week (2), 2-4 slices/week (3), 5-7 slices/week (4), 2-3 slices/day (5), >4 slices/day (6))	2.90	1.37
	Overall scale - Intention	2.3	2.1

Table 5.4 Correlation coefficients among TPB constructs and additional explanatory variables

	Variable	1	2	3	4	5	6	7	8	9
1	**Attitude**	1								
2	**SN**	0.25***	1							
3	**PBC**	0.25***	0.18*	1						
4	**Intention**	0.20**	0.20**	0.31***	1					
5	**WG Bread Intake**	0.19***	0.18*	0.35***	0.57***	1				
6	**Bread consumption pattern**	0.20*	0.08	0.36***	0.29***	0.28***	1			
7	**PROP Rating**	0.06	0.02	0.00	0.04	0.07	0.09	1		
8	**Liking rating of WG breads**	0.17*	0.15	0.08	0.22**	0.15	0.01	0.04	1	
9	**WG vs. refined grain bread preference**	-0.17*	-0.23**	-0.49***	-0.36***	-0.38***	-0.31***	0.04	-0.03	1

*p<0.01, **p<0.001, ***p<0.0001

Table 5.5 Multiple regression analysis of intention to consume whole grain breads on the TPB constructs and additional explanatory variables

Model 1 Intention on attitudes, PBC and SN					
Variables	**B**	**SE**	**Standardized B**	**T**	**Model R^2**
Attitude	0.04	0.02	0.09	1.49	0.13
PBC	0.05	0.01	0.26	4.29***	
SN	0.03	0.01	0.14	2.34*	
Model 2 Intention on attitudes, PBC, SN and mean liking rating					
Attitude	0.03	0.02	0.07	1.13	0.16
PBC	0.05	0.01	0.26	4.27***	
SN	0.02	0.01	0.12	2.01	
Mean liking rating	0.03	0.01	0.17	2.97**	
Model 3 Intention on attitudes, PBC, SN, and bread preference					
Attitude	0.03	0.02	0.08	1.39	0.17
PBC	0.03	0.01	0.16	2.35*	
SN	0.02	0.01	0.11	1.87	
Bread preference	-1.02	0.29	-0.23	-3.53***	
Model 4 Intention on attitudes, PBC, SN, mean liking rating, PROP rating and demographics					
Attitude	0.02	0.02	0.07	1.10	0.24
PBC	0.02	0.01	0.09	1.33	
SN	0.02	0.01	0.09	1.44	
Mean liking rating	0.02	0.01	0.16	2.62**	
PROP rating	0.001	0.005	0.01	0.19	
Bread preference	-1.01	0.29	-0.25	-3.75***	
Age	-0.004	0.01	-0.03	-0.41	
Gender	0.17	0.30	0.03	0.56	

Race	0.38	0.46	0.05	0.84
Education	-0.08	0.16	-0.03	-0.49
Marital status	0.34	0.31	0.08	1.10
Household composition	0.42	0.39	0.07	1.07
Exercise frequency	-0.15	0.25	-0.04	-0.61
WG bread consumption pattern	0.14	0.05	0.17	2.65**

*P<0.05; **P<0.01; ***P<0.001

Model 1: F = (df = 3, 257) = 12.50, p = <0.0001

Model 2: F = (df = 4, 257) =11.87, p = <0.0001

Model 3: F = (df = 4, 255) =12.92, p = <0.0001

Model 4: F = (df = 14, 255) = 5.47, p = <0.0001

Table 5.6 Poisson regression analysis of whole grain bread consumption on the TPB constructs and additional explanatory variables

Model 6 Intake on attitudes, PBC, SN, and intention								
Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		X2	P>X2	R2
Intercept	1	-0.929	0.160	-1.242	-0.615	33.65	<0.0001	0.45
Attitude	1	0.015	0.011	-0.008	0.037	1.63	0.202	
SN	1	0.003	0.005	-0.006	0.012	0.57	0.449	
PBC	1	0.020	0.006	0.009	0.032	11.63	0.001	
Intention	1	0.269	0.029	0.214	0.325	91.33	<0.0001	
Model 7 Intake on attitudes, PBC, SN, intention and mean liking rating								
Intercept	1	-1.071	0.352	-1.761	0.381	9.26	0.002	0.46
Attitude	1	0.014	0.011	-0.008	0.036	1.54	0.214	
SN	1	0.003	0.005	-0.006	0.012	0.51	0.477	
PBC	1	0.020	0.006	0.009	0.032	11.71	0.001	
Intention	1	0.268	0.030	0.212	0.323	87.94	<0.0001	
Mean liking rating	1	0.002	0.004	-0.006	0.010	0.21	0.649	

Model 8 Intake on attitudes, PBC, SN, intention and bread preference								
Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		X2	P>X2	R2
Intercept	1	-0.067	0.277	-0.609	0.476	0.06	0.810	0.49
Attitude	1	0.015	0.011	-0.008	0.037	1.68	0.194	
SN	1	0.001	0.005	-0.008	0.010	0.05	0.819	
PBC	1	0.013	0.006	0.001	0.026	4.49	0.034	
Intention	1	0.253	0.028	0.197	0.308	78.85	<0.0001	
Bread preference	0	-0.575	0.156	-0.881	-0.269	13.55	0.000	
Model 9 Intake on attitudes, PBC, SN, intention, mean liking rating, PROP rating, bread preference, and demographics								
Intercept	1	-2.764	0.952	-4.631	-0.897	8.42	0.004	0.53
Attitude	1	0.008	0.012	-0.016	0.031	0.39	0.532	
SN	1	0.0001	0.005	-0.010	0.010	0.00	0.982	
PBC	1	0.010	0.007	-0.004	0.022	1.87	0.172	
Intention	1	0.249	0.030	0.190	0.307	69.31	<0.0001	
Mean liking	1	0.009	0.005	-0.000	0.018	3.60	0.058	

rating								
PROP rating	1	0.002	0.002	-0.002	0.006	0.72	0.397	
Bread preference	1	-0.526	0.161	-0.841	-0.211	10.70	0.001	
Age	1	0.009	0.005	-0.001	0.020	2.96	0.085	
Gender	1	0.150	0.140	-0.123	0.423	1.16	0.281	
Race	1	-0.293	0.237	-0.757	0.171	1.53	0.217	
Education	1	0.116	0.083	-0.044	0.277	2.01	0.156	
Marital status	1	0.165	0.140	-0.110	0.440	1.38	0.241	
Household composition	1	0.213	0.191	-0.162	0.588	1.24	0.265	
Exercise	1	0.040	0.113	-0.181	0.260	0.12	0.725	
WG bread consumption pattern	1	0.276	0.054	0.170	0.382	25.92	<0.0001	

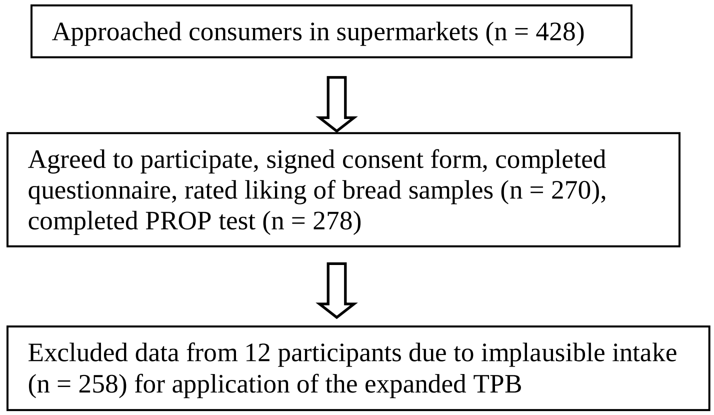
Model 6: χ^2/df = 1.08; deviance/df = 0.94

Model 7: χ^2/df = 1.09; deviance/df = 0.94

Model 8: χ^2/df = 1.09; deviance/df = 0.88

Model 9: χ^2/df = 1.01; deviance/df = 0.84

Figure 5.1 Data collection



Chapter 6 - Sensory characteristics and consumer liking of commercial 100% whole grain breads

Sara A. Sjoberg, MS

Improving the taste and liking of whole grain breads is one approach to increase dietary intake of whole grains. Many studies have used descriptive analysis (DA) to characterize whole grain breads and examine consumer liking. However, there are no studies that have used DA and assessed liking of commercial whole grain breads. Examining sensory attributes and consumer liking ratings of commercial whole grain breads can allow for better understanding of attributes that influence the liking of commercial whole grain breads available in the U.S. market. Objectives of this study were to examine liking differences among whole grain bread samples and between consumer groups; to determine if PROP tasters like the breads less than PROP nontasters; to examine associations between attributes from the descriptive analysis data from expert panelists and the consumer liking ratings of the whole grain breads; and to determine if the least liked bread was more bitter than the well liked bread. Consumers liked Cub Foods and Country Hearth whole grain breads the most for overall, flavor and texture liking and Natural Ovens bread the least. Consumer classification according to bread preference and PROP taster status had no effect on liking of bread samples. Differences in liking, attitudes and usual whole grain bread consumption pattern were observed among the clustered participants. Bitter taste and flavor attributes were significantly associated with liking of breads and supports the hypothesis that bitterness is related to liking of whole grain breads. Liking was affected by salty taste and flavor. Cub Foods bread had the highest salty taste and flavor in comparison to the other breads and may explain why this bread was most liked. Identifying sensory attributes that influence liking of whole grain breads can be used to modify commercially available whole grain breads that are appealing to consumers.

Introduction

The health benefits associated with dietary intake of whole grain foods provides evidence in support of the Dietary Guidelines recommendation to consume at least three daily servings (USDA Dietary Guidelines 2005). Despite these benefits consumption of whole grains is well below the recommended levels (O'Neil et al. 2010). Factors that contribute to a reduced intake of whole grain foods may be related to a dislike of the taste, texture and color (Britten et al. 2006; Larson et al. 2010). Yeast breads are one of the most frequently consumed grains in the U.S. (Bachman et al. 2008) and may provide an opportunity to increase whole grain intake in the general population through the substitution of whole grain flour for refined grain flour (Keast et al. 2011).

Several studies examined consumers' liking responses to whole grain breads (Lang and Walker 1990; Mialon et al. 2002; Bakke and Vickers 2007; Challacombe et al. 2011). Three studies examined liking differences between laboratory prepared whole wheat breads made with red and white wheat flour (Lang and Walker 1990; Bakke and Vickers 2007; Challacombe et al. 2011). There were no differences in preference (Lang and Walker 1990) and liking (Bakke and Vickers 2007) between the red wheat and white wheat breads. However, another study found that red whole wheat breads were liked more than the white wheat breads (Challacombe et al. 2011). Two studies examined liking differences between whole grain and refined grain breads (Mialon et al. 2002; Bakke and Vickers 2007). When comparing laboratory-prepared whole grain to refined grains breads, refined grain breads were liked more (Mialon et al. 2002; Bakke and Vickers 2007). However, there were no differences in liking between the artisan and commercial whole grain breads and refined grain breads (Bakke and Vickers 2007). Additionally there are currently no published studies that examined liking differences among commercial whole grain breads in the US.

Liking of foods is related to the taste (Moskowitz 1978). Although there are many factors that influence liking, a bitter taste can cause dislike or rejection of the food. Several food-related studies found taste to have a major influence on the liking of food products (Tuorila and Cardello 2002; Luckow and Delahunty 2004; Lyly et al. 2007; Teh et al. 2007; Sabbe et al. 2009). The bitter taste may be a primary reason for rejecting some foods (Drewnowski 1997a). Whole grain food products have been described as tasting bitter based upon the descriptive analysis of breads (Chang and Chambers 1992; Murray et al. 2002; Challacombe et al. 2011). The rejection of bitter taste is genetically related to the ability to taste 6-*n*-propylthiouracil (PROP) (Bartoshuk 1993; Drewnowski, Henderson and Shore 1997b). Results are conflicting as to whether PROP tasters like bitter foods less than PROP nontasters. Of the two bread studies that examined PROP taster status and liking of breads, one found an association (Bakke and Vickers 2007) and the other study did not (Bakke and Vickers 2011). The authors suggested these finding may be due to the breads having high levels of bitterness that were detected by all PROP tasters (Bakke and Vickers 2011). The results of these studies are conflicting as to whether bitterness has an effect on liking of whole grain breads.

Consumer expectations in regards to whole grain bread could be met by modifying sensory attributes, such as bitter taste. Identifying sensory attributes that describe breads can be determined through the use of descriptive analysis (DA). DA is a method used to characterize foods. Many studies used DA to characterize whole grain/whole meal breads (Johnson and Vickers 1991; Chang & Chambers 1992; Haglund 1998; Murray et al. 2002; Heinio et al. 2003; Shogren et al. 2003; Kihlberg et al. 2004; Hersleth et al. 2005; Battochio et al. 2006; Flander et al. 2006; Annett et al. 2007; Jensen et al. 2010; Challacombe et al. 2011). DA was used to characterize the breads and demonstrated differences in sensory attributes among the breads.

Associating the whole grain bread samples sensory characteristics to the bread consumers liking rating may allow for optimization of a bread product as found in other food-related studies (Lee and Chambers 2010; Young et al. 2005). There are four bread studies that used DA to characterize breads and measured liking ratings of breads (Heinio et al. 1997; Carson et al. 2000; Kihlberg et al. 2005; Challacombe et al. 2011). However, only one of the studies examined associations between the sensory attributes and hedonic ratings of whole grain breads (Challacombe et al. 2011). Participants were clustered based upon overall bread liking scores and correlated with the descriptive analysis data. For the first cluster, the whole grain breads were associated with wheat taste, malt, molasses, and astringent characteristics. The third cluster was associated with sweet taste of crumb and crust and yeasty aroma of the crumb for whole grain bread. There are no studies that examined the association between sensory attributes of whole grain breads and consumer liking of commercial whole grain breads. This will provide evidence as to whether the bitterness of whole grain breads is related to liking of breads as other bread studies found whole grain breads to taste bitter (Chang and Chambers 1992; Challacombe et al. 2011). Thus, consumer liking for a specific attribute of the whole grain bread may be one factor influencing the decision to consume particular whole grain bread.

Objectives

The objectives of this study were 1) to examine liking differences among bread samples and between consumer groups: whole grain versus refined grain bread preference, type of bread bag returned (whole grain or refined grain), and PROP taster status (supertaster, medium taster and nontaster); 2) to test the hypothesis that PROP tasters will like the breads less than PROP nontasters; 3) to examine liking differences among the bread overall liking clusters; 4) to examine if there are differences among the overall liking clusters for whole grain bread intake, attitudes, perceived behavioral control, subjective norms, usual whole grain bread consumption pattern, and PROP rating (refer to Chapter 5 Part 2 for measurement of these variables); and 5) to test the hypothesis that differences will exist by cluster groups for liking and TPB variables

Secondary objectives were related to examining associations between liking ratings of five whole grain breads and descriptive analysis of these five whole grain breads. The objectives were: 1) to examine if consumer liking ratings of the whole grain breads were affected by sensory attributes that were determined from the descriptive analysis data from expert panelists; 2) to determine if the least like breads were more bitter than the well liked breads, and 3) to test the hypothesis that bitter breads were liked less than the non-bitter breads.

Methods

Bread samples for liking ratings

The five whole grain breads that were selected for this study offered the greatest diversity in sensory qualities as determined from the previous descriptive analysis study that characterized 12 whole grain breads (Chapter 4) (Table 6.1). The previously mentioned descriptive analysis study explains in detail how these five breads were selected based upon multivariate principal component analysis. The bread samples were purchased from the grocery store 1-2 days prior to tasting and prepared by vertically slicing the bread samples in half and placing each bread sample in a Ziploc® plastic sandwich bag, labeled with a three-digit code, and served within 24 hours at room temperature.

Participants

Participants for the bread liking study (Chapter 5 Part 2) and descriptive analysis study are described as previously mentioned (Chapter 4).

Procedures

Bread liking study

The bread liking questionnaire assessed participants' liking responses of five commercial 100% whole grain bread samples (Table 6.1). Liking ratings of appearance, flavor, overall and texture of the five 100% whole grain breads were measured using a 120 point labeled affective magnitude scale (LAM) ranged from 0 = greatest imaginable disliking, 60 = neutral, and 120 = greatest imaginable liking (Schutz and Cardello 2001). The order of presentation of the bread samples was randomized. While the participants were standing at the counter height table, they were verbally told to open up the plastic sandwich bag and remove the bread slice. Participants first rated their liking of the appearance of the bread sample. Next, the participant took a bite of the crumb and crust of the bread sample. Participants rated flavor liking, overall liking and texture of the five 100% whole grain breads. They were instructed to place a mark anywhere on the line (labeled affective magnitude scale) corresponding to their response. The bread sample order of presentation was balanced across participants using a William's Latin Square design (Macfie et al. 1989).

Descriptive analysis

A total of 12 whole grain breads were characterized using DA and further details are provided in the previously mentioned study (Chapter 4). Sensory attributes describing Cub Foods, Country Hearth, Natural Ovens, Pepperidge Farms, and Sara Lee breads will be used for analyzing the effect of attributes on liking rating of breads.

Data analysis

Data were analyzed using Statistical Analysis System (SAS, version 9.2, Cary N.C). Significance of differences were defined as $P < 0.05$.

Bread liking data analysis

Mixed model ANOVAs were performed to determine if there were significant differences in the mean bread liking ratings (appearance, flavor, overall, and texture) among the bread samples (type 3 tests of fixed effects). Post-hoc Tukey paired comparisons tests were used to determine if there were significant differences in liking ratings between bread samples. For models 1-4, liking rating was the response variable and the predictor variables included bread sample, bread sample order of presentation, whole grain versus refined grain bread preference, type of bread bag returned (whole grain or refined grain), and PROP taster status (supertaster, medium taster, and nontaster). Model 1 (bread liking rating = participant (random) + bread sample + order + bread sample x order) was used to examine if order had an effect on bread liking rating. Since bread sample order of presentation was not significant for flavor, overall and texture liking in model 1 it was not included in models 2-6. The exception was for appearance liking of breads. In models 2-6 for appearance liking, order of bread presentation will be included as a predictor variable. Model 2 (liking = participant (random) + bread sample) was used to examine liking differences among bread samples. Differences in liking of the bread samples among the participants' whole grain versus refined grain bread preference were determined using the following model 3 (liking = participant (random) + bread sample + bread preference + bread sample x bread preference). Model 4 included type of bread bag returned (liking = participant (random) + bread sample + type of bread bag returned + bread sample x type of bread bag returned) to determine if there were significant differences in liking ratings of the bread samples among the type of bread bag returned. Differences in liking of samples with PROP taster status were determined using the following model: (model 5: liking = participant (random) + bread sample + PROP taster status + bread sample x PROP taster status).

Cluster analysis was used to cluster participants according to similarity on overall liking rating of whole grain breads to find homogenous overall liking rating groups. The overall liking ratings were centered by subtracting each participant's average overall liking ratings from each of their individual rating and then this mean for each participant was used in cluster analysis. This process allowed for cluster analysis to group participants based on their patterns of overall liking of the whole grain breads. Participants were segmented based on mean overall liking ratings of whole grain bread by using agglomeration hierarchical clustering with Ward's method. Data were analyzed using XLSTAT (XLSTAT, version 2.0). To determine if there were differences in liking of the bread samples among centered overall liking rating clusters a mixed ANOVA model 6 (liking ratings = participant (random) + cluster + bread sample + cluster x bread sample) was conducted. A mixed ANOVA model was used to determine if there were differences in variables used in the previously mentioned TPB study (attitudes, SN, PBC, whole grain bread intake and length of time consuming whole grain breads) among centered overall liking clusters (model 7 (attitudes, SN, PBC, whole grain bread intake and usual whole grain bread consumption pattern = cluster). Cluster was the predictor and the TPB variables were the independent variables. The significance level of $p \leq 0.05$ was used for all statistical tests. Post-hoc Tukey paired comparisons tests were used to determine if there were significant differences for these variables among consumer groups.

DA and bread liking associations

Data from the descriptive analysis study (Chapter 4) that described the five whole grain breads (Cub, Country Hearth, Natural Ovens, Pepperidge Farms, and Sara Lee) that were also used in the bread liking study will be used for data analysis in chapter 6. For the data analysis of associations between bread liking data and DA sensory attributes DA attributes were reduced down to mean values for 168 attributes for the 5 breads since attributes developed from DA were rated by trained panelists and are assumed to be more accurate than the bread liking data that contained four liking ratings (appearance, flavor, overall, and texture) for the five breads. Regression techniques were used to relate mean sensory attributes of the five whole grain breads to the bread liking data of the five whole grain breads. Since the slope of the lines of mean liking ratings across all attributes appeared to be more curvilinear than linear, a quadratic model was also applied to the data analysis. The dependent variables consisted of flavor, appearance and texture liking ratings and the independent variables consisted of flavor, appearance and texture attributes. Overall liking rating was the dependent variable with aroma and aftertaste attributes since the liking of aroma and aftertaste were not rated by the consumers. Linear and quadratic relationships were examined between the bread liking ratings and attributes using the following mixed ANOVA model: (liking rating = attribute + attribute x attribute). The model processed random effects by bread sample, and judge. A contrast was conducted on the linear and quadratic relationships of each attribute to predict bread liking and is reported in the results section.

The same linear and quadratic model was run on the bread sample loading scores for principal components (PC) 1-11 and bread liking data to determine if there were associations between these two variables. The dependent variables consisted of flavor, appearance and texture liking ratings and the independent variables consisted of bread sample loading scores of PC 1 to 11. Linear and quadratic relationships were examined between the bread liking ratings and loading scores for PC 1-11 using the following mixed ANOVA model: (liking = PC1 + PC1 x PC1). Again, this model processed random effects by bread sample, and judge. A contrast was conducted on the linear and quadratic relationships of each attribute.

ANOVA was conducted on bitter attributes that were significantly associated bread liking ratings using a general linear model to examine difference in bitter attribute ratings among the 5 bread samples. Differences in bread samples mean attributes among bread samples were determined using Tukey's honesty significant difference ($p \leq 0.05$).

Results

Bread liking study

According to the mixed design ANOVA results there was a significant difference in liking of appearance for bread sample order of presentation [$F(4, 1056) = 2.88$, $P = 0.02$]. However, according to the mixed design ANOVA results, there were no significant differences in liking for bread sample order of presentation for flavor liking [$F(4, 1056) = 0.26$, $P = 0.90$] , overall liking [$F(4, 1056) = 0.16$, $P = 0.96$] , and texture liking [$F(4, 1056) = 0.36$ $P = 0.84$]. Since bread sample order of presentation did not have a significant effect on flavor, texture and overall liking, it was not included in models 2-6. However, since order of presentation had an effect on appearance liking, order will be included in models 2-6. Bread sample order of presentation did not have a significant effect as a main effect or when order interacted with other variables in models 2-6 and will not be further mentioned. ANOVA model 2 demonstrated that liking of appearance [$F(4, 1076) = 7.37$, $P<0.0001$], liking of flavor [$F(4, 1076) = 39.76$, $P<0.0001$] , overall liking [$F(4, 1076) = 39.17$, $P<0.0001$] , and liking of texture [$F(4, 1076) = 34.90$, $P<0.0001$] was significantly different among the bread samples (Table 6.2). Cub Foods and Country Hearth breads were liked significantly more ($P\leq 0.05$) than Natural Ovens, Pepperidge Farm and Sara Lee breads for appearance, flavor, texture and overall liking. Natural Ovens bread was liked significantly least for flavor, overall and texture liking in comparison to the other breads.

Liking and whole grain versus refined grain bread preference

Approximately 64% of the participants who had a whole grain bread preference returned a whole grain bread bag, and 13% of participants who preferred refined grain bread returned a whole grain bread bag (data not shown). Mixed ANOVA showed there was no significant main effect of whole grain versus refined grain bread preference with appearance, flavor, overall and texture liking (Table 6.3).

Liking and type of bread bag returned

According to the mixed ANOVA there was no significant main effect of bread bag returned with flavor, overall and texture liking (Table 6.3). However there was a significant main effect of type of bread bag returned with appearance liking. Participants who returned a whole grain bread bag ($n = 72$) rated the appearance liking of the breads more (80.7) than participants who returned a refined grain bread bag ($n = 71$) (77.6) ($t = -2.21$, $p = 0.03$).

Liking and PROP taster status

PROP nontasters made up 13% of the participants, 59% were classified as medium tasters, and 28% were classified as supertasters. Mixed design ANOVA did not show a significant main effect of PROP taster status and appearance, overall and texture liking (Table 6.3). Mixed design ANOVA showed a significant main effect of PROP taster status and flavor liking, however after post-hoc Tukey tests there was no significant difference among the PROP tasters flavor liking (Table 6.3).

Clustering of overall liking ratings

The dendrogram displayed there were three groups of clusters. Cluster analysis identified three distinct clusters based on the centered overall liking ratings of whole grain breads (Table 6.4). Cluster one consisted of 109 participants, 127 participants were in cluster two and 34 participants were in cluster three. Cluster one group represented consumers who liked (flavor, overall and texture) the Pepperidge Farms bread significantly more than clusters two and three. The hypothesis was supported that there were differences in liking by cluster groups. Consumers in cluster one significantly had a lower overall liking, flavor and texture liking of Natural Ovens bread than participants in clusters two and three. Cluster two group represented consumers who liked some breads similarly to cluster one and other breads similarly to cluster three. Cluster one and cluster two had a greater overall liking and texture liking of Sara Lee bread than cluster three. In addition, cluster two and cluster three significantly liked the flavor, texture and overall liking of Natural Ovens more and Pepperidge Farms bread less than cluster one. Consumers in cluster three represented those who liked (flavor, overall and texture) Sara Lee bread significantly less than clusters one and two.

There were significant differences in attitudes, PBC and with usual whole grain bread consumption pattern (Table 6.5). In support of the hypothesis, participants in cluster 3 had significantly higher attitudinal beliefs, and consumed whole grain bread for a longer period of time than participants in cluster 1 and 2.

DA and liking associations

According to the mixed design ANOVA results there was a significant difference in liking for a total of 51 attributes ($p \leq 0.05$) (Table 6.6). The highly significant attributes ($p<0.0001$) for the crumb were: (crumb) fermented flavor, molasses flavor, uncooked flavor, brown aroma, level of aroma, sweet taste aftertaste, salty aftertaste, squishy, moist, gummy, soft and tooth packing texture. Additional attributes that were significantly ($p \leq 0.05$) related to liking ratings (crumb) included: cardboard flavor, oily flavor, oxidized flavor, butter aroma, fermented, grainy and hay aroma, sweet aftertaste, cardboard aftertaste, and chewy texture. For the crusts, the highly significant attributes ($p<0.0001$) included salty flavor of top crust, salty taste of bottom crust, bitter flavor of bottom crust, butter aroma of top crust and doughy aroma of top crust. Additional attributes that were significantly ($p\leq0.05$) related to liking (crust) included: bitter taste and flavor of top, salty taste of top, burnt, coffee flavor of top crust, starchy and dairy flavor of bottom crust, level of baked aroma of top and bottom, intensity aroma of bottom, grainy aroma of bottom, doughy aroma of bottom, appearance of surface (smooth-rough), salty, burnt, grainy and honey aftertaste of top, bitter and salty taste aftertaste of bottom, bitter and sour aftertaste of bottom, gritty and papery texture of top crust.

The hypothesis that bitter breads will be liked less was supported by the significant association of two bitter attributes (bitter taste and flavor of top crust) with bread liking ratings. The least liked (flavor, overall and texture liking) bread from the consumer bread liking study was Natural Ovens bread. Natural Ovens bread also had the highest bitter ratings for the bitter taste and flavor of the top crust (Table 6.7). However these bitter attributes for Natural ovens bread were significantly equal to Sara Lee bread. The bitter taste aftertaste and aftertaste of the bottom crust were significantly associated with overall liking; however, Natural Ovens bread had the lowest score for these two attributes in comparison to the other four breads (Table 6.7).

The uncooked flavor of the crumb, salty aftertaste of crumb, squishy and moist texture, salty taste and flavor of top crust, and salty taste of bottom crust were significantly associated with liking ratings, and these attributes were also rated significantly high for Cub Foods bread in comparison to the other breads (data not shown).

Mixed ANOVA results showed that the principal component had no effect on liking ratings after correction for multiple comparisons using Bonferoni test.

Discussion

The differences in overall liking, and appearance, flavor and texture liking of the bread clearly demonstrates the complexity that occurs for each person when deciding on bread they most prefer to consume. Clearly Cub and Country Hearth whole grain breads were the most liked breads and Natural Ovens bread was the least liked bread. Whole grain versus refined grain bread preference having no effect on liking contradicts the findings from Bakke and Vickers (2007; 2011), where there were differences in liking according to bread preference. This discrepancy may depend upon other factor affecting liking. Food preference may reflect an individuals' attitude toward the concept of the food rather than self-reported liking. It is speculated that some of the participants claimed to prefer whole grain breads because of health benefits associated with whole grains, but actual liking of whole grain breads may be dependent upon many other factors (e.g. sensory, demographics, socio-cultural).

Consumers who returned a refined grain bread bag liked the appearance of breads less than consumers who returned a whole grain bread bag was unexpected considering that another bread study (Bakke and Vickers 2007) found that participants who returned a refined bread bag liked the appearance of refined grain breads more than the whole grain breads.

Contrary to the hypothesis PROP tasters (super and medium tasters) liked the bread equally to the PROP nontasters. Similarly Bakke and Vickers (2011) found that the effect of added wheat bitter germ extract on liking did not depend upon PROP taster status. However, our results are conflicting with results from another bread study where liking differences with laboratory made whole wheat breads depended upon PROP taster status (Bakke and Vickers 2007). As Bakke and Vickers (2007) suggested with the commercial breads and artisan breads, the commercial whole grain bread in this current study may have contained enough sugar to suppress the bitterness of the bread and may explain why there were no differences in liking of breads according to PROP taster status. The bitterness of foods can be suppressed by the addition of sweeteners (Ly and Drewnowski 2001) and the presence of salt (Duffy and Bartoshuk 2000). Perhaps the bitterness of these commercial whole grain breads in the present study was less perceptible in comparison to other bitter tasting foods (e.g., breads made with low amounts of sugar, coffee and green tea). Several other food-related studies found no difference in liking of bitter foods such as broccoli (Turnbull and Matisso-Smith 2002; Bell and Tepper 2006), caffeine solution with added non-nutritive sweetener or chocolate

(Ly and Drewnowski 2001), black coffee, grapefruit juice, dark chocolate and tonic water (Tepper et al. 2009). Perhaps the bitter flavor of breads that has been suggested as a barrier is not a barrier to liking of whole grain breads and could be dependent upon other sensory attributes.

As expected the results from the cluster analysis clearly show differences in liking of the bread samples by cluster groups. Since participants were clustered based upon standardized overall liking and overall liking was correlated with appearance, flavor and texture liking (data not shown) it makes sense that there were also differences in appearance, flavor and texture liking among the cluster groups. Participants in cluster three who liked the Natural Oven more and Sara Lee bread less than participants in clusters one and two and had more positive attitudes, and consumed whole grains for a longer period of time. These participants may represent part of the population who like breads similar to Natural Ovens and have more positive attitudinal beliefs towards whole grain breads and may be related to the longer period of time consuming the whole grain bread. There was also a clear segment of participants for liking of Pepperidge Farms and Sara Lee breads. No significant differences in liking of Cub Foods bread and Country Hearth bread among the cluster groups could be a result of these two breads being the most liked breads by all participants.

Although there was a significant association between three bitter attributes and liking ratings of the bread, there is evidence that bitter taste and flavor is not a barrier to liking of whole grain breads. Results show that Natural Ovens bread had similar bitter ratings as the Sara Lee bread and the Sara Lee bread was liked more that Natural Ovens for flavor, overall and texture liking. In addition, the bitter aftertaste was lowest for Natural Ovens breads in comparison to the other breads. It appears that liking of whole grain breads may not be driven by bitter attributes.

Another sensory attribute that was significantly associated with liking was salty taste and flavor of the breads. When examining which breads had the highest salty taste and flavor attributes, Cub Foods was rated as the most salty bread sample. Cub Foods bread was also significantly liked the most for flavor, overall and texture liking in comparison to the other four breads. The saltiness of Cub Foods bread may explain why this bread was liked more in comparison to the other breads. This result was unexpected since no studies have examined associations of sensory attributes of whole grain breads with liking ratings. However, one study that examined associations of sensory attributes to chemically analyzed acidity of wholemeal sour rye breads found that salt improves the taste, texture and stability of the bread and strengthens the flavor (Helleman et al. 1988). Another bread study found that pleasantness rating of rye bread was related to the saltiness (Helleman et al. 1987). Two other studies characterized whole grain bread as tasting salty (Chang and Chambers 1992; Challacombe et al. 2011). A recent bread study that described and compared commercial whole grain breads to laboratory made breads found the commercial whole grain bread was more salty than the laboratory made breads (Annett et al. 2007). The greater salty taste and flavor may be one sensory factor that explains why Cub Foods bread was liked more than the other whole grain breads for overall and flavor liking.

Conclusion

This study provides evidence that commercial whole grain breads have distinct consumer liking differences according to brand. No significant differences in liking of breads based on consumer segmentation (whole grain versus refined grain bread preference and PROP taster status) reveals the complexity of factors that influence liking of foods. However, segmentation of participants by cluster analysis according to centered overall liking ratings resulted in liking differences of breads, differences in attitudes, and usual whole grain bread consumption pattern. In order to improve customer appeal of whole grain breads it is necessary to further examine both the attributes that describe the taste, flavor, aroma, appearance, aftertaste and oral texture of breads and relate those to the liking ratings of those breads. Relating bread sample sensory characteristics to the consumer bread liking ratings may allow for optimization of a platform for whole grain bread products that more closely meets consumer expectations, taste profiles, and ultimately increase dietary intake of whole grain breads over refined grain breads.

Table 6.1 Breads, type, and bread manufacturer information for the 5 whole grain breads included in the bread liking study

Breads	Bread Type (100%)	Manufacturer Name	Address
Cub Food	Whole wheat	Supervalu	Eden Prairie, MN
Country Hearth	Whole wheat	Pan O Gold Baking Company	St. Cloud, MN
Natural Ovens	Whole grain	Natural Ovens Bakery	Manitowoc, WI
Pepperidge Farms	Whole wheat	Pepperidge Farm Inc.	Norwalk, CT
Sara Lee	Whole wheat	Sara Lee Inc.	Downers Grove, IL

Table 6.2 Mean liking ratings of 270 participants for five 100% whole grain breads [ABC]

Breads	Appearance	Flavor	Overall	Texture
Cub Foods	78.03[a]	76.44[a]	77.53[a]	77.49[a]
Country Hearth	79.35[a]	76.31[a]	77.49[a]	78.91[a]
Natural Ovens	73.46[b]	57.09[b]	60.00[b]	60.94[b]
Pepperidge Farms	74.58[b]	67.48[c]	69.48[c]	70.80[c]
Sara Lee	75.22[b]	65.71[c]	68.85[c]	69.89[c]

[A] Ratings are on a 120 point labeled affective magnitude scale (120 = greatest imaginable like; 60 = neutral, and 0 = greatest imaginable dislike). Data are averaged over each whole grain bread sample.

[B] Bread samples with the same letter designation in the same column are not significantly different.

[C] Natural Ovens bread was 100% whole grain while the other breads were 100% whole wheat.

Table 6.3 Significance of consumer classifications on whole grain bread liking ratings (appearance, flavor, overall and texture). F and p-value are provided for the main effect for each consumer classification.

Consumer Classification	Appearance liking	Flavor liking	Overall liking	Texture liking
Bread preference	F = 0.39, p = 0.53	F = 1.2, p = 0.27	F = 0.71, p = 0.40	F = 2.5, p = 0.11
Type of bag returned	F = 4.9, p = 0.03	F = 0.26, p = 0.61	F = 0.03, p = 0.86	F = 2.0, p = 0.16
PROP taster status	F = 1.42, p = 0.24	F = 3.3, p = 0.04	F = 0.95, p = 0.39	F = 1.79, p = 0.17

Table 6.4 Mean liking rating (appearance, flavor, overall and appearance) of bread samples by clustering of mean centered overall liking ratings

Liking Rating	Bread Samples	Clusters of Mean Centered Overall Liking Rating		
		1	2	3
Appearance Liking	Cub	79.3a	77.0a	77.7a
	CH	83.3a	76.3a	78.0a
	NO	70.7a	74.5a	78.3a
	Pepp	78.8a	72.6a	68.4a
	Sara Lee	78.4a	75.5ab	64.2b
		1	2	3
Flavor Liking	Cub	79.0a	73.9a	77.8a
	CH	81.3a	70.9b	80.3ab
	NO	39.4a	66.4b	79.0b
	Pepp	75.7a	63.8b	54.8b
	Sara Lee	67.2a	70.3a	43.6b
		1	2	3
Overall Liking	Cub	79.6a	76.1a	76.3a
	CH	83.4a	71.8b	79.7ab
	NO	41.7a	69.9b	81.6b
	Pepp	78.7a	66.0b	52.9b
	Sara Lee	70.8a	74.6a	41.1b
		1	2	3
Texture Liking	Cub	79.9a	76.2a	74.7a
	CH	83.7a	74.9a	78.9a
	NO	46.1a	68.2b	81.2b
	Pepp	78.7a	67.4b	58.3b
	Sara Lee	70.9a	75.1a	46.9b

Mean ratings within a row that share the same letter designation are not significantly different, $p<0.05$.

Table 6.5 Means of whole grain bread intake, TPB constructs, intention, usual whole grain bread consumption pattern and PROP ratings by agglomerate hierarchical clustering of overall liking ratings

	Cluster		
Variables	1	2	3
Whole grain bread intake	1.6a	1.7a	2.4a
Attitudes	10.0a	10.2a	12.8b
Perceived behavioral control	8.4ab	5.7a	12.0b
Subjective norms	9.6a	9.8a	9.0a
Intention	-1.2a	-1.2a	-0.7a
Usual whole grain bread consumption pattern	5.4a	5.8a	7.1b
PROP rating	37.5a	34.1a	38.6a

Mean ratings within a row that share the same letter designation are not significantly different, $p \leq 0.05$.

Table 6.6. Results of analysis of variance contrast tests for differences in liking rating associated with attributes (significant differences shown)

CRUMB Attributes	F value	p-value
FLAVOR ATTRIBUTES x FLAVOR LIKING		
Fermented	42.25	<0.0001
Cardboard	3.32	0.04
Molasses	10.35	<0.0001
Oily	3.38	0.04
Uncooked	30.06	<0.0001
Oxidized	4.08	0.02
AROMA ATTRIBUTES x OVERALL LIKING		
Brown	13.77	<0.0001
Butter	8.17	0.0004
Xfermented	4.54	0.01
Xgrainy	6.11	0.003
Hay	6.14	0.003
Levelar	64.23	<0.0001
TASTE AFTERTASTEATTRIBUTES x OVERALL LIKING		
Tsweetaf	83.83	<0.0001
AFTERTASTE ATTRIBUTES x OVERALL LIKING		
Saltyaf	14.24	<0.0001
Sweetaf	6.92	0.001
Cardboardaf	6.64	0.002
ORAL TEXTURE ATTRIBUTES x TEXTURE LIKING		
Chewy	4.77	0.01
Squishy	26.03	<0.0001
Moisture	9.59	<0.0001
Gummi	11.17	<0.0001
Softness	13.87	<0.0001
Spongy	3.15	0.04
Tpacking	28.26	<0.0001
CRUST Attributes		
TASTE TOP ATTRIBUTES x FLAVOR LIKING		
Tbitterstfl	6.03	0.003
Tsaltystfl	8.08	0.0004
FLAVOR TOP ATTRIBUTES x FLAVOR LIKING		
Bitterstfl	4.37	0.01
Burntstfl	3.5	0.03
Coffeestfl	4.16	0.02
Saltystfl	14.41	<0.0001
TASTE BOTTOM ATTRIBUTES x FLAVOR LIKING		
Btsaltystfl	78.74	<0.0001
FLAVOR BOTTOM ATTRIBUTES x FLAVOR LIKING		
Bbitterstfl	13.11	<0.0001
Bstarchystfl	3.59	0.03
Bdairystfl	3.88	0.02

AROMA TOP ATTRIBUTES x OVERALL LIKING		
Butterstar	46.55	<0.0001
Doughystar	71	<0.0001
Leveltoastedstar	2.3	0.1
Levelbakedstar	3.59	0.03
CRUST Attributes	F value	p-value
AROMA BOTTOM ATTRIBUTES x OVERALL LIKING		
Bintensitystar	7.33	0.001
Bgrainystar	5	0.01
Bdoughystar	5.19	0.01
Blevelbakedstar	4.61	0.01
APPEARANCE BOTTOM ATTRIBUTES x APPEARANCE LIKING		
Surfacebstap	5.17	0.01
AFTERTASTE TOP ATTRIBUTES x OVERALL LIKING		
Saltystaf	5.79	0.004
Burntstaf	3.03	0.05
Grainystaf	4.5	0.01
Honeystaf	6.92	0.001
TASTE AFTERTASTE BOTTOM ATTRIBUTES x OVERALL LIKING		
Btbitterstaf	3.82	0.02
Btsaltystaf	9.05	0.0002
AFTERTASTE BOTTOM ATTRIBUTES x OVERALL LIKING		
Bbitterstaf	3.23	0.04
Bsourstaf	7.54	0.001
ORAL TEXTURE TOP ATTRIBUTES x TEXTURE LIKING		
Grittystot	7.91	0.001
Paperystot	3.16	0.04

Table 6.7 Mean attributes scores and general linear model analysis of the bitter attributes that were associated with liking ratings of breads.

Attributes	**CUB**	**CH**	**NO**	**Pepp**	**Sara Lee**	**F-value**	**p-value**
CRUST							
Bitter taste of top	2.8b	3.7b	5.0a	2.6b	4.9a	7.01	<0.0001
Bitter flavor of top	2.9bc	3.6b	5.4a	2.3c	5.5a	6.78	<0.0001
Bitter flavor of bottom	2.7a	2.4ab	1.0c	1.2bc	2.9a	4.08	<0.0001
Bitter taste aftertaste of bottom	1.6a	1.9a	0.58b	1.0ab	1.9a	3.31	0.0002
Bitter aftertaste of bottom	2.1ab	2.2a	0.68c	1.1c	1.9ab	2.35	<0.005

Means in the same row with the same letter designation are not significantly different ($p<0.05$).

Chapter 7. Overall discussion and implications

Sara A. Sjoberg, MS

Conclusions

The primary purpose of this research project was to examine behavioral and sensory factors that influence whole grain bread consumption among adults. Three studies were completed and described in Chapters 4-6. First, descriptive analysis was used to develop a lexicon and to characterize commercial 100% whole grain breads (Chapter 4). The next phase of the study (Chapter 5) included the development and testing of a theory-based questionnaire (Part 1). The questionnaire was used to identify and examine factors that influence intention to consume whole grain bread and dietary intake of whole grain bread (Part 2). The last phase (Chapter 6) involved identification of liking differences among five 100% whole grain bread samples. The effect of sensory attributes on consumer bread liking ratings was also determined.

In the first phase of this research project, sensory attributes of whole grain breads were described by descriptive analysis. Multivariate PCA was used to assess the main sources of variation among the sensory attributes that described the bread allowing for the ability to 1) reduce the number of attributes; 2) determine the important attributes, and 3) identify a small subset of diverse breads for use in the subsequent bread liking study (last phase of this research project).

In the second phase, a questionnaire was developed based on focus group results obtained from whole grain and refined grain bread consumers. The questionnaire contained 11 attitudinal beliefs, six normative beliefs, 16 control beliefs and two intentional beliefs related to whole grain bread consumption. Food frequency questions were also tested to measure whole grain bread intake. The inability of participants to adequately identify whole grain from refined grain breads led to the development of a brief educational presentation on the differences in these types of breads. The presentation was used prior to administration of the questionnaire to a larger sample of consumers to assess the usefulness of the TPB to explain intention and consumption with respect to whole grain bread.

Questionnaire results were used to examine behavioral and sensory factors that influence whole grain bread intake. In the standard model, PBC and SN significantly influenced intention to consume whole grain bread. The addition of sensory variables (mean whole grain bread liking rating, bread preference, and usual whole grain bread consumption pattern) to the standard model increased the variance in intention explained from 13-24%. Whole grain bread intake was influenced by PBC and intention in the standard model. Expanding the standard model for behavior with the addition of bread preference, and usual whole grain bread consumption pattern increased the proportion of variance explained from 45-53%. PROP rating was not a significant predictor for intention to consume whole grain breads or for whole grain bread intake. Participants had positive perceptions of whole grain bread with estimated intake (mean 1.3 servings/day) somewhat higher than the typical whole grain intake among US adults. The mean length of time consuming whole grain bread as part of the typical diet was reported to be 24-36 months and most subjects reported a preference of whole grain bread over refined grain bread. This was in contrast to the findings that intention to consume three whole grain bread servings daily was weak.

In the final phase, differences in liking of breads were determined among bread samples for consumers' sensory classification groups (bread preference and PROP taster status). In addition, bread consumers were segmented according to the mean liking rating of whole grain breads and these segments were then described based on consumers' whole grain bread intake, attitudes, SN, PBC and intention. The secondary purpose was to determine which sensory attributes had an effect on consumers' bread liking. The results showed that Cub Foods bread was liked the most by all subjects and was liked equally among groups clustered by liking ratings. Liking was not influenced by bread preference or PROP taster status. Through cluster analysis, three groups of consumers were identified. The first group of consumers liked Pepperidge Farms bread more and Natural Ovens bread less than consumers in group 2 and 3. Consumers in group 2 liked some bread similarly to consumers in group 2 and 3. The third cluster liked the Sara Lee bread the least compared to consumers in group 1 and 2. There were no differences in liking for Cub Foods bread among consumer groups. Bitter flavor and taste had a significant effect on the liking of breads. However, bitter flavor and taste of the least liked bread (Natural Ovens bread) was equal to the better liked whole grain bread (Sara Lee bread). This result implies that the least liked bread had the highest bitter flavor;

however, the disliking of this bread was also dependent on other contributing sensory attributes besides bitterness. This is further supported by evidence that PROP taster status had no influence on liking of breads as bitterness was not detected as a major attribute.

These studies addressed behavioral and sensory factors that influence whole grain bread consumption independently through a descriptive analysis study and a cross-sectional survey study among a convenience sample of adult bread consumers at a local grocery store. This research makes a significant contribution to the literature related to descriptive analyses of breads since there are no published studies that describe sensory attributes of commercial whole grain breads. There are also no published studies that applied an extended TPB to whole grain bread intake including sensory-related variables of liking, preference, usual whole grain bread consumption pattern and PROP rating.

Several strengths and limitations require further discussion when examining the design and outcomes of these studies. Strengths included examining factors that influence a specific food, such as whole grain bread, rather than a category of whole grain food products. Additional factors that might influence whole grain bread consumption were identified through the development of a lexicon to describe commercial whole grain breads and focus group findings with whole grain and refined bread consumers based on report of bread preference. Expanding the TPB to include sensory-related variables increased the variance explained in intention to consume whole grain bread and whole grain bread intake. This is the first study to include PROP rating in the TPB to predict whole grain bread intake. Measuring behavioral and sensory factors allowed for a more comprehensive examination of factors that explain whole grain bread consumption of a specific whole grain food. Including the PROP rating variable in the consumer bread liking study also provided a comprehensive investigation and innovative approach.

Limitations of these studies included recruitment of self-selected consumers who consisted of highly educated White females, which limits the ability to generalize to less educated, male and ethnically diverse consumers. Measurement of whole grain intake by use of food frequency questions may have resulted in an overestimation of whole grain bread intake. This could explain why estimated intake was not consistent with reported intention to consume three daily servings of whole grain bread. Interpretation of the SN results may have been difficult due to the use of mismatched response options for the motivation to comply statement.

Implications for future research

These studies suggest that consumption of whole bread is multifaceted and can be influenced by both behavioral and sensory factors. Future descriptive analysis studies should include whole grain breads containing white whole wheat flour as the diversity of whole grain breads in the market continue to grow. Consumption of whole grain bread may be increased among consumers by addressing control barriers found to be important such as availability and preferences for use of refined bread in some situations (for toast or sandwiches). This research together with other studies in the literature suggest that away from home settings are challenging environments (context) for consumers to meet their recommended three daily servings of whole grains. Increasing availability of whole grain bread away from home can increase exposure to whole grain bread building preferences for whole grain over refined grain bread, and result in a longer usual whole grain bread consumption pattern. These factors can lead to whole grain intake becoming a habitual behavior and thus increasing whole grain bread intake. For this to occur, more research is needed to identify barriers that prevent consumers from eating whole grain breads in a specific context when away from home versus at home. In addition, repeated exposure may lead to an acquired taste, an increase in intention and therefore to greater whole grain bread intake. Adaptation of the consumer palate with repeated exposure to whole grain breads should be examined through short- and long-term interventions in various consumer segments. Future research should investigate which psychosocial factors influence whole grain consumption among populations with less education, more ethnically diverse and among male consumers.

Considering that bread preference had no effect on liking ratings of bread implied that behavioral factors are influencing consumer choice of bread (whole grain versus refined grain). The influence of bread preference on intention to consume whole grain bread and whole grain bread intake points to the need for further examination of factors that influence consumption of whole grain bread among different bread preference groups. Dichotomizing bread consumers according to their bread preference might allow for tailoring of specific strategies to increase whole grain bread consumption for targeted consumer segments.

Although mean liking rating of whole grain bread was not a significant predictor of whole grain bread intake there were obvious differences in liking of breads among the participants. This reinforces the need for food manufacturers to continue to identify sensory attributes that drive consumer expectations for well-accepted whole grain breads. In turn, these sensory attributes will be incorporated into whole grain bread products based upon consumers' segmentation and liking of whole grain breads. To produce bread that is acceptable to most bread consumers, the food industry may want to develop whole grain bread based upon the sensory characteristics of the Cub Foods bread. Sensory attributes that had a significant effect on liking and significantly differentiated Cub Foods bread from other whole grain breads included uncooked flavor of the crumb, salty aftertaste of the crumb, squishy and moist texture of the crumb and salty taste and flavor of the crust. Perhaps sensory attributes for this bread are more similar to sensory attributes that describe commercial refined grain bread.

In conclusion, this research project provides insight into behavioral and sensory factors that influence consumption of whole grain breads. To increase consumption of whole grain bread, additional research is needed to understand PBC and how to increase consumers' control over consuming whole grain bread. Future research should examine how these factors relate to whole grain bread consumption and how they can be integrated into behavior change interventions. Acknowledging behavioral factors that influence whole grain bread intake, determining which sensory attributes characterize well-liked whole grain breads and improving the liking of whole grain breads could lead to increased consumption of whole grain bread and thereby reduce risk of chronic diseases.

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APPENDICES CHAPTER 4

Appendix A. Descriptive analysis crumb attributes lexicon

Category, sensory attributes, definition of attributes, and scale used by the trained panel for the crumb of the breads.

Category	**Attribute**	**Attribute definitions**	**Scale**
Taste/Flavor		The quality of something that affects the sense of taste while pinching your nose.	
	Bitter	Solutions of quinine, black coffee, caffeine, puckering sensation perceived	None-extreme
	Salty	Of or seasoned with salt.	None-extreme
	Sweet	The basic taste factor produced on the tongue by most sugars.	None-extreme
	Sour	Taste caused by acids. A tart, tangy, sharp, citrus-like taste.	None-extreme
Flavor		The quality of something that affects the sense of taste.	
	Alcohol/fermented	Fermented grain flavor.	None-extreme
	Cardboard	Bland, dull, dry taste.	None-extreme
	Coffee burnt	Taste similar to burnt coffee beans	None-extreme
	Grainy/wheaty	A light, baked, wheat flour aromatic.	None-extreme
	Honey/floral sweetness	A Sweet floral taste.	None-extreme
	Molasses	A molasses flavor	None-extreme
	Musty	A general term used to describe the dusty or musty taste associated with grains such as corn, oats, and wheat.	None-extreme
	Nutty	Wheaty-nutty, similar of chopped nuts.	None-extreme
	Oily	Overall impression of oil; an oily residue may be left in the mouth.	None-extreme
	Uncooked raw dough	Taste implying under-baked, uncooked product. Raw, rather than cooked, white flour or starch. Tastes flourier than dough. Underdone flavor witnessed.	None-extreme
	Oxidized oil/fat	Taste of old or bad oil/fat that was sitting around.	None-extreme

Category	**Attribute**	**Attribute definition**	**Scale**
Aroma		Sum of odors and feelings perceived through sniffing a product.	
	Brown bag	Reminiscent of "old brown paper bag".	None-extreme
	Browned butter	The sharp bad note of product that has been over baked.	None-extreme
	Caramelized	Odor much like that of a water dilution of white table sugar previously melted over low heat to form light brown syrup.	None-extreme
	Fermented/alcohol	A fermented-alcohol like aroma attributes that was made from yeast.	None-extreme
	Grainy/wheaty	A general term used to describe aromatics associated with grains such as corn, oats, and wheat.	None-extreme
	Hay/dry grass	Aromatics associated with hay/grass from a barn or farm.	None-extreme
	Honey/floral/sweet	A floral aromatic aroma.	None-extreme
	Molasses/brown sugar	A sweet aroma that is from brown sugar or molasses	None-extreme
	Oily	An odor of oil or oil from wheat germ.	None-extreme
	Sourdough	Combination of sour and doughy smell.	None-extreme
	Level of baked (toasted) aroma	Level of baked aroma	None-extreme
	Level of baked aroma	Moderately brown, cooked scent given	Toasted-burnt
	White flour/doughy	Odor implying under baked white bread or wet white flour	None-extreme
	Yeasty	Fermented yeast-like; Aromatic complex reminiscent of a water suspension of baker's dried yeast.	None-extreme

Category	Attribute	Definition	Scale
Appearance		What the product looks like to the eye.	
	Level of moisture	Appearance of moisture level in crumb.	moist-dry
	Grain piece size	Size of the grain pieces	Small-large
	Air cell size	Evenness of air cell size	Even-uneven
	Grain piece distribution	Distribution of grain pieces	Uniform-variable
	Texture	Appearance of texture.	Soft/light-dense
	Overall color (ignore grain pieces)	Uniformity of the overall color	Uniform-variable
	Air cell size	Size of air cells	Small-large
	Color (hold arms length away from you)	Color of crumb	Light brown-dark brown
Aftertaste	Bitter	Solutions of quinine, black coffee, caffeine, puckering sensation perceived	None-extreme
	Salty	Of or seasoned with salt.	None-extreme
	Sweet	The basic taste factor produced on the tongue by most sugars.	None-extreme
	Sour	Taste caused by acids. A tart, tangy, sharp, citrus-like taste.	None-extreme
	Cardboard (paper bag)	Bland, dull, dry taste.	None-extreme
	Fermented/ alcohol	Fermented grain flavor	None-extreme
	Oxidized oil	Taste of old or bad oil/fat that was sitting around.	None-extreme
	Grainy/wheaty	A light, baked, wheat flour aromatic.	None-extreme
	Toasted	Moderately brown, baked impression.	None-extreme
	Uncooked (raw dough)	Taste implying under-baked, uncooked product. Raw, rather than cooked, white flour or starch. Tastes flourier than dough. Underdone flavor witnessed.	None-extreme
	Wheat germ	An oxidized grainy aftertaste.	None-extreme
	Yeasty	Flavor of yeast with just water.	None-extreme

Category	Attribute	Definition	Scale
Oral Texture		The disposition or manner of particles or substances that is perceived/dictated by the sensory qualities.	
	Chewy	The amount of effort required to chew the bread before it can be swallowed	None-extreme
	Density	The extent to which the bread is heavy and compact.	Light/fluffy-Dense
	Doughy(squishy)	A texture that is squishy and sticks together. Cohesive	None-extreme
	Moisture Level	Ranging from dry to moist	Dry-Moist
	Elastic(when you bite with Front teeth)	Bread tends to stretch and stick together when chewed.	None-extreme
	Gritty (pieces of grains)	Bread has intense grainy texture, grains aren't easily chewed.	None-extreme
	Gummy (forms a gall in mouth)	Bread balls up in the mouth.	None-extreme
	Softness	Smooth or delicate in texture, grain, or fiber.	Soft-Hard
	Smoothness	Smooth or delicate in texture, grain, or fiber.	Smooth-Rough
	Spongy (springy)	Springy, bouncy texture.	None-extreme
	Tooth packing(gets stuck in teeth)	Packed into teeth feeling.	None-extreme

Appendix B. Descriptive analysis crust attributes lexicon. Category, sensory attributes, definition of attributes, and scales used by the trained panel for the crust of the breads.

Category	**Attribute**	**Attribute definitions**	**Scale**
Taste/Flavor		The quality of something that affects the sense of taste while pinching your nose.	
	Bitter	Solutions of quinine, black coffee, caffeine, puckering sensation perceived	None-extreme
	Salty	Of or seasoned with salt.	None-extreme
	Sweet	The basic taste factor produced on the tongue by sugars.	None-extreme
	Sour	Taste caused by acids. A tart, tangy, sharp, citrus-like taste.	None-extreme
Flavor			
	Burnt	The sharp bad note of a product that has been over baked.	None-extreme
	Coffee burnt	Taste similar to burnt coffee beans	None-extreme
	Grainy/wheaty	A light, baked, wheat flour aromatic.	None-extreme
	Coffee burnt	Taste similar to burnt coffee beans	None-extreme
	Grainy/wheaty	A light, baked, wheat flour aromatic.	None-extreme
	Molasses	A molasses flavor	None-extreme
	Oily	Overall impression of oil; an oily residue may be left in the mouth.	None-extreme
	Oxidized oil/fat	Taste of old or bad oil/fat that was sitting around.	None-extreme
	Toasted	Moderately brown, baked impression.	None-extreme
	Uncooked raw dough	Taste implying under-baked, uncooked product. Raw, rather than cooked, white flour or starch. Tastes flourier than dough. Underdone flavor witnessed.	None-extreme
	Starchy	Raw, rather than cooked, white flour or starch. Starch odor was often noticed when the yeasty note in the crumb was slightly old or old.	None-extreme

	Sweet (dairy)	A general term associated with products made from cow's milk (sweet in character).	None-extreme
	Nutty	Wheaty-nutty, similar of chopped nuts.	None-extreme

Category	**Attribute**	**Definition**	**Scale**
Aroma		Sum of odors and feelings perceived through sniffing a product.	
	Intensity of overall aroma of crust	Intensity of overall aroma of crust	None-extreme
	Browned butter	The sharp bad note of product that has been over baked.	None-extreme
	Caramelized	Odor much like that of a water dilution of white table sugar previously melted over low heat to form light brown syrup.	None-extreme
	Grainy/wheaty	A general term used to describe aromatics associated with grains such as corn, oats, and wheat.	None-extreme
	Sourdough	Combination of sour and doughy smell.	None-extreme
	Sweet	A fragrance from crust and crumb of fresh breads. Sweet fragrance is part of the caramel aroma.	
	White flour/doughy	Odor implying under baked white bread or wet white flour	None-extreme
	Level of baked aroma	Level of baked aroma	None-extreme
	Level of baked aroma	Moderately brown, cooked scent given	Toasted-burnt

Category	**Attribute**	**Definition**	**Scale**
Appearance		What the product looks like to the eye.	
	Grain toppings (flakes)	If applicable, number of grains on top	None-many
	Oat toppings	If applicable, number of oats on top	None-many
	Grain toppings (flakes) shape	If applicable, shape of grains	Uniform-not uniform
	Grain toppings (flakes) size	If applicable, size of grains	small-large
	Oat toppings size	If applicable, size of oats	Small-large
	Thickness of crust		Thin-thick
	Color (ignore corners)	Overall color of crust	Uniform-variable
	Bottom crust appear	Overall appearance of bottom crust	Dull-shiny
	Bottom crust surface	(Ignore corners of crust)	Smooth-rough
Aftertaste			
	Bitter	Solutions of quinine, black coffee, caffeine, puckering sensation perceived	None-extreme
	Salty	Of or seasoned with salt.	None-extreme
	Sweet	The basic taste factor produced on the tongue by most sugars.	None-extreme
	Sour	Taste caused by acids. A tart, tangy, sharp, citrus-like taste.	None-extreme
	Burnt	The sharp bad note of a product that has been over baked.	None-extreme
	Cardboard (paper bag)	Bland, dull, dry taste.	None-extreme
	Caramelized (burnt sugar)	Flavor much like sugar that was melted over low heat to form light brown syrup.	None-extreme
	Grainy/wheaty	A light, baked, wheat flour aromatic.	None-extreme

Category	Attribute	Definition	Scale
Aftertaste	Honey	A sweet floral taste.	None-extreme
	Wheat germ	Oxidized, grainy aftertaste	None-extreme
	Fermented/ alcohol	Fermented grain flavor	None-extreme
	Toasted	Moderately brown, baked impression.	None-extreme
Oral Texture			
	Chewy	The amount of effort required to chew the bread before it can be swallowed	None-extreme
	Lightness	Ranging from light to dense	Light-Dense
	Moisture Level	Ranging from dry to moist	Dry-Moist
	Gritty (pieces of grains)	Bread has intense grainy texture, grains aren’t easily chewed.	None-extreme
	Gummy (forms a gall in mouth)	Bread balls up in the mouth.	None-extreme
	Softness	Smooth or delicate in texture, grain, or fiber.	Soft-Hard
	Leathery(tough)	Crust is tough to chew apart like leather.	None-extreme
	Papery	Thin crisp like texture.	None-extreme
	Spongy (springy)	Springy, bouncy texture.	None-extreme

Appendix C. Descriptive analysis score sheet for aroma and appearance of breads

Bread Description Analysis Study

Good Morning, you are judge ??
Date: ______________________

Instructions:
Please re-familiarize yourself with the descriptors and their definitions before beginning.

You will be given a total of 4 samples this session. Please evaluate the samples in the order listed on your score sheets. Rate the intensity of each of the attributes for that sample by marking a <u>vertical line</u> on the appropriate scale.

*****<u>Remember that you are rating how intense these attributes are</u>.*****

0-0- 1

Sample # 001

Aroma relating to crumb of bread

Brown bag
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Browned butter
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Caramelized
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Fermented/alcohol
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grainy/wheaty
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Hay/dry grass
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Honey/floral/sweet
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Molasses/brown sugar
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oily
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sourdough
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Level of baked (toasted) aroma
None — Extreme
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 2

Level of baked aroma

Toasted — Burnt

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

White flour/doughy

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Yeasty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Appearance relating to crumb

Level of moisture

Moist — Dry

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grain Piece Size

Small — Large

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Air cell size

Even — Uneven

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grain Piece distribution

Uniform — Variable

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Texture

Soft/Light — Dense

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Overall color appearance (IGNORE GRAIN PIECES)

Uniform — Variable

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Air cell size

Small — Large

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Color (hold arms length away from you)

Light Brown — Dark Brown

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 3

Sample # 001

Aroma relating to top crust

Intensity of overall aroma of top crust

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Browned Butter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Caramelized

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grainy/wheaty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sourdough

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet (TOP)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

White flour/doughy

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Level of baked (toasted) aroma

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Level of baked aroma

Toasted — Burnt

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Aroma relating to <u>bottom crust</u>

Intensity of overall aroma of bottom crust

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Browned Butter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 1

Caramelized

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grainy/wheaty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sourdough

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet (BOTTOM)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

White flour/doughy

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Level of baked (toasted) aroma

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Level of baked aroma

Toasted — Burnt

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Appearance relating to <u>top crust</u>

Grain toppings (flakes) - If Applicable

None — Many

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oat toppings - If Applicable

None — Many

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grain toppings (flakes) shape-If Applicable

Uniform — Not Uniform

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grain toppings (flakes) size- If Applicable

Small — Large

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 2

Oat toppings size- If Applicable

Small — Large

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Thickness of crust

Thin — Thick

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Color (IGNORE CORNERS)

Uniform — Variable

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Appearance relating to <u>bottom crust</u>

Crust appearance

Dull — Shiny

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Bottom Crust surface (IGNORE CORNERS OF CRUST)

Smooth — Rough

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Thickness of crust

Thin — Thick

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Color (IGNORE Corners)

Uniform — Variable

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 3

Appendix D. Descriptive analysis score sheet for taste, flavor and oral texture of breads

Bread Description Analysis Study

Good Morning, you are judge ??
Date: ______________________

Instructions:
Please re-familiarize yourself with the descriptors and their definitions before beginning.

You will be given a total of 4 samples this session to taste, to determine the flavor and oral texture. Please drink water in between samples. Evaluate the samples in the order listed on your score sheets. Rate the intensity of each of the attributes for that sample by marking a <u>vertical line</u> on the appropriate scale.

*****<u>Remember that you are rating how intense these attributes are</u>.*****

0-0- 1

Sample # 005

Taste relating to crumb of bread

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sour

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Flavor relating to crumb of bread

Alcohol/fermented

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Cardboard

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Coffee Burnt

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grainy/wheaty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Honey/floral sweetness

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 2

Molasses

None Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Musty

None Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Nutty

None Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oily (wheatgerm)

None Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Uncooked raw dough

None Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oxidized Oil/fat

None Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oral Texture relating to crumb of the bread

Chewy

None Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Density

Light/fluffy Dense

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Doughy (squishy)

None Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Moisture Level

Dry Moist

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Elastic (when you bite with FRONT teeth)

None Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 3

Gritty (pieces of grains)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Gummi (forms a ball in mouth)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Softness

Soft — Hard

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Smoothness

Smooth — Rough

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Spongy (springy)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Toothpacking (gets stuck in teeth)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Taste relating to top crust of bread

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sour

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Flavor relating to top crust of bread

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 4

Burnt

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Burnt Coffee

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grainy

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Molasses

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oily (wheat germ)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oxidized oil

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Toastedness

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Uncooked (raw dough)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oral Texture relating to <u>top crust</u> of the bread

Chewy

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Lightness

Light — Dense

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 5

Moisture Level

Dry — Moist

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Gritty (like pieces of grain)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Gummi (forms a ball in mouth)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Softness

Soft — Hard

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Leathery (tough)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Papery

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Spongy (springy)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Taste relating to <u>bottom crust</u> of bread

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sour

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 6

Flavor relating to bottom crust of bread

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Flavor of toastedness

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grainy/wheaty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Starchy

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet (dairy)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Nutty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oral Texture relating to bottom crust of the bread

Chewy

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Lightness

Light — Dense

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Moisture Level

Dry — Moist

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 7

Gritty (like piece of grain)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Gummi (forms a ball in mouth)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Softness

Soft — Hard

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Leathery (tough)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Papery

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Spongy (springy)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 8

Appendix E. Descriptive analysis score sheet for taste aftertaste, and aftertaste of breads

Bread Description Analysis Study

Good Morning, you are judge ??
Date: ______________________

Instructions:
Please re-familiarize yourself with the descriptors and their definitions before beginning.

You will be given a total of 6 samples this session. Please evaluate the samples in the order listed on your score sheets. Rate the AFTERTASTE intensity of each of the attributes for that sample by marking a vertical line on the appropriate scale. Aftertaste is detected after you swallowed the sample of bread. Taste the samples while pinching your nose and determine flavor after you swallowed the sample normally.

*****Remember that you are rating how intense these attributes are.*****

0-0- 1

Sample # 001

Aftertaste relating to crumb of bread- TASTE the sample

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sour

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Aftertaste relating to crumb of bread- FLAVOR of the sample

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sour

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Cardboard (paper bag)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Fermented (alcohol)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Oxidized oil

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 2

Grainy (Wheaty)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Toasted

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Uncooked (raw dough)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Wheatgerm

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Yeasty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Aftertaste relating to top crust of bread- TASTE the sample

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sour

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Aftertaste relating to top crust of bread- FLAVOR of the sample

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 3

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sour

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Burnt

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Cardboard (paper bag)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Caramelized (burnt sugar)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grainy (wheaty)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Honey

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Wheatgerm

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Aftertaste relating to <u>bottom crust</u> of bread- TASTE the sample

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 4

Sour

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Aftertaste relating to <u>bottom crust</u> of bread- FLAVOR of the sample

Bitter

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Salty

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sweet

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Sour

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Burnt

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Fermented (alcohol)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Grainy (wheaty)

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Toasted

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Wheatgerm

None — Extreme

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

0-0- 5

Appendix F. SAS Code for descriptive analysis of breads

```
libname xxx 'e:';
run;
proc sort data=xxx.dadata;
by sample;
run;
proc GLM data=xxx.dadata;
title 'DA data GLM Analysis for random rep sample*rep subject*rep';
   class subject sample rep;
   model chewystot lightnessstot moisturestot grittystot gummistot
softnessstot leatherystot paperystot springystot bchewystot
blightnessstot bmoisturestot bgrittystot bgummistot bsoftnessstot
bleatherystot bpaperystot bspringystot tbitterstfl tsaltystfl
tsweetstfl tsourstfl bitterstfl burntstfl coffeestfl grainystfl
molassesstfl oilsstfl oxidizedstfl saltystfl toastedstfl uncookedstfl
btbitterstfl btsaltystfl btsweetstfl btsourstfl bbitterstfl bsweetstfl
btoastedstfl bgrainystfl bsaltystfl bstarchystfl bdairystfl bnuttystfl
intensitystar butterstar caramelstar grainystar sourdostar sweetstar
doughystar leveltoastedstar levelbakedstar bintensitystar bbutterstar
bcaramelstar bgrainystar bsourdostar bsweetstar bdoughystar
bleveltoastedstar blevelbakedstar graintopstap oattopstap oattopszstap
graintopshapestap graintopszstap thicktopstap colortopstap
crustbottomstap surfacebstap thicknessbotstap colorbotstap tbitterstaf
tsaltystaf tsweetstaf tsourstaf bitterstaf saltystaf sweetstaf sourstaf
burntstaf cardboardstaf caramelstaf grainystaf honeystaf wheatgermstaf
btbitterstaf btsaltystaf btsweetstaf btsourstaf bbitterstaf bsaltystaf
bsweetstaf bsourstaf bburntstaf bfermentedstaf bgrainystaf btoastedstaf
bwheatgermstaf chewy density squishy moisture elastic gritty gummi
softness smooth spongy tpacking tbitter tsalty tsweet tsour fermented
bitter cardboard coffee grainy honey molasses musty nutty oily uncooked
oxidized brown butter caramel xfermented xgrainy hay xhoney xmolasses
xoily sourdo levelar leveltoasted doughy yeasty moist grainpi aircell
grapiece texture overcol aircellsz color tbitteraf tsaltyaf tsweetaf
tsouraf bitteraf saltyaf sweetaf souraf cardboardaf fermentedaf
oxidizedaf grainyaf toastedaf uncookedaf wheatgermaf yeastyaf= sample
subject rep sample*subject sample*rep subject*rep;
random rep sample*rep subject*rep ;
lsmeans sample/pdiff=all adjust=tukey;
run;
quit;
proc GLM data=xxx.dadata;
title 'DA data GLM Analysis for random rep sample*rep subject*rep
lsmeans bon lines';
   class subject sample rep;
   model chewystot lightnessstot moisturestot grittystot gummistot
softnessstot leatherystot paperystot springystot bchewystot
blightnessstot bmoisturestot bgrittystot bgummistot bsoftnessstot
bleatherystot bpaperystot bspringystot tbitterstfl tsaltystfl
tsweetstfl tsourstfl bitterstfl burntstfl coffeestfl grainystfl
molassesstfl oilsstfl oxidizedstfl saltystfl toastedstfl uncookedstfl
btbitterstfl btsaltystfl btsweetstfl btsourstfl bbitterstfl bsweetstfl
btoastedstfl bgrainystfl bsaltystfl bstarchystfl bdairystfl bnuttystfl
intensitystar butterstar caramelstar grainystar sourdostar sweetstar
doughystar leveltoastedstar levelbakedstar bintensitystar bbutterstar
bcaramelstar bgrainystar bsourdostar bsweetstar bdoughystar
```

```
bleveltoastedstar blevelbakedstar graintopstap oattopstap oattopszstap
graintopshapestap graintopszstap thicktopstap colortopstap
crustbottomstap surfacebstap thicknessbotstap colorbotstap tbitterstaf
tsaltystaf tsweetstaf tsourstaf bitterstaf saltystaf sweetstaf sourstaf
burntstaf cardboardstaf caramelstaf grainystaf honeystaf wheatgermstaf
btbitterstaf btsaltystaf btsweetstaf btsourstaf bbitterstaf bsaltystaf
bsweetstaf bsourstaf bburntstaf bfermentedstaf bgrainystaf btoastedstaf
bwheatgermstaf chewy density squishy moisture elastic gritty gummi
softness smooth spongy tpacking tbitter tsalty tsweet tsour fermented
bitter cardboard coffee grainy honey molasses musty nutty oily uncooked
oxidized brown butter caramel xfermented xgrainy hay xhoney xmolasses
xoily sourdo levelar leveltoasted doughy yeasty moist grainpi aircell
grapiece texture overcol aircellsz color tbitteraf tsaltyaf tsweetaf
tsouraf bitteraf saltyaf sweetaf souraf cardboardaf fermentedaf
oxidizedaf grainyaf toastedaf uncookedaf wheatgermaf yeastyaf= sample
subject rep sample*subject sample*rep subject*rep;
random rep sample*rep subject*rep ;
lsmeans sample / pdiff=all lines adjust=tukey;
run;
quit;
proc means data=xxx.dadata;
title 'DA data PROC means all attributes';
class sample;
      var chewystot lightnessstot moisturestot grittystot gummistot
softnessstot leatherystot paperystot springystot bchewystot
blightnessstot bmoisturestot bgrittystot bgummistot bsoftnessstot
bleatherystot bpaperystot bspringystot tbitterstfl tsaltystfl
tsweetstfl tsourstfl bitterstfl burntstfl coffeestfl grainystfl
molassesstfl oilsstfl oxidizedstfl saltystfl toastedstfl uncookedstfl
btbitterstfl btsaltystfl btsweetstfl btsourstfl bbitterstfl bsweetstfl
btoastedstfl bgrainystfl bsaltystfl bstarchystfl bdairystfl bnuttystfl
intensitystar butterstar caramelstar grainystar sourdostar sweetstar
doughystar leveltoastedstar levelbakedstar bintensitystar bbutterstar
bcaramelstar bgrainystar bsourdostar bsweetstar bdoughystar
bleveltoastedstar blevelbakedstar graintopstap oattopstap oattopszstap
graintopshapestap graintopszstap thicktopstap colortopstap
crustbottomstap surfacebstap thicknessbotstap colorbotstap tbitterstaf
tsaltystaf tsweetstaf tsourstaf bitterstaf saltystaf sweetstaf sourstaf
burntstaf cardboardstaf caramelstaf grainystaf honeystaf wheatgermstaf
btbitterstaf btsaltystaf btsweetstaf btsourstaf bbitterstaf bsaltystaf
bsweetstaf bsourstaf bburntstaf bfermentedstaf bgrainystaf btoastedstaf
bwheatgermstaf chewy density squishy moisture elastic gritty gummi
softness smooth spongy tpacking tbitter tsalty tsweet tsour fermented
bitter cardboard coffee grainy honey molasses musty nutty oily uncooked
oxidized brown butter caramel xfermented xgrainy hay xhoney xmolasses
xoily sourdo levelar leveltoasted doughy yeasty moist grainpi aircell
grapiece texture overcol aircellsz color tbitteraf tsaltyaf tsweetaf
tsouraf bitteraf saltyaf sweetaf souraf cardboardaf fermentedaf
oxidizedaf grainyaf toastedaf uncookedaf wheatgermaf yeastyaf;
run;
Proc means n mean min max range std;
by sample;
run;
/*Principal component analysis of DA attributes*/
libname xxx 'e:';
```

```
run;
proc means  data=xxx.pcadadataless;
run;
proc princomp data=xxx.pcadadataless out=sample_Components n=11;
run;
proc corr noprint data=sample_Components out=pc_corr;
run;
```

APPENDICES CHAPTER 5-Part 1

Appendix A. Recruitment flyer for focus group study

Do you eat BREAD on a regular basis? If yes, you qualify for this study.

We are recruiting people for a study on breads that will be conducted by Sara Sjoberg, a graduate student in the Nutrition graduate program and Len Marquart, a faculty member in the Nutrition graduate program.

They will be running a test that will include filling out a questionnaire about the breads you eat and your eating habits, which will take about 5 minutes. You will also answer questions about breads in a group of 6-8 other people, and that will take about 50-60 minutes. You will be asked to bring in 2 bread wrapper/bags of the breads that you recently ate at home. The location of this test will be on the University of Minnesota, St. Paul Campus; Both parts together should take about an hour of your time.

At the end of the study, you will receive $10.00.

If you think you would be interested in taking part in this study, please answer all of the questions below and send the information to Sara Sjoberg sjob0030@umn.edu via e-mail.

Your information will be evaluated to see if you qualify to be part of the study. If you are one of the first 20-30 people to qualify, Sara will contact you in the next few days to schedule you for the study. Your may choose not to participate, even if you have qualified.

If you have any questions about the study, please contact Sara at sjob0030@umn.edu.

Please provide the following information about yourself. All information you provide is strictly confidential.

First Name __________ Last Name: ___________ Gender: M _____ F ______

Address with Apt. #: ____

City: ________________ State: ________ Zip code:____________

Day Phone: ____________ Evening phone: ____________ e-mail:_______________

Best way and time to contact______________________________________

Please indicate your age group?

18-23 ____ 24-35 ____ 36-45 ____ 46-55 ____

Do you consume white, wheat or whole wheat bread? _____________________ (Choose only 1 bread type)- On a REGULAR BASIS.

Please indicate the times you would be able to meet for the sessions. If you are available more than 1 of times, please mark ALL.

____ May 6th (Friday) 8:00am- 9:00am

____ May 9th (Monday) 8:00am-9:00am
____ May 9th (Monday) 3:30pm-4:30pm

____ May 10th (Tuesday) 8:00am-9:00am
____ May 10th (Tuesday) 3:30pm-4:30pm

This will take approximately 1 hour.

We will get back to you to let you know if you have qualified for this test and schedule your first meeting accordingly.

Please send email to sjob0030@umn.edu **when returning this form via email. Thank you!**

Appendix B. Consent form for focus group study

White.

SUBJECT # 1

CONSENT FORM
Assessment of Breads

You are invited to be in a research study about breads. You were selected as a possible participant because you are willing to participate and talk about why you consume certain breads. We ask that you read this form and ask any questions you may have before agreeing to be in this study.

This study is being conducted by: Sara Sjoberg in the Department of Food Science and Nutrition at the University of Minnesota.

Background Information
The purpose of this study is: to answer questions about breads. The information will help us understand more about why you eat certain breads over other types of breads.

Procedures:
If you agree to be in this study, we would ask you to do the following things:
We will ask you to fill out a questionnaire today about the breads you eat and your eating habits. It will take less than 5 minutes. You will also answer questions about breads in a group of 6-8 other people which will take about 50-60 minutes. With your permission, we will audiotape the conversation to obtain quality answers.

Risks and Benefits of being in the Study
There are no risks or benefits to participation in this study. This study has no benefits to you.

Compensation:
You will receive a payment of $10.00 for your hour of participation.

Confidentiality:
The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records and audiotape recordings will be stored securely and only researchers will have access to the records.

Voluntary Nature of the Study:
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to not answer any question or withdraw at any time with out affecting those relationships.

Contacts and Questions:
The researchers conducting this study are: Sara Sjoberg, Len Marquart, Zata Vickers, and Marla Reicks. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact Sara Sjoberg or Len Marquart at University of Minnesota, 612-624-1290, sjob0030@umn.edu; 612-624-3255, lmarquar@umn.edu.

IRB Code # 0605M86828
Version Date: June 22, 2006

1 of 2

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

You will be given a copy of this information to keep for your records.

Statement of Consent:

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

Signature:_ ________________ Date:_____________

Signature of
Investigator:________________________________ Date:_____________

IRB Code # 0605M86828
Version Date: June 22, 2006

Appendix C. Bread preference score sheet

Which bread do you prefer? **Subject #**4

X **Whole Wheat** ______ **White**

Appendix D. FFQ of whole grain bread intake for whole grain bread consumers

Subject # 26

Information About the breads you eat

INSTRUCTIONS:

- Think about when you usually eat in the last month.
- Report how many times per month, week or day you eat bread and, if you ate it, how much you usually had.
- **Place an "X" in one of the boxes to indicate your best answer. Please provide only one response for each question.**

1) How often do you eat **bread, toast or dinner rolls**, including bread as part of a sandwich (DO NOT count buns with hamburgers or hot dogs)?

☐ Never or less than 1 time per month
☐ 1 time per month
☐ 2-3 times per month
☐ 1-2 times per week
☐ 3-4 times per week
☐ 5-6 per week
☐ 1 time per day
☐ 2 or more times per day

2) Each time you eat **bread, toast or dinner rolls**, how much do you usually eat?

☐ 1 slice or 1 dinner roll
☐ 2 slices or 2 dinner rolls
☐ More than 2 slices or 2 dinner rolls

3) How often are the **bread, toast or dinner rolls**, you eat dark bread such as whole wheat, cracked wheat, rye, or multi-grain?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always
☐ Don't know

1

Demographic Information

Please place one mark for each question

1. How old are you? _________ years
2. Are you . . . __________ Female __________ Male
3. Are you . . .
   _________White _______ African American ________ Asian ________ Hispanic
   ______Other
4. What is the highest grade in school that you completed?
   __________ Up to 8^{th} grade
   __________ Some high school
   __________ High school or GED
   _________ Some college/technical school
   _________ College graduate

Appendix E. FFQ of whole grain bread intake for refined grain bread consumers

White

Subject # 1

Information About the breads you eat

INSTRUCTIONS:

- Think about when you usually eat in the last month.
- Report how many times per month, week or day you eat bread and, if you ate it, how much you usually had.
- **Place an "X" in one of the boxes to indicate your best answer. Please provide only one response for each question.**

Pr

1

1) How often do you eat **whole grain sandwich bread** (bread as part of a sandwich or toast)?
(DO **NOT** count English muffins, bagels, dinner rolls, buns with hamburgers or hot dogs)

This is a tool to find the total number of slices of bread consumed per week, month, or day. Place tick marks on each day that you eat this bread. Count the total.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

- ☐ Never
- ☐ 1-6 times per year
- ☐ 7-11 times per year
- [x] 1 time per month
- ☐ 2-3 times per month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

2) Each time you eat **whole grain sandwich bread** how much do you usually eat?

1 slice of bread = 1 serving of bread

Breakfast
- ☐ 1 slice
- ☐ 2 slices
- ☐ More than 2 slices

Lunch
- ☐ 1 slice
- [x] 2 slices
- ☐ More than 2 slices

Dinner
- ☐ 1 slice
- ☐ 2 slices
- ☐ More than 2 slices

Snacks
- [x] 1 slice
- ☐ 2 slices
- ☐ More than 2 slices

3) How often do you eat **refined white sandwich bread** (bread as part of a sandwich or toast)?
(DO **NOT** count English muffins, bagels, dinner rolls, buns with hamburgers or hot dogs).

This is a tool to find the total number of slices of bread consumed per week, month, or day. Place tick marks on each day that you eat this bread. Count the total.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

- ☐ Never
- ☐ 1-6 times per year
- ☐ 7-11 times per year
- [x] 1 time per month
- ☐ 2-3 times per month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

4) Each time you eat **refined white sandwich bread** how much do you usually eat?

1 slice of bread = 1 serving of bread

Breakfast	Lunch	Dinner	Snacks
☐ 1 slice	☐ 1 slice	☐ 1 slice	☐ 1 slice
☐ 2 slices	☒ 2 slices	☐ 2 slices	☐ 2 slices
☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices

5) How often do you eat **other breads** (English muffins, bagels, dinner rolls, pita bread or buns with hamburgers or hot dogs)?

This is a tool to find the total number of slices of bread consumed per week, month or day. Place tick marks on each day that you eat this bread. Count the total.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

- ☐ Never
- ☐ 1-6 times per year
- ☐ 7-11 times per year
- ☐ 1 time per month
- ☐ 2-3 times per month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☒ 1 time per day
- ☐ 2 or more times per day

6) Each time you eat **other breads** (English muffins, bagels, dinner rolls, pita bread or buns with hamburgers or hot dogs) how much do you usually eat?

Breakfast	Lunch	Dinner	Snacks
☐ 1 slice	☐ 1 slice	☒ 1 slice	☒ 1 slice
☒ 2 slices	☒ 2 slices	☐ 2 slices	☐ 2 slices
☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices

Are most of these OTHER BREADS Whole grain ☐ or refined ☒?

3

Please answer the following by making a check mark or 'X for each question.

Demographic Information

1. How old are you? __20__ Years

2. Are you . . . __X__ Female ______ Male

3. Are you . . .
__X__ White ______ African American ______ Asian ______ Hispanic ______ Other

4. What is the highest grade in school that you completed?
______ Up to 8th grade
______ Some high school
______ High school or GED
__X__ Some college/technical school
______ College graduate

5. Are you . . .
______ Married __X__ Single ______ Divorced ______ Separated ______

6. Do you live with . . .
______ Spouse
__X__ Boyfriend/girlfriend
______ Sisters/brothers
______ Others (who?____________)
______ Daughters/sons

7. How many servings of whole grain breads do you plan to eat for the next month?
______ None
______ 1 slice/week
__X__ 2-4 slices/week
______ 5-7 slices/week
______ 2-3 slices/day
______ > 4 slices/day

8. Do you exercise regularly (at least 5 times a week, 30 minutes each time)?
______ No __X__ Yes

9. How long have you consumed whole grain breads as a part of your typical diet?
______ 0 to 1 year
__X__ 1 to 2 years
______ 3-5 years
______ 5 – 10 years
______ > 10 years

4

Appendix F. Theory of planned behavior questionnaire for pilot study

Information about the breads you eat

INSTRUCTIONS:

We would like to know your opinions about whole grain breads. There are no right or wrong answers. Please place an "X" in one of the boxes (☐) that best describes your opinion. Please mark only one box for each question.

I believe that whole grain breads . . .

	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very likely
Taste good	☐	☐	☐	☐	☐
Make me feel full	☐	☐	☐	☐	☐
Prevent me from eating as much	☐	☐	☐	☐	☐
`re dark in color	☐	☐	☐	☐	☐
Are high in fiber	☐	☐	☐	☐	☐
Have a dense/heavy texture	☐	☐	☐	☐	☐
Are healthy	☐	☐	☐	☐	☐
Will make me gain weight	☐	☐	☐	☐	☐
Smell good	☐	☐	☐	☐	☐
Are hearty and robust	☐	☐	☐	☐	☐
Make me feel satisfied	☐	☐	☐	☐	☐
How likely is it that you will eat 3 servings of whole grain breads per day? serving= 1 slice bread	☐	☐	☐	☐	☐

Version October 24, 2006 1

How likely do the following think you should eat whole grain bread?

	Not applicable	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very likely
My family members think I should eat whole grain bread	I don't have any family members ☐	☐	☐	☐	☐	☐
My roommates think I should eat whole grain bread	I don't have any roommates ☐	☐	☐	☐	☐	☐
My spouse thinks I should eat whole grain bread	I don't have a spouse ☐	☐	☐	☐	☐	☐
My boyfriend/ girlfriend thinks I should eat whole grain bread	I don't have one ☐	☐	☐	☐	☐	☐
Magazine/ newspaper advertisements promote eating whole grain breads	I don't read them ☐	☐	☐	☐	☐	☐

How likely is it that the following encourage you to eat whole grain breads?

	Not applicable	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very likely
Food Companies	☐	☐	☐	☐	☐	☐
Health Claims on food packages	☐	☐	☐	☐	☐	☐

How much do the following influence your decision to eat whole grain bread?

	Not applicable	Not at all	A little bit	A fair amount	Much	Very much
My family members	I don't have any family members ☐	☐	☐	☐	☐	☐
My roommates	I don't have any roommates ☐	☐	☐	☐	☐	☐
My spouse	I don't have a spouse ☐	☐	☐	☐	☐	☐
My boyfriend/girlfriend	I don't have one ☐	☐	☐	☐	☐	☐

How much do the following influence your decision to eat whole grain bread?

	Not applicable	Not at all	A little bit	A fair amount	Much	Very much
Magazine/ newspaper advertisements	I don't read them ☐	☐	☐	☐	☐	☐
Food companies		☐	☐	☐	☐	☐
Health Claims		☐	☐	☐	☐	☐

How hard is it for you to . . .?

	Very hard	Hard	Neither hard nor easy	Easy	Very easy
Eat whole grain breads when eating away from home (at restaurants, parties and family functions)	☐	☐	☐	☐	☐
Eat whole grain breads when restaurants do not provide ingredient content information on breads served	☐	☐	☐	☐	☐
Understand whole grain bread packaging & labeling/ingredient list	☐	☐	☐	☐	☐

I think eating whole grain bread is hard because . . .

	Disagree a lot	Disagree a little	Neither disagree nor agree	Agree a little	Agree a lot
Whole grain breads are expensive	☐	☐	☐	☐	☐
I do not like to use whole grain bread for sandwiches	☐	☐	☐	☐	☐
I do not like to use whole grain bread for toast	☐	☐	☐	☐	☐
I do not like to read bread labels	☐	☐	☐	☐	☐

I think eating whole grain bread is hard because . . .

	Disagree a lot	Disagree a little	Neither disagree nor agree	Agree a little	Agree a lot
Everyone else in the household eats white bread	☐	☐	☐	☐	☐
I have to go to a certain grocery store/bakery to buy my type/brand of whole grain bread	☐	☐	☐	☐	☐
Certain grocery stores do not carry whole grain breads	☐	☐	☐	☐	☐
It is not as soft as white bread	☐	☐	☐	☐	☐
White bread is what I have always eaten	☐	☐	☐	☐	☐
There are pieces of grains in whole grain breads that are hard to bite and chew	☐	☐	☐	☐	☐
It takes over the taste of the ingredients inside or on top of the sandwich or bread (meat, cheese, peanut butter, jelly etc.)	☐	☐	☐	☐	☐
White bread goes better with some foods (peanut butter and jelly, grilled cheese) than whole grain bread	☐	☐	☐	☐	☐
White Italian & French bread go better with some foods	☐	☐	☐	☐	☐

Appendix G. FFQ of whole grain bread intake for pilot study

2

Information About the breads you eat

INSTRUCTIONS:

- Think about the type and amount of bread you ate last month.
- Report how many times per month, week or day you ate bread and, if you ate it, how much you usually had.
- **Place an "X" in one of the boxes to indicate your best answer. Please provide only one response for each question.**

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1) How often do you eat **whole grain sandwich bread** (bread as part of a sandwich, toast or with some other food on top (butter))?
(DO **NOT** count English muffins, bagels, dinner rolls, hamburgers or hot dog buns, or other bread products)

- ☐ Never
- ☐ 1-6 times per year
- ☐ 7-11 times per year
- ☐ 1 time per month
- ☒ 2-3 times per month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

2) Each time you eat **whole grain sandwich bread** how much do you usually eat?

Breakfast	**Lunch**	**Dinner**	**Snacks**
☒ 1 slice	☐ 1 slice	☒ 1 slice	☐ 1 slice
☐ 2 slices	☒ 2 slices	☐ 2 slices	☐ 2 slices
☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices

3) How often do you eat **refined white sandwich bread** (bread as part of a sandwich or toast)?
(DO **NOT** count English muffins, bagels, dinner rolls, buns with hamburgers or hot dogs).

- ☐ Never
- ☒ 1-6 times per year
- ☐ 7-11 times per year
- ☐ 1 time per month
- ☐ 2-3 times per month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

4) Each time you eat **refined white sandwich bread** how much do you usually eat?

Breakfast	**Lunch**	**Dinner**	**Snacks**
☒ 1 slice	☐ 1 slice	☒ 1 slice	☐ 1 slice
☐ 2 slices	☒ 2 slices	☐ 2 slices	☐ 2 slices
☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices

5) How often do you eat **other whole wheat breads** (English muffins, bagels, dinner rolls, pita bread or buns with hamburgers or hot dogs)?

- ☐ Never
- ☐ 1-6 times per year
- ☒ 7-11 times per year
- ☐ 1 time per month
- ☐ 2-3 times per month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

6) Each time you eat **other whole wheat breads** (English muffins, bagels, dinner rolls, pita bread or buns with hamburgers or hot dogs) how much do you usually eat?

Breakfast	Lunch	Dinner	Snacks
☒ 1 slice	☒ 1 slice	☒ 1 slice	☐ 1 slice
☐ 2 slices	☐ 2 slices	☐ 2 slices	☐ 2 slices
☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices

7) How often do you eat **other refined white breads** (English muffins, bagels, dinner rolls, pita bread or buns with hamburgers or hot dogs)?

- ☐ Never
- ☒ 1-6 times per year
- ☐ 7-11 times per year
- ☐ 1 time per month
- ☐ 2-3 times per month
- ☐ 1 time per week
- ☐ 2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 1 time per day
- ☐ 2 or more times per day

8) Each time you eat **other refined white breads** (English muffins, bagels, dinner rolls, pita bread or buns with hamburgers or hot dogs) how much do you usually eat?

Breakfast	Lunch	Dinner	Snacks
☒ 1 slice	☐ 1 slice	☒ 1 slice	☐ 1 slice
☐ 2 slices	☒ 2 slices	☐ 2 slices	☐ 2 slices
☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices	☐ More than 2 slices

Please answer the following by making a check mark or 'X for each question.

Demographic Information

1. How old are you? ___43___ Years
2. Are you . . . ________ Female ___X___ Male
3. Are you . . .
___X___ White _______ African American ________ Asian ________ Hispanic ______ Other
4. What is the highest grade in school that you completed?
__________ Up to 8th grade
__________ Some high school
__________ High school or GED
___X___ Some college/technical school
_________ College graduate
5. Are you . . .
_________ Married ___X___ Single ________ Divorced ________ Separated
6. Do you live (with) . . .
______ Spouse
__X__ Boyfriend/girlfriend
_____ Sisters/brothers
__ Others (who?____________)
________ Daughters/sons
________ Alone
7. How many servings of whole grain breads do you plan to eat for the next month?
__________ None
__________ 1-2 slices/month
____X____ 1 slice/week
__________ 2-4 slices/week
_________ 5-7 slices/week
_________ 2-3 slices/day
_________ >4 slices/day
8. Do you exercise regularly (at least 5 times a week, 30 minutes each time)?
________ No ___X___ Yes
9. How long have you consumed whole grain breads as a part of your typical diet?
__________ 0 months
__________ 0-6 months
__________ 6-12 months
_________ > 1 year
_________ 2 years
_________ 3-5 years
_________ 5-10 years
____X____ > 10 years

Appendix H. SAS Code for focus groups and pilot study

```
libname xxx 'e:';
run;
data xxx.pilotTPB2;
set xxx.pilotTPB;
sb1=sn1*m1;
sb2=sn2*m2;
sb3=sn3*m3;
sb4=sn4*m4;
sb5=sn5*m5;
sb6=sn6*m6;
sb7=sn7*m7;
sb12=sn12*m12;
sb22=sn22*m22;
sb32=sn32*m32;
sb42=sn42*m42;
sb52=sn52*m52;
sb62=sn62*m62;
sb72=sn72*m72;
snew1=sb1 +sb2+sb3+sb4+sb5+sb6+sb7;
snew12=sb12 +sb22+sb32+sb42+sb52+sb62+sb72;
atti=a1+a2+a3+a4+a5+a6+a7+a8+a9+a10+a11;
atti2=a12+a22+a32+a42+a52+a62+a72+a82+a92+a102+a112;
pc=c1 +c2+ c3+ c4+ c5+ c6+ c7+ c8+ c9+ c10+ c11+ c12b+ c13+ c14+ c15+
c16;
pc2=c12 +c22+ c32+ c42+ c52+ c62+ c72+ c82+ c92+ c102+ c112+ c122+
c132+ c142+ c152+ c162;
bi=bi1 + bi2;
bi2=bi12 + bi22;
run;
PROC MEANS  data=xxx.pilotTPB2;
VAR  atti snew1  pc bi1 bi2 bi atti2 snew12  pc2 bi12 bi22 ;
RUN;
proc corr alpha data=xxx.pilotTPB2 NOMISS;
title 'corr of pilot 1st and 2nd';
var atti snew1  pc bi1 bi2 bi atti2 snew12  pc2 bi12 bi22 Bi2 ;
run;
proc corr alpha data=xxx.pilotTPB2 NOMISS;
title 'corr of pilot a1-a11 and a12-a112';
var a1 a2 a3 a4 a5 a6 a7 a8 a9 a10 a11 a12 a22 a32 a42 a52 a62 a72 a82
a92 a102 a112;
run;
proc corr alpha data=xxx.pilotTPB2 NOMISS;
title 'corr of pilot c1-c16 and c12b-c162';
var c1 c2 c3 c4 c5 c6 c7 c8 c9 c10 c11 c12 c13 c14 c15 c16 c12b c22 c32
c42 c52 c62 c72 c82 c92 c102 c112 c122 c132 c142 c152 c162;
run;
proc corr alpha data=xxx.pilotTPB2 NOMISS;
title 'corr of pilot m1-m7 and m12-m72';
var m1 m2 m3 m4 m5 m6 m7 m12 m22 m32 m42 m52 m62 m72;
run;
proc corr alpha data=xxx.pilotTPB2 NOMISS;
title 'corr of pilot sn1-sn7 and sn12-sn72';
var sn1 sn2 sn3 sn4 sn5 sn6 sn7 sn12 sn22 sn32 sn42 sn52 sn62 sn72;
run;
```

```
proc corr alpha data=xxx.pilotTPB2 NOMISS;
title 'corr of pilot sn1-sn7 and sn12-sn72';
var sn1 sn2 sn3 sn4 sn5 sn6 sn7 sn12 sn22 sn32 sn42 sn52 sn62 sn72;
run;
```

APPENDICES CHAPTER 5-Part 2

Appendix A. Consent form

SUBJECT #___

CONSENT FORM
Influences on bread consumption

You are invited to be in a research study to evaluate your eating habits and your liking of bread products. You were selected as a possible participant because you visited this grocery store today. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by: Sara Sjoberg, MS, in the Department of Food Science and Nutrition at the University of Minnesota.

Background Information
The purpose of this study is: to determine what influences eating habits of adults, and what type of breads are typically liked by adults. This information will help us to better understand why consumers like/dislike certain breads over others. This will be helpful in developing more acceptable breads.

Procedures:
If you agree to be in this study, we would ask you to do the following things:
You will be given a lesson on breads. You will fill out a questionnaire and answer questions regarding consumption of breads. You will also taste 4-7 samples of breads and rate your overall liking, appearance liking, texture liking and flavor liking of each. You will rate a variety of remembered visual and auditory sensations varying in intensities using a scale. You will also taste a bitter tasting piece of paper and rate the bitterness of it. It will take about 15-20 minutes to answer the questions.

Risks and Benefits of being in the Study
If you are pregnant or in poor health, reported history of thyroid disease, dry mouth, nasal disorders, severe respiratory infections, ear infections you are at risk while tasting 6-n-Propylthiouracil (PROP). Anyone with any of these conditions should not participate in this study. PROP is a bitter-tasting compound. You will taste a piece of paper that will contain approximately 1.6 mg PROP which is low compared to the typical 300 mg/day given as a therapeutic dose to subjects with hyperthyroidism. Therefore, it appears there is little or no risk to human subjects while tasting PROP and those who do not have the above health conditions.

The benefits to participation are: none.

Compensation:
You will receive a small token for completing all of the required activities in the grocery store. You will first receive payment a gift and a Cub Foods $5.00 gift card. You will receive a Cub Foods $10.00 gift card in the mail) after returning the 1-2 bread bags via the U.S. mail to Sara Sjoberg.

Confidentiality:
The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records.

IRB Code # 0605M86828
Version Date: December 11, 2006

1 of 2

Voluntary Nature of the Study:
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to not answer any question or withdraw at any time with out affecting those relationships.

Contacts and Questions:
The researchers conducting this study are: Sara Sjoberg, Len Marquart, Zata Vickers, and Marla Reicks. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact Sara Sjoberg or Len Marquart at University of Minnesota, 612-624-1290, sjob0030@umn.edu; 612-624-3255, lmarquar@umn.edu.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

You will be given a copy of this information to keep for your records.

Statement of Consent:
I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

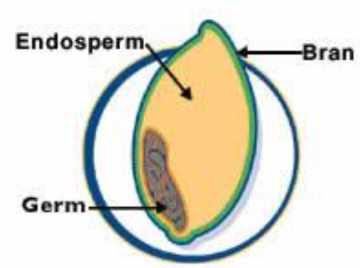
Signature: ______________________________ Date: ______________

Signature of Investigator: ______________________________ Date: ______________

Appendix B. Whole grain bread lesson

Grain Foods

A whole grain is the entire seed (kernel) of the plant. Whole grains contain 3 parts:



Grains are **refined** to remove the germ and bran. All whole grain and refined breads have nutritional value.

What is the difference between whole grain bread and refined bread?

WHOLE GRAINS

- Products that contain 51% or more of whole grain ingredients by weight.
- "Diets rich in whole grain foods and other plant foods and low in total fat, saturated fat, and cholesterol, may help reduce the risk of heart disease and certain cancers."
- Before whole grains are milled or refined all grains are whole.
- Look for the words "whole" or "whole grain" before the name of the grain (e.g. whole wheat).

Whole wheat
Whole grain (oats)
Whole (other grain)
Stone-ground whole (grain)

- A "100% whole wheat" bread must be made with only whole wheat flour.
- Look at the 1st ingredient listed on bread label, it must be "whole" (whole wheat)
- Look at the 2nd ingredient, it should not be refined grain
- High fiber does not mean whole grain.
  - Some breads have fiber added back with the refined white flour so that the amount of fiber is high but it doesn't have all of the nutrients that come with whole grain ingredients.

- White whole wheat is lighter in color and is used in whole grain breads.

REFINED

- Look at the 1st ingredient listed as "refined" flour, wheat flour, unbleached wheat flour, or unbleached enriched wheat flour.

- Some of the ingredients may have some whole grains, but there is also refined white flour
- Refined breads are made with enriched flour
    - These breads have B-vitamins and iron added back into it when the wheat was refined.
    - They are also fortified with folic acid which reduces birth defects

Appendix C. TPB questionnaire on whole grain bread intake

Information About the Breads You Eat

SUBJECT #

INSTRUCTIONS

- We would like to know your opinions about whole grain breads.
- There are no right or wrong answers. Please mark the response that best describes your opinion.
- Please provide only one response for each question.
- Use a No. 2 pencil only.
- Do not use ink, ballpoint, or felt tip pens.
- Make solid marks that fill the response completely.
- Erase cleanly any marks you wish to change.
- Make no stray marks on this form.

CORRECT: ● INCORRECT: ⊘⊠◒◔

I believe that whole grain breads...	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very likely
Taste good	○	○	○	○	○
Make me feel full	○	○	○	○	○
Prevent me from eating as much	○	○	○	○	○
Are dark in color	○	○	○	○	○
Are high in fiber	○	○	○	○	○
Have a dense/heavy texture	○	○	○	○	○
Are healthy	○	○	○	○	○
Will make me gain weight	○	○	○	○	○
Smell good	○	○	○	○	○
Are hearty and robust	○	○	○	○	○
Make me feel satisfied	○	○	○	○	○
How likely is it that you will eat 3 servings of whole grain breads per day? 1 serving= 1 slice bread	○	○	○	○	○

How likely do the following think you should eat whole grain bread?

	Not applicable	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very likely
My family members think I should eat whole grain bread	I don't have any family members					
My spouse thinks I should eat whole grain bread	I don't have a spouse					
My friends think I should eat whole grain bread	I don't have friends					
Magazine/newspaper advertisements promote eating whole grain breads	I don't read them					

How likely is it that the following encourage you to eat whole grain breads?

	Not applicable	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very likely
Food Companies						
Health Claims on food packages						

How much do the following influence your decision to eat whole grain bread?

	Not applicable	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very likely
My family members	I don't have any family members					
My spouse	I don't have a spouse					
My friends	I don't have friends					

How much do the following influence your decision to eat whole grain bread?

	Not applicable (I don't read them)	Very unlikely	Unlikely	Neither unlikely nor likely	Likely	Very likely
Magazine/newspaper advertisements						
Food companies						
Health Claims on food packages						

How hard is it for you to . . .?

	Very hard	Hard	Neither hard nor easy	Easy	Very easy
Eat whole grain breads when eating away from home (at restaurants, parties and family functions)					
Eat whole grain breads when restaurants do not provide ingredient content information on breads served					
Understand whole grain bread packaging & labeling/ingredient list					

I think eating whole grain bread is hard because . . .

	Disagree a lot	Disagree a little	Neither agree nor disagree	Agree a little	Agree a lot
Whole grain breads are expensive					
I do not like to use whole grain bread for sandwiches					
I do not like to use whole grain bread for toast					
I do not like to read bread labels					

FRONT

FRONT

I think eating whole grain bread is hard because . . .	Disagree a lot	Disagree a little	Neither agree nor disagree	Agree a little	Agree a lot
Everyone else in the household eats white bread					
I have to go to a certain grocery store/bakery to buy my type/brand of whole grain bread					
It is hard to find whole grain bread in the store where I/we usually buy bread					
It is not as soft as white bread					
White bread is what I have always eaten					
There are pieces of grains in whole grain breads that are hard to bite and chew					
It takes over the taste of the ingredients inside or on top of the sandwich or bread (meat, cheese, peanut butter, jelly etc.)					
White bread goes better with some foods (peanut butter and jelly, grilled cheese) than whole grain bread					
White Italian & French bread go better with some foods					

Office of Measurement Services

Appendix D. FFQ of whole grain bread intake

Information About the Breads You Eat

SUBJECT #

INSTRUCTIONS

- Think about the type and amount of bread you ate last month.
- Report how many times per month, week or day you ate bread and, if you ate it, how much you usually had.
- Please provide only one response for each question.
- Use a No. 2 pencil only.
- Do not use ink, ballpoint, or felt tip pens.
- Make solid marks that fill the response completely.
- Erase cleanly any marks you wish to change.
- Make no stray marks on this form.

CORRECT: ● INCORRECT: ✓ ☒ ◒ ◔

1. How often do you eat *whole grain sandwich bread* (bread as part of a sandwich, toast or with some other food on top (butter))? (*DO NOT* count English muffins, bagels, dinner rolls, pita bread, hamburgers or hot dog buns, or other bread products.)

- ○ Never (go to question 3)
- ○ 1-6 times per year
- ○ 7-11 times per year
- ○ 1 time per month
- ○ 2-3 times per month
- ○ 1 time per week
- ○ 2 times per week
- ○ 3-4 times per week
- ○ 5-6 times per week
- ○ 1 time per day
- ○ 2 or more times per day

2. Each time you eat *whole grain sandwich bread* how much do you usually eat? (ONLY MARK THE MEALS THAT APPLY.)

Breakfast	Lunch	Dinner	Snacks
○ 1 slice	○ 1 slice	○ 1 slice	○ 1 slice
○ 2 slices	○ 2 slices	○ 2 slices	○ 2 slices
○ More than 2 slices	○ More than 2 slices	○ More than 2 slices	○ More than 2 slices

3. How often do you eat *refined white sandwich bread* (bread as part of a sandwich or toast)? (*DO NOT* count English muffins, bagels, dinner rolls, pita bread, hamburgers or hot dog buns, or other bread products.)

- ○ Never (go to question 5)
- ○ 1-6 times per year
- ○ 7-11 times per year
- ○ 1 time per month
- ○ 2-3 times per month
- ○ 1 time per week
- ○ 2 times per week
- ○ 3-4 times per week
- ○ 5-6 times per week
- ○ 1 time per day
- ○ 2 or more times per day

4. Each time you eat *refined white sandwich bread* how much do you usually eat? (ONLY MARK THE MEALS THAT APPLY.)

Breakfast	Lunch	Dinner	Snacks
○ 1 slice	○ 1 slice	○ 1 slice	○ 1 slice
○ 2 slices	○ 2 slices	○ 2 slices	○ 2 slices
○ More than 2 slices	○ More than 2 slices	○ More than 2 slices	○ More than 2 slices

5. **How often do you eat *other whole grain* breads (English muffins, bagels, dinner rolls, pita bread hamburgers or hot dog buns, or other bread products)?**

◯ Never (go to question 7)	◯ 2-3 times per month	◯ 5-6 times per week
◯ 1-6 times per year	◯ 1 time per week	◯ 1 time per day
◯ 7-11 times per year	◯ 2 times per week	◯ 2 or more times per day
◯ 1 time per month	◯ 3-4 times per week	

6. **Each time you eat *other whole grain* breads (English muffins, bagels, dinner rolls, pita bread, hamburgers or hot dog buns, or other bread products) how much do you usually eat? (ONLY MARK THE MEALS THAT APPLY.)**

Breakfast	Lunch	Dinner	Snacks
◯ 1 slice	◯ 1 slice	◯ 1 slice	◯ 1 slice
◯ 2 slices	◯ 2 slices	◯ 2 slices	◯ 2 slices
◯ More than 2 slices	◯ More than 2 slices	◯ More than 2 slices	◯ More than 2 slices

7. **How often do you eat *other refined white* breads (English muffins, bagels, dinner rolls, pita bread, hamburgers or hot dog buns, or other bread products)?**

◯ Never (go to last page)	◯ 2-3 times per month	◯ 5-6 times per week
◯ 1-6 times per year	◯ 1 time per week	◯ 1 time per day
◯ 7-11 times per year	◯ 2 times per week	◯ 2 or more times per day
◯ 1 time per month	◯ 3-4 times per week	

8. **Each time you eat *other refined white* breads (English muffins, bagels, dinner rolls, pita bread, hamburgers or hot dog buns, or other bread products) how much do you usually eat? (ONLY MARK THE MEALS THAT APPLY.)**

Breakfast	Lunch	Dinner	Snacks
◯ 1 slice	◯ 1 slice	◯ 1 slice	◯ 1 slice
◯ 2 slices	◯ 2 slices	◯ 2 slices	◯ 2 slices
◯ More than 2 slices	◯ More than 2 slices	◯ More than 2 slices	◯ More than 2 slices

Demographic Information

1. **How old are you?** ___ Years

2. **Are you ...**
   - Female
   - Male

3. **Are you ...**
   - White
   - African American
   - Asian
   - Hispanic
   - Other

4. **What is the highest grade in school that you completed?**
   - Up to 8th grade
   - Some high school
   - High school or GED
   - Some college/technical school
   - College graduate

5. **Are you ...**
   - Married
   - Single
   - Divorced
   - Separated

6. **Do you live (with) . . . (Mark all that apply.)**
   - Spouse
   - Boyfriend/girlfriend
   - Sisters/brothers
   - Daughters/sons
   - Others (who? ________)
   - Alone

7. **How many servings of whole grain breads do you plan to eat for the next month?**
   - None
   - 1-2 slices/month
   - 1 slice/week
   - 2-4 slices/week
   - 5-7 slices/week
   - 2-3 slices/day
   - >4 slices/day

8. **Do you exercise regularly (at least 5 times a week, 30 minutes each time)?**
   - No
   - Yes

9. **How long have you consumed whole grain breads as a part of your typical diet?**
   - 0 months
   - 0-6 months
   - 6-12 months
   - 12-24 months
   - 24-36 months
   - 3-5 years
   - 5-10 years
   - > 10 years

Appendix E. Bread liking score sheet

You will receive 5 samples coded with 3 digit numbers. Rate your response to the sample attributes on the score sheet provided. Please make sure the score sheet code matches the sample code. Place a mark anywhere on the line corresponding to your response.

Sample #125

Please rate your liking of the sample based on its APPEARANCE only.

Appearance Liking

Greatest Imaginable Disliking | Dislike Extremely | Dislike Very Much | Dislike Moderately | Dislike Slightly | Neutral | Like Slightly | Like Moderately | Like Very Much | Like Extremely | Greatest Imaginable Liking

Now taste the sample, and rate your liking of the bread for the following attributes.

Overall Liking

Greatest Imaginable Disliking | Dislike Extremely | Dislike Very Much | Dislike Moderately | Dislike Slightly | Neutral | Like Slightly | Like Moderately | Like Very Much | Like Extremely | Greatest Imaginable Liking

Texture Liking

Greatest Imaginable Disliking | Dislike Extremely | Dislike Very Much | Dislike Moderately | Dislike Slightly | Neutral | Like Slightly | Like Moderately | Like Very Much | Like Extremely | Greatest Imaginable Liking

Flavor Liking

Greatest Imaginable Disliking | Dislike Extremely | Dislike Very Much | Dislike Moderately | Dislike Slightly | Neutral | Like Slightly | Like Moderately | Like Very Much | Like Extremely | Greatest Imaginable Liking

Additional Comments:

Appendix F. PROP taster score sheet

Are you a PROP taster??

Please rate the intensity of the following sensations on the scales provided by placing a vertical mark at a position that best describes how intense you remember/imagine that sensation to be.

no sensation — barely detectable — weak — moderate — strong — very strong — strongest imaginable sensation of any kind

Brightness of a dimly lit restaurant					
Brightness of the sun when looking directly at it					
Loudness of a whisper					
Loudness of a normal conversation					
Warmth of warm bread in your mouth					
Smell of a rose					
Sweetness of a Coke®					
Bitterness of black coffee					
Saltiness of potato chips					
Loudness of a plane taking off 10 feet from you					
Strongest sweetness experienced					
Sourness of a fresh lemon slice					
Burn from drinking cold carbonated soda					
Brightness of this room					
Strongest oral burn experienced (e.g. hot pepper)					
Strongest oral pain experienced (e.g. a toothache)					
Strongest pain of any kind experienced					
Heat felt standing 5 feet from a large bonfire					
Taste intensity of the PROP paper					
Candy (sweetness)					

Appendix G. SAS code for Chapter 5 Part 2

```
libname xxx 'e:';
run;
/* The normative scale is being changed back to -2 to +2 and the not
applicable responses is blank. Oct 21 2011 the scale responses for SN
and Motivation to comply is 1 to 5 */
data xxx.shortTPBallnot2;
set xxx.shorttpballnot;
if bi2=1 then bi2=0;
if bi2=2 then bi2=1;
if bi2=3 then bi2=2;
if bi2=4 then bi2=3;
if bi2=5 then bi2=4;
if bi2=6 then bi2=5;
if bi2=7 then bi2=6;
if sn1= 1 then sn1=-2;
if sn1= 2 then sn1=-1;
if sn1= 3 then sn1=-0;
if sn1= 4 then sn1=1;
if sn1= 5 then sn1=2;
if sn2= 1 then sn2=-2;
if sn2= 2 then sn2=-1;
if sn2= 3 then sn2=0;
if sn2= 4 then sn2=1;
if sn2= 5 then sn2=2;
if sn3= 1 then sn3=-2;
if sn3= 2 then sn3=-1;
if sn3= 3 then sn3=0;
if sn3= 4 then sn3=1;
if sn3= 5 then sn3=2;
if sn4= 1 then sn4=-2;
if sn4= 2 then sn4=-1;
if sn4= 3 then sn4=0;
if sn4= 4 then sn4=1;
if sn4= 5 then sn4=2;
if sn5= 1 then sn5=-2;
if sn5= 2 then sn5=-1;
if sn5= 3 then sn5=0;
if sn5= 4 then sn5=1;
if sn5= 5 then sn5=2;
if sn6= 1 then sn6=-2;
if sn6= 2 then sn6=-1;
if sn6= 3 then sn6=0;
if sn6= 4 then sn6=1;
if sn6= 5 then sn6=2;
if racegr='white' then racegrn=1;
if racegr='other' then racegrn=2;
if statusgr='married' then statusgrn=1;
if statusgr='unmarri' then statusgrn=2;
run;
data xxx.finaltpbnot;
set xxx.shorttpballnot2;
sb1=sn1*m1;
sb2=sn2*m2;
```

```
sb3=sn3*m3;
sb4=sn4*m4;
sb5=sn5*m5;
sb6=sn6*m6;
snew1=sum(of sb1-sb6);
snew2=sum(of sn1-sn6);
atti=a1+a2+a3+a4+a5+a6+a7+a8+a9+a10+a11;
mc=m1+m2+m3+m4+m5+m6
pc=c1 +c2+ c3+ c4+ c5+ c6+ c7+ c8+ c9+ c10+ c11+ c12+ c13+ c14+ c15+
c16;
bi=bi1 + bi2;
run;
/* NOTES ON DEMOGRAPHICS AND METHODS FOR CALCULATING WG BREAD INTAKE*/
AGE
If 10 LE age LE 20  then agegr=1;
else If 20 LE age LE 30 then agegr=2;
else If 30 LE age LE 40 then agegr=3;
else If 40 LE age LE 50 then agegr=4;
else If 50 LE age LE 60 then agegr=5;
GENDER
If gender=1 then gendergr='female';
else if gender=2 then gendergr='male';
RACE
If race=1 then racegr='white';
else if race=2 or race=3 or race=4 or race=5 then racegr='other';
EDUCATION
If edu=1 or edu=2 or edu=3 then edugr='highschool';
/* edugroup 1 is highschool or lower*/
else if edu=4 then edugr='somecollege';
/* edugroup 2 is somecollege*/
else if edu=5 then edugr='collgrad';
/* edugroup 3 is collgrad or higher*/
MARITAL STATUS
If status=1 then statusgr='married';
else if status=2 or status=3 or status=4 then statusgr='unmarried';
/* statusgroup 1 is married and 2 is notmarried*/
LIVING STATUS
If live=1 then livegr=1;
/* livegroup 1 lives with spouse*/
else if live=2 then livegr=2;
/* livegroup 1 lives with boygirl*/
else if live=3 then livegr=3;
/* livegroup 1 lives with sisbro*/
else if live=4 then livegr=4;
/* livegroup 1 lives with dason*/
else if live=5 then livegr=5;
/* livegroup 1 lives with others*/
else if live=6 then livegr=6;
/* livegroup 1 lives with alone*/
else if live=7 then livegr=7;
/* livegroup 1 lives with dason and spouse*/
else if live=8 then livegr=8;
/* livegroup 1 lives with dason and boygirl*/
else if live=9 then livegr=9;
/* livegroup 1 lives with others and spouse*/
```

```
else if live=10 then livegr=10;
/* livegroup 1 lives with others and sisbro*/
else if live=11 then livegr=11;
/* livegroup 1 lives with others and dason*/
else if live=12 then livegr=12;
/* livegroup 1 lives with alone and spouse*/
else if live=13 then livegr=13;
/* livegroup 1 lives with others, dason and spouse*/
else if live=14 then livegr=14;
/* livegroup 1 lives with others, dason and boygirl*/
if livegr=6 then Alivegr='1';
else if livegr <6 then Alivegr='2';
else if livegr >6 then Alivegr='2';
run;
EXERCISE
If exer=1 then exergr='no';
/* exercisegroup 1 not more than 5 times per week*/
else if exer=2 then exergr='yes';
/* exercisegroup 2 more than 5 times per week**/
WGTIME
/*wgtime is the length of time they consumed whole grains*/
If wgtime=1 then wgtimegr='none';
If wgtime=2 then wgtimegr='sixmo';
If wgtime=3 then wgtimegr='sixtwel';
If wgtime=4 then wgtimegr='onetwo';
If wgtime=5 then wgtimegr='twothree';
If wgtime=6 then wgtimegr='threefive';
If wgtime=7 then wgtimegr='fiveten';
If wgtime=8 then wgtimegr='tenormore';
run;
FFQ
/*Frequency responses were standardized from times per year, month or
week to times per day using the frequency if a single number or the
midpoint if frequency was a range. For example if WG=2 or 1-6times/year
so 3.5/365day in a year = 0.0096; if WG=4 or 1 time per month so 1/30
days in one month = 0.033 etc…*/
If WG=1 then NWG=0;
else if WG=2 then NWG=0.0096;
else if WG=3 then NWG=0.025;
else if WG=4 then NWG=0.033;
else if WG=5 then NWG=0.0822;
else if WG=6 then NWG=0.143;
else if WG=7 then NWG=0.286;
else if WG=8 then NWG=0.5;
else if WG=9 then NWG=0.785;
else if WG=10 then NWG=1;
else if WG=11 then NWG=2;
If oWG=1 then NotherWG=0;
else if oWG=2 then NotherWG=0.0096;
else if oWG=3 then NotherWG=0.025;
else if oWG=4 then NotherWG=0.033;
else if oWG=5 then NotherWG=0.0822;
else if oWG=6 then NotherWG=0.143;
else if oWG=7 then NotherWG=0.286;
else if oWG=8 then NotherWG=0.5;
```

```
else if oWG=9 then NotherWG=0.785;
else if oWG=10 then NotherWG=1;
else if oWG=11 then NotherWG=2;
/*total amount of WG bread, otherWG bread consumed (sum of breakfast,
lunch, dinner and snack) */
WGT=WGB + WGL + WGD+ WGS;
oWGTl=oWGB + oWGL + oWGD+ oWGS;
/*Daily total amount of WG bread and otherWG bread consumed multiplied
by the daily frequency factor as determined from above SAS code*/
fWG=NWG*WGT;
fNoWG=NotherWG*oWGTl;
/*total amount of WG Bread consumed*/
WGbr=fWG + fNoWG;
run;
/* END OF NOTES */

/* Demographic Frequencies in Table 3*/
proc freq data= xxx.finaltpbnot;
title ' Frequency Distribution Demographics tastern -chisquare';
tables tastern ;
run;
/* NOTES: tastern=PROP taster status; wgbr=whole grain bread intake;
status=marital status; live=living status; WGtime= whole grain bread
consumption pattern */
/* Demographic Frequencies in Table 3*/
proc freq data= xxx.finaltpbnot;
title ' Frequency Distribution Demographics -chisquare';
tables age gender race edu status live exer wgtime ;
run;
proc means data= xxx.finaltpbnot;
title 'Means wgbr intake ';
var wgbr;
run;
proc freq data= xxx.finaltpbnot;
title 'Frequency Distribution wgbr whbr intake';
tables wgbr;
run;
/*Determine significant differences in WGbr by demographics, Student T-
tests and Mixed ANOVA were conducted */
proc mixed data=xxx.finaltpbnot;
     title 'ANOVA MIXED  wgbr and agegr';
class  agegr;
model wgbr=agegr;
lsmeans agegr / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc ttest data= xxx.finaltpbnot alpha=0.05;
title 'ttest   Wgbr and gender groups ';
class  gendergr ;
var wgbr;
run;
proc mixed data=xxx.finaltpbnot;
     title 'ANOVA MIXED  wgbr and RACE';
class  race;
model wgbr=race;
```

```
lsmeans race / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc ttest data= xxx.finaltpbnot alpha=0.05;
title 'ttest   Wgbr and race groups ';
class  racegr ;
var wgbr;
run;
proc mixed data=xxx.finaltpbnot;
     title 'ANOVA MIXED wgbr and edu';
class  edu;
model wgbr=edu;
lsmeans edu / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc mixed data=xxx.finaltpbnot;
     title 'ANOVA MIXED wgbr and edugr';
class  edugr;
model wgbr=edugr;
lsmeans edugr / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc ttest data=xxx.finaltpbnot alpha=0.05;
title 'ttest   Wgbr and status groups ';
class  statusgr ;
var wgbr;
run;
/*Alivegr is living status grouped at with=1 and alone=2 */
proc ttest data= xxx.finaltpbnot alpha=0.05;
title 'ttest   Wgbr and Alivegr groups ';
class Alivegr ;
var wgbr;
run;
proc ttest data=xxx.finaltpbnot alpha=0.05;
title 'ttest   Wgbr and exer groups ';
class  exergr ;
var wgbr;
run;
proc mixed data=xxx.finaltpbnot;
     title 'ANOVA MIXED  wgbr and wgtime';
class  wgtime;
model wgbr=wgtime;
lsmeans wgtime / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc mixed data=xxx.finaltpbnot;
     title 'ANOVA MIXED  wgbr and tastern';
class  tastern;
model wgbr=tastern;
lsmeans tastern / adjust=tukey diff cl alpha=0.05;
random judge;
run;
/*bagnew grouping of subjects who returned a bread bag; bagnew=1 is WG
bag returned; bagnew=2 RG bag returned*/
proc means data= xxx.finaltpbnot;
```

```
title 'Means wgbr by pref bagnew tastern ';
class pref bagnew tastern;
var wgbr;
run;
/* Student t-tests and ANOVA MiXEd run to determine differences in WG
bread intake according to demographic categories and bread consumer
type: bread preference (whole grain or refined grain), bread bag choice
(whole grain or refined grain bread), PROP taster status*/
proc ttest data= xxx.finaltpbnot alpha=0.05;
title 'ttest   wgbr and bread pref  ';
class  pref;
var wgbr;
run;
proc mixed data=xxx.finaltpbnot ;
     title 'ANOVA MIXED  wgbr by bagnew';
class  bagnew;
model wgbr=bagnew ;
lsmeans bagnew / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc mixed data=xxx.finaltpbnot;
     title 'ANOVA MIXED  wgbr= tastern';
class  tastern ;
model wgbr=tastern ;
lsmeans tastern/ adjust=tukey diff cl alpha=0.05;
random judge;
run;
/* Pearson correlation coefficients were used to examine associations
between TPB model constructs and other factors in study.  */
proc corr alpha data= xxx.finaltpbnot NOMISS;
title 'ALL cronbach alpha NOMISS all TPB wgbr wgtime prop overall
moverall pref ';
var atti snew1 pc bi wgbr wgtime prop moverall pref ;
run;
/* Means of TPB individual beliefs */
proc means  data= xxx.finaltpbnot;
title 'Means a1-a11 atti sn1-sn6 m1-m6 mc snew1 snew2 c1-c16 pc bi1 bi2
bi ';
var a1-a11 atti sn1-sn6 m1-m6 mc snew1 snew1 c1-c16 pc bi1 bi2 bi;
run;
/* Pearson correlation coefficients were used to examine associations
between TPB model constructs and other factors in study.  */
proc corr alpha data= xxx.finaltpbnot;
title 'ALL cronbach alpha all TPB + demographics ';
var atti snew1 pc bi wgbr wgtime prop moverall pref ;
run;
/* Multiple regression analysis was used to examine the associations
among the constructs with the reported intention to consume whole grain
bread and the extended model included overall liking, PROP ratings,
bread preference and demographics*/
/* Predictors of Intention */
/*Model 1*/
proc reg data= xxx.finaltpbnot;
title 'multiple regression for Bi on atti  snew1   pc';
model bi=atti  snew1   pc  /b stb ;
```

```
run;
/*MODEL 2*/
proc reg data= xxx.finaltpbnot;
title 'multiple regression for Bi on atti snew1 pc and top3 mean
moverall liking ';
model bi = atti  snew1   pc moverall /b stb ;
run;
/*MODEL 3b*/
proc reg data= xxx.finaltpbnot;
title 'multiple regression for Bi on atti snew1 pc and PROP';
model bi = atti  snew1   pc prop /b stb ;
run;
/*MODEL 3*/
proc reg data= xxx.finaltpbnot;
title 'multiple regression for Bi on atti snew1 pc and bread PREF ';
model bi = atti  snew1   pc pref /b stb ;
run;
/*MODEL 3*/
proc reg data= xxx.finaltpbnot;
title 'multiple regression for Bi on atti snew1 pc and wgtime ';
model bi = atti  snew1   pc wgtime /b stb ;
run;
/*MODEL 4*/
proc reg data= xxx.finaltpbnot;
title 'multiple regression for Bi on atti  snew1   pc Moverall Prop
pref age gender race edu status live exer wgtime ';
model bi = atti  snew1 pc moverall Prop pref age gender racegrn edu
statusgrn Alivegr exer wgtime/b stb ;
run;
/* Poison regression was used instead of proc reg because the data were
NOT normally distributed and some people did NOT eat WG bread at all-
they only ate white bread and the model measures for WGbr=constructs*/
/*Poisson regression model was used to examine the associations among
the constructs with the reported WGBR intake and the extended model
included overall liking, PROP ratings and demographics */
/*MODEL 5*/
proc genmod data=xxx.finaltpbnot;
title 'Null POISSON REGRESSION WGBR= to conduct likelihood ratio test
of goodness of fit NO OUTLIERS to calculate R2 value from equation ';
            model wgbr= / dist    = poisson
                          link    = log
                              type1
                          type3;
   run;
/*MODEL 6*/
proc genmod data=xxx.finaltpbnot;
title 'POISSON REGRESSION WGBR= atti  snew1   pc  bi ';
            model wgbr=atti  snew1   pc  bi / dist    = poisson
                          link    = log
                              type1
                          type3;
   run;
/*MODEL 7*/
proc genmod data=xxx.finaltpbnot;
```

```
title 'POISSON REGRESSION WGBR= ATTI  snew1   pc  bi and Moverall
liking';
            model wgbr= atti  snew1   pc  bi moverall / dist    =
poisson
                          link    = log
                        type1
                          type3;
   run;
 /*MODEL 8*/
proc genmod data=xxx.finaltpbnot;
title 'POISSON REGRESSION WGBR= atti  snew1   pc  bi bread PREF ';
            model wgbr=atti  snew1   pc  bi pref / dist    = poisson
                          link    = log
                              type1
                          type3;
   run;
    /*MODEL 8*/
proc genmod data=xxx.finaltpbnot;
title 'POISSON REGRESSION WGBR= atti  snew1   pc  bi wgtime ';
            model wgbr=atti  snew1   pc  bi wgtime / dist    = poisson
                          link    = log
                              type1
                          type3;
   run;

  /* Model 9*/
   proc genmod data=xxx.finaltpbnot;
title 'POISSON REGRESSION WGBR= ATTI  snew1   pc  bi, Moverall liking,
PROP, PREF and demographics ';
            model wgbr= atti  snew1   pc  bi moverall PROP Pref age
gender racegrn edu statusgrn Alivegr  exer wgtime/ dist    = poisson
                          link    = log
                        type1
                          type3;
   run;
```

APPENDICES CHAPTER 6

Appendix A. Bread liking score sheet

You will receive 5 samples coded with 3 digit numbers. Rate your response to the sample attributes on the score sheet provided. Please make sure the score sheet code matches the sample code. Place a mark anywhere on the line corresponding to your response.

Sample #125

Please rate your liking of the sample based on its APPEARANCE only.

Appearance Liking

Greatest Imaginable Disliking | Dislike Extremely | Dislike Very Much | Dislike Moderately | Dislike Slightly | Neutral | Like Slightly | Like Moderately | Like Very Much | Like Extremely | Greatest Imaginable Liking

Now taste the sample, and rate your liking of the bread for the following attributes.

Overall Liking

Greatest Imaginable Disliking | Dislike Extremely | Dislike Very Much | Dislike Moderately | Dislike Slightly | Neutral | Like Slightly | Like Moderately | Like Very Much | Like Extremely | Greatest Imaginable Liking

Texture Liking

Greatest Imaginable Disliking | Dislike Extremely | Dislike Very Much | Dislike Moderately | Dislike Slightly | Neutral | Like Slightly | Like Moderately | Like Very Much | Like Extremely | Greatest Imaginable Liking

Flavor Liking

Greatest Imaginable Disliking | Dislike Extremely | Dislike Very Much | Dislike Moderately | Dislike Slightly | Neutral | Like Slightly | Like Moderately | Like Very Much | Like Extremely | Greatest Imaginable Liking

Additional Comments:

Appendix B. SAS Code for Chapter 6

```
libname xxx 'e:';
run;
proc means  data= xxx.likingtpb;
title 'Means liking by sample ';
class  sample ;
var appear flavor overall texture;
run;
/* Mixed model of liking ratings to determine if there are any
differences in liking with order of presentation and the interaction of
sampleXorder.
USED xxx.likingtpb file for the liking DATA*/
/*MODEL 10*/
Proc Mixed data=xxx.likingtpb;
title 'Proc Mixed on appear by sample and order';
Class judge sample order ;
Model appear = sample order sample*order;
random int/subject=judge;
lsmeans sample / adjust=tukey;
lsmeans sample*order / adjust=tukey;
lsmeans order / adjust=tukey;
run;
Proc Mixed data=xxx.likingtpb;
title 'Proc Mixed on Flavor, by sample and order';
Class judge sample order;
Model flavor = sample order sample*order;
random int/subject=judge;
lsmeans sample / adjust=tukey;
lsmeans sample*order / adjust=tukey;
run;
Proc Mixed data=xxx.likingtpb;
title 'Proc Mixed on overall, by sample order';
Class judge sample order;
Model overall = sample order sample*order;
random int/subject=judge;
lsmeans sample / adjust=tukey;
lsmeans sample*order / adjust=tukey;
run;
Proc Mixed data=xxx.likingtpb;
title 'Proc Mixed on texture, by sample order';
Class judge sample order;
Model texture = sample order sample*order;
random int/subject=judge;
lsmeans sample / adjust=tukey;
lsmeans sample*order / adjust=tukey;
run;
/* Mixed model of liking ratings to determine if there are any
differences in liking among bread samples*/
/*MODEL 11*/
Proc Mixed data=xxx.likingtpb;
title 'Proc Mixed on APPEAR liking by sample and judge was random';
Class judge sample;
Model appear = sample;
random int/subject=judge;
lsmeans sample / adjust=tukey;
```

```
run;
Proc Mixed data=xxx.likingtpb;
title 'Proc Mixed on Flavor liking by sample and judge was random ';
Class judge sample;
Model flavor = sample;
random int/subject=judge;
lsmeans sample / adjust=tukey;
run;
Proc Mixed data=xxx.likingtpb;
title 'Proc Mixed on OVERALL liking by sample and judge was random ';
Class judge sample;
Model overall = sample;
random int/subject=judge;
lsmeans sample / adjust=tukey;
run;
Proc Mixed data=xxx.likingtpb;
title 'Proc Mixed on TEXTURE liking by sample and judge was random ';
Class judge sample;
Model texture = sample;
random int/subject=judge;
lsmeans sample / adjust=tukey;
run;
/* Mixed model of liking ratings to determine if there are any
differences in liking among  according to bread preference by bread
samples.  */
/*MODEL 12*/
Proc Mixed data= xxx.likingtpb;
  title 'ANOVA MIXED appear liking with bread pref by sample random
judge ';
class  sample pref;
model appear= sample|pref;
lsmeans sample*pref / adjust=tukey diff cl alpha=0.05;
random judge;
run;
Proc Mixed data= xxx.likingtpb;
  title 'ANOVA MIXED flavor liking with bread pref by sample random
judge ';
class  sample pref;
model flavor= sample|pref;
lsmeans sample*pref / adjust=tukey diff cl alpha=0.05;
random judge;
run;
Proc Mixed data= xxx.likingtpb;
  title 'ANOVA MIXED overall liking with bread pref by sample random
judge ';
class  sample pref;
model overall= sample|pref;
lsmeans sample*pref / adjust=tukey diff cl alpha=0.05;
random judge;
run;
Proc Mixed data= xxx.likingtpb;
  title 'ANOVA MIXED texture liking with bread pref by sample random
judge ';
class  sample pref;
model texture= sample|pref;
```

```
lsmeans sample*pref / adjust=tukey diff cl alpha=0.05;
random judge;
run;
/*MODEL 14 the xxx.likingtpbbag file contains subjects who only
returned a bread bag*/
proc mixed data=xxx.likingtpbbag;
     title 'ANOVA MIXED appear liking by bag choice by sample random
judge ';
class  bag sample;
model appear=sample bag bag*sample;
lsmeans bag / adjust=tukey diff cl alpha=0.05;
lsmeans bag*sample / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc mixed data=xxx.likingtpbbag;
     title 'ANOVA MIXED flavor liking by bag choice by sample random
judge';
class  bag sample;
model flavor=sample bag bag*sample;
lsmeans bag / adjust=tukey diff cl alpha=0.05;
lsmeans bag*sample / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc mixed data=xxx.likingtpbbag;
     title 'ANOVA MIXED overall liking by bag choice by sample random
judge';
class  bag sample;
model overall=sample bag bag*sample;
lsmeans bag / adjust=tukey diff cl alpha=0.05;
lsmeans bag*sample / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc mixed data=xxx.likingtpbbag;
     title 'ANOVA MIXED texture liking by bag choice by sample random
judge';
class  bag sample;
model texture=sample bag bag*sample;
lsmeans bag / adjust=tukey diff cl alpha=0.05;
lsmeans bag*sample / adjust=tukey diff cl alpha=0.05;
random judge;
run;
/*MODEL 15*/
/* ANOVA MiXEd to determine differences in liking between prop tastern
*/
proc mixed data=xxx.likingtpb;
     title 'ANOVA MIXED  appear liking by sample random judge ';
class  sample tastern ;
model appear=sample tastern tastern*sample;
random judge;
lsmeans tastern/ adjust=tukey diff cl alpha=0.05;
lsmeans sample*tastern/ adjust=tukey diff cl alpha=0.05;
run;
proc mixed data=xxx.likingtpb;
     title 'ANOVA MIXED  flavor liking by sample random judge';
class  sample tastern ;
```

```
model flavor=sample tastern tastern*sample;
random judge;
lsmeans tastern/ adjust=tukey diff cl alpha=0.05;
lsmeans sample*tastern/ adjust=tukey diff cl alpha=0.05;
run;
proc mixed data=xxx.likingtpb;
     title 'ANOVA MIXED  overall liking by sample random judge ';
class  sample tastern ;
model overall=sample tastern tastern*sample;
random judge;
lsmeans tastern/ adjust=tukey diff cl alpha=0.05;
lsmeans sample*tastern/ adjust=tukey diff cl alpha=0.05;
run;
proc mixed data=xxx.likingtpb;
     title 'ANOVA MIXED  texture liking by sample random judge ';
class  sample tastern ;
model texture=sample tastern tastern*sample;
random judge;
lsmeans tastern/ adjust=tukey diff cl alpha=0.05;
lsmeans sample*tastern/ adjust=tukey diff cl alpha=0.05;
run;
/* Since order was significantly different with appearance liking I re-
ran the rest of the appearance liking models with order or presentation
within the models. Order had NO effect on appearance liking for
preference, type of bag returned or PROP tastern status. */
/*MODEL 12*/
Proc Mixed data= xxx.likingtpb;
  title 'ANOVA MIXED appear liking with bread pref by sample random
judge ';
class  sample pref order;
model appear= sample|pref|order;
lsmeans sample*pref / adjust=tukey diff cl alpha=0.05;
random judge;
run;
/*MODEL 14 the xxx.likingtpbbag file contains subjects who only
returned a bread bag*/
proc mixed data=xxx.likingtpbbag;
     title 'ANOVA MIXED appear liking by bag choice by sample random
judge ';
class  bag sample order;
model appear=sample|bag|order;
lsmeans bag / adjust=tukey diff cl alpha=0.05;
lsmeans bag*sample / adjust=tukey diff cl alpha=0.05;
random judge;
run;
/*MODEL 15*/
/* ANOVA MiXEd to determine differences in liking between prop
tastern*/
proc mixed data=xxx.likingtpb;
     title 'ANOVA MIXED  appear liking by sample random judge ';
class  sample tastern order;
model appear=sample|tastern|order;
random judge;
lsmeans tastern/ adjust=tukey diff cl alpha=0.05;
lsmeans sample*tastern/ adjust=tukey diff cl alpha=0.05;
```

```
run;
/* SN (normative beliefs rescaled and 2nd intention statement rescaled
0-6 */
data xxx.Classnot2;
set xxx.Classnot;
if bi2=1 then bi2=0;
if bi2=2 then bi2=1;
if bi2=3 then bi2=2;
if bi2=4 then bi2=3;
if bi2=5 then bi2=4;
if bi2=6 then bi2=5;
if bi2=7 then bi2=6;
if sn1= 1 then sn1=-2;
if sn1= 2 then sn1=-1;
if sn1= 3 then sn1=-0;
if sn1= 4 then sn1=1;
if sn1= 5 then sn1=2;
if sn2= 1 then sn2=-2;
if sn2= 2 then sn2=-1;
if sn2= 3 then sn2=0;
if sn2= 4 then sn2=1;
if sn2= 5 then sn2=2;
if sn3= 1 then sn3=-2;
if sn3= 2 then sn3=-1;
if sn3= 3 then sn3=0;
if sn3= 4 then sn3=1;
if sn3= 5 then sn3=2;
if sn4= 1 then sn4=-2;
if sn4= 2 then sn4=-1;
if sn4= 3 then sn4=0;
if sn4= 4 then sn4=1;
if sn4= 5 then sn4=2;
if sn5= 1 then sn5=-2;
if sn5= 2 then sn5=-1;
if sn5= 3 then sn5=0;
if sn5= 4 then sn5=1;
if sn5= 5 then sn5=2;
if sn6= 1 then sn6=-2;
if sn6= 2 then sn6=-1;
if sn6= 3 then sn6=0;
if sn6= 4 then sn6=1;
if sn6= 5 then sn6=2;
run;
data xxx.Classnot3;
set xxx.Classnot2;
sb1=sn1*m1;
sb2=sn2*m2;
sb3=sn3*m3;
sb4=sn4*m4;
sb5=sn5*m5;
sb6=sn6*m6;
snew1=sum(of sb1-sb6);
snew2=sum(of sn1-sn6);
atti=a1+a2+a3+a4+a5+a6+a7+a8+a9+a10+a11;
```

```
pc=c1 +c2+ c3+ c4+ c5+ c6+ c7+ c8+ c9+ c10+ c11+ c12+ c13+ c14+ c15+
c16;
bi=bi1 + bi2;
run;
Proc sort data=xxx.class;
by judge;
run;
Proc sort data=xxx.Classnot3;
by judge;
run;
data xxx.classalltpbnot;
/*merged by judge for xxx.alltpbClass3 and class for each judge*/
merge xxx.class  xxx.Classnot3;
by judge;
run;
Proc sort data=xxx.class;
by judge;
run;
Proc sort data= xxx.likingtpb;
by judge;
run;
data xxx.classlikingtpb;
/*merged by judge for likingtpb file and class file*/
merge xxx.class  xxx.likingtpb;
by judge;
run;
/*CLUSTER DATA AND ALL OTHER VARIABLES*/
Proc sort data=xxx.classlikingtpb;
by sample;
run;
proc means  data=xxx.classlikingtpb;
title 'Means appear flavor overall texture';
class class  ;
var appear flavor overall texture  ;
by sample;
run;
proc mixed data=xxx.classlikingtpb;
     title 'ANOVA MIXED appear by sample with cluster class';
class class sample;
model appear=class class*sample ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
lsmeans class*sample / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc mixed data=xxx.classlikingtpb;
     title 'ANOVA MIXED flavor by sample with cluster class';
class class sample;
model flavor=class class*sample ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
lsmeans class*sample / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc mixed data=xxx.classlikingtpb;
     title 'ANOVA MIXED overall by sample with cluster class';
class class sample;
```

```
model overall=class class*sample ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
lsmeans class*sample / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc mixed data=xxx.classlikingtpb;
     title 'ANOVA MIXED texture by sample with cluster class';
class class sample;
model texture=class class*sample ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
lsmeans class*sample / adjust=tukey diff cl alpha=0.05;
random judge;
run;
proc means  data= xxx. classalltpbnot;
title 'Means wgbr atti pc bi wgtime prop ';
class class ;
var wgbr atti pc snew1 bi wgtime prop  ;
run;
proc mixed data=xxx.classalltpbnot;
     title 'ANOVA MIXED wgbr with cluster class';
class class ;
model wgbr=class ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
run;
proc mixed data=xxx.classalltpbnot;
     title 'ANOVA MIXED atti with cluster class';
class class ;
model atti=class ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
run;
proc mixed data=xxx.classalltpbnot;
     title 'ANOVA MIXED pc with cluster class';
class class ;
model pc=class ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
run;
proc mixed data=xxx.classalltpbnot;
     title 'ANOVA MIXED snew1 with cluster class';
class class ;
model snew1=class ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
run;
proc mixed data=xxx.classalltpbnot;
     title 'ANOVA MIXED bi with cluster class';
class class ;
model bi=class ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
run;
proc mixed data=xxx.classalltpbnot;
     title 'ANOVA MIXED wgtime with cluster class';
class class ;
model wgtime=class ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
run;
proc mixed data=xxx.classalltpbnot;
```

```
     title 'ANOVA MIXED prop with cluster class';
class class ;
model prop=class ;
lsmeans class  / adjust=tukey diff cl alpha=0.05;
run;
proc means  data=xxx.classalltpbnot;
title 'Means wgbr atti pc snew1 bi wgtime prop';
class class  ;
var wgbr atti pc snew1 bi wgtime prop  ;
run;
/*Renamed liking data samples to the same name as DA data liking
samples 1=cub 100%WW; 2=CH 100%WW; 3=NO 100%WG; 4=Pepp 100% WW; 5=Sara
100%WW --xxx.DAlike5sample file samples 1=cub,6 =CH,10=NO, 11=PEPP,and
12=SARAL  */
data xxx.likingdalike;
set xxx.likingda;
If sample=1 then sample=1;
if sample=2 then sample=6;
if sample=3 then sample=10;
if sample=4 then sample=11;
if sample=5 then sample=12;
run;
Proc sort data=xxx.dalike5sample;
by sample;
run;
Proc sort data=xxx.likingdalike;
by sample;
run;
data xxx.DAlike5sample2;
/*merged by sample for dalike5sample and likingdalike */
merge xxx.dalike5sample  xxx.likingdalike;
by sample;
run;
/* Mixed model of a response (such as flavor liking) on a predictor
(one of
the DA attribute scores)
  Are the differences in the response associated with that DA score? */
%MACRO RunQuadraticMixed(response=, predictor=);
Proc Mixed data=xxx.DAlike5sample2;
title "Proc Mixed for &response on &predictor, with quadratic term";
Class judge;
Model &response = &predictor &predictor*&predictor/s;
random int &predictor &predictor*&predictor / subject=judge;
random int / subject=sample;
contrast "&predictor" &predictor 1,
                      &predictor*&predictor 1;
run;
%MEND RunQuadraticMixed;
%RunQuadraticMixed(response=flavor, predictor=tbitter)
%RunQuadraticMixed(response=flavor, predictor=tsalty)
%RunQuadraticMixed(response=flavor, predictor=tsweet)
%RunQuadraticMixed(response=flavor, predictor=tsour)
%RunQuadraticMixed(response=flavor, predictor=fermented)
%RunQuadraticMixed(response=flavor, predictor=bitter)
%RunQuadraticMixed(response=flavor, predictor=cardboard)
```

```
%RunQuadraticMixed(response=flavor, predictor=coffee)
%RunQuadraticMixed(response=flavor, predictor=grainy)
%RunQuadraticMixed(response=flavor, predictor=honey)
%RunQuadraticMixed(response=flavor, predictor=molasses)
%RunQuadraticMixed(response=flavor, predictor=musty)
%RunQuadraticMixed(response=flavor, predictor=nutty)
%RunQuadraticMixed(response=flavor, predictor=oily)
%RunQuadraticMixed(response=flavor, predictor=uncooked)
%RunQuadraticMixed(response=flavor, predictor=oxidized)
%RunQuadraticMixed(response=overall, predictor=brown)
%RunQuadraticMixed(response= overall, predictor=butter)
%RunQuadraticMixed(response =overall, predictor=caramel)
%RunQuadraticMixed(response=overall, predictor=xfermented)
%RunQuadraticMixed(response=overall, predictor=xgrainy)
%RunQuadraticMixed(response=overall, predictor=hay)
%RunQuadraticMixed(response=overall, predictor=xhoney)
%RunQuadraticMixed(response=overall, predictor=xmolasses)
%RunQuadraticMixed(response=overall, predictor=xoily)
%RunQuadraticMixed(response=overall, predictor=sourdo)
%RunQuadraticMixed(response=overall, predictor=levelar)
%RunQuadraticMixed(response=overall, predictor=leveltoasted)
%RunQuadraticMixed(response=overall, predictor=doughy)
%RunQuadraticMixed(response=overall, predictor=yeasty)
%RunQuadraticMixed(response=appear, predictor=moist)
%RunQuadraticMixed(response=appear, predictor=grainpi)
%RunQuadraticMixed(response=appear, predictor=aircell)
%RunQuadraticMixed(response=appear, predictor=grapiece)
%RunQuadraticMixed(response=appear, predictor=texture)
%RunQuadraticMixed(response=appear, predictor=overcol)
%RunQuadraticMixed(response=appear, predictor=aircellsz)
%RunQuadraticMixed(response=appear, predictor=color)
%RunQuadraticMixed(response=overall, predictor=tbitteraf)
%RunQuadraticMixed(response=overall, predictor=tsaltyaf)
%RunQuadraticMixed(response=overall, predictor=tsweetaf)
%RunQuadraticMixed(response=overall, predictor=tsouraf)
%RunQuadraticMixed(response=overall, predictor=bitteraf)
%RunQuadraticMixed(response=overall, predictor=saltyaf)
%RunQuadraticMixed(response=overall, predictor=sweetaf)
%RunQuadraticMixed(response=overall, predictor=souraf)
%RunQuadraticMixed(response=overall, predictor=cardboardaf)
%RunQuadraticMixed(response=overall, predictor=fermentedaf)
%RunQuadraticMixed(response=overall, predictor=oxidizedaf)
%RunQuadraticMixed(response=overall, predictor=grainyaf)
%RunQuadraticMixed(response=overall, predictor=toastedaf)
%RunQuadraticMixed(response=overall, predictor=uncookedaf)
%RunQuadraticMixed(response=overall, predictor=wheatgermaf)
%RunQuadraticMixed(response=overall, predictor=yeastyaf)
%RunQuadraticMixed(response=texturel, predictor=chewy)
%RunQuadraticMixed(response=texturel, predictor=density)
%RunQuadraticMixed(response=texturel, predictor=squishy)
%RunQuadraticMixed(response=texturel, predictor=moisture)
%RunQuadraticMixed(response=texturel, predictor=elastic)
%RunQuadraticMixed(response=texturel, predictor=gritty)
%RunQuadraticMixed(response=texturel, predictor=gummi)
%RunQuadraticMixed(response=texturel, predictor=softness)
```

```
%RunQuadraticMixed(response=texturel, predictor=smooth)
%RunQuadraticMixed(response=texturel, predictor=spongy)
%RunQuadraticMixed(response=texturel, predictor=tpacking)
%RunQuadraticMixed(response=flavor, predictor=tbitterstfl)
%RunQuadraticMixed(response=flavor, predictor=tsaltystfl)
%RunQuadraticMixed(response=flavor, predictor=tsweetstfl)
%RunQuadraticMixed(response=flavor, predictor=tsourstfl)
%RunQuadraticMixed(response=flavor, predictor=bitterstfl)
%RunQuadraticMixed(response=flavor, predictor=burntstfl)
%RunQuadraticMixed(response=flavor, predictor=coffeestfl)
%RunQuadraticMixed(response=flavor, predictor=grainystfl)
%RunQuadraticMixed(response=flavor, predictor=molassesstfl)
%RunQuadraticMixed(response=flavor, predictor=oilsstfl)
%RunQuadraticMixed(response=flavor, predictor=oxidizedstfl)
%RunQuadraticMixed(response=flavor, predictor=saltystfl)
%RunQuadraticMixed(response=flavor, predictor=toastedstfl)
%RunQuadraticMixed(response=flavor, predictor=uncookedstfl)
%RunQuadraticMixed(response=flavor, predictor=btbitterstfl)
%RunQuadraticMixed(response=flavor, predictor=btsaltystfl)
%RunQuadraticMixed(response=flavor, predictor=btsweetstfl)
%RunQuadraticMixed(response=flavor, predictor=btsourstfl)
%RunQuadraticMixed(response=flavor, predictor=Bbitterstfl)
%RunQuadraticMixed(response=flavor, predictor=bsweetstfl)
%RunQuadraticMixed(response=flavor, predictor=Btoastedstfl)
%RunQuadraticMixed(response=flavor, predictor=Bgrainystfl)
%RunQuadraticMixed(response=flavor, predictor=bsaltystfl)
%RunQuadraticMixed(response=flavor, predictor=bstarchystfl)
%RunQuadraticMixed(response=flavor, predictor=bdairystfl)
%RunQuadraticMixed(response=flavor, predictor=bnuttystfl)
%RunQuadraticMixed(response=overall, predictor=intensitystar)
%RunQuadraticMixed(response=overall, predictor=butterstar)
%RunQuadraticMixed(response=overall, predictor=caramelstar)
%RunQuadraticMixed(response=overall, predictor=grainystar)
%RunQuadraticMixed(response=overall, predictor=sourdostar)
%RunQuadraticMixed(response=overall, predictor=sweetstar)
%RunQuadraticMixed(response=overall, predictor=doughystar)
%RunQuadraticMixed(response=overall, predictor=leveltoastedstar)
%RunQuadraticMixed(response=overall, predictor=levelbakedstar)
%RunQuadraticMixed(response=overall, predictor=Bintensitystar)
%RunQuadraticMixed(response=overall, predictor=Bbutterstar)
%RunQuadraticMixed(response=overall, predictor=Bcaramelstar)
%RunQuadraticMixed(response=overall, predictor=Bgrainystar)
%RunQuadraticMixed(response=overall, predictor=Bsourdostar)
%RunQuadraticMixed(response=overall, predictor=Bsweetstar)
%RunQuadraticMixed(response=overall, predictor=Bdoughystar)
%RunQuadraticMixed(response=overall, predictor=Bleveltoastedstar)
%RunQuadraticMixed(response=overall, predictor=Blevelbakedstar)
%RunQuadraticMixed(response=appear, predictor=graintopstap)
%RunQuadraticMixed(response=appear, predictor=oattopstap)
%RunQuadraticMixed(response=appear, predictor=graintopshapestap)
%RunQuadraticMixed(response=appear, predictor=graintopszstap)
%RunQuadraticMixed(response=appear, predictor=oattopszstap)
%RunQuadraticMixed(response=appear, predictor=thicktopstap)
%RunQuadraticMixed(response=appear, predictor=colortopstap)
%RunQuadraticMixed(response=appear, predictor=crustbottomstap)
```

```
%RunQuadraticMixed(response=appear, predictor=surfacebstap)
%RunQuadraticMixed(response=appear, predictor=thicknessbotstap)
%RunQuadraticMixed(response=appear, predictor=colorbotstap)
%RunQuadraticMixed(response=overall, predictor=Tbitterstaf)
%RunQuadraticMixed(response=overall, predictor=Tsaltystaf)
%RunQuadraticMixed(response=overall, predictor=Tsweetstaf)
%RunQuadraticMixed(response=overall, predictor=Tsourstaf)
%RunQuadraticMixed(response=overall, predictor=Bitterstaf)
%RunQuadraticMixed(response=overall, predictor=saltystaf)
%RunQuadraticMixed(response=overall, predictor=sweetstaf)
%RunQuadraticMixed(response=overall, predictor=sourstaf)
%RunQuadraticMixed(response=overall, predictor=burntstaf)
%RunQuadraticMixed(response=overall, predictor=cardboardstaf)
%RunQuadraticMixed(response=overall, predictor=caramelstaf)
%RunQuadraticMixed(response=overall, predictor=grainystaf)
%RunQuadraticMixed(response=overall, predictor=honeystaf)
%RunQuadraticMixed(response=overall, predictor=wheatgermstaf)
%RunQuadraticMixed(response=overall, predictor=btbitterstaf)
%RunQuadraticMixed(response=overall, predictor=btsaltystaf)
%RunQuadraticMixed(response=overall, predictor=btsweetstaf)
%RunQuadraticMixed(response=overall, predictor=btsourstaf)
%RunQuadraticMixed(response=overall, predictor=Bbitterstaf)
%RunQuadraticMixed(response=overall, predictor=Bsaltystaf)
%RunQuadraticMixed(response=overall, predictor=Bsweetstaf)
%RunQuadraticMixed(response=overall, predictor=Bsourstaf)
%RunQuadraticMixed(response=overall, predictor=Bburntstaf)
%RunQuadraticMixed(response=overall, predictor=Bfermentedstaf)
%RunQuadraticMixed(response=overall, predictor=Bgrainystaf)
%RunQuadraticMixed(response=overall, predictor=Btoastedstaf)
%RunQuadraticMixed(response=overall, predictor=Bwheatgermstaf)
%RunQuadraticMixed(response=texturel, predictor=chewystot)
%RunQuadraticMixed(response=texturel, predictor=lightnessstot)
%RunQuadraticMixed(response=texturel, predictor=moisturestot)
%RunQuadraticMixed(response=texturel, predictor=grittystot)
%RunQuadraticMixed(response=texturel, predictor=gummistot)
%RunQuadraticMixed(response=texturel, predictor=softnessstot)
%RunQuadraticMixed(response=texturel, predictor=leatherystot)
%RunQuadraticMixed(response=texturel, predictor=paperystot)
%RunQuadraticMixed(response=texturel, predictor=springystot)
%RunQuadraticMixed(response=texturel, predictor=bchewystot)
%RunQuadraticMixed(response=texturel, predictor=bchewystot)
%RunQuadraticMixed(response=texturel, predictor=blightnessstot)
%RunQuadraticMixed(response=texturel, predictor=bmoisturestot)
%RunQuadraticMixed(response=texturel, predictor=bgrittystot)
%RunQuadraticMixed(response=texturel, predictor=bgummistot)
%RunQuadraticMixed(response=texturel, predictor=bsoftnessstot)
%RunQuadraticMixed(response=texturel, predictor=bleatherystot)
%RunQuadraticMixed(response=texturel, predictor=bpaperystot)
%RunQuadraticMixed(response=texturel, predictor=bspringystot)
/* Mixed model of LIKING for each PC1-11 Are there any differences in
liking among pc1-pc11? */
Proc sort data=xxx.breadscoresPC;
by sample;
run;
Proc sort data=xxx.likingdalike;
```

```
by sample;
run;
data xxx.breadsPCLIKE;
/*merged by sample for danew and liking*/
merge xxx. breadscoresPC  xxx.likingdalike;
by sample;
run;
/* Mixed model of LIKING for each PC1-11 Are there any differences in
liking among pc1-pc11? */
%MACRO RunQuadraticMixed(response=, predictor=);
Proc Mixed data= xxx.breadsPCLIKE;
title "Proc Mixed for &response on &predictor, with quadratic term";
Class judge;
Model &response = &predictor &predictor*&predictor/s;
random int &predictor &predictor*&predictor / subject=judge;
random int / subject=sample;
contrast "&predictor" &predictor 1,
                      &predictor*&predictor 1;
run;
%MEND RunQuadraticMixed;
%RunQuadraticMixed(response=appear, predictor=prin1)
%RunQuadraticMixed(response=appear, predictor=prin2)
%RunQuadraticMixed(response=appear, predictor=prin3)
%RunQuadraticMixed(response=appear, predictor=prin4)
%RunQuadraticMixed(response=appear, predictor=prin5)
%RunQuadraticMixed(response=appear, predictor=prin6)
%RunQuadraticMixed(response=appear, predictor=prin7)
%RunQuadraticMixed(response=appear, predictor=prin8)
%RunQuadraticMixed(response=appear, predictor=prin9)
%RunQuadraticMixed(response=appear, predictor=prin10)
%RunQuadraticMixed(response=appear, predictor=prin11)

%RunQuadraticMixed(response=flavor, predictor=prin1)
%RunQuadraticMixed(response=flavor, predictor=prin2)
%RunQuadraticMixed(response=flavor, predictor=prin3)
%RunQuadraticMixed(response=flavor, predictor=prin4)
%RunQuadraticMixed(response=flavor, predictor=prin5)
%RunQuadraticMixed(response=flavor, predictor=prin6)
%RunQuadraticMixed(response=flavor, predictor=prin7)
%RunQuadraticMixed(response=flavor, predictor=prin8)
%RunQuadraticMixed(response=flavor, predictor=prin9)
%RunQuadraticMixed(response=flavor, predictor=prin10)
%RunQuadraticMixed(response=flavor, predictor=prin11)

%RunQuadraticMixed(response=overall, predictor=prin1)
%RunQuadraticMixed(response=overall, predictor=prin2)
%RunQuadraticMixed(response=overall, predictor=prin3)
%RunQuadraticMixed(response=overall, predictor=prin4)
%RunQuadraticMixed(response=overall, predictor=prin5)
%RunQuadraticMixed(response=overall, predictor=prin6)
%RunQuadraticMixed(response=overall, predictor=prin7)
%RunQuadraticMixed(response=overall, predictor=prin8)
%RunQuadraticMixed(response=overall, predictor=prin9)
%RunQuadraticMixed(response=overall, predictor=prin10)
%RunQuadraticMixed(response=overall, predictor=prin11)
```

```
%RunQuadraticMixed(response=texturel, predictor=prin1)
%RunQuadraticMixed(response=texturel, predictor=prin2)
%RunQuadraticMixed(response=texturel, predictor=prin3)
%RunQuadraticMixed(response=texturel, predictor=prin4)
%RunQuadraticMixed(response=texturel, predictor=prin5)
%RunQuadraticMixed(response=texturel, predictor=prin6)
%RunQuadraticMixed(response=texturel, predictor=prin7)
%RunQuadraticMixed(response=texturel, predictor=prin8)
%RunQuadraticMixed(response=texturel, predictor=prin9)
%RunQuadraticMixed(response=texturel, predictor=prin10)
%RunQuadraticMixed(response=texturel, predictor=prin11)
```