

Quality Improvement of Whole Wheat Precooked Alkaline Noodles

A THESIS
SUBMITTED TO THE FACULTY OF
UNIVERSITY OF MINNESOTA
BY

Wang Wang

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF FOOD SCIENCE

Advisor: Len Marquart
Co-advisor: Gary G. Hou

April 2014

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Acknowledgements

I would like to express my sincere gratitude to my advisor Dr. Len Marquart, for helping and supporting me to finish this project, and for the opportunity to study whole grain foods, and most of all for his endless encouragement and patience. I do learn a lot of his skills of making connections with people from food service chains when solving social problems in whole grain food consumption area; Dr. Gary Hou, I would like to thank him for his dedicated technical expertise and instruction on how to use noodle production line and conduct chemical and physical tests on whole wheat precooked noodles, for his kind assistance in improving my performance on balanced experimental design, accurate data analysis and key problems anchoring; Elizabeth Ardnt, for her generous support of raw materials in the project and detailed suggestion on potential marketplaces for a newly developed product; Eric Niu and Xin Liu for their research assistance in the noodle production and physical variable tests; Staff at the Wheat Marketing Center for their warm support and friendship during the accomplishing of this project. Special thanks go to my committee Prof. Koushik Seetharaman and Prof. Joanne Slavin for taking their valuable time to review my thesis paper. Besides, I would like to thank my parents and sister for their continuous encouragement, care and trust, which drive me to overcome the difficulties in this study.

Dedication

This thesis is dedicated to my dear father and mother.

Abstract

Asian noodles are popular foods commonly consumed in Asia and rapidly expanding into new markets throughout the world. The purpose of this study was to develop a convenient whole-wheat precooked alkaline noodle and to examine its quality attributes.

Key variables studied in this project included effects of whole-wheat flour ratio, water addition in the formula, mixing condition, flour protein content and functional ingredients on quality characteristics of the noodle product. The color test, Texture Profile Analysis (TPA), Rapid Visco Analysis (RVA) of the starch, and sensory evaluation of cooked noodles were conducted to verify the effects of these variables.

The color test showed that an increase in whole-wheat flour made the noodle color darker and yellower. Vacuum mixing condition and water addition level had negative correlations with the noodle color. High protein content induced larger color change after 24 h storage.

For starch pasting properties, the higher whole-wheat flour ratio decreased peak, trough and final viscosity values. Protein content did not have any significant effects on pasting properties. Phosphates blends increased peak and final viscosities while decreased setback values were observed for the low and the high protein whole-wheat flour blends.

TPA results showed that although the higher whole-wheat flour ratio impaired texture properties of cooked noodles, the vacuum mixing condition improved the texture profile by enhancing the gluten development. Functional ingredients improved the noodle texture but the effects were dependent on protein content.

Sensory evaluation indicated a lower perceived quality for springiness and mouth-feel for whole-wheat precooked noodles. However, no significant differences were noticed in the whole-wheat flour and the refined flour precooked noodles concerning water addition level, mixing condition, and protein content.

In conclusion, the overall quality of the newly developed whole-wheat precooked alkaline noodle was quite acceptable. This noodle appears to satisfy consumer's needs for taste and convenience, and their potential desire for whole grains and related health benefits.

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1. Introduction

Asian noodles are popular foods around the world, where in Asia nearly 50% of all wheat is consumed in noodle form (Hou, 2001). Various types of noodles are characterized by their distinct flavor, texture and quality. With the increasing awareness of the benefits of eating whole grains, the concept of *noodles* and *whole grains* has gained the attention in the food industry.

Food required less preparation along with increased time pressures have created consumer necessity around the use of convenience foods in our modern society (Story et al., 2008). Short culinary preparation time is one critical reason for consumers to choose their diets. Given that certain whole grain foods take longer time to prepare (Dammann et al., 2011), developing a new type of convenient whole grain noodles with high quality has become a desiring and beneficial process.

Obstacles limiting whole grain consumption are not only due to the limited availability and unhealthy eating environments, but also the impaired eating qualities of whole grain products (Murray et al., 2002; Bakke et al., 2007). The gradual change from refined flour products to 100% whole grain foods requires technical improvements in processing procedures, ingredient formulations and new product advertisement and promotion. Moreover, the launch of this new product is also a connection between grain growers, flour millers, food companies and restaurants to improve whole grain food consumption in certain eating environments.

However, the research about whole grain noodles is very limited at present (Niu et al., 2014a, Niu et al., 2014b). There are no studies to examine quality characteristics of noodles made with whole grain and refined flour blend.

Precooked alkaline noodles have the advantages of a short preparation time, a special flavor and yellow color, and a chewy and springy texture. To meet the current needs of both whole grain foods and convenient products in the marketplace, objectives of this study were to develop a new whole wheat precooked alkaline noodle with improved quality attributes.

The specific objectives are:

First Objective (Major): To analyze effects of key variables on the whole wheat precooked alkaline noodle quality, including whole wheat ratios, mixing conditions, water levels and blend flour gluten contents. Color, texture and pasting properties are determined to detect the quality profiles of the noodle products.

Second Objective: To examine the effects of functional ingredients in whole wheat precooked alkaline noodles. Functional ingredients include phosphates and phospholipids.

Third Objective: To detect consumer acceptance by the product-oriented sensory test. To get a general sensory profile of the differences between whole wheat and refined flour precooked alkaline noodles.

2. Review of Literature

2.1 Whole Grain

2.1.1 Whole Grain Ingredient Definition and Nutritional Attributes

Cereals and pseudocereals consumed in whole form are all considered whole grains, including wheat, rice, barley, corn, rye, oats, millets, sorghum, amaranth, buckwheat, and quinoa, etc (AACCI, 2007). A whole grain ingredient is defined as one that contains the bran, germ and endosperm in their naturally occurring proportions

(AACCI, 2000). The bran and germ, which are subsequently removed in non-whole grain (NWG) ingredients, contain vitamins E and B6, minerals, dietary fiber, folate and phytochemicals (Truswell, 2002; McKeown et al., 2002). The endosperm is less-nutrient dense and contains fewer phytochemicals, as compared to the bran and germ components.

2.1.2 The Health Benefits of Whole Grains

The benefits of whole grains are documented in numerous studies including reduced risk of: stroke (30-36%), type 2 diabetes (21-30%), heart disease (25-28%) and weight maintenance (Steffen et al., 2003; Liese et al., 2003; Koh-Banerjee et al., 2005; Marquart et al., 2007).

The mechanisms responsible for the potential health effects of consuming whole grains remain unclear. Based on lipid metabolism, β -glucans contained in whole grains, such as oats and barley, can reduce total and low density lipoprotein (LDL) cholesterol concentration during the fasting state (Biörklund et al., 2005). Studies also found that postprandial insulin and triglyceride response, which are parameters closely related to type 2 diabetes and cardiovascular disease risks, are reduced with whole grain diets compared with refined cereal diets (McKeown, 2004). For glucose digestion, some clinical studies showed that insulin sensitivity and glucose regulation have been improved. However, other studies have shown little effect of whole grains on blood glucose and insulin response (Andersson et al., 2007; Brownlee et al., 2010; Giacco et al., 2010). Moreover, risk factors like inflammation or oxidative stress have been improved by habitual whole grain intake (Jensen et al., 2006). Despite extensive epidemiological work in support of the association between whole grain intake and

reduced risk of chronic disease more work needs to be conducted to demonstrate direct mechanistic explanations for these findings.

To achieve the health benefits associated with whole grain intake, the Dietary Guidelines Committee recommended at least 48 g/day (~3 servings) of whole grain intake for each person or consume half their grains as whole (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2010).

2.1.3 Whole Grain Food Definition

Foods made with 100% whole grain ingredients are easily identified as whole grain foods. However, products made with both whole grain and refined grain ingredients can be confusing for consumers. According to the AACC International Board of Directors (2013), a whole grain food product must contain 8 grams or more of whole grain per 30 grams of product.

This AACCI definition not only gives uniform and clarified information for consumers when selecting whole grain foods, but also facilitates increased participation by the grain industry around a common definition and reduces consumers' confusion caused by multiple standards. In step with the definition of whole grain foods, the Whole Grains Council launched the Whole Grain Stamp which can be placed by manufacturers on the outside panel of product packages. Whole Grain Stamps include the basic stamp and the 100% stamp (Whole Grains Council, 2006). Products must contain at least 8 g/serving whole grain to use the basic stamp, while a whole grain product must contain at least 16g/serving to use the 100% stamp. With the assistance of the Whole Grain Stamp, consumers can choose to eat three servings of whole grain products with the 100% stamp or six servings of products bearing the basic stamp in meeting at least 48 g/day (~3 servings) of whole grain intake as recommended by the Dietary Guidelines

(U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2010).

2.1.4 Whole Grain Food Consumption Situation and Obstacles

According to data from the 2010 National Health and Nutrition Examination Survey (NHANES), the average consumption of whole grains is 14 g/day per person in the U.S., which is far below the recommended level.

Although awareness of the benefits of whole grain foods has become more common among consumers, there still exist certain obstacles to increasing consumption of these foods.

Existing and emerging problems regarding whole grain foods include sensory quality, processing, preparation and culinary time, cost, availability, labeling and identification of whole grain foods on the food shelf (Adams et al., 2000).

A stronger and slightly bitter taste and rougher texture are attributes of whole grain foods that may make them less desirable for the general US population (Bakke et al., 2007). The lack of better sensory attributes are direct obstacles preventing people from accepting enough whole grain foods in an easy and desirable form for consumers (Snow, 1999; Murray et al., 2002).

For the grain milling and food manufacturing industries, processing procedures need to be adjusted for whole grain food production. For example, the whole grain noodles and pasta with bran particles in the flour prevent gluten structure development during mixing, cooking, cooling and related procedures (National Pasta Association, 2005). Therefore machine parameters and processing time must be re-configured prior to large-scale production of whole grain products.

Additional requirements for pre-preparation, cooking and service of whole grain foods create inconvenience for chefs, food service staff and consumers. For whole grain foods such as brown rice, culinary time will be longer compared to their refined counterparts. For other whole grain types like pasta, although culinary time is relatively shorter, overcooking and holding will induce significantly undesirable eating qualities (Manthey et al., 2002).

Although there is little difference in price for whole grain products like cookies, crackers and chips compared with their counterparts, there still exists a 25% increase in the cost of whole grain products for other foods (Kantor et al., 2001; Buzby, 2005; Crawford et al., 2010). The slight price increase does not induce huge obstacles for individual buyers, but it is a decisive issue for big scale buyers like schools and other institutions (Chan et al., 2009; Hesse et al., 2009).

Although whole grain foods are slowly increasing in supermarkets catering to consumer demand, the availability of whole grain products in convenient stores and the low-income neighborhood remains limited (Jetter et al., 2005; Glanz et al., 2007). Moreover, certain types of whole grain foods are less popular in grocery stores, like bulgur and quinoa (Kantor et al., 2001). In restaurant environments, limited whole grain menu items compel dining-out consumers to choose refined or even less healthy foods.

Some food labels for whole grain products are in the form of “brown rice”, “oatmeal” or “barley flakes” which are very confusing (AACCI, 2006). Limited understanding of differences between whole grains and high fiber foods can also prevent consumers from purchasing and effectively introducing more whole grain foods into their diets (Britten et al., 2006). Therefore, the words “whole grain” are recommended on the package for manufacturers to clarify the product ingredients.

2.1.5 Campaign to Improve Whole Grain Consumption

Although there are many barriers preventing consumers from eating enough whole grain foods, efforts from various sectors, including government, industry and non-profit organizations support the whole grain food campaign.

The U.S. government has launched programs, such as the National School Lunch Program (NSLP), to build healthier school dining environments through recommendations to consume more whole grain foods (U.S. Department of Agriculture Food and Nutrition Service, 2005; Nutrition Standards for School Meals, 2012).

The Grains for Health Foundation recently launched *GrainUp!* in the Twin Cities in 2013. This initiative is designed to increase whole grain menu offerings at restaurants and invite the community to learn and enjoy more whole grain foods (Grains for Health Foundation, 2013). This effort is underpinned by a consortium representing industry, universities and government in creating a strategic plan for delivery of tasty whole grain foods.

Advertisement through internet, websites such as *The Healthy Dining Finder*, informs consumers about restaurants offering whole grain dishes within a reasonable distance and an acceptable price range (Healthy Dining Finder, 2013). Food companies have continued to develop new whole grain products with a steady increase in the area of ready-to-eat cereal, fresh bread and pasta (Nielsen Retail Sales, 2010).

2.2 Noodle Products

Noodles are consumed in large quantity in Asia, where 20-50% of wheat is consumed in noodle form (Hou, 2001). Noodles have also received wide acceptance in western countries where they have not traditionally been a mainstay in the diet.

According to the World Instant Noodles Association, 101,420 million bags/cups of instant noodles were consumed around the world in 2013 (World Instant Noodles Association, 2013).

Asian noodles can be divided into several types based on their characteristics and advantages. They can be divided into soft- and hard-bite noodles by their texture, while fresh, frozen, dried, boiled, steamed or cooked noodles by their processing procedures (Hou, 2001; Okusu et al., 2010).

2.2.1 Precooked Alkaline Noodles

Precooked alkaline noodles enjoy wide popularity because of its special alkaline flavor and color. Named “hokkien noodles” in Southeast Asia and “wet noodles” in Taiwan, precooked alkaline noodles are distinguished by its firm, chewy and elastic texture. Moreover, the final parboiling procedure also helps to denature polyphenol oxidase and discoloration during storage (Hou 2010a). The noodle is usually made of refined white flour, salt and alkali (Na_2CO_3 and/or K_2CO_3). The color can be an important indicator of its quality and shelf life. Precooked noodles usually have a shelf life of 2-3 days at ambient temperature and 7-10 days at refrigerated temperature (Morris, 2000). Since the noodle is precooked with uncooked centrals, it can be quickly recooked, which greatly simplifies culinary preparation. This type of noodle satisfies the need for convenience in preparation and accommodates a fast-paced consumer lifestyle.

2.2.2 Position of Whole Wheat Precooked Alkaline Noodles in the Market

Given the consumer advantages of the short culinary preparation time and the special flavor, precooked noodles may have accessed the fast track for launching into the whole grain market. Consumer pursuit of convenience along with time pressure has

influenced quick food preparation time and more practical food choices (Jabs et al., 2006). The feeling of limited time can drive people to choose convenient and ready-to-eat foods in grocery stores or choose to eat at fast food restaurants where unhealthy foods occupied a large percentage of the menu.

However, this fast-paced life style provides great opportunities for restaurants and retailers to combine economic benefits with a healthier eating environment. It has been reported that the change of whole grain crust of pizza even increased the consumer acceptance due to its delicious bakery flavor (Tritt et al., 2013). Less brown rice is wasted compared with white rice in Chinese restaurant dining environments in the Twin Cities (Liu et al., unpublished). Plate waste studies conducted in elementary schools indicate that children consume 76-78% of spaghetti, fettuccini and rotini pasta made with whole grain blend flour (Chan et al., 2009). Therefore, the whole grain precooked noodles may have a potential role in the marketplace for whole grain consumers.

2.2.2.1 Chain Restaurants in U.S.

Given that Panda Express® and P.F. Chang's® currently serve brown rice, they could be a potential franchise to launch whole grain precooked noodles. Their original menus include several types of noodles, such as Lo Mein, Chow Mein and Fried Noodles. The 1-2 min preparation time for precooked noodles will provide great competence and convenience for the restaurant runners. Given the success of fried brown rice in Chinese restaurants, fried whole grain noodles may be a logical option for health conscious consumers versus only the traditional refined grain noodles.

2.2.2.2 Household Kitchens

With more women working outside the home in the 21st century, fulfilling job tasks and enjoying after-working time become more challenging for a typical family (Story et al., 2008). For families with several kids to take care of, the quick-cooked precooked whole grain noodles could be their preferred choice to assist in preparing a healthy and delicious meal. Additionally, the introduction of certain types of whole grain foods into household kitchens can potentially influence other or most family members to accept whole grains (Burgess-Champoux et al., 2006).

2.2.2.3 Grocery Stores and Retailers

With the increased quantity of freezers and improved storage conditions in grocery stores, the launch of ready-to-eat and convenient whole grain food is effective. Moreover, with several whole grain pasta and noodles already on the shelf in these grocery stores, such as Rainbow, Walmart and Carrefour, the advent of whole grain precooked noodles may facilitate the introduction of more of these products in the marketplace.

2.2.3 Precooked Alkaline Noodle Processing

Based on the dough sheet and the noodle strand forming procedure, noodles can be divided into extruded and sheeted categories. Extruded noodles are made by forcing the noodle dough through a die while sheeted noodles are made by forming noodle sheets first and then cutting into strands. The formation of the gluten structure is different for extruded or sheeted noodles, resulting in a varied texture and appearance profile of final noodle products. The precooked alkaline noodles belong to the sheeted noodle family. The preparation procedures include seven steps: mixing, dough resting, dough

sheet compounding, dough sheet resting, dough sheet thickness reducing, noodle slitting and parboiling (Hou, 2010a).

2.2.3.1 Mixing

Given the simple principle ingredients in noodle products (water, flour and salts), the mixing step will change ingredient dispersion, processing efficiency and product qualities significantly if mixing variables are adjusted (Carini et al, 2010).

2.2.3.2 Dough Resting

Dough resting is an important procedure for flour-based products. In wheat noodle production, dough resting can induce the smoother and less streaky dough by facilitating water distribution in dough particles. Moreover, resting will intensify the gluten structure and improve dough sheet formation later (Hou, 2010a).

2.2.3.3 Dough Sheet Compounding, Reduction and Noodle Slitting

The crumbly dough pieces are compounded between a pair of compounding rolls to form the original noodle sheets. For noodle products, the rough and weak sheets need to be rested again for further gluten development and water distribution. After this, the continuous compounding rolls with reduced gap distances will not only make noodle sheets thinner, but also induce the gluten alignment in the direction of rolls. The noodle will be cut into the desired width by rotating cutters (Hou, 2010a).

2.2.3.4 Precooking

Precooking is the key step to distinguish precooked noodles from other types. Because of the short pre-cooking time which is in accord with different types of flour, water level and additives, precooked noodles have uncooked central cores surrounded

by gelatinized flour. The benefits of this process are 1) Shorten the culinary time for final products; 2) Denature polyphenol oxidase (PPO) and cause less discoloration during storage; 3) Sanitize noodles for longer shelf life (Hou, 2010a).

2.3 Asian Noodles Research

2.3.1 Processing Procedure Improvement

Researchers report that application of vacuum mixing could strengthen the protein structure outside starch granules, which results in a change in the texture profile. This process could improve the gloss and translucency of fresh noodles (Solah et al., 2007). Vacuum mixing has also been found to enhance water and solid interaction, reduce water activity and improve preservation time for fresh noodles (Li et al., 2012). However, most of these studies focus on noodles made of refined wheat flour instead of whole grain flour. The function of the vacuum mixing condition can influence the final noodle quality due to the type of noodles, such as fresh or cooked noodles.

2.3.2 Effects of Functional Ingredients

Several functional ingredients have been applied in noodle products to improve texture, flavor and shelf life profiles. For alkaline noodles, alkaline salts (Na_2CO_3 and K_2CO_3) are added to form unique flavor, color and texture by detaching flavones from polysaccharides, allowing the yellow color to become manifest (Morris, 2000). Other functional ingredients include phosphate, emulsifiers, free fatty acids, hydrocolloids, dietary fiber and protein, etc (Sozer, 2008; Choo et al., 2009; Heo et al., 2013).

2.3.2.1 Function of Phosphates

According to the Code of Federal Regulation (CFR), food-grade phosphates can be classified into generally recognized as safe (GRAS). In meat products, phosphate usage is limited to 0.5% by final product weight. Although there is no particular upper limits and codes for phosphate application in wheat products, good manufacturing practice provides general guidance for use in food (Federal Register 1979). Given these standards the acceptable human consumption level of phosphates is 70 mg/kg/day, which is 1% in a 2800-calorie diet per day for an adult (JECFA, 1964; JECFA, 1982).

Several studies show that phosphates have decreased flour suspension pH, causing changes in pasting parameters detected by the Rapid Visco Analyser (Zhou et al., 2012). Studies also demonstrate that adding phosphates or phosphate blends into noodles can increase water retention, act as chelating agents, inhibit α -amylase activity in the dough system, and modify starch gelatinization process during cooking (Fu, 2008; Tan et al, 2009). Wang et al. (2011a) found that the addition of three phosphate salts induce lighter color and softer texture of non-fried instant noodles with significantly increased flour peak viscosity and final viscosity values. Delaying effects of phosphates on the gelatinization properties of starch in whole wheat flour was also detected (Niu et al., 2014a). The change in noodle color is explained by the chelating effects of Cu^{2+} .

Moreover, certain phosphate mixes have been commercialized to be applied specifically in noodle products. Mianjia® family produced by ICL Performance Products (St. Louis, Missouri) is the phosphate series which can be applied to different types of noodles to improve their qualities in texture, color, consistency, processability and shelf life. Through controlling pH in noodle dough, Mianjia® mixes deliver better color for targeted noodle types. Meanwhile, they can be cost saving by replacing or reducing

modified starch content up to 30%. They can also extend noodle shelf life by increasing antioxidant ability and antimicrobial synergy action (ICL Performance, 2011).

2.3.2.2 Function of Lecithin

Several studies indicate that the application of free fatty acids and their esters can cause binding effects with starch (Niihara et al., 1973; Mohri, 1980). The addition of lecithin at 0.5% level increases the strength of dry noodles (Rho et al., 1989). Moreover, they can also reduce noodle stickiness and cooking water cloudiness, retard starch retrogradation and shorten noodle rehydration (Chen, 1994; Li, 1996).

2.3.2.3 Function of Hydrocolloids

Studies show that the addition of hydrocolloids in noodles can control the swelling degree of starch granules owing to its high water binding capacity (Silva et al., 2012). These functions can affect stickiness, adhesiveness and elasticity of pasta through imitating the function of gluten to strengthen dough structure (Brennan et al., 2007).

2.3.2.4 Noodle Sensory Tests

Sensory test analysis is important in designing, testing, launching and rethinking new food products (Cavicchi et al., 2010). Moreover, it is a reliable method for measuring quality attributes of noodles.

Generally, there are two types of sensory tests: product-oriented and consumer-oriented tests (Fu et al., 2010). In products-oriented tests, trained panelists evaluate the quality attributes of a product free from personal bias and subjectivity. In consumer-oriented tests, untrained panelists evaluate the overall acceptability of a product, mainly focusing on subjective preference and liking.

Desirable texture profiles vary with different types of noodles. Expected characteristics for alkaline noodles are firm, elastic, and smooth in texture while bright and clean in appearance. Noodles should also maintain a good texture in the hot broth (Moss et al., 1987).

Several sensory methods have been developed to evaluate noodle quality (Anon, 1985; Konik et al., 1994; Crosbie et al., 1999; Hou, 2001). Testing variables cover three areas: process, color and texture. Sensory attributes include firmness, elasticity, smoothness, tolerance, speckiness and chewiness, etc. Noodles can be served with broth or sauce during the sensory test. The evaluation process can also be different with noodles consumed immediately or held in water for several minutes before consumption. Total scores of acceptance can be calculated by accumulating points for each characteristic.

2.4 Whole Grain Noodle Research

There is limited research related to whole grain noodles at present (Niu et al., 2014a; Niu et al. 2014b). To our knowledge, there are also no studies in the literature to examine the quality of noodles made with a whole grain and refined flour blend. There are several studies that have analyzed whole grain pasta quality including: the correlation between enzyme activity and pasta colors (Borrelli et al., 1999), the internal moisture transport mechanism during drying (Mercier et al. 2014), texture properties of whole grain pasta with dietary fiber fortification (Edwards et al., 1995), and the influence of gluten protein on cooking quality (Cubadda et al., 2007). Niu et al. (2014a) investigated the effects of the addition of phosphates in fresh whole wheat noodles. The introduction of inorganic phosphates induced increases in gelatinization temperature and enthalpy of starch melting. Moreover, the texture profile was improved with phosphates.

Given the increased emphasis on whole grain foods, there are emerging quality issues related to the use of whole wheat flour in noodle production. This includes deteriorated mouth-feel, darker appearance and impaired texture (Bakke et al., 2007).

2.5 Significance of this Study

Given the present consumer needs for whole grain foods and promising markets for convenient products, the development and analysis of a new type of whole wheat precooked alkaline noodle is highly desirable.

Moreover, the launch of this new product encourages collaboration between grain growers, flour millers, food companies and restaurants to improve whole grain consumption within the confines of economic profit and consumer well-being.

3. Materials and Methods

3.1 Materials

Whole wheat flour (Ultragrain® hard white) and refined hard red wheat flour were kindly provided by ConAgra Mills, Inc (Omaha, Nebraska). Freshly milled wheat flour were shipped directly to Wheat Marketing Center, Inc. and stored in the refrigerator. Parameters of basic flour analysis are listed in Table 1. The moisture, protein, and ash contents were 9.31%, 12.87% (14% mb), and 1.60% (14% mb) for Ultragrain® flour, respectively.

Table 1. Basic Flour Analysis Data

Parameters		Ultragrain®	High Protein(HP)	Medium Protein(MP)	Low Protein(LP)
Color	L*	85.53	89.74	90.45	89.80
	a*	-0.31	-1.74	-1.6	-1.77
	b*	11.62	9.24	8.44	9.04
Protein (%)		12.865	14.48	12.712	11.510
Moisture (%)		9.31	12.74	12.69	13.48
Ash (%)		1.602	0.503	0.557	0.516
Falling number (s)		424	534	343	453
Wet Gluten (%)		26.9	39.6	35.4	29.8
Starch Damage (%)		3.92	4.42	4.82	4.57
Farinograph Quality Number(I)		103	274	118	173

Based on the preliminary screening results, lecithin and four phosphate salts/blends were selected for this research: disodium phosphate (DSP), sodium tripolyphosphate (STPP), Mianjia310® and Mianjia400®. Mianjia310® is the trade name for a blend of Food Chemicals Codex (FCC) Grade sodium phosphates. Mianjia400® is the trade name for a blend of FCC Grade sodium and potassium phosphates. Specification limits of Mianjia310® and Mianjia400® are listed in Table 2. Phosphate salts were supplied

by ICL Performance Products LP (St. Louis, MO). Soy Lecithin was supplied by Chef Will Goldfarb (Miami Beach, FL). Sodium Chloride (NaCl) and Sodium Carbonate (Na₂CO₃) were supplied by ChemProducts (Portland, OR). Potassium Carbonate (K₂CO₃) was supplied by Food GMP Manufactured Product (France).

Table 2. Specification Limits of Mianjia310® and Mianjia400®

Blend	Equivalent P2O5, %	pH, 1% Solution @ 25.0°C
Mianjia310®	49.0-52.0	11.5-12.5
Mianjia400®	43.0-46.0	8.8-9.8

3.2 Noodle Formulation and Strand Sizes

Precooked alkaline noodles were formulated based on the flour weight.

- Ultragrain® Flour: 0%, 30%, 50% 100%
- Water: 35%, 38%, 41%
- NaCl: 1.2%
- K₂CO₃: 0.45%
- Na₂CO₃: 0.45%
- Blend flour: low protein, medium protein and high protein

Noodle strand (L*W*T): 300 mm*1.67 mm*1.5 mm

Table 3. Flour Blend Groups

Group	Ultragrain®	Refined High Protein Flour	Refined Medium Protein Flour	Refined Low Protein Flour
A	0%	100%	/	/
B	0%	/	100%	/
C	0%	/	/	100%
D	30%	70%	/	/
E	30%	/	70%	/
F	50%	50%	/	/
G	50%	/	50%	/
H	50%	/	/	50%

Ultragrain® and refined flour were blended in designed ratio. Blend Groups are listed in Table 3.

The selection of addition levels of functional ingredients was based on previous studies of Wang et al. (2011a) and Zhou and Hou (2012), or based on product recommended levels (Table 4.).

Table 4. Functional Ingredients Adding Levels

Salt	Percentage (%)
DSP	0.3
STPP	0.3
Mianjia310®	0.5
Mianjia400®	0.5
Lecithin	0.5

3.3 Preparation of Precooked Noodles

The noodle preparation procedures included seven steps (Hou, 2010b): mixing, dough resting, dough sheet compounding, dough sheet resting, dough sheet thickness reducing, noodle slitting and parboiling. Detailed steps are:

- 1) Prepare salt and alkaline solution. Weigh the flour and place in the mixing tank. Set the mixing rate to 90 rpm at first and mix for 2 min. Then stop to clean the beaters and inside walls of the mixer. Set the mixer to 120 rpm and continue to mix for 8min and stop to clean the mixer again. Then mix for another 2 min at 120 rpm.
- 2) Remove the dough and rest it in polyethylene bags for 30 min at room temperature.
- 3) Compress the dough between two pairs of sheeting rolls at a 3-mm gap. Combine the two formed dough sheets between a pair of compounding rolls at a 5-mm gap to form one dough sheet.
- 4) Roll the dough sheet around a rolling pin and place it in the polyethylene bags for another 30 min.

- 5) Pass the dough sheet through continuous reduction rollers four times, gradually reducing the thickness to 4,3,2 and 1.5 mm. Cut a piece of the dough sheet before it passes through the final calibration rolls (1.5 mm gap).
- 6) After calibration, pass the dough sheet through rollers and noodle slitters to form strips.
- 7) Weigh and cook 100-200 g of raw noodles in boiling water for 45 s and rinse in 24-27°C tap water for 10 s with stirring. Place noodles in a strainer and drain excess water forcefully 10 times. Add 3% of vegetable oil based on precooked noodle weight and mix well. Finally, store the noodles in polyethylene bags at room temperature.

Specifications of equipment used in noodle production are listed in Table 5.

Table 5. Equipment Specification of Noodle Production Line

Equipment	Characteristics	Company
Vacuum Mixer	Horizontal pin type	Model MT-1-3, Tokyo Menki Co., Tokyo, Japan
Pilot-scale Noodle-making machine	2 pairs sheeting rolls 1 pair compounding rolls 5 pairs reduction rolls Various sizes of slitters	Model WR8-100, Tokyo Menki Co., Tokyo, Japan
Noodle cooker	Gas cooker Capacity: 12.7 gallons Continuous tap water supplied	Model GCSC, Frymaster, Shreveport, LA

3.4 Color Measurement of Precooked Noodle Sheets

A chroma meter (CR-410, Konica Minolta Sensing, Inc., Japan) equipped with a 50-mm diameter measuring head was used to measure CIE L*, a* and b* values of precooked noodle sheets according to the method described by Hou (2010b). Representation of L*, a* and b* values are the color value location on whiteness-blackness, redness-greenness and yellowness-blueness axes, respectively. Three noodle pieces (8 cm*8 cm) were cut from noodle sheets before passing through

calibration rollers. Noodle pieces were boiled in boiling water for 45 s, and rinsed in 24-27°C water for 10 s with stirring. The surfaces were dried with a paper towel.

After calibrating the chroma meter with a white standard plate, three noodle sheets were stacked together on a piece of white paper as the background. Two readings were taken on each side of two noodle sheets and an average of 8 readings was calculated. Detection of noodle sheet color was determined at in 0 h and 24 h.

3.5 Measurement of Pasting Properties of Ultragrain® Whole Wheat Flour Blend

Pasting properties of Ultragrain® whole wheat flour blends were determined with a Rapid Visco Analyzer (RVA-4, Newport Scientific, Inc., Australia), using the AACC Method 76-21 (AACCI 2000).

The 3.5 g flour sample (14% mb) and 25 ml of prepared solution (alkaline solution with/without phosphate salts) were mixed to form slurries. The flour and solution mixture was stirred by the analyzer at 960 rpm for 10 s, and then at 160 rpm for the remainder of the test. The heating temperature was initially set at 50 °C and held for 1 min and raised to 95 °C over 3.75 min, then the slurry was held at 95 °C for 2.5 min, cooled to 50 °C over 3.75 min, and held at 50 °C for 2 min.

The Rapid Visco Analysis (RVA) results were expressed in rapid visco units (RVU). Peak viscosity, trough viscosity, breakdown, final viscosity and setback were recorded to characterize the starch pasting properties of the Ultragrain® whole wheat flour blends (Figure 1.).

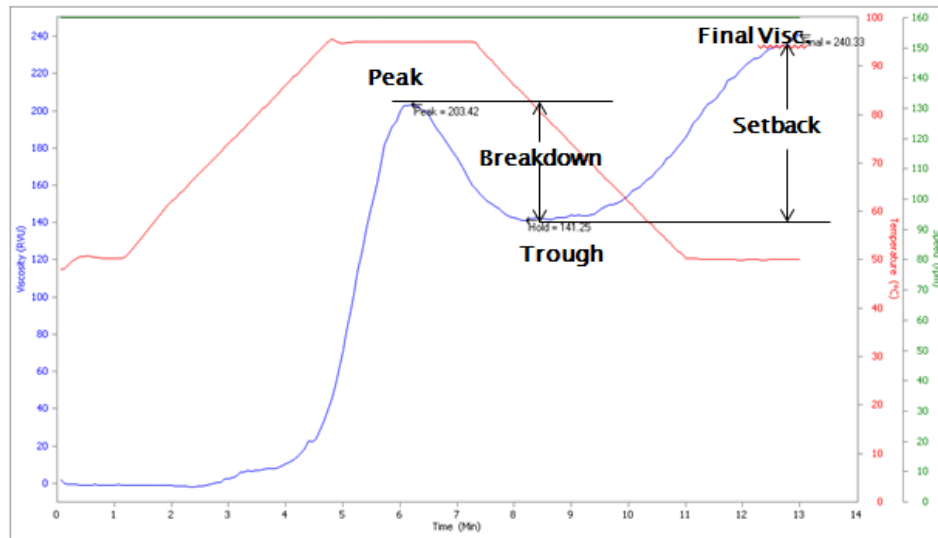


Figure 1. Representative RVA Curve.

Blue=Viscosity in RVA Unit; Red=Temperature

3.6 Textural Profile Analysis (TPA) of Cooked Noodles

Precooked noodle textural properties were determined by using a TA-XT plus texture analyzer (Texture Technology Corp., Scarsdale, NY, USA) according to methods and programs described by Hou (2010b).

Texture analyzer setting parameters are listed in Table 6.

Five parameters were recorded during the texture testing: hardness, springiness, cohesiveness, chewiness and resilience. The program model was a mimic of first and second bites by consumers when they were eating noodles. The definitions of testing parameters in TPA were based on noodle texture testing protocols (Texture Profile Analysis, 2009) (Figure 2. & Table 7.).

Table 6. Textural Profile Analysis Settings

Parameter	Setting
Load cell	5kg
Mode	TPA
Pretest speed	4.0mm/s
Test speed	1.0mm/s
Post-test speed	1.0mm/s
Target mode	Strain
Strain	70%
Time	1.0 second
Trigger force	10.0 gram
Tare mode	Auto
Advanced options	On
Distance	Millimeters
Force	Gram
Time	Seconds
Probe	5mm flat Lexan pasta blade

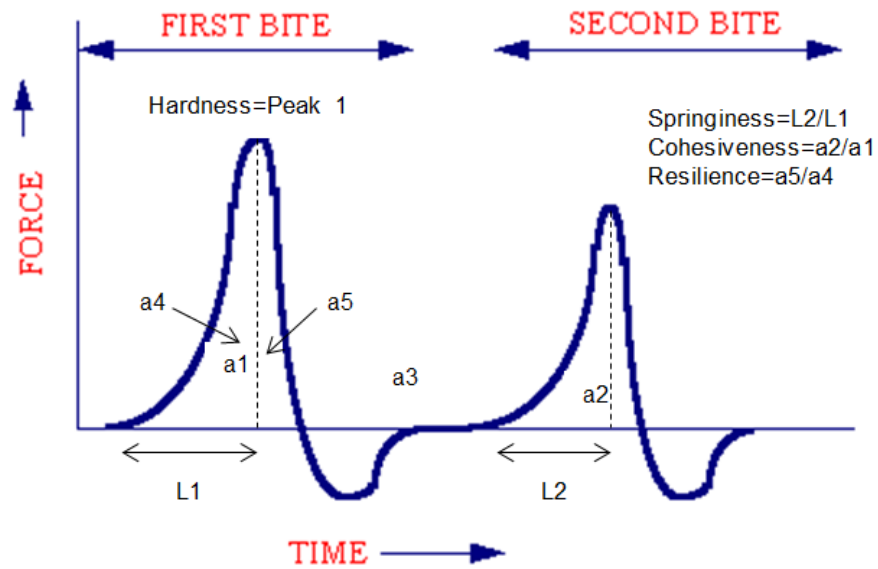


Figure 2. Noodle Textural Profile Analysis

Table 7. Textural Parameter Definition

Parameter	Definition	Calculation
Hardness	The hardness value is the peak force of the first compression of the product	Peak 1
Cohesiveness	Cohesiveness is how well the product withstands a second deformation relative to how it behaved under the first deformation	a_2/a_1
Springiness	Springiness is how well a product physically springs back after it has been deformed during the first compression	L_2/L_1
Chewiness	Chewiness is the sensation of sustained and elastic resistance	Cohesiveness*Hardness *Springiness
Resilience	Resilience is how well a product regains its original position. It can be regarded as instant springiness before the waiting period starts.	a_5/a_4

After storing at room temperature for 24h in polyethylene bags, 100g of precooked noodles were boiled in 100°C water for 1min. Cooked noodles were removed and rinsed in 24-27°C tap water for 10s with stirring. Noodles were placed in a strainer and tapped forcefully 10 times on the edge of a sink to drain excess water. Then noodles were placed in a bowl with a cover. Three sound and uniform noodle strands were selected, cut into 6cm long pieces and placed on a plastic film. Five noodle pieces were selected and placed side by side on the Lexan platform of the TA-XT plus texture analyzer.

Values of hardness, springiness, cohesiveness, chewiness and resilience were recorded. Each test was repeated 2-3 times until the coefficient of variance is less than 5% for the hardness value.

3.7 Sensory Test

The sensory panel included 5 trained panelists from the Wheat Marketing Center, Portland, OR. The sensory test procedures were based on the method by Hou et al. (2010b).

The evaluation form was listed in Table 8.

Table 8. Sensory Test Evaluation Form

		Test	
	Quality Factor	Evaluation Item	Score(1-10)
First evaluation	Texture after cooking precooked noodles for 1min	Bite	
		Springiness	
		Mouth-feel	
		Bitterness	
Second evaluation	Texture after cooking precooked noodles for 1min and holding for 5min in hot water	Bite	
		Springiness	
		Mouth-feel	
		Tolerance in the water	
		Bitterness	
Total score			

The meanings of 10 points for each variable are:

- Bite: extremely hard
- Springiness: extremely springy
- Mouth-feel: very good
- Bitterness: extremely bitter
- Tolerance: very good shape in the water

One control and two to four noodle test samples were prepared for each run. 100 grams of noodles were cooked for 1min and then poured into 1200ml bowls with 600ml of hot water.

The first textural evaluation was performed immediately by scoring the form. Remaining noodles were kept in hot water for another 5 min and then the second textural evaluation was performed.

The control group includes noodles with 35% water, 100% medium protein refined flour and a normal mixing condition.

Total scores were calculated by adding scores for bite, springiness, mouth-feel, tolerance and subtracting scores for bitterness.

Testing sequences for noodle samples were listed in Table 9.

Table 9. Noodle Sample Sequences in Sensory Test

Run #	Samples	Ultragrain® Level	Blend flour type	Water Level	Mixing condition
Run 1	Control	0%	MP	35%	Normal
	Test 1	30%	HP	35%	Normal
	Test 2	50%	HP	35%	Normal
	Test 3	100%	HP	35%	Normal
Run 2	Control	0%	MP	35%	Normal
	Test 4	100%	HP	35%	Normal
	Test 5	100%	HP	38%	Normal
	Test 6	100%	HP	41%	Normal
Run 3	Control	0%	MP	35%	Normal
	Test 7	50%	HP	35%	Normal
	Test 8	50%	HP	35%	Vacuum
	Test 9	30%	MP	35%	Normal
	Test 10	30%	MP	35%	Vacuum
Run 4	Control	0%	MP	35%	Normal
	Test 11	50%	HP	35%	Normal
	Test 12	50%	MP	35%	Normal

3.8 Statistical Analysis

All tests were run at least in duplicate in a completely randomized design. Results were expressed as mean \pm standard deviation. Data were analyzed by one-way analysis of variance (ANOVA) with software SPSS Statistics 20. $P < 0.05$ were considered to be significant by using Duncan's test.

4. RESULTS AND DISCUSSION

4.1 Color

Color is a significant parameter since it provides the first and most direct impression for consumers about the noodle quality and taste. The bright and light yellow color is appealing to most consumers based on their initial judgment, especially in Asian countries where darker whole grain foods are associated with poverty and low social status (Pitchford, 2003). Several factors influence the brightness and yellowness in the noodle color, including milling extraction rate, protein content, starch damage, and brown and yellow pigments (Baik et al., 1995).

Alkaline noodles owe their characteristic yellow color to the chromophoric shift that occurs when endogenous flavonoids in flour react in the presence of caustic solutions of kansui (Na_2CO_3 and K_2CO_3) (Bellido et al., 2009). The intensity of the yellowness is a function of the alkali added and the amount of flavonoids present (Miskelly, 1996; Mares et al., 1997). Moreover, the stability of the color is a good indication of noodle qualities and shelf life. The deterioration of noodle brightness has a good correlation ($r=0.87$) with polyphenol oxidase (PPO) content after a 24-hour period (Kruger et al., 1994). Variables inducing different results include flour blend composition and water contents (Solah et al., 2007).

4.1.1 Effects of Water Level on Noodle Color

The noodle color is perceived via specific combinations of reflected light. The water content in formulation has an important influence on color values. In this study, by increasing water content from 35% to 41% there was a decrease in lightness (L^*) and an increase in yellowness (b^*) in high protein Ultragrain® whole wheat precooked noodles

(50% Ultragrain® + 50% high protein refined flour) (Table 10.). These results were in accordance with Morris et al. (2000), as the alkaline noodle color for the L* value was reduced while the b* value increased with the addition of water to the noodle formula. With the additional water content, the noodle sheet darkening process was slowed. However, the final color remained darker with the 41% versus the 35% water content after 24 h. With the additional water content in formulation, water activity can be increased in noodle dough (Baik et al., 1995). The PPO activity was reported as one of the mechanism to induce noodle discoloration (Fuerst et al., 2006). It is hypothesized that the higher water activity and the change in PPO activity increase alkaline noodle darkening.

Table 10. Effects of Water Addition Level on Precooked Noodle Sheet Color (50% Ultragrain®, High Protein Refined Flour & Normal Mixing)

Water Ratio	0h		
	L*	a*	b*
35%	60.78±1.11 ^c	5.59±1.32 ^a	28.73±1.16 ^{NS}
38%	59.18±0.69 ^b	5.61±1.02 ^a	28.74±2.52
41%	57.11±0.71 ^a	6.97±0.38 ^b	28.79±0.52
Water Ratio	24h		
	L*	a*	b*
35%	57.04±1.09 ^b	5.16±0.24 ^{NS}	26.2±0.78 ^{NS}
38%	55.88±0.94 ^a	5.26±0.08	26.21±0.54
41%	55.33±1.76 ^a	5.37±0.24	26.44±0.49
Water Ratio	Color Change		
	Δ L*	Δ a*	Δ b*
35%	3.73±1.13 ^b	0.43±1.35 ^a	2.53±1.74 ^{NS}
38%	3.30±0.81 ^b	0.35±0.98 ^a	2.54±1.17
41%	1.79±1.50 ^a	1.60±0.30 ^b	2.35±0.56

4.1.2 Effects of Ultragrain® Flour Ratio on Noodle Color

A high ratio of Ultragrain® flour induced a decrease in lightness (L^*) and an increase in yellowness (b^*) (Table 11.). It was reported that darker pigments and higher polyphenol oxidases in wheat bran induced darker color in Ultragrain® whole wheat noodles (Jiang et al., 2011). However, there was no significant difference in the color change after 24 h for the Ultragrain® whole wheat flour and refine wheat flour noodles. It is hypothesized that the parboiling process denatured polyphenol oxidases in noodles and resulted in the relatively stable noodle color.

Table 11. Effects of Ultragrain® Flour Ratio on Precooked Noodle Sheet Color (35% Water, High Protein Refined Flour & Normal Mixing)

Ultragrain® Flour Ratio	0h		
	L^*	a^*	b^*
0%	68.58±0.66 ^d	0.69±0.24 ^a	23.29±0.93 ^a
30%	62.24±0.47 ^c	4.43±1.02 ^b	27.6±1.39 ^b
50%	60.78±1.11 ^b	5.59±1.32 ^c	28.73±1.16 ^b
100%	58.98±0.60 ^a	7.25±1.25 ^d	30.34±0.63 ^c
Whole Grain Flour Ratio	24h		
	L^*	a^*	b^*
0%	63.96±1.42 ^d	0.99±0.44 ^a	22.43±0.37 ^a
30%	58.01±1.18 ^c	4.00±0.25 ^b	24.89±0.62 ^b
50%	57.04±1.09 ^b	5.16±0.24 ^c	26.2±0.78 ^c
100%	54.83±0.73 ^a	6.68±0.36 ^d	27.60±0.96 ^d
Whole Grain Flour Ratio	Color Change		
	ΔL^*	Δa^*	Δb^*
0%	4.62±1.86 ^{NS}	-0.30±0.61 ^{NS}	0.87±0.68 ^a
30%	4.23±1.32	0.43±0.88	1.48±2.53 ^b
50%	3.73±1.13	0.43±1.35	2.53±1.74 ^b
100%	4.14±1.16	0.57±0.99	2.73±0.38 ^b

4.1.3 Effects of Vacuum Mixing Condition on Noodle Color

Vacuum mixing can reduce noodle color darkening through both enzymatic and non-enzymatic mechanisms. A non-enzymatic mechanism includes the effects of protein oxidation in noodles (Asenstorfer et al., 2010). Vacuum mixing can create a pressure-tight environment by removing air from the water and flour system of fresh noodles (Li et

al., 2012). The lower oxygen content in the dough reduces the oxidation of polyphenols and proteins, inducing a lesser degree of darkening.

Vacuum mixing conditions can enhance the interaction of solids and water molecules, inducing a decrease in water activity and better noodle colors (Karathanos et al., 1995).

In this study, the -0.10 MPa vacuum degree mixing condition was applied. There were no color changes at the 35% water level when compared to the normal mixing condition (Table 12. & Table 13.). However, with higher water levels, the vacuum mixing caused more darkness and less yellowness in noodle sheets. Meanwhile, the vacuum mixing condition slowed the color change at 35% and 38% water level.

Table 12. Effects of Water Addition Level and Vacuum Mixing Condition on Precooked Noodle Sheet Color (50% Ultragrain® & High Protein Refined Flour)

Water ratio	Mixing Condition	0h		
		L*	a*	b*
35%	Vacuum	61.43±0.64 ^b	7.03±0.63 ^a	30.50±0.63 ^c
38%	Vacuum	54.01±0.41 ^a	7.81±0.40 ^b	27.55±0.37 ^b
41%	Vacuum	53.86±0.73 ^a	7.58±0.69 ^{ab}	26.79±0.35 ^a
Water ratio	Mixing Condition	24h		
		L*	a*	b*
35%	Vacuum	59.16±0.84 ^c	5.02±0.22 ^a	27.58±0.64 ^b
38%	Vacuum	52.46±0.45 ^b	5.81±0.22 ^b	24.99±0.41 ^a
41%	Vacuum	51.29±0.24 ^a	6.07±0.16 ^c	24.54±0.29 ^a
Water ratio	Mixing Condition	Color Change		
		Δ L*	Δ a*	Δ b*
35%	Vacuum	2.27±0.78 ^{ab}	2.01±0.51 ^{NS}	2.93±0.47 ^b
38%	Vacuum	1.55±0.75 ^a	1.99±0.58	2.56±0.63 ^{ab}
41%	Vacuum	2.57±0.85 ^b	1.51±0.76	2.26±0.32 ^a

In this study, a slower color change was detected in the Ultragrain® whole wheat precooked noodles with a low water content; however, the vacuum mixing condition caused a darker color in Ultragrain® whole wheat noodles with the higher water content, which was not desirable.

The mechanism behind this phenomenon is not clear. It is hypothesized that more bran and germ particles in Ultragrain® flour induce further impairment in noodle gluten structure. Given the weakened gluten structure, vacuum mixing condition and higher water content can contribute to a darker noodle color. Moreover, the water content and the vacuum mixing condition could have interactive effects on polyphenol oxidase activity and cause a darker color.

Table 13. Effects of Mixing Condition on Precooked Noodle Sheet Color (50% Ultragrain® & High Protein Refined Flour)

Water ratio	Mixing Condition	0h		
		L*	a*	b*
35%	Normal	60.78±1.11	5.59±1.32*	28.73±1.16*
35%	Vacuum	61.43±0.64	7.03±0.63	30.50±0.63
Water ratio	Mixing Condition	24h		
		L*	a*	b*
35%	Normal	57.04±1.09*	5.16±0.24	26.20±0.78*
35%	Vacuum	59.16±0.84	5.02±0.22	27.58±0.64
Water ratio	Mixing Condition	Color Change		
		Δ L*	Δ a*	Δ b*
35%	Normal	3.73±1.13*	0.43±1.35*	2.53±1.74
35%	Vacuum	2.27±0.78	2.01±0.51	2.93±0.47
Water ratio	Mixing Condition	0h		
		L*	a*	b*
38%	Normal	59.18±0.69*	5.61±1.02*	28.74±0.72*
38%	Vacuum	54.01±0.41	7.81±0.40	27.55±0.37
Water ratio	Mixing Condition	24h		
		L*	a*	b*
38%	Normal	55.88±0.94*	5.26±0.08*	26.21±0.54*
38%	Vacuum	52.46±0.45	5.81±0.22	24.99±0.41
Water ratio	Mixing Condition	Color Change		
		Δ L*	Δ a*	Δ b*
38%	Normal	3.30±0.81*	0.35±0.98*	2.54±1.17
38%	Vacuum	1.55±0.75	1.99±0.58	2.56±0.63
Water ratio	Mixing Condition	0h		
		L*	a*	b*
41%	Normal	57.11±0.71*	6.97±0.38*	28.79±0.52*
41%	Vacuum	53.86±0.73	7.58±0.69	26.79±0.35
Water ratio	Mixing Condition	24h		
		L*	a*	b*
41%	Normal	55.33±0.98*	5.37±0.24*	26.44±0.49*
41%	Vacuum	51.29±0.24	6.07±0.16	24.54±0.29
Water ratio	Mixing Condition	Color Change		
		Δ L*	Δ a*	Δ b*
41%	Normal	1.79±1.50	1.60±0.30	2.35±0.56
41%	Vacuum	2.57±0.85	1.51±0.76	2.26±0.32

4.1.4 Effects of Protein Content on Noodle Color

Previous studies indicate that with increasing protein content of flour, the L* value for noodle dough decreases while the ΔL^* value during storage increases (Baik et al. 1995). Thus, the protein content of wheat flour has a negative correlation with the noodle brightness (Asenstorfer et al., 2010).

In this study, the color of Ultragrain® whole wheat precooked noodles was lighter and less yellow with the higher protein content at 0 h (Table 14.). The change in lightness of high and medium protein noodles was larger than low protein noodles, resulting in a relatively darker color in high protein noodles. No significant differences were found in the change in yellowness for noodles with different protein content.

Table 14. Effects of Protein Content on Precooked Noodle Sheet Color (50% Ultragrain®, 35% Water & Normal Mixing)

Protein Content	0h		
	L*	a*	b*
High Protein	60.78±1.11 ^b	5.59±1.32 ^a	28.73±1.16 ^a
Medium Protein	60.36±0.44 ^{ab}	5.83±1.04 ^a	29.51±0.93 ^a
Low Protein	59.79±0.27 ^a	7.20±0.57 ^b	30.53±0.43 ^b
Protein Content	24h		
	L*	a*	b*
High Protein	57.04±1.09 ^a	5.16±0.24 ^a	26.2±0.78 ^a
Medium Protein	57.49±0.87 ^a	5.39±0.08 ^b	27.24±0.54 ^b
Low Protein	58.71±0.45 ^b	5.09±0.25 ^a	27.58±0.53 ^b
Protein Content	Color Change		
	ΔL^*	Δa^*	Δb^*
High Protein	3.73±1.13 ^b	0.43±1.35 ^a	2.53±1.74 ^{NS}
Medium Protein	2.87±0.90 ^b	0.45±1.07 ^a	2.28±0.70
Low Protein	1.08±0.61 ^a	2.11±0.67 ^b	2.95±0.56

This color change after 24 h was in accordance with a previous study using refined flour alkaline noodles related to protein oxidation (Asenstorfer et al., 2010). However, the

negative correlation of the protein content and noodle brightness were not perceived in Ultragrain® whole wheat noodles. It is hypothesized that the flour blend composition and characteristics, including bran particles and PPO content, could be correlated with protein content and influence noodle color.

4.1.5 Effects of Functional Ingredients on Noodle Color

The DSP and Mianjia400® increased lightness for both low protein and high protein Ultragrain® whole wheat noodles (Table 15. & Table 16.). All functional ingredients increased the yellowness of Ultragrain® whole wheat precooked noodles. There were no significant differences in colors for low protein noodle and high protein Ultragrain® whole wheat noodles.

These results agree with reports from Wang et al. (2011b) and Niu et al. (2014a) that the addition of phosphates induced brighter and yellower color in instant noodles and fresh whole wheat noodles. The mechanism may be partially related to polyphenol oxidases activity (Asenstorfer et al., 2010). With phosphates binding to Cu^2 in active sites of PPO, formation of colored compounds has been influenced and the darkening of noodles has been reduced (Fuerst 2006). Naturally occurring flavones in flour were reported previously to cause the yellow color of alkaline noodles (Fortmann et al., 1978). These compounds are colorless at acidic or neutral pH levels and become yellow under alkaline pH (Wang et al., 1995; Ward et al., 1995; Miskelly, 1996). In the study an increase in the b^* value of whole wheat precooked noodles after adding functional ingredients was due to increased pH values.

Table 15. Effects of Functional Ingredients on Precooked Noodle Sheet Color (50% Ultragrain® & Low Protein Refined Flour)

Functional ingredient	0h		
	L*	a*	b*
Control	59.79±0.27 ^{ab}	7.20±0.57 ^a	30.53±0.43 ^a
DSP (0.3%)	61.07±0.40 ^c	8.16±0.28 ^b	32.13±0.29 ^c
STPP (0.3%)	59.21±1.54 ^{ab}	8.27±0.73 ^b	31.08±0.55 ^b
Mianjia310® (0.5%)	59.3±0.74 ^{ab}	8.29±0.33 ^b	31.66±0.24 ^c
Mianjia400® (0.5%)	60.02±0.91 ^b	7.31±0.89 ^a	30.99±0.87 ^{ab}
Lecithin (0.5%)	58.86±0.63 ^a	8.14±0.32 ^b	30.74±0.27 ^{ab}
Functional ingredient	24h		
	L*	a*	b*
Control	58.71±0.45 ^{bc}	5.09±0.25 ^a	27.58±0.53 ^a
DSP	60.18±0.48 ^d	6.01±0.29 ^{bcd}	29.64±0.38 ^c
STPP	58.45±1.40 ^{ab}	6.33±0.41 ^d	29.34±0.31 ^c
Mianjia310®	59.41±0.46 ^{cd}	6.11±0.27 ^{cd}	29.56±0.31 ^c
Mianjia400®	59.11±0.32 ^{bc}	5.85±0.38 ^{bc}	28.67±0.77 ^b
Lecithin	57.86±0.95 ^a	5.73±0.22 ^b	28.52±0.20 ^b
Functional ingredient	Color Change		
	Δ L*	Δ a*	Δ b*
Control	1.08±0.61 ^b	2.11±0.67 ^b	2.95±0.56 ^c
DSP	0.89±0.63 ^b	2.15±0.39 ^b	2.49±0.46 ^{bc}
STPP	0.75±0.32 ^b	1.94±0.40 ^{ab}	1.74±0.34 ^a
Mianjia310®	-0.11±0.89 ^a	2.18±0.50 ^b	2.10±0.54 ^{ab}
Mianjia400®	0.92±0.83 ^b	1.46±0.86 ^a	2.32±1.01 ^{ab}
Lecithin	1.01±0.95 ^b	2.41±0.39 ^b	2.22±0.15 ^{ab}

Table 16. Effects of Functional Ingredients on Precooked Noodle Sheet Color (50% Ultragrain® & High Protein Refined Flour)

Functional ingredient	0h		
	L*	a*	b*
Control	59.60±0.51 ^b	6.72±0.28 ^a	29.78±0.22 ^a
DSP (0.3%)	60.49±0.62 ^c	7.03±0.52 ^{ab}	30.47±0.25 ^b
STPP (0.3%)	59.36±0.47 ^b	7.45±0.20 ^b	30.11±0.18 ^a
Mianjia310® (0.5%)	59.41±0.46 ^b	7.49±0.56 ^b	30.57±0.56 ^b
Mianjia400® (0.5%)	60.52±0.28 ^c	7.34±0.35 ^b	31.02±0.35 ^c
Lecithin (0.5%)	57.89±1.13 ^a	7.23±0.70 ^b	29.79±0.33 ^a
Functional ingredient	24h		
	L*	a*	b*
Control	58.40±0.37 ^{ab}	5.23±0.07 ^a	27.42±0.24 ^a
DSP	59.70±0.62 ^c	5.50±0.28 ^b	28.06±0.53 ^b
STPP	58.63±0.54 ^b	5.87±0.11 ^d	28.24±0.16 ^{bc}
Mianjia310®	58.74±0.71 ^b	5.73±0.24 ^{cd}	28.32±0.56 ^{bc}
Mianjia400®	59.88±0.21 ^c	5.54±0.12 ^{bc}	28.50±0.21 ^c
Lecithin	57.86±0.69 ^a	5.12±0.31 ^a	27.42±0.29 ^a
Functional ingredient	Color Change		
	Δ L*	Δ a*	Δ b*
Control	1.21±0.45 ^b	1.50±0.29 ^a	2.36±0.39 ^b
DSP	0.79±1.23 ^{ab}	1.54±0.71 ^a	2.41±0.68 ^b
STPP	0.73±0.75 ^{ab}	1.58±0.21 ^{ab}	1.87±0.25 ^a
Mianjia310®	0.67±1.03 ^{ab}	1.76±0.49 ^{ab}	2.25±0.36 ^{ab}
Mianjia400®	0.64±0.38 ^{ab}	1.81±0.34 ^{ab}	2.52±0.35 ^b
Lecithin	0.03±1.19 ^a	2.11±0.75 ^b	2.36±0.35 ^b

4.2 Pasting Properties of Ultragrain® Flour Blends

Researchers have reported a relationship between pasting properties of wheat flour and noodle qualities (Crosbie 1991; An et al., 2009). Pasting properties analyzed in this study are peak viscosity, trough viscosity, breakdown, final viscosity and setback.

Peak viscosity is a good indicator of swelling of starch granules. The breakdown trend can be measured when swollen granules disrupt and amylose molecules come into solution (Dufour et al 2009; Zhang et al., 2008). These two variables of wheat flour

have been reported to have good correlation with alkaline noodle hardness and smoothness (Miskelly et al., 1985; Batey et al., 1997).

Trough value is related to the ability of starch to resist break down after crowding and mutual pressure during the peak viscosity point (Collado et al., 1999). The promotion of interaction with starch molecules and building up ordered crystalline structure will help create higher trough viscosity values (Wang et al., 2011b).

The promotion of the recrystallization process among starch molecules in the cooling period will cause gel formation and a higher final viscosity value (Niu et al., 2014a). Larger setback value means a higher amylose retrogradation trend (Wang et al., 2011b).

4.2.1. Effects of Ultragrain® Whole Wheat Flour Ratio on Pasting Properties

Only water was added in the high protein Ultragrain® flour blend during the first round RVA test. It was found the higher Ultragrain® flour ratio induced decreases in peak viscosity, trough and final viscosity values (Table 17.). However, the breakdown and setback values were relatively small for Ultragrain® flour. It is hypothesized that increasing bran particles and impaired water distribution in whole grain flour does not promote swollen granule disruption, but prevented the recrystallization process during the setback period. Studies have shown that the open and porous gluten microstructure in whole grain noodles is due to adherence of wheat bran particles to starch granules and protein fibrils (Pomeranz et al., 1977; Niu et al., 2014a). The level of amylase activity in grains can influence pasting properties of flour during processing procedures and higher amylases in Ultragrain® flour could also reduce pasting viscosities (Kruger et al., 2006; Ragaei et al., 2006).

Table 17. Effects of Ultragrain® Flour Ratio on Pasting Properties (Water Addition Only)

Flour blend	100%HP	30% Ultragrain® Whole+70%HP	50% Ultragrain® Whole+50%HP	100% Ultragrain® Whole
Peak Viscosity	217.25±10.01 ^C	194±7.31 ^B	179.59±8.01 ^B	131.88±4.31 ^A
Trough	115.33±5.66 ^C	105.34±5.54 ^{BC}	95.46±5.48 ^B	68.92±1.53 ^A
Breakdown	101.92±4.36 ^C	88.67±1.77 ^B	84.13±2.54 ^B	62.96±2.77 ^A
Final Viscosity	226.42±6.36 ^C	206.84±9.43 ^{BC}	193.42±10.13 ^B	151.13±0.88 ^A
Setback	111.08±0.71 ^C	101.5±3.89 ^B	97.96±4.65 ^B	82.21±0.65 ^A

After adding alkali (NaCl, K₂CO₃ and Na₂CO₃) to the formula, peak, trough and final viscosity were greatly increased for the Ultragrain® flour blend (Table 18., Figure 3.- Figure 7.). There were no significant differences of breakdown values with the higher Ultragrain® flour ratios for the alkaline flour mixture. At lower Ultragrain® ratios, alkaline solution decreased breakdown values compared with water. Setback was higher for a 100% whole grain flour ratio with alkaline solution than for a lower whole grain ratio mixture. It was found that alkaline solution could help promote starch granules swelling and gel formation for whole wheat flour which influenced noodle quality. It was reported that peak viscosity of wheat flour was positively correlated with the cooked alkaline noodle smoothness and negatively correlated with alkaline noodle hardness through sensory tests (Miskelly et al., 1985; Batey et al., 1997).

Table 18. Effects of Ultragrain® Flour Ratio on Pasting Properties (Alkaline Solution Addition)

Flour blend	100%HP	30% Ultragrain® Whole+70%HP	50% Ultragrain® Whole+50%HP	100% Ultragrain® Whole
Peak Viscosity	254.67±5.30 ^c	234.42±14.50 ^{bc}	230.67±2.24 ^b	204.46±1.47 ^a
Trough	190.79±1.47 ^c	170.96±6.89 ^b	163.75±8.73 ^b	144.67±4.83 ^a
Breakdown	63.88±6.78 ^{NS}	63.46±7.60	66.92±6.48	59.80±3.36
Final Viscosity	284.34±0.83 ^b	260.84±10.37 ^a	256.92±7.07 ^a	245.00±6.60 ^a
Setback	93.54±0.65 ^b	89.88±3.47 ^a	93.17±1.65 ^a	100.33±1.77 ^a

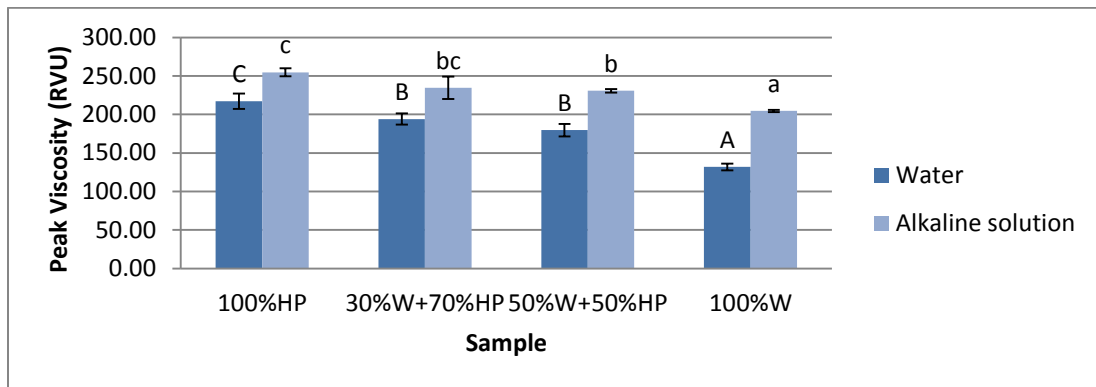


Figure 3. Peak Viscosity of Ultragrain® Whole Wheat Flour Blend with Water or Alkaline Solution

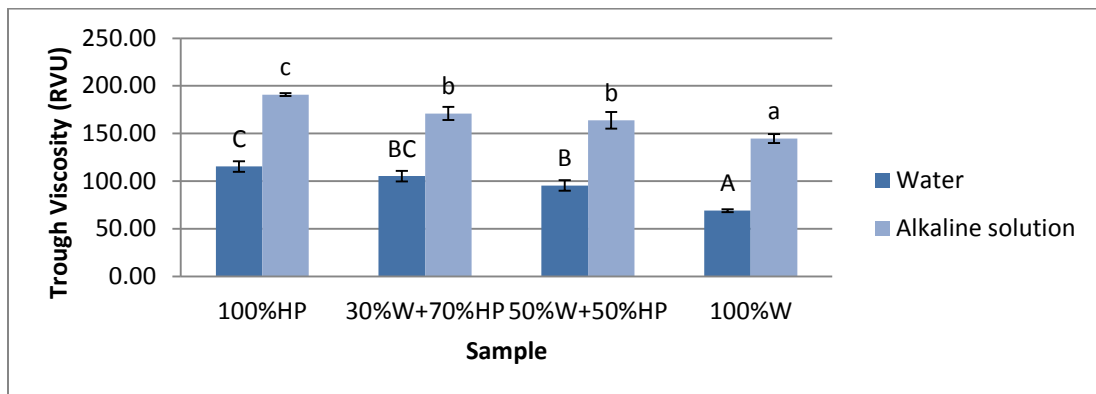


Figure 4. Trough Viscosity of Ultragrain® Whole Wheat Flour Blend with Water or Alkaline Solution

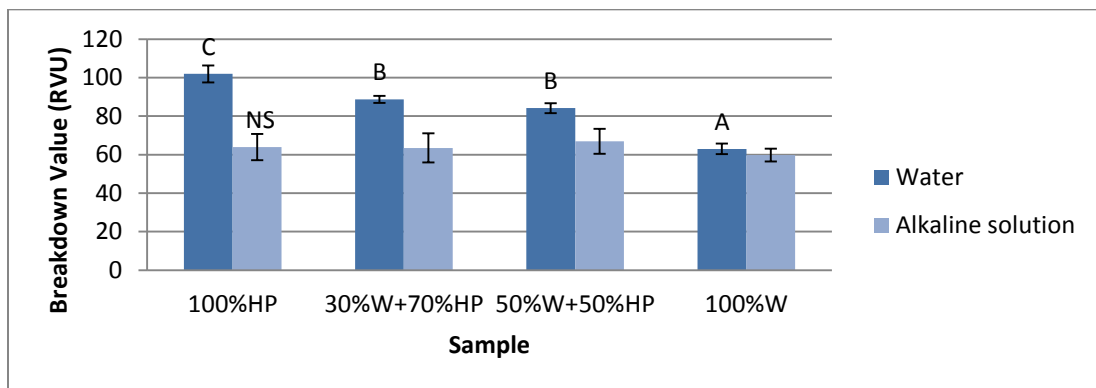


Figure 5. Breakdown Value of Ultragrain® Whole Wheat Flour Blend with Water or Alkaline Solution

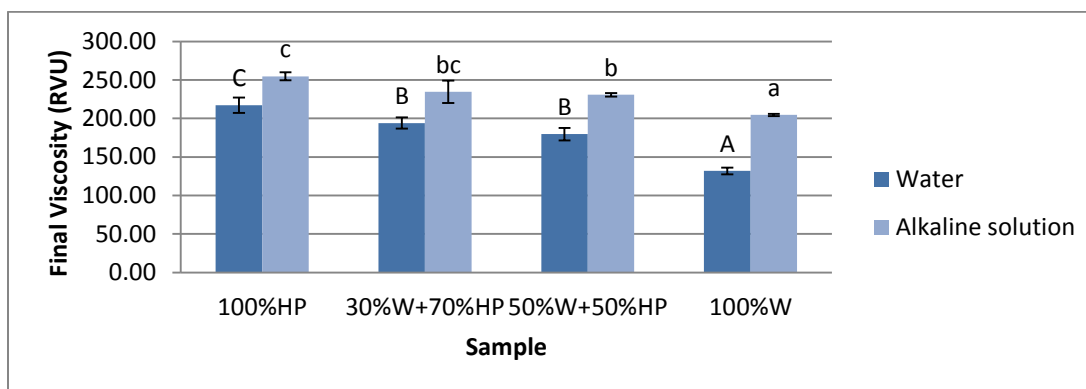


Figure 6. Final Viscosity of Ultragrain® Whole Wheat Flour Blend with Water or Alkaline Solution

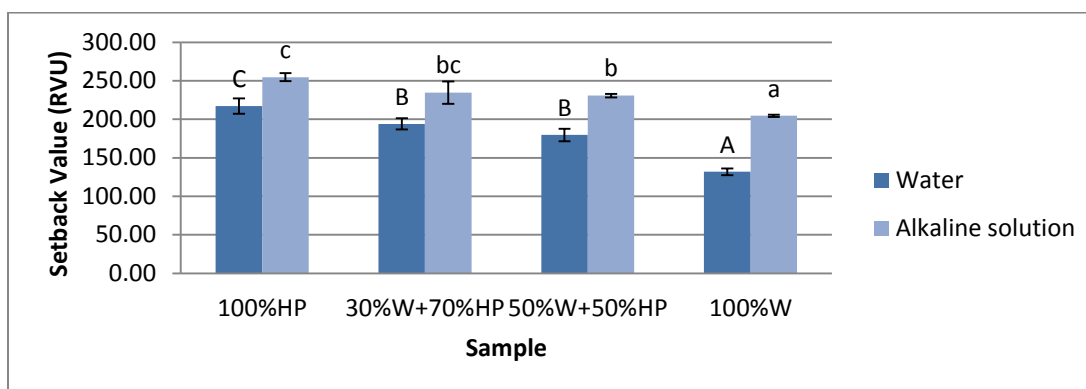


Figure 7. Setback Value of Ultragrain® Whole Wheat Flour Blend with Water or Alkaline Solution

4.2.2 Effects of Protein Content on Pasting Properties

No significant differences of pasting properties were found between Ultragrain® flour + high protein refined flour (HP), Ultragrain® flour + medium protein refined flour (MP) and Ultragrain® flour + low protein refined flour (LP) with alkaline solution (Table 19.).

It was found that protein content did not have a major influence on whole wheat flour blend pasting properties. No previous studies have analyzed the relationship of pasting properties and protein content of whole wheat flour. It is reported that paste breakdown is low in refined flour with high protein content (Singh et al., 2011). It is hypothesized that

Ultragrain® whole wheat flour is the determining fact for the pasting properties of the blend flour.

Table 19. Effects of Protein Content of Flour Blend on Pasting Properties (Alkaline Solution Addition)

Flour blend	50% Ultragrain® Whole+50%HP	50% Ultragrain® Whole+50%MP	50% Ultragrain® Whole+50%LP
Peak Viscosity	230.67±2.24 ^{ab}	236.17±3.66 ^b	226.21±1.24 ^a
Trough	163.75±8.73 ^{NS}	156.55±8.66	159.50±2.23
Breakdown	66.92±6.48 ^{NS}	79.63±5.01	66.71±1.00
Final Viscosity	256.92±7.07 ^{NS}	248.38±10.54	254.25±5.19
Setback	93.17±1.65 ^{NS}	91.84±1.89	94.75±2.94

4.2.3 Effects of Functional Ingredients on Pasting Properties

Adding functional ingredients in alkaline solution had different effects on peak, trough and final viscosity of blend flour. For 50% Ultragrain® + 50% high protein refined flour blend, DSP and Mianjia400® increased peak viscosity, trough, final viscosity and setback with decreased breakdown values. Lecithin reduced trough value and increased setback (Figure 8.). It was in accordance with previous studies that certain phosphate salts could interact with starch molecules closely and form more ordered and stable structure (Wang et al 2011b). In noodles, fatty acid esters were reported to interact with starches (Niihara et al., 1973; Mohri, 1980). The remaining functional ingredients did not show significant change on pasting properties.

For 50% Ultragrain® + 50% low protein refined flour blend, Mianjia400® increased peak viscosity, final viscosity and setback with decreased breakdown (Figure 9.).

There were no significant differences found between high and low protein flour blends in pasting properties (Figure 10.).

Pasting properties are related to amylase activities and several factors such as the pH and temperature. The presence of minerals can be used to control the amylase activity (Ragae et al., 2006). The Addition of functional ingredients influenced whole wheat flour pasting properties through controlling amylase activities.

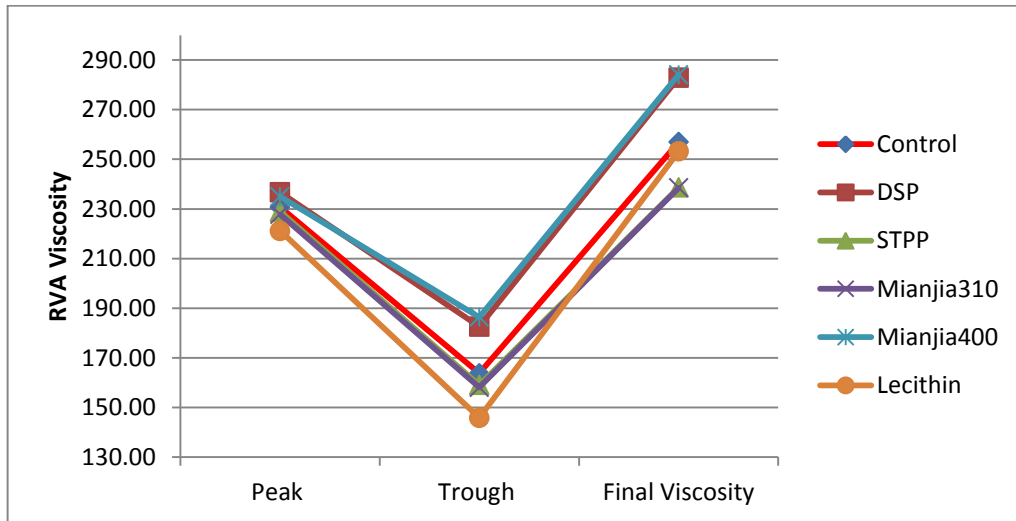


Figure 8. Effects of Functional Ingredients on Ultragrain® & High Protein Flour Blend Pasting Properties

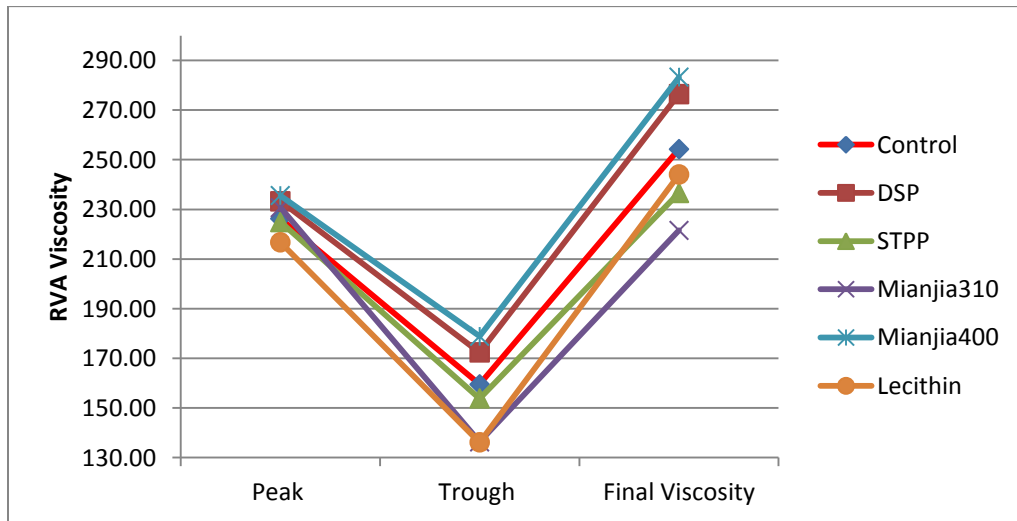


Figure 9. Effects of Functional Ingredients on Ultragrain® & Low Protein Flour Blend Pasting Properties

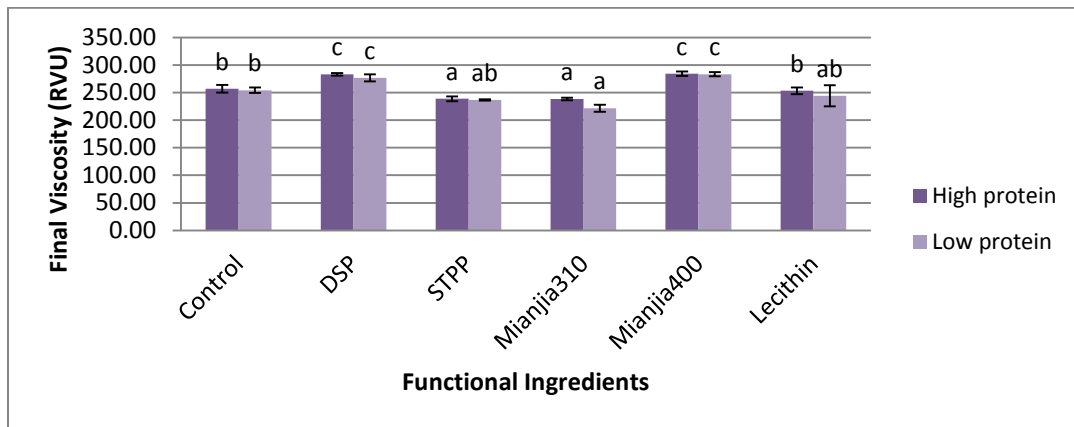


Figure 10. Effects of Functional Ingredients on High and Low Protein Flour Blend Final Viscosity

4.3 Texture

Texture of pre-cooked noodles is important in determining eating experience and quality (Wang et al., 2011a). In this study, hardness, springiness, chewiness, cohesiveness and resilience were tested by using the Texture Profile Analysis (TPA).

4.3.1 Effects of Water Ratio on Precooked Noodle Texture

For the 50% Ultragrain® ratio high protein noodles, the water content did not change texture properties at normal and vacuum mixing conditions, except that the 38% water level increased hardness under the vacuum mixing condition (Table 20, 24 & 25).

There was an interactive effect of mixing conditions and water contents on textural properties of precooked noodles. It is hypothesized that increasing water content to the medium level can strengthen noodle hardness by improving gluten structure development through the vacuum mixing condition.

Table 20. Effects of Water Addition Level on Boiled Noodle Texture (50% Ultragrain®, High Protein Refined Flour & Vacuum Mixing)

Water Ratio	35%	38%	41%
Hardness	1116.6±0.9 ^a	1260.7±14.5 ^b	1148.8±44.3 ^a
Springiness	0.950±0.003 ^{NS}	0.965±0.006	0.981±0.022
Cohesiveness	0.557±0.004 ^{NS}	0.528±0.016	0.559±0.009
Chewiness	590.6±5.2 ^{NS}	641.6±8.1	629.1±28.5
Resilience	0.244±0.000 ^{NS}	0.230±0.013	0.260±0.012

4.3.2. Effects of Ultragrain® Flour Ratio on Precooked Noodle Texture

A higher Ultragrain® flour ratio reduced hardness, chewiness, springiness and cohesiveness (Table 21.). High levels of bran particles have been reported to impair development of gluten structures in noodles at a microstructural level and prevent formation of a relatively close gluten network (Niu et al., 2014a).

Given the higher Ultragrain® flour ratio, the impaired texture qualities are related to reduced peak, trough and final viscosity values of the pasting properties.

With a decreasing ability of flour blends to resist swelling forces between starch molecules and to retrograde after cooling, the high Ultragrain® ratio precooked noodles showed undesirable textural properties by TPA.

Table 21. Effects of Ultragrain® Flour Ratio on Boiled Noodle Texture (35% Water, High Protein Refined Flour & Normal Mixing)

Ultragrain® Flour Ratio	0%	50%	100%
Hardness	1155.3±43.2 ^b	1107.4±55.9 ^b	971.4±3.8 ^a
Springiness	0.964±0.008 ^{NS}	0.966±0.003	0.928±0.027
Cohesiveness	0.603±0.001 ^c	0.543±0.012 ^b	0.480±0.009 ^a
Chewiness	670.6±18.4 ^c	580.0±17.9 ^b	432.5±19.4 ^a
Resilience	0.276±0.021 ^b	0.233±0.013 ^{ab}	0.187±0.006 ^a

4.3.3. Effects of Mixing Conditions on Precooked Noodle Texture

It has been reported that the vacuum mixing condition improved texture properties for refined wheat noodles. These effects were detected in the 0% whole grain precooked noodles in this study.

Although vacuum mixing improved whole wheat precooked noodle texture, these effects are not as significant as the refined flour precooked noodles. The mechanism behind this phenomenon is not clear. The vacuum mixing condition improves air elimination and water distribution in refined flour noodles. However, the increasing germ and bran particles in Ultragrain® flour induced a weakened gluten network for whole wheat noodles (Karathanos et al., 1995). It is hypothesized the modification of the microstructural environment in the whole wheat noodles impairs improvement in textural properties from vacuum mixing conditions.

Tables are listed in Appendices (Table 26.-Table 30.).

4.3.4. Effects of Protein Content on Precooked Noodle Texture

Under the normal mixing condition, the springiness value was higher for 100% low protein refined flour noodles while the value for chewiness was larger for 100% high protein refined flour noodles. However, with an increasing Ultragrain® ratio, there were no differences in texture properties between low, medium and high protein Ultragrain® whole wheat noodles (Figure 11.- Figure 15.).

Similar results were found under the vacuum mixing condition.

These results corresponded with the pasting property results that no significant differences were found between low, medium and high protein Ultragrain® whole wheat blend flour.

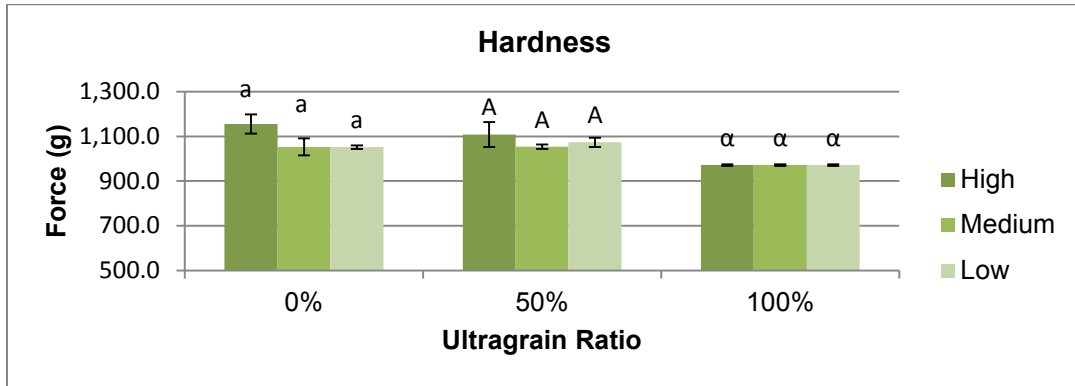


Figure 11. Effects of Flour Protein Content on Boiled Noodle Hardness (Normal Mixing)

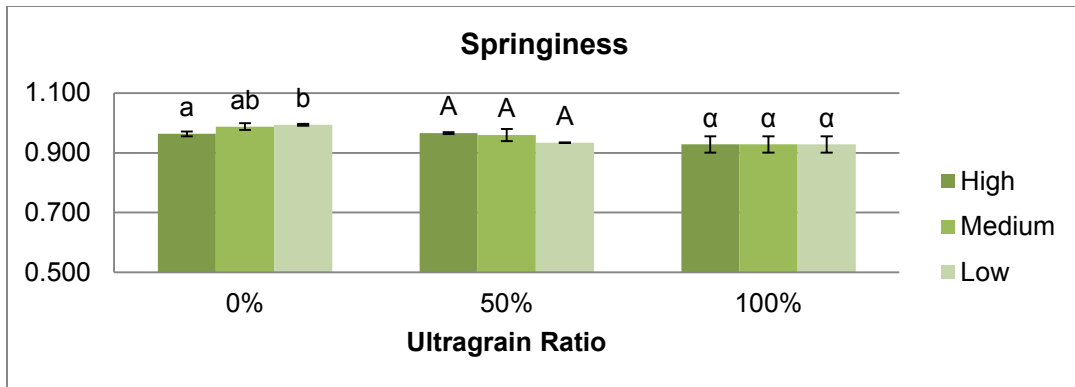


Figure 12. Effects of Flour Protein Content on Boiled Noodle Springiness (Normal Mixing)

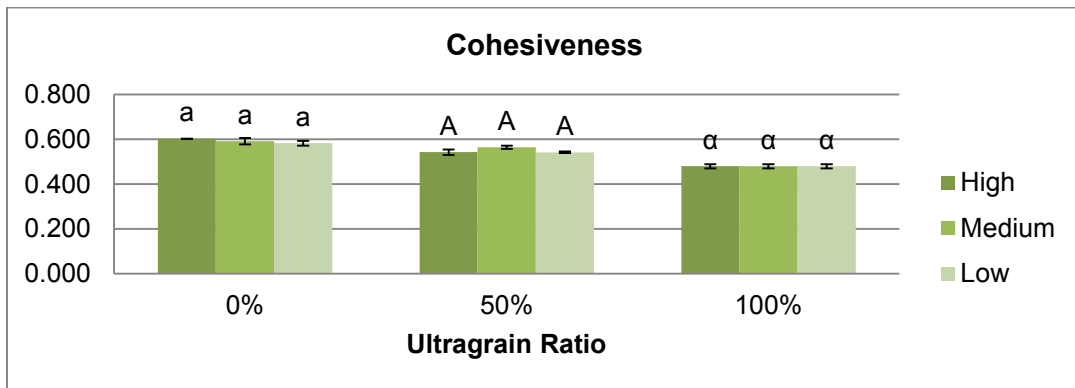


Figure 13. Effects of Flour Protein Content on Boiled Noodle Cohesiveness (Normal Mixing)

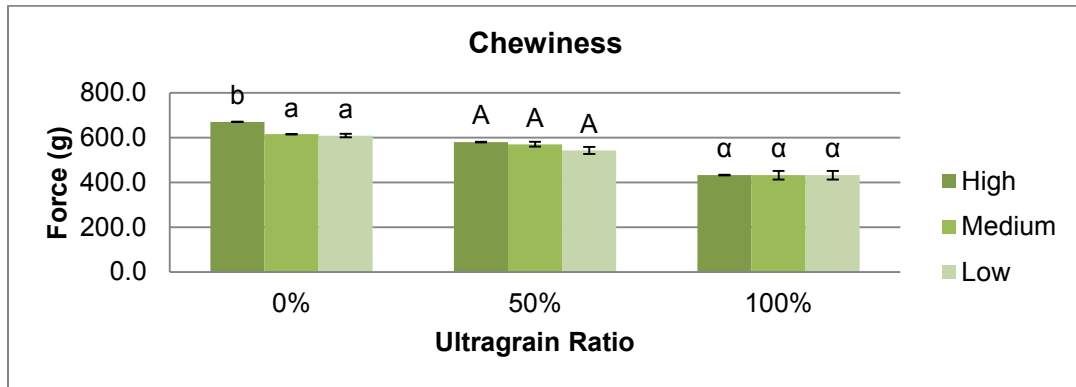


Figure 14. Effects of Flour Protein Content on Boiled Noodle Chewiness (Normal Mixing)

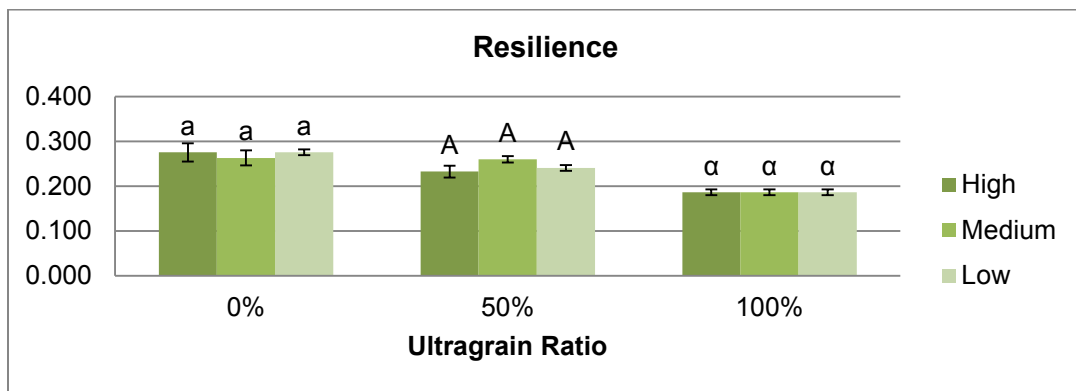


Figure 15. Effects of Flour Protein Content on Boiled Noodle Resilience (Normal Mixing)

4.3.5 Effects of Functional Ingredients on Precooked Noodle Texture

Functional ingredients improved texture properties of 50% Ultragrain® + 50% high protein refined flour precooked noodles. STPP and Mianjia310® increased noodle hardness. Lecithin increased noodle cohesiveness. STPP, Mianjia310® and lecithin increased noodle chewiness. However, Mianjia400® decreased noodle resilience (Table 22., Figure 16.- Figure 19.).

However, there were no significant differences for 50% Ultragrain® + 50% low protein refined flour precooked noodles after adding functional ingredients (Table 23.).

The improved textural properties due to these functional ingredients are related to their hydroxyl groups which can polymerize with starch (Li, 1996; Shah et al., 2006;

Ward et al., 2006). This mechanism may explain texture changes with the addition of phosphates and phospholipids in precooked noodles.

However, no good correlation between flour pasting properties and texture profiles were found for Ultragrain® whole wheat precooked noodles after the addition of functional ingredients.

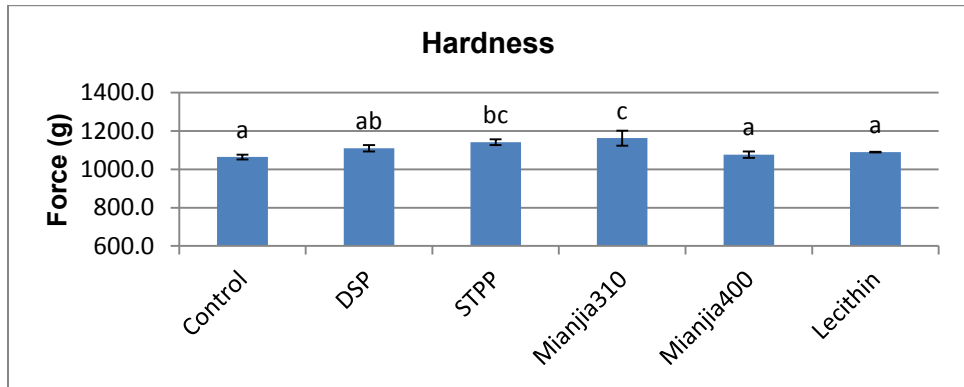


Figure 16. Effects of Functional Ingredient on Boiled Noodle Texture (High Protein Flour Blend)-A

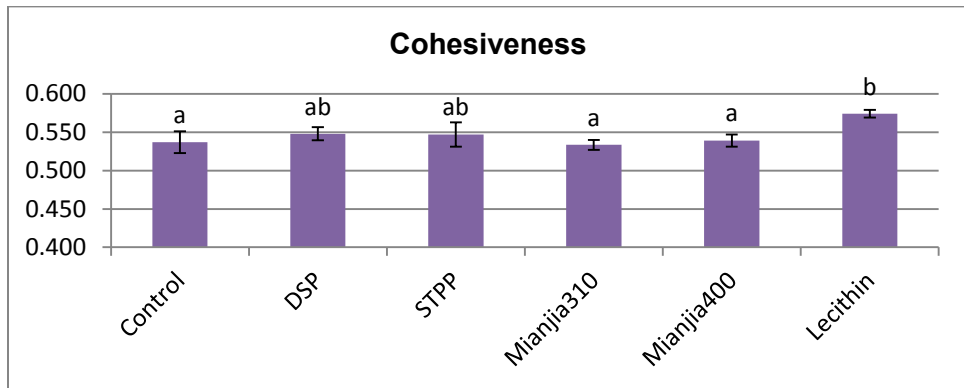


Figure 17. Effects of Functional Ingredient on Boiled Noodle Texture (High Protein Flour Blend)-B

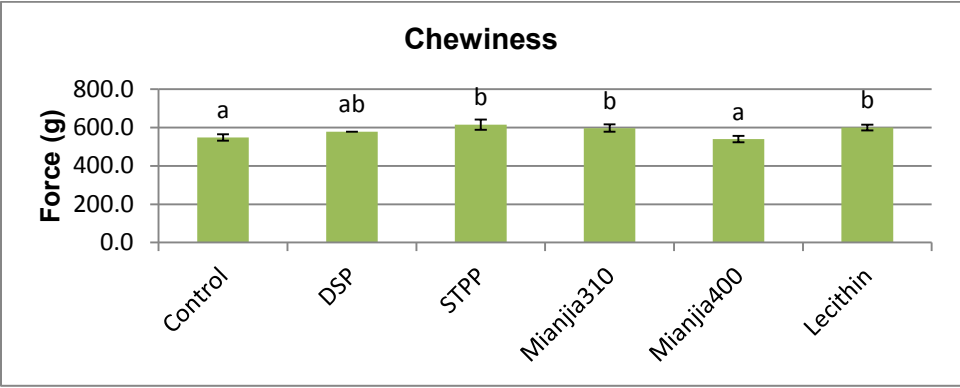


Figure 18. Effects of Functional Ingredient on Boiled Noodle Texture (High Protein Flour Blend)-C

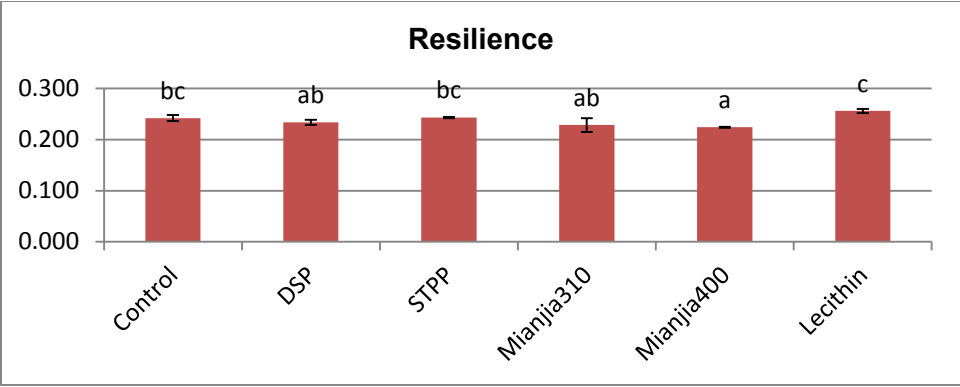


Figure 19. Effects of Functional Ingredient on Boiled Noodle Texture (High Protein Flour Blend)-D

Table 22. Effects of Functional Ingredient on Boiled Noodle Texture (High Protein Flour Blend)

Sample	Control	DSP	STPP	Mianjia310®	Mianjia400®	Lecithin
Hardness	1063.8±13.0 ^a	1109.0±16.5 ^{ab}	1141.3±14.7 ^{bc}	1162.3±39.1 ^c	1076.3±16.4 ^a	1089.5±2.4 ^a
Springiness	0.960±0.016 ^{NS}	0.952±0.030	0.985±0.026	0.963±0.013	0.930±0.030	0.959±0.018
Cohesiveness	0.537±0.014 ^a	0.548±0.008 ^{ab}	0.547±0.016 ^{ab}	0.534±0.006 ^a	0.539±0.008 ^a	0.574±0.005 ^b
Chewiness	548.1±16.1 ^a	578.2±0.6 ^{ab}	615.3±26.6 ^d	596.8±18.9 ^d	539.4±16.9 ^a	599.4±15.3 ^d
Resilience	0.242±0.006 ^{bc}	0.234±0.005 ^{ab}	0.243±0.001 ^{bc}	0.229±0.013 ^{ab}	0.224±0.001 ^a	0.256±0.004 ^c

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Table 23. Effects of Functional Ingredient on Boiled Noodle Texture (Low Protein Flour Blend)

Sample	Control	DSP	STPP	Mianjia310®	Mianjia400®	Lecithin
Hardness	1108.4±3.9 ^{NS}	1067.8±2.2	1144.0±16.2	1061.5±9.9	1101.4±20.7	1038.0±21.4
Springiness	0.969±0.002 ^{NS}	0.964±0.008	0.982±0.026	0.940±0.026	0.973±0.013	0.939±0.012
Cohesiveness	0.529±0.007 ^{NS}	0.538±0.011	0.553±0.003	0.513±0.011	0.535±0.003	0.551±0.017
Chewiness	568.2±7.7 ^{NS}	563.9±7.3	620.9±4.3	511.6±7.6	573.2±15.0	537.3±1.3
Resilience	0.231±0.004 ^{NS}	0.233±0.004	0.244±0.003	0.228±0.016	0.237±0.003	0.238±0.013

4.4 Sensory Test

The sensory tests were conducted according to the protocol by Hou (2001). The results could provide a better understanding of the consumer acceptance of the newly developed whole wheat precooked alkaline noodles. In the first textural evaluation, noodles were evaluated immediately (0 min) after being boiled. The remaining noodles were kept in hot water for another 5 min and then the second textural evaluation was performed.

4.4.1. Effects of Water Levels on Sensory Evaluation

No significant differences were found with different water contents for 100% Ultragrain® precooked noodles at 0 and 5 min (Figure 20., Figure 21.).

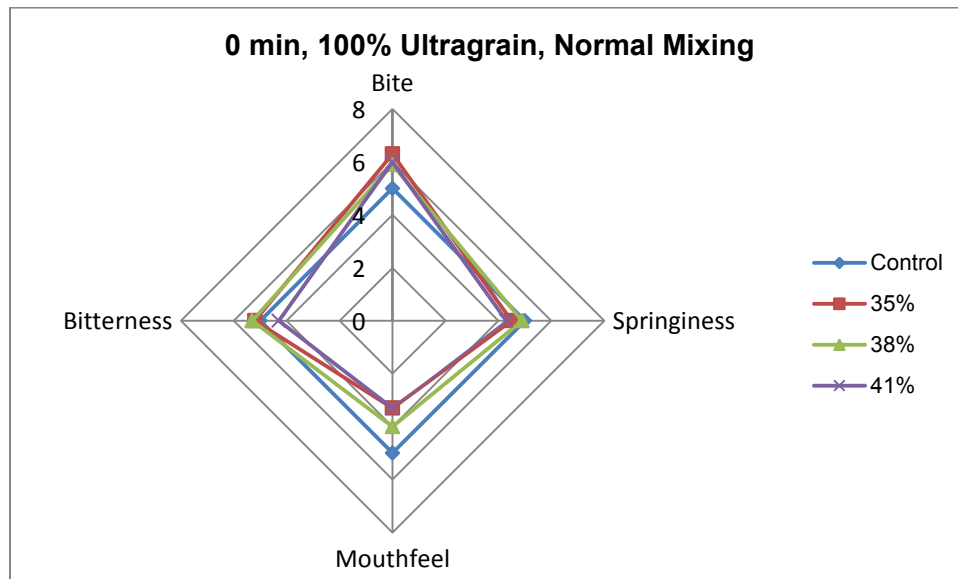


Figure 20. Effects of Water Addition Level on Noodle Sensory Evaluation-0 min

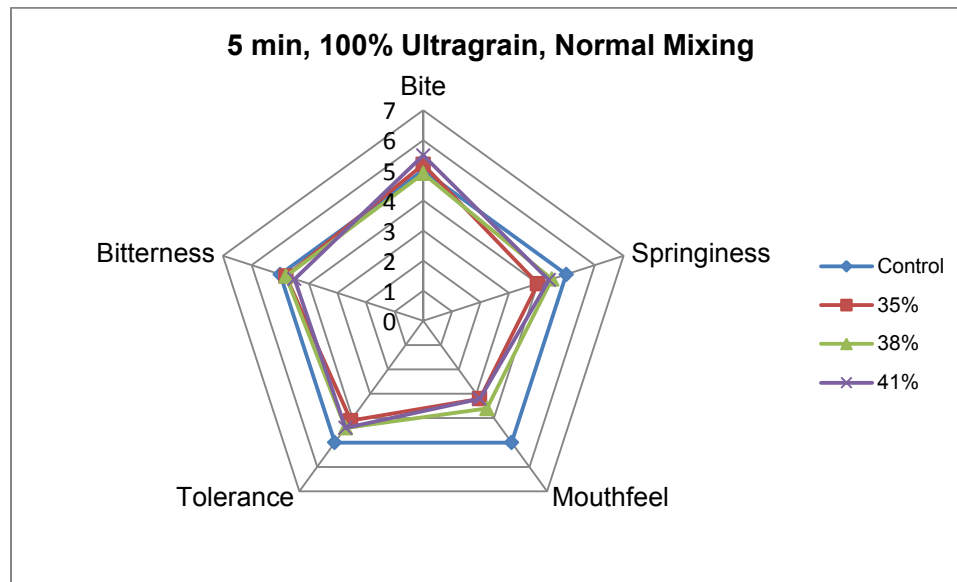


Figure 21. Effects of Water Addition Level on Noodle Sensory Evaluation-5min

Higher water content induced darker color for whole wheat precooked noodles. This created considerable challenges since the noodle color is the major indicator of qualities. Therefore, under the premise of no differences in human sensation, the lower water content, which is 35% in this study, are satisfactory to guarantee the noodle quality.

4.4.2. Effects of Ultragrain® Flour Ratio on Sensory Evaluation

For high protein precooked noodles, mouth-feel scores were lower than the control group for all Ultragrain® flour levels at 0 min. There were no significant differences in sensory scores with increasing Ultragrain® ratios for other sensory parameters (Figure 22.).

At 5 min, mouth-feel and springiness scores for 100% Ultragrain® ratio noodles were significantly lower than other groups. There were no significant differences between groups in scores for bite, bitterness and tolerance (Figure 23.).

There were no significant differences in texture qualities between 0 min and 5 min. The total score for 100% Ultragrain® noodles were lower than the control group. There were no differences in the total scores for 0%, 30% and 50% Ultragrain® ratio groups.

Bitterness in whole wheat has been a potential problem for consumers, particularly for those who are sensitive to this sensory attribute. This problem can reduce consumer's overall acceptance of whole wheat foods. Given the hard white whole wheat flour (Ultragrain® Products, 2013) used in this study is lighter in color with relatively less bitter attributes, it is quite possible the increase use of whole wheat flour did not induce increasing bitterness in final products. Moreover, the addition of an alkaline solution along with parboiling could also exert masking effects on whole wheat bitterness in the final noodle products.

Given a similar soaking tolerance is found for who Ultragrain® precooked noodles compared with refined noodles, the benefits may allow the use in various preparation and serving styles, such as fried noodles with sauce or boiled noodles in broth. Therefore, serving Ultragrain® precooked noodles in broth may not induce problems in a dining environment.

However, the phenomenon of impaired springiness and mouth-feel quality of 100% Ultragrain® precooked noodles is present, which may be attributed to the increasing bran particles in the noodles. Weakened gluten structure of whole wheat noodles is also hypothesized to be the reason for low level springiness and mouth-feel based on human sensory tests. This sensory result is in accordance with texture profile analysis detected by the texture analyzer. Therefore, a gradual process of increasing Ultragrain® levels in

noodles should be undertaken when improving consumer's acceptance of a newly developed whole wheat product.

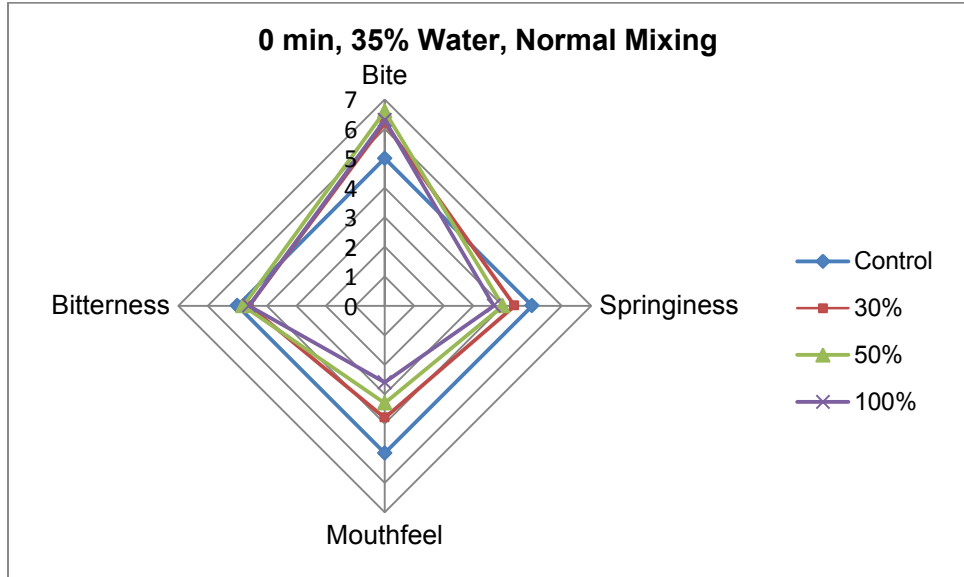


Figure 22. Effects of Ultragrain® Ratio on Noodle Sensory Evaluation-0min

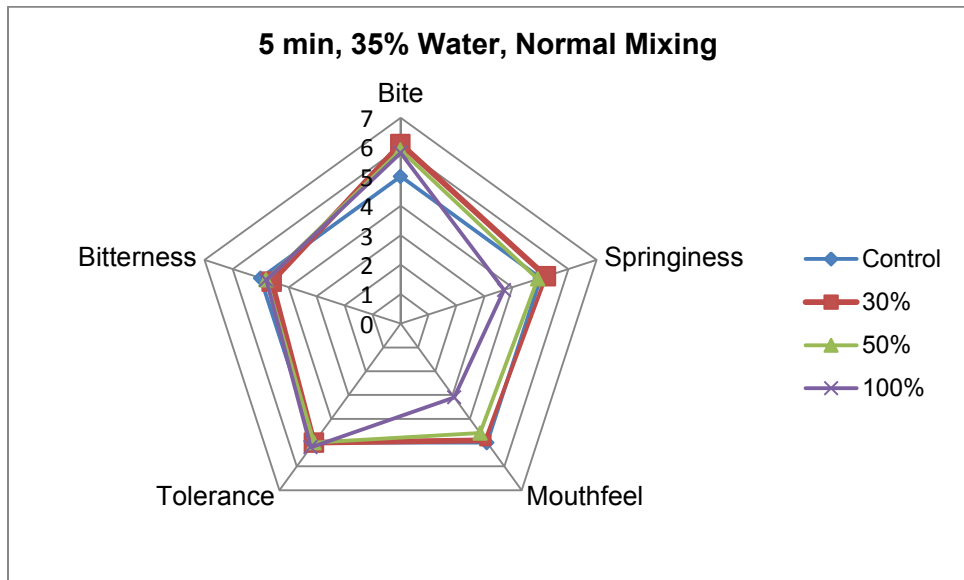


Figure 23. Effects of Ultragrain® Ratio on Noodle Sensory Evaluation-5min

4.4.3. Effects of Mixing Conditions on Sensory Evaluation

No significant differences were found between normal and vacuum mixing conditions for both high protein and medium protein blend flour at the 0.05 significance level (Figure 24.-Figure 27.). At the 0.10 significance level, the vacuum mixing condition increased the bite quality for medium protein precooked noodles at 0 min. Total scores at the 0 min were higher for vacuum mixing high protein precooked noodles at the 0.10 significant level. But there were no differences in the total scores of all variables for high protein noodles. For medium protein noodles, total scores of all variables under the vacuum mixing condition were higher than the normal mixing condition.

The human sensory test results at 0 min were in accordance with texture results as vacuum mixing conditions could improve texture profiles for Ultragrain® precooked noodles. However, after soaking in hot water for 5 min, the noodle quality difference under the normal and vacuum mixing condition were no longer detected by human sensation.

These results could provide background information regarding the combination of processing conditions and service of precooked noodles. According to data in this study, precooked noodles made under vacuum mixing conditions could possess advantages over normal mixing conditions when noodles are stir fried, immediately consumed or served with sauces instead of broth. Given higher requirements and costs for vacuum mixing equipment, the balancing consideration of whether to apply vacuum mixing conditions is recommended to noodle producers.

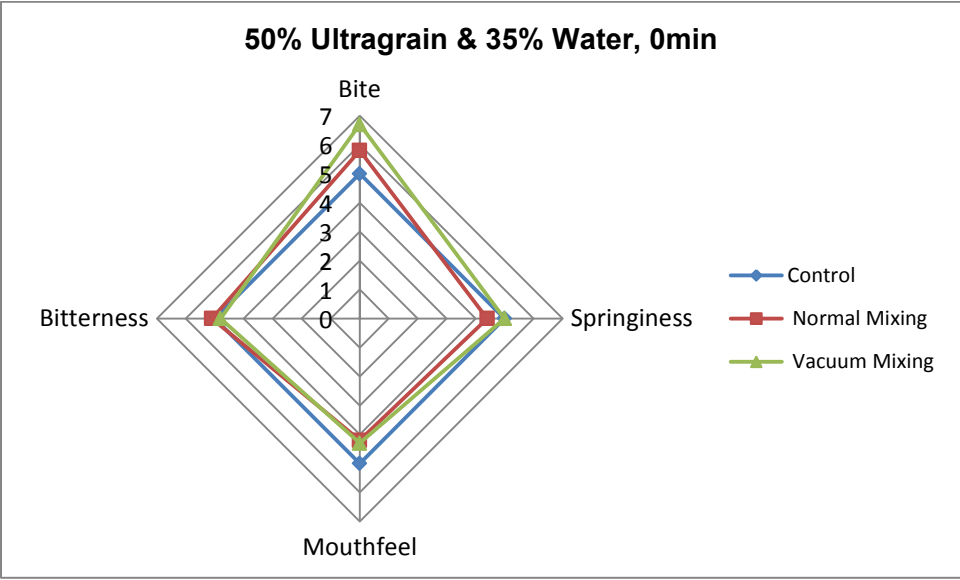


Figure 24. Effects of Mixing Condition on Noodle Sensory Evaluation (50% Ultragrain® & High Protein Refined Flour)-0min

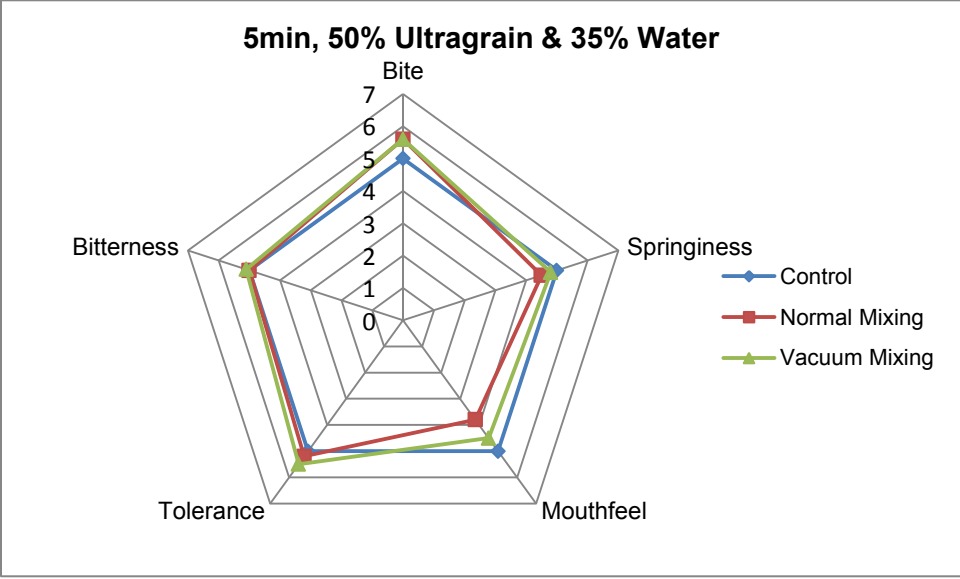


Figure 25. Effects of Mixing Condition on Noodle Sensory Evaluation (50% Ultragrain® & High Protein Refined Flour)-5min

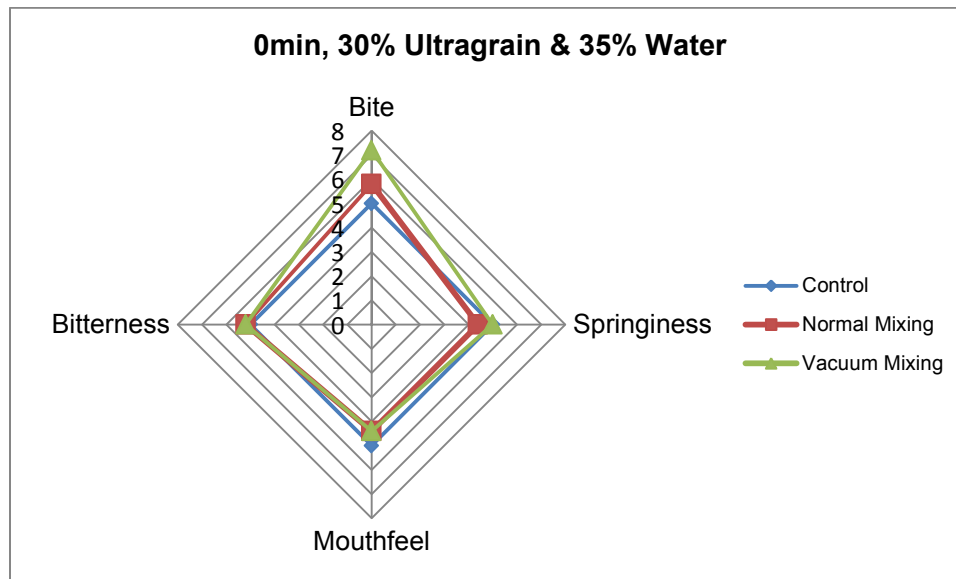


Figure 26. Effects of Mixing Condition on Noodle Sensory Evaluation (30% Ultragrain® & 70% Medium Protein Refined Flour)-0min

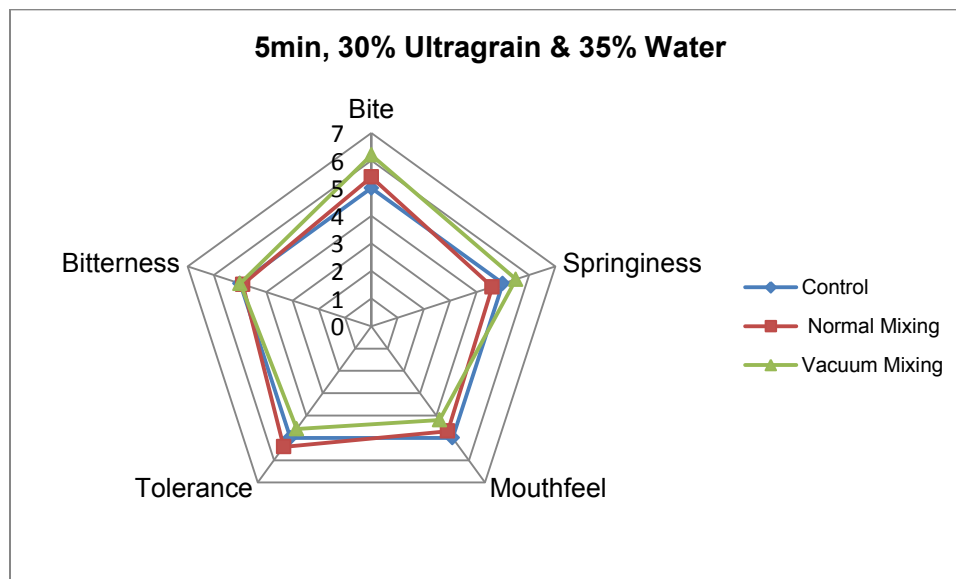


Figure 27. Effects of Mixing Condition on Noodle Sensory Evaluation (30% Ultragrain® & 70% Medium Protein Refined Flour)-5min

4.4.4. Effects of Protein Content on Sensory Evaluation

There were no significant differences between high protein and normal protein noodles in all sensory variables and total scores.

The similar sensory qualities of whole wheat precooked noodles with different protein content provide useful information for noodle producers when choosing wheat flour. If protein content is not the staple or major variables considered in the final product quality, wheat flour with a range of protein content can suffice in balancing cost and nutritional value.

5. CONCLUSION

The overall acceptability of Ultragrain® whole wheat precooked alkaline noodles is acceptable. The quality of the final product was improved by adjusting a combination of variables in the formulation.

Increasing the Ultragrain® ratio induced problems of impaired quality in springiness and mouth-feel and darker color. However, Ultragrain® precooked noodles showed similar bitterness and tolerance in sensory tests.

Higher water content induced darker color, slightly increased hardness and showed no effects on sensory properties.

The vacuum mixing condition improved texture profiles, but induced a darker color. Moreover sensory data showed slight improvement in noodle texture with the vacuum mixing condition at 0 min without soaking in hot water.

The protein content did not show major effects on noodle quality in the range from 11% to 15% which provided more choices for noodle producers when choosing flour for quality-guaranteed products.

Functional ingredients improved flour pasting properties by increasing peak and final viscosities and decreasing setback values. Noodle color was lighter and yellower and hardness was increased after adding functional ingredients.

The 30% and 50% Ultragrain® ratio precooked noodles were closer in appearance and texture qualities compared to the refined flour precooked noodles. However, the 100% Ultragrain® precooked noodles showed impaired qualities related to texture. A gradual increase in the Ultragrain® ratio is recommended for this type of noodle product.

6. LIMITATION and FUTURE WORK

Useful data have been collected and analyzed based upon this study. However, there are still several limitations.

- 1) Given a range of vacuum levels (0.0~-0.1MPa) can be applied in the mixing process, these effects should be examined in the final products.
- 2) Differences in thermal properties of wheat flour formulation need to be analyzed to determine noodle properties under standardized cooking or heating conditions.
- 3) Larger-scale product-oriented and consumer-oriented sensory tests need to be conducted. Differences in quality attributes for whole wheat precooked noodles can be detected by instruments instead of human sensory tests. Larger-scale experiments can confirm whether the correlation between instrumental data and human sensory data exists. Except for product characteristics, consumer's purchasing behaviors can be influenced by other factors like personal preference, advertisement and food packages (Cavicchi et al., 2010). Therefore, consumer-oriented tests can provide more understanding of product market positioning and promotional strategies.
- 4) Consumer feedback related to a pilot launching of the whole-wheat precooked alkaline noodle will need to be analyzed.

Related work need to be conducted in future study.

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APPENDICES

Table 24. Effects of Water Ratio on Boiled Noodle Texture (50% Whole Wheat, High Protein Refined Flour & Normal Mixing)

Water Ratio	35%	38%	41%
Hardness	1107.4±55.9 ^{NS}	1052.8±43.2	1070.3±21.9
Springiness	0.966±0.003 ^{NS}	0.974±0.054	0.975±0.025
Cohesiveness	0.543±0.012 ^{NS}	0.551±0.013	0.549±0.001
Chewiness	580.0±17.9 ^{NS}	563.9±21.1	573.4±27.8
Resilience	0.233±0.013 ^{NS}	0.242±0.001	0.247±0.008

Table 25. Effects of Water Ratio on Boiled Noodle Texture (100% Whole Wheat, High Protein Refined Flour & Normal Mixing)

Water Ratio	35%	38%	41%
Hardness	971.4±3.8 ^a	1079.6±54.0 ^b	949.5±21.9 ^a
Springiness	0.928±0.027 ^{NS}	0.895±0.011	0.907±0.033
Cohesiveness	0.480±0.009 ^{NS}	0.448±0.017	0.471±0.016
Chewiness	432.5±19.4 ^{NS}	432.2±0.2	405.3±8.6
Resilience	0.187±0.006 ^a	0.175±0.000 ^a	0.206±0.008 ^b

Table 26. Effects of Whole Wheat Ratio on Boiled Noodle Texture (35% Water, High Protein Refined Flour & Vacuum Mixing)

Whole Wheat Flour Ratio	0%	50%	100%
Hardness	1409.4±7.9 ^b	1116.6±0.9 ^a	1030.1±48.6 ^a
Springiness	0.992±0.000 ^b	0.950±0.003 ^{ab}	0.905±0.028 ^a
Cohesiveness	0.616±0.021 ^c	0.557±0.004 ^b	0.471±0.007 ^a
Chewiness	860.8±24.0 ^c	590.6±5.2 ^b	438.5±13.5 ^a
Resilience	0.282±0.008 ^c	0.244±0.000 ^b	0.189±0.001 ^a

Table 27. Effects of Whole Wheat Ratio on Boiled Noodle Texture (35% Water, Medium Protein Refined Flour & Normal Mixing)

Whole Wheat Flour Ratio	0%	50%	100%
Hardness	1052.9±37.6 ^b	1053.1±9.8 ^b	971.4±3.8 ^a
Springiness	0.988±0.011 ^{NS}	0.960±0.021	0.928±0.027
Cohesiveness	0.592±0.015 ^b	0.564±0.007 ^b	0.480±0.009 ^a
Chewiness	615.0±0.1 ^c	570.3±10.5 ^b	432.5±19.4 ^a
Resilience	0.263±0.017 ^b	0.260±0.007 ^b	0.187±0.006 ^a

Table 28. Effects of Whole Wheat Ratio on Boiled Noodle Texture (35% Water, Medium Protein Refined Flour & Vacuum Mixing)

Whole Wheat Flour Ratio	0%	50%	100%
Hardness	1417.0±45.3 ^c	1265.7±46.0 ^b	1030.1±48.6 ^a
Springiness	1.002±0.016 ^b	0.950±0.023 ^{ab}	0.905±0.028 ^a
Cohesiveness	0.591±0.004 ^c	0.541±0.005 ^b	0.471±0.007 ^a
Chewiness	838.3±19.5 ^c	649.5±34.0 ^b	438.5±13.5 ^a
Resilience	0.281±0.000 ^c	0.229±0.004 ^b	0.189±0.001 ^a

Table 29. Effects of Whole Wheat Ratio on Boiled Noodle Texture (35% Water, Low Protein Refined Flour & Normal Mixing)

Whole Wheat Flour Ratio	0%	50%	100%
Hardness	1051.5±7.7 ^b	1073.4±21.0 ^b	971.4±3.8 ^a
Springiness	0.994±0.003 ^b	0.934±0.001 ^a	0.928±0.027 ^a
Cohesiveness	0.583±0.011 ^c	0.542±0.004 ^b	0.480±0.009 ^a
Chewiness	609.0±8.2 ^c	543.2±15.7 ^b	432.5±19.4 ^a
Resilience	0.276±0.006 ^c	0.241±0.006 ^b	0.187±0.006 ^a

Table 30. Effects of Whole Wheat Ratio on Boiled Noodle Texture (35% Water, Low Protein Refined Flour & Vacuum Mixing)

Whole Wheat Flour Ratio	0%	50%	100%
Hardness	1354.4±34.7 ^b	1206.5±55.9 ^b	1030.1±48.6 ^a
Springiness	0.980±0.017 ^b	0.961±0.016 ^{ab}	0.905±0.028 ^a
Cohesiveness	0.585±0.006 ^c	0.535±0.010 ^b	0.471±0.007 ^a
Chewiness	776.0±41.5 ^c	619.4±6.9 ^b	438.5±13.5 ^a
Resilience	0.287±0.000 ^c	0.237±0.003 ^b	0.189±0.001 ^a