EVALUATING THE AGRICULTURAL, HISTORICAL, NUTRITIONAL, AND SUSTAINABLE USES OF PULSE GRAINS AND LEGUMES

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Chapter One

DIETARY GUIDANCE FOR PULSES: THE CHALLENEGE AND OPPORTUNITY TO BE PART OF BOTH THE VEGETABLE AND PROTEIN FOOD GROUPS

The text of this chapter is a reprint of the material as it appears in, “Dietary guidance for pulses: the challenge and opportunity to be part of both the vegetable and protein food groups,” previously published by *Annals of the New York Academy of Sciences.*[1] The content has been reformatted to meet university guidelines.

Summary

Pulses are a dry, edible variety of beans, peas, and lentils that have been consumed for 10,000 years. Pulses are rich in plant-based protein and fiber, as well as micronutrients such as iron and potassium. The satiating effect of both fiber and protein assist in managing weight and combating obesity. The high fiber content and low glycemic index of pulses aid people with diabetes in maintaining blood glucose and insulin levels. Pulse consumption may improve serum lipid levels to reduce the risk of cardiovascular disease. Pulses developed as both a member of the protein and vegetable food group as a result of its high content of plant-based protein and dietary fiber. The last two revisions of the Dietary Guidelines saw the transformation from the MyPyramid, "Meat and beans group," to the MyPlate, "Protein Foods Group," a nutrient name, rather than a food source. Research suggests that consumers better identify with food source examples rather than nutrient names. The 2015 Dietary Guidelines also came with a new area: sustainable diets. Encouraging the consumption of sustainable food sources, like pulses, is imperative to ensuring a secure, healthy food supply for the U.S. population over time and for future generations.

Introduction

Pulses are annual crops, whose life cycle, from germination to the production of seeds, is terminated after 1 year, and members of the Leguminosae family.[2] Pulses are estimated to have been consumed for at least 10,000 years and they are one of the most extensively used foods in the world.[3]

Historically, the consumption of legumes and other plants was thought to prevent illness and disease ranging from headache to heart disease.[4]

Today, in the developed world, many consumers may find it challenging to include pulses in their daily diet owing to a lack of proper preparation and cooking skills.[5] Pulses are part of more than one food group in the Dietary Guidelines for Americans 2015-2020 (DGAs): the protein and the vegetable groups. A food group is a collection of foods that share common nutritional and biological compositions. Under the dietary guidelines, recommended dietary serving sizes are provided for each food group.[6] The vegetable food group is comprised of plant-based dark-green vegetables, red and orange vegetables, starchy vegetables, beans and peas and other vegetables and the serving size for each subgroup of vegetable varies depending on the diet pattern and caloric intake of the individual.[6] The protein food group comprises protein-rich meat, poultry, seafood, beans and peas, eggs, processed soy products, nuts and seeds and the recommended serving size is also dependent upon the diet pattern and caloric intake of the consumer.[6] With pulses being part of both the protein and vegetable groups because of their nutritional composition, confusion and misinterpretation of dietary guidelines may further discourage pulse consumption. The United Nations (UN) declared 2016 the International Year of Pulses, which helps facilitate discussion on the nutritional composition, health benefits, dietary guidance, and sustainability of pulse grains.[7]

Definition of Foods Referred to as Pulses

Pulses are defined by the Food and Agricultural Organization (FAO) of the United Nations as, “limited to crops harvested solely for dry grain, thereby excluding crops harvested green for food (green peas, green beans, etc.), which are classified as vegetable crops.”[2] Pulses also exclude crops such as soybeans and groundnuts, which are used primarily for oil extractions, and leguminous crops used solely for sowing purposes, such as alfalfa. The FAO acknowledges 11 principal pulses: dry beans (e.g., kidney, lima, adzuki, butter, mungo, black gram, scarlet runner, and golden beans) dry broad beans (such as horse, broad, and field beans), dry peas, chickpeas (including garbanzos), dry cowpeas (including black-eyed peas/beans), pigeon peas, lentils, bambara beans, vetches, lupins, and minor pulses (jack, winged, sword, guar, velvet, and yam beans).[2,8]

Nutritional Composition

Pulses are moderately low in energy density, offering an average of 1.3 kilocalories per gram.[9] Additionally, pulses are high in fiber (~7g/0.5c serving), with the majority containing both insoluble and soluble fibers.[10]Pulses are very low in fat (0.8-1.5%) when compared to oilseeds such a soybean, canola, and flax; they are beneficial sources of mono- and polyunsaturated fat, and contain plant sterols.[11–15] Pulses are characterized as a good source of digestible protein, providing an average of 7.7g/0.5c serving and 17-30% of the dry weight of pulses.[9,16] Pulses are abundant in the essential amino acids lysine (~64 mg/g of protein) and threonine (~38mg/g of protein), which are typically low in other plant-based protein sources; however, pulses are low in other amino acids including methionine, tryptophan, and cysteine.[15–17] Since pulses are lacking in these essential amino acids, they are considered to be lower quality sources of protein.[8] Therefore, it is recommended that pulses be consumed in conjunction with other plant-based and/or animal protein sources that contain the limiting essential amino acids to form a meal or diet containing a high quality protein mixture. Pulses also contain a high carbohydrate content (~50-65%) and 22-45% of pulse grain weight from starch, depending on the source, cooking, and processing.[18,19] Slowly digestible starches, resistant starches, protein content, and the protein-starch matrix have been attributed to the low Glycemic Index (GI) of pulses, which ranges from approximately 29 to 48.[9,20] Table 1-1 outlines the calorie, protein, fat, carbohydrate and fiber content of various pulses per 100 grams.

Pulses are rich sources of many micronutrients, including selenium, thiamin, niacin, folate, riboflavin, pyridoxine, potassium, zinc, vitamin E, and vitamin A.[11,12,14] Pulses can also be a good source of iron depending on the pulse variety. For example, cooked white beans (3.70mg iron/100g) contain almost three times as much iron as split peas (1.29 mg iron/100g)(Table 1-1). Since pulses are a plant-based protein, bioavailability of nutrients may be a limitation. Iron is a nutrient of concern for both adolescent and premenopausal females and, unfortunately, the bioavailability of nutrients, such as iron, from plant-based diets is usually lower than a diet containing animal-based food sources.[21] Iron, as well as calcium and protein, from a vegetarian diet is less bioavailable due to the presence of phytates. Iron found in pulses is bound to phytates, which reduces iron adsorption in the body.[22–24] Pulses are also a good source of potassium, a mineral associated with a lower risk of metabolic syndrome and a regulator of blood pressure.[25] Potassium has been recognized by the 2015 Dietary Guidelines Advisory Committee as a shortfall nutrient that is underconsumed in the U.S. population.[21] Increased consumption of pulses could assist in increasing the overall U.S. population's potassium consumption. Eating a variety of foods is beneficial to maintaining a balanced diet, and the inclusion of pulses as a part of a healthy diet may improve overall micronutrient consumption.[21]

Health Benefits

Consumption of pulses is encouraged in the diets of the general population, as their nutrient profile can have a positive health impact.[7,11,21] Nearly half of all adult Americans have one or more preventable chronic diseases related to physical inactivity or poor diet quality including cardiovascular disease (CVD), diabetes, and hypertension.[26] Nonnutrient and nutrient components of pulse grains have been linked to a reduction in the risk of obesity, CVD, and diabetes, which may help reduce the incidence of preventable chronic diseases among groups such as the American population.[11,15,27]

The high fiber content of pulses has been shown to result in an increase in satiety.[28–30] Satiety, brought on by hormonal and neural signals within the body, is the sensation of fullness an individual experiences after consuming a meal.[31] The sensation of fullness is enhanced by increased gastric distention and a slowed rate of gastric emptying into the intestine, which are results of the gelling effect of viscous soluble fibers.[32] In addition, fiber fermentation within the colon increases satiety-related hormone release, resulting in an increased perception of fullness.[32] A meta-analysis by Howarth *et al.* analyzed the results of more than 50 intervention studies that evaluated the relationship between body weight, energy intake, and fiber intake. It was determined that increasing fiber intake by 14 g per day was associated with a weight loss of approximately 2 kg and a 10% decrease in energy intake over a 4-month period.[33] Similar to fiber, protein is also a component of pulse grains that affects satiety. Protein is the most satiating macronutrient and, when consumed, elicits the secretion of satiety-related hormones in the small intestine such as cholecystokinin, peptide YY, and glucagon-like peptide 1.[34] Protein and fiber both contribute to satiety and may also contribute to decreasing the occurrence of obesity by interfering with caloric intake.[32] With pulses being rich sources of both protein and fiber, they are ideal candidates for increasing satiety, reducing calorie intake, and managing body weight over time.[35] Modest weight loss has been shown to decrease the risk of developing type 2 diabetes and CVD.[36]

Evidence suggests that the consumption of pulses may improve lipid profiles, thus reducing atherosclerosis and overall risk of CVD.[36] Many growing bodies of research suggest that a pulse-rich diet decrease two leading factors of CVD, total serum triglycerides and cholesterol.[27,37–40] Both plant sterols and mono- and polyunsaturated fats, which are present in pulses, lower low-density lipoprotein (LDL) and total cholesterol and increase high-density lipoprotein (HDL).[13–15] Bazzano *et al.* conducted a meta-analysis on 9,632 men and women who participated in the First National Health and Nutrition Examination Survey Epidemiologic Follow-up Study (NHEFS) and evaluated the effect of pulse consumption on cholesterol levels.[41] The study indicated a significant inverse relationship between legume intake and risk of coronary heart disease (CHD) and suggest that a diet rich in pulses reduced both total and LDL cholesterol.[41] Similarly, Finley et al. conducted a study on 40 adult men and women aged 18-55 years of age for a 16-week period and reported that consuming a one-half cup serving of cooked dry beans daily reduced total cholesterol by 8%.[38] While much evidence supports an improved lipid profile with pulse consumption, other studies assessing blood pressure, platelet activity, and inflammation also support the relationship between consuming a diet rich in pulses and CVD risk reduction.[40,42–45]

Pulses are an ideal food choice for individuals with diabetes because of their low GI and their high fiber content.[9,10,20] Sievenpiper et al. conducted a systematic review and meta-analysis of 41 randomized controlled experimental trials and found that low GI and high fiber (such as pulses) diets improved glycemic control by lowering fasting blood glucose and insulin levels, glycosylated blood proteins, and fasting blood glucose.[46] Additionally, Jenkins *et al.* conducted a study on 121 participants with type 2 diabetes mellitus. Participants were asked to either consume a low-GI legume diet or a diet high in insoluble fiber such as whole-wheat products for 3 months. The study found the reduction in hemoglobin A_{1c} (HbA_{1c}) values was greater in low GI legume diets than in whole-wheat fiber diets by -0.2%. Jenkins *et al.* concluded that legumes as part of a low-GI diet improved glycemic control.[47] Consumption of high GI foods leads to an elevated postprandial blood glucose and insulin response, which is not ideal for individuals with diabetes.[48] Therefore, consuming pulses as part of a low GI diet may help lower the risk of diabetes-related complications.[47] Additionally, insulin sensitivity and glucose tolerance are improved with the presence of resistant starches in pulses, which also helps reduce risks associated with diabetes.[49]

Evolution of Dietary Guidelines

As aforementioned, pulses are comprised of a rich nutritional profile that may assist in the prevention of obesity, CVD, and diabetes. The nutritional composition of pulses has also afforded pulses the opportunity to be categorized in both the vegetable and protein groups in the Dietary Guidelines for Americans. Historically, pulses have not always been explicitly considered in both food groups. Pulses, usually considered as either beans and peas or legumes in the DGA, have shifted positions within food groups from the 1992 Food Guide Pyramid, to the 2005 MyPyramid, to the current 2011 MyPlate. The advancement of nutritional understanding, the reformation of the dietary guidelines and the evolution of new food guidance tools mark the journey of the pulse through the food groups.

In 1992, the United States Department of Agriculture (USDA) officially released the Food Guide Pyramid after having conducted studies to determine the ideal graphic for effective food guidance.[50] On the Food Guide Pyramid graphic, pulses fell in to the protein group, which was labeled as the, "meat, poultry, fish, dry beans, eggs, and nuts," group.[51] In the 1995 Dietary Guidelines for Americans, it was first explicitly written that dry beans, peas, and lentil could be listed in either the, "meat and bean group or vegetable group," but not both.[52] Though not listed on the Food Guide Pyramid diagram, legumes were also listed as food sources in the vegetable group in the supplementary reading materials that accompanied the Food Guide Pyramid graphic of 1992.[53] Although additional reading materials concerning the Food Guide Pyramid were available, many people did not utilize these documents. Instead, the Food Guide Pyramid diagram was often used alone, leading to misinterpretation and confusion among users. The Pyramid was contested for combining red meat with foods low in saturated fat, fish, poultry, nuts, and legumes; not distinguishing whole grains from refined grains; and not defining unsaturated fats as separate from saturated fats.[54]

The drawbacks of the Food Guide Pyramid of 1992 led to the development of a more simplistic food guidance diagram: MyPyramid.[55] The new illustration was introduced in 2005 along with the Dietary Guidelines for Americans of 2005. In the 2005 DGAs, pulses were listed as a serving in either the "meat and beans" group or the "vegetable" group, but not both. The MyPyramid symbol did not include detailed diet guidance; users needed to access dietary guidance materials via MyPyramid.gov. The simplicity of MyPyramid was designed to engage users through their participation in the online programs provided on MyPyramid.gov.[56] Online, users could enter their anthropometric details to receive personalized dietary guidance. The inclusion of the personalized diet plan, MyPyramid Tracker (to track diet and physical activity over time), informational food materials, and promotion of physical activity were all online resources intended to help Americans live a healthy lifestyle.[57] However, as with the Food Guide Pyramid, MyPyramid faced opposition. Experts were disappointed that the grain recommendation did not exclusively promote whole grains, the healthfulness of unsaturated fat was not addressed, MyPyramid.gov did not include information on healthy body weight (most individuals are not aware of their healthy weight range), and the underprivileged may not have Internet access to utilize the online guidance materials.[58] Although some experts believed MyPyramid succeeded in emphasizing physical activity and was less complicated than the Food Guide Pyramid of 1992, experts such as Walter Willett, MD, professor of epidemiology and nutrition at the Harvard School of Public Health, Boston, criticized, “unfortunately, people will need to go elsewhere for better information.”[58]

Due to the many limitations, the MyPyramid guidance tool was short-lived, with MyPlate replacing MyPyramid in 2011. The MyPlate diagram features the Fruit, Grain, Vegetable, Protein Foods, and Dairy Groups depicted as a plate and cup. Interestingly, the previously named, “meat and beans,” group was changed to the Protein Foods Group. Unlike other groups of MyPlate, the Protein Foods

Group is named after a nutrient rather than a food type. Haven et al. suggest that the group was renamed to, "teach consumers that protein is available in a variety of foods."[59] However, a consumer research study for educational messages revealed that consumers understand food-based names better than nutrient terminology.[60] Though the food group name changed, the inclusion of pulses in both the Protein Foods and Vegetable Group did not. ChooseMyPlate.gov recognizes that pulses are an excellent source of plant proteins and iron and zinc (similar to meats, poultry, and fish) as well excellent sources of dietary fiber, folate and potassium (comparable to foods in the Vegetable Group).[6] Papanikolaou found that consumers of beans had better overall nutrient intake of fiber, potassium, magnesium, and iron than did non-consumers, suggesting that plant-based protein sources improve dietary quality.[42] On the other hand, animal products provide higher quality and quantity protein than do plant foods; therefore, individuals should consume a variety of both plant- and animal-based protein food sources to meet nutrient recommendations.[21,61] ChooseMyPlate.gov also explains that pulses should be considered a protein if the total amount consumed does not meet or exceed the suggested intake from the Protein Foods Group. Alternately, pulses should be considered as part of the bean and peas subgroup in the Vegetable Group if the amount consumed exceeds the suggested intake level in the Protein Foods Group.[62] This way of considering pulses is applicable for individuals who do no consume adequate amounts of meat, poultry, and fish, such a vegetarians.

The Importance of Sustainability and Increasing Pulse Consumption

The Dietary Guidelines Advisory Committee commented on the sustainability aspect of diets for the first time in 2015.[21] Sustainable diets recognize the impact of food and beverages on environmental outcomes, such as farm to plate to waste disposal. Food sustainability is imperative to ensuring a secure, healthy food supply for the U.S. population over time and for future generations. Global food production is responsible for over 70% of fresh water use, 80% of deforestation, and up to 30 percent of greenhouse gas (GHG) emissions.[63] Energy costs, population growth, climate change, and shifts in dietary patterns will put pressure on land use, soil quality, and sustainable water sources in the future.[64]

The Scientific Report of the 2015 Dietary Guidelines Advisory Committee concluded that a diet high in plant-based foods and lower in animal-based foods promotes health and is associated with less environmental impact than an average U.S. diet. Thus, a diet rich in pulse grains could help promote sustainable energy, water, and land use.[21] Pulses such as lentils and peas support a lower carbon footprint because they are nitrogen-fixing crops requiring very little, if any, nitrogen fertilizer.[65] Nitrogen-fixing pulse crops can be grown in rotation with other crops to lower GHG emissions in comparison to nitrogen-fertilizer systems.[66] Padhan et al. further explored GHG emissions by analyzing global dietary patterns that varied by food and energy content. The dietary patterns were measured per capita and sorted into four categories: intake of low, moderate, high, and very high kcal diets. The dietary patterns were then compared to corresponding GHG emissions. Low-energy diets were comprised of more than 50% cereals or more than 70% cereals, starchy roots, and pulses and contained less than 2,100 kcals/cap/day. Very high calorie diets, which were composed of high amounts of meat and more than 2,800 kcal/cap/day, exhibited high total per capita CO_2 emissions. The high CO_2 emissions are associated with the developed world and can be attributed to high carbon intensity and high intake of animal products. Conversely, low-energy diets had the lowest total CO_2 emissions per capita.[67] Since pulses are a low-energy food, it can be deducted that the pulse carbon footprint would be much lower compared to a meat food source.

Pulses have the potential to significantly reduce GHG emissions yet their consumption remains low. The 2015 Dietary Guidelines suggest a legume serving size of ½ cup (~90 grams) and for a Healthy U.S.-Style Eating Pattern.[6] The Data from the National Health and Nutrition Examination Survey (NHANES) 1999-2000 revealed that adults are consuming an average of 0.1 to 0.3 servings of legumes per day, which is one third or less than the recommendation.[68] Mitchell *et al.* also found that only 7.9% of the U.S. population from 1999 to 2002 consumed beans, peas, or lentils on any given day with refried beans, pinto beans, baked beans, chili and Hispanic dishes being the main sources.[69] Though pulse consumption within the United States has been low, recent literature suggests that culinary education may assist in increasing pulse consumption. Confidence in cooking, health outcomes, an increase in time devoted to cooking, an enhanced approach toward cooking and consumption of healthy foods have all been attributed to culinary education.[70–72] Literature has established a strong correlation between time passed in the kitchen and mortality rate and between improved dietary quality and healthy food preparation skills.[73,74]

As a result of the influence of cooking on health, it has been recommended that nutrition education focus on developing culinary skills such as food storage, food preparation, grocery shopping, and meal planning rather than only nutrients.[75–77] Establishing knowledge of cooking techniques may help the U.S. population become familiarized with skills that promote the preparation of legumes. Becoming engaged in cooking skills may help Americans learn to soak, rinse, boil, freeze, and puree legumes along with incorporating legumes into their everyday lifestyle. Polak *et al.* offer not only legume recipes, but practical suggestions for increasing pulse consumption such as: always have a kitchen pantry stocked with lentils since they are easily prepared; purchase legumes even if there is no foreseeable or intended use; save time by cooking more lentils than necessary and freezing the leftovers; soak a double portion of legumes at once and freeze the remaining soaked legumes; eat homemade legume salads at work for lunch; and use leftover legumes in at soup or stew.[5] Incorporating legume consumption into everyday life may help Americans learn to enjoy the flavor, aroma and texture of legumes and while also inadvertently offering nutritional, health and environmental benefits.

Conclusion

Pulses contain a nutrient-dense profile, which offers many health benefits for consumers. While research supports the beneficial effects of pulses on cardiovascular health, diabetes, and obesity, more research must be conducted to clarify results. In addition, the unique nutritional composition of pulses allows them to be considered in both the protein and vegetable food group. Though the nutrient profile of pulses warrants pulse inclusion in both groups, users may misunderstand or misinterpret dietary recommendations. Further education regarding recommended pulse consumption is needed to improve consumer understanding and increase consumption. Dietary consumption of pulses in the United States is currently low, especially among non-vegetarians. Orlich et al. conducted a study on more than 89,000 men and women over a five-year period and found that non-vegetarians consumed on average less legumes (52 g/day) than vegans (84 g/day) and pesco-vegetarians (75 g/day).[78] The 2015 Dietary Guidelines suggest a legume serving size of ½ cup (~90 grams) and for a Healthy U.S.-Style Eating Pattern and a Healthy Mediterranean-Style Eating Pattern, 1½ cups/week is recommended for a 2,000 calorie diet.[6,79] The dietary guidelines not only promote an increase in pulse consumption but diets such as the Healthy U.S.-Style Eating Pattern and Healthy Mediterranean-Style Eating Pattern which promote diets rich in wide variety of foods.[6] These diets promote the consumption of foods such as legumes, dark green, red, and orange vegetables, fruits, whole grains and seafood, all of which contribute to a balanced diet, while limiting the consumption of high calorie, low nutrient dense foods.[6]

Participating in culinary education may increase legume consumption resulting in not only beneficial dietary impacts but environmental impacts as well. Increased consumption of plant-based protein from pulses could help decrease the carbon footprint associated with animal-based proteins.

CHAPTER ONE TABLE

Table 1-1. Nutritional composition of various pulses per 100 grams

	Calories	Protein (g)	Fat (g)	Carbohydrate (g)	Fiber (g)	Iron (mg)	Potassium (mg)
Adzuki beans, cooked	128	7.52	0.10	24.77	7.3	2.00	532
White beans, cooked	139	9.73	0.35	25.09	6.3	3.70	561
Small white beans, cooked	142	8.97	0.64	25.81	10.4	2.84	463
Lima beans, cooked	115	7.80	0.38	20.88	7.0	2.39	508
Great northern beans, canned	114	7.37	0.39	21.02	4.9	1.57	351
Pink beans, cooked	149	9.06	0.49	27.91	5.3	2.30	508
Black beans, cooked	132	8.86	0.54	23.71	8.7	2.10	355
Black turtle beans, cooked	130	8.18	0.35	24.35	8.3	2.85	433
Refried beans, canned, traditional	89	4.98	2.01	13.55	3.7	1.44	319
Pinto beans, cooked	143	9.01	1.11	15.41	9.0	2.09	436
Kidney beans, cooked	127	8.67	0.50	22.80	6.4	2.22	403
Navy beans, cooked	140	8.23	0.62	26.05	10.5	2.36	389
Yellow beans, cooked	144	9.16	1.08	25.28	10.4	2.48	325
Lentils, cooked	116	9.02	.38	20.13	7.9	3.33	369
Chickpeas, cooked	164	8.86	2.59	27.42	7.6	2.89	291
Yardlong beans, cooked	118	8.29	0.45	21.09	3.8	2.64	315
Cranberry (romano) beans, cooked	136	9.34	0.46	24.46	8.6	2.09	387
Split peas	118	8.34	0.39	21.10	8.3	1.29	362

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Chapter Two

INVESTIGATING SEVENTEEN DIFFERENT PULSES AND LEGUMES: A LITERATURE REVIEW

SUMMARY OF THE SEVENTEEN PULSES AND LEGUMES INVESTIGATED

Introduction

Of the seventeen legumes investigated, all are considered pulses, which are annual crops harvested for their dry grains.[1,80,81] Pulses also have anywhere between 1 and 12 grains or seeds of different sizes, shapes, and colors per pod.[80,82] Pulses do not include fresh beans and peas or legumes such as soybeans or peanuts, which are used in oil extractions.[80] The reviewed pulses include: black, adzuki, navy, pinto, kidney, mayocoba, mung, faba, and bambara beans; green, yellow, and pigeon peas; red and green lentils; chickpeas, cowpeas, and lupins.

Background and uses in food

Pulses are grown all over the world, from Canada to Australia, with some pulse varieties thriving in areas where other pulses may not thrive. For instance, while the navy bean may thrive in temperate climates, the cowpea grows well in semi-arid regions.[80,83] Just as pulses flourish in varying regions around the world, they also are prepared and consumed in different ways. In Japanese culture, the adzuki bean is, “the king of beans,” as it is often used as red bean paste and incorporated into confections, soups or stews, and rice dishes.[80,82,84] Alternately, lupins are preserved via pickling or soaking in a brine with the skin either removed or intact in parts of Europe and South America.[80] Another popular use for different types of pulses, including pigeon peas, chickpeas, or red lentils, is in the preparation of *daal*, which is a combination of spices, such as curry or turmeric, and pulses cooked to create a thick, stew-like dish which is popular in Asia, including India[80]

Nutrition and health benefits

Nutrition

Pulses have varying, yet impressive nutritional profiles. The U.S. Department of Agriculture and the Food and Agriculture Organization of the United Nations report that the pulses reviewed contain between 6.8 and 15.6 grams of protein per 100 grams of cooked pulse grains and between 2.8 and 10.8 grams of fiber per 100 grams of cooked pulse grains.[12,85] While the lupin boasts 15.6 grams of protein, it only contains 2.8 grams of fiber. Similarly, while the Bambara bean contains 10.8 grams of fiber, it only contains 6.9 grams of protein, the second lowest of the pulses and legumes reviewed. Alternately, the mayocoba bean contains 9.2 grams of protein and 10.4 grams of fiber and the pinto bean contains 9.0 grams each of fiber and protein, indicating that these two pulses contain desirable levels of both protein and fiber.[12,85] Figures 2-1 and 2-2 summarize the protein and fiber content of each pulse investigated. In addition to protein content, protein digestibility corrected amino acid scores (PDCAAS) were also collected for each individual pulse, with multiple scores not being found.[86] A majority of scores were obtained via PulseCanada while others were found in research or as a flour blend. Some research also suggests that different forms of processing may affect the PDCAAS of various pulses.[86,87] In conclusion, more research must be conducted to make PDCAAS scores of pulse grains more widely available.

Health benefits

Not only does research indicate that pulses are low in fat and sodium, cholesterol- and gluten-free, and rich in protein, fiber, iron, folate, and potassium, but other health benefits have also been attributed to pulse grains.[12,80,85] A majority of pulse grain research indicates that pulses have the potential to be anti-inflammatory, anti-carcinogenic, anti-atherogenic, high in antioxidant activity, and many other health-enhancing attributes.[88–90] While there are also anti-nutritional components associated with pulse grains, research indicates that a majority of them can be reduced or eliminated upon soaking and cooking.[91,92] In addition to health benefits, the incidence of allergic reactions among pulse grain varieties was also investigated. While some pulses were more likely than others to illicit allergic responses, the lupin was of greatest concern as it is known for its cross reactivity with peanuts and it is identified as one of the 14 major allergens by the European Union's Food Standards Agency.[93–95]

Processing

Various forms of processing were investigated; however, the most consistent form of processing across all varieties of pulses reviewed included soaking and cooking legumes in water or a solution.[80,96] Other forms of processing investigated included fermentation, drying, milling, or extrusion. Extrusion was investigated, in some instances, for its ability to use raw beans, grind them into flour and extrude them at low heat, continuous-use shear force under high pressure.[97,98] This process eliminated the soaking, blanching, cooking and drying steps, which resulted in reduced water and energy usage and the elimination of waste and antinutritional factors.[97,98] Extrusion was also used extensively among patent information involving the processing of various pulses and legumes, particularly in the manufacturing of pulse-based snack products.[99] Fermentation of pulses was also considered as a means to decrease oligosaccharide content, increase probiotic activity when added to yogurt, enhance emulsifying power, improve overall nutritional quality, and many other uses.[100–102]

Production

Pulse production has been steadily rising over the past few decades. Between 1990 and 2014, the world has seen an increase of 31% in global pulse production.[80] In 2014, total pulse production was 77.6 million tons with multiple regions seeing annual growth.[80] North America alone has an annual growth rate in pulse production of 7.7%, followed by growth rates in Africa, South America, and Asia.[80] While North America's growth rate is the highest, various regions of the world, including India, Canada, Myanmar, China, and Nigeria are responsible for 50% of world production of pulses.[80] While overall global production statistics are available, for specific pulse varieties, the data is limited.

Conclusion

While pulse production has been steadily increasing, more information concerning appropriate processing techniques must still be investigated to access pulses' full potential. Pulses are abundant in health and nutrition benefits; however, literature is lacking in both production quantity information and protein digestibility information for specific pulse grains and, therefore, more research must be conducted.

BLACK BEANS

Background

Introduction

Phaseolus vulgaris, also known as the common bean, includes black beans in addition to several other bean varieties. *P. vulgaris* originated in North America and is primarily consumed in the western society as a green vegetable or dried and used to produce canned baked beans.[83,103,104] In both Latin America and Africa, *P. vulgaris* is a main source of protein, vitamins, minerals and fiber and is considered a dietary staple for individuals of those regions.[103,104] While carbon dating of *P. vulgaris* suggests that the crop was domesticated by approximately 5000 B.C. in Mexico, the crop now has wide distribution among the Americas down to northwestern Argentina.[103–105] During the 16th century, the Spanish and Portuguese carried *P. vulgaris* to Europe where the species eventually spread across the world.[103] *P. vulgaris* is also known for being grown best in temperate climates and for being nitrogen fixing.[83,103]

Uses in food

Black beans are consumed in many countries world-wide and also come by other names such as turtle beans, preto, Zaragoza, and frijoles negros.[106] China has acknowledged the benefits of black beans since the 16th century with recognition of the black bean even today with the use of black bean sauces and fermented products. In Chinese meals, the fermented products, *In-yu, a black bean sauce,* and *tou-si* or *in-si*, the dried mash of black bean sauce, are used frequently in cuisine.[107,108] In India, a dish known as wari may be prepared with fermented black beans. The fermented black beans are then formed into a small hollow cake measuring 2-30 cm^2 across and weighing 1-30 grams.[109] Another Indian dish, known as wari muth may also be prepared, which consists of slowly cooking black beans in a variety of seasonings, including garam masala.[110] A Portuguese dish, known as feijoada, consists of a black bean stew made with beef and pork.[111] This dish has been consumed in places such as Portugal, Brazil, India and Mozambique. It is most common for this stew to be made of black beans when prepared in Brazil.[111] Another cuisine made in both Brazil and West Africa is known as acarajé.[112] This dish is typically made from peeled black beans that are seasoned and then formed into a ball or a scone shape and deep-fried.[112] Another traditional use for black beans is in Mexican dishes, such as burritos, Dominican dishes, such as rice and beans, and in Cajun and Creole cuisines.[113]

Nutrient Composition and Health Benefits

Nutrition

Black beans have an impressive nutritional profile. The United States Department of Agriculture reports that black, mature beans that are cooked in boiling water without salt contain 8.70 grams of fiber and 8.86 grams of protein per 100 grams of black beans.[12] Table 2-1 lists the nutritional composition of 100 grams of cooked, mature black beans while Table 2-2 lists the nutritional composition of 100 grams of raw, mature black beans. Black beans are very low in oil content and are an enticing source of protein for both extraction and modification as their protein content is approximately 20-25%.[103,114] Evangelho *et. al* studied the effects of hydrolysis on the nutritional and functional properties of black bean protein concentrates and their potential value to the food industry, which is discussed further in the processing section.[114] Additionally, PulseCanada reports that the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of black beans is 0.53.[86] Additional PDCAAS information on the black bean and black bean/grain flour mixes can be observed in Table 2-3.

Starch composition

In all starches, amylopectin is the primary constituent.[115] With an average molecular weight of approximately 10^7-10^9, amylopectin is comprised of linear chains of α (1–4)-D-glucose attached to α (1-6) linkages, forming double helices.[115,116] The other major component of starch is amylose, whose molecular weight ranges from 1×10^5 to 1×10^6.[19] Depending on the starch, the ratio of amylose to amylopectin varies greatly.[19] Table 2-4 outlines the composition of black bean starch as well as characteristics of amylose from a black bean. The extensive range of values for total amylose content may be due to under or overestimating the amount of amylose as a result of failing to remove lipids and/or from inaccurately identifying amylose from a an amylose/amylopectin mixture from a standard curve.[19] Other reasons for the wide amylose range include the use of alternating methods for the detection of amylose content, difference in black bean cultivars, and the physiological condition of the black bean seed.[117–119] Table 2-5 displays the amylose content of two black bean cultivars, CDC nighthawk and black jack.[120] Additional characteristics of black bean starch includes the swelling factor and power, amylose leaching and gelatinization parameters, which can be observed in Tables 2-6 and 2-7.[19]

Fermentation benefits

In 2006, I-Hsin Lee and Cheng-Chun Chou explored the possibility of increasing the nutrient profiles of black bean kojis fermented with filamentous fungi.[121] Results indicated an increase in aglycone, a bioactive isoflavone which has been linked to the prevention of hypercholesterolemia, postmenopausal syndrome, osteoporosis, and cancer.[122–125] In another study, Xu and Chang investigated the effects of thermal processing on the antiproliferative and cellular antioxidant properties and phytochemical content on black beans.[126] A significant decrease in total phenolic content, phytic acid content, total saponin content was observed. Researchers also discovered that raw black beans possessed cellular antioxidant activities, which was decreased or completely removed upon exposure to thermal processing. Ant-proliferation capabilities against human gastric and colorectal cancer cells were observed under specific doses of raw black bean hydrophilic extracts. Upon cooking, beans lost their anti-proliferation and cellular antioxidant capabilities which indicated that different modes of processing may be best suited to preserve the positive health benefits of black beans.[126] Another study conducted by Elizabeth Rondini and Maurice Bennik explored the effect of a black bean flour diet in azoxymethane-induced colon cancer in rats.[127] Rats were injected with azoxymethane and either fed a control, black bean flour, or a soy flour-based diet. At the conclusion of 31 weeks, microarrays were completed on the RNA of the distal colonic mucosa. Results indicated that black bean-fed rats showed a lower incidence of gene activation by azoxymethane, indicating that the black bean flour may inhibit colon carcinogenesis by reducing inflammation, protecting the mucosal barrier and moderating cellular kinetics.[127]

Antinutritional factors

P. vulgaris is known for containing toxic factors, as are many other legumes. In the case of *P. vulgaris,* haemagglutinins are toxic, destroying red blood cells in animals if the raw seeds are consumed.[103] In addition, *P. vulgaris* is known for containing antinutritional compounds that are able to limit the bioavailability and digestibility of nutrients. Such compounds include polyphenols, flavonoids, and protease inhibitors.[128]

Allergenicity

While there are numerous allergies associated many pulse grain varieties, the literature does not indicate that allergic responses are overly present with the black bean variety. On the other hand, there are legumes within the same species as the black bean (*Phaseolus vulgaris),* which have been identified as potentially eliciting an allergic response. These legumes include the wax bean, also known as either the French bean, green bean or haricot bean, and the red kidney bean.[129]

Processing

Patent

US publication number 20130202774 A1 describes a method for extruding a legume snack food into a puff product.[99] This patent begins with dried legume powder, which may include that of a black bean that is then combined with starch, extruded and then created into a shape. The patent describes the puff product to be similar to that of a product marketed under the name Cheetos™, yet would be made of a bean-based product. The patent states that the desired shape of the finished puff product would resemble that of a pea pod, reminiscent of the origin shape of the legume. The goal of this product would be to offer 1/3-1/2 of a serving of vegetables per 1 ounce serving size of the puff legume product.[99]

Hydrolysis

Evangelho *et. al* published a study in 2017 evaluating the effects of hydrolysis on the functional, thermal, physicochemical, and nutritional properties of black bean protein concentrate.[114] The black beans used had a nutritional composition of 23.1% protein, 4.3% ash, 1.2% fat, 48.6% starch and 22.8% fiber. The black bean protein concentrate was extracted resulting in a protein content of 81.6%. The black bean protein was then either hydrolyzed with pepsin enzyme or alcalase enzyme. After completing analysis on the hydrolyzed black bean protein, researchers concluded that black bean protein hydrolysates treated with alcalase showed higher hydrophobicity than those treated with pepsin enzyme. In addition, hydrolysates treated with alcalase did not undergo a phase separation during 30 days of storage in comparison to the hydrolysates treated with pepsin. Alcalase-treated hydrolysates not showing a phase separation indicate that the emulsifying power is stronger, which may be a useful finding for the food industry when emulsion stability is desired in food or liquid applications. Conversely, the black bean protein hydrolysates obtained from pepsin showed a much faster rate of hydrolysis in comparison to the black bean protein treated with alcalase.[114] Additionally, under different methods, both the protein concentrate and hydrolysates treated with either alcalase or pepsin showed good antioxidant activity. With favorable antioxidant activity, the uses of black bean protein concentrate and hydrolysates as dietary protein supplements or bioactive food ingredients could be explored.[114]

Process of fermentation

Oligosaccharides are generally defined as a carbohydrate comprised of 2-20 monomeric units and they include soluble carbohydrates known for their function as dietary fiber.[130] Found within the group α-galacto-oligosaccharides is the raffinose family of oligosaccharides (RFO), which are relatively abundant in pulses and legumes.[130,131] Raffinose, stachyose, and verbascose are the oligosaccharides in the raffinose family which are most widely researched in relation to pulses.[10] As a result of its role in causing flatulence, the RFO in legumes has been focused on with the hope of reducing the total RFO content in pulses.[132] Fermentation of raffinose, stachyose, verbascose, soluble fiber, and resistant starch in the colon generate the gastrointestinal discomfort and flatulence that many individuals experience.[133] Studies have shown that initiating natural fermentation in legumes may decrease the content of raffinose, stachyose, verbascose, resistant starch, and soluble fiber and subsequently decrease the action of the intestinal microbial flora causing the fermentation process.[134] In addition, fermentation may increase bioavailability of carbohydrates via the break down of raffinose, stachyose, and verbascose by microorganisms to produce di- and mono- saccharides that may then be converted into organic acids.[135]

In the case of black beans, Tewary and Muller used fermentation on black beans and soybeans during the preparation of wari.[109] Wari, an Indian fermented food, is a brittle and hollow cake that measures 2-30 cm^2 across and weighs 1-30 grams.[109] Tewary and Muller were able to utilize *Lactobacillus bulgaricus* and *Streptococcus thermophiles* to lower the content of raffinose, stachyose and verbascose from 4.4% to 0.6%.[109] Granito *et al.* was able to effectively remove the presence of raffinose, stachyose, and verbascose upon fermenting whole black beans and bean flour at 42°C for 48 hours.[134] In an additional study, Granito and Alvarez studied the effects of natural lactic acid fermentation of black beans.[136] Following fermentation, *Lactobacillus casei* and *Lactobacillus plantarum* were present on the fermented black bean seeds. A decrease of 63.35% in soluble fiber content and a decrease of 88.6% raffinose content were found. After fermentation of the black bean samples, the products were cooked under atmospheric pressure, which resulted in a decrease of trypsin inhibitors and tannins in addition to an increase in in vitro and in vivo digestibility of black beans. These results concluded that *L. casei* could potentially be used as a probiotic starter culture in the food industry to decrease compounds causing flatulence and increase the nutritional profile of the beans.[136] Not only does fermentation help decrease the presence of flatulence and increase nutrient bioavailability, but it is an economic method of preserving, processing and storing food.[134]

Production

The United States Department of Agriculture and Economic Research Service reported that in the 2006-08 crop year, the dry bean crop averaged a $759 million farm value with an estimate of approximately $2 billion in consumer sales.[137] The leading states for most dry bean crops included North Dakota (38%), Michigan (14%), Nebraska (11%), Minnesota (10%), and Idaho (7%).[137]

Among the top five leading dry edible bean varieties for the 2006-08 crop years was black beans.[137] During the 2006-08 crop season, black beans were the third largest crop grown with 11% of all edible dry beans being black beans. The state that produced the largest number of black beans in 2006-08 was Michigan; fifty-eight percent of U.S. black bean output is from Michigan. Not only is Michigan the leader in black bean production nationally, but also the majority of Michigan's dry edible bean crop output is black beans at 45%. In Michigan, Saginaw Valley and the Bay Thumb area are the primary bean production locations in the state. Although Nebraska also produces black beans, Minnesota, the fourth leading dry bean producer, dedicates 10% of its dry edible bean crop to black beans. Polk, Marshall, Otter Tail and Hubbard counties are the leading producers of the dry bean crop in Minnesota. The sixth leading producer of dry edible beans nationally is California, producing approximately 5% of the nation's dry bean crop. California dedicates nearly 21% of its dry edible bean crop to producing a mix of black-eyed peas and black beans. The counties in California growing the largest amount of dry beans include Stanislaus, San Joaquin, and Sutter.[137]

In the 2007-08 crop season, the United States realized a dry bean export trade resulting in a $131 million gain, which was a significant increase from the previous 2006-07 crop season where dry bean trade was only $96 million.[137] Black beans were among the top dry edible bean varieties exported in 2007-08, making up 12% of the exported dry beans. Aside from exports, the United States has taken to importing dry beans as of the 21st century. Dry bean imports in the 2007-08 crop season reached $141 million, with 322 million pounds entering the United States. Black beans have been a major source of dry bean imports during the 2000's with nearly 20% of domestic black bean consumption being from black beans imports. While the U.S. trades dry beans closely with Canada and Mexico, China is the second leading U.S. supplier of dry edible beans. Black beans accounted for 40% of the beans imported from China in the 2007-08 crop season.[137]

ADZUKI BEAN

Background

Introduction

The adzuki bean (also known as aduki or azuki beans) can be found in the species *Vigna angularis* and more specifically, *Vigna angularis* (Willd.) Ohwi and Ohash.[83,84] Adzuki beans are small, brownish red beans that offer a sweet, nutty flavor.[82] The adzuki bean is sometimes interchanged with the term, “red bean,” though precise species names may give clearer indications of the bean in question.[138] Interestingly, the adzuki bean cannot be found in its wild form.[83] The bean is believed to have originated in Asia in the Himalayas with cultivation moving throughout China, Nepal and Japan.[80,83] Commercially, the bean has been grown in South America, parts of Africa, and in the southern United States.[83] A potential disadvantage of the adzuki bean is its relatively slow rate of germination and its inability to thrive among weed species when in its early stages of growth.[83] Poor success rate when in competition with weeds results in a need for an effective and advanced weed control program during the plant’s early, vulnerable stages of growth.[83] Another disadvantage of the growth of the adzuki bean is the fragility of the seedpod upon nearing maturation.[83] Great care must be taken to ensure successful harvest.[83]

Uses in foods

Adzuki beans are popular in Asian cultures, particularly in Japan where they are referenced as, “the king of beans.”[80,82] Japanese cuisines often incorporate adzuki beans into their confections.[82] A popular Japanese confection is a dish known as blintz.[138,139] A blintz is comprised of ice cream and adzuki bean paste wrapped in a mochi, also known as a rice cake.[138–140] In some renditions, the blintz may then be topped with a sweet mashed mixture of adzuki beans and plums.[138] The adzuki bean paste used in the blintz confection may also be called red bean paste or red bean jam.[84] Another sweet Japanese dish containing adzuki beans is amanattō.[84] Amanattō is made by simmering adzuki beans in sugar syrup, rolling them in granulated sugar and drying the coated beans, usually in an oven.[84] Another Japanese use for adzuki beans is zenzai, or oshiruko, which is a thick sweet soup made of condensed red adzuki beans often served with mocha.[84] Another version of this soup is known as shiruko, which is a more thin, sweet bean paste soup served with mocha.[84] Another Japanese dish known as sekihan, literally translates to, “red rice,” as a result of the red adzuki bean leaching its color onto the rice.[84,141] This dish is popular during festivals or for special occasions throughout the calendar year.[84,141] Sekihan is made using short-grain rice or mochi rice and mixed with cooked red adzuki beans.[84,141] Another area of the world that uses adzuki beans is Ghana.[80] In Ghana, a dish called red-red stew is homemade with adzuki and other bean varieties, palm oil and spices.[80]

Nutrient Composition and Health Benefits

Nutrient Composition

Adzuki beans have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature adzuki beans contains 7.30 grams of fiber and 7.52 grams of protein.[12] 2-8 lists the nutritional composition of 100 grams of raw, mature adzuki beans while Table 2-9 lists the nutritional composition of 100 grams of cooked, mature adzuki beans. Additionally, PulseCanada does not report the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of adzuki beans and this information was not found in any other source. Tables 2-10 through 2-13 give additional information concerning the composition of the adzuki bean starch composition.

Antioxidant

A recent study published in 2016 by Luo et al. examined the phytochemical distribution in the hulls and cotyledon's of adzuki beans.[88] Luo et al. reported that many farmers and adzuki bean processors discard the seed coats without understanding the value of these components. Upon completing the study, results indicated that phytochemical (total phenolics, total flavonoid, condensed tannin, and total saponin) distribution in the hulls of adzuki beans was the highest when compared with cotyledons and the whole bean. The antioxidant effects were evaluated using 2-diphenyl-1-picrylhydrazyl (DPPH) activity as well as ferric reducing antioxidant power assay. Aldose reductase and protease inhibitory assays were used to evaluate the effects of beans on *in vitro* and anti-diabetic and anti-inflammatory properties. Assay results indicated that adzuki bean hulls provided antioxidant, anti-diabetic, and anti-inflammatory effects of the whole grain. Since the study indicated that adzuki bean hulls have great potential as an antioxidant, anti-diabetic, and anti-inflammatory, more research should be conducted to possibly incorporate adzuki bean hulls into food and/or pharmaceutical industries.[88]

Obesity

Kitano-Okada et al. conducted a study on the effects of polyphenol-rich adzuki bean extracts on triglyceride accumulation, lipid metabolism, and pro-inflammatory cytokine secretion *in vivo* and *in vitro.*[142] The *in vivo* study used rats that were divided into four groups: A group was fed a control diet with 1% adzuki bean extract, C was fed a control diet, group CF was fed a high fat diet, and group AF was fed a high fat diet with 1% adzuki bean extract. The *in vitro* study included monitoring cultured human adipocytes for the effect of adzuki bean extract on triglyceride incorporation, glycerol phosphate dehydrogenase activity, and inflammatory response. The *in vivo* results indicated that adzuki bean extract significantly reduced total hepatic lipid accumulation and lipid secretion in feces on group AF, the high fat diet with 1% adzuki bean extract. The *in vivo* study also resulted in improved lipid metabolism in both the normal and high-fat diet groups containing 1% adzuki extract (groups A and AF). Similarly, cultured human adipocytes incubated with adzuki bean extract resulted in significantly lower glycerol phosphate dehydrogenase activity, triglyceride accumulation and inflammatory responses. With results indicating improved lipid metabolism and reduced lipid accumulation, adzuki beans have the potential to serve as a natural anti-obesity agent.[142]

Obesity-related diseases

Nonalcoholic fatty liver disease (NAFLD) involves the accumulation of fat in more than 5% of the liver.[143] NAFLD is a common liver disease that is correlated with metabolic disease and may lead to severe liver disease. Due to

NAFLD's strong correlation to dietary patterns and lifestyle, a study was conducted on the effects of adzuki beans on lipid accumulation and oxidation in NALFD-induced, 6-week-old, male mice.[143] Mice were separated into 4 groups and were fed a normal diet, a high-cholesterol and high-fat diet (HCD), and a HCD with either 10% or 20% adzuki bean for a period of 10 weeks. In groups consuming adzuki beans, fasting blood glucose, serum hepatic triglyceride and cholesterol levels, and antioxidative enzyme activity were "ameliorated."Adzuki beans suppressing hepatic messenger RNA expression of lipogenic and inflammatory mediators in NAFLD resulted in a decrease of both lipid accumulation and oxidative stress-induced inflammation. Therefore, NAFLD-related complications may be reduced by adzuki bean consumption and future human clinical trials should be explored.[143]

Allergy

While there are numerous allergies associated with many pulse grain varieties, the literature does not indicate that allergic responses are overly present with the adzuki bean variety. Similarly, the literature does not indicate that incidences of allergic reaction frequently occur within the adzuki bean species, *Vigna angularis*. More research must be conducted to conclude a strong correlation between the adzuki bean and consumer allergic reactions.[92]

Bioactives and anti-nutritional constituents

In 2016, Gohara et al. conducted a study on the nutritional and bioactive compounds of adzuki bean cultivars.[144] Their studies concluded that tocopherols were extremely high in adzuki beans when compared to all others. All adzuki bean cultivars contained good levels of manganese, zinc, and iron, which help aid in the maintenance of human biological systems and function as cofactors in metabolic reactions. In addition, the ratios of polyunsaturated fatty acids to saturated fatty acids and omega-6 fatty acids to omega-3 fatty acids were consistent with maintaining a healthy biological system. Finally, the overall lipid fraction profile was shown to be anti-thrombogenic, hypocholesterolemic, and anti-atherogenic.[144]

A number of antinutritional constituents have been identified in the adzuki bean.[145] Among the most common antinutritional components found in the adzuki bean are the trypsin inhibitor, tannins, saponins, and flavonoids. Trypsin inhibitors are known for reducing the activity of the trypsinase enzyme, which has a role in the digestion of protein. Similarly, the presence of tannins are known for reducing the digestibility of binding proteins. Saponins may interfere with nutrient absorption or cause gastrointestinal tract irritation. Lastly, flavonoids, along with tannins, are responsible for reducing digestibility of binding proteins.[145] Possible methods for eliminating certain anti-nutrients are discussed in the processing section.

Processing

Anti-nutritional processing

In the case of tannins, which are primarily confined to the hull, dehulling generally removes the presence of tannins, eliminating the risk of reduced protein digestibility by tannins.[146] Additionally, in adzuki beans, proper storage, soaking and cooking are critical components for increasing seed quality and reducing the effects of unwanted tannin interactions.[91] Water imbibition is extremely important in adzuki processing and without it, can lead to the “hard shell” phenomenon.[91] When beans fail to imbibe water they are exposed to the “hard-to-cook” phenomenon in which the cotyledon fails to hydrate but the seed hydrates normally during the cooking process.[91] Impeded water intake and/or gelatinization of the starch lead to the hard-to-cook phenomenon in the cotyledon.[91] Disrupted water intake and gelatinization may have to do with the presence of tannins as well.[91] Condensed tannins bind with macromolecules like proteins and carbohydrates, which result in an increase in cell wall material and lignification of the middle lamella and the cell wall.[91] Reduced pectin dissolution, increased cell clustering, reduced cell water penetration, and reduced starch gelatinization may occur as a result of the lignification.[91] Overall, properly storing, soaking, and cooking adzuki beans can greatly decrease the possible adverse side effects of the presence of tannins.[91]

While most of these anti-nutritional factors are eliminated upon soaking and heating, some researchers are interested in extracting trypsin inhibitory proteins as a means to improve texture in a plethora of foods such as meatballs, low-salt fish products, or sausages.[147] In summary, the trypsin inhibitor was successfully extracted with the use of 0.15 M NaCl with the resulting molecular weight being approximately 14 kDa.[148] The purified, extracted trypsin inhibitor remained stable in various pH and heating conditions as well as in salt up to 3%.[148] Researchers conducting this study suggested that purified trypsin inhibitor may be used as a proteinase inhibitor in surimi, a type of processed, gel-like product make from fish or seafood and usually meant to substitute lobster or crab, in an effort to prevent softening.[148]

Fermentation

Diseases such as liver injury, cancer, and cardiovascular disorders may develop as the result of DNA mutation, membrane protein damage and cell membrane disintegration brought on by reactive oxygen species (ROS).[149] Irreversible oxidative damage may result from continuous exposure to pollutants, leading to the accumulation of extensive amounts of free radicals in the body.[149] Dietary compounds, such as phenolic compounds (anthocyanins and catechins), vitamins, and minerals, which are present in adzuki beans, may have beneficial effects on oxidative stress-induced disease.[149] Cheng et al. investigated the effects of fermentation with *Monascus pilosus* on the physiological activities of adzuki beans.[149] *Monascus* has been used in the fermentation of red yeast rice for centuries, which, in clinical studies, was shown to lower blood-lipid levels and cholesterol concentrations.[149] For fermentation, the adzuki bean was soaked for 16 hours, slightly ground, and inoculated with *Monascus* and left to ferment at 25°C for 15 days.[149] The results of fermentation indicated a significant increase in ferrous antioxidant reducing power, nitric oxide scavenging activity, ferrous ion-chelating activity, DPPH free radical scavenging activity, total flavonoid contents, crude protein and crude fiber content, and total phenolics.[149] Another interesting result of the fermentation process was an increase in the presence of monacolin K, which is an anti-hypercholesterolemic agent.[149] Researchers concluded that fermentation of adzuki beans with *Monascus* may improve oxidative stress and high blood cholesterol levels.[149]

Processing for sensory

An is described as a foodstuff derived from the adzuki bean.[150] An is extremely popular in East Asia and promotes improved immune system and blood lipid levels, and protection against cancers.[150] The seed coats of adzuki beans in particular are known for their strong antioxidant capacity and potential to reduce blood glucose, liver damage, and blood pressure.[150] An, which is often produced without the seed coat to soften the product, suffers from a loss of nutrients to protect texture.[150] Xinmiao et al. examined the effects of cooking conditions on the sensory quality of adzuki an.[150] An was made with a bean coat to protect nutrient composition.[150] Sensory scores indicated that adzuki beans with seed coats processed at 50 minutes of cooking, heating power of 1.1 kW, 2 hours of sugar soaking time, and with an additional soak at a pH of 8.0 had highest consumer acceptability.[150] The study also confirmed that soaking with 10% sodium tripolyphosphate buffer solution helped decrease the toughness of the cooked beans.[150] Researchers concluded that while more research should be conducted, the potential of creating an acceptable an product with intact seed coat is plausible with this method.[150]

Production

In the United States, the adzuki bean is grown in Michigan and Iowa.[82] Companies producing and supplying adzuki beans can be seen in Table 2-14.[82]

As mentioned earlier, commercial cultivation has occurred in parts of the southern United States, South America, and Africa, particularly in the Congo, with strong evidence of origination occurring in Asia, specifically the Himalayas, China, Nepal and Japan.[80,83] In recent years, New Zealand has become a major producer of organic pulse farming with adzuki beans being among those harvested. In the future, New Zealand stands to become a major supplier of food and organic pulse grain crops in Oceania.[80] While production information could not be found specifically for the adzuki bean, production information was found for the small red bean, which is believed to be characteristically similar to the adzuki bean.[137] This information can be seen in Table 2-15.

BAMBARA GROUNDNUT

Background

Introduction

Vigna subterranea, or the Bambara groundnut, is believed to have originated in West Africa with the pulse being grown solely in Africa today.[80] In fact, the name, “Bambara,” comes from Mali’s Bambara language, where Bamabara beans are consumed frequently, as well as in Burkina Faso, Chad, Ghana, Niger, Nigeria, Senegal, and Togo.[80] Bambara nuts are resilient to climate change in that they can grow in very poor, arid soils where other crops are not able to survive, making them agronomically value.[80] Bambara groundnuts are similar to peanuts in that they grow in the ground; however, their protein and fat content is considerably lower.[80] In addition to Bambara seed color varying dependent upon variety, Bambara beans also have very hard seeds, making it necessary to boil the seed for extensive amounts of time before they can be consumed.[80]

Uses in food

Bambara beans are a staple in small African communities where they are eaten as a snack, boiled in a stew, consumed as a relish, or added to enrich porridges or flours.[80,151] Bambara groundnuts may be eaten fresh as snacks that are either boiled or roasted or they may be consumed after they have been dried.[152] The dried nuts may be milled and sieved into flour and used to prepare various dishes including, cakes, biscuits, or dumplings.[152] The use of the

Bambara groundnut as a vegetable milk beverage has also been investigated.[151,153]

Nutrition and Health Benefits

Nutrition

Bambara beans have an impressive nutritional profile. The Food and Agriculture Organization of the United Nations reports that 100 grams of cooked, boiled Bambara beans contain an impressive 10.8 grams of fiber and 6.9 grams of protein.[85] Table 2-16 lists the nutritional composition of 100 grams of cooked Bambara beans while Table 2-17 lists the nutritional composition of 100 grams of dried, raw Bambara beans. Additionally, PulseCanada does not report the protein digestibility corrected amino acid score (PDCAAS) of Bambara groundnuts; however, Ijarotimi and Keshino report that a flour blend of 70% popcorn, 20% Bambara groundnut, and 10% African locust bean has a PDCAAS of .44.[154] Mune *et al.* also found that the PDCAAS scores of Bambara bean flour and Bambara protein concentrate were .33 and .25, respectively.[155] Information concerning the composition of the Bambara groundnut starch composition has suggested that amylose content can range from 20-35%. Table 2-18 lists the starch yield and amylose content of various Bambara bean cultivars. Table 2-19 outlines nutritional starch characteristics of varying starch extracts in Bambara groundnuts.

Health benefits

As seen with the mung bean, the usages of the Bambara groundnut have largely been identified as medicinal.[156] Some of the uses of Bambara groundnuts have been identified as the alleviation of venereal diseases, diarrhea, polymenorrhea, internal bruising, nausea, vomiting, inflammation, menorrhagia, gonorrhea, ulcers, hematomas, and cataracts.[156]

Aside from medicinal uses, the Bambara groundnut may be able to alleviate diet deficiencies and protein energy malnutrition due to the sufficient quantities of protein, carbohydrate and lipids present within the bean.[156] In rural locations in Africa, kwashiorkor, a protein deficiency disease, is a problem that may be combatted by consumption of Bambara groundnuts.[156]

One other study found that fermented Bambara groundnuts had the ability to reduce oxidative stress in streptozotocin-induced diabetic rats.[157] The fermented Bambara groundnuts reversed the effects of high liver damage marker enzymes and malondialdehyde levels, and low detoxifying enzymes and antioxidant enzymes.[157] The ability of the Bambara bean to reverse these effects was attributed to the bean's high phenolic content and antioxidant capacity.[157]

In addition, both fermented and unfermented Bambara groundnuts have been reported to protect against lipid peroxidation, which is implicated in atherogenesis and cardiovascular disease.[158] Lipid perioxidation inhibitory capacity was increased in fermented Bambara groundnuts.[158] Additionally, in both fermented and unfermented groundnuts, free soluble phenols showed better lipid peroxidation inhibitory capacity than bound phenols.[158]

Antinutritional factors

The Bambara groundnut contains antinutritional factors, including polyphenols and phytic acid, which restrict the nutritional value of the bean.[159] El-Gasim et al. conducted a study on different forms of processing and their effect on Bambara beans.[159] The study revealed that thermal treatments were most effective in reducing total polyphenol content.[159] Dry roasting at approximately 230°C until the moisture content reached 1.5% was the most effective thermal treatment for reducing total polyphenol content.[159] To eliminate phytic acid content, germination was found to be the most effective method.[159] Before germination, seeds were soaked overnight in the dark at room temperature in a solution of sodium azide (0.0005M).[159] Following soaking, the seeds were transferred to trays filled with wet sandy soil.[159] Germination was most effective at reducing phytic acid content when seeds were allowed to germinate for 6 days at room temperature.[159]

Table 2-20 outlines some of the antinutritional factors present in Bambara groundnuts and ways in which to eliminate or reduce their content in the bean.[160–164]

Allergenicity

The Bambara groundnut has been identified as containing allergenic protein, which was revealed via an enzyme-linked immunosorbent assay (ELISA).[165] In addition, Bambara groundnuts have shown immunoglobulin E reactivity and also cross-reactivity with peanuts and soybeans.[165] Palupi et al. found that, while boiling and steaming for 30 minutes reduced allergenic protein of Bambara groundnuts, some protein allergens still remained.[166] Thus, more information concerning the allergenicity of Bambara beans may need to be determined before incorporating the groundnut into food products.[165]

Processing

Protein and Starch Digestibility and Content

El-Gasim et al. studied the effects of different processing methods on protein and starch content and digestibility in Bambara groundnuts.[159] The study revealed that pre-soaking seeds overnight in the dark at room temperature in a solution of sodium azide (0.0005M) followed by 6 days of germination in wet sandy soil increased the protein content and decreased the level of starch in the beans.[159] While germination for 6 days was most effective at increasing the total protein content, germination for 4 days most significantly increased the in vitro protein digestibility.[159] Boiling the seeds for 1 hour, that were pre-soaked via the same method, was most effective at decreasing the in vitro starch digestibility.[159]

Beverage

Poulter and Caygill evaluated the vegetable milk processing and rehydration characteristics of eight different cultivars of the Bambara groundnut.[153] Seeds were soaked, dehulled and one cultivar was selected for suitability as a base for vegetable milk.[153] The cultivar was milled into flour and homogenized with soya bean or coconut oil to produce an emulsion containing 20 grams of protein (Nx5.71) and 30 ml of oil liter^{-1}.[153] The emulsion created remained stable following pasteurization and the curds produced from the

Bambara groundnut milk were similar to those obtained from traditional soya beans.[153] The end product not only has a high protein content but a trypsin inhibitor content that was significantly lower than that of the untreated vegetable milk.[153]

Murevanhema and Jideani reviewed the potential of Bambara groundnut milk as a probiotic beverage.[151] The review indicated that soy and Bambara groundnut milk share chemical similarities, which may make the Bambara groundnut a good candidate for probiotic beverage production.[151] Since probiotics do not grow quickly in cow's milk, soy has been studied as a good substrate for lactobacillus, thereby lowering the final pH more rapidly, improving production time.[151] The study suggests that Bambara groundnut milk may also be a good medium for producing a probiotic beverage as it shares chemical qualities with soy, though more research should be conducted to confirm the suggestion.[151] Additionally, a study conducted by Brough *et al.* indicated that Bambara groundnut milk, when compared to cowpea, pigeon pea, and soybean milk, ranked highest, as the lighter colored milk and flavor was most preferred.[151,167] Brough *et al.* did state that the "beany" flavor attributed to legumes could be reduced by a heat treatment, in this case dry-frying, to increase consumer acceptability.[151,167]

Snacks

Oyeyinka *et al*. evaluated the effects of storage on value added snacks produced with Bambara groundnut paste or flour.[168] Bambara flour was prepared by dehulling, drying at 60°C for 48 hours in an oven and grinding into flour and sieved.[168] The paste was prepared by deulling and milling the seeds into a thick paste.[168] Samples were then flattened and deep-fried in vegetable oil at approximately 170°C for 5 minutes.[168] Snacks produced with Bambara groundnut flour exhibited higher protein content than those prepared with groundnut paste at 23.41 g/100g and 19.35 g/100g, respectively.[168] On the other hand, snacks prepared with Bambara paste received higher sensory scores than samples made with Bambara flour.[168] Over time, the color intensity of the snacks decreased as the snacks picked up moisture during the storage period.[168] Packaging of the snacks in polyethylene bags at 25°C helped extend shelf life though the snacks began to grow mold after 4 weeks of storage.[168]

Another study conducted by Adegunwa *et al.* evaluated the quality of snacks made from various unripe plantain-Bambara nut-turmeric flour blends.[169] To prepare the flours, the turmeric and unripe plantains were washed, dried and milled.[169] The Bambara groundnut was soaked in tap water for 12 hours at room temperature, dehulled, dried in a cabinet drier at 60°C for 24 hours, and ground into flour.[169] The snacks were prepared by adding salt, sucrose, egg white, and milk powder in the ratio of 100 grams of the composite flour.[169] The mix was kneaded, extruded with a hand extruder, and deep-fried at 150-190°C for 3 minutes.[169] The study revealed that the snack with the greatest acceptability rating was the 35:60:5 unripe plantain-Bambara nut-turmeric blend, which was the blend containing the second highest Bambara nut ratio.[169] Not only was the 35:60:5 blend most accepted, but the protein content was also increased.[169]

Ogunmuyiwa *et al.* also conducted a study evaluating the quality of snacks made from a blend of Bambara groundnut and corn bran flour and cassava starch.[170] Researchers indicated that corn bran was used since it is a by-product of wet and dry milling of corn and it is a valuable source of protein.[170] Researchers also indicated that the Bambara groundnut is an underutilized legume, which lead to the incorporation of this bean into the extruded snack samples.[170] The groundnut flour was prepared by washing, soaking at a room temperature of ~30°C for 12 hours, and drying at 65°C for 24 hours.[170] After drying, decortication, and aspiration, the Bambara groundnut was milled to create a flour.[170] Flour blends of the three foods were created, mixed with water, and extruded at 70°C and 2,500 rpm screw speed with a die diameter of 5 mm.[170] Snack extrudates were then cut into 5 cm pieces and dried in a Genlab drying cabinet at 65°C for 18 hours.[170] Results indicated that a protein dense and fiber-rich snack was produced using a blend of Bambara groundnut, cassava and corn bran.[170]

Production

From 1994 to 2014, the world production of Bambara beans increased from 59,795 tonnes to 160,379 tonnes.[171] The Food and Agriculture Organization of the United Nations reports that 100% of the Bambara groundnuts produced come from Africa.[171] In Africa, the small country of Burkina Faso produces the most Bambara groundnuts at an average of 41,619 tonnes followed by Niger, Mali, and Cameroon at 18,679, 17,970, 17,643 tonnes, respectively.[171] In addition to Burkina Faso, Niger, Mali, and Cameroon, Bambara groundnuts are also grown in Chad, Ghana, Nigeria, Senegal, Togo, and Democratic Republic of the Congo. Outside of Africa, it has also been reported that Bambara groundnuts have been cultivated in Brazil where it is known as, "mandubi d' Angola," with cultivation also possible in West Java, southern Thailand, Syria, Greece, and the Middle East.[151] Cultivation of the crop on a small-scale has also been successful in the United States, in Florida.[151,172]

CHICKPEAS

Background

Introduction

The species *Cicer arietinum* L. is comprised of the chickpea, which is also known as gram, Bengal gram, and garbanzo bean. The chickpea is thought to originate in central and western Asia with cultivation today occurring largely in the Middle East and Iran.[83,173] Other sources assert that the chickpea originated in what is modern day Turkey.[80] Chickpeas are cool-season crops in India as well as a winter crop in parts of the Mediterranean.[83] While the chickpea crop tolerates drought, it does not fair well in tropical, humid regions.[83] The chickpea has a hearty, nut-like flavor, a creamy, buttery texture and it is generally taupe to light yellow in color.[82] Chickpeas are not only valued for their flavor but their nutritional value, potential for storing, and widespread culinary uses around the world.[80]

Uses in food

As a world-wide culinary cuisine, the chickpea has several uses including whole in dahls, as a pulse when split, or as chickpea flour.[83] In Middle Eastern and Indian cuisines, three types of chickpeas are recognized: ‘desi,’ which are small, colorful seed cultivars; ‘bambai,’ which is dark and larger than desi; and ‘kabuli,’ which is a cultivar with large, white seeds.[80,83] In India, chickpeas are also ground into flour to form flatbreads and fritters or used to make curries.[80,82] In popular Indian dishes as well as Middle Eastern cuisines, fresh chickpeas are used in hummus, falafels, creamy soups, pesto, and in tossed salads.[80,82,83] In

North America, chickpea hummus is a popular food product. Innovations in the flavoring of the chickpea hummus range from Argentine chimichurri to horseradish.[80] In Mexico, chickpeas may be salted, mixed with chilies, roasted, or toasted, added to soups and stew, used to create a honeyed chickpea dessert, paired with poultry dishes, or added to botanas, which are appetizers or snacks.[80] In Spain, chickpeas are the main ingredient in more than 20 different variations of cocido, which is a type of stew, known as puchero in the Canary Islands.[80] In the Netherlands, hutspot or hotchpotch, is a dish of thick mash made with meat, vegetables, and chickpeas.[80] In Turkey, a simple dish of rice and chickpeas is known as nohutlu pilav while karisik tursu is a dish made from chickpeas with spiced and pickled vegetables still on their vines.[80] In Pakistan, pindi chana is a hot and spicy dish that features chickpeas as the primary ingredient.[80] In North Africa, a stew known as marqa is made with lamb, vegetables and chickpeas.[80] Similar to the way in which fairs sell chips in Western countries, street vendors at Moroccan markets sell steamed chickpeas salted with cumin.[80] Another popular dish sold at markets in Morocco is kalinti or karane, which is made from chickpea flour and served in paper bags or in rolls meant to be consumed as a hearty meal for workers and school children.[80]

Nutrition and health benefits

Nutrition

Chickpeas have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature chickpeas contain 7.60 grams of fiber and 8.86 grams of protein.[12] Table 2-21 lists the nutritional composition of 100 grams of raw, mature chickpeas while Table 2-22 lists the nutritional composition of 100 grams of cooked, mature chickpeas. While chickpeas contain a considerable amount of iron, the iron in chickpeas is not easily absorbed.[80] To combat this issue, chickpeas are often consumed with vitamin C as the combination aids in iron absorption.[80] Additionally, PulseCanada reports that the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of chickpeas is 0.52, which can be observed in Table 2-23.[86] Tables 2-24 and 2-25 give additional information concerning the composition of the chickpea starch composition.

Health benefits

Mollard et al. examined the effects of frequent consumption of pulses on metabolic risk factors in overweight and obese adults.[174] Participants either consumed a five cup/week meal containing chickpeas and other pulses for 8 weeks or a reduced energy intake diet of 500 kcal/day.[174] Researchers measured body weight, waist circumference, blood pressure, fasting blood parameters and 24 hour food intakes at weeks 1, 4, and 8.[174] Researchers concluded that regular consumption of pulses in an ad libitum diet reduced the symptoms of metabolic syndrome just as effectively, if not more effectively, than a diet restrictive in energy intake.[174]

Hernandez-Salazar et al. evaluated the cooked seeds of chickpeas and other pulses for their indigestible fractions, polyphenol content, antioxidant capacity, and in vitro fermentability, including the production of short-chain fatty acids.[175] It was found that, after 24 hours, chickpeas and all other pulses produced short chain fatty acids following in vitro fermentation by the human colonic microflora.[175] Researchers found that chickpeas were associated with the highest polyphenols content.[175] While more research is needed, researchers concluded that the indigestible fractions of chickpeas and other pulses may be an important source of bioactive compounds.[175]

Allergy

Chickpeas are among the top pulse grains that produce major allergic reactions for individuals in Indian populations.[129] One study explored the incidence of allergenicity to chickpeas in the Indian population.[129] The study screened 1,400 patients for allergy with 142 of those patients testing positive for a food allergy.[129] Of the 142 that tested positive for food allergy, 59 have allergenicity to chickpeas.[129] Of those 59, a double blind placebo controlled food challenge was performed which identified 31 individuals who were positive for chickpea allergy.[129] Additionally, the incidence of food allergy from chickpeas among children in Spanish populations is approximately 20%.[129] Not only is there an influx of allergic reactions among Spanish children but there exists a cross reactivity between chickpeas and lentils.[129] Reports have indicated that chickpeas cause IgE-mediated hypersensitivity reactions with predominance among pediatric patients.[80] In addition, two allergenic polypeptides have been identified from chickpeas, Cic a 2S albumin and Cic a 11S globulin.[129] Exposure to vapors produced by cooking chickpeas has also been shown to induce an allergic reaction or even bronchial asthma.[129] A potential method for eliminating

IgE-binding proteins from chickpeas is autoclaving.[129] Chickpeas boiled for 60 minutes were found to still contain multiple IgE-binding proteins; however, autoclaving at 2.56 atm for 30 minutes significantly reduced the IgE-binding protein content.[129]

Processing

Introduction

An interesting fact about chickpeas is that they are the only pulse grain that needs to be cooked in water that is already hot or boiling.[80] Other pulses are put into cold water upon initiating the boiling and cooking process.[80] If chickpeas are cooked with cold water, the pea will undergo an abrupt change in temperature which will cause the chickpea to harden and prevent uniform and complete cooking.[80]

Patents

Patent number RU2462047C2 titled, "Method for preparation of snack food product for healthy alimentation."[176] The premise of the invention is to produce a sliced product that is low in fat, ready to eat, and has a taste and texture usually associated with fried snack products.[176] In summary, preliminary thermal conditioning is performed on a food dough that may be comprised of legumes, such as chickpeas.[176] Once the dough is pre-conditioned, it is molded into dough-containing slices.[176] By way of explosive dehydration, the moisture content is also conditioned to less than 20% in a microwave oven.[176] Explosive dehydration is used to mimic the dehydration profile of a product that would be fried.[176]

Another patent, WO2008009061A1, titled, "A spreadable food product and a manufacturing process therefor," describes the process of producing a spreadable food product that has a nut-like taste but is allergen-free or has low-allergenicity.[177] This product would ideally have the spreadability of a peanut butter.[177] Of the non-nut legumes proposed for this method, the chickpea is the main pea recommended for the application.[177] To begin, the chickpea is first germinated to improve the nutritional profile of the product.[177] For germination, the chickpea kernel is wetted and incubated under light-deprived conditions at room temperature for about 24 hours.[177] The process then involves grinding the chickpea to a flour at a temperature of 60°C which is followed by a sifting step to achieve the desired particle size.[177] The product is then roasted at a preferred temperature of 200°C for 3.5-4 minutes, which is crucial for achieving a nut-like flavor in the spread.[177] A steaming step is then done to neutralize the bean flavor, which preferably is done at a temperature of 100°C for 35 minutes.[177] The product is then ideally combined with an edible, unsaturated canola oil, salt, and a sweetening agent.[177] A suggestion in the patent is to add milk or dark chocolate to produce a chocolate nut-free chickpea spread.[177]

Production

The chickpea is known for its use as both a cool-season and winter crop in India and the Mediterranean, respectively.[83] Other areas where the crop is widely grown includes the Middle East and Iran, with 84.3% of all chickpea production occurring in Asia.[80,83] India is responsible for 67% of the worldwide production of chickpeas, making it the largest chickpea producer in the world.[80] India's production of chickpeas is 10 times the amount of chickpeas Australia produces, the second largest producer of chickpeas.[80] The production of chickpeas occurs primarily in developing countries at approximately 95%.[80] Over the past 30 years, the production of chickpeas has grown from 4.8 million tonnes to 11.1 million tonnes.[80] Other important areas producing chickpeas include Pakistan, Turkey, Mexico and Canada.[80]

Chickpeas were the fourth most population pulse crop grown in North American between 2010 and 2014 at 259 thousand tonnes. In Central America and the Caribbean, chickpeas are the second largest pulse grain produced at approximately 172 thousand tonnes. South America produced an average of 51 thousand tonnes between 2010 and 2013. Europe produced approximately 140 thousand tonnes of chickpeas between 2009 and 2013. In Eastern Europe and Western Asia, chickpeas are the largest pulse grain produced at 648 thousand tonnes.[80] In South and South East Asia, chickpeas are the highest produced pulse crop at 8,864 thousand tonnes. The Far East and the Pacific produce approximately 13 thousand tonnes of chickpeas. North Africa produced an average of 95 thousand tonnes of chickpeas between 2010 and 2013. In Western and Central Africa, chickpea production is approximately at 567 thousand tonnes, while East and Southern Africa produce 567 thousand tonnes.[80]

Several states in the United States are currently growing chickpeas including Washington, Idaho, California, Arizona and Nebraska.[82] In the U.S., Washington is the leading producer of chickpeas, with California and Idaho also leading in chickpea production.[82] Table 2-26 includes a list of chickpea suppliers in the United States. Aside from producing its own chickpeas, North America imported approximately 29 thousand tonnes of chickpeas between 2009 and 2013.[80] On the other hand, North America exported approximately 119 thousand tonnes between 2009 and 2013 as well.[80] Table 2-27 lists the acreage, yield, production, and value of U.S. chickpeas from 1989 to 2010.[137]

FABA BEAN

Background

Introduction

Vicia faba L., or faba beans, have a creamy texture and nutty flavor and are thought to be native to the Near East, where they were also originally domesticated.[83] Faba beans, also known as pigeon beans or Windsor beans, spread from the Near East, westward along the Mediterranean to Spain.[80,83] Via the silk route, the crop also made it to China, a major producer of faba beans.[83] The ancient Romans also cultivated faba beans and used them as an offering to the gods during the celebration of the Roman feast, Fabaria.[80] In general, *Vivia faba* L. goes by either broad beans, field beans or faba beans, and are grouped according to their main production purpose.[83] Broad beans are defined as beans that are harvested immature and either eaten fresh, frozen, processed, or canned.[83] Field beans are harvested mature and the dried seeds are used as stock feed where the smaller varieties are known as tic beans and the larger as horse beans.[83] Faba beans are harvested for the entire plant, which is often used for silage or hay stock feed.[83] Faba beans also tolerate harsh and cold climates very well.[80] A potential disadvantage of the faba bean is that the seed ripens very slowly, to the extent in which the plant will turn black as leaves are lost prior to the maturity of the seed.[83]

Uses in food

As mentioned, faba beans have a rich, smooth texture and nut-like flavor.[80] Their texture and flavor along with their tough light brown skin make the faba bean a wonderful addition to various dishes.[80] While typically known to be made of chickpeas, the Arabic and Jewish cuisine, falafel is often made from broad beans as well.[80] To make the faba bean falafel, the beans are soaked in water, the skins are removed and they are blended.[80] An assortment of spices, herbs, and vegetables are mixed in and they are shaped into pointed balls where they are then fried in olive oil.[80] In the Atlas Mountains, faba beans are also used to create a dish known as bissara, in which the beans are blended into a hearty puree.[80]

Faba beans may also be used to make dips. One such bean dip is made with boiled faba beans, sautéed chopped onion, sugar and salt.[80] The mixture is then cooked down again and then processed in a food processor with additional lemon juice.[80] The final product is then served with chopped dill, a sprinkle of olive oil and fresh spring onions.[80] Another Asian dish of sautéed faba beans is lily broad beans.[80] Onion and ginger are sautéed in olive oil and cooked broad beans are added to the sautéing mixture.[80] Lilies, red pepper, sugar, vinegar and salt are added and sautéed.[80] A combination of starch and water are also added to thicken the faba bean mixture, which is then served hot.[80]

Nutrition and Health Benefits

Nutrition

Faba beans have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature faba beans contains 5.4 grams of fiber and 7.6 grams of protein.[12] Table 2-28 lists the nutritional composition of 100 grams of raw, mature faba beans while Table 2-29 lists the nutritional composition of 100 grams of cooked, mature faba beans. Tables 2-30 gives additional information concerning the composition and characteristics of the faba bean starch and amylose.[19] Additionally, PulseCanada does not report the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of faba beans; however, Gimenez *et al.* reports that a spaghetti product made with 70% corn and 30% faba bean flour had a PDCAAS score of .50.[178]

Cancer and cardiovascular disease

Siah *et al.* conducted a study on functional properties, including the inhibitory effects on angiotensis-converting enzyme (ACE), alpha-glucosidase and pancreatic lipase in addition to chemopreventative and antioxidant capacities of three different Australian-grown faba bean genotypes.[179] The three different phenotypes were *Nura* (yellow-colored), *Rossa* (red-colored), and *TF(Ic*As)*483/13* (white-colored).[179] The beans were prepared via roasting at 150°C in a dry heat oven for approximately 1 hour.[179] After roasting, the beans were ground to flour and the phenolic extracts were prepared. In colored genotypes that were roasted, antioxidant activity was increased as shown by the cell culture-based antioxidant activity assay.[179] In faba bean extracts, cellular protection against H_20_2-induced DNA damage was detected and the inhibition of proliferation of all human cancer cell lines were evaluated.[179] In general the colored beans, *Nura* and *Rossa* revealed comparable results while the white colored beans exhibited the lowest phenolic content in addition to the lowest enzyme inhibition and antioxidant activities.[179]

León-Espinosa *et al.* studied the effects of faba bean protein hydrolysates on mice fed a hypercholesterolemic diet.[180] Researchers found that the most protective effect was obtained when a low dose of faba bean hydrolysates (10 mg/kg) was given to the mice being fed a hypercholesterolemic diet with an injection of azoxymethane.[180] It was determined that this diet inhibited the development of lesions and aberrant crypt foci to a level that was consistent with a normocholesterolemic diet.[180] Researchers concluded that more research should be conducted to determine the appropriate dose of faba bean hydrolysates to produce the most effective results.[180]

Antinutritional factors

Siah *et al.* found that roasting of faba beans at 150°C in a dry heat oven for approximately 1 hour reduced phenolic content by 10-40%.[179] Chromatograms coupled with HPLC revealed active phenolic compounds in colored genotypes (*Nura* and *Rossa*) while white-colored beans, *TF(Ic*As)*483/13*, did not show any phenolic activity.[179]

Elsheikh *et al.* studied the effects of cooking on antinutritional factors and in vitro protein digestibility.[181] Researchers discovered that boiling 100 seeds in 500 ml of distilled water for 45 minutes followed by drying and grinding of the seeds significantly increased the protein digestibility for all samples, ranging from 74.6-84.6%.[181] The study concluded that the increase of in vitro protein digestibility was a consequence of the significant reduction in the antinutritional factors, tannins and phytic acid present in faba beans.[181] The cooked faba bean tannin content ranged from 0.10 to 0.25% when compared with the uncooked seeds, which ranged from 0.20 to 0.46%.[181] Similarly the phytic acid content of cooked seeds ranged from 0.05 to 0.17% while the uncooked seeds ranged from 0.12 to 0.27%.[181] Trypsin inhibitor was also reduced in the cooked seeds, ranging from 2.5 to 5.6 trypsin inhibitor units compared to 7.5 to 12.8 trypsin inhibitor units in the uncooked seeds.[181]

Processing

Table 2-31 outlines the swelling power and amylose leaching properties of faba beans at various temperatures.[19]

Snack

Smith and Hardacre studied the development of an extruded snack product made from faba beans.[182] In producing an extruded snack acceptable to consumers, researchers altered physical properties of the snack by varying screw speed, particle size of flour, variety of faba bean, and absence or presence of the bean hull.[182] The final faba bean snacks were created in the likeness of a commercially available product, though the faba bean snack contained three times the protein and four times the fiber of the control extruded corn product.[182] Faba bean snacks with the most preferred texture were made from whole beans that were ground to 500 μm.[182] Faba bean snack products that were most similar to the crispiness and hardness of the commercial product were the Disco and Melodie faba bean variety, hulls intact, produced at 300 rpm.[182] Researchers also found that products produced at a particle size between 1-2 mm and 2.5 mm were significantly more gritty than snacks produced at 0.5 mm particle size flour.[182] Smith and Hardacre concluded that the faba bean variety, Melodie, including its hull, milled through a 500 μm screen and extruded at a screw speed of 300 rpm exhibited the most desirable properties.[182]

Gimenez *et al.* studied the effect of extrusion conditions on the physiochemical and sensorial properties of a corn and faba bean spaghetti-type pasta.[183] Researchers found that the addition of faba beans improved the nutritional quality of the corn pasta-like product.[183] The product was prepared with a corn to faba bean flour blend of 70:30 with a Brabender 10 DN single-screw extruder with a 3:1 compression ratio.[183] The study also concluded that at a moisture content of 28% and a temperature of 100°C the extrusion was most effective in producing a high protein, and high dietary fiber content pasta of adequate quality.[183]

Patent

Inventors Reetta Kivela and Anna Hakamies filed a patent, EP3155903A1, for a method of manufacturing a textured food product and a texturized food product which involves preparing a slurry of which the dry matter contains 35% by weight of legume protein, which they state may be of faba bean origin.[184] The objective of their invention was to create a nutritionally improved, textured food product manufactured by cooking and extruding legume protein.[184] Once their slurry is prepared, the slurry is cooked in an extruder cooker and extruded to form a texturized food product.[184] The method states that the most advantageous form of cooking is at 175°C to produce the best structure for the textured product.[184] The method also states that among the most preferred legume proteins to create the slurry, faba bean protein concentrate and faba bean protein isolate are listed.[184]

Production

Faba, or broad, beans are grown in Australia, Bolivia, China, Ecuador, Egypt, Ethiopia, Peru, and Venezuela.[80] The faba bean is grown on approximately 2.5 million ha of land worldwide, with East and Central Asia growing 39% and Sub-Saharan Africa contributing 21% to the total area of cultivated faba beans.[80] Aside from total area of land used to grow broad beans, China also produces 37% of the global production of broad beans.[80] In North America, 5 thousand tonnes of faba beans are imported per year with 6 thousand tonnes also being exported per year.[80] In Central America and the Caribbean, the faba bean is the fourth most produced pulse grain at 47 thousand tonnes.[80] South America produces more faba beans than North America with their production average between 2010 and 2013 being approximately 136 thousand tonnes. Europe produced approximately 700 thousand tonnes of broad beans on average between 2009 and 2013, with imports averaging 98 thousand tonnes and exports averaging 427 thousand tonnes. The faba bean is the number one produced pulse in the Far East and the Pacific at 1,610 thousand tonnes.[80]

In the Far East and the Pacific, the average value of production of the faba bean between 1990 and 2013 was approximately $705.71 million USD.[80] Of the 1,610 thousand tonnes of faba beans produced, on average, 9 thousand tonnes of faba beans were imported and 17 thousand tonnes were exported.[80] The top pulse produced in Northern Africa is also the broad bean at 529 thousand tonnes produced on average between 2010 and 2013.[80] In Northern Africa, the average value of production of the faba beans between 1990 and 2013 was approximately $271.89 million USD. Northern Africa imports approximately 355 thousand tonnes of faba beans and exports about 16 thousand tonnes as well.[80] Western and Central Africa also produce faba beans at approximately 848 thousand tonnes with imports at 6 thousand tonnes and exports at 45 thousand tonnes.[80] In Western and Central Africa, the value of production was approximately $1,726.62 million USD between 1990 and 2013.[80] Eastern and Southern Africa produce a similar amount of faba beans at approximately 847 thousand tonnes with imports at 6 thousand tonnes and exports at 45 thousand tonnes. The value of production between 1990 and 2013 in Eastern and Southern Africa was $590 million USD.[80]

Kidney Beans

Background

Introduction

Phaseolus vulgaris, is a species comprised of kidney beans along with a plethora of other pulses originating in North America.[83] In temperate areas, *Phaseolus vulgaris* is typically cultivated for the immature green pods, which are then canned or frozen.[83] Of the kidney beans, there exist different varieties such as dark red kidney beans or light red kidney beans.[82] Dark red kidney beans are large and brownish-red in color with a robust, earthy flavor and tender texture.[82] Light red kidney beans are paler in color than dark red kidney beans but still share a hearty, full-bodied flavor and soft texture.[82] Red kidney beans also retain their red coloring upon cooking, making them aesthetically desirable in cuisines.[80]

Uses in food

Dark and light red kidney beans are often used as ingredients in chili, salads, or in rice mixtures.[82] In South America, red kidney beans are often added to chili con carne because of the bean's tender, mealy texture.[80] In northern India, a dish known as rajma is prepared, consisting of red kidney beans in a thick, spiced, curry gravy and served with rice.[80] Red kidney beans are traditionally added to Creole dishes and combined with rice in southern Louisiana.[80] A typical Louisiana-style rice and beans may include cooking kidney beans with onion, smoked Andouille sausage, and seasonings such as Tabasco sauce and serving the beans with rice.[185]

Nutrition and Health Benefits

Nutrition

Kidney beans have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature kidney beans contains 6.40 grams of fiber and 8.67 grams of protein.[12] Table 2-32 lists the nutritional composition of 100 grams of raw, mature kidney beans while Table 2-33 lists the nutritional composition of 100 grams of cooked, mature kidney beans. Additionally, PulseCanada reports that the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of kidney beans is 0.55, which can be observed in Table 2-34.[86] Tables 2-35 and 2-36 give additional information concerning the composition of the kidney bean starch composition.

Health benefits

Kan et al. characterized 26 kidney bean cultivars, examining the kidney bean's phytochemical and antioxidant activities.[186] The kidney beans examined contained low levels of lipids (1.05-2.83%) and sugars (1.55-9.07%) but high levels of dietary fiber (29.32-46.77%), protein (22.06-32.63%), and resistant starch (9.16-18.09%).[186] Researchers also found that the main fatty acid was polyunsaturated fatty acids, making up 47.54-67.26% of all total fatty acids.[186] Significant antioxidant activities were also seen with tocopherol content ranging from 12.83-68.35 μg/g, phenolic levels of 0.25-3.79 mg gallic acid equivalent/g dry weight, and flavonoid levels of 0.19-7.05 mg rutin equivalent/g dry weight.[186] As a result of characterizing the phytochemicals and antioxidant activities, researchers concluded that most kidney beans are an excellent source of protein, dietary fiber and resistant starch; kidney beans are rich in phenolics and γ-tocopherol; and all kidney beans possess levels of antioxidants, making them an exceptional source of health-promoting compounds.[186]

Allergy

Some recent studies published on the allergenicity of the kidney bean have identified that 31 kDa is a major allergen of the kidney bean and, as a phytohemagglutinin, has cross-reactivity to peanut and black gram.[129,187] While there are numerous allergies associated many pulse grain varieties, the literature does not indicate that allergic responses are overly present with the kidney bean variety. On the other hand, there are legumes within the same species as the kidney bean (*Phaseolus vulgaris),* which have been identified as potentially eliciting an allergic response. The known allergen from the *Phaseolus vulgaris* species is pha v3, which is a non-specific lipid transfer protein 1. Additional allergic reactions associated with *Phaseolus vulgaris* include vapor inhalation when boiling beans, exposure to raw beans, and contact dermatitis from the leaves of bean plants in farmers.[188–191]

Processing

Extrusion optimization

Agathian et al. conducted an experiment to determine the optimal barrel temperature and kidney bean flour percentages based on various physical properties of extruded snacks.[192] The physical properties analyzed included water solubility index, bulk density, water absorption index, flash off percentage, radial expansion ratio, and overall acceptability.[192] For this experiment, a single screw extruder was used and the study was conducted with a central composite rotatable design using response surface methodology.[192] For the duration of the experiment, feed moisture content was kept at 16.0 ± 0.5%.[192] Numerical optimization techniques were used to optimize the experimental conditions and results indicated that the optimum barrel temperature and kidney bean flour percentages were 120°C (T_1) and 142.62°C (T_2=T_3) and 20%, respectively (desirability value=0.909).[192] Taste panelists were most accepting of snack products that were made with 80% rice flour and 20% kidney bean flour, while anything above 20% kidney bean flour decreased the overall acceptability rating.[192]

Low-fat snack slices

Patent number RU2462047C2 titled, "Method for preparation of snack food product for healthy alimentation."[176] The premise of the invention is to produce a slice product that is low in fat, ready to eat, and has a taste and texture usually associated with fried snack products.[176] In summary, preliminary thermal conditioning is performed on a food dough that may be comprised of legumes, such as kidney beans.[176] Once the dough is pre-conditioned, it is molded into dough-containing slices.[176] By way of explosive dehydration, the moisture content is also conditioned to less than 20% in a microwave oven.[176] Explosive dehydration is used to mimic the dehydration profile of a product that would be fried.[176]

Production

Dark and light red kidney beans are grown in several states in the United States including Washington, Idaho, North Dakota, California, Minnesota, Wisconsin, and Michigan, while light red kidney beans alone are grown in Colorado, Nebraska, and New York.[82] While Michigan is a leading producer of kidney beans, Minnesota is the nation's leader in dark red kidney bean production.[82] Tables 2-37 and 2-38 list the U.S. companies supplying dark red kidney beans and light red kidney beans.[82] Tables 2-39 and 2-40 list the average acreage, yield, production and value of U.S. kidney beans from 1990-2010.

Lupins

Background

Introduction

Lupinus spp., or lupins, are native to the Mediterranean basin and both North and South America.[83] Lupins may be cultivated and harvested for soil enrichment, grain, and animal fodder; however, cultivation of the lupin crop has declined significantly.[83] Lupin seeds are moderately high in alkaloid content, which may explain why crop production has decreased.[83] In addition, the domestication of other leguminous crops may have contributed to the crop production decline.[83] Low-alkaloid leguminous crops are being developed by plant breeders, which boast both “sweet” and “bitter” lupin crop lines.[83] The *Lupinus mutabilis* is known to be a sweet legume variety, also known as the pearl lupin.[83] The pearl lupin originated in the Andes, Peru and Colombia and is a principal seed variety in breeding of new lupin lines.[83] Unique to the pearl lupin is its oil content; pearl lupins have the highest oil level among all domesticated lupins.[83]

Uses in food

Historically, lupins were a popular staple in ancient Rome, as they were cultivated all throughout the Roman Empire. Today, lupins are commonly consumed in the Mediterranean and in Australia as both appetizers and as snacks.[193] In Europe, white lupini beans are often pickled in a brine with the skin either removed or intact.[80] Similar to Europe, South Americans are also known for preserving lupins with either or a brine or a pickling method.[80]

Pastas, biscuits, breads, crusts and various bakery products are often enhanced by the addition of lupin flour, a practice that typically occurs throughout Europe.[193] The addition of lupin flour has also been used as a substitute for soy and gluten in various food products as well as an enrichment additive as lupins can contain up to 40% protein.[80,94]

Nutrition and health benefits

Nutrition

Lupins have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature lupins contains 2.80 grams of fiber and an impressive 15.57 grams of protein.[12] Table 2-41 lists the nutritional composition of 100 grams of raw, mature lupins while Table 2-42 lists the nutritional composition of 100 grams of cooked, mature lupins. Additionally, PulseCanada does not report the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of lupins and this information was not found in any other source. Additionally, information concerning the composition of the lupin starch composition has not yet been found.

Health benefits

A study was published in Australia reporting that lupins can assist in lowering the risk of heart disease in humans.[194] Researchers ground the lupin bean down into a 40% lupin bean flour and prepared bread, pasta, and biscuits with the product.[194] Researchers recruited 130 overweight, but otherwise healthy, Australians of whom half ate lupin flour products while the others consumed whole-meal goods for a period of 12 months.[194] Blood pressure, levels of fat, and insulin were among some of the risk factors of heart disease monitored.[194] An improvement in insulin sensitivity and a substantially lower risk of heart disease was observed in the group consuming lupin flour products.[194] Dr. Belski commented, “A bean we’ve had in our country for many, many years that has pretty much just gone to cattle can actually improve the heart health of Australians.”[194]

Allergy

Within recent years, addition of lupin flours to food products has raised concern over the possibility of creating a ‘hidden’ allergen.[94] The European Union’s (EU) Food Standards Agency (FSA) identifies 14 major allergens, one of which is lupins, “Yes, lupin is a flower, but it’s also found in flour! Lupin flour and seeds can be used in some types of bread, pastries and even pasta.”[95] Prior to lupins being added to the list of major allergens in the EU, reports suggested that lupins were linked to anaphylaxis, asthma, and urticaria, a form of skin rash or hives.[195,196] Of major concern is the possibility of cross-allergy between lupin and peanuts. Individuals who are allergic to peanuts are at a 30-60% risk of also being allergic to lupins.[93] In the U.S. in 1994, after consuming a pasta meal fortified with sweet lupin seed flour, a girl of 5 years of age experienced urticaria and angioedema, swelling of the skin.[197] Upon further investigation, a controlled study found that 5 of 7 subjects with a peanut sensitivity reacted adversely to a needle prick containing lupin residue.[197] Additional reports of lupin allergy have been reported with varying results. A study held in the Mediterranean region reported that among 1,160 patients who reported being atopic patients, 4.1% showed sensitivity to lupins.[198] Another study conducted in Denmark used a double-blind placebo controlled food challenge to evaluate 39 peanut-sensitive patients for lupin sensitivity. Results indicated that 82% of patients were sensitized to lupins, while 35% of the study population showed clinically relevant sensitization to lupins.[199]

Processing

Fermentation

Kasprowicz-Potocka et al. studied the effects of 24-hour fermentation of lupin seeds by different strains of yeast on chemical composition.[102] After fermentation for 24 hours, the yeast enzymes were deactivated for 10 minutes at 70°C and the product was then dried at 55°C.[102] Four replicates were obtained and analyzed for their protein characteristics and chemical composition.[102] Results indicated that the protein fractions increased and in vitro digestibility and biological activity was significantly enhanced.[102] Additionally, results indicated a reduction in some antinutritional factors, improvement of the amino acid profile and an increase in nutritional value.[102] The most favorable outcomes were obtained from lupin seeds fermented with *Saccharomyces cerevisiae* baker's yeast and Fermivin 7013 strain.[102]

Patent

A patent granted by the World Intellectual Property Organization issued as WO2006133492A1 and titled, "Use of lupin bran in high-fibre food products," was published in 2006.[200] The patent described the process of separating lupins hulls from their seed kernels and milling the lupin hulls to form lupin bran that has a particle size between 10-4000 micrometers.[200] The patent details commercial dehulling of lupins for animal stock feed in areas such as Australia and Korea, where the hulls are considered a low-value by-product.[200] The patent describes milling the lupins by either a hammermill, cutter mill, classifying mill, or a pin mill.[200] A high-fiber mixture of the lupin bran with ingredients such as flours and coarse grits of wheat, barley, corn, rice, tapioca, potato, or triticale is created.[200] The mixture is then preconditioned with water or heating and then extruded with possible flavorants such as those that may be added to produce a snack-food product.[200] In the patent, the inventor states, “highly palatable extruded snackfoods (products similar to Cheezels - Registered trade mark of Arnott's SBAH Pty Ltd, Burger Rings and Twisties - Registered trade marks of Frito-Lay Trading Company GmbH), but with a unique health focus (high-fibre, gluten free) can be prepared with lupin bran.”[200]

Production

Lupins are the fourth largest pulse crop grown in South America, with production reaching 56 thousand tonnes between the years 2010 and 2013.[80] Though only the seventh largest pulse grain crop produced in Europe, lupin production reached 268 thousand tonnes in the years 2009 to 2013.[80] Another region, growing 122 thousand tonnes of lupins, is Eastern Europe and Western Asia.[80] Western and Central Africa and Eastern and Southern Africa also produce 17 thousand tonnes of lupins each.[80] Northern Africa also grows lupins, producing an average of 2 thousand tonnes between the years 2010 and 2013.[80]

MAYOCOBA BEANS

Background

Introduction

The mayocoba bean, also known as the canary or canario bean and the Peruvian or Peruano bean, is native to Central America.[201] These beans, also known as yellow or azufrado beans, are medium in size, beige-to-yellow in color and are mild in flavor with a creamy, smooth texture.[201] The mayocoba bean is a popular bean cultivar in northern Mexico and is considered a bean of choice in Mexico not only for its taste but its texture as well.[202,203]

Uses in food

Mayocoba beans can be mixed into a plethora of dishes though hearty stews and soups are a common way to consume the bean.[201]

Nutrition and Health Benefits

Nutrition

Mayocoba beans have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature mayocoba beans contain 10.4 grams of fiber and 9.16 grams of protein.[12] Table 2-43 lists the nutritional composition of 100 grams of mature, cooked mayocoba beans while Table 2-44 lists the nutritional composition of 100 grams of raw, mature mayocoba beans. Table 2-45 shows the chemical composition of the mayocoba bean. Additionally, PulseCanada does not report the Protein Digestibility

Corrected Amino Acid Score (PDCAAS) of mayocoba beans and this information was not found in any other source.

Antioxidants, antinutritional factors and nutraceutical properties

Valdez-Ortiz *et al.* evaluated the nutraceutical and functional properties of protein hydrolysates obtained from three cultivars of the mayocoba bean: Azufrado Higuera, Azufrado Noroeste, and Azufrado Regional ’87.[204] To isolate the proteins, the mayocoba beans were ground into flour and stored at -20°C until utilized.[204] Flours were mixed with 10g/100ml of deionized water and the pH was adjusted to 9.0 via the addition of 2 mol/L NaOH.[204] Then, the flours were soaked for 1 hour and then centrifuged at 4°C for 30 minutes.[204] The recovered supernatant was adjusted to a pH of 4.3 with 2 mol/L HCl to reach the protein isoelectric point and then stored at 4°C for 1 hour.[204] The solution was then centrifuged again at 4°C for 10 minutes, washed with deionized water, and centrifuged under the same condition.[204] The supernatant was discarded and the remaining pellets were freeze dried at -47°C and 300 x 10^{-3} MPa.[204] Enzymes used to digest the bean protein concentrates were Alcalase, Thermolysin, and Pancreatin.[204] Overall, researchers discovered the Azufrado Higuera cultivar showed the best protein yield/concentration ratio compared to the other cultivars.[204] Researchers concluded that the hydrolysates showed good antioxidative capacity with values reaching up to 99% radical-scavenging capacity to complement ACE-I activity.[204] Of the cultivars, Azufrado Higuera with an alcalase treatment showed the highest 1-diphenyl-2-picrylhydrazyl (DPPH) scavenging activity at 40%; however, the ABTS method with Azufrado Regional

’87 and alacalase treatment was the best, at 99.89% of scavenging.[204] The study also concluded that the bean hydrolysates also possessed an adequate balance of aromatic and essential amino acids, especially prevalent with alcalase and thermolysin’s strong hydrolytic power.[204] The results of the study showed that Azufrado bean protein hydrolysates are suitable for the development of nutraceutical products that aid in prevention and control of degenerative diseases such as hypertension or those derived from cellular oxidation.[204]

Iniestra-Gonzalez evaluated the antinutritional and antioxidant activity of the mayocoba bean.[205] The beans were first removed of their seed coats and then ground and passed through a 100 mesh sieve to produce flour.[205] Antinutritional factors were evaluated as well as the antioxidant capacity over the course of ten days.[205] The results indicated that the mayocoba bean showed the highest average amount of phytic acid, which varied from 0.10 to 0.22%, which the researchers comment is lower than the interval of 0.6 to 2.7% reported for the common bean.[205] In addition, the mayocoba bean presented great antioxidant activity through the sixth day of analysis.[205] Researchers concluded that there is a potential for beans of high antioxidant activity to help in disease prevention.[205] Other bean varieties that have also been indicated as being synonymous with the mayocoba bean were evaluated in this study as well.[205]

Fermentation

Campos-Vega *et al.* studied the chemical composition and in vitro polysaccharide fermentation of various beans, including the cultivar Azufrado Higuera, which has been identified as being synonymous with the mayocoba bean.[206] To prepare the beans, 50 grams of fresh, unsoaked beans were put into a beaker with 250 mL of HPLC-grade water and boiled at 90°C for 2.5 hours.[206] The cooked seeds and the broth water were ground, lyophilized and stored in polyethylene bags at 4°C until ready for use.[206] The samples were then sieved through a 35 mesh screen and total dietary fiber content, proximate composition, resistant starch, oligosaccharide, and condensed tannin content was determined.[206] Fermentation was completed by placing samples in tubes in a 37°C water bath and introducing them to a fecal slurry.[206] The pH and SCFA production during fermentation was assessed at 6, 12, and 24 hours.[206] Fermentation was then halted by placing tubes in a -70°C freezer.[206] Results indicated that, following processing, Azufrado Higuera showed an increase in verbascose content from 0.2 to 0.5 mg/g.[206] Results also indicated that the condensed tannin content was undetected in the yellow-seeded Azufrado Higuera.[206] In addition, SCFA molar ratios of acetate:propionate:butyrate after 24 hours for Azufrado Higuera were 58:21:21, indicating that, of the other beans examined, Azufrado Higuera had the highest and lowest concentrations of propionate (14 mmol/L) and acetate (39 mmol/L), respectively.[206]

Processing

Soaking

A common issue with beans, such as mayocoba beans, that are stored under high temperature and humidity conditions is the production of the "hard-to-cook" defect.[207] Similar to the region of northern Mexico, other beans grown and stored in tropical and subtropical regions may undergo this phenomenon. To combat this issue, soaking of the bean before cooking is used to hydrate the seed.[208] Carmona-García *et al.* conducted a study on the effect of soaking on mayocoba beans, in which a non-soaked bean, and beans soaked in various liquids including distilled water, sodium chloride (1%, weight/volume (w/v)), sodium bicarbonate (1%, w/v) and a mixed solution (1% NaCl and 0.75% sodium bicarbonate, w/v) were compared.[202] Carmona-García *et al.* found that soaking the uncooked beans for 12 hours in the mixed solution resulted in the shortest cooking time at 149±0.05 minutes.[202] Additionally, beans soaked for 12 hours in the sodium bicarbonate solution resulted in the lowest starch availability and highest resistant starch contents, at 27.4% and 6.3%, respectively.[202] Mayocoba beans soaked in distilled water had the highest amount of available starch at 31.4% and also the lowest amount of resistant starch at 5.1%.[202] Additional study results found that soaking did not affect the predicted glycemic index or the hydrolysis index.[202]

Patent

Patent, CN101449690A, details the method of preparation of a snack cake containing yellow bean powder, which has been identified as being synonymous with the mayocoba bean.[209] The main components of the snack cake are 60% glutinous rice flour, rice flour at 9%, 9% pulp hawthorn, 4% sucrose, 8% peanut flour, 5% spices, 0.1% stabilizer and 5% bean flour, which may include yellow bean flour.[209] The mixed ingredients are then pressure cooked for 40 minutes, baked in an oven, cut, and packaged to produced a shelf-stable, nutritious snack cake.[209]

Abandoned patent, US20110256293A1, details the method for making legume-based dough and nutritional product therefrom.[210] The patent details soaking legumes, which may include the canary bean, which has been identified as being synonymous with the mayocoba bean, for 40 minutes in water or lime-water followed by boiling in a kettle for 20-25 minutes.[210] The patent also suggests pressure cooking of the bean between 10 and 15 psi of the to reduce cooking time.[210] Then, the beans are ground and mixed into dough, which may comprise 40-45% cooked legumes, 5% oil, and 20-30% starch.[210] The dough may be comprised of various ingredients by weight according to the patent and may be cooked in an oven at a temperature ranging from 250-450°F depending on how the dough is formed.[210] The purpose of this patent is to provide the advantages of pressure cooked legumes, eliminating soaking and cooking times.[210] Another is to offer processing methods that reduce the risk of producing off flavors that may occur if the beans are burned.[210]

Production

In the United States, there are two companies that supply the mayocoba bean, including Trinidad Benham Corporation and Aileen Quirk & Sons, Inc.[82] Being that the mayocoba bean also goes by the, “yellow bean,” other companies that may produce the bean include: Buchholz Enterprises, Inc.; Colusa Produce Corp.; Goya Foods, Inc.; Kelley Bean Co., Inc.; Melmont Bean & Seed, Inc.;

Meridian Seeds; Multigrain International, LLC.; Nebraska Bean, Inc.; Rhodes Stockton Bean Co-op; Russell E. Womack, Inc.; and Tarke Bean, LLC.[82]

Mung bean

Background

Introduction

The mung bean, or green gram, is an olive-colored, small and oval bean.[80] The mung bean is cultivated in several regions of the world, including India, China, Southeast Asia, Southern Europe and southern regions of the United States.[80] In addition to the bean being consumed as a pulse grain, it may also be used as a cover crop for the protection and enrichment of soil.[83] When used as a cover crop, the bean may be used as livestock fodder or as a vegetable. The mung bean is typically cultivated in the tropics in which the ideal growing temperature is between 86 and 95°F and the rainfall level is moderate to low, as the species is drought tolerant.[83]

Uses in food

In Asia, the mung bean is used for the production of bean shoots, otherwise known as bean sprouts, affording the bean a high culinary and economic value.[80,83] In places such as Southern Europe and the southern United States, the mung bean is not only used as an ingredient in savory dishes, but sweet cuisines as well.[80] In Pakistan, mung beans and pink lentils are cooked together and mixed with spices and rice or curry.[80] In Japan, South Korea, and Taiwan, mung beans are consumed in large quantities and incorporated into many traditional dishes, which may be due to early interaction with western cultures, subsequently bringing the bean east.[80] In Nepal, a traditional cuisine eaten during the *Gun Puhi* festival is *kwa¯ti* soup, which is made with nine different pulses, including the mung bean.[80] In Mongolia, *kashk*, which is typically made from dairy, is instead made with mung beans and rice and formed into balls.[80]

Nutrition and Health Benefits

Nutrition

Mung beans have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature mung beans contain 7.60 grams of fiber and 7.02 grams of protein.[12] Table 2-46 lists the nutritional composition of 100 grams of raw, mature mung beans while Table 2-47 lists the nutritional composition of 100 grams of cooked, mature mung beans. Additionally, via the Office of Food Additive Safety, Center for Food Safety and Applied Nutrition, and the Food and Drug Administration the company, Hampton Creek, when applying for GRAS status, reported that the PDCAAS of mung bean protein isolate for cooked batches ranged from 50-55%.[211] Tables 2-48 through 2-50 give additional information concerning the composition of the mung bean starch composition.

Health Benefits

A recent study evaluated the effects of consuming a mung bean coat in mice with type 2 diabetes.[212] Five week old mice were fed a diet containing mung bean coat extract at 1% for seven weeks.[212] The results indicated that serum glucose levels, blood glycated hemoglobin and the homeostasis model assessment for insulin resistance in mung bean coat group mice were significantly lower than the control group of mice.[212] Thiobarbituric acid reactive substance levels were reduced and activity of catalase, superoxide dismutase, and gluthione peroxidase in the liver were elevated in the group consuming mung bean extract when compared to the control group.[212] These results indicated that hyperglycemia and antioxidant activity may be improved with the consumption of mung bean extract in type 2 diabetes mellitus.[212]

Antioxidants

A recent study published in 2016 by Luo et al. examined the phytochemical distribution in the hulls and cotyledon's of mung beans.[88] Luo et al. reported that many farmers and mung bean processors discard the seed coats without understanding the value of these components.[88] Upon completing the study, results indicated that phytochemical (total phenolics, total flavonoid, condensed tannin, and total saponin) distribution in the hulls of mung beans was the highest when compared with cotyledons and the whole bean.[88] The antioxidant effects were evaluated using 2-diphenyl-1-picrylhydrazyl (DPPH) activity as well as ferric reducing antioxidant power assay.[88] Aldose reductase and protease inhibitory assays were used to evaluate the effects of beans on in vitro and anti-diabetic and anti-inflammatory properties.[88] Assay results indicated that mung bean hulls provided antioxidant, anti-diabetic, and anti-inflammatory effects of whole grains.[88] Since the study indicated that mung bean hulls have great potential as an antioxidant, anti-diabetic, and anti-inflammatory, more research should be conducted to possibly incorporate mung bean hulls into food and/or pharmaceutical industries.[88]

Antinutritional factors

The mung bean contains several antinutritional factors, including tannins, trypsin inhibitor, hemagglutinin, phytic acid, stachyose and raffinose.[213] Mubarak has found that germination as well as cooking processes may decrease the carbohydrate fractions and antinutritional factors in mung beans.[213] While Mubarak found that dehulling, soaking, and germination were less effective than cooking to reduce trypsin inhibitor, tannins, and hemagglutinin activity, Mubarak also stated that germination was effective in reducing phytic acid, stachyose, and raffinose as well as retaining minerals when compared to all other forms of processing.[213] The study also indicated that all processes improved protein digestibility and protein efficiency ratio of the mung bean.[213] Mubarak concluded that, for household and restaurant use, microwaving and autoclaving are the most effective methods of mung bean preparation to improve nutritional quality and decrease cooking time.[213]

Allergy

The mung bean being widely cultivated and consumed throughout India, Pakistan, Bangladesh, Thailand, Laos, Cambodia, Vietnam, Malaysia, Indonesia, China, Formosa, and Sri Lanka may increase the likelihood of consumer sensitization to the allergic proteins present in the mung bean.[129] It has been identified that the protein Vig r1 is an allergen present in the mung bean seedling.[129] While Vig rl is present in the seedling, Verma *et al.* also identified Vig r2 (52 kDa), Vig r3 (50kDa) and Vig r4 (30 kDa) proteins as exhibiting similarities with the allergens of lupins, lentils, peas, and soybeans.[129]

Processing

Snacks

Sharma *et al*. evaluated the use of rice and mung beans as a nutritious snack with enhanced protein quality and quantity.[214] This study evaluated the replacement of 30% rice flour with mung bean flour at different feed moisture contents, screw speeds, and barrel temperatures.[214] It was determined that increasing feed moisture lowered the specific mechanical energy, water absorption index and water solubility index while increasing bulk density and hardness.[214] A higher screw speed had negative linear effect on water absorption index and a positive, linear effect on specific mechanical energy.[214] Increased barrel temperature resulted in a linearly decreased specific mechanical energy, density, and hardness of the extrudates.[214] It was concluded that feed moisture had the greatest effect on the properties of the extrudates, which was followed by temperature and screw speed.[214] The most promising results were achieved at low feed moisture, high screw speed, and medium barrel temperature, which yielded high expansion ratio and low density and hardness.[214] These results indicate promising potential for extruded mung bean and rice blended snack products.[214]

Fried legumes are a popular snack throughout India and with concerns over the side effects of high-fat food consumption, a lower fat product may be desired.[215] Holikar *et al.* evaluated the use of pectin and calcium chloride treatment on fried mung bean splits to create a low-fat product.[215] Mung bean splits were prepared by soaking in a calcium chloride solution for 3 hours followed by air drying and dipping the product into pectin solution for 10 minutes.[215] After being dipped in pectin, the mung bean splits were again air dried and then fried in groundnut oil at approximately 170°C for 2 minutes.[215] Results indicated that soaking the splits in 7.5 g l^{-1} calcium chloride in a 1:5 ratio for 180 minutes followed by a single coating of 50 g l^{-1} pectin solution for 10 minutes and then surface drying for 30 minutes reduced the oil content of the fried mung bean splits from 335 g/kg^{-1} to 211.7 g/kg^{-1}.[215] From a nutritional viewpoint, soaking in calcium chloride and dipping in pectin resulted in a reduced fat and added calcium fried mung bean split snack product.[215]

In addition, Tables 2-51 and 2-52 outline pasting and gelatinization characteristics of mung bean starch.

Production

The World Vegetable Center reports that the mung bean is most heavily cultivated in South, East and Southeast Asia, accounting for 5% of global pulse production.[216] However, New Zealand is also a major supplier of organic pulses throughout Oceania, with mung beans being among those cultivated.[80] In Pakistan, the mung bean is the second largest pulse grain crop produced in the country.[80] The World Vegetable Center reports that the mung bean accounts for 14% of the total pulse production in Pakistan where it is mainly used for its ability to intercrop with sugar cane, preventing erosion and increasing soil fertility.[80,217] In the United States, the Department of Agronomy/Horticulture at Iowa States reports that Oklahoma is the main location of mung bean cultivation, with around

100,000 acres dedicated to their production.[218] One company that ships mung beans in the U.S. Tumac Commodities which is located in Portland, Oregon.[82]

NAVY BEANS

Background

Introduction

Phaseolus vulgaris, is a species comprised of navy beans along with a plethora of other pulses originating in North America.[83] In temperate areas, *Phaseolus vulgaris* is typically cultivated for the immature green pods, which are then canned or frozen.[83] Dried beans alone or dried beans used to prepare canned navy or baked beans are typically cultivated in warmer regions.[83] Navy beans are small, white beans that have a smooth yet dense texture.[83]

Uses in food

A popular bean canning company in the United States, BUSH'S, reports that the navy bean was named due to its popularity in the U.S. Navy since the time of the 1800's.[219] In the U.S., the navy bean is popularly used to create a dish called Boston baked beans, which usually involves baking the beans for 4-6 hours in a mixture of ingredients such as onion, molasses, brown sugar, bacon, maple syrup and mustard.[220] Not only in the United States but in Italian cuisine, navy beans are used; navy beans are a popular bean used in the Italian soup minestrone.[185] Likewise, a Tuscan vegetable stew known as ribollita contains white beans, such as navy beans, along with kale, carrots, celery, and tomatoes.[185]

Nutrition and Health Benefits

Nutrition

Navy beans have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature navy beans contains 10.5 grams of fiber and 8.23 grams of protein.[12] Table 2-53 lists the nutritional composition of 100 grams of raw, mature navy beans while Table 2-54 lists the nutritional composition of 100 grams of cooked, mature navy beans. Additionally, PulseCanada reports that the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of navy beans is 0.68, which can be observed in Table 2-55.[86] Tables 2-56 and 2-57 give additional information concerning the composition of the navy bean starch composition.

Cancer

The use of cooked navy bean powder in reducing the incidence and recurrence of colonic polyps and precancerous growths has recently been studied.[89,221] Borresen *et al.* (2016) found that increasing navy beans and rice bran consumption in colorectal cancer survivors increases dietary fiber intake when consuming 35 grams per day of navy bean powder and 30 grams per day of heat-stabilized rice bran. The study also supports the feasibility of consuming navy bean and rice bran to inhibit carcinogenesis and improve colorectal cancer chemoprevention.[89]

Cardiovascular disease and obesity

The combination of navy beans and rice bran was also studied as a means to regulate serum cholesterol.[90] While the consumption of navy beans and rice bran to regulate cholesterol has been studied in adult populations, it has not been extensively studied in hypercholesterolemic children.[90] Borresen *et al.* (2017) examined children ages 8-13 who exhibited abnormal lipid levels, subsequently increasing their risk of cardiovascular disease.[90] Children consumed muffins and smoothies daily that contained navy bean powder and/or heat-stabilized rice bran.[90] Results indicated that children's total fiber intake increased in groups that consumed only navy bean powder and those that consumed a combination of navy bean powder and rice bran.[90] In groups that consumed only navy bean powder, high-density lipoprotein (HDL) cholesterol levels were higher than the control group, which did not include consumption of any navy bean powder or rice bran.[90]

Navy beans have also been examined in their use for reducing the risk of metabolic syndrome in overweight and obese individuals.[174,222] One study examined the effect of consuming ready-to-eat canned navy beans at 5 cups per week for 4 weeks in obese adults.[222] After 4 weeks, results indicated a reduction in waist circumference in both females and males.[222] Male subjects showed a decrease in pulse rate, total cholesterol and low-density lipoprotein cholesterol, indicating that navy bean consumption has the potential to reduce metabolic risk factors associated with obesity.[222]

Allergens

While there are numerous allergies associated many pulse grain varieties, the literature does not indicate that allergic responses are overly present with the navy bean variety. On the other hand, there are legumes within the same species as the navy bean (*Phaseolus vulgaris),* which have been identified as potentially eliciting an allergic response. The known allergen from the *Phaseolus vulgaris* species is pha v3, which is a non-specific lipid transfer protein 1. Additional allergic reactions associated with *Phaseolus vulgaris* include vapor inhalation when boiling beans, exposure to raw beans, and contact dermatitis from the leaves of bean plants in farmers.[188–191]

Processing

Navy beans are considered a top contender as a form of gluten-free flour products by Michigan bean growers.[96] While rice flour is a popular gluten-free flour substitute, rice flour is also lacking in minerals, vitamins, protein and fiber.[92] On the other hand, dry bean powder is known to create off-flavors or, "off beany flavors," when substituted into grain-based food products.[223] Han *et. al* conducted a study on the use of various, commercially available, pulse grain flours in formulating a gluten-free cracker snack.[223] The results of the study found that navy bean flour had the lowest marks of acceptability among panelists when compared to crackers made with chickpea, green lentil, red lentil, pinto bean, yellow and pea flours as well as pea protein and fiber isolates.[223] Panelists ranked the flour of navy bean the lowest, between dislike moderately and dislike slightly, with other categories including color, crispiness and the overall appeal of the cracker.[223]

Extrusion

The standard method for processing bean flour includes soaking, blanching, cooking, drying, and grinding the beans into flour. This process removes oligosaccharides, which induce flatulence, as well as anti-nutrients including lectins and phytohemagglutinins.[92] While this method, known as the standard commercial bean powder process, improves the nutritional quality of the bean flour, the process requires a large amount of energy input and consumes a significant amount of water, making the process rather unjustifiable.[98] A more sustainable method for producing bean flour may be extrusion, which involves pushing product through a barrel designed to use low heat and a continuous-use shear force process under high pressure.[98] Extrusion removes the soaking, blanching, cooking, and drying steps used in the standard commercial bean powder, which reduces the amount of water, lowers the energy input used to generate heat, and eliminates waste.[97] Additionally, extrusion also eliminates most anti-nutritional factors, similar to the standard commercial process.[97] While extensive research on how the aroma chemistry of bean flours is affected by extrusion has not been completed, one possible method has been proposed.[224] Simons suggests that extrusion produces protein-lipid and starch-lipid complexes which may inhibit the oxidation of lipids and improve the overall flavor of bean powder.[224]

Szczygiel et al. conducted a study specifically on navy bean powder and the acceptability of products made with navy bean flour.[98] The study used a twin-screw extruder with a 19 mm barrel diameter and a 3 mm exit die.[98] With the extruded navy bean powder, white shortened cakes, seasoned crackers, and vegetarian chicken nuggets were created.[98] When tested among participants, the seasoned navy bean crackers were significantly preferred when compared to products that were produced with standard commercial navy bean powder.[98] The study also showed that the vegetarian nuggets made with bean flour were similarly rated in comparison to the control nugget containing no beans.[98] Additionally, the extruded navy bean powder indicated less oxidation compared to the commercial navy bean powder.[98] Results of the study also suggest that aldehyde and ketone production following lipid oxidation of unsaturated fats may be a major source of aroma chemistry beany flavors.[98]

While extrusion may be a valuable method of processing bean flours, the type of extrusion may also play an important role in the quality of the flour. It has been reported that high temperature extrusion may undesirably affect the functional, nutritional, and sensory properties of the bean flour, including protein solubility, water absorption, solubility index, bulk density, and expansion ratio.[225–227] Kelkar *et al.* examined the effects of low temperature extruding on processing navy bean flour.[96] After washing and soaking the beans for 8 hours in a bean-to-water ratio of 1:2 (w/v), the beans were oven dried and ground. The navy beans were then extruded in a twins extruder at 85, 100, and 120°C.[96] Results indicated that the navy beans extruded at 100°C were darker in color and less appealing, indicating that a lower extrusion temperature was preferred.[96] In order to sufficiently lower phytohemagglutinin levels, an extrusion temperature of a least 80°C was necessary, therefore extruding at 85°C was determined to be the optimum temperature to ensure production of a quality navy bean flour.[96] Extrusion at 85°C was able to effectively remove the beany flavor of the flour while also not permitting the development of a burned flavor which may be present at higher extrusion temperatures.[96] While extrusion at 85°C effectively reduced lectin content in navy bean flour, it did not effectively reduce oligosaccharides, raffinose and stachyose, as sufficiently as the standard steam cooking method.[96] Kelkar et al. propose a greater ratio of beans-water (>1:5) in the soaking step prior to extrusion to help reduce oligosaccharide content.[96]

Fermentation

Scientists at the University of Central Oklahoma published a preliminary report on the effects of navy bean extract on the fermentation time and the quality of yogurt.[101] Researchers successfully isolated the oligosaccharide raffinose from navy beans, which was added to 2% reduced fat milk.[101] After pasteurizing and adding commercial yogurt culture to the product, it was determined that the addition of navy bean extract decreased fermentation time.[101] Additionally, probiotic activity was increased due to an increase in acidification and decrease in pH levels.[101] While further research needs to be conducted on the possibility of adding navy bean extract to yogurt to increase quality and fermentation, this preliminary research may guide future studies.[101]

Patent

U.S. publication US20100285196A1 or application number US12463673 describes a method of creating a legume-baked puff cake with the use of a rotary cooker.[228] Among the legumes that may be used to produce this cake is a navy bean.[228] The patent includes cakes made solely from legumes and also cakes made in combination with whole grains.[228] The method includes cooking legumes in a rotary cooker under steam and water until the moisture is approximately 20-

45%.[228] After cooking in the rotary, the legumes are then dried until 10-17% moisture.[228] After this, the legumes are puffed in what would be described as a standard rice cake popping machine, such as the Lite Energy Rice Cake Machine.[228] The temperature of puffing may range from 450-470°F for 2 seconds at a mold pressure of approximately 950 psi.[228] The inventors of the patent realized that the starch in the legumes needs to achieve further gelatinization than can be offered by a standard steaming method; therefore, a rotary cooking method is used.[228]

Production

The United States Department of Agriculture and Economic Research Service reported that in the 2006-08 crop year, the dry bean crop averaged a $759 million farm value with an estimate of approximately $2 billion in consumer sales.[137] The leading states for most dry bean crops included North Dakota (38%), Michigan (14%), Nebraska (11%), Minnesota (10%), and Idaho (7%).[137]

The navy bean is the second most popular dry bean produced in the United States per capita.[229] In the United States, the Northarvest Bean Growers Association, which represents the dry bean growers of North Dakota and Minnesota, is the largest group of dry bean growers.[82] Among the primary beans that the Northarvest growers produce is the navy bean.[82] North Dakota is the U.S. leading producer of navy beans with Michigan and Minnesota also contributing to the growth of navy beans.[82] Michigan is the second-leading producer of dry beans with navy beans (34 percent) being the second most dominate bean crop in the state.[137] In the United States, the navy bean was the second leading variety of dry edible bean produced in the United States as 17%.[137] Across the United States, navy beans are grown in Idaho, Wyoming, Kansas, Nebraska, New Mexico, Colorado, Minnesota, Michigan, and North Dakota.[82] Table 2-58 lists the wide range of companies that produce and supply navy beans.[82]

In 2009-2010, the United States exported 153,252,583 pounds of navy beans with 98,035,232 of those pounds going to the United Kingdom, 40,507,767 going to Canada, and 10,121,397 pounds going to Mexico.[230] Table 2-59 summaries the acreage, yield, and production values of navy beans in the United States from 1987-2010 while Table 2-60 summarizes the average cost per year of 100 pounds of navy beans. With increases in price over the last decade, the demand for navy beans has also increased.[231] In 2008, the average American consumed 0.9 pounds of navy beans.[231]

PIGEON PEA

Background

Introduction

Pigeon peas or, *Cajanus cajan*, are native to India and possibly in parts of Africa where they are referred to as the Congo peas.[80] Pigeon peas, also known as red gram, are an important crop in India, southern and eastern Africa and Central America.[83] During colonization, settlers introduced pigeon peas to the Caribbean, where the pulse would become a major crop cultivar.[80] In eastern countries, pigeon peas are utilized as housing for insects for the production of ink and resin.[80] Pigeon peas are agronomically valuable due to their ability to thrive in poor soils and their drought resistance; however, the crop does not fair well in excessive amounts of shade, extreme wetness, or humidity.[83] Another advantage of pigeon peas are their deep growing roots, which makes them valuable as a cover crop as they will not compete with other crops for water.[80] In tandem with this feature, they grow slowly when in their early stages, allowing other crops to produce roots and subsequently preventing soil erosion.[80] Within the last 10 years, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has begun experimenting with the pigeon pea.[83] Their efforts have improved the pigeon pea crop's productivity, which has resulted in plant maturation after only 100-150 days.[83] Shorter maturation time has resulted in greater yields per unit area for the pigeon pea crop.[83]

Uses in food

In India, the importance of pigeon peas is comparable to chickpeas, as they can also be combined with cereals to create a complete protein meal or used to make *daal*.[80] For instance, in India, *daal tadka* is a curry that is made with pigeon peas. Another is *osaman daal*, which is a spicy soup made with pigeon peas. In Brazilian cuisine, pigeon peas may be used to create a dish called, "farofa campiera," a dish which may be comprised of ingredients such as cornmeal, bacon, onion, pumpkin, eggs and chilies.[80]

Nutrition and Health Benefits

Nutrition

Pigeon peas have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature pigeon peas contain 6.76 grams of fiber and 6.70 grams of protein.[12] Table 2-61 lists the nutritional composition of 100 grams of raw, mature pigeon peas while Table 2-62 lists the nutritional composition of 100 grams of cooked, mature pigeon peas. Additionally, PulseCanada does not report the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of pigeon peas and this information was not found in any other source. Tables 2-63 and 2-64 give additional information concerning the composition of the pigeon pea starch composition.

Health Benefits

Interestingly, the pigeon pea has been identified as a major source of herbal medicine. Various parts of the plant, including the seed, leaves, roots, and flowers, are used to improve symptoms of a plethora of ailments, from inflammation to dysentery, diabetes to jaundice, and influenza to stroke.[232] Some of the countries identified as using the pigeon pea plant for medicinal uses include Argentina, Brazil, China, Cuba, Dominican Republic, Haiti, India, Malaysia, Mexico, Peru, and Trinidad.[232] Extensive research around the turn of the 21st century revealed that flavonoids in the pigeon pea leaves, such as hordenine, juliflorine, betulinic acid, stigmasterol, and beta-sitosterol, may contain antibacterial, anti-inflammatory, antiviral, antifungal, and anticancer properties.[232]

Antinutritional factors

Pigeon peas contain antinutritional factors including polyphenols (phenols and tannins), phytolectins, enzyme inhibitors (trypsin, chymotrypsin and amylase), oligosaccharides (raffinose and verbascose), and unavailable carbohydrates that inhibit the bioavailability of some important nutrients.[232] As for phytolectins, their heat sensitive properties allowing them to be denatured and destroyed during cooking, eliminating their antinutritional effects.[233] A way to minimize the presence of polyphenols and enzyme inhibitor activity may be to select a different cultivar of pigeon pea.[233] For example, it has been reported that red-seeded pigeon pea cultivars contain three times the amount of pholyphenols as white seeded pigeon peas.[233] In addition, since the tannins are usually present in the seed coat, dehulled red pigeon pea seed coats pose no antinutritional threat.[233] It has also been reported that pigeon peas cooked after germination reduce the activity of oligosaccharides and also enhances their starch digestibility.[234] Early reports also indicate that fermentation of pigeon pea seeds decreases the inhibitory activity of digestive enzymes.[234]

Allergy

Pigeon peas are among the pulse crops that cause major allergic food reactions in India.[129] Verma *et al.* have indicated that there are five immunoglobulin E (IgE) binding proteins from the cupin superfamily which elicit an allergic reaction including Caj c1 (66 kDa), Caj c2 (45 kDa, pI 5.3), Caj c3 (45 kDa, pI 5.9), Caj c4 (45 kDa, pI 6.6) and Caj c5 (30 kDa).[129] In addition, the pigeon pea cross-reacts with soybeans, chickpeas, green grams (mung beans), and all of the Fabaceae family.[129]

Processing

Rampersad *et al.* investigated the physico-chemical and sensory attributes of flavored snacks made with a combination of cassava and pigeon pea flours.[235] Various blends of cassava to pigeon pea flour ratios were extruded with a 2.5 centimeter diameter single screw Wenger X-5 extruder.[235] Following extrusion, the extrudates were cut and seasoned with either a chocolate, paprika, hickory or cheese/onion flavoring.[235] After sensory analysis, results indicated that the extradate containing the lowest ratio of pigeon pea to cassava flour, which was 5% pigeon pea flour to 95% cassava flour, had the most suitable crispness and texture.[235] Additionally, products containing ratios of pigeon pea flour had higher protein, bulk density, and water absorption.[235] In acceptability, all flavored products were liked moderately to very much with the chocolate extrudates being most liked in flavor and color when compared to the paprika, hickory and cheese/onion products.[235]

Fasoyiro *et al.* evaluated the storage and sensory attributes of fermented, extruded maize and blanched pigeon pea flour blended snacks.[236] Pigeon peas were boiled for 20 minutes, dehulled, dried in a forced draft oven at 60°C for 5 hours and milled into flour with a 2 mm sieve.[236] The maize was washed and fermented for 48 hours and oven-dried at 60°C for 5 hours and then milled.[236] The fermented maize and pigeon pea flour were then combined at ratios of 9:1, 8:2, 7:3, 6:4, and 5:5 w/w, respectively.[236] The flours were then prepared with a mix of water and seasoning where it was then formed into strands via a steel hand screw press with a 2 mm die hole.[236] The strands were then either dried at 50°C for 10 minutes or fried in a frying pan with hot vegetable oil for 3 minutes.[236] Results indicated that the addition of pigeon pea flour to maize increased the calcium and iron quality while retaining a good keeping quality.[236] It was also concluded that dried product could be kept for approximately 8 weeks while the fried products only kept for about 4 weeks.[236] Of the ratios of fermented maize to pigeon pea flour, those with the highest overall acceptability ratings included the 9:1 dried and 8:2 fried extradites.[236]

Additionally, Tables 2-65 and 2-66 list gelatinization and pasting properties of pigeon pea starch

Production

Major producers of pigeon peas worldwide include India, Africa and Central America.[80] Between 1994 and 2014, it was reported that Asia produced an average of 85.6% of the world's pigeon pea crop, with an average of 2.5 million tonnes produced in India and nearly half a million tonnes produced in Myanmar.[171] During that same time period, Africa reportedly produced an average of 12.5% of the world's pigeon peas while the Americas produced only 1.8%.[171] In Africa, pigeon peas are grown and eaten in large amounts in Lesotho, Niger, and Sierra, although Malawi reportedly produced the most in the continent in 2014 at 335,165 tonnes.[80,171] In addition, Burkina Faso, Chad, Ghana, Nigeria, Senegal, Togo and Mali are also major producers and consumers of pigeon peas.[80]

PINTO BEANS

Background

Introduction

The pinto bean is among other ‘common beans’ found in the species, *Phaselous vulgaris* which originate in North America.[96,237] In temperate areas, *Phaseolus vulgaris* is typically cultivated for the immature green pods, which are then canned or frozen.[83] Pinto beans are oval, medium-sized beans, with mottled tan and brown skin, a deep, earthy flavor and a soft gritty, powdery texture.[82] The name pinto beans literally means, ‘painted bean,’ in Spanish due to the mottled or smeared skin of the pinto bean, which disappears upon cooking.[96,237]

Uses in food

In the United States and Mexico, pinto beans are commonly used as refried beans, as fillings for burritos, as a common bean used to make chili stew, or served with rice and eaten with cornbread or tortillas.[96] Frijoles refritos, or refried beans, are a Mexican dish made with cooked, mashed pinto beans simmered with onions and pork lard.[185] Frijoles churros, also known as cowboy beans, are pinto beans cooked with tomatoes, onion, bacon, poblano chiles, and coriander.[185] In Ghana and Chad, particularly in the south, pinto beans are frequently eaten.[80] Ghana uses pinto beans in a dish called red-red stew which is comprised of beans, palm oil and spices.[80] Additionally, in Burundi, pinto beans are consumed daily, often combined with potatoes.[80] In Mexico, and Central and South America, an herb known as epazote is often added to dishes using pinto beans and other beans to act as both a spice and to aid in digestion.[237,238] The herb is known to add a robust flavor to Mexican and Guatemalan cuisines and also reduce flatulence and bloating which is often produced as a result of the bean consumption.[237,238] Similar to the epazote herb, in East Asia, a type of seaweed, Kombu, is also added to the beans for the purpose of improving digestion.[237]

Nutrition and Health Benefits

Nutrition

Pinto beans have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature pinto beans contains 9.0 grams of fiber and 9.01 grams of protein.[12] Table 2-67 lists the nutritional composition of 100 grams of raw, mature pinto beans while Table 2-68 lists the nutritional composition of 100 grams of cooked, mature pinto beans. Additionally, PulseCanada reports that the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of pinto beans is 0.59, which can be observed in Table 2-69.[86] Table 2-70 provides additional information concerning the composition of the pinto bean starch composition.

Antifungal and Antitumoral

The pinto bean has recently been investigated for its potential antifungal and antitumor properties. Yin *et al.* recently isolated lectins, or hemagglutinins, and a defensin-like antifungal peptide from the Hokkaido large pinto bean.[239] The hemagglutinin was found to possess antitumor properties as it inhibited the proliferation of human breast cancer, hepatoma cells, and nasopharyngeal carcinoma.[239] Similarly, the defensin possessed antifungal properties, as it was able to inhibit mycelial growth of *Mycosphaerella arachidicola, Setosphaeria turcica, Bipolaris maydis,* and *Fusarium oxysporum.*[239]

In a similar study, glucosmine-binding lectin was isolated from the Chinese pinto bean and examined for its antiproliferative and antifungal effects.[240] Researchers discovered that the isolated lectin was capable of inhibiting mycelial growth of *Valsa mali* by 30.6% and nasopharyngeal carcinoma HONE-1 cell proliferation was also suppressed.[240] The isolation of lectins for their antitumoral properties has been discovered in many plant species; however, the use of *P. vulargis*, the common bean such as the pinto bean, in isolating lectins is desirable as the bean is relatively inexpensive, there are numerous cultivars, and the anticancer potential is high.[239]

Antioxidants and Antinutrients

Some confusing information exists on the antinutritional versus antioxidative properties of certain compounds found in legumes. While Yin *et al* and Ang *et al* report that lectins have antiproliferative and antifungal properties, Martin-Cabrejas *et al* reports that compounds such as lectins, enzyme inhibitors, phytates, cyanoglycosides, and phenolics are antinutrients that could adversely affect human health.[239–241] Isoflavones, protease (trypsin) inhibitors, phytosterols, phytic acids, and saponin have, in the past, been known to be anticarcinogenic in soybeans.[242] More recently, tannins, saponins, and phytic acids, “so-called antinutrients,” have been found to possess disease preventative and health promoting properties.[243] In contrast, the presence of health promoting compounds in legumes is dependent upon processing. While processing of legumes improves flavor, palatability, and increases the bioavailability of nutrients, it also significantly decreases the antioxidant activities and antiproliferation properties.[126] Xu and Chang investigated the effects of thermal processing on the antiproliferative and cellular antioxidant properties and phytochemical content on pinto beans.[126] A significant decrease in total phenolic content, phytic acid content, and total saponin content was observed. Researchers also discovered that raw pinto beans possessed cellular antioxidant activities, which was decreased or completely removed upon exposure to thermal processing. Antiproliferation capabilities against human gastric and colorectal cancer cells were observed under specific doses of raw pinto bean hydrophilic extracts. Upon cooking, beans lost their antiproliferation and cellular antioxidant capabilities which indicated that different modes of processing may be best suited to preserve the positive health benefits of pinto beans.[126]

Cardiovascular Disease

Finley *et al.* studied the effect of pinto bean consumption on short-chain fatty acids profiles in fecal fermentations, bacterial populations of the lower bowels and lipid profiles in the blood of humans.[244] Forty adults with premetabolic syndrome and 40 control adults were randomly assigned to either consume a ½ cup meal of dried, cooked pinto beans or an isocaloric chicken soup meal for 12 weeks.[244] Results of the study showed that individuals consuming beans had lower total serum cholesterol and HDL and LDL cholesterol.[244] Propionate production, which has been linked to a reduction in serum cholesterol, was higher in individuals consuming beans than those consuming soup when expressed as a difference between baseline and treatment.[244] While the study did not explicitly define pinto bean consumption with improved colon cancer risk, it does offer evidence that pinto bean consumption may improve lipid profiles associated with cardiovascular disease.[244]

In a similar study, Winham *et al.* conducted a randomized, crossover 3x3 block design with 7 men and 9 women who were mildly insulin resistant.[245] The experiment took place over the course of 8 weeks with 2 weeks of washouts in which participants consumed ½ cup of pinto beans, black-eyed peas or carrots (placebo).[245] Results indicated that pinto bean consumption differed significantly from the placebo with reductions in total cholesterol and LDL cholesterol.[245] Researchers concluded that pinto bean consumption should be encouraged to reduce the risk of cardiovascular disease.[245]

Allergy

While there are numerous allergies associated many pulse grain varieties, the literature does not indicate that allergic responses are overly present with the pinto bean variety. On the other hand, there are legumes within the same species as the pinto bean (*Phaseolus vulgaris),* which have been identified as potentially eliciting an allergic response. The known allergen from the *Phaseolus vulgaris* species is pha v3, which is a non-specific lipid transfer protein 1. Additional allergic reactions associated with *Phaseolus vulgaris* include vapor inhalation when boiling beans, exposure to raw beans, and contact dermatitis from the leaves of bean plants in farmers.[188–191]

Processing

Extrusion

While extrusion may be a valuable method of processing bean flours, the type of extrusion may also play an important role in the quality of the flour. It has been reported that high temperature extrusion may undesirably affect the functional, nutritional, and sensory properties of the bean flour, including protein solubility, water absorption, solubility index, bulk density, and expansion ratio.[225–227] Kelkar *et al.* examined the effects of low temperature extruding on processing pinto bean flour.[96] After washing and soaking the pinto beans for 8 hours in a bean-to-water ratio of 1:2 (w/v), the beans were oven dried and ground. The pinto beans were then extruded in a twins extruder at 85, 100, and 120°C.[96] Results indicated that the pinto beans extruded at 100°C were darker in color and less appealing, indicating that a lower extrusion temperature was preferred.[96] In order to sufficiently lower phytohemagglutinin levels, an extrusion temperature of a least 80°C was necessary, therefore extruding at 85°C was determined to be the optimum temperature to ensure production of a quality pinto bean flour.[96] Extrusion at 85°C was able to effectively remove the beany flavor of the flour while also not permitting the development of a burned flavor which may be present at higher extrusion temperatures.[96] Extrusion at 85°C effectively removed lectins content in pinto bean flour, as well as effectively reducing oligosaccharides, stachyose, to a level significantly lower than that of the standard steam cooking method.[96] Kelkar et al. propose a greater ratio of beans-water (>1:5) in the soaking step prior to extrusion to help reduce oligosaccharide content.[96]

Fermentation

Fermentation is an ancient technology that is both a simple and inexpensive method of processing food to increase palatability and digestibility.[246] Lactic acid fermentation is an effective method for processing and preserving vegetables, cereals, and legumes because it requires little energy, and produces high yields of flavorful and palatable products.[247] Studies completed by Egounlety and Aworh have shown that legume fermentation reduces some antinutritional compounds such as phytic acid, oligosaccharides, and trypsin inhibitor while also improving the nutritional value, protein digestibility, and the biological value of legumes.[134,248,249]

Martin-Cabrejas studied the impact of fermentation and autoclaving on dietary fiber and antinutritional factors in *P. vulgaris,* the species from which pinto beans are derived.[241] Two different methods of fermentation were used: natural and lactic acid fermentation. Natural fermentation involved suspending bean flour in sterile tap water that was left to ferment naturally at 37°C for 48 hours while being stirred.[241] Lactic acid fermentation involved inoculating bean flour with *Lactobacillus plantarum* at 10% saline solution and fermenting again at 37°C for 48 hours while being stirred.[250] A portion of each type of fermented bean flour was also autoclaved at 121°C for 20 minutes.[241] Results indicated that natural fermentation plus autoclaving or lactic acid fermentation plus autoclaving eliminated the cyanogenetic glycosides as well as the lectins.[241] Lactic acid fermentation and natural fermentation alone decreased the lectin content, though it was not completely eliminated.[241] All of the processed beans saw a significant decrease in soluble dietary fiber content as well as cellulose content; however, higher levels of resistant starch were observed in all processed beans except those fermented by lactic acid.[241]

Patent

Patent number US20070160728A1 and application number US11580705 titled, "Gluten-free food products including deflavored bean powder," describes a process for creating deflavored bean powder, which may include a bean such as the pinto bean.[251] The patent relates to a gluten-free or a gluten-reduced product that has improved taste, texture, or nutritional value in comparison to conventional, gluten-free food products that may not be produced with deflavored bean powder.[251] The deflavored bean powder is produced by contacting a millable vegetable, such as a pinto bean, and exposing it to steam for 3-12 minutes at 95°C to 130°C.[251] Specifically, the method used includes processing two thousand pounds of pinto beans by steam treating them at 120°C for 4 minutes.[251] The pinto beans were then dried at 70°C for approximately 3 hours to 5 wt-% moisture, followed by milling in a 300 mesh until a deflavored pinto bean flour is produced.[251] The process also includes contacting the vegetable or pinto bean with air that previously went through the cooling apparatus during milling.[251] The deflavored pinto bean powder may act as a base for products such as a raspberry or a cinnamon flavored cereal, bread, muffin, pasta, or a cookie.[251] A panel tested cookies and muffins made with both raw pinto bean flour and deflavored pinto bean flour and found that those products made with raw pinto bean flour exhibited a raw pinto bean flavor and a fish oxidation flavor.[251]

Production

The pinto bean is the most popular dry bean produced in the United States per capita.[229] Pinto beans are grown in many states, including Washington, Idaho, Montana, North Dakota, Wyoming, Utah, Arizona, New Mexico, Colorado, Nebraska, Kansas, Texas, Minnesota, and Michigan.[82] North Dakota is the largest U.S. producer of pinto beans, with a majority of the crop being produced in the Red River Valley.[82] In addition, Wyoming is known for being a leader in producing, "bright, packaging-quality" pinto beans.[82] Idaho, along with Minnesota and Nebraska, is known for being a leading producer of pinto beans and Idaho is also the US's largest producer of certified dry bean seed.[82] The Rocky Mountain Bean Dealers Associations, which has been shipping and producing beans since 1916, is the largest production region in the Unites States for pinto beans.[82] Other companies that both produce and supply pinto beans are listed in Table 2-71.[82]

In the year 2009-2010, the United States exported approximately 211,661,909 pounds of pinto beans, with 50,429,411 of those pounds going to Mexico, 50,658,715 pounds going to the Dominican Republic, and 27,458,522 pounds going to Haiti.[230] Table 2-72 summaries the acreage, yield, and production values of pinto beans in the United States from 1987-2010 while Table 2-73 summarizes the average cost per year of 100 pounds of pinto beans.

LENTILS

Background

Identified via the inspection of the lentil's genetic stock, the lentil originated in three lines collected in northern and southern Syria and Turkey.[252] Being that their point of origination is defined as the Middle East, Asia, and North Africa, lentils are one of the hardiest and oldest foods, ranging in color from yellow to red-orange and greenish brown to black.[80] Lentils have been consumed for so many years that archaeological digs have discovered them buried with ancient Egyptian pharaohs, indicating that the lentil held high mythical standings.[80] In the taxa *Lens culinaris*, there exists two main seed types with the first being a small convex pod containing 3-6 mm diameter seeds, convex cotyledons and small pink or purple-blue flowers.[103] The second main seed type is described as a large, flat pod with 6-9 mm in diameter flat seeds, yellow to orange cotyledons, and large white or blue flowers.[103] Lentils have been recognized as very hardy crops; they grow with very little water, can survive the coldest of climates, and they tolerate arid lands as well.[80] Although lentils are known to grow in an expansive range of soils, they will not thrive under wet conditions. The lentil crop is considered a cool season crop, often grown in temperate regions as a winter crop.[83] While the lentil crop is not a tropical crop, it may be grown in the tropics during the dry season at higher altitudes.[83] Regions where the lentil is extensively cultivated include France, India, Middle East, and the Mediterranean.[83]

Allergenicity

While there are numerous allergies associated with *Lens ensculenta*, the literature does not indicate that allergic responses are overly present specific to red lentils. For *Lens ensculenta*, the major allergens that have been identified include allergens of molecular weight 72, 70, 68, 54, 52,40, 38, 30, 21, 18, and 16-12 kDa.[253] Additional allergens of *Lens ensculenta* the allergen Len c1 of the protein family Vicilin with a molecular weight of 48 kDa, Len c2 of the seed biotinylated protein family with a molecular weight of 66 kDa, and Len c3 of the non-specific lipid transfer protein 1 family with a molecular weight of 9 kDa.[129] Lentils are among the most frequent foods associated with IgE mediated hypersensitivity reactions, especially in Mediterranean and Spanish populations.[129] Boiling lentils does not seem to affect the allergenicity of lentils; however, autoclaving at 2.56 atm for 30 minutes significantly decreases IgE binding capacity of lentil protein allergens.[129] One case study reported that a young 8 year-old boy experienced symptoms of anaphylaxis upon both the ingestion and inhalation of green lentils, requiring him to seek medical aid.[254] More research must be conducted to conclude a strong correlation between red lentils specifically and consumer allergic reactions.

Production

By region, Asia is the largest worldwide producer of lentils, producing approximately 56.1% of the world's lentils.[171] The Americas are the second worldwide leader of lentil production at 35.8% of the world's lentil production, followed by Oceania at 3.6%, Africa at 3.1% and Europe at 1.6%.[171] By country, Canada is the world's leader in lentil production at 1,146,943 tonnes on average between the years 1994-2016.[171] India is the second top produced of lentils at 944,393 tonnes on average between 1994-2016, followed by Turkey at 470,110 tonnes.[171] World production of lentils has been rising with production at 2,832,140 tonnes in 2008 to 6,315,858 tonnes in 2016.[171]

Companies such as Ackerman Marketing, Aileen Quirk & Sons, Inc., Blackhive Corp, Inc., Camex, Inc., Central Valley Ag Exports, Inc., Columbia Bean & Produce Co. Inc., D.W. Sturt & Company, EP International Corp., Hinrichs Trading Company, Idaho Bean & Elevator Company, KC Trading Company, LLC, Latinex Intl., L.H. Virkler & Co., Inc., Slauson Trading Company, LLC, St. Hilare Seed Company, Inc., Trinidad Benham Corp., Tumas Commodities, Yanez International – Sales Agent., and Zateca Foods, Inc. supply lentils in the U.S.[82]

Red Lentils

Background

Uses in food

Lentils are ideal for casseroles, thickening soups, and making daals when combined with various spices.[80] Additionally, red lentils, also known as Egyptian lentils or masoor daal, do not require soaking before cooking and they disintegrate into a thick puree upon cooking, making them of high culinary value.[80] Red lentils can be integrated as flour, whole, or pureed and mixed into new foods such as smoothies, shakes, hearty soups, Greek lentil salads, zesty gazpacho, lettuce wraps, tomato pasta sauce, meatloaf, citrus herb sauces, biscuits, granola bars, cakes, cookies and fruity popsicles.[106] Another popular use for red lentils is in creating vegetarian burgers.[80] Cooking lentils and mixing in fine bulgur wheat or semolina is the first step in making red lentil burgers.[80] Then, sautéed chopped onions and pepper paste, lemon juice, pomegranate molasses, cumin, paprika, and chopped herbs are added to the lentil mixture.[80] Finally, the lentil mixture is formed into patties and served with lettuce.[80]

Nutrition and Health Benefits

Nutrition

Red lentils have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature red lentils contains 5.8 grams of fiber and 9.3 grams of protein.[12] Table 2-74 lists the nutritional composition of 100 grams of raw, mature red lentils while Table 2-75 lists the nutritional composition of 100 grams of cooked, mature red lentils. Red lentils are also rich in folate at approximately 21 μg per 100 grams of cooked lentils, making them an ideal food of choice for women who aim to prevent neural tube defects in their babies during pregnancy.[80] Additionally, PulseCanada reports that the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of red lentils is 0.54.[86] PulseCanada also reports that a 20:80 lentil-rice flour blend has a PDCAAS of 0.74 while a 25:75 lentil-wheat flour blend has a PDCAAS of 0.71.[86]

Health benefits

Zhang *et al.* examined the phenolic profiles of 10 red lentil cultivars and their contribution to antioxidant activity and inhibitory effects on alpha-glucosidase and pancreatic lipase.[255] Researchers stated that oxidative damage caused by free radicals may be one of the major factors associated with human chronic disease which may include cancer, diabetes, Parkinson's disease, Alzheimer's, and cardiovascular disease.[255] Phenolic compounds may prevent the onset of oxidative stress-related disease in the human body.[255] Inhibiting alpha-glucosidase, which reduces intestinal glucose digestion and absorption, may control post-prandial glycaemic response.[255] Management of obesity may be possible by inhibiting the enzyme lipase.[255] Results of the study indicated that 21 phenolic compounds were identified, with flavonoids being the majority, including procyanidins, catechin/epicatechin glucosides, and kaempeferol glycosides.[255] The phenolic compounds identified contributed significant antioxidant activity and inhibited alpha-glucosidase and lipase, which aided in controlling blood glucose and obesity.[255] Researchers stated that flavonols, rather than flavanols, inhibited the activity of pancreatic lipase and alpha-glucosidase.[255] Researchers concluded that improved development of lentil cultivars and functional foods may aid in managing weight and controlling blood glucose.[255]

Antinutritional factors

Manan *et al.* studied the effect of cooking on phytic acid content and nutritive value in red lentils.[256] The red lentils were prepared by soaking in deionized water for 4 hours at room temperature.[256] Then, the red lentils were boiled for 40 minutes, oven-dried at 105°C, and ground.[256] The 9-6 red lentil variety saw a reduction in phytic acid from 5.98 g/kg^{-1} to 1.57 g/kg^{-1} upon cooking as well as an increase in true protein digestibility and biological value from 67.0% to 90.2% and 42.5% to 54.0%, respectively, upon cooking.[256]

Wang studied the effect of variety and crude protein content on dehulling quality and on the resulting chemical composition of red lentils.[257] Red lentils of the varieties Crimson, Blaze, Redwing and Robin were collected.[257] The red lentils were sieved into fractions ranging from 4.5 to 5.0 mm and 30 milligrams of sample was put into a container and water up to 12.5% moisture was added.[257] Samples were soaked for 24 hours and then the red lentils were processed in a mill for 38 seconds at a speed of 1100 rpm.[257] After dehulling, the red lentils were sieved and hulled and dehulled samples were separated.[257] Results of the experiment indicated that dehulled seeds exhibited higher protein, starch, phytic acid, stachyose, and verbascose content but lower trypsin inhibitor activity, tannin, raffinose, and sucrose content than the raw seeds.[257] The researcher concluded that the removal of the seed coat significantly reduced tannins in the dehulled seeds.[257]

Processing

Starch processing characteristics of various red lentil cultivars can be seen in Table 2-76.[258]

Effect of processing on protein quality

Nosworthy *et al.* evaluated the effects of processing on the in vivo and in vitro protein quality of red lentils.[259] Researchers compared the results of extrusion, baking and cooking to determine the most effective method.[259] The red lentils were prepared by milling with a Jacobson 120-B hammer mill and sifting.[259] Samples were then extruded using a Clextral Evolum HT 25 twin screw extruder with a screw diameter of 25 mm L/D ratio of 40.[259] The screw speed was 650 rpm and the barrel temperatures were 30-50°C, 70-90°C, and 100-120°C. After extrusion, the samples were milled.[259] To bake samples, 4 kg of red lentil flour was mixed with 2 kg of water for 4 minutes.[259] Then, the dough was mixed at speed #1 for 1.5 minutes and at speed #2 for 2.5 minutes.[259] Once the dough was mixed, it was molded and baked between 330-380°F for 35 minutes, cooled and milled.[259] To cook the lentils, they were soaked in a 1:4 ratio of water for 16 hours.[259] Red lentils were then boiled for approximately 25-35 minutes, drained, freeze dried and milled.[259] The results indicated that extruded red lentil flour had higher PDCAAS scores than cooked samples, at 63.01 and 57.40, respectively.[259] Additionally, baked samples had a lower PDCAAS score than cooked samples at only 53.84.[259] The Digestible Indispensable Amino Acid Score was 0.54 while the Protein Efficiency Ratio of extruded flour was 1.30 and the baked flour was 0.98.[259]

Snack

Dogan *et al.* investigated the effects of protein, lipid and moisture contents of feed mixture; screw speed and cooking temperature on starch gelatinization; protein insolubility; and lipid complexation of an expanded food product made from red lentil flour, corn starch, and corn oil.[260] All products were mixed together and stored until equilibrium. Then, the mixture was extruded in a counter-rotating, twin-screw extruder with nozzle diameter of $4x10^{-3}$ m and a feeding screw speed of 35 rpm. The feed rate was 5×10^{-4} kg/s and extradites were dried overnight at 45°C until 4-5 kg moisture/100 kg was reached. The results of the experiment indicated that the optimum feed composition was 67% lentil flour, 30% corn starch, and 3% corn oil. The mixture was processed at 15% moisture and at a temperature of 178°C. Degree of gelatinization was 0.70 while expansion ratio was 3.7.[260]

Production

During a Global Pulse Convention, Gaetan Bourassa of AGT Foods estimated that, in 2016, of the approximately 6 million MT of pulses produced, 75% of them, or 4.5 million MT, are red lentils.[261] Bourassa also estimated the red lentil trade in 2016 at approximately 2.5 million MT and, with India and

Turkey as the major buyers, they would purchase approximately 1.2 million MT and 350,000 MT, respectively.[261]

<u>GREEN LENTIL</u>

Background

Uses in food

Green lentils, also known as continental lentils, do not require soaking before cooking and while red lentils disintegrate, green lentils still retain their shape, making them ideal for casseroles, stuffing, and vegetarian pate or daal when mixed with herbs.[80] Green lentils can be integrated whole, pureed, or in flour form into new foods such as smoothies, shakes, Greek lentil salads, zesty gazpacho, mixed pulse vinaigrette salads, lettuce wraps, biscuits, granola bars, cakes, and cookies.[106]

Nutrition and Health Benefits

Nutrition

Green lentils have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature green lentils contains 5.8 grams of fiber and 9.3 grams of protein.[12] Table 2-77 lists the nutritional composition of 100 grams of raw, mature green lentils while Table 2-78 lists the nutritional composition of 100 grams of cooked mature green lentils. Additionally, PulseCanada reports that the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of green lentils is 0.63.[86] PulseCanada also reports that a 20:80 lentil-rice flour blend has a PDCAAS of 0.74 while a 25:75 lentil-wheat flour blend has a PDCAAS of 0.71.[86]

Health benefits

Amarowicz *et al.* examined the free radical-scavenging capacity, antioxidant activity, and phenolic composition of green lentils.[262] Antioxidants can scavenge reactive oxygen and nitrogen species, which, evidence suggests, may be important in preventing the onset of oxidative diseases within the human body.[262] Additionally, researchers suggest that phenolic-rich foods may decrease several chronic disease states.[262] To examine the composition of the green lentils, phenolics were extracted with 80% aqueous acetone and extracts were then separated with a Sephadex LH-20 column.[262] The first fraction was eluted from the column with 95% ethanol, while the second fraction, containing tannins, was eluted with the mobile phase with a 1:1 ratio of acetone to water.[262] Results indicated that the dominant phenolics in green lentils were catechin, epicatechin, glucosides, procyanindin dimers, quercetin diglycoside, and trans-p-coumaric acid.[262] Researchers concluded that the green lentil is among the leguminous crops that is an important source and good level of phenolic compounds which should be included daily into the diet.[262]

Antinutritional factors

Wang *et al.* examined the influence of cooking and dehulling on nutritional composition of several green lentil varieties including Laird, CDC Sovereign, CDC Richlea, CDC Vantage, Eston, and Milestone.[263] Upon determination of the appropriate cook times, 100 grams of each green lentil were soaked in distilled water at a ratio of 1:4 for 24 hours at room temperature.[263] The water was then drained and the samples were cooked in distilled water until 80% of the seeds were cooked.[263] The cooked samples were drained and frozen at -18°C and freeze-dried in a Virtis Freeze Drier.[263] Seeds were then ground to a flour with a 0.5 mm sieve and stored at 4°C in a plastic bag.[263] To dehull the samples, green lentils were sieved into fractions ranging from 4.5 to 5.0 mm and 30 milligrams of sample was put into a container and water to 12.5% moisture was added.[263] Samples were soaked for 3 days at 4°C and then the green lentils were processed in a mill for 38 seconds at a speed of 1100 rpm.[263] After dehulling, the green lentils were sieved and hulled and the dehulled samples were separated.[263] Results indicated that CDC Richlea and Milestone had the lowest soluble dietary fibers of all cooked green lentils at 12.7 g/kg dry matter; however, Richlea also had the highest value of resistant starch of cooked green lentils.[263] On the other hand, of the cooked green lentil varieties, Eston had the highest soluble dietary fiber content at 16.5 g/kg dry matter.[263] Of dehulled samples, CDC Sovereign had the highest soluble dietary fiber content at 13.4 g/kg dry matter while Milestone had the lowest soluble dietary fiber at 9.5 g/kg dry matter.[263] Researchers concluded that green lentils cooked in boiling water experienced a significant increase in protein, starch, insoluble and total dietary fiber, resistant starch, calcium, copper, and manganese and a decrease in phytic acid, tannins, trypsin inhibitor activity, oligosaccharides, sucrose, ash, iron, potassium, magnesium, phosphorus, and zinc.[263]

Processing

Starch processing characteristics of various green lentil cultivars can be seen in Table 2-79.[258]

Effect of processing on protein quality

Nosworthy *et al.* evaluated the effects of processing on the in vivo and in vitro protein quality of green lentils.[259] Researchers compared the results of extrusion, baking and cooking to determine the most effective method.[259] The green lentils were prepared by milling with a Jacobson 120-B hammer mill and sifting.[259] Samples were then extruded using a Clextral Evolum HT 25 twin screw extruder with a screw diameter of 25 mm L/D ratio of 40.[259] The screw speed was 650 rpm and the barrel temperatures were 30-50°C, 70-90°C, and 100-120°C. After extrusion, the samples were milled.[259] To bake samples, 4 kg of green lentil flour was mixed with 2 kg of water for 4 minutes.[259] Then, the dough was mixed at speed #1 for 1.5 minutes and at speed #2 for 2.5 minutes.[259] Once the dough was mixed, it was molded and baked between 330-380°F for 35 minutes, cooled and milled.[259] To cook the lentils, they were soaked in a 1:4 ratio of water for 16 hours.[259] Green lentils were then boiled for approximately 25-35 minutes, drained, freeze dried and milled.[259] The results indicated that extruded green lentil flour had higher PDCAAS scores than cooked samples, at 57.09 and 52.92, respectively.[259] Additionally, baked samples had a lower PDCAAS score than cooked samples at only 47.14.[259] The Digestible Indispensable Amino Acid Score was 0.49 while the Protein Efficiency Ratio of extruded flour was 1.34 and the baked flour was 1.09.[259]

Bakery items

Borsuk evaluated the incorporation of green lentil flour in various baked products, including pita and pan bread.[264] In the first experiment that created pita bread, green lentils were dehulled, milled and blended at 25, 50, 75, and 100% with all-purpose wheat flour.[264] To create the dough, a moisture content of 14% was achieved and active dry yeast, salt, and gum were added.[264] Dough was allowed to ferment and rest, then the dough was run through a sheeter and proofed before being baked for 1 minute at 288°C.[264] Results indicated that the greatest variation in physical parameters was seen with the green lentil flour with variation in color and texture varying greatly between green lentil and whole wheat flour blends.[264] The researcher concluded that more studies on the effect of particle size in pita bread baking should be investigated.[264]

The second experiment, evaluating the use of green lentil flour in pan bread, used a blend of 10, 15, and 25% lentil flour mixed with wheat flour.[264] To prepare the green lentil flour, seeds were first dehulled, milled and blended at different ratios with the wheat flour.[264] Water, yeast, salt, sugar, shortening, whey, malt syrup, ascorbic acid, and ammonium phosphate were mixed together.[264] The dough was allowed to ferment and was then formed into six inch rolls and proofed.[264] The dough was then baked at 204°C for 25 minutes and cooled.[264] Results of the experiment indicated that green lentil flour substitution should not exceed 10% for optimal dough conditions.[264]

Production

During a Global Pulse Convention, Gerald Donkersgoed of Ilta Grain, gave an overview of the green lentil market.[261] Donkersgoed gave the 2015 estimates of the largest green lentil producers: Canada producing 600,000 MT; U.S. producing 180,000 MT; and Turkey producing 20,000 MT.[261] Donkersgoed states that in the U.S., green lentils make up approximately 75% of lentil production.[261] For 2016, Donkersgoed estimated the green lentil crop: U.S. producing 450,200 MT and Canada producing 650,000 MT.[261]

PEAS

Background

Introduction

A wide variety of peas exist within the species *Pisum sativum*. There are four main varieties: picking peas harvested for the fresh vegetables or tender pods; vining peas harvested for freezing or canning of the tender seeds; forage peas used for animal fodder; and combining peas harvested for their dry seed.[83] The reason for the extensive variety in the pea species may be due to the early circulation of pea crops across a large majority of the world.[83] For example, current pea cultivars have been developed from areas including southwest Asia, North America, India, China, Europe, and Africa.[83] In addition to these regions of the world, it is believed that the pea may originate in Ethopia, central Asia, and near the Mediterranean basin with another origination site being the Middle East.[265] Today, peas are harvested mainly in northern Europe, northwest USA, China, and regions of Russia, with the leading producer of peas being Canada.[80,83] Peas may be grown not only in temperate climates but in the cool season of tropical regions, particularly at high altitudes.[83]

Uses in food

Peas are soft when young and require drying and may be available either whole or split.[80] Split peas are usually boiled or steamed and, upon cooking, will disintegrate into a thick puree that is ideal for casseroles, soups, daals, and purees.[80] Historically, peas were used in various eastern cultures as flours, soups, and snacks.[80]

YELLOW PEAS

Background

Uses in food

One Chinese dish involves the use of yellow split peas to make pudding.[80] The process involves taking dry yellow peas and boiling them in water until the peas split.[80] The peas are then drained, mashed and mixed with white sugar.[80] The mixture is then put into a pudding form tray, cooled and cut and served.[80] It is said that the yellow color and rich flavor of the pudding were the main reasons why this pudding was a favorite among royals during the Qing Dynasty.[80]

Nutrition and Health Benefits

Nutrition

Yellow peas have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature yellow peas contains 4.4 grams of fiber and 8.5 grams of protein.[12] Table 2-80 lists the nutritional composition of 100 grams of raw, mature yellow peas while Table 2-81 lists the nutritional composition of 100 grams of cooked, mature yellow peas. Additionally, PulseCanada reports that the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of yellow split peas is 0.64.[86] Another study conducted by Nosworthy *et al.* found that yellow split pea flour had, on average, a PDCAAS score of 0.68, while the optimal PDCAAS scores were achieved upon cooking the yellow split pea flour, rather than baking or extruding, which yielded a score of 0.69.[266] Details of this study are discussed further in the processing section.

Glycemic control

The Canadian International Grains Institute and Dr. Nancy Ames of the Agriculture Agri-Canada with support from the Canadian Pulse Growers conducted research on using yellow pea flour to improve the glycemic profile of cereal products.[267] This study goes over flour milling techniques, which are discussed further in the processing section.[267] Research indicates that the particle size of flour can impact the in vitro glycemic response, which is what was explored in this study.[267] The study found that coarse yellow pea semolina at a particle size of approximately 600 μm, had a lower in vitro glucose release than refined yellow pea flour of approximately 150 μm particle size.[267] Their findings suggest that the larger particle size impacted glucose release; however, upon subjecting the pea flour and semolina to high temperature extrusion, the difference in glycemic response was eliminated.[267] When the yellow pea semolina and flour were incorporated into extruded breakfast cereals, they showed low in vitro glucose release over 300 minutes when compared to extruded breakfast cereals made of only corn.[267] Overall, the researchers concluded that the incorporation of yellow pea flours into extruded breakfast cereals may help improve the glycemic profile.[267]

Metabolic syndrome

Yellow peas have also been examined in their use for reducing the risk of metabolic syndrome in overweight and obese individuals.[174] One study examined the effect of consuming yellow peas at 5 cups per week for 8 weeks compared to a reduced energy 500 kcal/day plan in two groups of 19 and 21-year-old overweight or obese adults.[174] After 8 weeks, both groups reported a reduction in waist circumference, energy intake, systolic blood pressure, glycosylated HbA1c and glucose AUC. HDL and C-peptide increased by 4.5 and 12.3% in the pulse groups but decreased by 0.8 and 7.6% in the energy-restricted group.[174] Researchers concluded that consumption of pulses reduced the risk factors of metabolic syndrome to the same effect and, in some instances, more strongly than counseling for a reduced energy diet.[174]

Antinutritional factors and oligosaccharide presence

One study investigated the effect of processing on the reduction of oligosaccharides in yellow peas.[268] Raffinose, stachyose, and verbascose were detected in yellow peas with raffinose and stachyose comprising approximately 47% of total oligosaccharide content of yellow peas.[268] To soak the peas, 100 grams of yellow peas were soaked in 400 ml of distilled water for 3-12 hours.[268] Some peas were soaked with ultrasound at 47 kHz for 1.5-3.0 hours or with high hydrostatic pressure (HHP) at 621 MPa for 0.5-1.0 hours.[268] After soaking, 50 grams of yellow peas were cooked in 250 mL of water for 30 minutes at 98°C.[268] Yellow peas were drained, dried at 55°C for 12 hours, and ground with a cyclone mill for oligosaccharide content determination.[268] Soaking with ultrasound for 3 hours or with HHP for 1 hour reduced the oligosaccharide content by 39.2 and 36.1%, respectively.[268]

Antinutritional factors such as polyphenols, phytic acid, and trypsin inhibitor can limit the use of raw pea flour as an ingredient in food products.[269] To reduce the antinutritional factors and improve the flavor and nutritive value of raw pea flour, heat treatment can be used.[269]

Wang *et al.* evaluated the effect of variety and processing on nutrients and certain antinutrients in yellow pea cultivars, Delta, CDC Mozart, and Eclipse.[270] Peas were prepared by soaking 100 grams in distilled water at a ratio of 1:4 at room temperature for 24 hours.[270] Seeds were then drained, freeze-dried and ground into flour for analysis.[270] Some seeds were also soaked, boiled, freeze-dried and ground into flour for analysis.[270] Other seeds were dehulled and ground into flour for analysis.[270] Yellow pea variety, Delta, had the lowest content of soluble dietary fiber for cooked peas at 13.9g/kg^{-1} dry matter as well as a significantly increased content of raffinose by dehulling.[270] Additionally, CDC Mozart showed the lowest reduction in both stachyose and verbascose upon dehulling, at 5.0% and 8.6%, respectively.[270] As with Delta, Eclipse also significantly increased in raffinose content upon dehulling in addition to having the lowest reduction in ash upon soaking.[270]

Allergenicity

While there are numerous allergies associated many pulse grain varieties, the literature does not indicate that allergic responses are overly present with the yellow pea variety. One study found that a 10 year old female, with a history of peanut allergy, consumed a soup of cooked yellow peas and she experienced throat pruritus and abdominal pain.[271] It was discovered that skin testing on allergy assessment was positive to boiled peas but negative to raw peas, suggesting that boiling reduced the allergenicity of the pea.[271] More research must be conducted to conclude a strong correlation between the yellow pea and consumer allergic reaction.

Processing

Starch processing characteristics of various yellow pea cultivars can be seen in Table 2-82.[258]

Milling

The Canadian International Grains Institute and Dr. Nancy Ames of the Agriculture Agri-Canada with support from the Canadian Pulse Growers conducted research on using yellow pea flour to improve the glycemic profile of cereal products.[267] In this study, they also investigated a method of milling the yellow pea into flour. A roller miller, specifically a Buhler roller miller, was used to grind the yellow pea into flour. First, rollers break peas into coarse particles, which are then sifted and either rolled again and sifted or put through a purifier. Figure 1 shows a flow diagram of the milling process used to mill the yellow pea into flours with varying particle sizes.

Effects of processing on protein quality

Nosworthy *et al.* conducted a study on the effects of processing on protein quality in yellow split pea flour.[266] The researchers obtained yellow split peas and milled the samples via a Jacobson 120-B hammer mill with a screen hole size of 0.50 inches around.[266] To extrude, samples were prepared via a Clextral Evolum HT 25 twin screw extruder at 36 kg/h, moisture addition of 0.8 kg/h and a screw speed of 650 rpm.[266] Barrel temperatures were 30-50°C, 70-90°C, and 100-

120°C. Baked samples were prepared by taking 4.0 kg of yellow split pea flour and mixing for 4 minutes with 2.0 kg of water.[266] The dough that was created was sheeted to a thickness of 2-4 mm and cut and transferred to baking trays for a 30 minute rest prior to baking.[266] After rest, the dough was baked at various temperatures for 35 minutes in a Doyon FC2-III tunnel conveyor oven.[266] After baking, the samples were milled and sifted.[266] Boiled samples were prepared by soaking in tap water at a ratio of 1:4 for 16 hours.[266] In fresh water, the yellow peas were boiled for 25-35 minutes and then drained, freeze-dried, and milled with a hammer mill.[266] The PDCAAS of yellow split peas was .646 for extruded products, .689 for baked, and .692 for cooked.[266]

Snack

Colla and Gamlath evaluated the use of inulin and maltodextrin as a fat replacer in a baked, savory yellow split pea cracker.[272] The yellow split peas were soaked in water for ten hours and surface water was removed.[272] Then the peas were processed for three minutes and hydrolyzed fat replacers were added and processed for another 30 seconds.[272] The mixture was then rolled out to a 2.0 mm thickness and sliced into 2.0x4.0 cm crackers.[272] Crackers were baked in a conventional fan-forced Mareno oven at 125°C for 34 minutes.[272] Results indicated that the snack with 75% fat replacement using inulin and maltodextrin received the mean overall acceptability score compared to the control and to the similar commercial product.[272] The yellow split pea snack was able to claim that they were a good source of protein, an excellent source of dietary fiber, and a reduced fat snack, based on the Australian Food Standards Code.[272]

Production

Yellow peas account for 2/3 of the U.S. production of dry peas.[273] In 2008, the United States produced 307,826 metric tons (MT) of yellow peas.[273] There are several companies that supply yellow peas in the United States. Some of those companies include, Ackerman Marketing, Blackhive Corporation, Inc., D.W. Sturt & Company, Latinex Intl., Meridian Seeds, LLC, Slauson Trading Company, LLC, Stateline Producers Cooperative, Trinidad Benham Corp., and Woodland Foods.[82,274] Companies that manufacture yellow peas include C and F Foods, Inc., Healthy Food Ingredients, and Timeless Seeds, Inc.[274]

GREEN PEAS

Background
Uses in food

Green peas can also be used in stir-fry dishes, pot pies, salads, and casseroles.[269] In Asian countries, green peas may be roasted and salted.[269] In the Mediterranean, green peas are added to meat and potatoes to make rich stews.[269]

Nutrition and Health Benefits

Nutrition

Green peas have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature green peas contains 5.0 grams of fiber and 9.1 grams of protein.[12] Table 2-83 lists the nutritional composition of 100 grams of raw, mature green peas while Table 2-84 lists the nutritional composition of 100 grams of cooked, mature green peas. Additionally, PulseCanada reports that the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of green peas is 0.50.[86] Another study conducted by Nosworthy *et al.* found that green split pea flour had, on average, a PDCAAS score of 0.71, while the optimal PDCAAS scores were achieved upon baking the green split pea flour, which was 0.75.[266] Details of this study are discussed further in the processing section.

Health benefits

Veenstra *et al.* conducted a study on the effect of pulse consumption on perceived flatulence and gastrointestinal function in healthy males.[275] Test subjects were between the ages of 19 and 40 and they consumed 100 grams of various legumes including green peas over 28 consecutive days.[275] Researchers found that greens peas were among the pulses that had the highest level of dietary fiber but they did not have the highest levels of oligosaccharides.[275] The study concluded that consumption of green peas was well tolerated among the adult males and the effects observed on severity of flatulence and GI symptoms from pulse consumption do not likely cause sufficient concern for reducing or avoiding the consumption of pulses and reaping the cardiovascular, diabetic and chronic disease prevention benefits.[275]

Antinutritional factors and oligosaccharide presence

One study investigated the effect of processing on the reduction of oligosaccharides in green peas.[268] Raffinose, stachyose, and verbascose were detected in green peas with raffinose and stachyose comprising approximately 40% of total oligosaccharide content of green peas.[268] To soak the peas, 100 grams of green peas were soaked in 400 ml of distilled water for 3-12 hours.[268] Some peas were soaked with ultrasound at 47 kHz for 1.5-3.0 hours or with high hydrostatic pressure at 621 MPa for 0.5-1.0 hours.[268] After soaking, 50 grams of green peas were cooked in 250 mL of water for 30 minutes at 98°C.[268] Green peas were drained, dried at 55°C for 12 hours, and ground with a cyclone mill for oligosaccharide content determination.[268] The most effective method for reduction of oligosaccharides in green peas was after soaking in water for 12 hours with ultrasound for up to 3 hours.[268]

Antinutritional factors such as polyphenols, phytic acid, and trypsin inhibitor can limit the use of raw pea flour as an ingredient in food products.[269] To reduce the antinutritional factors and improve the flavor and nutritive value of raw pea flour, heat treatment can be used.[269] Mineral absorption can be adversely affected by the presence of oxalates, which primarily affect calcium absorption.[276] Dried green split peas contain low amounts of calcium.[276]

Wang *et al.* evaluated the effect of variety and processing on nutrients and certain antinutrients in green pea cultivars, SW parade, Nitouche, and Keoma.[270] Peas were prepared by soaking 100 grams in distilled water at a ratio of 1:4 at room temperature for 24 hours.[270] Seeds were then drained, freeze-dried and ground into flour for analysis.[270] Some seeds were also soaked, boiled, freeze-dried and ground into flour for analysis.[270] Other seeds were dehulled and ground into flour for analysis.[270] Green pea varieties SW Parade and Keoma showed the highest reduction in trypsin inhibitor activity after cooking.[270] Unfortunately, raffinose content was significantly increased in SW Parade following dehulling; however, Keoma had the highest reduction in both stachyose and verbascose following dehulling, at a reduction of 10% and 33.6%, respectively.[270] Nitouche showed the highest reduction in ash content during soaking as well as the highest soluble dietary fiber content for cooked peas at 17.8 g/kg^{-1} dry matter.[270]

One study evaluated the effect of extrusion and conventional processing methods on protein and antinutritional factor content in pea seeds.[277] The cultivars Renata, Solara, and Ballet were investigated for their tannin, trypsin, chymotrypsin, alpha-amylase inhibitors and haemagglutinating activities.[277] The seeds were prepared by dehulling, soaking in double-deionized water at a 1:5 ratio for 12 hours at 30°C, and then drying at 50°C in an air circulation oven.[277] Seeds were then germinated at 25°C at 24, 48, and 72 hours and then dried in an air oven at 50°C overnight.[277] The peas were then ground and extruded at 148°C, 25% moisture and 100 rpm.[277] The results indicated that extrusion conditions were the most effective in reducing tannin, trypsin, chymotrypsin, alpha-amylase inhibitors, and haemagglutinating activity without altering protein content.[277] Trypsin and chymotrypsin inhibitors and haemagglutinating activities in peas were reduced more readily by extrusion treatment than was chymotrypsin inhibitory activity.[277]

Allergenicity

While there are numerous allergies associated many pulse grain varieties, the literature does not indicate that allergic responses are overly present with the green pea variety. One study investigating the allergenicity of green peas found that all levels of green pea seeds show IgE-binding capacity, as well as immature seeds.[278] Researchers also asserted that the total IgE-binding capacity of the green pea increases as maturation of the seeds progresses.[278] This suggests that there is a potential for allergenic potency in the green pea.[278] More research must be conducted to conclude a strong correlation between the green pea and consumer allergic reactions.

Processing

Starch processing characteristics of various green pea cultivars can be seen in Table 2-85.[258]

Effects of processing on protein quality

Nosworthy *et al.* conducted a study on the effects of processing on protein quality in green split pea flour.[266] The researchers obtained green split peas and milled the samples via a Jacobson 120-B hammer mill with a screen hole size of 0.50 inches around.[266] To extrude, samples were prepared via a Clextral Evolum HT 25 twin screw extruder at 36 kg/h, moisture addition of 0.8 kg/h and a screw speed of 650 rpm.[266] Barrel temperatures were 30-50°C, 70-90°C, and 100-120°C.[266] Baked samples were prepared by taking 4.5 kg of green split pea flour and mixing for 4 minutes with 2.36 kg of water.[266] The dough that was created was sheeted to a thickness of 2-4 mm and cut and transferred to baking trays for a 30 minutes rest prior to baking.[266] After rest, the dough was baked at various temperatures for 29 minutes in a Doyon FC2-III tunnel conveyor oven.[266] After baking, the samples were milled and sifted.[266] Boiled samples were prepared by soaking in tap water at a ratio of 1:4 for 16 hours.[266] In fresh water, the green peas were boiled for 25-35 minutes and then drained, freeze-dried, and milled with a hammer mill.[266] The PDCAAS of green split peas was .74 for extruded products, .75 for baked, and .72 for cooked.[266]

Snack

Ahmad Wani and Kumar investigated the characteristics of extrudates enriched with health promoting ingredients.[279] Prior to conducting their study of enrichment via fenugreek seed flour and fenugreek leave powder, researchers established a control flour which they would enrich.[279] Various mixtures of composite flour, barley flour, and dry green pea flour were used to establish the control.[279] The various mixtures were extruded at 125°C, 14% moisture, in a twin screw extruder at 200 rpm with a 4 mm die.[279] From this study, researchers concluded that the mixture of composite flour, barley flour, and dry green flour at 70:20:10, respectively, was ideal.[279]

Production

The most important grading factor for green peas used for human consumption is seed color.[273] Green peas are very susceptible to bleaching caused by bright sunshine, warm temperatures, and bright sunshine as the seeds mature.[273] That being said, regions that have mastered the growing of green peas are East and Southern Africa.[273] In East and Southern Africa, green peas are the fourth most widely produced pulse at approximately 550 thousand tonnes produced.[80] In the U.S. in 2011, a total of 295,060 metric tons (MT) dry peas were produced. In 2008, the United States produced 208,784 MT of green peas. By state, North Dakota produced the most pounds of green peas in 2008.[273]

Production companies

There are several companies that supply green peas in the United States.[274] Some of those companies include Blackhive Corp, Inc., Great West, Inc., Latinex Intl., and Trinidad Benham Corp.[274] Companies that manufacture green peas include C and F Foods, Inc., Healthy Foods, and Woodland Foods.[274]

COWPEAS

Background

Introduction

The United States Dry Bean Council reports that the cowpea is also known as the blackeye bean or black-eyed peas.[82] Other names may include southern pea, crowder pea, lubia, niebe, coupe, or asparagus bean.[80,83] For the purpose of this review, sources will be utilized that reference the cowpea as blackeye beans, black-eyed peas or any of the previously listed names.

The cowpea belongs to the species *Vigna unguiculata* (L.) Walf. and is believed to have originated and been domesticated in tropical Africa.[83] The general consensus is that the crop was taken to Egypt, then parts of the Mediterranean where it was eventually carried to Asia.[83] Development of the crop is believed to have occurred in India with further development occurring upon reaching the West Indies and subsequently the United States.[83] Cowpeas are known to survive in semi-arid regions and they are unique in their ability to coexist with other crops.[80]

The cowpea is characterized by its white skin with small black eye, kidney shape and fine wrinkles.[82] Other characteristics of the cowpea include its creamy texture, fragrant aroma, and distinct, unique flavor.[82] Cowpeas are unique in that they do not require a pre-soaking step suggesting that they have the potential to be cooked at a rapid pace.[82]

Uses in food

Cowpeas are consumed all across Asia, Africa, Southern Europe, and Central and South America.[80] Cowpeas are known for their use as a primary ingredient in both Creole and Indian curries.[80]

Nutrition and Health Benefits

Nutrition

Cowpeas have an impressive nutritional profile. The United States department of Agriculture reports that 100 grams of cooked, mature cowpeas contains 6.50 grams of fiber and 7.73 grams of protein.[12] Table 2-86 lists the nutritional composition of 100 grams of raw, mature cowpeas while Table 2-87 lists the nutritional composition of 100 grams of cooked, mature cowpeas. Tables 2-88 and 2-89 give additional information concerning the composition of the cowpea starch composition. Additionally, PulseCanada does not report the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of cowpeas. Boye et al. reports the PDCAAS scores of two Egyptian cowpeas that were processed with two different methods.[87] The cowpea processed via roasting for 15 minutes at 180°C in a sand bath, dried overnight at 55°C and ground had a reported PDCAAS score of .43, with a recalculated score of .58.[87] The Egyptian cowpea processed via autoclaving in water and dried overnight at 55°C and ground had a reported PDCAAS score of .72, with a recalculated score of .97.[87] These results suggest that variations in processing methods may affect the protein digestibility.[87]

Health benefits

A study evaluated the effects of methanol extract and solvent fractions of cowpea seeds and isolated compounds.[280] Ethyl acetate and n-butanol fractions of cowpea seeds and active compounds, linolenic acid and linoleic acid, were found to inhibit nitric oxide production significantly.[280] Linoleic acid was also found to suppress the production of pro-inflammatory cytokines such as interleukin (IL)-1B, IL-6 and tumor necrosis factor in LPS-induced macrophage cells.[280] The researchers concluded that the polyunsaturated fatty acids such as linolenic and linoleic acid in cowpea seeds lead to the strong anti-inflammatory activity.[280]

A study was published on the effects of cowpea peptides on insulin resistance.[281] Researchers exposed L6 rat skeletal muscles to varying doses of cowpea peptides for 20 hours or insulin for 30 minutes.[281] From the treated cells, proteins were isolated and analyzed for phosphorylation of Akt.[281] The results suggested that cowpea peptides are able to induce Akt phosphorylation in the cell culture, indicating that cowpea peptides are able to activate the insulin signaling cascade in the skeletal muscle cells.[281] Researchers concluded that cowpea peptides likely have the ability to mimic the action of insulin by activating the identical signaling cascade.[281]

Processing

Extrusion

A study was published evaluating the effects of extrusion on snacks made from blends of cowpea and acha flours.[282] In Nigeria, cowpea and acha are complementary foods that contribute large quantities of protein and carbohydrate to the Nigerian diet.[282] The study showed that upon extruding, the protein content increased from 7.98% for acha flour to 16.03% and 18.73% for blends containing 30.0% and 40.0% cowpea flour.[282] It was also observed that the increase in extrusion temperature and feed moisture content caused the trypsin inhibitor activity to decrease by 76.0% to 92.1%.[282] The researchers concluded that a blend of acha and cowpea flours have potential as an enriched food product.[282]

Fermentation and germination

The cowpea is inexpensive and is rich in protein at 25%, making it a valuable pulse grain for experimental processing.[283] A study investigated the effect of two pre-treatments, germination and fermentation, on the emulsifying properties of cowpea protein.[283] Cowpeas were ground into flour and then soaked at room temperature for 16 hours.[283] Cowpea seeds that were incubated at 24, 48, and 72 hours were germinated in sterile petri dishes containing cotton wool soaked in sterile water.[283] The cowpea flour was prepared by fermenting at room temperature at approximately 2°C for 48, 72, and 96 hours.[283] Control flour was also created. Researchers discovered that, during the germination process, aggregates are better stabilized in the oil/water interface.[283] Fermentation of cowpea protein, on the other hand, lead to destabilization of the emulsion as a result of degradation of proteins by microorganisms.[283] In conclusion, the cowpea germinated for 72 hours created the most stable emulsion and studies including longer germination time may be examined in the future.[283]

Production

Cowpeas are the fifth most popular variety of pulses grown in North America, with an average of 23 thousand tonnes produced between 2010 and 2014.[80] Cowpeas are grown in several locations in the United States including California, Arizona, and Texas.[82] While California's unique climate allows for the growth of almost all pulse grain varieties, the cowpea is one of four beans that make up 82% for California's bean crop. Table 2-90 includes a list of cowpea suppliers in the United States. The FAO also reports that the biogeographic zone of Sahel, Africa is the world-wide major producer of cowpeas with the country of Nigeria as the top producer of cowpeas.[80] The Far East and the Pacific produce 13 thousand tonnes of cowpeas, North Africa produces 33 thousand tonnes of cowpeas, and Eastern and Southern Africa produce 444 thousand tonnes of cowpeas, while Western and Central Africa produce an impressive 6,397 thousand tonnes of cowpeas.[80] Other places of production include Asia, Southern Europe, and Central and South America.[80] The FAO reports that Central America and the Caribbean produced 2 thousand tonnes of cowpeas, while South America produced an average of 26 thousand tonnes between 2010 and 2013.[80] Additionally, Europe produced an average of 304 thousand tonnes of cowpeas between 2009 and 2013, Eastern Europe and Western Asia produced only 1 thousand tonnes, and South and East Asia produced 169 thousand tonnes of cowpeas.[80]

Financial Support

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CHAPTER TWO FIGURES AND TABLES

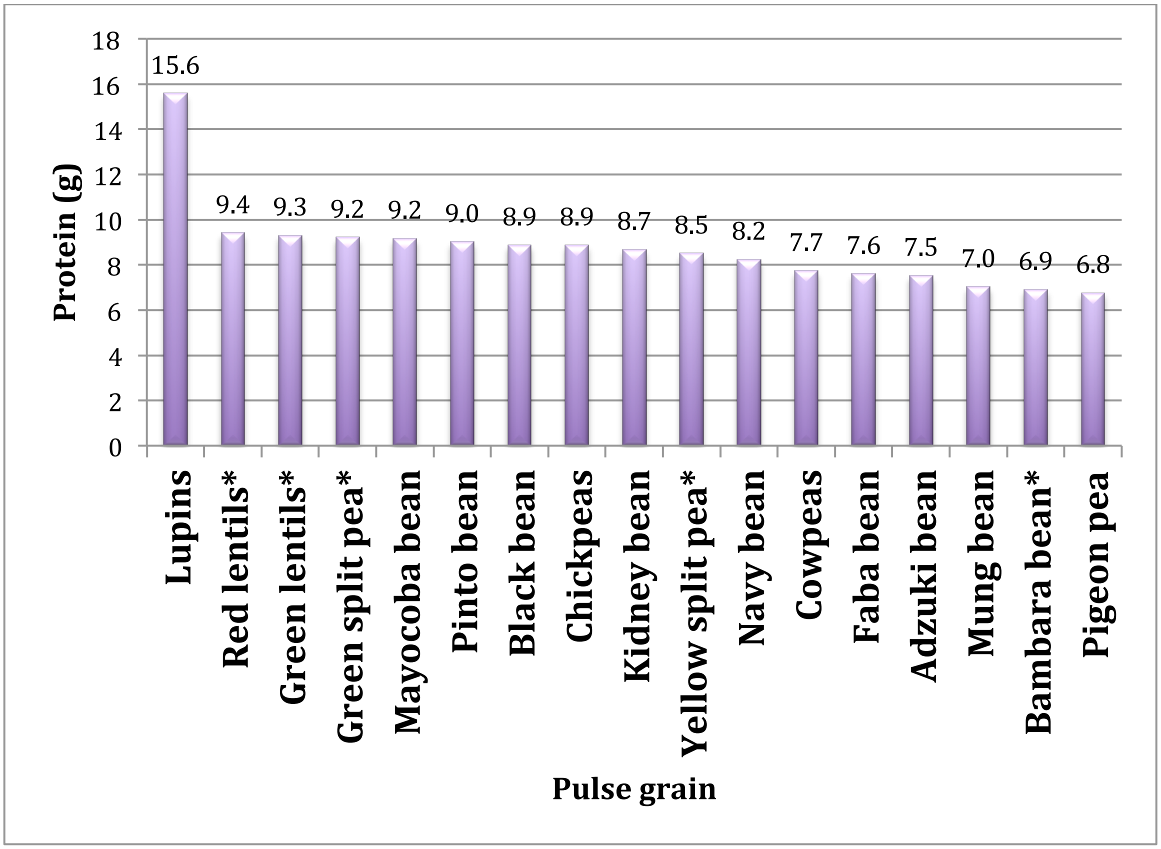

Figure 2-1. Protein content per 100 grams of cooked pulse grains

12,85

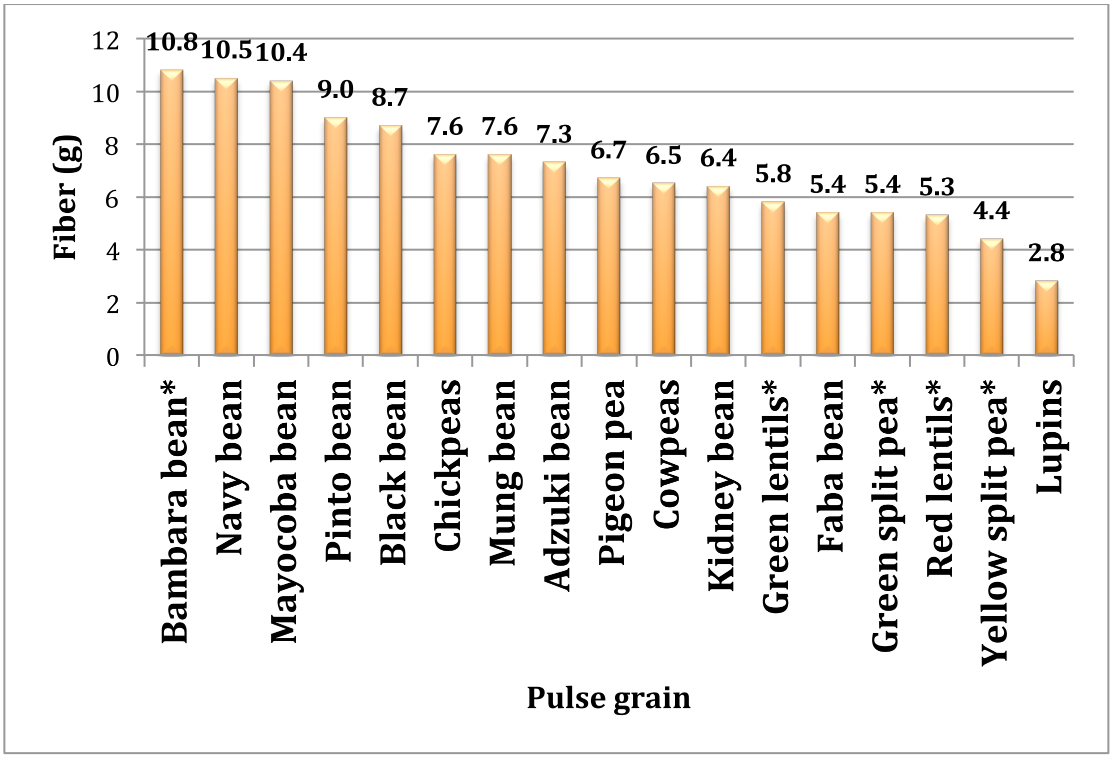

Figure 2-2. Fiber content per 100 grams of cooked pulse grains

12,85

Table 2-1. Nutrient composition of 100 grams of boiled, unsalted and mature black beans

Nutrient	Unit	Value per 100 gram (g)
Water	g	65.74
Energy	kcal	132
Protein	g	8.86
Total lipid (fat)	g	0.54
Carbohydrate, by difference	g	23.71
Fiber, total dietary	g	8.7
Sugars, total	g	0.32
Minerals		
Calcium, Ca	mg	27
Iron, Fe	mg	2.1
Magnesium, Mg	mg	70
Phosphorus, P	mg	140
Potassium, K	mg	355
Sodium, Na	mg	1
Zinc, Zn	mg	1.12
Vitamins		
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.244
Riboflavin	mg	0.059
Niacin	mg	0.505
Vitamin B-6	mg	0.069
Folate, DFE	µg	149
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	6
Vitamin E (alpha-tocopherol)	mg	0.87
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	3.3
Lipids		
Fatty acids, total saturated	g	0.139
Fatty acids, total monounsaturated	g	0.047
Fatty acids, total polyunsaturated	g	0.231
Fatty acids, total trans	g	0
Cholesterol	mg	0

[12]

Table 2-2. Nutrient composition of 100 grams of raw, mature black beans

Nutrient	Unit	Value per 100 gram (g)
Water	g	11.02
Energy	kcal	341
Protein	g	21.6
Total lipid (fat)	g	1.42
Carbohydrate, by difference	g	62.36
Fiber, total dietary	g	15.5
Sugars, total	g	2.12
Minerals		
Calcium, Ca	mg	123
Iron, Fe	mg	5.02
Magnesium, Mg	mg	171
Phosphorus, P	mg	352
Potassium, K	mg	1483
Sodium, Na	mg	5
Zinc, Zn	mg	3.65
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.9
Riboflavin	mg	0.193
Niacin	mg	1.955
Vitamin B-6	mg	0.286
Folate, DFE	µg	444
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	17
Vitamin E (alpha-tocopherol)	mg	0.21
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	5.6
Fatty acids, total saturated	g	0.366
Fatty acids, total monounsaturated	g	0.123
Fatty acids, total polyunsaturated	g	0.61
Fatty acids, total trans	g	0
Cholesterol	mg	0

12

Table 2-3. PDCAAS values for black beans and black bean/rice flours

Item	Amino Acid Score[1]	True Protein Digestibility (%)[2]	PDCAAS[3]
Black Beans	0.76	70	0.53-0.75†
Black Bean-Rice (25:75) Blend*	0.81	93	0.75

[1] Limiting the amino acid with the lowest ratio relative to the established amino acid requirement values for humans ages 2-5 years of age is known as the amino acid score.
[2] AOAC Method 991.29 (n=10).
[3] Amino Acid Score x % True Protein Digestibility.
†[284]
86

Table 2-4. Composition and characteristics of black bean starch and amylose

	Composition[a]				Amylose characteristics[b]	
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)	Iodine Affinity	Molecular Weight x 10^6g/mol
Black bean	16.4-22.2	0.2-0.5	27.2-39.3	0.04-0.07	22	1.62

a118,120,285
b286,287
19

Table 2-5. Amylose content of CDC nighthawk and black jack black bean cultivars

Starch source and cultivar	Apparent amylose[1]	Total amylose[2]	Lipid-complexed amylose[3]
Black bean			
CDC nighthawk	35.21±0.68[b]	39.32±1.70[b]	10.37±2.82[a]
Black jack	33.07±1.19[b,c]	37.17±0.68[b,c]	11.04±3.14[a]

[1] Apparent amylose determined by iodine binding without removal of free and bound lipids.

[2] Total amylose determined by iodine binding after removal of free and bound lipids.

[3] ((Total amylose−apparent amylose)/total amylose)100.
120

Table 2-6. Swelling factor, swelling power and amylose leaching of black bean starch at varying temperatures

Starch source	Parameter	Temperature (°C)			
		60	70	80	90
Black bean[a]	Swelling factor[1]	24.5-29.5	N/A	N/A	N/A
	Swelling power[2]	2.1	4.2	8	10
	Amylose leaching[3]	1.7	3.4	8.8	15.5

[1]Swelling of the granual is measured as the swelling factor (the volume of swollen starch granules to the volume of dry starch, measuring only intra granular water)
[2]Swelling of the granual is measured as swelling power (g/g), measuring both intra and inter granular water
[3]Amylose leaching is reported as the amount of amylose leached (mg) per 100 mg of starch on a dry basis
19
a118,288

Table 2-7. Parameters of gelatinization for black bean starch by differential scanning calorimetry

Starch source	Starch to water	Gelatinization parameters			
		[1]T_o (°C)	[1]T_p (°C)	[1]T_c (°C)	[2]**Δ**HJ/g
Black bean[a]	1 to 3	61.0-66.9	69.9-76.5	81.2-86.7	11.2-12.9

[1] T_o, T_p and T_c represent the on-set, midpoint and conclusion temperatures of gelatinization, respectively.
[2]Enthalpy of gelatinization = **Δ**H
a118,120
19

Table 2-8. Nutrient composition of 100 grams of raw, mature adzuki beans

Nutrient	Unit	Value per 100
Water	g	13.44
Energy	kcal	329
Protein	g	19.87
Total lipid (fat)	g	0.53
Carbohydrate, by difference	g	62.9
Fiber, total dietary	g	12.7
Calcium, Ca	mg	66
Iron, Fe	mg	4.98
Magnesium, Mg	mg	127
Phosphorus, P	mg	381
Potassium, K	mg	1254
Sodium, Na	mg	5
Zinc, Zn	mg	5.04
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.455
Riboflavin	mg	0.22
Niacin	mg	2.63
Vitamin B-6	mg	0.351
Folate, DFE	µg	622
Vitamin B-12	µg	0
Vitamin A, RAE	µg	1
Vitamin A, IU	IU	17
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Fatty acids, total saturated	g	0.191
Fatty acids, total monounsaturated	g	0.05
Fatty acids, total polyunsaturated	g	0.113
Fatty acids, total trans	g	0
Cholesterol	mg	0

[12]

Table 2-9. Nutrient composition of 100 grams of boiled, unsalted and mature adzuki beans

Nutrient	**Unit**	**Value per 100 g**
Water	g	66.29
Energy	kcal	128
Protein	g	7.52
Total lipid (fat)	g	0.1
Carbohydrate, by difference	g	24.77
Fiber, total dietary	g	7.3
Calcium, Ca	mg	28
Iron, Fe	mg	2
Magnesium, Mg	mg	52
Phosphorus, P	mg	168
Potassium, K	mg	532
Sodium, Na	mg	8
Zinc, Zn	mg	1.77
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.115
Riboflavin	mg	0.064
Niacin	mg	0.717
Vitamin B-6	mg	0.096
Folate, DFE	µg	121
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	6
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Fatty acids, total saturated	g	0.036
Fatty acids, total monounsaturated	g	0.009
Fatty acids, total polyunsaturated	g	0.021
Fatty acids, total trans	g	0
Cholesterol	mg	0

12

Table 2-10. Parameters of gelatinization for adzuki bean starch by differential scanning calorimetry

Starch source	Starch to water	Gelatinization parameters			
		[1]T_o (°C)	[1]T_p (°C)	[1]T_c (°C)	[2]HJ/g
Adzuki bean	1 to 3	66.9	73.4	76.6	11.7

[1] T_o, T_p and T_c represent the on-set, midpoint and conclusion temperatures of gelatinization, respectively.
[2]Enthalpy of gelatinization = **Δ**H
19,289

Table 2-11. Composition and characteristics of adzuki bean starch and amylose

	Composition[a]				Amylose characteristics[b]			
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)	Average Chain Length	DP_n[1]	DP_w[2]	Iodine Affinity
Adzuki bean	21.5	0.03-0.60	17.6-34.9	0.01-0.07	290	1350-1600	4710	16.0-19.5

a290–292

b290

[1]Number average degree of polymerization
[2]Weight average degree of polymerization
19

Table 2-12. Characteristics of adzuki bean amylopectin

Starch source	Iodine Affinity	Average Chain Length
Adzuki bean	1.36-1.75	21

19,290

Table 2-13. Pasting characteristics of adzuki bean starch

Starch source	Method[1] (units)[2]	Moisture (% w/v)	Pasting characteristics		
			Pasting temperature (°C)	Highest viscosity	Breakdown viscosity
Adzuki bean	RVA (RVU)	9.0	71.8	445	130

[1]RVA is the rapid viscoanalyzer
[2]RVU are rapid viscounity (ICP=12RVU)
19,290

Table 2-14. Companies producing and supplying adzuki beans

Companies
Agri Broker, LLC
Global Merchandising Corp.
PFI International, Inc.
Toyota Tsusho America, Inc.
Tumac Commodities
Nebraska Bean, Inc.

82

Table 2-15. U.S. small red beans: acreage, yield, production and value from 1987-2010

	Acreage					
	Planted	Harvested	Yield	Production	Season average price 1/	Value of production 2/1
Year	1,000 acres		Pounds	1,000 cwt	$/cwt	$1,000
1987	18.7	18.6	2,118	394	16.33	6,434
1988	27.1	26.8	2,097	562	24.52	13,782
1989	31.2	30.8	2,269	699	24.10	16,845
1990	30.8	30.3	2,139	648	22.74	14,736
1991	35.3	34.9	2,152	751	17.74	13,323
1992	33.2	32.6	1,862	607	22.48	13,645
1993	41.9	41.3	1,898	784	21.96	17,217
1994	38.5	38.1	2,029	773	21.50	16,620
1995	37.2	36.9	2,019	745	21.26	15,839
1996	20.7	20.2	2,005	405	28.62	11,591
1997	42.5	41.1	2,170	892	20.96	18,696
1998	32.1	31.8	2,075	660	19.31	12,745
1999	42.6	42.1	2,138	900	14.55	13,095
2000	17.4	17.2	1,820	313	15.57	4,873
2001	18.8	13.2	1,303	172	23.82	4,097
2002	30.9	30.4	1,947	592	19.93	11,799
2003	33.2	32.8	1,771	581	20.84	12,108
2004	33.2	31.9	1,884	601	22.44	13,486
2005	50.9	49.5	1,824	903	19.71	17,798
2006	35.5	34.4	1,887	649	22.80	14,797
2007	30.6	29.7	1,808	537	34.24	18,387
2008	42.3	41.4	1,971	816	41.14	33,570
2009	35.1	34.3	2,050	703	30.69	21,575
2010	22.9	22.8	2096	478	29	13862

137

Table 2-16. Nutrient composition of 100 grams of soaked, cooked, boiled, unsalted Bambara groundnuts

ENERGY(kcal)	121
WATER(g)	66.2
PROT (g)	6.9
CHO (g)	12.5
FIBER(g)	10.8
FAT (g)	2.4
CHOLE(mg)	0
FA SAT(g)	0.6
FA MS(g)	0.45
FA PU(g)	0.81
ASH(g)	1.3
CA(mg)	13
CU(mg)	0.18
FE(mg)	0.9
K(mg)	371
MG(mg)	54
MN(mg)	0.43
NA(mg)	1
P(mg)	75
ZN(mg)	0.65
THIA(mg)	0.01
RIBF(mg)	0.02
NIA(mg)	0.6
NIA EQUIVALENT FROM TRYPTOPHAN(mg)	1.3

85

Table 2-17 Nutrient composition of 100 grams of dried, raw Bambara groundnuts

ENERGY(kcal)	325
WATER(g)	9
PROTEIN(g)	18.4
CHO (g)	33.7
FIBER (g)	28.9
FAT (g)	6.4
CHOLE(mg)	0
FA SAT(g)	1.6
FA MS(g)	1.21
FA PU(g)	2.19
ASH(g)	3.4
CA(mg)	40
CU(mg)	0.69
FE(mg)	2.7
K(mg)	1330
MG(mg)	172
MN(mg)	1.15
NA(mg)	2
P(mg)	224
ZN(mg)	1.94
THIA(mg)	0.04
RIBF(mg)	0.07
NIA(mg)	2.3
NIA EQUIVALENT FROM TRYPTOPHAN (mg)	4.2

85

Table 2-18. Yield and amylose content of Bambara groundnut starch

Bambara groundnut seed coat color	Starch yield (%)	Amylose content (%)
Not specified	45.57	21.67
White	Not reported	25.0
Black	Not reported	27.8
Not specified	22.0-33.0	19.6-35.1
Maroon, Brown, Cream	28.0-35.0	31.5-32.9

293

Table 2-19. Predicted glycemic index of starches and nutritional starch fractions extracted from Bambara groundnut

Starch	RDS (%)	SDS (%)	RS (%)	GI
Maroon bambara	12.3 ± 0.1	16.3 ± 0.2	71.4 ± 0.1	40.1 ± 0.1
Brown bambara	13.3 ± 0.1	16.9 ± 0.1	69.7 ± 0.1	40.1 ± 0.2
Cream bambara	11.5 ± 0.2	15.9 ± 0.2	72.6 ± 0.1	40.1 ± 0.1

Mean ± SD. Mean with different superscript letters along a column are significantly different ($p < 0.05$).
RDS, rapidly digestible starch, SDS, slowly digestible starch, RS, resistant starch, GI, glycemic index.
294

Table 2-20. Food processing technologies to reduce or remove antinutritional factors in Bambara groundnuts

Bambara groundnut	Soaking (in cold or hot water)	Decreased trypsin inhibitors by an average of 12%–31%	Barimalaa and Anoghalu (1997)
	Soaking	Decreased trypsin inhibitors by 53%, hemagglutinin by 52%, tannin by 55%, phytate by 24%, raffinose by 36%, and stachyose by 51%	Omoikhoje et al. (2006)
	Dehulling	Decreased trypsin inhibitors by 64%, hemagglutinin by 65%, tannin by 64%, phytate by 32%, raffinose by 46%, and stachyose by 57%	Omoikhoje et al. (2006)
	Germination	Decreased trypsin inhibitors by an average of 17%	Barimalaa and Anoghalu (1997)
	Germination	Decreased trypsin inhibitors by 70%, hemagglutinin by 78%, tannin by 73%, phytate by 61%, raffinose by 74%, and stachyose by 83%	Omoikhoje et al. (2006)
	Germination	Decreased trypsin inhibitors by 17%, tannins by 21%, phytate by 25%, and hemagglutinin by 20%	Okafor et al. (2014)
	Fermentation (spontaneous)	Decreased trypsin inhibitors by an average of 40%	Barimalaa and Anoghalu (1997)
	Boiling	Decreased tannin by 43% and phytate by 26%	Adegunwa et al. (2014)
	Autoclaving	Decreased tannin by 69% and phytate by 39%	Adegunwa et al. (2014)
	Roasting	Decreased tannin by 26% and phytate by 4%	Adegunwa et al. (2014)
	Roasting	Decreased trypsin inhibitors by 37%, tannins by 43%, phytate by 30%, and hemagglutinin by 41%	Okafor et al. (2014)

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Table 2-21. Nutrient composition of 100 grams of raw, mature chickpeas

Nutrient	**Unit**	**Value per 100 g**
Water	g	7.68
Energy	kcal	378
Protein	g	20.47
Total lipid (fat)	g	6.04
Carbohydrate, by difference	g	62.95
Fiber, total dietary	g	12.2
Sugars, total	g	10.7
Minerals		
Calcium, Ca	mg	57
Iron, Fe	mg	4.31
Magnesium, Mg	mg	79
Phosphorus, P	mg	252
Potassium, K	mg	718
Sodium, Na	mg	24
Zinc, Zn	mg	2.76
Vitamins		
Vitamin C, total ascorbic acid	mg	4
Thiamin	mg	0.477
Riboflavin	mg	0.212
Niacin	mg	1.541
Vitamin B-6	mg	0.535
Folate, DFE	µg	557
Vitamin B-12	µg	0
Vitamin A, RAE	µg	3
Vitamin A, IU	IU	67
Vitamin E (alpha-tocopherol)	mg	0.82
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	9
Lipids		
Fatty acids, total saturated	g	0.603
Fatty acids, total monounsaturated	g	1.377
Fatty acids, total polyunsaturated	g	2.731
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

[12]

Table 2-22. Nutrient composition of 100 grams of mature, cooked, boiled, and unsalted chickpeas

Nutrient	**Unit**	**Value per 100 g**
Water	g	60.21
Energy	kcal	164
Protein	g	8.86
Total lipid (fat)	g	2.59
Carbohydrate, by difference	g	27.42
Fiber, total dietary	g	7.6
Sugars, total	g	4.8
Minerals		
Calcium, Ca	mg	49
Iron, Fe	mg	2.89
Magnesium, Mg	mg	48
Phosphorus, P	mg	168
Potassium, K	mg	291
Sodium, Na	mg	7
Zinc, Zn	mg	1.53
Vitamins		
Vitamin C, total ascorbic acid	mg	1.3
Thiamin	mg	0.116
Riboflavin	mg	0.063
Niacin	mg	0.526
Vitamin B-6	mg	0.139
Folate, DFE	µg	172
Vitamin B-12	µg	0
Vitamin A, RAE	µg	1
Vitamin A, IU	IU	27
Vitamin E (alpha-tocopherol)	mg	0.35
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	4
Lipids		
Fatty acids, total saturated	g	0.269
Fatty acids, total monounsaturated	g	0.583
Fatty acids, total polyunsaturated	g	1.156
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

[12]

Table 3-23. Protein Digestibility Corrected Amino Acid Scores (PDCAAS) for chickpeas

Item	Amino Acid Score[1]	True Protein Digestibility (%)[2]	PDCAAS[3]
Chickpeas	0.61	85	0.52

[1] Limiting the amino acid with the lowest ratio relative to the established amino acid requirement values for humans ages 2-5 years of age is known as the amino acid score.
[2] AOAC Method 991.29 (n=10).
[3] Amino Acid Score x % True Protein Digestibility.
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Table 2-24. Composition and characteristics of chickpea starch and amylose

	Composition[a]				Amylose characteristics[b]	
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)	DP_n[1]	Molecular Weight x 10^6g/mol
Chickpeas	29.10-46.0	0.10-0.50	30.4-35.0	0.08-0.10	1420	1.45-6.30

[1]Number average degree of polymerization
19

Table 2-25. Parameters of gelatinization for chickpea starch by differential scanning calorimetry

Starch source	Starch to water	Gelatinization parameters			
		[1]T_o (°C)	[1]T_p (°C)	[1]T_c (°C)	[2]HJ/g
Chickpeas	1 to 3	57.9-64.8	63.5-72.5	69.8-81.5	1.2-17.6

[1] T_o, T_p and T_c represent the on-set, midpoint and conclusion temperatures of gelatinization, respectively.
[2]Enthalpy of gelatinization = **Δ**H
19

Table 2-26. List of U.S. chickpea suppliers

Companies
Agri Broker, LLC
BeansR4U, Inc.
Blackhive Corp, Inc.
Cal-Bean & Grain Cooperative, Inc.
Camex Inc.
Central Valley AG Exports, Inc
Colusa Produce Corp.
Cornerstone Commodities, LLC
EP International Corp.
Faribault Foods, Inc
Global Merchandising Corp.
Goya Foods, Inc.
Hinrichs Trading Company
Idaho Bean & Elevator Company
KC Trading Company, LLC
Kelley Bean Company
Kirsten Company, LLC
Latinex INTL.
L.H. Virkler & Co., Inc.
Martori Farms
Meridian Seeds
Northwest Trading Company, Inc.
PL International, LLC
Rhodes Stockton Bean CO-OP
Trinidad Benham Corp.
Tumac Commodities
Western Trading Company

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Table 2-27. U.S. chickpea: acreage, yield, production, and value from 1989-2010

Year	Acreage		Yield	Production	Season average price 1/	Value of production
	Planted	Harvested				
	1,000 acres		Pounds	1,000 cwt	$/cwt	$1,000
1989	3.4	3.3	1,060	35	28.86	1,010
1990	5.3	5.2	520	27	27.70	748
1991	3.5	3.5	740	26	31.86	828
1992	23.0	22.9	1,153	264	33.28	8,786
1993	27.3	25.7	1,171	301	25.95	7,812
1994	21.9	21.9	1,498	328	33.86	11,107
1995	30.6	28.6	1,654	473	32.00	15,136
1996	42.7	39.4	1,279	504	29.88	15,060
1997	24.3	24.0	1,633	392	30.47	11,944
1998	28.5	28.0	1,493	418	30.35	12,686
1999	62.0	58.8	1,323	778	26.49	20,609
2000	116.2	105.2	1,268	1,334	20.72	27,640
2001	148.7	128.5	1,254	1,612	16.04	25,856
2002	85.5	74.1	1,162	861	18.58	15,997
2003	43.5	41.4	1,007	417	22.89	9,545
2004	45.0	43.4	1,366	593	28.29	16,776
2005	89.8	86.3	1,229	1,061	28.05	29,761
2006	136.8	132.9	1,158	1,539	28.56	43,954
2007	125.2	121.3	1,249	1,515	34.53	52,313
2008	83.5	82.1	1,362	1,118	31.02	34,680
2009	96.1	93.9	1,538	1,444	29.74	42,945
2010	146	144.1	1346	1939	33	63987
1/ Value of production estimated by ERS using average grower bids from USDA, AMS, Bean Market News						

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Table 2-28. Nutrient composition of 100 grams of raw, mature faba beans

Nutrient	**Unit**	**Value per 100 g**
Proximates		
Water	g	10.98
Energy	kcal	341
Protein	g	26.12
Total lipid (fat)	g	1.53
Carbohydrate, by difference	g	58.29
Fiber, total dietary	g	25
Sugars, total	g	5.7
Minerals		
Calcium, Ca	mg	103
Iron, Fe	mg	6.7
Magnesium, Mg	mg	192
Phosphorus, P	mg	421
Potassium, K	mg	1062
Sodium, Na	mg	13
Zinc, Zn	mg	3.14
Vitamin C, total ascorbic acid	mg	1.4
Thiamin	mg	0.555
Riboflavin	mg	0.333
Niacin	mg	2.832
Vitamin B-6	mg	0.366
Folate, DFE	µg	423
Vitamin B-12	µg	0
Vitamin A, RAE	µg	3
Vitamin A, IU	IU	53
Vitamin E (alpha-tocopherol)	mg	0.05
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	9
Lipids		
Fatty acids, total saturated	g	0.254
Fatty acids, total monounsaturated	g	0.303
Fatty acids, total polyunsaturated	g	0.627
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

[12]

Table 2-29. Nutrient composition of 100 grams of cooked, mature faba beans

Nutrient	Unit	Value per 100 g
Proximates		
Water	g	71.54
Energy	kcal	110
Protein	g	7.6
Total lipid (fat)	g	0.4
Carbohydrate, by difference	g	19.65
Fiber, total dietary	g	5.4
Sugars, total	g	1.82
Minerals		
Calcium, Ca	mg	36
Iron, Fe	mg	1.5
Magnesium, Mg	mg	43
Phosphorus, P	mg	125
Potassium, K	mg	268
Sodium, Na	mg	5
Zinc, Zn	mg	1.01
Vitamin C, total ascorbic acid	mg	0.3
Thiamin	mg	0.097
Riboflavin	mg	0.089
Niacin	mg	0.711
Vitamin B-6	mg	0.072
Folate, DFE	µg	104
Vitamin B-12	µg	0
Vitamin A, RAE	µg	1
Vitamin A, IU	IU	15
Vitamin E (alpha-tocopherol)	mg	0.02
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	2.9
Lipids		
Fatty acids, total saturated	g	0.066
Fatty acids, total monounsaturated	g	0.079
Fatty acids, total polyunsaturated	g	0.164
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

[12]

Table 2-30. Composition and characteristics of faba bean starch and amylose

	Composition[a]				Amylose characteristics[b]		
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)	DP_n[1]	Molecular Weight x 10^6 g/mol	Iodine Affinity
Faba bean	39.9	0.08-1.40	17.0-42.0	0.33-0.43	1400	1.91	19.6

[1]Number average degree of polymerization

a 295–297

b 287

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Table 2-31. Swelling power and extent of amylose leaching of faba bean starch at different temperatures

Starch source	Parameter	Temperature (°C)				
		50	60	70	80	90
Faba Bean	Swelling power	21.1-25.7	40.4-43.1	-	-	51.8-63.8
	Amylose leaching	0.9-1.3	10.5-11.5	-	-	22.1-27.0

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Table 2-32. Nutrient composition for 100 grams of raw, mature kidney beans

Nutrient	Unit	Value per 100 g
Water	g	11.75
Energy	kcal	333
Protein	g	23.58
Total lipid (fat)	g	0.83
Carbohydrate, by difference	g	60.01
Fiber, total dietary	g	24.9
Sugars, total	g	2.23
Minerals		
Calcium, Ca	mg	143
Iron, Fe	mg	8.2
Magnesium, Mg	mg	140
Phosphorus, P	mg	407
Potassium, K	mg	1406
Sodium, Na	mg	24
Zinc, Zn	mg	2.79
Vitamins		
Vitamin C, total ascorbic acid	mg	4.5
Thiamin	mg	0.529
Riboflavin	mg	0.219
Niacin	mg	2.06
Vitamin B-6	mg	0.397
Folate, DFE	µg	394
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	0
Vitamin E (alpha-tocopherol)	mg	0.22
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	19
Lipids		
Fatty acids, total saturated	g	0.12
Fatty acids, total monounsaturated	g	0.064
Fatty acids, total polyunsaturated	g	0.457
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

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Table 2-33. Nutrient composition of 100 grams of cooked, boiled, and unsalted mature kidney beans

Nutrient	**Unit**	**Value per 100 g**
Water	g	66.94
Energy	kcal	127
Protein	g	8.67
Total lipid (fat)	g	0.5
Carbohydrate, by difference	g	22.8
Fiber, total dietary	g	6.4
Sugars, total	g	0.32
Minerals		
Calcium, Ca	mg	35
Iron, Fe	mg	2.22
Magnesium, Mg	mg	42
Phosphorus, P	mg	138
Potassium, K	mg	405
Sodium, Na	mg	1
Zinc, Zn	mg	1
Vitamins		
Vitamin C, total ascorbic acid	mg	1.2
Thiamin	mg	0.16
Riboflavin	mg	0.058
Niacin	mg	0.578
Vitamin B-6	mg	0.12
Folate, DFE	µg	130
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	0
Vitamin E (alpha-tocopherol)	mg	0.03
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	8.4
Lipids		
Fatty acids, total saturated	g	0.073
Fatty acids, total monounsaturated	g	0.039
Fatty acids, total polyunsaturated	g	0.278
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

[12]

Table 2-34. PDCAAS score for kidney beans

Item	Amino Acid Score[1]	True Protein Digestibility (%)[2]	PDCAAS[3]
Kidney bean	0.7	78.6	0.55

[1] Limiting the amino acid with the lowest ratio relative to the established amino acid requirement values for humans ages 2-5 years of age is known as the amino acid score.
[2] AOAC Method 991.29 (n=10).
[3] Amino Acid Score x % True Protein Digestibility.
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Table 2-35. Composition and characteristics of kidney bean starch and amylose

	Composition[a]				Amylose characteristics[b]			
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)	Average Chain Length	DP_n[1]	DP_w[2]	Iodine Affinity
Kidney bean	25-45	0.18	34.0-41.5	0.02-0.05	240	650-1300	4100	20

[1]Number average degree of polymerization
[2]Weight average degree of polymerization
19

Table 2-36. Parameters of gelatinization for adzuki bean starch by differential scanning calorimetry

Starch source	Starch to water	Gelatinization parameters			
		[1]T_o (°C)	[1]T_p (°C)	[1]T_c (°C)	[2]HJ/g
Kidney bean	1 to 3	61.4-66.9	66.7-70	76.0-90.8	10.8-15.4

[1] T_o, T_p and T_c represent the on-set, midpoint and conclusion temperatures of gelatinization, respectively.
[2]Enthalpy of gelatinization = **Δ**H
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Table 2-37. U.S. companies supplying dark red kidney beans

Companies
Agri Broker, LLC
BeansR4U, Inc.
Blackhive Corp, Inc.
Bonanza Bean LLC
Central Valley AG Exports, Inc
Chippewa Valley Bean Company
Cooperative Elevator Company
Cornerstone Commodities, LLC
Faribault Foods, Inc
Freeland Bean & Grain, Inc.
Global Merchandising Corp.
Goya Foods, Inc.
Haberer Foods International, Inc.
Kelley Bean Company
L.H. Virkler & Co., Inc.
Meridian Seeds
North Central Commodities
PL International, LLC
P.W. Montgomery, LLC
The Rice Company
Slauson Trading Company, LLC
Steele & Company
Thompsons
Trinidad Benham Corp.
Tumac Commodities
United Pulse Trading, Inc.
Walhalla Bean Company

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Table 2-38. U.S. companies supplying light red kidney beans

Companies
Ackerman Marketing
Agri Broker, LLC
Bayside Best Beans, LLC
BeansR4U, Inc.
Blackhive Corp, Inc.
Bonanza Bean LLC
Central Valley AG Exports, Inc
C & F Foods, Inc.
Chippewa Valley Bean Company
Colusa Produce Corp.
Cooperative Elevator Company
Cornerstone Commodities, LLC
EP International Corp.
Faribault Foods, Inc
Global Merchandising Corp.
Goya Foods, Inc.
Haberer Foods International, Inc.
KC Trading Company, LLC
Kelley Bean Company
Kirsten Company, LLC
L.H. Virkler & Co., Inc.
Meridian Seeds
Nebraska Bean, Inc.
New York Bean, LLC
Nexus Trading Group, LLC.
North Central Commodities
PL International, LLC
P.W. Montgomery, LLC
Rhodes-Stockton Bean Co-Op
Russell E. Womack, Inc.
Slauson Trading Company, LLC
Steele & Company
The Rice Company
Tumac Commodities
Trinidad Benham Corp.
Tumac Commodities
United Pulse Trading, Inc.
Yanez International - Sales Agents

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Table 2-39. U.S. light red kidney beans: acreage, yield, production, and value from 1990-2010

Year	Acreage		Yield	Production	Season average price 2/	Value of production
	Planted	Harvested				
	1,000 acres		Pounds	1,000 cwt	$/cwt	$1,000
1990	78.1	73.6	1,694	1,247	17.56	21,897
1991	60.9	59.8	1,677	1,003	24.86	24,935
1992	76.5	70.9	1,550	1,099	29.18	32,069
1993	94.1	83.2	1,466	1,220	23.71	28,926
1994	82.9	79.7	1,690	1,347	23.30	31,385
1995	83.9	77.2	1,705	1,316	22.23	29,255
1996	68.1	64.1	1,621	1,039	31.48	32,708
1997	89.3	86.9	1,862	1,618	21.11	34,156
1998	76.0	72.0	1,575	1,134	25.98	29,461
1999	90.5	83.1	1,655	1,375	20.13	27,679
2000	83.0	80.5	1,680	1,352	19.56	26,445
2001	67.8	59.0	1,315	776	26.04	20,207
2002	70.4	67.1	1,799	1,207	21.74	26,240
2003	67.1	64.1	1,708	1,095	23.17	25,371
2004	54.7	51.5	1,584	816	27.34	22,309
2005	71.4	68.8	1,612	1,109	21.39	23,722
2006	44.4	40.8	1,887	770	24.47	18,842
2007	47.4	46.0	1,767	813	39.40	32,032
2008	56.3	54.2	1,887	1,023	52.00	53,196
2009	56.3	52.4	1,845	967	35.00	33,845
2010	53.1	49.4	1,955	966	32.00	30,912

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Table 2-40. U.S. dark red kidney beans: acreage, yield, production, and value from 1990-2010

Year	Acreage		Yield	Production	Season average price 2/	Value of production
	Planted	Harvested				
	1,000 acres		Pounds	1,000 cwt	$/cwt	$1,000
1990	65.5	62.6	1,752	1,097	29.60	32,471
1991	78.4	76.0	1,737	1,320	19.01	25,093
1992	64.2	59.9	1,444	865	33.95	29,367
1993	72.5	64.3	1,289	829	31.21	25,873
1994	86.7	81.8	1,786	1,461	20.11	29,381
1995	74.4	65.1	1,441	938	27.65	25,936
1996	69.3	65.5	1,640	1,074	25.71	27,613
1997	67.1	64.1	1,548	992	21.67	21,497
1998	64.2	61.8	1,362	842	26.74	22,515
1999	66.9	64.3	1,617	1,040	20.25	21,060
2000	65.3	62.5	1,622	1,014	19.01	19,276
2001	57.4	52.8	1,394	736	27.99	20,601
2002	71.1	65.6	1,732	1,136	19.37	22,004
2003	49.9	48.4	1,746	845	22.94	19,384
2004	51.3	46.6	1,472	686	27.40	18,796
2005	60.7	58.0	1,807	1,048	20.92	21,924
2006	48.8	46.4	1,776	824	26.86	22,133
2007	40.2	39.1	1,696	663	36.40	24,133
2008	50.8	49.3	2,012	992	35.00	34,720
2009	50.5	47.3	1,797	850	33.88	28,798
2010	48.5	45.7	1,823	833	37.00	30,821

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Table 2-41. Nutrient composition of 100 grams of mature, raw lupins

Nutrient	Unit	Value per 100 g
Water	g	10.44
Energy	kcal	371
Protein	g	36.17
Total lipid (fat)	g	9.74
Carbohydrate, by difference	g	40.37
Fiber, total dietary	g	18.9
Minerals		
Calcium, Ca	mg	176
Iron, Fe	mg	4.36
Magnesium, Mg	mg	198
Phosphorus, P	mg	440
Potassium, K	mg	1013
Sodium, Na	mg	15
Zinc, Zn	mg	4.75
Vitamins		
Vitamin C, total ascorbic acid	mg	4.8
Thiamin	mg	0.64
Riboflavin	mg	0.22
Niacin	mg	2.19
Vitamin B-6	mg	0.357
Folate, DFE	µg	355
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	0
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Lipids		
Fatty acids, total saturated	g	1.156
Fatty acids, total monounsaturated	g	3.94
Fatty acids, total polyunsaturated	g	2.439
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

[12]

Table 2-42. Nutrient composition of 100 grams of cooked, boiled, unsalted lupins

Nutrient	**Unit**	**Value per 100 g**
Water	g	71.08
Energy	kcal	119
Protein	g	15.57
Total lipid (fat)	g	2.92
Carbohydrate, by difference	g	9.88
Fiber, total dietary	g	2.8
Minerals		
Calcium, Ca	mg	51
Iron, Fe	mg	1.2
Magnesium, Mg	mg	54
Phosphorus, P	mg	128
Potassium, K	mg	245
Sodium, Na	mg	4
Zinc, Zn	mg	1.38
Vitamins		
Vitamin C, total ascorbic acid	mg	1.1
Thiamin	mg	0.134
Riboflavin	mg	0.053
Niacin	mg	0.495
Vitamin B-6	mg	0.009
Folate, DFE	µg	59
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	7
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Lipids		
Fatty acids, total saturated	g	0.346
Fatty acids, total monounsaturated	g	1.18
Fatty acids, total polyunsaturated	g	0.73
Fatty acids, total trans	g	0
Cholesterol	mg	0

[12]

Table 2-43. Nutrient composition of 100 grams of cooked, mature mayocoba beans

Nutrient	**unit**	**Per 100 grams**
Water	g	62.98
Energy	kcal	144
Protein	g	9.16
Total lipid (fat)	g	1.08
Carbohydrate, by difference	g	25.28
Fiber, total dietary	g	10.4
Sugars, total	g	0.34
Minerals		
Calcium, Ca	mg	62
Iron, Fe	mg	2.48
Magnesium, Mg	mg	74
Phosphorus, P	mg	183
Potassium, K	mg	325
Sodium, Na	mg	5
Zinc, Zn	mg	1.06
Vitamins		
Vitamin C, total ascorbic acid	mg	1.8
Thiamin	mg	0.187
Riboflavin	mg	0.103
Niacin	mg	0.708
Vitamin B-6	mg	0.129
Folate, DFE	µg	81
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	2
Vitamin E (alpha-tocopherol)	mg	0.94
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	3.5
Lipids		
Fatty acids, total saturated	g	0.279
Fatty acids, total monounsaturated	g	0.094
Fatty acids, total polyunsaturated	g	0.466
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

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Table 2-44. Nutrient composition of 100 grams of raw, mature mayocoba beans

Nutrient	Unit	Value per 100 g
Water	g	11.1
Energy	kcal	345
Protein	g	22
Total lipid (fat)	g	2.6
Carbohydrate, by difference	g	60.7
Fiber, total dietary	g	25.1
Minerals		
Calcium, Ca	mg	166
Iron, Fe	mg	7.01
Magnesium, Mg	mg	222
Phosphorus, P	mg	488
Potassium, K	mg	1042
Sodium, Na	mg	12
Zinc, Zn	mg	2.83
Vitamins		
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.69
Riboflavin	mg	0.33
Niacin	mg	2.43
Vitamin B-6	mg	0.442
Folate, DFE	µg	389
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	6
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Lipids		
Fatty acids, total saturated	g	0.671
Fatty acids, total monounsaturated	g	0.226
Fatty acids, total polyunsaturated	g	1.118
Fatty acids, total trans	g	0
Cholesterol	mg	0

[12]

Table 2-45. Chemical composition of the mayocoba bean

Analysis	Content (%)
Moisture	9.65 ± 0.02
Ash	4.54 ± 0.01
Lipid	1.98 ± 0.10
Proteinb	23.41 ± 0.16
Total starch	43.51 ± 0.76
Total dietary fibre	16.42 ± 0.01
[a]Means of the triplicates ± SE; dry basis.	
[b]*N* × 5.85.	

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Table 2-46. Nutrient composition of 100 grams of mature, raw mung beans

Nutrient	**Unit**	**Value per 100 g**
Water	g	9.05
Energy	kcal	347
Protein	g	23.86
Total lipid (fat)	g	1.15
Carbohydrate, by difference	g	62.62
Fiber, total dietary	g	16.3
Sugars, total	g	6.6
Minerals		
Calcium, Ca	mg	132
Iron, Fe	mg	6.74
Magnesium, Mg	mg	189
Phosphorus, P	mg	367
Potassium, K	mg	1246
Sodium, Na	mg	15
Zinc, Zn	mg	2.68
Vitamin C, total ascorbic acid	mg	4.8
Thiamin	mg	0.621
Riboflavin	mg	0.233
Niacin	mg	2.251
Vitamin B-6	mg	0.382
Folate, DFE	µg	625
Vitamin B-12	µg	0
Vitamin A, RAE	µg	6
Vitamin A, IU	IU	114
Vitamin E (alpha-tocopherol)	mg	0.51
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	9
Lipids		
Fatty acids, total saturated	g	0.348
Fatty acids, total monounsaturated	g	0.161
Fatty acids, total polyunsaturated	g	0.384
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

12

Table 2-47. Nutrient composition of 100 grams of mature, cooked, boiled, and unsalted mung beans

Nutrient	**Unit**	**Value per 100 g**
Water	g	72.66
Energy	kcal	105
Protein	g	7.02
Total lipid (fat)	g	0.38
Carbohydrate, by difference	g	19.15
Fiber, total dietary	g	7.6
Sugars, total	g	2
Minerals		
Calcium, Ca	mg	27
Iron, Fe	mg	1.4
Magnesium, Mg	mg	48
Phosphorus, P	mg	99
Potassium, K	mg	266
Sodium, Na	mg	2
Zinc, Zn	mg	0.84
Vitamin C, total ascorbic acid	mg	1
Thiamin	mg	0.164
Riboflavin	mg	0.061
Niacin	mg	0.577
Vitamin B-6	mg	0.067
Folate, DFE	µg	159
Vitamin B-12	µg	0
Vitamin A, RAE	µg	1
Vitamin A, IU	IU	24
Vitamin E (alpha-tocopherol)	mg	0.15
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	2.7
Lipids		
Fatty acids, total saturated	g	0.116
Fatty acids, total monounsaturated	g	0.054
Fatty acids, total polyunsaturated	g	0.128
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

[12]

Table 2-48. Characteristics of mung bean starch and amylose

	Composition[a]				Amylose characteristics[b]			
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)	Average Chain Length	DP_n[1]	Molecular Weight x 10^6 g/mol	Iodine Affinity
Mung bean	31.1	0.04-0.32	33-45.3	0.02-0.05	367-568	1585-2200	1.83-2.45	19.4

[1] Number average degree of polymerization
a 289,298,299
b 286,287,300
19

Table 2-49. Characteristics of mung bean amylopectin

Starch source	Iodine Affinity	Average Chain Length
Mung bean	1	19.7-22.7

19,300

Table 2-50. Rapidly digestible (RDS), slowly digestible (SDS) and resistant starch (RS) content of mung bean starch

Starch source	Method	Digestible starch (%)		RS%
		RDS	SDS	
Mung bean	Englyst	5.3-14.8	29.7-41.5	43.7-65.2

19,286

Table 2-51. Parameters of gelatinization for mung bean starch by differential scanning calorimetry

Starch source	Starch to water	Gelatinization parameters			
		[1]T_o (°C)	[1]T_p (°C)	[1]T_c (°C)	2ΔHJ/g
Mung bean[a]	01:02.3	59	65	75	6.11
Mung bean[b]	1:03	58-62.2	67-67.4	72.1-82	7.9-18.5

[1] T_o, T_p and T_c represent the on-set, midpoint and conclusion temperatures of gelatinization, respectively.
[2]Enthalpy of gelatinization = ΔH
a 298
b 286,299
19

Table 2-52. Pasting characteristics of mung bean starch

Starch source	Method[1] (units)[2]	Moisture (% w/v)	Pasting characteristics			
			Pasting temperature (°C)	Highest viscosity	Breakdown viscosity	Set-back
Mung bean	RVA (CP)	11.9	76.5	591	-	-
Mung bean	RVA (mPa s)	6	50.2	6107	2523	1195
Mung bean	BVA (BU)	6	80	200	-	140
Mung bean	BVA (BU)	8	72	-	490	1400

[1] RVA is the rapid viscoanalyzer, BVA-Brabender viscoamylogram
[2] Cp, BU, and mPa s represent centipoises, Brabender units, and millipascals per second, respectively
19,286,298

Table 2-53. Nutrient composition for 100 grams of raw, mature navy beans

Nutrient	Unit	Value per 100 g
Water	g	12.1
Energy	kcal	337
Protein	g	22.33
Total lipid (fat)	g	1.5
Carbohydrate, by difference	g	60.75
Fiber, total dietary	g	15.3
Sugars, total	g	3.88
Calcium, Ca	mg	147
Iron, Fe	mg	5.49
Magnesium, Mg	mg	175
Phosphorus, P	mg	407
Potassium, K	mg	1185
Sodium, Na	mg	5
Zinc, Zn	mg	3.65
Thiamin	mg	0.775
Riboflavin	mg	0.164
Niacin	mg	2.188
Vitamin B-6	mg	0.428
Folate, DFE	µg	364
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	0
Vitamin E (alpha-tocopherol)	mg	0.02
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	2.5
Fatty acids, total saturated	g	0.17
Fatty acids, total monounsaturated	g	0.128
Fatty acids, total polyunsaturated	g	0.873
Fatty acids, total trans	g	0

12

Table 2-54. Nutrient composition of 100 grams of boiled, unsalted and mature navy beans

Nutrient	Unit	Value per 100 g
Water	g	63.81
Energy	kcal	140
Protein	g	8.23
Total lipid (fat)	g	0.62
Carbohydrate, by difference	g	26.05
Fiber, total dietary	g	10.5
Sugars, total	g	0.37
Calcium, Ca	mg	69
Iron, Fe	mg	2.36
Magnesium, Mg	mg	53
Phosphorus, P	mg	144
Potassium, K	mg	389
Sodium, Na	mg	0
Zinc, Zn	mg	1.03
Vitamin C, total ascorbic acid	mg	0.9
Thiamin	mg	0.237
Riboflavin	mg	0.066
Niacin	mg	0.649
Vitamin B-6	mg	0.138
Folate, DFE	µg	140
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	0
Vitamin E (alpha-tocopherol)	mg	0.01
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	0.6
Fatty acids, total saturated	g	0.098
Fatty acids, total monounsaturated	g	0.142
Fatty acids, total polyunsaturated	g	0.49
Fatty acids, total trans	g	0

12

Table 2-55. PDCAAS value for navy beans

Table 1	Amino Acid Score[1]	True Protein Digestibility (%)[2]	PDCAAS[3]
Navy Beans	0.83	80	0.67

[1] Limiting the amino acid with the lowest ratio relative to the established amino acid requirement values for humans ages 2-5 years of age is known as the amino acid score.
[2] AOAC Method 991.29 (n=10).
[3] Amino Acid Score x % True Protein Digestibility.
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Table 2-56. Composition and characteristics of navy bean starch and amylose

	Composition[a]				Amylose characteristics[b]		
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)	DP_n[1]	Iodine Affinity	Molecular Weight x 10^6g/mol
Navy bean	24.0-25.0	0.09-0.60	28.6-41.4	0.02-0.05	1300	18.5	1.65

[1]Number average degree of polymerization
a118,120,285,289
b287
19

Table 2-57. Characteristics of navy bean amylopectin

Starch source	Average chain length	Amylopectin chain length distribution (%)		
		[1]DP 6-12	IDP 13-24	I DP 25-36
Navy bean	17.7	24.3	59.8	16

19,301

Table 2-58. Companies producing and supplying navy beans

Companies
ADM/Edible Bean Specialties Inc.
Agri Broker, LLC
Bamp Marketing & Consulting Inc.
Bayside Best Beans, LLC Blackhive Corp, Inc.
Caldak International, LLC Central Valley AG Exports, Inc
C & F Foods, Inc.
Colgate Commodities, Inc.
Cooperative Elevator Company
Cornerstone Commodities, LLC
D.W. Sturt & Company
EP International Corp. Faribault Foods, Inc Freeland Bean & Grain, Inc. Global Merchandising Corp. Goya Foods, Inc.
KC Trading Company, LLC Kelley Bean Company Kirsten Company, LLC Latinex INTL.
Lee Bean & Seed, Inc. L.H. Virkler & Co., Inc. Meridian Seeds
North Central Commodities PL International, LLC
P.W. Montgomery, LLC The Rice Company
Star Of The West Milling Company
Steele & Company
Thompsons
Trinidad Benham Corp.
United Pulse Trading, Inc.
Yanez International - Sales Agents

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Table 2-59. U.S. navy beans: acreage, yield, production & value from 1987-2010

Year	Acreage					
	Planted	Harvested	Yield	Production	Season average price	Value of production 1/
	1,000 acres		Pounds	1,000 cwt	$/cwt	$1,000
1987	568.4	515.8	1,396	7,199	--	--
1988	422.3	337.1	1,002	3,379	--	--
1989	473.1	388.7	1,147	4,457	--	--
1990	511.1	492.6	1,338	6,593	16.12	106,279
1991	490.4	482.2	1,715	8,268	13.99	115,669
1992	418.7	385.9	1,300	5,018	17.98	90,224
1993	442.9	389.2	1,355	5,275	19.43	102,493
1994	428.4	380.1	1,391	5,289	28.44	150,419
1995	487.1	450.1	1,625	7,314	19.22	140,575
1996	418.2	404.3	1,480	5,984	18.37	109,926
1997	385.9	365.6	1,511	5,524	13.92	76,894
1998	255.5	243.3	1,598	3,887	19.22	74,708
1999	440.3	403.3	1,809	7,294	12.70	92,634
2000	346.2	307.1	1,554	4,771	11.16	53,244
2001	213.3	163.8	1,411	2,311	20.73	47,907
2002	345.3	307.7	1,751	5,389	12.23	65,907
2003	158.2	150.9	1,666	2,514	18.53	46,584
2004	185.1	162.5	1,318	2,142	24.89	53,314
2005	236.4	223.4	1,788	3,995	19.16	76,544
2006	280.7	263.9	1,649	4,353	20.66	89,933
2007	221.9	211.2	1,814	3,832	33.68	129,062
2008	250.6	242.1	1,876	4,542	25.28	114,822
2009	194.9	186.5	1,787	3,332	32.00	106,624
2010	279.5	271.7	1,754	4,766	30.00	142,980
1/ Value of production estimated by ERS using average grower bids from USDA, AMS, Bean Market News						

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Table 2-60. Average grower prices of navy beans for crop years 2000-2010

Year	Average Dollars per cwt
2000	11.16
2001	20.73
2002	12.23
2003	18.53
2004	24.90
2005	19.07
2006	20.66
2007	33.68
2008	25.28
2009	32.00
2010	26.81

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Table 2-61. Nutrient composition of 100 grams of mature, raw pigeon peas

Nutrient	**Unit**	**Value per 100 g**
Water	g	10.59
Energy	kcal	343
Protein	g	21.7
Total lipid (fat)	g	1.49
Carbohydrate, by difference	g	62.78
Fiber, total dietary	g	15
Minerals		
Calcium, Ca	mg	130
Iron, Fe	mg	5.23
Magnesium, Mg	mg	183
Phosphorus, P	mg	367
Potassium, K	mg	1392
Sodium, Na	mg	17
Zinc, Zn	mg	2.76
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.643
Riboflavin	mg	0.187
Niacin	mg	2.965
Vitamin B-6	mg	0.283
Folate, DFE	µg	456
Vitamin B-12	µg	0
Vitamin A, RAE	µg	1
Vitamin A, IU	IU	28
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Lipids		
Fatty acids, total saturated	g	0.33
Fatty acids, total monounsaturated	g	0.012
Fatty acids, total polyunsaturated	g	0.814
Fatty acids, total trans	g	0
Cholesterol	mg	0

[12]

Table 2-62. Nutrient composition of 100 grams of mature, cooked, boiled, and unsalted pigeon peas

Nutrient	**Unit**	**Value per 100 g**
Water	g	68.55
Energy	kcal	121
Protein	g	6.76
Total lipid (fat)	g	0.38
Carbohydrate, by difference	g	23.25
Fiber, total dietary	g	6.7
Minerals		
Calcium, Ca	mg	43
Iron, Fe	mg	1.11
Magnesium, Mg	mg	46
Phosphorus, P	mg	119
Potassium, K	mg	384
Sodium, Na	mg	5
Zinc, Zn	mg	0.9
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.146
Riboflavin	mg	0.059
Niacin	mg	0.781
Vitamin B-6	mg	0.05
Folate, DFE	µg	111
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	3
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Lipids		
Fatty acids, total saturated	g	0.083
Fatty acids, total monounsaturated	g	0.003
Fatty acids, total polyunsaturated	g	0.205
Fatty acids, total trans	g	0
Cholesterol	mg	0

[12]

Table 2-63. Yield and composition of pigeon pea starch

	Composition			
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)
Pigeon pea	29.7-49.3	0.11	27.0-46.4	0.02-0.05

19,234,302,303

Table 2-64. Rapidly digestible (RDS), slowly digestible (SDS) and resistant starch (RS) content of pigeon pea starch

Starch source	Method	Digestible starch (%)		RS%
		RDS	SDS	
Pigeon pea	Englyst	4.2	16.9	78.9

19,286

Table 2-65. Parameters of gelatinization for pigeon pea starch by differential scanning calorimetry

Starch source	Starch to water	Gelatinization parameters			
		[1]T_o (°C)	[1]T_p (°C)	[1]T_c (°C)	[2]ΔHJ/g
Pigeon pea	1:3	69.3-74	75.5-81	80.6-87	10.4-10.7

[1] T_o, T_p and T_c represent the on-set, midpoint and conclusion temperatures of gelatinization, respectively.
[2]Enthalpy of gelatinization = ΔH
19,286,303

Table 2-66. Pasting characteristics of pigeon pea starch

Starch source	Method[1] (units)[2]	Moisture (% w/v)	Pasting characteristics			
			Pasting temperature (°C)	Highest viscosity	Breakdown viscosity	Set-back
Pigeon pea	RVA (mPa s)	6	50.9	4025	967	2882
Pigeon pea	BVA (BU)	6	-	277	-	178
Pigeon pea	BVA (BU)	6	89	80	-	140

[1] RVA is the rapid viscoanalyzer, BVA-Brabender viscoamylogram
[2] BU, and mPa s represent Brabender units, and millipascals per second, respectively
19,234,286,303

Table 2-67. Nutrient composition for 100 grams of raw, mature pinto beans

Nutrient	Unit	Value per 100 g
Water	g	11.33
Energy	kcal	347
Protein	g	21.42
Total lipid (fat)	g	1.23
Carbohydrate, by difference	g	62.55
Fiber, total dietary	g	15.5
Sugars, total	g	2.11
Minerals		
Calcium, Ca	mg	113
Iron, Fe	mg	5.07
Magnesium, Mg	mg	176
Phosphorus, P	mg	411
Potassium, K	mg	1393
Sodium, Na	mg	12
Zinc, Zn	mg	2.28
Vitamins		
Vitamin C, total ascorbic acid	mg	6.3
Thiamin	mg	0.713
Riboflavin	mg	0.212
Niacin	mg	1.174
Vitamin B-6	mg	0.474
Folate, DFE	µg	525
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	0
Vitamin E (alpha-tocopherol)	mg	0.21
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	5.6
Lipids		
Fatty acids, total saturated	g	0.235
Fatty acids, total monounsaturated	g	0.229
Fatty acids, total polyunsaturated	g	0.407
Fatty acids, total trans	g	0
Cholesterol	mg	0

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Table 2-68. Nutrient composition for 100 grams of cooked, mature pinto beans

Nutrient	Unit	Value per 100 g
Water	g	62.95
Energy	kcal	143
Protein	g	9.01
Total lipid (fat)	g	0.65
Carbohydrate, by difference	g	26.22
Fiber, total dietary	g	9
Sugars, total	g	0.34
Minerals		
Calcium, Ca	mg	46
Iron, Fe	mg	2.09
Magnesium, Mg	mg	50
Phosphorus, P	mg	147
Potassium, K	mg	436
Sodium, Na	mg	1
Zinc, Zn	mg	0.98
Vitamins		
Vitamin C, total ascorbic acid	mg	0.8
Thiamin	mg	0.193
Riboflavin	mg	0.062
Niacin	mg	0.318
Vitamin B-6	mg	0.229
Folate, DFE	µg	172
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	0
Vitamin E (alpha-tocopherol)	mg	0.94
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	3.5
Lipids		
Fatty acids, total saturated	g	0.136
Fatty acids, total monounsaturated	g	0.133
Fatty acids, total polyunsaturated	g	0.235
Fatty acids, total trans	g	0
Cholesterol	mg	0

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Table 2-69. PDCAAS value for pinto beans

Table 1	Amino Acid Score[1]	True Protein Digestibility (%)[2]	PDCAAS[3]
Pinto Beans	0.77	76.2	0.59

[1] Limiting the amino acid with the lowest ratio relative to the established amino acid requirement values for humans ages 2-5 years of age is known as the amino acid score.
[2] AOAC Method 991.29 (n=10).
[3] Amino Acid Score x % True Protein Digestibility.
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Table 2-70. Yield and composition of pinto bean starch

	Composition			
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)
Pinto bean	25.0-31.1	0.12	31.3-37.4	0.05-0.07

19,118,120,289

Table 2-71. Companies producing and supplying pinto beans

Companies	Multigrain International, LLC
21st Century Bean Processing LLC	Nebraska Bean, Inc.
Ackerman Marketing	Nebraska Dry Bean Associates, Inc.
Adm/Edible Bean Specialties Inc.	New Alliance Bean
Agri Broker, LLC	Nexus Trading Group, LLC.
Aileen Quirk & Sons, Inc.	North Central Commodities
Bamp Marketing & Consulting Inc.	Northern Feed & Bean
Blackhive Corp, Inc.	Northwood Bean Co.
Caldak International, LLC	PL International, LLC
Camex Inc.	P.W. Montgomery, LLC
Central Valley AG Exports, Inc	Rangen, Inc.
Central Valley Bean Cooperative	Red River Bean of Oslo, Inc.
C & F Foods, Inc.	The Rice Company
Colgate Commodities, Inc.	Russell E. Womack, Inc.
Columbia Bean & Produce Co., Inc.	SKE Midwestern, Inc.
Commodity Specialists Company	Slauson Trading Company, LLC
Cooperative Elevator Company	SRS Commodities, Ltd.
Cornerstone Commodities, LLC	St Hilaire Seed Company, Inc.
D.W. Sturt & Company Faribault Foods, Inc	Star Of The West Milling Company
Forest River Bean Co., Inc. Freeland Bean & Grain, Inc. G. F. Bean Company, LLC Global Merchandising Corp. Goya Foods, Inc.	Stateline Producers Cooperative
Johnstown Bean Company KC Trading Company, LLC	Steele & Company
Kelley Bean Company	Thompsons
Kirkeide's Northland Bean + Seed Co., Inc.	Trinidad Benham Corp.
Kirsten Company, LLC	United Pulse Trading, Inc.
Larson Grain Company	Walhalla Bean Company
L.H. Virkler & Co., Inc.	Walton Ag Services
L.M. Davenport, Inc.	Western Trading Company
Mayport Farmers Coop Edible Bean Division	Weststar Food Co., LLC
Meridian Seeds	Yanez International - Sales Agents

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Table 2-72. Acreage, yield, production and value for pinto beans during crops years 1987-2010

Year	Acreage		Yield	Production	Season average price 1/	Value of production 2/1
	Planted	Harvested				
	1,000 acres		Pounds	1,000 cwt	$/cwt	$1,000
1987	637.6	617.1	1,549	9,560	--	--
1988	580.5	556.6	1,293	7,199	--	--
1989	766.2	707.8	1,334	9,439	--	--
1990	964.2	925.1	1,476	13,650	14.89	203,249
1991	839.8	814.1	1,676	13,643	11.78	160,715
1992	682.8	636.9	1,440	9,172	16.51	151,430
1993	821.9	687.5	1,165	8,006	25.76	206,235
1994	929.2	827.9	1,534	12,703	15.16	192,577
1995	841.0	758.2	1,484	11,253	18.56	208,856
1996	821.7	778.2	1,558	12,123	18.85	228,519
1997	773.8	707.7	1,543	10,920	18.84	205,733
1998	977.1	923.0	1,572	14,511	12.77	185,305
1999	706.2	645.9	1,681	10,857	11.64	126,375
2000	724.5	652.2	1,653	10,778	12.01	129,444
2001	558.6	509.4	1,718	8,750	25.18	220,325
2002	832.3	742.3	1,777	13,188	13.79	181,863
2003	663.9	639.2	1,635	10,453	15.84	165,576
2004	643.9	567.7	1,362	7,730	26.84	207,473
2005	777.8	719.1	1,723	12,389	13.94	172,703
2006	684.9	647.6	1,471	9,523	21.15	201,411
2007	694.2	674.7	1,746	11,778	27.99	329,666
2008	629.3	606.9	1,690	10,257	26.94	276,324
2009	690.3	654.6	1,667	10,914	25.05	273,396
2010	842.7	809.7	1,706	13,814	23.00	317,722

1/ Average grower prices (Sep-Aug) as reported by Bean Market News.2/ Production times average price.

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Table 2-73. Average crop grower prices of pinto beans for crop years 2000-2010

Year	Average
	Dollars per cwt
2000	12.01
2001	25.18
2002	13.79
2003	15.84
2004	26.87
2005	13.95
2006	21.15
2007	27.99
2008	26.94
2009	25.05
2010	20.23

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Table 2-74. Nutrient composition of 100 grams of mature, cooked red lentils

Nutrient	Unit	Value per 100 g
Water	g	67.1
Energy	kcal	120
Protein	g	9.4
Total lipid (fat)	g	0.3
Carbohydrate, by difference	g	17.1
Fiber, total dietary	g	5.3
Minerals		
Calcium, Ca	mg	12
Iron, Fe	mg	2.7
Magnesium, Mg	mg	32
Phosphorus, P	mg	112
Potassium, K	mg	266
Sodium, Na	mg	3
Zinc, Zn	mg	1.47
Vitamin C, total ascorbic acid	mg	1.8
Thiamin	mg	0.11
Riboflavin	mg	0.03
Niacin	mg	0.4
Vitamin B-6	mg	0.09
Folate, DFE	µg	21
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	3.33
Lipids		
Fatty acids, total saturated	g	0.18
Fatty acids, total monounsaturated	g	0.16
Fatty acids, total polyunsaturated	g	0.35
Cholesterol	mg	0

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Table 2-75. Nutrient composition of 100 grams of mature, raw red lentils

Nutrient	Unit	Value per 100 g
Water	g	12.7
Energy	kcal	317
Protein	g	25
Total lipid (fat)	g	0.9
Carbohydrate, by difference	g	45.3
Fiber, total dietary	g	14.1
Minerals		
Calcium, Ca	mg	38
Iron, Fe	mg	8.5
Magnesium, Mg	mg	98
Phosphorus, P	mg	331
Potassium, K	mg	941
Sodium, Na	mg	10
Zinc, Zn	mg	4.33
Vitamin C, total ascorbic acid	mg	7.8
Thiamin	mg	0.44
Riboflavin	mg	0.1
Niacin	mg	1.6
Vitamin B-6	mg	0.34
Folate, DFE	µg	110
Vitamin B-12	µg	0
Vitamin A, RAE	µg	1
Vitamin A, IU	IU	6.66
Lipids		
Fatty acids, total saturated	g	0.18
Fatty acids, total monounsaturated	g	0.16
Fatty acids, total polyunsaturated	g	0.35
Cholesterol	mg	0

[85]

Table 2-76. Mean starch characteristics of red lentil cultivars grown in the USA in 2016

Market Class	Cultivar	Peak Viscosity (RVU[1])	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Red Lentil	CDC Maxim	142	134	8	236	103	5.51	75.9
	CDC Redcoat	123	112	11	236	124	5.00	74.3

[1] Rapid viscounits
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Table 2-77. Nutrient composition of 100 grams of mature, cooked green lentil

Nutrient	**Unit**	**Value per 100 g**
Water	g	67
Energy	kcal	119
Protein	g	9.3
Total lipid (fat)	g	0.4
Carbohydrate, by difference	g	16.6
Fiber, total dietary	g	5.8
Minerals		
Calcium, Ca	mg	14
Iron, Fe	mg	2.6
Magnesium, Mg	mg	32
Phosphorus, P	mg	102
Potassium, K	mg	259
Sodium, Na	mg	2
Zinc, Zn	mg	1.34
Vitamin C, total ascorbic acid	mg	1.4
Thiamin	mg	0.05
Riboflavin	mg	0.03
Niacin	mg	0.4
Vitamin B-6	mg	0.1
Folate, DFE	µg	22
Vitamin B-12	µg	0
Vitamin A, RAE	µg	1
Vitamin A, IU	IU	3.33
Lipids		
Fatty acids, total saturated	g	0.09
Fatty acids, total monounsaturated	g	0.09
Fatty acids, total polyunsaturated	g	0.17
Cholesterol	mg	0

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Table 2-78. Nutrient composition of 100 grams of mature, raw green lentils

Nutrient	**Unit**	**Value per 100 g**
Water	g	12.6
Energy	kcal	316
Protein	g	24.7
Total lipid (fat)	g	1.2
Carbohydrate, by difference	g	44.1
Fiber, total dietary	g	15.3
Minerals		
Calcium, Ca	mg	43
Iron, Fe	mg	8
Magnesium, Mg	mg	100
Phosphorus, P	mg	300
Potassium, K	mg	916
Sodium, Na	mg	7
Zinc, Zn	mg	3.95
Vitamin C, total ascorbic acid	mg	6.3
Thiamin	mg	0.19
Riboflavin	mg	0.12
Niacin	mg	1.5
Vitamin B-6	mg	0.39
Folate, DFE	µg	120
Vitamin B-12	µg	0
Vitamin A, RAE	µg	1
Vitamin A, IU	IU	10
Lipids		
Fatty acids, total saturated	g	0.23
Fatty acids, total monounsaturated	g	0.23
Fatty acids, total polyunsaturated	g	0.45
Cholesterol	mg	0

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Table 2-79. Mean starch characteristics of green lentil cultivars grown in the USA in 2016

Market Class	Cultivar	Peak Viscosity (RVU[1])	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Green Lentil	Avondale	149	132	17	232	99	5.2	74.4
	CDC Imvincible CL	146	127	19	225	99	4.73	76
	CDC Meteor	154	140	14	233	93	5.27	75.5
	CDC Richlea	152	134	18	241	107	5.07	76.2
	CDC Viceroy	124	117	6	211	93	5.27	74.6
	Merrit	141	127	14	235	108	5.00	75.9

[1] Rapid viscounits
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Table 2-80. Nutrient composition of 100 grams of mature, cooked yellow peas

Nutrient	Unit	Value per 100 g
Water	g	61.3
Energy	kcal	145
Protein	g	8.5
Total lipid (fat)	g	0.7
Carbohydrate, by difference	g	24
Fiber, total dietary	g	4.4
Minerals		
Calcium, Ca	mg	12
Iron, Fe	mg	1.5
Magnesium, Mg	mg	36
Phosphorus, P	mg	127
Potassium, K	mg	348
Sodium, Na	mg	2
Zinc, Zn	mg	1
Vitamin C, total ascorbic acid	mg	1.2
Thiamin	mg	0.2
Riboflavin	mg	0.07
Niacin	mg	0.9
Vitamin B-6	mg	0.05
Folate, DFE	µg	44
Vitamin B-12	µg	0
Vitamin A, RAE	µg	4
Vitamin A, IU	IU	26.6
Lipids		
Fatty acids, total saturated	g	0.28
Fatty acids, total monounsaturated	g	0.24
Fatty acids, total polyunsaturated	g	0.73
Cholesterol	mg	0

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Table 2-81. Nutrient composition of 100 grams of mature, raw yellow peas

Nutrient	**Unit**	**Value per 100 g**
Water	g	9.9
Energy	kcal	338
Protein	g	19.8
Total lipid (fat)	g	1.6
Carbohydrate, by difference	g	55.9
Fiber, total dietary	g	10.3
Minerals		
Calcium, Ca	mg	34
Iron, Fe	mg	4
Magnesium, Mg	mg	98
Phosphorus, P	mg	330
Potassium, K	mg	1080
Sodium, Na	mg	7
Zinc, Zn	mg	2.58
Vitamin C, total ascorbic acid	mg	4.6
Thiamin	mg	0.72
Riboflavin	mg	0.2
Niacin	mg	3.3
Vitamin B-6	mg	0.17
Folate, DFE	µg	200
Vitamin B-12	µg	0
Vitamin A, RAE	µg	9
Vitamin A, IU	IU	63.3
Lipids		
Fatty acids, total saturated	g	0.28
Fatty acids, total monounsaturated	g	0.24
Fatty acids, total polyunsaturated	g	0.73
Cholesterol	mg	0

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Table 2-82. Mean starch characteristics of yellow pea cultivars grown in the USA in 2016

Market Class	Cultivar	Peak Viscosity (RVU[1])	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Yellow	AAC Carver	110	108	3	193	85	5.47	76.7
	Abarth	163	157	7	304	147	5.4	75
	AC Earlystar	137	132	5	249	116	5.43	75.8
	Admiral	140	133	7	230	97	5.33	75.1
	Agassiz	135	124	11	236	112	5.21	75.4
	Bridger	153	138	15	236	98	5	75
	Carousel	162	142	20	267	125	5.13	75.8
	CDC Meadows	149	134	15	287	154	5.13	74.2
	Durwood	137	126	11	193	68	5.27	76
	Jetset	126	117	9	205	88	5.61	75.3
	Leroy	146	132	14	253	122	5.33	75.9
	Mystique	142	131	11	241	110	5.18	75.5
	Nette	151	125	26	250	124	4.87	72.6
	Universal	139	119	20	216	97	4.93	74.2
	Unknown	155	139	16	273	134	5.21	75.3

[1] Rapid viscounits
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Table 2-83. Nutrient composition of 100 grams of mature, cooked green peas

Nutrient	**Unit**	**Value per 100 g**
Water	g	61.9
Energy	kcal	142
Protein	g	9.1
Total lipid (fat)	g	0.7
Carbohydrate, by difference	g	22.3
Fiber, total dietary	g	5
Minerals		
Calcium, Ca	mg	13
Iron, Fe	mg	1.4
Magnesium, Mg	mg	33
Phosphorus, P	mg	122
Potassium, K	mg	313
Sodium, Na	mg	5
Zinc, Zn	mg	1.21
Vitamin C, total ascorbic acid	mg	1
Thiamin	mg	0.2
Riboflavin	mg	0.07
Niacin	mg	0.8
Vitamin B-6	mg	0.05
Folate, DFE	µg	43
Vitamin B-12	µg	0
Vitamin A, RAE	µg	4
Vitamin A, IU	IU	26.6
Lipids		
Fatty acids, total saturated	g	0.12
Fatty acids, total monounsaturated	g	0.13
Fatty acids, total polyunsaturated	g	0.31
Cholesterol	mg	0

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Table 2-84. Nutrient composition of 100 grams of mature, raw green peas

Nutrient	**Unit**	**Value per 100 g**
Water	g	11.2
Energy	kcal	326
Protein	g	21.5
Total lipid (fat)	g	1.2
Carbohydrate, by difference	g	51
Fiber, total dietary	g	12.6
Minerals		
Calcium, Ca	mg	36
Iron, Fe	mg	3.4
Magnesium, Mg	mg	76
Phosphorus, P	mg	326
Potassium, K	mg	959
Sodium, Na	mg	11
Zinc, Zn	mg	3.05
Vitamin C, total ascorbic acid	mg	3.5
Thiamin	mg	0.71
Riboflavin	mg	0.21
Niacin	mg	2.8
Vitamin B-6	mg	0.17
Folate, DFE	µg	200
Vitamin B-12	µg	0
Vitamin A, RAE	µg	8
Vitamin A, IU	IU	53.3
Lipids		
Fatty acids, total saturated	g	0.07
Fatty acids, total monounsaturated	g	0.1
Fatty acids, total polyunsaturated	g	0.2
Cholesterol	mg	0

[85]

Table 2-85. Mean starch characteristics of green pea cultivars grown in the USA in 2016

Market Class	Cultivar	Peak Viscosity (RVU[1])	Hot Paste Viscosity (RVU)	Breakdown (RVU)	Cold Paste Viscosity (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Green	Aragorn	152	134	18	267	133	4.93	73.4
	Arcadia	173	144	29	296	153	4.97	76.3
	Ariel	163	144	19	276	132	5.2	77.1
	Banner	137	120	17	222	101	5.24	76.5
	Blue Moon	131	128	3	217	90	5.6	78.3
	CDC Raezer	123	116	7	225	109	5.13	74.3
	CDC Striker	138	124	14	243	119	5.22	76.5
	Columbian	129	115	13	182	67	5.33	79.9
	Daytona	125	106	19	219	113	5.23	72.5
	Ginny	141	122	19	255	133	4.91	75.1
	Greenwood	151	139	12	264	125	5.18	76.4
	Majoret	141	122	19	259	137	4.77	75.9
	Shamrock	148	140	8	244	104	5.33	77.4
	Viper	174	154	20	337	183	5.3	76.3

[1] Rapid viscounites

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Table 2-86. Nutrient composition of 100 grams of mature, raw cowpeas

Nutrient	Unit	Value per 100 g
Water	g	11.95
Energy	kcal	336
Protein	g	23.52
Total lipid (fat)	g	1.26
Carbohydrate, by difference	g	60.03
Fiber, total dietary	g	10.6
Sugars, total	g	6.9
Minerals		
Calcium, Ca	mg	110
Iron, Fe	mg	8.27
Magnesium, Mg	mg	184
Phosphorus, P	mg	424
Potassium, K	mg	1112
Sodium, Na	mg	16
Zinc, Zn	mg	3.37
Vitamins		
Vitamin C, total ascorbic acid	mg	1.5
Thiamin	mg	0.853
Riboflavin	mg	0.226
Niacin	mg	2.075
Vitamin B-6	mg	0.357
Folate, DFE	µg	633
Vitamin B-12	µg	0
Vitamin A, RAE	µg	3
Vitamin A, IU	IU	50
Vitamin E (alpha-tocopherol)	mg	0.39
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	5
Lipids		
Fatty acids, total saturated	g	0.331
Fatty acids, total monounsaturated	g	0.106
Fatty acids, total polyunsaturated	g	0.542
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

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Table 2-87. Nutrient composition of 100 grams of mature, cooked, boiled, and unsalted cowpeas

Nutrient	**Unit**	**Value per 100 g**
Water	g	70.04
Energy	kcal	116
Protein	g	7.73
Total lipid (fat)	g	0.53
Carbohydrate, by difference	g	20.76
Fiber, total dietary	g	6.5
Sugars, total	g	3.3
Minerals		
Calcium, Ca	mg	24
Iron, Fe	mg	2.51
Magnesium, Mg	mg	53
Phosphorus, P	mg	156
Potassium, K	mg	278
Sodium, Na	mg	4
Zinc, Zn	mg	1.29
Vitamins		
Vitamin C, total ascorbic acid	mg	0.4
Thiamin	mg	0.202
Riboflavin	mg	0.055
Niacin	mg	0.495
Vitamin B-6	mg	0.1
Folate, DFE	µg	208
Vitamin B-12	µg	0
Vitamin A, RAE	µg	1
Vitamin A, IU	IU	15
Vitamin E (alpha-tocopherol)	mg	0.28
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	1.7
Lipids		
Fatty acids, total saturated	g	0.138
Fatty acids, total monounsaturated	g	0.044
Fatty acids, total polyunsaturated	g	0.225
Fatty acids, total trans	g	0
Cholesterol	mg	0
Other		
Caffeine	mg	0

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Table 2-88. Composition of cowpea starch

	Composition			
Starch source	Yield (%)	Total lipid (%)	Total amylose (%)	Nitrogen (%)
Cowpeas	37	0.20-1.33	25.8-33.0	0.06-0.09

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Table 2:89. Parameters of gelatinization for cowpea starch by differential scanning calorimetry

Starch source	Starch to water	Gelatinization parameters			
		[1]T_o (°C)	[1]T_p (°C)	[1]T_c (°C)	[2]HJ/g
Cowpeas	1 to 3	70.5-72.7	75.4	81	15.2-16.9

[1] T_o, T_p and T_c represent the on-set, midpoint and conclusion temperatures of gelatinization, respectively.
[2]Enthalpy of gelatinization = **Δ**H
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Table 2-90. List of U.S. companies supplying cowpeas

Companies
Agri Broker, LLC
Cal-Bean & Grain Cooperative, Inc.
C & F Foods, Inc.
CHS, Inc
Colusa Produce Corp.
EP International Corp.
Global Merchandising Corp.
Kelley Bean Company
Kirsten Company, LLC
Latinex INTL.
L.H. Virkler & Co., Inc.
Northwest Trading Company, Inc.
PL International, LLC
P.W. Montgomery, LLC
Rhodes-Stockton Bean Co-Op
SKE Midwestern, Inc.
Superior Bean & Seed
Trinidad Benham Corp.
Tumac Commodities
Western Trading Company

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