OPTIMIZATION AND SENSORY QUALITY OF A PEANUT-BASED CALCIUM-FORTIFIED PASTA

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INTRODUCTION

In many countries worldwide vegetable protein is used as an extender or replacement for animal protein, particularly in developing countries where traditional sources of protein such as meat, poultry and dairy products are unavailable or unaffordable to large segments of the population (Chompreeda *et al.*, 1988). Plant proteins, which contain predominantly unsaturated fat as replacements for animal proteins which contain more saturated fat, have also gained interest in the United States in an effort to reduce risk factors for heart disease and some types of cancer (Coulston, 1999). Plant proteins that contain unsaturated fats include foods such as nuts and seeds, and oil from grains and seeds (Coulston, 1999).

Peanuts (*Arachis hypogaea* L.) are actually legumes, members of the pea and bean family, Leguminosae, which provide the best source of concentrated protein in the plant kingdom (Pszcola, 2000). Peanuts, also known as groundnuts, are grown in 108 countries (Future Harvest, 2002) with the vast majority being grown in India, China, Argentina, Brazil, West Africa, Indonesia, Burma, Mexico, Australia, and the United States. In 2001 the worldwide production of peanuts totaled 35 million tons (Future Harvest, 2002). China, the largest producer of peanuts from 1996-2000 with an average of 11.5 million tons followed by India with 7.1 million tons and the United States with an average of 1.7 million tons make up the top three peanut producing countries in the world (Revoredo and Fleetcher, 2002). In the U.S. most of the peanut crop is consumed as whole nut products or peanut butter with only a small portion crushed for oil, whereas countries such as India use most of their peanut crop to produce edible oil (Ory and Flick, 1994). Peanut meal is a byproduct of the oil extraction process and is mainly utilized for animal feeds or as fertilizer (Ory and Flick, 1994). Peanut meal, however, contains a high amount of protein as well as other nutrients contained in whole peanuts, and can be converted into edible-grade protein flours that may be used to develop value-added food products for human consumption (Ory and Flick, 1994).

Recently many studies have focused on the benefits of incorporating nuts into the diet. Hu *et al.* (1998) looked at a cohort of 86,016 women in the Nurse's Health Study to evaluate the effects of frequent nut consumption on coronary heart disease in women. Their findings showed that frequent nut consumption was associated with a reduced risk of both fatal coronary heart disease and non-fatal myocardial infarction (Hu *et al.*, 1998). Another major epidemiological study of over 27,000 Seventh Day Adventists in California showed that frequent consumption (five or more times per week) of nuts reduced the risk of developing a nonfatal or fatal myocardial infarction by 53 percent (Fraser *et al.*, 1992).

Peanuts contain 25-32% protein (average of 25% digestible protein) and 42-52% oil (Putnam *et al.*, 1991). Six of the 13 essential vitamins and 35 percent of the essential minerals needed for normal growth, maintenance, and tissue repair (American Peanut Council, 2000) make up the overall micronutrient profile of peanuts. Peanuts are also a good source of fiber and are considered a low glycemic index food. Defatted peanut flour is also an excellent source of the same essential vitamins, minerals and fiber found in whole peanuts (USDA, 2002). While the beneficial fats are lower in the defatted peanut flour compared with whole peanuts, the protein contained in peanut flour is higher than that in wheat flour. Protein Digestability Corrected Amino Acid Scoring, or PDCAAS is a method used to determine a protein's quality. If the PDCAAS is greater than or equal to 1.00, the protein is a good source of essential amino acids. Peanut meal has a score of 0.52 while wheat gluten has a score of only 0.25 compared to casein, egg whites, and ground beef which each have a score of 1.00 (Deis, 2000). The protein quality of peanuts, however, can be significantly enhanced by combining them with cereal grains or other plant proteins having complementary amino acids (Ory and Flick, 1994).

Development of food products containing defatted peanut flour has been limited to doughnuts, muffins, tortillas, and Chinese-type noodles (McWatters, 1986; Hinds, 2000; Holt *et al.*, 1992; Chompreeda *et al.*, 1988). With the interest in incorporating more plant proteins into a healthy nutrition regime in the U.S. as well as improving protein consumption for people in developing countries, defatted peanut flour offers a wide variety of possible uses. It could be used to fortify low protein foods such as soups, gravies, bakery items, milk-type beverages or to prepare analogs of high-protein animal foods such as meatballs, sausages, ground meat products, or cheeses (Ory and Flick, 1994). Peanut flour can be used to fortify low-protein foods or to prepare a variety of food products without any changes in color, taste, or texture of the traditional product (Ory and Flick, 1994). Pasta-type products, traditionally made from semolina or wheat flour would benefit from fortification with peanut flour because a more balanced amino acid ratio could be achieved. Therefore, not only will the total protein content be improved, the nutritional quality of the protein will be enhanced as well.

Statement of Problem

Protein deficiency is a problem in many developing countries that rely heavily on cultivated cereal grains as the main staple in their diets. In addition, the benefits of incorporating plant proteins into the typical U.S. diet in an effort to increase nutrient content and reduce the risk of heart disease has been a focus in nutritional research for many years (Coulston, 1999). Inadequate calcium intake may also exist in developing countries because of inadequate dairy intake due to high cost or unavailability (Weaver, 2001). In the U.S., the increased popularity for plant proteins and preferences for vegetarian diets that exclude dairy products may cause inadequate calcium intake to become an even greater challenge. A calcium-fortified pasta-type product made with defatted peanut flour would provide a low-cost, high-protein, low-saturated fat, cholesterol-free, nutrient dense product that could be easily stored. Additionally, economic stability of the worldwide peanut industry could be enhanced as a result of value-added utilization of a byproduct (peanut flour) which is not widely used for human consumption.

Objectives

The objectives of this study were:

1. To evaluate the effects of defatted peanut flour on physical and sensory properties of a short pasta-type product.
2. To evaluate the effects of carboxymethylcellulose (CMC) on the physical and sensory properties of a short-type pasta product made with defatted peanut flour.

3. To fortify experimental pasta containing defatted peanut flour and CMC with a level of calcium based on the results of a pilot study to test the effects of tri-calcium citrate, tri-calcium phosphate, and calcium carbonate on physical and sensory attributes of pasta made with defatted peanut flour (60% semolina replacement).

Specific objectives for this study were accomplished in two parts as follows:

Part I

A) Evaluated the effects of the three calcium sources on physical and sensory quality of pasta containing defatted peanut flour (60% semolina replacement).

B) Investigated the effects of defatted peanut flour and CMC on the following physical properties of a short pasta-type product fortified with tricalcium phosphate: Color, moisture content, and dimensions of frozen pasta; and texture and color of the cooked product.

Part II

Investigated the effects of defatted peanut flour and CMC on physical and sensory properties of those treatments identified in part I to have the optimum physical properties.

Hypotheses

The following null hypotheses were postulated for this research:

H1: There will be no significant difference in physical and sensory properties between control pasta (100% semolina plus 1% CMC) containing 23 mg calcium per 56 g serving and experimental pasta made with defatted peanut flour (60% semolina replacement plus 1% CMC) fortified with tri-calcium citrate (TCC), tri-calcium phosphate (TCP), or calcium carbonate (CC) at 200, 400, and 600 mg/56 g serving.

H2: There will be no significant difference between calcium-fortified (TCP 250-300 mg/56 g serving) control pasta (100% semolina) and calcium-fortified (TCP 250-300 mg/56 g serving) experimental pasta made with defatted peanut flour (60% semolina replacement) and up to 1.0% carboxymethylcellulose as measured by objective tests including texture profile (hardness, cohesiveness, springiness, gumminess, chewiness) of cooked pasta; color (chroma, hue, and L-value) of thawed uncooked and cooked pasta; and dimensions (twirl factor) and moisture content of frozen pasta.

H3: There will be no significant difference in acceptability of sensory attributes (appearance, aroma, taste, texture, aftertaste) and purchase intent between optimum treatments of experimental pasta containing defatted peanut flour (up to 60% semolina replacement) and carboxymethylcellulose (up to 1.0%) fortified with tri-calcium phosphate (250-300 mg/56 g serving) and calcium fortified (TCP 250-300 mg/56 g serving) control pasta (100% semolina).

Assumptions

The following assumptions were made by the author at the beginning of the study:

1. Replacement of semolina with defatted peanut flour will negatively affect texture due to lack of gluten formation in defatted peanut flour.
2. Adding carboxymethylcellulose to pasta containing defatted peanut flour will improve the texture.

3. Carboxymethylcellulose was chosen based on the recommendation from a technical representative of a company who produces food additives/gums to enhance texture in food products such as pasta.
4. Fortification with calcium will enhance texture (hardness) of pasta as this is commonly used in industry to improve textural attributes of baked products and canned vegetables.
5. The consumer panel will be representative of a large population.
6. Results from frozen pasta will be applicable to commercial market as frozen, fresh, and dried forms of pasta are currently sold in commercial markets.

Limitations

The limitations of this study are:

1. Results of frozen pasta using 100% semolina may differ from dried pasta using 100% semolina. No frozen commercial reference made with 100% semolina was available in the twirl-shape of pasta used for this study.
2. Due to time limitations in this study, it was not possible to test every type of gum available to examine their effects on the texture of the pasta. Guar gum used in preliminary trials was not as effective as the carboxymethylcellulose.
3. Sensory panelists may not represent a true random sample of the total population.
4. All environmental parameters including temperature and relative humidity upon extrusion, immediate freeze temperature and storage freezer temperature were monitored and recorded. However, environmental conditions (temperature and

relative humidity) could not be controlled during extrusion process and some variation between preparation of treatments may have occurred.

CHAPTER II

LITERATURE REVIEW

Overview of Peanuts

Peanuts (*Arachis hypogaea* L.) are legumes, members of the pea and bean family, Leguminosae, which provide the best source of concentrated protein in the plant kingdom (Pszcola, 2000). Recently, many studies have focused on the nutritional benefits of incorporating plant-based proteins such as peanuts into the diet to help reduce the incidence and complications of diseases such as cardiovascular disease and diabetes mellitus, and to increase the nutrient content of the diet. In addition, peanuts are more economically available to populations who cannot afford more costly forms of protein such as meat, eggs, and milk. Therefore, peanuts and peanut products (e.g. defatted peanut flour) offer a good source of low-cost, cholesterol-free, low-saturated fat, nutrient dense protein.

Peanut Production

Legumes make up one of the world's most important sources of food protein, energy and other nutrients (Ory and Flick, 1994). Peanuts are native to South America, and were found in Brazil and Peru in 950 BC (Conkerton and Ory, 1987). Peanuts are grown in many countries including India, China, Argentina, Brazil, West Africa, Indonesia, Burma, Mexico, Australia, and the United States. The five-year average world production from 1996-2000 was 29 million tons (Revoredo and Fleetcher, 2002).

China and India produce more than half of the world crop with five-year averages from 1996-2000 of 11.5 and 7.1 million tons respectively, while the United States produced approximately 6% of the world crop or 1.7 million tons over the same five-year period (Revoredo and Fleetcher, 2002). In the U.S. peanuts are an important agricultural commodity with Georgia, Oklahoma, Texas, New Mexico, Virginia, North Carolina, Florida, and Louisiana providing the largest percentage of peanuts grown in the United States. According to the Peanut Institute in Atlanta, Georgia, approximately 2.4 billion pounds of peanuts on average are consumed in the U.S. each year, with about 50% consumed as peanut butter (The Peanut Institute, 2000).

A small portion of the U.S. crop is used for oil extraction and flour production compared with countries such as India where most of the peanut crop is used to obtain edible oil and meal/flour byproducts (Ory and Flick, 1994). The meal/flour byproduct is used primarily for animal feeds and fertilizer (Ory and Flick, 1994). Development of food products containing defatted peanut flour would not only increase dietary nutrient/protein content, but would also incorporate a byproduct currently underutilized for human consumption and in turn enhance the economic stability of the peanut industry worldwide.

Nutritional Quality of Peanuts/Peanut Flour

Peanuts are an excellent source of concentrated protein, containing on average 28% protein, 50% oil and 18% carbohydrates. Peanuts also provide a rich source of nutrients containing 6 of the 13 essential vitamins and 35 percent of the essential minerals needed for normal body growth, maintenance, and tissue repair (American Peanut

Council, 2000). The vitamins included in peanuts are vitamin E, niacin, folate, thiamin, and riboflavin. The minerals provided by peanuts consist of magnesium, copper, phosphorus, potassium, zinc, iron, and calcium. One ounce (30 grams) of peanuts contains approximately 7 grams of protein and 2 grams of fiber (The Peanut Institute, 2000).

Health Benefits of Peanuts and Peanut Products

Consumption of peanuts and peanut products provide many health benefits. In the United States one of the leading causes of death is cardiovascular disease. Diets high in total and saturated fat place a person at a higher risk of developing cardiovascular disease (Coulston, 1999). Lowering fat in the diet and raising carbohydrate intake was recommended for a time to lower a person's cardiovascular risk factors. However, recent studies have shown the importance of consuming the right types of fats in the diet instead of just focusing on limiting fat as a whole. Monounsaturated fatty acids and polyunsaturated fatty acids are the more healthy types of fats recommended for a person's diet. Peanuts consist of a combination of saturated, polyunsaturated and monounsaturated fatty acids with approximately 50% being monounsaturated and 33% polyunsaturated (American Peanut Council). A study directed by Dr. Penny Kris-Etherton at Pennsylvania State University looked at the benefits of monounsaturated fatty acids (MUFA) in the diet. The study showed that while low-fat diets increase plasma triacylglycerol and decrease HDL-cholesterol concentrations, thereby potentially adversely affecting cardiovascular disease risk, high-MUFA cholesterol-lowering diets do not raise triacylglycerol or lower HDL cholesterol (Kris-Etherton *et al.*, 1999). Diets high in monounsaturated fatty acids from foods such as peanuts reduced the risk of heart disease by 21% while a low-fat diet replacing saturated fat with carbohydrate reduced it by 12% (Kris-Etherton *et al.*, 1999).

The antioxidant vitamin E found in peanuts helps to prevent LDL cholesterol from oxidizing and sticking to artery walls, and helps protect against cellular damage caused by free radicals, potentially providing some protection against heart and lung disease as well as cancer (Forcinio, 2000). Research has also shown that adequate intakes of vitamin E can help reduce the effects of aging on the immune system and central nervous system. A study published in the New England Journal of Medicine concluded that getting vitamin E from natural food sources was more preferable than taking supplements for protecting against coronary heart disease (Kushi *et al.*, 1996).

Peanuts are also a good source of folate. Folate intake has been inversely correlated with blood concentrations of the amino acid homocysteine. High homocysteine levels have been linked with atherosclerosis (Selhum *et al.*, 1995). Adequate intake of folate by pregnant women has also been shown to reduce the incidence of neural tube defects in the fetus (Morrison *et al.*, 1996).

Peanuts also offer a good source of fiber and are classified as a low glycemic index food (The Peanut Institute, 2000), which makes them a good choice for individuals with diabetes, as well as those who want to reduce their risk of diabetes. Adequate dietary fiber is important for persons with diabetes in that it helps control blood sugar levels and reduces the risk of chronic illness. A report published in the Journal of the American Medical Association concluded that women who consume diets high in cereal fiber and low in starchy, sugary carbohydrates with high glycemic indices can significantly lower their risk of developing non-insulin dependent diabetes (Salmeron *et al.*, 1997).

Phytosterols such as beta-sitosterol have been studied for their protective role against different types of cancers such as colon, prostate, and breast cancer. Peanuts and peanut products are good sources of phytosterols, containing 55-60 mg/100 g (Awad *et al.*, 2000). Peanuts also contain resveratrol, a phytochemical shown to act as an anti-oxidant that has also exhibited anti-cancer properties (Jang *et al.*, 1997). Resveratrol, a compound contained in grape skins and red wine, may be responsible for the health benefits of red wine consumption, and ounce for ounce, peanuts contain almost 30 times more resveratrol than grapes (Sanders, 2000).

Previous Research with Defatted Peanut Flour

The research conducted on the utilization of defatted peanut flour in products developed for human consumption has been very limited. Defatted peanut flour has been used in doughnuts, muffins, tortillas, non-dairy beverages, and Chinese-type noodles (McWatters, 1986; Holt *et al.*, 1992; Hinds *et al.*, 1997 a, b, c; and Chompreeda *et al.*, 1988). Defatted peanut flour, a byproduct obtained during the oil extraction from peanuts, has traditionally been used in the U.S. for animal feed. However, with the increasing awareness of the nutritional benefits that plant-based proteins such as peanuts can provide, the interest in utilizing peanut flour in products designed for human consumption has grown.

Defatted peanut flour offers many of the nutritional benefits of peanuts without the high fat content found in peanut products such as peanut butter. Defatted peanut flour contains between 50-60% protein and can be used to fortify low-protein foods or to prepare a variety of food products without any changes in color, taste, or texture of the traditional items (Ory and Flick, 1994). In combination with other plant proteins, peanut proteins can provide a relatively low cost means of raising protein levels of marginal diets while providing a balanced ratio of amino acids and maintaining nutritional quality of the dietary protein (Sipos, 1990; Rhee, 1985; Ory *et al.*, 1979; Lusas and Rhee, 1986; McWatters, 1986).

Overview of Pasta

Pasta comes in many shapes and sizes that may be divided into three main production groups: Long-cut pasta, short-cut pasta, and nest-shaped pasta. The basic pasta formulation consists of flour and water. Durum wheat semolina or flour and common wheat flour are the most widely used major ingredients in pasta (Dalbon *et al.*, 1996). Other ingredients such as eggs and vegetable powders are also added to some types of pasta. The two main types of pasta on the market include dried, frozen and fresh, with consumption of dry pasta exceeding that of fresh pasta due to its storability and lower price. The demand for fresh pasta is growing, however, due to its shorter preparation time (Mbabaali, 1997). The shelf life for fresh pasta, however, is limited at around 30-45 days (Varriiano-Marston and Stoner, 1996) and freezing fresh pasta can extend the shelf life up to 3-4 months (Mbabaali, 1997).

Pasta Production

Many countries have a pasta or pasta-type product that serves as a staple food item in their respective culture(s). Pasta products have also become an increasingly popular food item in the U.S. with consumption of approximately five billion pounds of pasta in 2000 (Boland and Barton, 2002). Low price, convenience, low-fat content, and storability are among some of the reasons for the growth in consumption. In addition, an increased focus on value-added and diversification are expected to enhance the growth potential for the industry (Mbabaali, 1997). New pasta products such as soy pasta and whole wheat pasta containing milled flax seed are among some of the new value-added pasta products recently placed on the commercial market.

Nutritional Quality of Pasta

Traditional pasta made with durum semolina is high in complex carbohydrates. A one-half cup serving of pasta contains approximately 99 calories, less than half a gram of fat, and less than 5 milligrams of sodium (Feeney, 2000). As a result of fortification, pasta is also a source of nutrients such as thiamin, riboflavin, niacin, and iron, and is an excellent source of folate, providing 25 percent of the recommended daily intake in a 2 oz serving of dry pasta (Feeney, 2000). The Federal Drug Administration has determined that diets adequate in folic acid may reduce a woman's risk of having a child with brain or spinal cord defects (Feeney, 2000).

Enrichment Standards for Pasta/Noodle Products

Pasta and noodle products are mandated by law in the U.S. as well as other countries to contain a specified amount of nutrient enrichment. The U.S. Code of Federal Regulations (CFR), Section 139.115 and 139.155 states that enriched macaroni and noodle products contain not less that 8.82 milligrams (mg) and not more than 11.0 mg of thiamin per kilogram, not less than 3.75 mg and not more than 4.85 mg of riboflavin per kilogram, not less than 59.5 mg and not more than 75.0 mg of niacin or niacinamide per kilogram, not less than 2.0 mg and not more than 2.64 mg of folic acid per kilogram, and not less than 28.7 mg and not more than 36.4 mg of iron per kilogram. Vitamin D at not less than 550 IU and not more than 2200 IU per kilogram, and calcium at not less than 1.10 g and not more than 1.38 g per kilogram are optional nutrient enrichment categories for these products per the CFR regulations (Roche, 2000).

Alternative Flours in Pasta Production

The use of defatted peanut flour in a pasta-type product was studied by Chompreeda *et al.* (1988) who looked at the modeling effects of peanut and cowpea flour supplementation on the quality of Chinese-type noodles. The levels of peanut flour and cowpea flour used included 0, 7, 14, 21% and 0, 4, 8, 12%, respectively. Results showed a positive correlation between the protein content of the noodles and the level of peanut/cowpea flour. Color and cutting force were negatively affected in relation to the amount of the cowpea/peanut flour used. While the darker color of the fortified noodles was attributed mainly to the cowpea flour, the peanut flour was found to be the main contributor to loss of firmness in the noodles due to a decrease in the amount of gluten formation arising from a reduction in the amount of wheat flour. Sensory evaluation for this study was performed using experienced judges selected from a pool of faculty, students and staff at Kasetsart University in Bangkok, Thailand. Sensory scores for firmness and color were also negatively affected by the supplementation of cowpea and peanut flour in the noodles. Response surface regression revealed that up to 15% peanut flour and 8% cowpea flour could be used without significantly reducing the sensory quality of the noodles (Chompreeda *et al.*, 1988).

Spaghetti pasta containing corn gluten meal, replacing 5-10% semolina, had similar cooked weight and cooking loss but was less firm compared with the control. Flavor was decreased with increased corn gluten meal. Results showed that spaghetti with acceptable quality could be prepared with 5% water/ethanol-washed corn gluten meal (Wu *et al.*, 2001).

Sangronis *et al.* (1997) evaluated rice bran as a replacement for granular flour (at a 10 and 20% replacement) and durum semolina (at a 10 and 20% replacement) in a spaghetti pasta. Cooking time, water absorption, solid loss, color, hardness, and sensory evaluation were performed. Protein Efficiency Ratio and Apparent Digestibility in vivo were also determined. Results indicated that the rice bran improved solid loss during cooking and increased cooking time. There was no significant difference in PER but apparent digestibility decreased when rice bran was increased. Sensory evaluation determined pasta to be hard and dark, but comparable with high fiber pasta (Sangronis *et al.*, 1997).

Overview of Calcium Fortification

Dairy products are the major foods that naturally contain significant quantities of calcium (Weaver, 1998). Some individuals, however, due to physiological, economical, or availability constraints may not be able to consume an adequate amount of dairy products to achieve their dietary calcium needs. Although calcium is available in many foods other than dairy, the bioavailabiltiy of calcium in these foods varies from a low of approximately 5% in spinach to a high of over 50% in Brassica vegetables when fed at comparable calcium loads (Weaver and Plawecki, 1994). The question then arises whether or not it is realistic to believe that a person could consume large enough quantities of food sources other than dairy on a daily basis in order to meet calcium needs. In addition, the increasing consumption of beverages other than milk has led to inadequate calcium consumption in certain populations (Weaver, 1998). Food fortification with calcium offers an alternative source for individuals who may be at risk of consuming inadequate amounts of calcium.

Importance of Adequate Dietary Calcium

Adequate dietary calcium has been linked with a risk reduction in diseases such as osteoporosis, arterial hypertension, and colon cancer (Gueguen and Pointillart, 2000). Adequate intake (AI) of calcium varies by life stage group. Adequate intake, identified in the Dietary Reference Intakes of the Food and Nutrition Board, is based on observed or experimentally determined estimates of average nutrient intake by a group (or groups) of healthy people (Food and Nutrition Board, 1997). In the U.S. the AI for calcium in adults is 1000 mg per day, rising to 1200 mg for elderly populations and up to 1300 mg per day for adolescents. Requirements were determined in relation to the intake that resulted in maximal calcium retention (Weaver, 2001). Additionally, the Tolerable Upper Intake Level (UL), defined as the highest level of daily nutrient intake that is likely to pose no risks of adverse health effects to almost all individuals in the general population, is set at 2.5 g calcium/day for populations over the age of 12 months (Food and Nutrition Board, 1997).

Calcium intakes of most populations, especially adolescent females, are below the recommended AI level (Bryant *et al.*, 1999). A recent review of calcium consumption in France determined the percentage of each sector of the population that consumed less than two-thirds of the RDA, the critical threshold for defining groups at risk. These groups included about 20% to 25% of men aged 18-65, 30% of women aged 18-50, 50% of adolescent girls and men aged over 65, and 75% of women over the age of 55. Elderly women living in institutions had particularly low calcium intakes (Guegucn and Pointillart, 2000).

Calcium Homeostasis

Blood calcium levels are almost invariant and therefore do not reflect nutritional status (Weaver, 2001). Calcium homeostasis involves three basic mechanisms along with a system of hormonal controls in order to maintain plasma calcium levels within a narrow, normal range. The first mechanism involves intestinal absorption-excretion balance which adjusts calcium absorption in the intestines with excretion of the remainder. Absorption is the result of two processes, active transport which is saturable and regulated by dietary intake and the needs of the body, and passive diffusion which is not saturable and therefore, increases with dietary intake (Gueguen and Pointillart, 2000). The second mechanism involves renal adjustment of calcium excretion in the urine; and finally, there is maintenance of calcium stores in the bone. Calcium balance is also controlled by three interrelated hormones: calcitriol (vitamin D hormone), parathyroid hormone, and calcitonin (Williams, 1997).

Calcium Bioavailability

The intestine is the dominant site of adaptation to dietary calcium deficiency (Weaver, 2001). Calcium absorbability, or the availability of calcium for absorption by the small intestines, is often used as a synonym for bioavailability (Gueguen and Pointillart, 2000). The potential absorbability of calcium depends on the food, whereas absorption depends also on the absorptive capacity of the intestines, which is affected by physiological factors such as calcium reserves, hormonal regulation or previous dietary calcium supply. Bioavailability of calcium may be defined as the fraction of dietary calcium that is potentially absorbable by the small intestines and can be used for physiological functions, particularly bone mineralization, or to limit bone loss (Gueguen and Pointillart *et al.*, 2000).

Calcium:Phosphorus Ratio

Incorporation of absorbed calcium into bone is stimulated by phosphorus, but excess phosphorus may also cause undesirable ectopic calcification (outside the bone) (Gueguen and Pointillart, 2000). Excess dietary phosphorus has also been thought to increase fecal excretion of calcium. However, contrary to this widely held view, excess phosphorus intake does not reduce calcium absorption, at least if calcium intake is adequate (Gueguen and Pointillart, 2000). Additionally, while western-type meals have a Ca/P ratio well below 1, which favors the precipitation of calcium, this does not prevent the normal absorption of calcium (Gueguen and Pointillart, 2000). Increasing calcium intake through use of supplements or food fortificants resulting in a high Ca:P ratio may result in a phosphorus deficiency (Heaney and Nordin, 2002) in some populations such as the elderly who may be at risk for both calcium and phosphorus deficiency as a result of overall inadequate nutrition.

Comparison of Calcium Salts

Dairy products are naturally rich in dietary calcium. However, for some individuals who may be lactose intolerant, who opt for vegetarian diets that exclude dairy products, or who simply do not prefer dairy products, adequate calcium intake becomes a challenge. Calcium supplements and calcium-fortified foods have become an alternative way to reach optimal calcium intake for individuals who do not consume dairy products on a regular basis.

Calcium supplements and calcium-fortified foods contain various calcium salts. The ideal calcium source used to fortify foods will be highly absorbable and available to enhance bone mass, inexpensive and safe, and compatible with the food delivery vehicle (Weaver, 1998). The ultimate measure of the best nutritional choice is the benefit of the calcium source to increasing peak bone mass during growth and to reduce bone loss later in life (Weaver, 1998).

Ranhotra *et al.* (1997) looked at the effects of calcium carbonate, calcium sulfate, calcium citrate, and calcium lactate on relative bioavailability as assessed by femur calcium content in rats as well as calcium absorption data. No differences of any physiologic significance were observed in relative bioavailability among the five calcium sources tested (Ranhotra *et al.*, 1997).

Calcium bioavailability from calcium citrate, calcium lactate, calcium acetate, oyster-shell, eggshell, and β-tri calcium phosphate was evaluated by Bao *et al.* (1997) using isotope-dilution in rat studies to determine true absorption and intermediate utilization for the five sources tested. All calcium sources revealed an extremely high absorbability and utilizability. Bao *et al* (1997) state that the chemical formulation, therefore, does not seem to be the primary factor in calcium bioavailability in the practical diet.

Inhibitors to Calcium Absorption

Absorption of calcium naturally present in a food or calcium added as a fortificant can be inhibited by oxalic and phytic acid components contained in a food product. Oxalate forms a salt with calcium which decreases the solubility and therefore decreases absorption. Additionally, phytic acid forms a salt with calcium that cannot completely be dissociated in the gut and is too large to be absorbed intact by the paracellular route (Weaver, 2001). Oxalic acid is abundant in spinach, rhubarb, sweet potatoes, and legumes. However, soybeans have high calcium bioavailability, despite a high oxalate content; the reason is not currently understood (Weaver 1998). Soy milk fortified with tricalcium phosphate for example has a fractional calcium absorption of 23.7% in a 240 g serving which contains an estimated 300 mg calcium compared with a 32.1% fractional calcium absorption in an equivalent serving size of milk containing 300 mg calcium (Weaver, 2001). Phytic acid significantly reduces calcium absorption in such foods as beans and wheat (Weaver et al., 1993; Weaver et al., 1991) but the inhibition is modest compared with oxalates except in foods very rich in phytic acid such as wheat bran (Weaver, 1998). Moreover, the calcium balance in the body only seems to be affected by phytates if the diet is unbalanced (Gueguen and Pointillart, 2000). The inhibitory effect of phytate on calcium absorption can be substantially reduced by processing methods that hydrolyze or remove phytate, such as fermentation, selective precipitation of proteins or use of phytase sprays (Weaver, 1998) in addition to insuring that there is adequate amount of calcium in the diet.

Optimization Using Response Surface Methodology

Response surface methodology (RSM) is a statistical procedure used for optimization of quality characteristics in product development (Osborne and Armacost, 1996). It uses quantitative data from an appropriate experimental design to determine and simultaneously solve multivariate problems (Madamba, 2002). Box and Wilson (1951) provided the pioneer work in the use of RSM. Their derivation of statistical methodology associated with this technique lead to the publication "On the Experimental Attainment of Optimum Conditions" (Box and Wilson, 1951). The methodology requires the identification of those factors (independent variables) that are significant predictors of the response variable (quality characteristic) to be optimized. The next step involves identification of various levels of each independent variable considered to be important in predicting the response variable (Osborne and Armacost, 1996). Classical RSM experimental designs include Box-Behnken and central composite designs (Kuntz, 1993) which are imbedded factorial designs with center points which are augmented with a group of "star points" that allow estimation of curvature (Engineering Statistics Handbook, 1998). If the distance from the center of the design space to a factorial point is ± 1 unit for each factor, the distance from the center of the design space to a star point is $\pm\alpha$ with $|\alpha| \geq 1$ (Engineering Statistics Handbook, 1998). The use of an incomplete balanced block central composite design allows for fewer experimental runs resulting in less time and resources needed to obtain a statistically valid conclusion (Kuntz, 1993).

RSM generates equations that describe the effects of the test variables on the responses, determine interrelationships among the test variables, and represent the combined effect of all test variables in the response (Madamba, 2002). Data are analyzed using multiple regression which yields an estimate of the unknown model parameters, thereby providing a predicted response function (Osborne and Armacost, 1996). Tests are then performed to check adequacy, and adjustments within the model are made until an area is identified where the more desirable response values can be found. If model adequacy is assured, the surface is mapped and optimum factor settings are identified (Osborne and Armacost, 1996). ANOVA tables, generated prior to running RSM, provide information on the significant independent variables as well as the interactions of these variables. The ANOVA tables will indicate the statistical significance of the response models for all terms (linear, quadratic, and interaction), and the residual variances for all the responses (Madamba, 2002).

Carboxymethylcellulose

Carboxymethylcellulose (CMC) is a cellulose gum. Gums are complex hydrophilic carbohydrates found in plants (McWilliams, 1997). In food products, gums function as thickening agents, fat replacers, anticrystallizing agents in frozen foods, and as enhancers of shelf life and textural attributes in baked products (McWilliams, 1997). CMC 2500 F powder (Ticalose®) is a sodium carboxymethylcellulose gum produced by TIC Gums, Inc. It is approved for use in both food and pharmaceutical applications. According to specifications listed by TIC Gums, Ticalose® is soluble in either cold or hot water and compatible with most water-soluble polymers. Cellulose gum meets the standards established by the U.S. Code of Federal Regulations, Title 21, Section 182.1745 and is listed on the GRAS list. It is also listed in the Food Chemicals Codex (TIC Gums, 2001).

Summary

Peanuts are one of the largest oilseed crops grown worldwide. Grown primarily for human consumption, peanuts have several uses as whole seeds or processed to make peanut butter, oil, peanut meal, and other products. Recent studies suggest the nutritional benefits of incorporating nuts into the diet to decrease the risk of cardiovascular disease, cancer, and diabetes. Defatted peanut flour or peanut meal, a byproduct of the oil extraction process, is currently underutilized for human consumption. Defatted peanut flour is approximately four times higher in protein than wheat flour. The macro and micronutrient profile of defatted peanut flour suggests its potential in development of foods for human consumption to increase the macro and micronutrient profile in foods typically containing wheat flour. Pasta or pasta-type products, traditionally made with wheat flour, serve as staple food items in many countries worldwide. Low price, convenience, and low-fat are some of the attributes that have caused pasta to increase in popularity. Value-added food products are also increasing in popularity as a result of the health and economic needs worldwide. Pasta-type products made with defatted peanut flour (replacing a percentage of wheat flour/semolina) and fortified with calcium offer a value-added food item utilizing a byproduct (defatted peanut flour) not currently utilized for human consumption, thus potentially enhancing the economic stability of the peanut industry worldwide.

CHAPTER III

PHYSICAL CHARACTERISTICS OF A PEANUT-BASED CALCIUM-FORTIFIED PASTA INCLUDING AN OPTIMIZATION STUDY USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT

Peanuts (*Arachis hypogaea* L.) are one of the largest oilseed crops grown worldwide. Grown primarily for human consumption, peanuts have several uses as whole seeds or processed to make peanut butter, oil, peanut meal, and other products. Defatted peanut flour or peanut meal is a byproduct of the oil extraction process and is currently underutilized for human consumption. A review of the macro and micronutrient profiles of defatted peanut flour suggests its contribution to increased nutritional potential when used as a replacement in foods typically containing 100% wheat flour. Pasta products are traditionally made from 100% wheat flour/semolina. Recently, however, pasta products made with alternative flours such as soy have been

launched on the commercial market. Information on utilization of peanut flour in a pasta-type product has been limited to Chinese-type noodles containing 15% peanut flour.

The objectives of this study were to investigate the physical properties of a short, frozen, pasta-type product made with defatted peanut flour (PF) and carboxymethylcellulose (CMC), and to predict optimum combinations using response surface methodology (RSM) to produce a product comparable to the control (100% semolina). All pasta was fortified with tri-calcium phosphate (TCP) at 250-300 mg/56 g serving. A Box-Behnken design for a 5^2 incomplete factorial arrangement of PF (20, 40, 60, 80 and 100%) and CMC (0, 0.4, 0.8, 1.2, and 1.6% of total flour weight) was used in a standard short pasta formulation. Pasta treatments were immediately frozen (-20 to -25° C) following extrusion and held for 90-120 days prior to evaluation. Moisture was evaluated on the frozen pasta. Dimensions and color (Minolta chroma-meter) were evaluated on both thawed pasta and cooked pasta. Additionally, texture profile [TA XT2*i* Texture Analyzer fitted with a TA-25 cylindrical probe (50 mm diameter), 25 kg load cell, plus Texture Expert Exceed Software and a test speed of 1 mm/sec] and cooked yield were evaluated on the cooked pasta. The moisture of the pasta was significantly affected ($P<0.05$) by CMC. Pasta containing 20% PF with 0.8% CMC (30.4±1.60) was significantly less ($P<0.05$) moist than formulations containing 40% PF with 0.4% CMC (34.6±1.45), 60% PF with 0%CMC (33.0±3.07), 60% PF with 1.6% CMC (34.2±1.33) and 100% PF with 0.8% CMC (33.9±1.59). PF had no significant effect ($P>0.05$) on moisture. The twirl factor was affected by interactive effects of PF and CMC ($P<0.01$). The twirl factor decreased as CMC was increased for treatments containing ≤ 80% PF. Formulations containing > 0.8% CMC were significantly ($P<0.05$) less twirled

(1.14±0.04 to 1.20±0.08) than the control (1.59±0.23). The overlay plot of all textural attributes (hardness, springiness, cohesiveness, gumminess, and chewiness) examined using RSM revealed that formulations containing 41-50% PF would need some CMC, for example, 50% PF could be used with 0.15-0.38% CMC. However, formulations containing <40% PF might not require CMC because appropriate levels predicted, when PF is 25-40% or 0-20%, are 0-0.4% CMC and 0-0.7% CMC, respectively. The maximum percent PF replacement predicted to produce pasta with texture similar to the control is 50%. Three-dimension plots were constructed using RSREG procedure to evaluate the effects of PF and CMC on the color of the uncooked and cooked pasta. As peanut flour increased, hue of the uncooked and cooked pasta decreased and the pasta became more brown. Chroma of the uncooked pasta with >67% PF was more intense, and formulations containing CMC at levels <0.53% and >1.07% with PF <33% had a more intense brown color. Similar results were seen in the chroma of the cooked pasta. As peanut flour increased, the L-value of the uncooked pasta decreased and the pasta became darker, showing a similar trend to the L-value of the cooked pasta with the exception that when PF was >67%, the cooked pasta became slightly lighter. CMC had no affect on L-value of uncooked or cooked pasta. In conclusion it is predicted that up to 30% PF could be used with < 0.4% CMC, and 50% PF could be used with a CMC level of 0.15-0.38%, whereas pasta containing <20% PF would require 0-0.7% CMC to produce pasta with physical properties similar to that of a control (100% semolina).

INTRODUCTION

Peanuts (*Arachis hypogaea* L.) have drawn attention in recent years because of the nutritional benefits they offer. Whole peanuts, peanut oil, and peanut butter have a common place in the diet of many cultures. Peanut flour, however, a byproduct obtained from oil extraction, is not widely utilized for human consumption. Defatted peanut flour offers many of the nutritional benefits of peanuts without the high fat content found in peanut products such as peanut butter. Defatted peanut flour contains between 50-60% protein and can be used to fortify low-protein foods or to prepare a variety of food products without any changes in color, taste, or texture of the traditional items (Ory and Flick, 1994). For example, defatted peanut flour has been utilized to prepare Chinese-type noodles (Chompreeda *et al.*, 1988), baked goods (McWatters, 1986; Holt *et al.*, 1992), and beverages (Hinds *et al.*, 1997 a, b, c). In combination with other plant proteins, peanut proteins can provide a relatively low cost means of raising protein levels of marginal diets while providing a balanced ratio of amino acids, and maintain nutritional quality of the dietary protein (Sipos, 1990; Rhee, 1985; Ory *et al.*, 1979; Lusas and Rhee, 1986; McWatters, 1986).

Pasta, a staple food in many areas of the world, is an increasingly popular and inexpensive addition to the diets of many western cultures (New Zealand Institute, 2002). Pasta is traditionally made with 100 percent durum semolina, durum flour, or a combination of durum and other hard wheat flours (farina) (Wheat Foods Council, 2002). Nontraditional flour such as defatted peanut flour, however, could be used to prepare pasta-type products in an effort to increase the nutrient content (including increased protein), utilize more readily available flours when wheat flour is not as economical or easily accessible, and increase variety in a food item that is typically low price, convenient, low-fat, and shelf-stable.

In addition to increasing protein content in a traditionally grain-based food item, increasing calcium through fortification would add to the value of this product. Many populations worldwide have difficulty meeting calcium needs from traditional dairy sources due to economic, availability, or physiologic constraints. Adequate dietary calcium has been linked with a risk reduction in diseases such as osteoporosis, arterial hypertension, and colon cancer (Gueguen and Pointillart, 2000).

The objectives of this study were to fortify a pasta-type product with calcium based on the findings of a preliminary calcium study evaluating the physical and sensory characteristics of a pasta-type product fortified with tri-calcium citrate, tri-calcium phosphate, or calcium carbonate at 200, 400, and 600 mg/56 g serving of pasta; examine the physical characteristics of a short-type pasta made with peanut flour and carboxymethylcellulose and fortified with 250-300 mg tri-calcium phosphate/56 g serving, and predict optimal formulations to maximize peanut flour content without significantly affecting physical properties of the calcium-fortified pasta.

MATERIALS AND METHODS

Preliminary Calcium Study

Experimental Design: A 3x3 factorial arrangement in a randomized complete block design with three calcium forms [tri-calcium citrate (TCC), tri-calcium phosphate (TCP), and calcium carbonate (CC)] at three levels of fortification (200 mg, 400 mg, and 600 mg/56 g serving) in a short-type pasta made with defatted peanut flour (60%

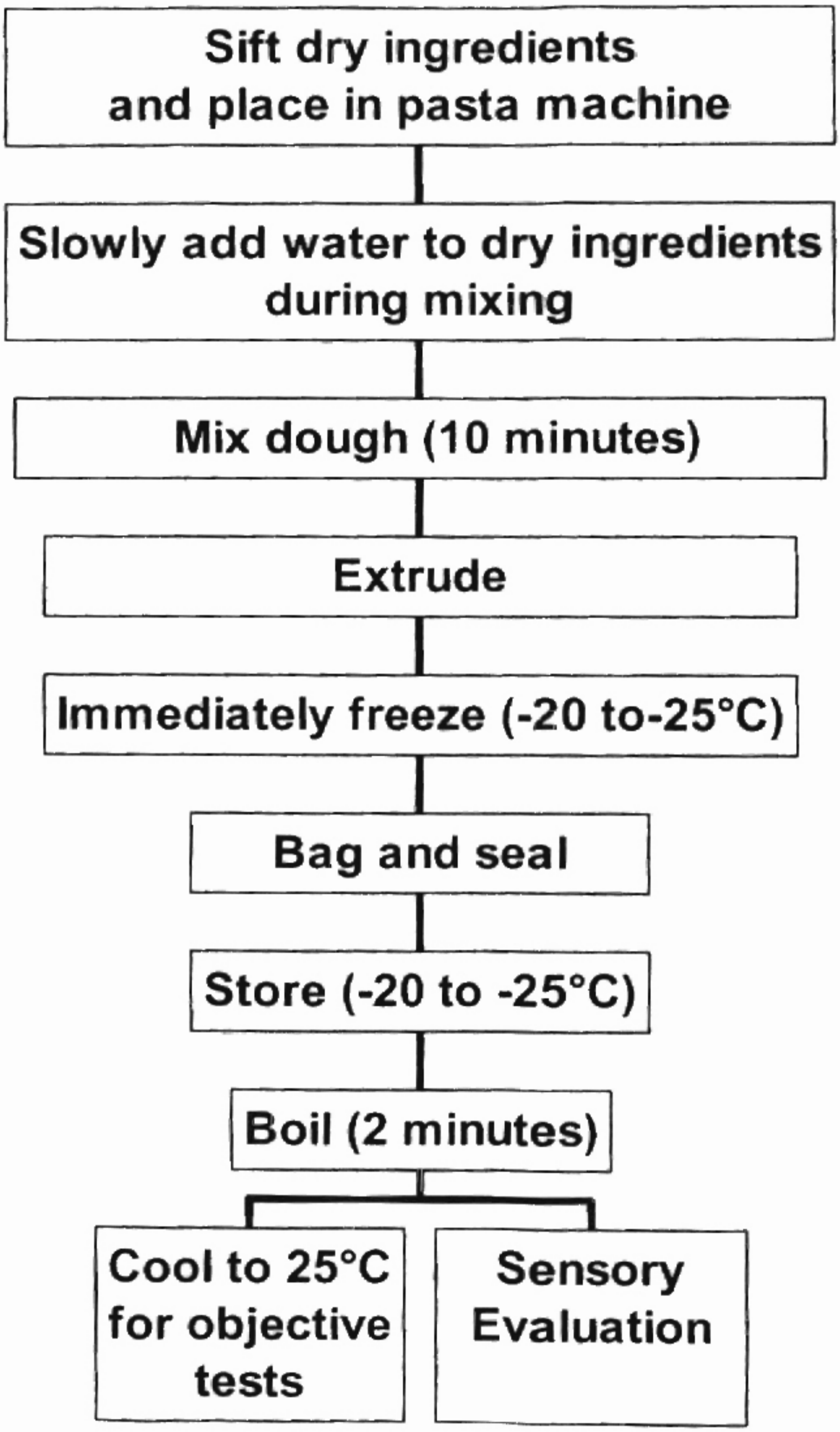
semolina replacement) was used. Carboxymethylcellulose (CMC) at 1.0% of total flour content was incorporated into the pasta recipe to improve texture due to loss of gluten formation when using peanut flour to replace wheat flour. The control pasta was prepared with defatted peanut flour (60% semolina replacement) and 1.0% CMC.

Materials: Defatted peanut flour containing 50% protein and 12% fat was donated by Golden Peanut Company, Alpharetta, Georgia. Enriched semolina (King Midas) was donated by Conagra, Omaha, Nebraska. CMC 2500 F powder (Ticalose®) was donated by TIC Gums, Belcamp, Maryland. Tri-calcium citrate and tri-calcium phosphate were donated by Gadot Biochemicals, Rolling Meadows, Illinois. Calcium carbonate was donated by American Ingredients, Anaheim, California.

Pasta Preparation: The calcium content of the defatted peanut flour was analyzed using an atomic absorption spectrophotometer (Model: Perkin Elmer 5100 AAS). Prior to AAS analysis, the peanut flour samples were ashed in a Lindberg 847 ashing oven. The peanut flour contained 1g/kg calcium. Fortification levels of 200, 400, and 600 mg/56 serving of TCC, TCP, and CC were calculated per the manufacturer's standard specifications for each calcium salt assay at 24%, 39%, and 40%, respectively, and added to the dry ingredients prior to mixing. A rigatoni-shaped, short-type, frozen pasta was prepared in a PastaMatic 700 pasta machine per method shown in Figure 1, replacing 60% of semolina with defatted peanut flour and adding 1% CMC. Prior to objective evaluation of the cooked product, frozen pasta was boiled for 2-3 minutes, drained, and cooled to 25-30°C and then covered to prevent drying. Texture profile was performed on cooled pasta within 15 minutes. Pasta prepared for sensory evaluation was boiled for 2-3 minutes, drained, immediately tossed with Carapelli™ light olive oil and held in covered 4-ounce Styrofoam cups for ≤ 15 minutes prior to evaluation.

Color: Nine pieces of pasta per treatment were randomly selected for color evaluation. Color was measured using a Minolta Chroma Meter Reflectance System (Model CR-2000, Minolta, Japan) set in the CIE L*C*h° mode using a C light source at 2° observer angle. In the CIE system, hue is the color descriptor and is measured in a 360 degree angle where the first quadrant 0-90 degrees represents red to yellow, the second quadrant 90-180 degrees represents yellow to green, the third quadrant 180-270 degrees represents green to blue, and the fourth quadrant 270-360 degrees represents blue to red. Chroma, as defined by the CIE system, is the intensity of the hue, and the L-value measures the degree of lightness and darkness on a gray scale where 0 represents black and 100 represents white. Calibration was based on a standard tile with the following color space chromaticity co-ordinates: $Y = 94.3$, $x = 0.3134$, and $y = 0.3207$ ($L^* = 97.75$, $a^* = -0.58$, and $b^* = +2.31$). Measurements were taken on three separate randomly selected pieces of frozen (thawed) pasta to obtain one set of color values. This process was done in triplicate.

Figure 1
Method for Preparation of Pasta



Texture: Texture of cooked pasta was measured using a TA-XT2*i* Texture Analyzer (Texture Technologies Corp., Scarsdale, New York) fitted with a TA-45 knifeblade, 25 kg load cell, plus Texture Expert Exceed Software using a penetration depth of 3 mm and a test speed of 5 mm/sec. Five randomly selected pieces of cooked pasta per treatment were selected for texture evaluation. Each single piece of pasta was centered beneath the knifeblade and hardness was evaluated and interpreted as the maximum shear force (kg) required by the knifeblade to cut the pasta.

Sensory Analysis: A panel of 24 untrained panelists evaluated the following attributes of the cooked pasta: color, aroma, taste, texture, and aftertaste using a 9-point Hedonic Scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, 9=like extremely).

Statistical Analysis: Statistical Analysis Software (SAS, 1999) version 8.1 was used to compute one-way ANOVA and determine significant differences between means using Tukey's Studentized Range (HSD) Test.

Main Study

Experimental Design: An initial screening of the two independent variables in this study, peanut flour and CMC, provided some ground work for establishing the maximum levels which could be used to produce a pasta-type product that was grossly similar to the control (100% semolina). It was estimated that 0-100% peanut flour and 0-1.6% CMC could be used to produce a pasta-type product with visual physical characteristics similar to that of the control. A 5x5 complete factorial arrangement was then constructed using peanut flour at 20, 40, 60, 80, and 100% levels and CMC 2500 at 0, 0.4, 0.8, 1.2, and 1.6% levels (Appendix 1A). In order to reduce the amount of time and resources that it would take to run all 25 combinations identified in the complete factorial arrangement, a Box-Behnken balanced incomplete 5^2 central composite design was utilized. A total of nine treatments were identified using this type of imbedded factorial design (Box and Draper, 1987) with center points (coded 0, 0) , augmented with a group of "star points" to allow estimation of curvature (Engineering Statistics Handbook, 1998). Appendix 1B illustrates the coded and uncoded experimental design. Five levels (coded –2, -1, 0, +1, +2) were used for each independent variable, and coded pairs (-2, +2) and (-1, +1) are equidistant 'star points' from the center points (0, 0), Appendix 1B). All experimental formulations were fortified with 250-300 mg TCP/56 g serving uncooked pasta. Pasta containing 100% semolina, 0% CMC, and 250-300 mg TCP/56 g serving was used as the control against which the effects of the peanut flour and CMC on the reformulated pasta could be compared. Color and dimensions were evaluated on both thawed pasta and cooked pasta. Additionally, texture profile and cooked yield were evaluated on the cooked pasta. Response surface methodology (RSM) was used to predict optimum combinations of peanut flour and CMC to produce a product comparable to the control (100% semolina).

Materials: Defatted peanut flour containing 50% protein and 12% fat was purchased from Golden Peanut Company, Alpharetta, Georgia. Enriched semolina (King Midas) was donated by Conagra, Omaha, Nebraska. Carboxymethylcellulose (Ticalose®) was donated by TIC Gums, Belcamp, Maryland. Tri Calcium Phosphate was donated by Gadot Biochemicals.

Pasta Preparation: A rotini-shaped, short-type frozen pasta was prepared in a La Parmigiana (Model D-45) pasta machine (Fidenza, Italy) per method shown in Figure 1 and preparation conditions outlined in Appendix 2A&2B. Pasta was stored at -20 to -25°C for 90-120 days. Prior to objective evaluation of the cooked product, frozen pasta was boiled for 2-3 minutes, drained, and cooled to 25-30 degrees Celsius. Pasta prepared for sensory evaluation was boiled for 2-3 minutes, drained, immediately tossed with Carapelli™ light olive oil and held in covered Styrofoam cups for $\leq$ 15 minutes prior to evaluation.

Color: Color of thawed frozen pasta and cooked pasta was evaluated. Nine pieces of pasta per treatment were selected for color evaluation. Color was measured using a Minolta Chroma Meter Reflectance System (Model CR-2000, Minolta, Japan) set in the CIE L*C*h° mode using a C light source at 2° observer angle. In the CIE system, hue is the color descriptor and is measured in a 360 degree angle where the first quadrant 0-90 degrees represents red to yellow, the second quadrant 90-180 degrees represents yellow to green, the third quadrant 180-270 degrees represents green to blue, and the fourth quadrant 270-360 degrees represents blue to red. Chroma, as defined by the CIE system, is the intensity of the hue, and the L-value measures the degree of lightness and darkness on a gray scale where 0 represents black and 100 represents white. Calibration was based on a standard tile with the following color space chromaticity co-ordinates: $Y = 94.3$, $x = 0.3134$, and $y = 0.3207$ ($L^* = 97.75$, $a^* = -0.58$, and $b^* = +2.31$). Three measurements were taken of three randomly selected pieces of pasta to obtain one set of data points. This process was done in triplicate for both thawed and cooked pasta.

Dimensions: Rotini-shaped pasta is naturally twirled. Therefore, dimensions of thawed frozen (rotini-shaped) experimental pasta were calculated as twirl factor according to the following formula: un-twirled length (flat length) divided by twirled length. Thus, the higher the twirl factor value the greater was the degree of twirl in the sample. Dimensions were evaluated in triplicate for each formulation.

Texture: Three (2.0 + 0.5 g) randomly selected aliquots of each treatment were evaluated. Pasta was arranged in a plastic weighing dish within a 25 mm diameter circle and placed directly underneath the probe of the texture analyzer. Texture profile of cooked pasta was performed using a TA-XT2*i* Texture Analyzer (Texture Technologies Corp., Scarsdale, New York) fitted with a TA-25 cylindrical probe (50 mm diameter), 25 kg load cell, plus Texture Expert Exceed Software and a test speed of 1 mm/sec. Each sample was compressed to a distance of 6.0 mm, measured from the top surface of the sample prior to the first compression. A 5-second rest period was allowed between the two compressions. The textural attributes that were evaluated are defined as follows. Hardness is the peak force, calculated in grams, of the first compression of the product. Springiness is how well a product physically springs back after it has been deformed during the second compression. Cohesiveness measures how well a product withstands a second deformation relative to how it behaved under the first deformation. Gumminess is the interaction between hardness and cohesiveness, whereas chewiness is the interaction between springiness and gumminess (Texture Technologies Corp., 2000).

Statistical Analysis: Statistical Analysis Software (SAS Version 8.1) was used to compute one-way ANOVA, determine significant differences between means of physical attributes using Tukey's Studentized Range (HSD) Test, determine significant differences between process replications using Dunnett's Test, and perform Response Surface Regression (RSREG) to determine effects of independent variables (peanut flour and CMC) on physical properties of the pasta. RSREG is based on a second order polynomial equation of the type:

$$Y = b_0+b_1x_1+b_2x_2+b_3x_1^2+b_4x_2^2+b_5x_1x_2$$

where Y = response variable (e.g. hardness),

X_1 = peanut flour, X_2 = carboxymethylcellulose,

b_0 = intercept, and b_{1-5} = regression coefficients.

Response Surface Regression facilitated modeling by providing coefficients for the independent variables. These coefficients were used to derive equations (Table 6) that illustrated the effects of peanut flour and CMC on the dependent (response) variables. The equations were also used to plot contours and three-dimensional surfaces to predict values for the dependent (response) variables from data points that were not actually used in the experimental design.

RESULTS AND DISCUSSION

Preliminary Calcium Study Results

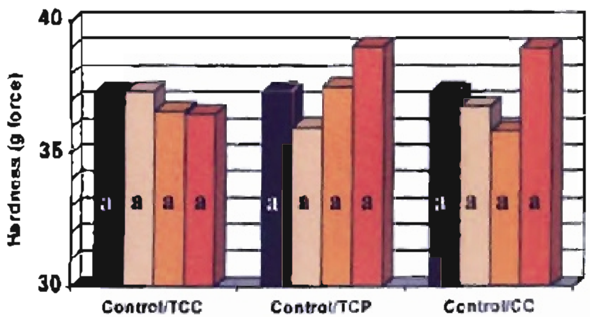
Physical Properties: Evaluation of texture revealed no significant difference in hardness means between the control pasta (37.3 ± 3.5 g force) and any of the nine experimental pasta treatments (35.9 ± 3.0 to 39.1 ± 2.7 g force) (Figure 2).

Color evaluation indicated no significant difference in hue between the control pasta (73.1 ± 0.1) and the nine experimental pasta treatments (72.5 ± 0.3 to 73.7 ± 0.3) (Figure 3). Chroma was not significantly different ($P>0.05$) between the control pasta

(32.9 ± 0.3) and the nine experimental treatments (31.8 ± 0.3 to 33.1 ± 0.3) (Figure 4). No significant difference (P>0.05) in L value was noted between control pasta (58.8 ± 0.9) and nine experimental pasta treatments (58.9 ± 0.6 to 60.2 ± 0.6) (Figure 5).

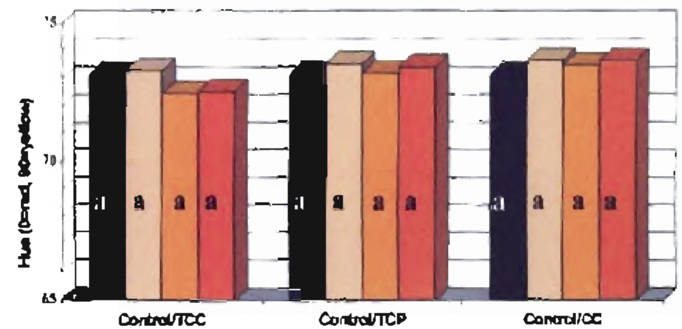
Sensory Evaluation: No significant difference (P>0.05) was noted in sensory attributes (color, aroma, taste, texture and aftertaste) between the control pasta and high levels (600 mg/56 g serving) of TCC, TCP, and CC fortified pasta. All sensory attributes for all pasta (control and fortified) formulations were acceptable (≥ 6) on a 9-point Hedonic scale, except the texture of the TCC-fortified formulation (means ± sd) which was disliked slightly to neither liked nor disliked (Figure 6).

Fig. 2: Effect of Tri Calcium Citrate (TCC), Tri Calcium Phosphate (TCP), and Calcium Carbonate on Hardness of Pasta.



*Means with the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test (α=0.05).

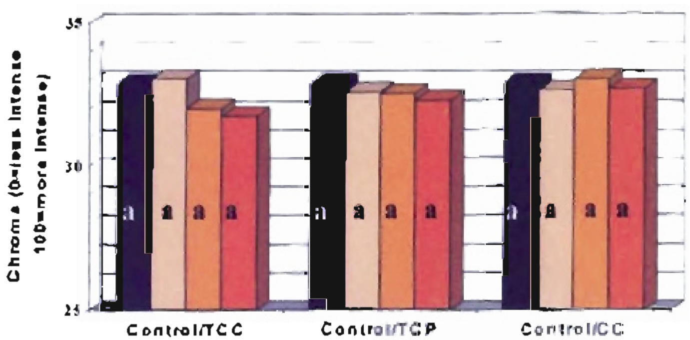
Fig. 3: Effect of Tri Calcium Citrate (TCC), Tri Calcium Phosphate (TCP), and Calcium Carbonate on Hue of Pasta.



*Means with the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test (α=0.05).

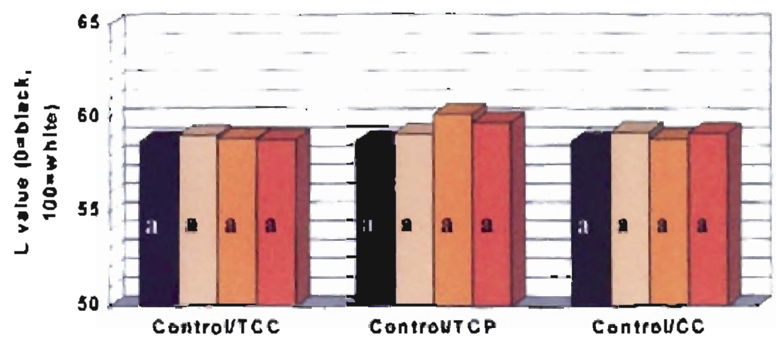
■ Control ■ 200 mg ■ 400 mg ■ 600 mg

Fig. 4: Effect of Tri Calcium Citrate (TCC), Tri Calcium Phosphate (TCP), and Calcium Carbonate on Chroma of Pasta.



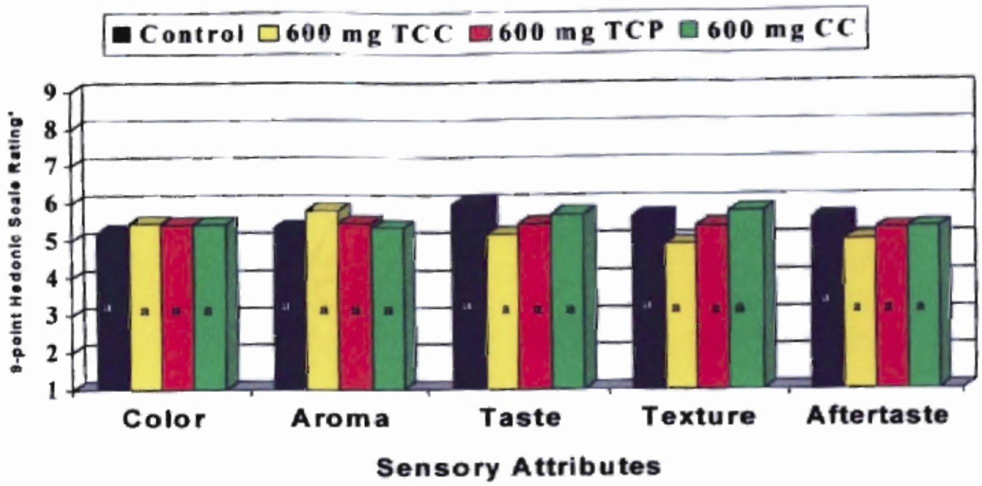
*Means with the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test (α=0.05).

Fig. 5: Effect of Tri Calcium Citrate (TCC), Tri Calcium Phosphate (TCP), and Calcium Carbonate on L value of Pasta.



*Means with the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test (α=0.05).

Figure 6
Effect of Tri Calcium Citrate (TCC), Tri Calcium Phosphate (TCP), and Calcium Carbonate (CC) on Sensory Acceptability (Mean Scores[a]) of Pasta



[a]Means with the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test (α=0.05).

Preliminary Calcium Study Discussion

When choosing an ideal calcium source to use for food fortification, factors that must be considered include absorption and bioavailability to enhance bone mass, cost and safety, and compatibility with the delivery vehicle (Weaver, 1998). Results from this study indicate that physical properties (texture and color) and sensory attributes (color, aroma, taste, texture, and aftertaste) were not significantly affected by fortification of TCC and TCP at levels ranging from 200-600 mg/56 g serving of pasta. Therefore, bioavailability and cost of calcium preparations may be more of a determining factor when choosing a calcium salt to use for fortification in a short-type pasta made with defatted peanut flour (60% semolina replacement). TCP was selected as the calcium source for the main part of the study because it is approximately one-fourth the cost of TCC and provides a source of phosphorus along with calcium for those individuals whose diet may be deficient in both nutrients such as the elderly population as a result of overall inadequate nutrition (Heaney and Nordin, 2002).

Preliminary Calcium Study Conclusions

Results of the calcium study indicate that TCC, TCP, and CC at 200, 400, and 600 mg/56 g serving could be used to fortify a pasta-type product made with defatted peanut flour (60% semolina replacement) without affecting its physical attributes (hardness and color). TCC at 200 and 400 mg/56 g serving and TCP and CC at 200, 400 and 600 mg/56 g serving could be used in the same pasta-type product without affecting the sensory attributes (color, aroma, taste, texture, and aftertaste).

Main Study Results

Effects of Peanut Flour (PF) and CMC on Moisture: Moisture content of the uncooked pasta was significantly affected ($P<0.05$) by CMC only, but not by PF (Table 1). Evaluation of moisture (means ± sd) revealed no significant difference between experimental pasta (30.4±1.60 to 34.6±1.45) and the control (33.0±1.49) as shown in Table 2. However, pasta containing 20% PF with 0.8% CMC (30.4±1.60) was significantly ($P<0.05$) less moist than formulations containing 40% PF with 0.4% CMC (34.6±1.45), 60% PF with 0% CMC (33.9±3.07), 60% PF with 1.6% CMC (34.2±1.33) and 100% PF with 0.8% CMC (33.9±1.59).

Table 1

ANOVA: Overall Effect of Independent Variables on Response Variables[α]

Independent Variable	Dependent Variable					
	Moisture	Twirl Factor[β]				
PF	NS	**				
CMC	*	**				
PF*PF	NS	NS				
CMC*PF	NS	**				
CMC*CMC	NS	NS				
	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	
PF	NS	**	NS	NS	NS	
CMC	NS	NS	NS	NS	**	
PF*PF	**	**	**	**	**	
CMC*PF	**	NS	**	**	NS	
CMC*CMC	**	**	**	**	**	
	Hue1[γ]	Chroma1[γ]	Lval1[γ]	Hue2[ε]	Chroma2[ε]	Lval2[ε]
PF	**	NS	**	**	NS	**
CMC	*	*	NS	**	**	NS
PF*PF	**	NS	**	**	NS	**
CMC*PF	NS	NS	NS	*	NS	NS
CMC*CMC	NS	*	NS	**	NS	NS

[α]Significance level: $**P \leq 0.01$, $*P \leq 0.05$

NS = not significant

[β] Twirl factor = flat length (mm)/twirled length (mm) of uncooked thawed pasta

[γ] Hue1, Chroma1, Lval1: Color dimensions of uncooked pasta

[ε] Hue2, Chroma2, Lval2: Color dimensions of cooked pasta

Effects of Peanut Flour and CMC on Twirl Factor: Twirl factor of the uncooked pasta was affected by interactive effects of PF and CMC ($P<0.01$) (Table 1). Formulations containing 40% PF with 1.2% CMC (1.14±0.04), 60% PF with 0.8% CMC (1.30±0.14), 60% PF with 1.6% CMC (1.14±0.15), and 80% PF with 1.2% CMC (1.20±0.08) were significantly ($P\leq0.05$) less twirled than the control (1.59±0.23), and excluding the 60% PF with 0.8% CMC formulation, were significantly ($P\leq0.05$) different from formulations containing 60% PF with 0% CMC (1.49±0.18) and 80% PF with 0.4% CMC (1.56±0.17) (Table 2). Twirl factor decreased as CMC was increased for treatments containing ≤ 80% PF. Formulations containing > 0.8% CMC were significantly ($P \leq 0.05$) less twirled (1.14±0.04 to 1.20±0.08) than the control (1.59±0.23) (Table 2).

Table 2
Effect of Formulation on Moisture and Twirl Factor (means[α] ± sd) of Pasta

Formulation[β] PF %	CMC %	Moisture (%)	Twirl Factor[σ]
0	0	33.0±1.49 ab	1.59±0.23 a
20	0.8	30.4±1.60 b	1.37±0.15 abc
40	0.4	34.6±1.45 a	1.33±0.16 abc
40	1.2	33.1±1.47 ab	1.14±0.04 c
60	0	33.9±3.07 a	1.49±0.18 ab
60	0.8	33.4±1.90 ab	1.30±0.14 bc
60	1.6	34.2±1.33 a	1.14±0.15 c
80	0.4	32.1±1.62 ab	1.56±0.17 ab
80	1.2	32.4±1.92 ab	1.20±0.08 c
100	0.8	33.9±1.59 a	1.37±0.04 abc
ANOVA	Pr > F	0.01	<.0001
	F value	2.78	7.21

[α] Means for the same variable (column) followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) test at $\alpha = 0.05$
[β] PF = % peanut flour (PF) replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients.
[σ] Twirl factor = flat length (mm)/twirled length (mm) of uncooked thawed pasta.

Effects of Peanut Flour and CMC on Texture Profile: Tables 1 and 3 show the effects of PF and CMC on the texture profile of the calcium-fortified pasta. Hardness, cohesiveness, and gumminess were significantly affected ($P<0.01$) by the interactive effects of PF and CMC (Table 1). Springiness of the pasta was significantly affected

((P<0.01) by PF and the quadratic term of CMC, whereas chewiness was significantly influenced (P<0.01) by CMC and the quadratic term of PF (Table 1). As peanut flour increased, the hardness of the pasta decreased for formulations containing ≤ 0.4% CMC (Table 3). All experimental pasta formulations excluding 40% PF with 0.4% CMC (252.0±18.9) were alike in hardness (76.0±6.9 to 139.6±55.2) and were significantly different (P≤0.05) from the control (221.5±85.5) (Table 3). In addition, the 40% PF with 0.4% CMC treatment was not significantly (P>0.05) different from the control (Table 3). In regards to springiness, all experimental pasta formulations, excluding 60% PF with 1.6% CMC (0.861±0.097), were similar (0.896±0.033 to 0.951±0.031) to the control (0.952±0.016). The control formulation and the 40% PF with 1.2% CMC (0.951±0.031) were significantly (P≤0.05) more springy than the 60% PF with 1.6% CMC (0.861±0.097), (Table 3). Cohesiveness of the pasta decreased as levels of peanut flour increased to ≥ 80%, and also decreased with increased CMC at ≥ 0.8% when PF was ≥ 60%. Pasta formulations containing 60% PF with 1.6% CMC (0.667±0.092), 80% PF with 1.2% CMC (0.699±0.042), and 100% PF with 0.8% CMC (0.652±0.031) were significantly (P≤0.05) different in cohesiveness compared with the control (0.831±0.013). Gumminess generally decreased with increased PF, and decreased with increased CMC when PF was ≤ 40% (Table 3). The control (183.5±69.2) and the 40% PF with 0.4% CMC (208.0±12.5) formulations were significantly (P≤0.05) more gummy than all other experimental treatments (053.3±07.2 to 110.7±42.4) (Table 3). Additionally, treatments containing 20% PF with 0.8% CMC (110.7±42.4) and 60% PF with 0.8% CMC were significantly (P≤0.05) more gummy than treatments containing 80% PF with 1.2% CMC (53.3±7.2) and 100% PF with 0.8% CMC (53.6±9.2) (Table 3). Chewiness of the pasta generally decreased with increased PF, and decreased with increased CMC when PF was $\leq$ 40% (Table 3). The experimental treatment containing 40% PF with 0.4% CMC (192.7±17.7) and the control (171.1±63.3) were significantly ($P\leq0.05$) more chewy compared with all other experimental treatments (47.9± 7.4 to 103.2± 41.0) (Table 3). Additionally, treatments containing 20% PF and 0.8% CMC (103.2±41.0) and 60% PF with 0.8% CMC (97.9±10.1) were significantly ($P\leq0.05$) more chewy than the 100% PF with 0.8% CMC (47.9±7.4) formulation (Table 3).

Results from the texture profile indicate that some pasta formulations containing up to 40% PF with 0.4% CMC may be similar in textural attributes compared with the control pasta containing 100% semolina.

Table 3
Effect of Formulation on Texture Profile (means[α] ± sd) of Pasta

Formulation[β]			Texture	Profile		
PF (%)	CMC (%)	Hardness (g force)	Springiness	Cohesiveness	Gumminess	Chewiness
0	0	221.5±85.5a	0.952±0.016a	0.831±0.013a	183.5±69.2a	171.1±63.3a
20	0.8	139.6±55.2b	0.929±0.036ab	0.798±0.046a	110.7±42.4b	103.2±41.0b
40	0.4	252.0±18.9a	0.925±0.035ab	0.826±0.022a	208.0±12.5a	192.7±17.7a
40	1.2	102.3±08.8b	0.951±0.031a	0.821±0.021a	083.9±06.1bc	079.7±06.2bcd
60	0	102.3±11.2b	0.936±0.024ab	0.797±0.015a	081.4±08.1bc	076.1±06.1bcd
60	0.8	137.6±18.0b	0.924±0.025ab	0.773±0.024ab	106.1±11.3b	097.9±10.1bc
60	1.6	105.9±26.5b	0.861±0.097b	0.667±0.092c	069.4±13.3bc	059.4±10.6bcd
80	0.4	081.8±16.7b	0.925±0.037ab	0.777±0.020a	063.4±11.6bc	058.4±09.5bcd
80	1.2	076.0±06.9b	0.923±0.016ab	0.699±0.042bc	053.3±07.2c	049.2±07.2cd
100	0.8	082.6±15.4b	0.896±0.033ab	0.652±0.031c	053.6±09.2c	047.9±07.4d
ANOVA	Pr>F	<0.0001	0.018	<0.0001	<0.0001	<0.0001
	F value	17.58	2.53	17.37	23.31	23.99

[α] Means for the same variable (column) followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) test at α=0.05.
[β] PF = % peanut flour replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients.

Color of Uncooked Pasta: Color, measured in its three dimensions (hue, chroma, and L-value), was analyzed on both cooked and uncooked pasta. Hue is a color descriptor and is measured in a 360 degree angle where the first quadrant 0-90 degrees represents red to yellow. The hue of the uncooked pasta was not significantly ($P>0.05$) affected by interactions between PF and CMC, but was affected by PF ($P<0.01$) and CMC ($P<0.05$) individually (Table 1). However, as PF increased, hue decreased and formulations containing all levels of PF and CMC were significantly different ($P\leq0.05$) in hue (69.8±1.04 to 81.5±1.60) from the control pasta (93.5±0.58) (Table 4). Treatments containing 20% PF with 0.8% CMC (81.5±1.60) and 40% PF with 0.4% CMC (78.1±1.95) were similar and significantly more ($P\leq0.05$) yellow than treatments containing >40% PF (69.8±1.04 to 73.3±2.20) (Table 4). Pasta formulations containing defatted peanut flour were browner than the control pasta.

Chroma, which is the intensity of the hue, was found to be affected ($P\leq0.05$) only by the CMC. All uncooked experimental formulations (25.8±1.34 to 29.4±1.36) were similar in chroma to the uncooked control (28.6±2.27) (Table 4). Pasta treatments containing 40% PF with 0.4% CMC (26.0±1.15) and 60% PF with 0.8% CMC (25.8±1.34) were a significantly less ($P\leq0.05$) intense brown than the treatment containing 80% PF with 1.2% CMC (Table 4).

The L-value is the measurement of lightness and darkness of a color on a scale where 0 = black and 100 = white. The L-value of the uncooked pasta was significantly affected ($P<0.01$) by the PF (Table 1), and similar to the hue, as PF increased, the L-value decreased and the pasta became darker (Table 4). Experimental pasta formulations were significantly different ($P\leq0.05$) in L-value (53.7±1.39 to 67.9±2.61) from the control

(74.7±1.16) (Table 4). Treatments containing 20% PF with 0.8% CMC (67.9±2.61) and 40% PF with 0.4% CMC were significantly lighter (P≤0.05) than experimental pasta made with > 40% PF (Table 4).

Color of Cooked Pasta: The hue of the cooked pasta was significantly affected (P≤0.05) by interactive effects of PF and CMC (Table 1). In general, the hue of the cooked pasta decreased as PF was increased (Table 5). All experimental pasta formulations were significantly different (P≤0.05) in hue (74.1±0.86) to 82.5±0.88) from the control (96.9±0.53) (Table 5). Pasta containing 20% PF and 0.8% CMC (82.5±0.88) was significantly more (P≤0.05) yellow than all other experimental treatments (74.1±0.86 to 77.0±1.29) (Table 5). In addition, treatments containing 40% PF with 0.4% CMC (76.4±1.66) and 40% PF with 1.2% CMC (77.0±1.29) were significantly less (P≤0.05) brown than all treatments containing 80% PF (74.4±0.61 and 74.1±0.86) (Table 5). The treatment containing 40% PF with 1.2% CMC was significantly (P≤0.05) more yellow than experimental treatments containing ≥ 80% PF (Table 5).

The chroma of the cooked pasta was significantly affected (P<0.01) by CMC (Table 1). Table 5 indicates that cooked pasta containing all levels of PF and CMC were similar (25.1±1.74 to 28.5±2.49) to the control (26.6±1.15) in terms of chroma. Pasta treatments containing 20% PF with 0.8% CMC (28.5±22.49), and 40% PF with 1.2% CMC (28.3±0.72) were significantly (P≤0.05) more intense in color than treatments containing 60% PF with 0% CMC (25.1±1.74), 80% PF with 0.4% CMC (25.5±1.24), and 100% PF with 0.8% CMC (25.3±0.37) (Table 5).

The L-value of the cooked pasta was significantly influenced (P<0.01) by PF (Table 1). Table 5 shows that as PF increased up to 80%, the L-value decreased and all experimental formulations were significantly different in L-value (58.9±2.23 to 67.0±1.86) from the control (75.7±1.12). The pasta formulation containing 20% PF with 0.8% CMC (67.0±1.86) was also significantly lighter (P≤0.05) compared with all other experimental formulations (58.9±2.23 to 61.7±1.98) (Table 5).

Table 4
Effect of Formulation on Color (means[α] ± sd) of Uncooked Pasta

Formulation[β]		Color (uncooked pasta)		
PF %	CMC %	Hue (°)	Chroma	L-value
0	0	93.5±0.58 a	28.6±2.27ab	74.7±1.16 a
20	0.8	81.5±1.60 b	26.9±2.24 ab	67.9±2.61 b
40	0.4	78.1±1.95 bc	26.0±1.15 b	66.2±1.82 bc
40	1.2	75.3±3.03 cd	27.2±1.96 ab	62.7±2.24 cd
60	0	73.3±2.20 de	27.7±1.30 ab	57.9±2.88 e
60	0.8	72.5±1.87 de	25.8±1.34 b	59.2+2.05 de
60	1.6	72.5±2.58 de	28.3±0.59 ab	58.5±3.43 e
80	0.4	71.0±1.02 e	27.5±0.88 ab	56.0±1.59 ef
80	1.2	69.8±1.04 e	29.4±1.36 a	53.7±1.39 f
100	0.8	72.2±0.73 de	27.5±0.98 ab	56.6+0.77 ef
ANOVA	Pr>F	<0.0001	0.0028	<0.0001
	F value	89.85	3.35	55.27

[α]Means for the same variable (column) followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) test at $\alpha = 0.05$.
[β]PF = % peanut flour replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients.

Table 5
Effect of Formulation on Color (means[α] ± sd) of Cooked Pasta

Formulation[β]		Color (cooked pasta)		
PF %	CMC %	Hue (°)	Chroma	L-value
0	0	96.9±0.53 a	26.6±1.15 abc	75.7±1.12 a
20	0.8	82.5±0.88 b	28.5±2.49 a	67.0±1.86 b
40	0.4	76.4±1.66 cd	28.0±2.38 ab	61.7±1.98 c
40	1.2	77.0±1.29 c	28.3±0.72 a	61.7±2.60 c
60	0	75.8±0.62 cde	25.1±1.74 c	60.1±2.83 c
60	0.8	75.1±1.24 cde	26.7±0.57 abc	58.9±1.96 c
60	1.6	75.6±0.79 cde	27.2±0.86 abc	60.0±1.13 c
80	0.4	74.4±0.61 e	25.5±1.24 bc	59.3±0.78 c
80	1.2	74.1±0.86 e	26.0±0.86 abc	58.8±2.23 c
100	0.8	74.8±0.91 de	25.3±0.37 c	61.2±2.73 c
ANOVA	Pr>F	<0.0001	0.0001	<0.0001
	F value	293.59	4.73	39.75

[α] Means for the same variable (column) followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) test at $\alpha = 0.05$.
[β] PF = % peanut flour replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients.

Response Surface Regression: Response surface regression (RSREG) was performed to examine the effects of independent variables, peanut flour (PF) and carboxymethylcellulose (CMC) on the following dependent variables: color measured in its three dimensions, hue, chroma, and L-value; twirl factor, flat length divided by twirled length; and texture profile concentrating on hardness, gumminess, cohesiveness, springiness, and chewiness. For each dependent (response) variable, the regression coefficients obtained from RSREG were used to derive equations to predict the effect of PF and CMC on that particular variable (Table 6). Plotting of these equations facilitated creation of surfaces that enabled location of data points for formulations that were not actually tested. RSREG facilitated identification of predicted optimum levels of PF and CMC for use in the pasta.

Table 6
Predictive Regression Models for the Dependent Variables as Functions of Peanut Flour (PF) and Carboxymethylcellulose (CMC)

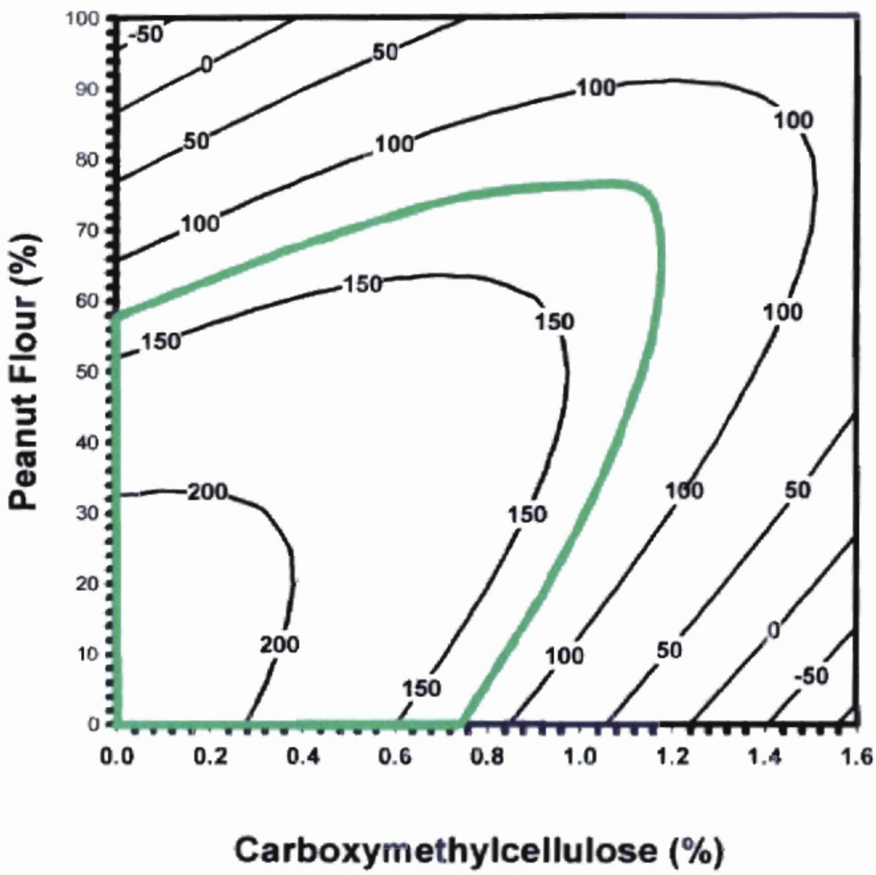
Dependent Variable	Predictive Model
Moisture	$33.042048+0.060401*X_1-5.163963*X_2-0.000720*X_1^2+0.052012*X_1*X_2+1.220707*X_2^2$
Twirl Factor	$1.578407-0.005001*X_1-0.201839*X_2+0.000070295*X_1^2-0.003059*X_1*X_2+0.075111*X_2^2$
Texture Profile	
Hardness	$228.808062+0.159447*X_1-80.414377*X_2-0.032135*X_1^2+3.118915*X_1*X_2-84.076240*X_2^2$
Springiness	$0.947038-0.000061900*X_1+0.024551*X_2-0.000004149*X_1^2+0.000123*X_1*X_2-0.037939*X_2^2$
Cohesiveness	$0.820668+0.001244*X_1+0.044740*X_2-0.000024828*X_1^2-0.000401*X_1*X_2-0.060247*X_2^2$
Gumminess	$188.760619+0.207645*X_1-63.360526*X_2-0.028464*X_1^2+2.585274*X_1*X_2-76.594765*X_2^2$
Chewiness	$178.554601+0.123373*X_1-57.917496*X_2-0.026230*X_1^2+2.415450*X_1*X_2-73.467974*X_2^2$
Color Uncooked Pasta	
Hue	$93.539912-0.492667*X_1-4.940596*X_2+0.002712*X_1^2+0.046683*X_1*X_2+0.618478*X_2^2$
Chroma	$28.678435-0.047888*X_1-4.164824*X_2+0.000463*X_1^2+0.016960*X_1*X_2+2.533007*X_2^2$
Lval	$74.888973-0.363964*X_1+2.428633*X_2+0.001597*X_1^2+0.001026*X_1*X_2-2.119133*X_2^2$
Color Cooked Pasta	
Hue	$96.432300-0.539941*X_1-9.215837*X_2+0.003341*X_1^2+0.061131*X_1*X_2+3.313128*X_2^2$
Chroma	$26.711885-0.010816*X_1+4.251783*X_2-0.000220*X_1^2-0.010249*X_1*X_2-1.575046*X_2^2$
Lval	$75.708999-0.459936*X_1-2.417791*X_2+0.003336*X_1^2-0.014135*X_1*X_2+1.959117*X_2^2$

X_1 = % peanut flour replacing semolina, **X_2** = carboxymethylcellulose as wt (%) of dry ingredients.

Contour plots were developed for each attribute in texture profile and areas of interest were defined by using means ± s.d. of the control pasta (0% PF, 0% CMC), Table 3, for the particular attribute. Hardness of the experimental pasta decreased as CMC and PF were increased (Figure 7). The contour plot for hardness predicted that up to 70% PF with 0.8-1.0% CMC and PF levels < 60% with <0.6% CMC could be used to produce pasta with hardness similar to the control (Figure 7). The springiness plot (Figure 8) showed that as PF and CMC increased, springiness decreased, and indicated that formulations containing 50% PF would need between 0.2-0.6% CMC to produce results similar to the control, whereas with <40% PF, a CMC level of 0-0.9% could be used in pasta. Cohesiveness of pasta also decreased as PF and CMC increased (Figure 9). Pasta formulations with ≤50% PF and ≤ 0.8% CMC would produce cohesive qualities similar to the control. Contour plot for gumminess (Figure 10) revealed that 0.9% CMC would be needed in pasta containing 65% PF. However, pasta with <50% PF would need <0.7% CMC to exhibit gumminess equivalent to a 100% semolina pasta. Similar results were found with the contour plot for chewiness (Figure 11) where 0.9% CMC could be used in pasta formulations containing 62.5% PF, but with less than 52.5% PF, CMC <0.8% would be needed to produce results comparable to the control. The effects of PF and CMC on twirl factor are exhibited in Figure 12, and indicate that if 100% PF was used, zero up to approximately 0.9% CMC would be needed. Formulations containing 50% PF would need a level of ≤0.38% CMC, and levels of <10% PF could utilize all levels of CMC in order to produce twirl factor results similar to the control pasta.

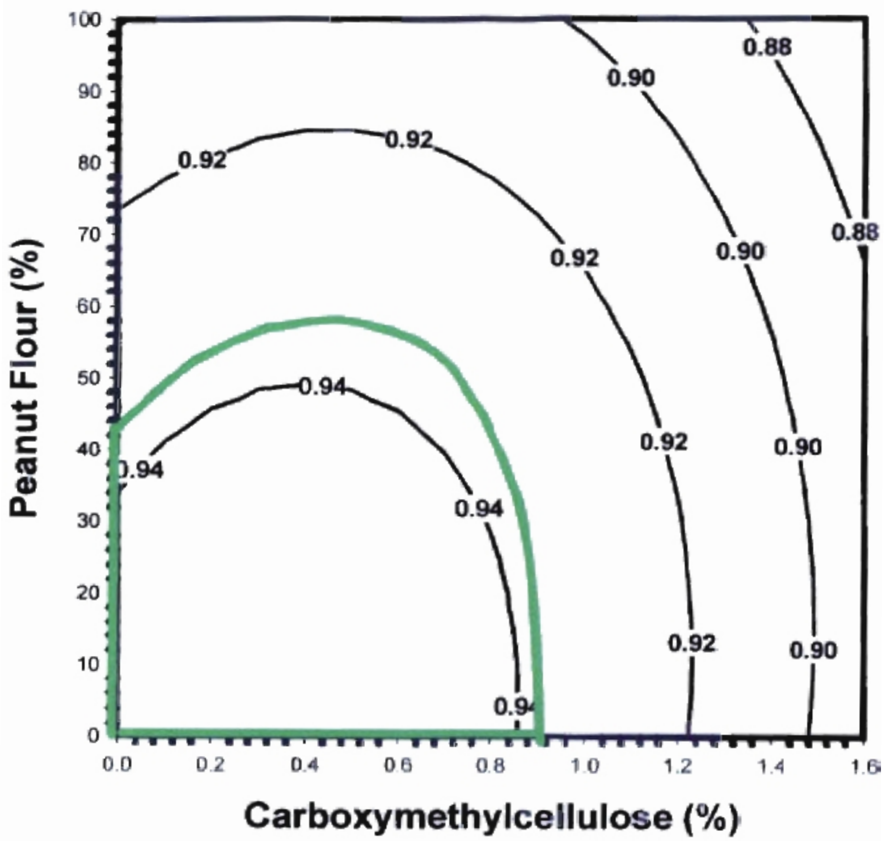
An overlay plot (Figure 13) generated from contour plots of texture profile (hardness, springiness, cohesiveness, gumminess, chewiness) and twirl factor predicted that formulations within the shaded region would produce an overall texture profile similar to control pasta containing 100% semolina (Figure 13). Formulations containing 41-50% PF would need some CMC, e.g. 50% PF could be used with 0.15-0.38% CMC. However formulations containing ≤ 40% PF might not require CMC because appropriate levels predicted when PF is 25-40% or 0-20% are 0-0.4% CMC and 0-0.7% CMC respectively. Twirl factor is not applicable to pasta that does not have twist properties, and when this factor is withdrawn from the contour plot, the region of interest increases allowing for higher levels of CMC, but the maximum percent PF replacement predicted for texture similar to the control remains at 50%.

Figure 7. Effects of Peanut Flour and CMC on Hardness of Pasta



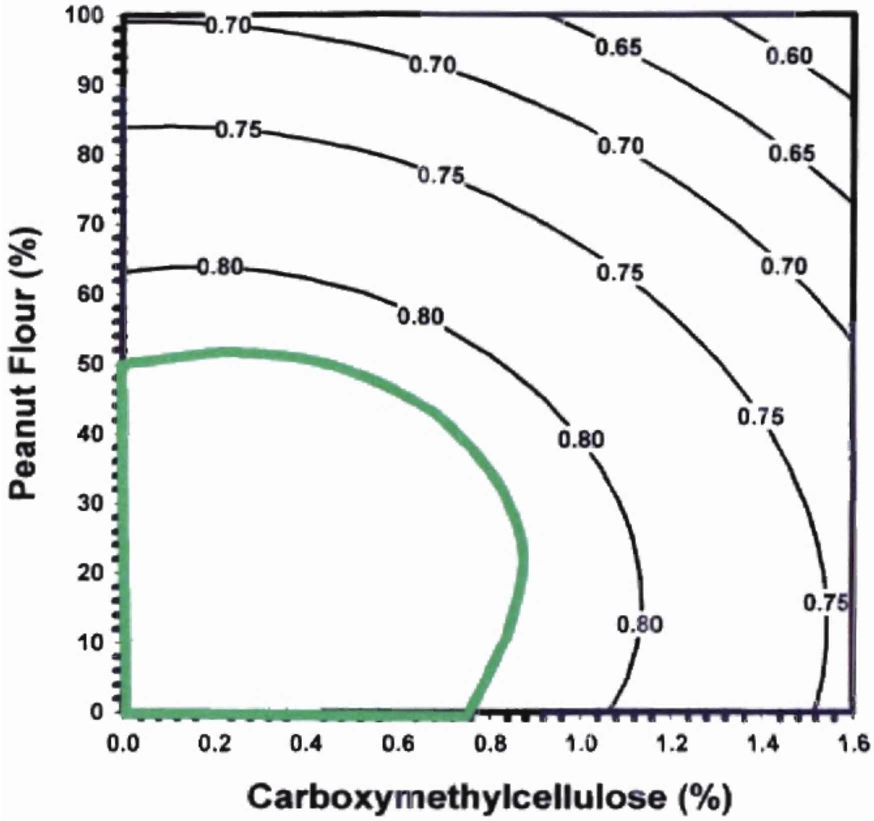
—All Experimental Treatments Within the Green Boundary are Not Significantly Different

Figure 8. Effects of Peanut Flour and CMC on Springiness of Cooked Pasta



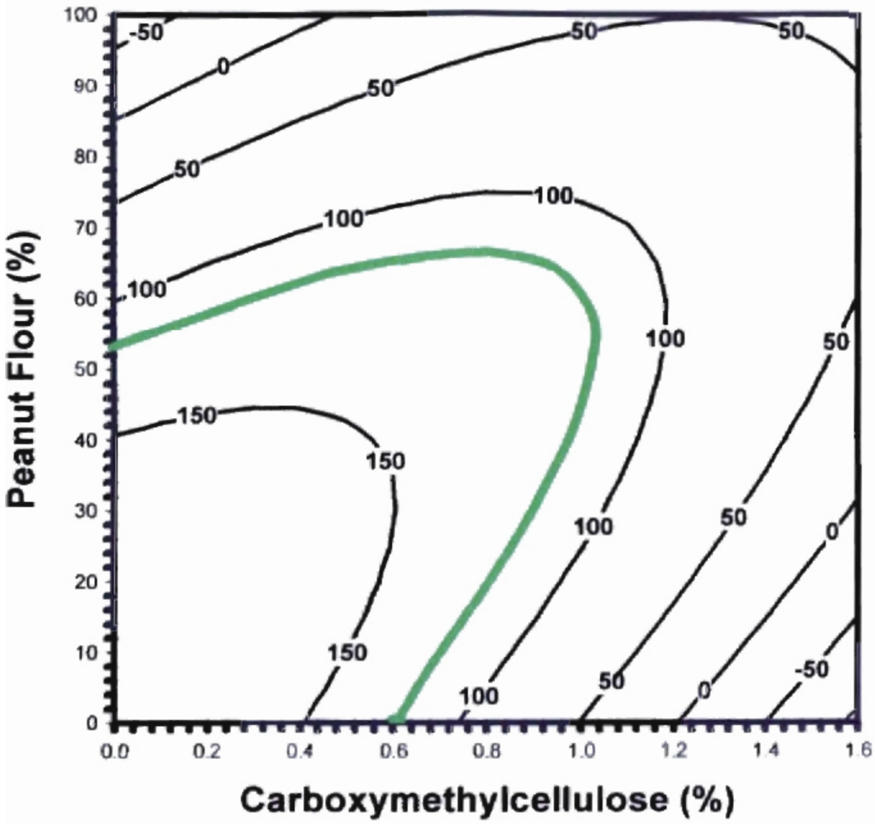
—All Experimental Treatments Within the Green Boundary are Not Significantly Different

Figure 9. Effects of Peanut Flour and CMC on Cohesiveness of Cooked Pasta



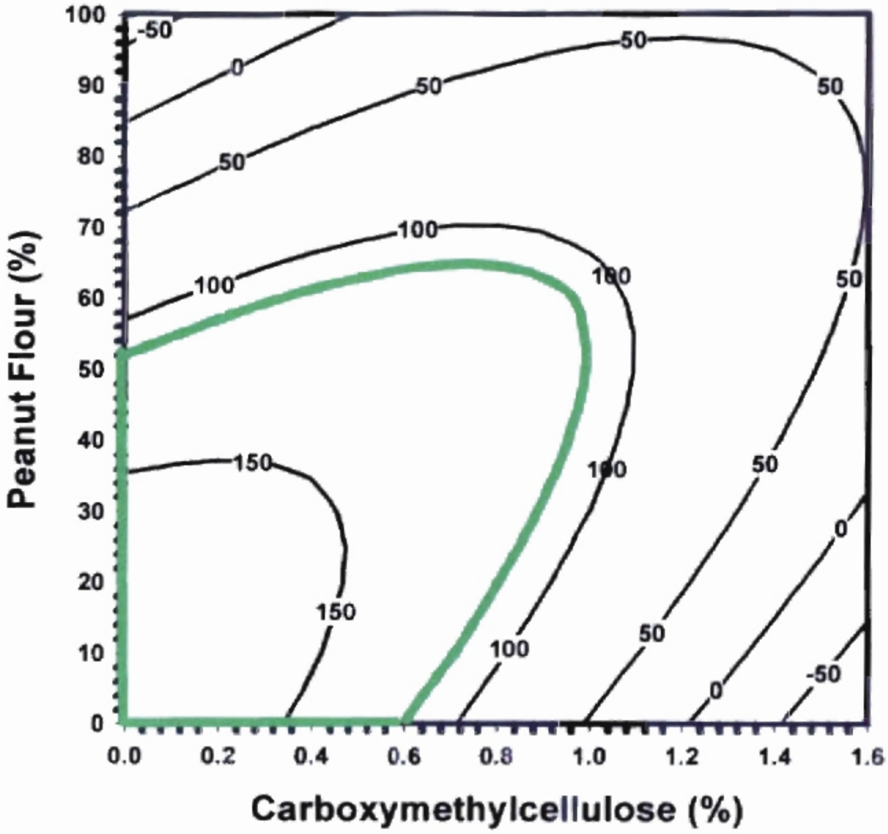
— All Experimental Treatments Within the Green Boundary are Not Significantly Different

Figure 10. Effects of Peanut Flour and CMC on Gumminess of Cooked Pasta



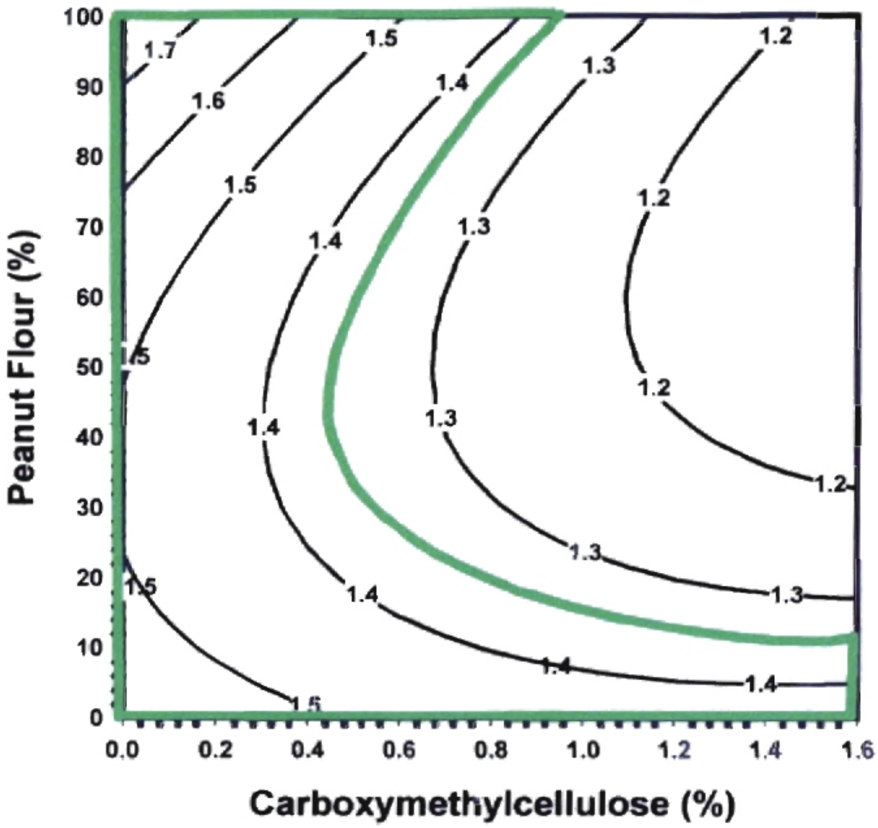
---All Experimental Treatments Within the Green Boundary are Not Significantly Different

Figure 11. Effects of Peanut Flour and CMC on Chewiness of Cooked Pasta



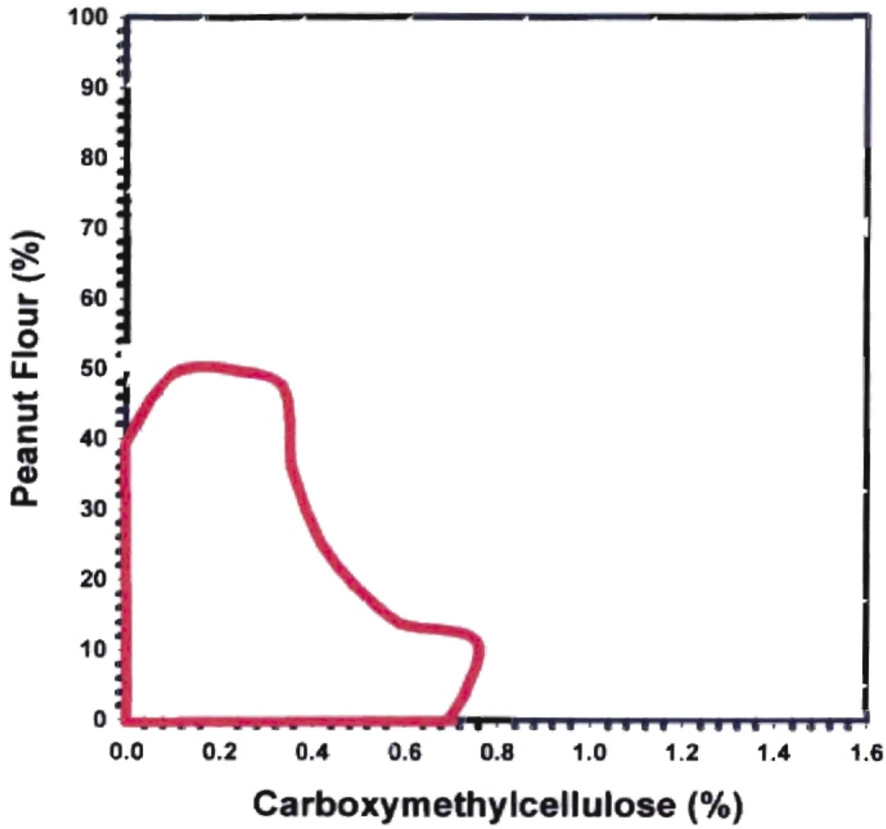
---All Experimental Treatments Within the Green Boundary are Not Significantly Different

Figure 12. Effects of Peanut Flour and CMC on Twirl Factor of Cooked Pasta



¹All Experimental Treatments Within the Green Boundary are Not Significantly Different

Figure 13. Overlay Plot Showing The Effects of Peanut Flour and CMC on the Texture Profile and Twirl Factor of Cooked Pasta



---All Experimental Treatments Within the Red Boundary are Not Significantly Different.

Three-dimensional plots were constructed using RSREG procedure to evaluate the effects of PF and CMC on the color of the uncooked and cooked pasta. The 3-D plot showing the hue of the uncooked pasta is illustrated in Figure 14, and shows PF percent represented on the Y axis, CMC percent on the X axis, and hue on the Z axis. Hue is the color descriptor and is measured on a 360-degree angle where the first quadrant 0-90 degrees represents red to yellow. As peanut flour increased from 0-100%, hue decreased from approximately 90 down to 72, thus the pasta became more brown (Figure 14). CMC showed no effect on the hue of the uncooked pasta (Figure 14).

Chroma, which indicates the effects of PF and CMC on the intensity of color in the uncooked pasta revealed that pasta made with >67% PF had a greater color intensity (Figure 15) that treatments with lower levels of PF. Additionally, CMC at levels < 0.53% and > 1.07% with PF of < 33% had a more intense brown color (Figure 15). L-value, which describes the lightness and darkness of a color with 0 = black and 100 = white, showed that as peanut flour increased, the L-value of uncooked pasta decreased and the pasta became darker (Figure 16). CMC had no affect on L-value of uncooked pasta (Figure 16).

Color attributes of cooked pasta (hue, chroma, and L-value) showed similar trends to color attributes of uncooked pasta. As PF increased, hue of the cooked pasta decreased and the pasta became more brown (Figure 17). CMC had an effect on hue of cooked pasta made with high levels of PF in that when CMC increased the pasta became more yellow (Figure 17). Intensity of color in cooked pasta as shown in a 3-D plot for chroma (Figure 18) indicated that as peanut flour increased, chroma decreased slightly, and as CMC increased, chroma increased and pasta became a more intense brown (Figure 18).

The three-dimensional plot for L-value of cooked pasta showed that as PF increased up to 67%, the pasta became darker, and as PF increased further, the pasta became slightly lighter (Figure 19). CMC had no affect on L-value of cooked pasta (Figure 19).

Figure 14. Effects of Peanut Flour and CMC on Hue of Uncooked Pasta

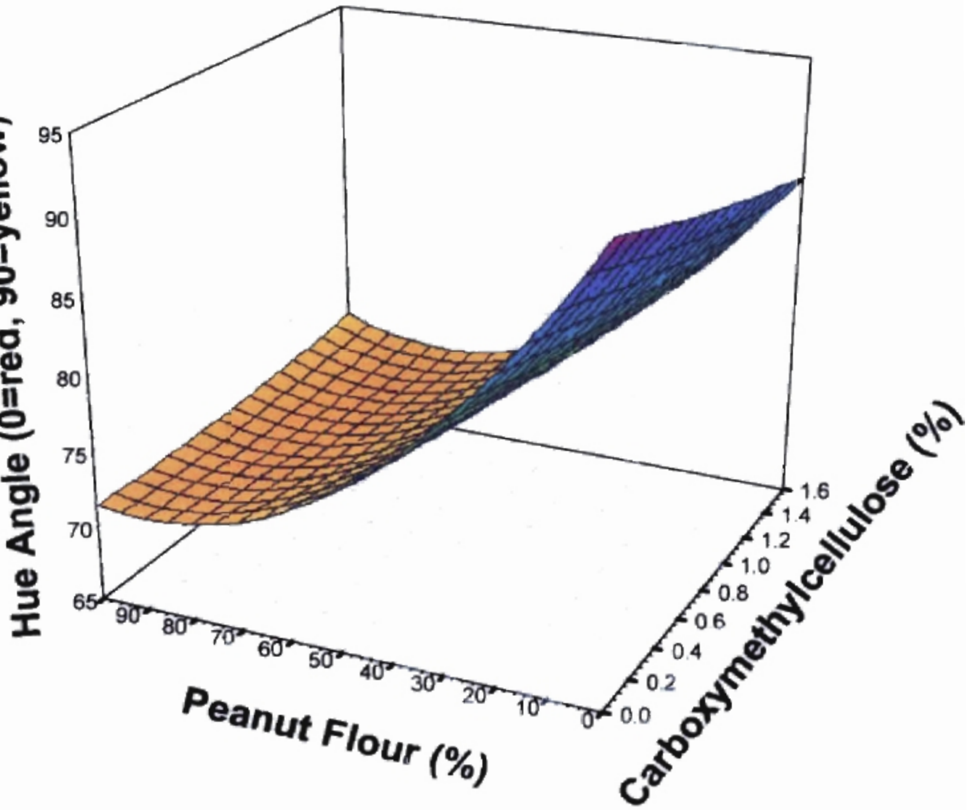


Figure 15. Effects of Peanut Flour and CMC on Chroma of Uncooked Pasta

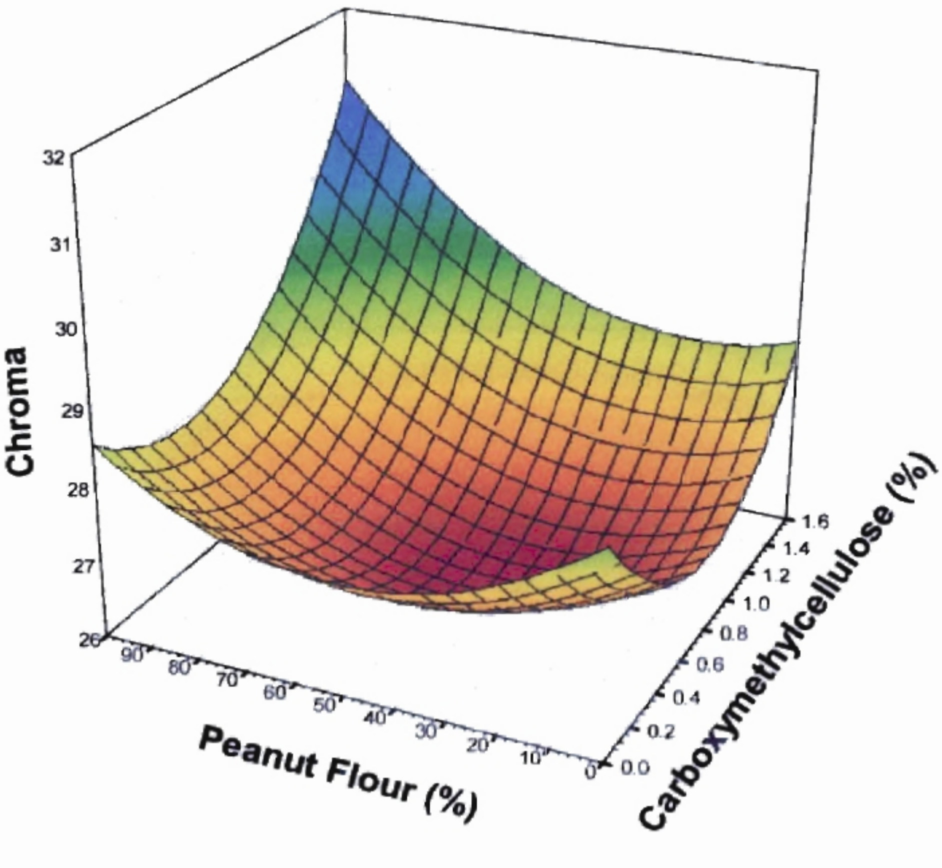


Figure 16. Effects of Peanut Flour and CMC on L Value of Uncooked Pasta

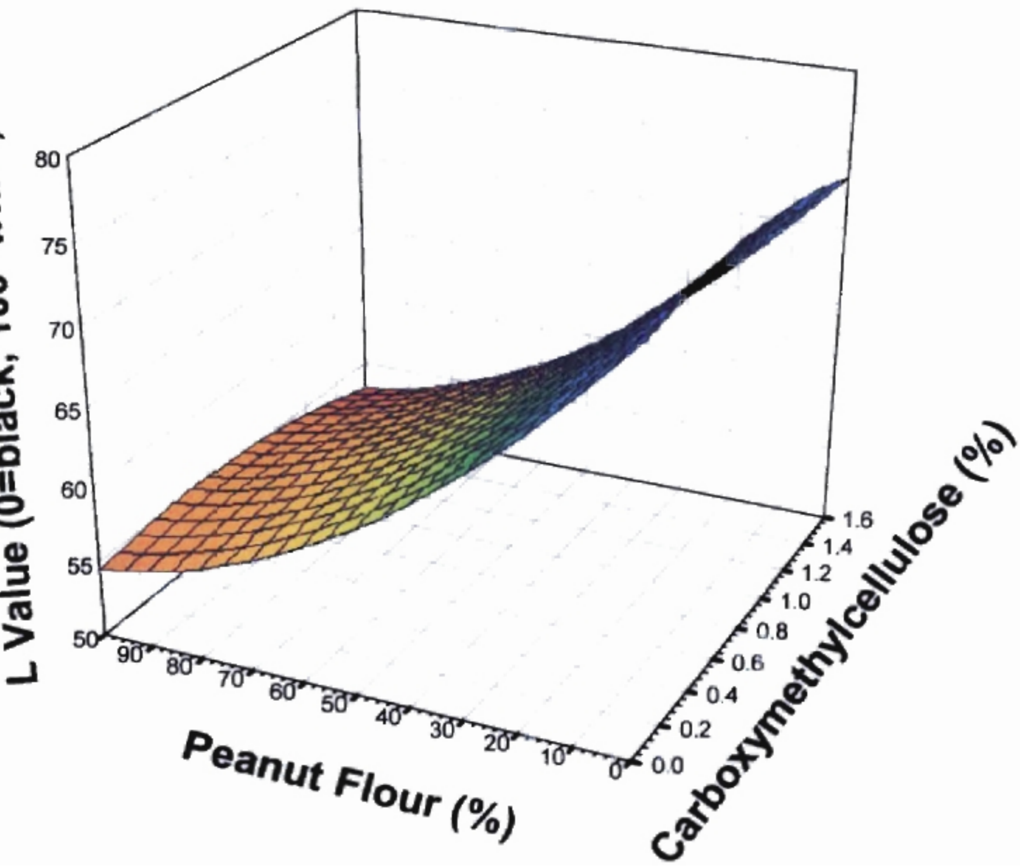


Figure 17. Effects of Peanut Flour and CMC on Hue of Cooked Pasta

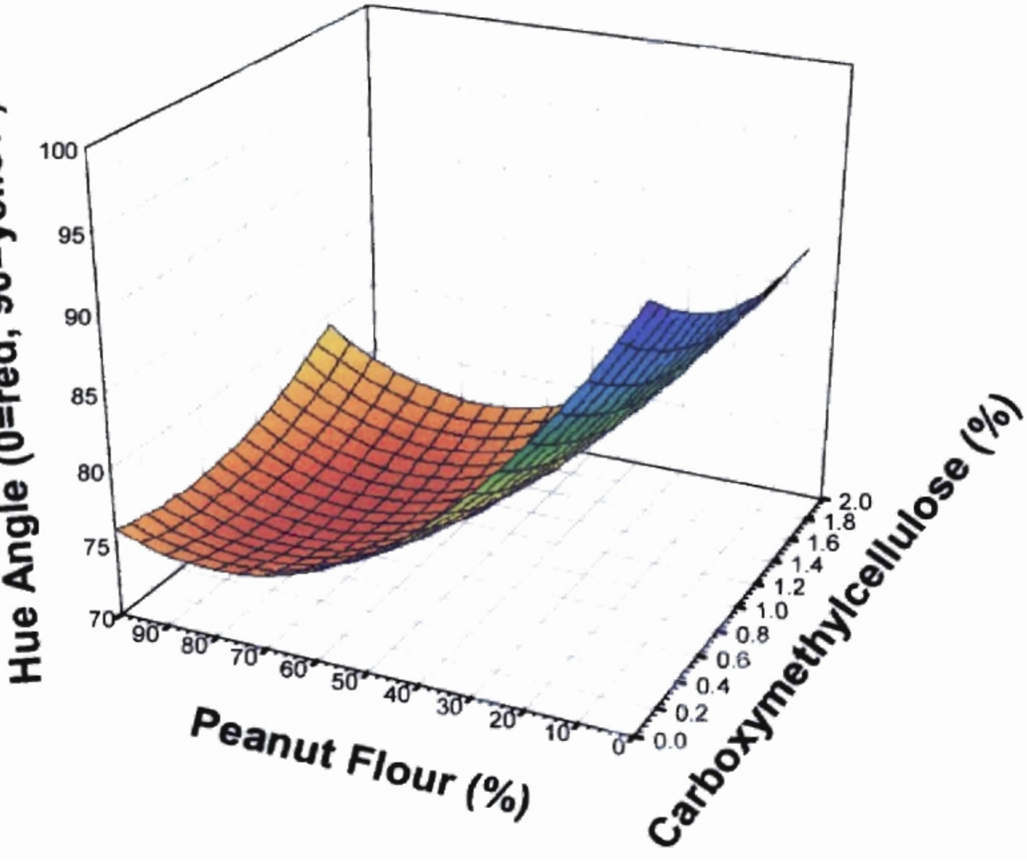


Figure 18. Effects of Peanut Flour and CMC on Chroma of Cooked Pasta

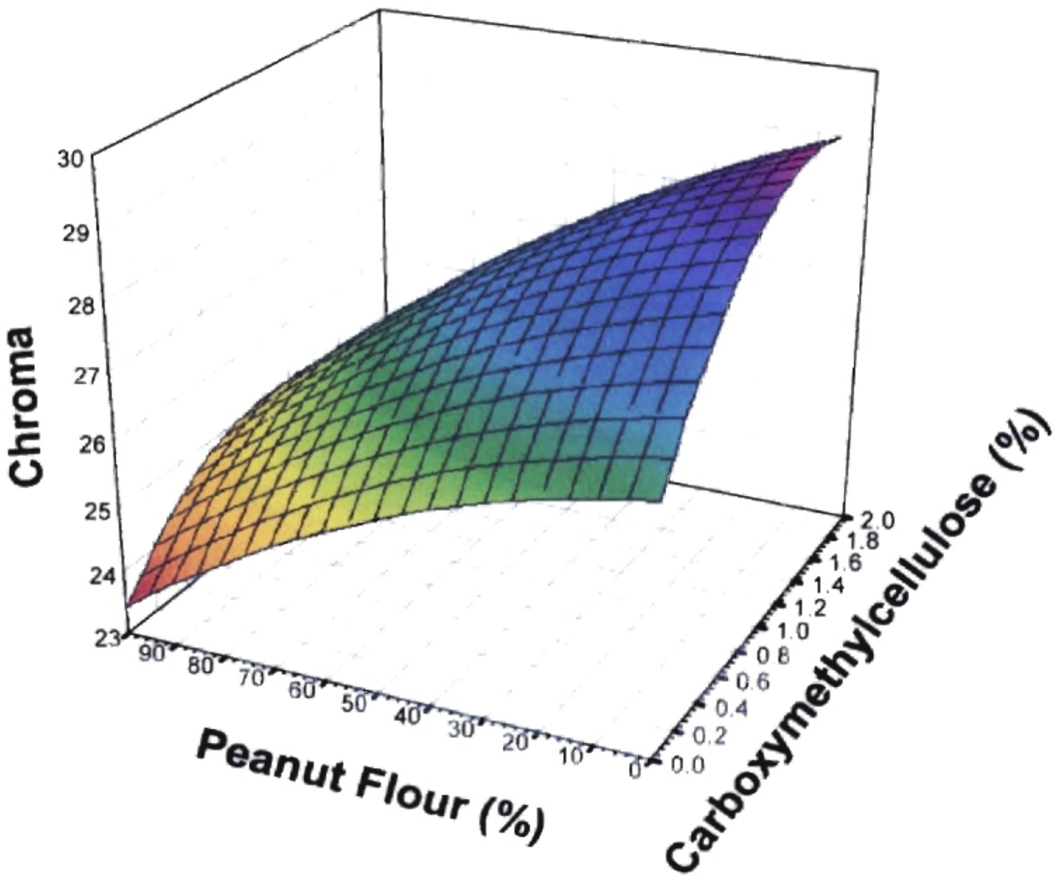
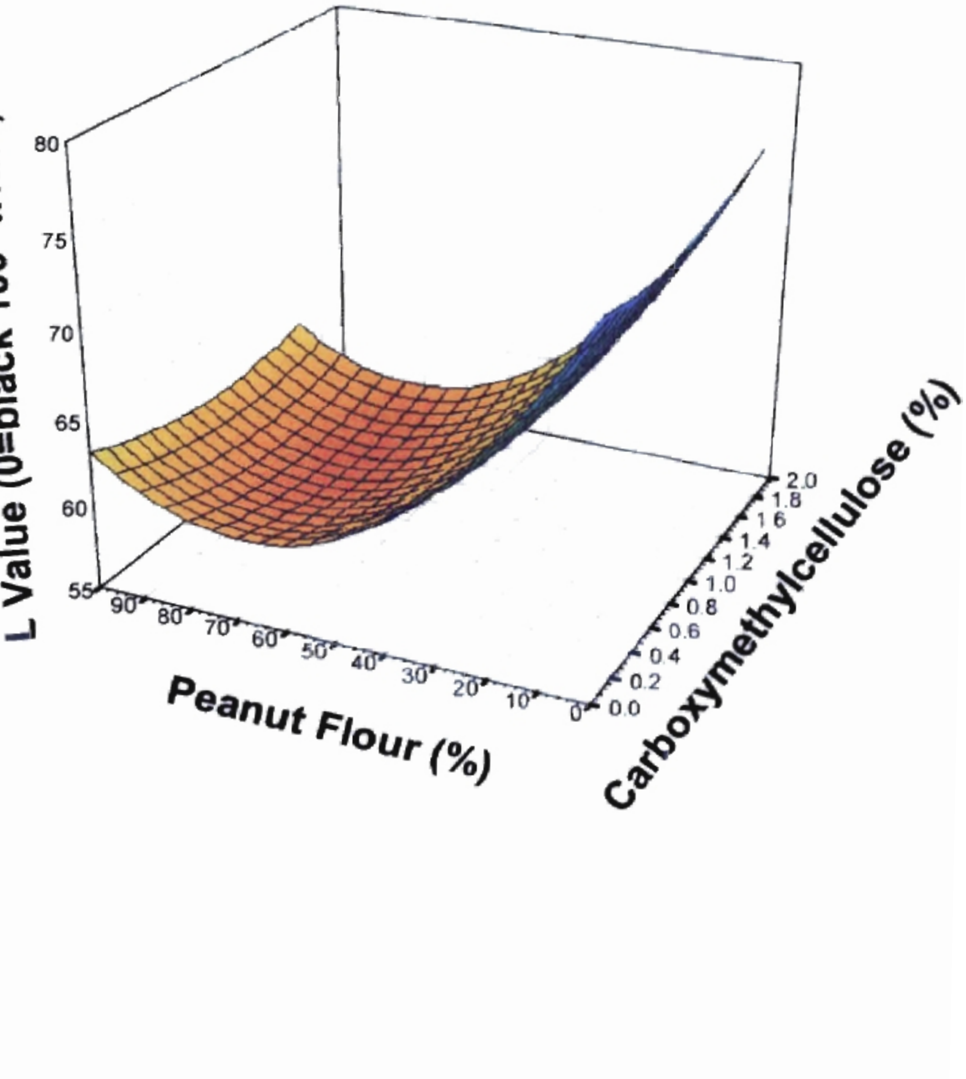


Figure 19. Effects of Peanut Flour and CMC on L Value of Cooked Pasta



Main Study Discussion

Physical characteristics including hardness, springiness, cohesiveness, gumminess, chewiness, and twirl factor are important characteristics in a pasta product (D'Egidio and Nardi, 1996). Depending on the type of pasta, twirl factor may also be an important attribute. While the textural profile of experimental formulations containing high levels of peanut flour was significantly affected, results show that up to a 50% replacement of semolina by PF would be similar in textural attributes to that of control pasta containing 100% semolina. Moisture content ranged from 30.4±1.60 to 34.6±1.45 which falls within the typical moisture content for packaged fresh pasta of 26-34% (Varriano-Marston and Stoner, 1996)

Color profile results (Figures14-19) indicate that as peanut flour increases, pasta becomes more brown and darker in color. Commercial pasta ranges from light yellow in a traditional semolina pasta to a darker brown in whole-wheat pasta to a variety of other colors such as red and green due to vegetable powders included in the dough mixture. While it is important to evaluate color as it pertains to the specific product, it may not be a determining factor in potential acceptance of this product. Therefore, contour plots from the color attributes were not included in the overlay plot to select predicted optimum experimental pasta treatments.

Contour plots for hardness (Figure 7), springiness (Figure 8), cohesiveness (Figure 9), gumminess (Figure 10), chewiness (Figure 11), and twirl factor (Figure 12) were generated using response surface methodology, and this predicted optimum formulations of the independent variables peanut flour and CMC that would be similar to the control for each separate dependent variable. An overlay plot shown in Figure 13 shows the effects of all textural attributes and twirl factor superimposed on each other to obtain an optimum region of peanut flour and CMC that could be used to produce a pasta product with textural attributes similar to the control. Results of the overlay plot indicate that up to 30% PF could be used with ≤ 0.4% CMC, and 50% PF could be used with a CMC level of 0.15-0.38%. Pasta containing <20% PF would require 0-0.7% CMC. The limiting variable seen with formulations using 0.4-0.7% CMC is twirl factor. As the CMC was increased above 0.4%, the pasta became easier to extrude and therefore did not twirl as well as the formulations using less than 0.4% CMC. Formulations containing ≤40% PF would be able to utilize up to 1.2% CMC without affecting the twirl factor. However, as PF increases >40% with >0.8% CMC, the twirl factor decreases significantly ($P \leq 0.05$) compared with the control. This decrease is likely due in part to the increased fat content in the products containing >40% PF as a result of the increased fat content in the final product. As pasta comes in all shapes and sizes, twirl factor may or may not be a determining factor in the potential marketing of a peanut-based pasta.

Conclusion and Prediction of Optimum Treatments

Convenience, low cost, and international popularity of pasta make it an ideal food product to incorporate non-traditional components such as calcium and defatted peanut flour in an effort to create a new value-added product. Results of the preliminary study indicated that tricalcium citrate or tricalcium phosphate at levels of 200, 400, and 600 mg/56 g serving of pasta made with defatted peanut flour (60% semolina replacement) could be used as a fortificant. Results of the main study using response surface methodology to predict optimum formulations of peanut flour and CMC that would be similar to 100% semolina pasta indicated that 50% peanut flour with 0.15-0.38% CMC, 41-49% peanut flour with a minimum of 0.01-0.15% CMC, and 0-0.4% CMC for 0-40% peanut flour could be used to produce a pasta-type product with physical characteristics similar to traditional pasta made with 100% semolina. Future research with this product would therefore evaluate and validate the physical and sensory characteristics of the predicted optimum experimental pasta treatments compared with traditional control pasta containing 100% semolina.

CHAPTER IV

PHYSICAL AND SENSORY PROPERTIES OF A PEANUT-BASED CALCIUM-FORTIFIED PASTA

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ABSTRACT

Physical and sensory characteristics may be used to evaluate a new food product in relation to its commercial counterparts, and predict potential consumer acceptability. The objectives of this study were to evaluate physical characteristics and sensory acceptability of the following five treatments of peanut-based, calcium-fortified pasta: PF13 (13% PF with 0.6% CMC), PF20 (20% PF with 0.2% CMC), PF40 (40% PF with 0.4% CMC), PF50 (50% PF with 0.38% CMC) and PF60 (60% PF with 0.8% CMC) which were predicted to have similar physical properties to a control formulation containing 100% semolina based on the findings of a previous optimization study using Response Surface Methodology. Pasta treatments, which had been frozen at -20 to -25°C for 90 to 120 days, were boiled for 2-3 minutes, drained, and cooled to 25-30°C for objective evaluation. Pasta for sensory evaluation was boiled for 2-3 minutes, and

subsequently subjected to objective and sensory tests. Objective evaluation included dimensions (twirl factor) of thawed uncooked pasta, color (Minolta chroma-meter) of thawed uncooked and cooked pasta and texture profile (TA XT2*i* Texture Analyzer fitted with a 25 kg load cell and a TA-25 cylindrical probe at a test speed of 1 mm/sec), and cooked yield of cooked pasta. A Randomized Complete Block Design for a 6-product test was used for sensory evaluation in which each panelist evaluated all 6 treatments (a control of 100% semolina pasta, PF13, PF20, PF40, PF50, PF60) using a 9-point Hedonic scale to evaluate appearance, aroma, taste, texture, and aftertaste; and a 5-point scale to evaluate purchase intent.

All experimental pasta treatments were significantly alike ($P<0.05$) in hardness (127.8±0.82 to 252.0±21.15) and were not significantly different ($P>0.05$) from the control (221.5±95.60). No significant difference ($P>0.05$) in springiness (0.92±0.028 to 0.96±0.001) or cohesiveness (0.77±0.027 to 0.83±0.014) was identified among the treatments. In general, gumminess decreased with increased PF with the exception of PF40. All experimental treatments were similar in gumminess (104.5±8.41 to 208.0±14.03) to the control (183.5±77.41), however treatments PF50 (104.5±8.41) and PF60 (106.1±12.62) were significantly ($P<0.05$) less gummy compared with treatment PF40 (208.0±14.03). Chewiness also decreased as PF increased with the exception of PF40. All experimental pasta treatments were similar in chewiness (97.9±11.29 to 192.7±19.78) to the control (174.1±70.81). Treatment PF60 (97.9±11.29) was significantly less chewy compared with treatment PF40 (192.7±19.78).

All three color dimensions (hue, chroma, and L value) of uncooked and cooked pasta were significantly affected ($P<0.05$) by the different formulations. As PF increased, the hue of both uncooked (71.9±0.20 to 81.9±1.35) and cooked (74.2±0.35 to 82.9±0.25) pasta became significantly ($P \leq 0.05$) more brown than the uncooked (93.5±0.57) and cooked (96.9±0.53) controls. Uncooked treatments PF50 (71.9±0.20) and PF60 (72.5±1.87), and cooked treatments PF40 (76.4+1.66), PF50 (74.2±0.35) and PF60 (75.1±1.24) were significantly more ($P \leq 0.05$) brown than all their other uncooked (78.0±0.95 to 93.5±0.58) and cooked (79.8±0.80 to 96.9±0.53) counterparts. No significant difference ($P > 0.05$) in chroma was seen between any of the uncooked treatments. All cooked experimental formulations were similar to the cooked control (26.6±1.15) in intensity except PF20 (30.0±1.65), which was more intense. As peanut flour increased, the L-value of both uncooked and cooked pasta decreased and the pasta became darker. The L-value of all experimental uncooked (58.5±0.72 to 70.1±2.55) and cooked (58.9±1.96 to 68.0±0.10) treatments were significantly ($P \leq 0.05$) darker than their respective uncooked (74.7±1.16) and cooked (75.7±1.12) controls.

All pasta treatments including the control were similar in regards to their twirl factor. No significant difference ($P \leq 0.05$) in cooked yield was identified among all six treatments.

All sensory attributes (appearance, aroma, taste, texture, and aftertaste) were significantly affected ($P < 0.05$) by the different formulations. Appearance scores of pasta treatments containing peanut flour were significantly different ($P < 0.05$) from the control (7.8±1.07). Treatments PF13 and PF20 were also significantly ($P < 0.05$) more acceptable than treatments containing ≥ 40% PF which were disliked slightly or neither liked nor disliked. Similar findings were seen with aroma where formulations PF40, PF50, PF 60 were significantly different from the control (7.4±1.38) and formula PF20 (6.4±1.45).

The control, PF13, and PF20 were considered acceptable in aroma. Pasta treatments PF13 and PF20 were not significantly different in taste compared with the control, and were considered acceptable. Additionally, PF40 was considered marginally acceptable in taste with a score of 5.50±1.86. Formulations PF13, PF20 and the control were given acceptable scores in regards to texture. Pasta treatments containing ≤20% PF were alike in acceptable aftertaste, and were significantly different from the treatments containing ≥40% which were unacceptable. Panelists indicated that they would purchase treatments PF13, PF20 and the control. Utilizing information obtained from the physical and sensory evaluations, it is concluded that up to 20% PF with 0.2-0.4% CMC would produce an acceptable value-added pasta-type product.

INTRODUCTION

Evaluation of a new food product involves many parameters. Physical and sensory characteristics include quantitative and qualitative information that can be used to evaluate a new product in relation to its commercial counterparts (physical) and predict potential consumer acceptability (sensory). Thousands of new food products are developed every year and only a small percentage of these products actually make it to retail introduction (Rudolph, 2000). This small percentage, however, is estimated within the global market to be about one new food product launched every twenty minutes (Robinson, 2000). In addition, while there are no published data on successes and failures of new food products, it is estimated that 80 to 90% of them fail within one year of introduction (Rudolph, 2000). In the U.S., the cost of failed new food products is estimated at $20 billion dollars (Morris, 1993). Therefore it is essential that during all stages of food product development, every effort be taken to reduce the risk of potential failure by strategically planning and adequately evaluating the process at every turn.

Food characteristics of cooked pasta can be grouped in two main categories: geometric and mechanical. The first group is related to physical structure of the material (geometry) namely size, shape, and orientation of particles, and is reflected in the arrangement of the constituents. Evaluation of this group is for the most part qualitative (Szczesniak, 1963). The mechanical characteristics are of primary importance for pasta products; they are related to stress response and can be defined as follows. Hardness, represents the degree of resistance to the first bite and is sensorially defined as the force required to penetrate pasta with the teeth. Cohesiveness is defined as the force of internal bonds holding the pasta structure. Springiness represents the capacity of a deformed pasta to go back to its initial condition when the deforming force is removed. Gumminess is the force with which the cooked pasta's surface adheres to other materials, e.g. tongue, teeth, palate, and fingers. Chewiness is defined as the time required to masticate a sample at the rate of one chew per second for reducing it to the consistency suitable for swallowing (Szczesniak, 1963). The textural characteristics of pasta products play an essential role in determining the final acceptance by consumers, although other factors (color, flavor and nutritional value) are also implicated (D'Egidio and Nardi, 1996).

Sensory evaluation may be defined as a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing (Stone and Sidel, 1993). It is the ultimate authority regarding the determination of sensory properties of foods. Affective sensory testing is a good predictor of consumer acceptability. It is a reliable test method for pasta because it allows the overall textural characteristics of cooked pasta to be evaluated. Sensory evaluation, moreover, constitutes the main reference against which the results obtained by chemical or instrumental methods should be compared with the aim of accepting, checking or improving processing parameters (D'Egidio and Nardi, 1996).

The aim of this study was to validate, by sensory evaluation, the findings of a previous optimization study (Hardy and Hinds, 2002), which evaluated the physical characteristics of a calcium-fortified pasta made with defatted peanut flour (at 0-100% semolina replacement) and carboxymethylcellulose (CMC). The specific objectives of this study were to evaluate the physical properties and sensory acceptability of the following five treatments of a peanut-based, calcium-fortified pasta: 13% PF with 0.6% CMC, 20% PF with 0.2% CMC, 40% PF with 0.4% CMC, 50% PF with 0.38% CMC, and 60% PF with 0.8% CMC. Response surface regression in the previous optimization study (Hardy and Hinds, 2002) predicted that these five treatments would have similar physical properties to pasta made with 100% semolina.

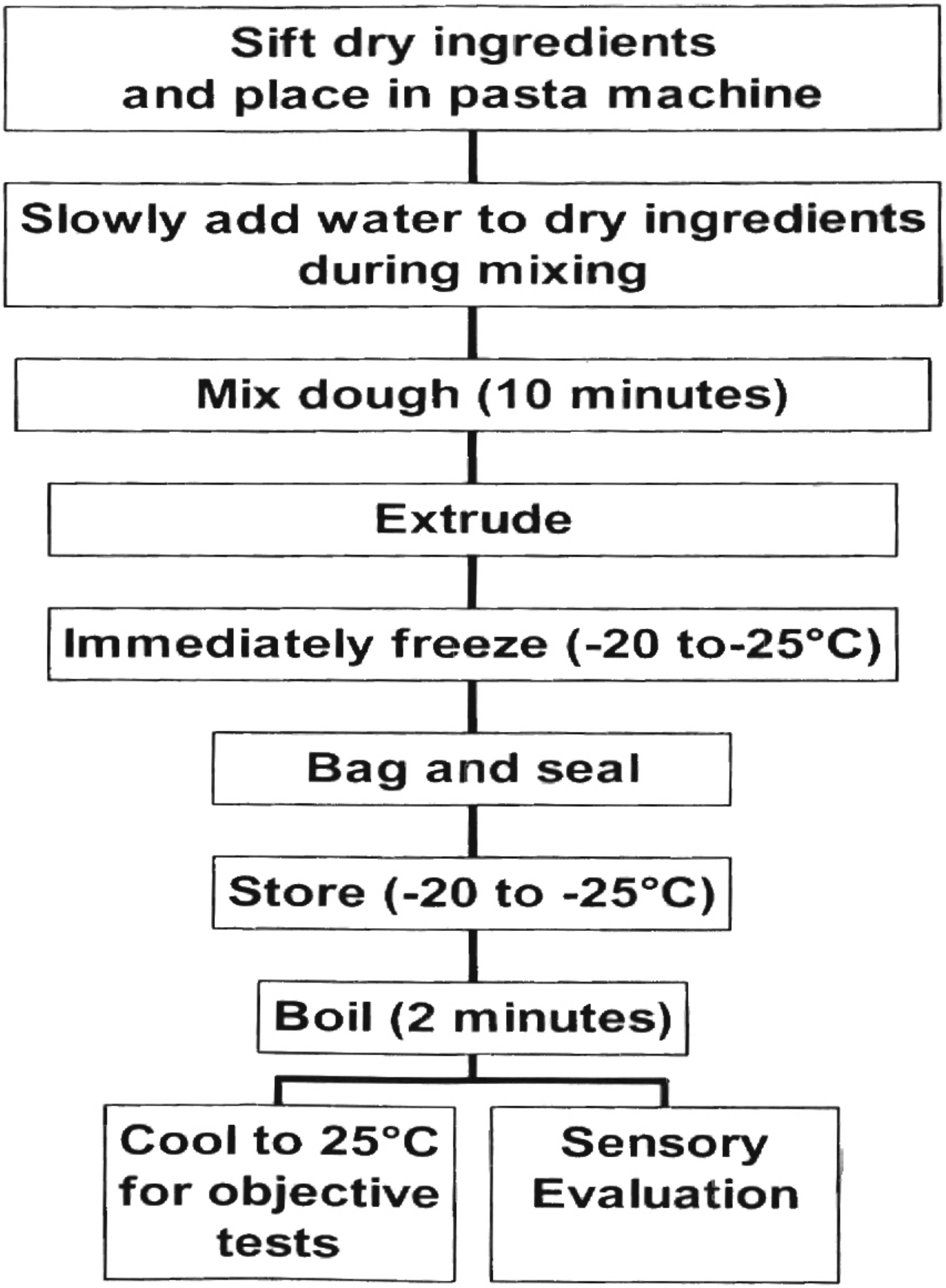
MATERIALS AND METHODS

Pasta Formulations: Five experimental pasta formulations made with defatted peanut flour (PF) and carboxymethylcellulose (CMC) were included in this study as shown: PF13 (13% PF with 0.6% CMC), PF20 (20% PF with 0.2% CMC), PF40 (40% PF with 0.40% CMC), PF50 (50% PF with 0.38% CMC), and PF60 (60% PF with 0.80% CMC) plus a control (0% PF with 0% CMC). All pasta formulations contained 250-300 mg tri-calcium phosphate/56 g serving. Physical (texture profile, color, dimensions, and cooked yield) and sensory (appearance, aroma, taste, texture, aftertaste, purchase intent, and demographic data) characteristics were evaluated.

Materials: Defatted peanut flour containing 50% protein and 12% fat was purchased from Golden Peanut Company, Alpharetta, Georgia. Enriched semolina (King Midas) was donated by Conagra, Omaha, Nebraska. CMC 2500 F powder (Ticalose®) was donated by TIC Gums, Belcamp, Maryland. Tri-calcium phosphate was donated by Gadot Biochemicals, Rolling Meadows, Illinois.

Pasta Preparation: A rotini-shaped, short-type fresh-frozen pasta was prepared in a La Parmigiana (Model D-45) pasta machine (Fidenza, Italy) using the method shown in Figure 1. Pasta was stored at –20 to -25°C for 90-120 days. Prior to objective evaluation of the cooked product, frozen pasta was boiled for 2-3 minutes, drained, and cooled to 25-30° C. Pasta prepared for sensory evaluation was boiled for 2-3 minutes, drained, immediately tossed with Carapelli™ light olive oil, and 3-4 g portions were held in coded and covered four ounce Styrofoam cups for minutes prior to evaluation.

Figure 1
Method of Preparation of Pasta



Physical Tests

Texture analysis: Three (2.0 ± 0.5 g) randomly selected aliquots of each treatment (control PF13, PF20, PF40, PF50, and PF60) were evaluated. Each aliquot of pasta was arranged in a plastic weighing dish within a 25 mm diameter and placed directly underneath the probe of the texture analyzer. Texture profile of the cooked pasta was evaluated using a TA-XT2*i* Texture Analyzer (Texture Technologies Corp., Scarsdale, New York) fitted with a 25 kg load cell and a TA-25 cylindrical probe (50 mm diameter) at a test speed of 1 mm/sec, plus Texture Expert Exceed Software. Each sample was compressed to a distance of 6.0 mm, measured from the top surface of the sample prior to the first compression. A 5-second rest period was allowed between the two compressions. The textural attributes that were evaluated are defined as follows. Hardness is the peak force of the first compression of the product. Springiness is how well a product physically springs back after it has been deformed during the second compression. Cohesiveness measures how well a product withstands a second deformation relative to how it behaved under the first deformation. Gumminess is the interaction between hardness and cohesiveness, whereas chewiness is the interaction between springiness and gumminess (Texture Technologies Corp., 2000).

Dimensions: Rotini-shaped pasta is naturally twirled. Therefore, dimensions of the thawed uncooked (rotini-shaped) experimental pasta were calculated as twirl factor according to the following formula: un-twirled length (flat length) divided by twirled length. Thus, the higher the twirl factor value the greater the degree of twirl in the sample. Dimensions were evaluated in triplicate for each formulation.

Color: Color of thawed uncooked pasta and cooked pasta was evaluated. Nine pieces of pasta per treatment were selected for color evaluation. Color was measured using a Minolta Chroma Meter Reflectance System (Model CR-2000, Minolta, Japan) set in the CIE $L^*C^*h^o$ mode using a C light source at 2° observer angle. Calibration was based on a standard tile with the following color space chromaticity co-ordinates: $Y = 94.3$, $x = 0.3134$, and $y = 0.3207$ ($L^* = 97.75$, $a^* = -0.58$, and $b^* = +2.31$). Three measurements were taken of three randomly selected pieces of pasta to obtain one set of data points. This process was done in triplicate for both thawed and cooked pasta.

Cooked Yield: The cooked yield was determined by measuring 35±0.2 g frozen pasta, placing the pasta in a 1.425 L saucepan (13.5 cm in diameter and 9.5 cm deep) with 500 ml water, and boiling for an average of 3 minutes. The pasta was then removed from the heat, immediately drained for 15 seconds, and reweighed. The cooked weight divided by the uncooked weight x 100 gives the percentage of cooked yield.

Statistical Analysis: Statistical Analysis Software (SAS, 1999) version 8.1 was used to compute one-way ANOVA and determine significant differences between means using Tukey's Studentized Range (HSD) test. Frequencies and the influence of demographic variables on acceptability of the products were determined.

Sensory Analysis

Experimental Design and Testing Instruments for Sensory Study. A Randomized Complete Block Design for a 6-product test (Stone and Sidel, 1993) was used in which each panelist (block) evaluated all 6 products (control, PF15, PF20, PF40, PF50, PF60) in one session (Appendix 3). The sensory evaluation laboratory located in the Oklahoma

Food and Agricultural Products Research and Technology Center, Oklahoma State University, Stillwater, Oklahoma served as the central location for the sensory study. Affective Sensory Evaluation Method (Stone and Sidel, 1993) was used to perform sensory testing. Institutional Review Board Forms (Appendix 4) were submitted and approved prior to sensory evaluation. Students and staff members at Oklahoma State University were randomly invited to participate in the study (Appendix 5). Exclusions included persons who are allergic to peanut and wheat products or who dislike pasta-type products. Prior to participation in the sensory study, panelists were explained the sensory protocol, and then were asked to review and sign the consent form (Appendix 6).

Sensory Evaluation: A total of 60 untrained panelists consisting of students and staff members at Oklahoma State University participated in the study. Panelists were assigned three-digit codes for identification purposes. Demographic questions including gender, age-range, and consumption frequency of pasta was included on each score sheet (Appendix 7). The following attributes of the cooked pasta: appearance, aroma, taste, texture, and aftertaste were evaluated using a 9-point Hedonic Scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, 9=like extremely). Purchase intent was evaluated using a 5-point scale (1=definitely would buy, 2=probably would buy, 3=may or may not buy, 4 probably would not buy, 5=definitely would not buy). Panelists evaluated a total of six samples (5 experimental formulations and a control) served in a monadic sequence. Sensory evaluation was performed in a central location with panelists seated at individual booths under fluorescent lighting. Panelists were required to rinse their mouths with distilled water before and after evaluating each sample.

RESULTS AND DISCUSSION

Physical Tests

Texture Profile: Table 1 shows the effects of peanut flour (PF) and CMC, defined as treatments PF13, PF20, PF40, PF50, PF60 and the control on the texture profile of pasta. All experimental pasta treatments were significantly alike ($P<0.05$) in hardness (127.8±0.82 to 252.0±21.15 g shear force) and were not significantly different ($P>0.05$) from the control (221.5±95.60 g). No significant difference ($P>0.05$) in springiness was observed among all treatments (0.92±0.028 to 0.96±0.001). Additionally, no significant difference ($P>0.05$) was identified among all treatments with regards to cohesiveness (0.77±0.027 to 0.83±0.014). Gumminess of all treatments was also similar (104.5+8.41 to 183.5±77.41), except for PF40 (208.0±14.03) which was significantly ($P\leq 0.05$) more gummy. Chewiness showed some decrease but not significantly, as peanut flour increased, however, again treatment PF40 was the exception. All experimental pasta treatments were similar in chewiness (97.9±11.29 to 192.7±19.78) compared with the control (174.1±70.81). Treatment PF60 (97.9±11.29) however, was significantly ($P\leq0.05$) less chewy compared with treatment PF40 (192.7±19.78). Comparing these texture profile results with those from the response surface methodology (RSM) used in the previous study by Hardy and Hinds (2002), there are similar results in hardness in that the previous study predicted that up to 70% PF could be used to produce a pasta similar to the control. This study only used up to 60% PF and all experimental formulations were similar to the control. Additionally, all experimental formulations were alike in springiness and cohesiveness which differs, however, when compared to the previous RSM study (Hardy and Hinds, 2002) in which the formulation PF60 would not have been similar to the control. Gumminess and chewiness of all experimental formulations were similar to the control formulation in this study and the same trend was predicted in the previous RSM optimization study (Hardy and Hinds, 2002).

Table 1
Effect of Formulation on Texture Profile (means[α] ± sd) of Cooked Pasta

Formula Code	Formulation[β] PF (%)	CMC (%)	Texture Profile Hardness (g shear force)	Springiness	Cohesiveness	Gumminess	Chewiness
Control	0	0	221.5±95.56a	0.95±0.018a	0.83±0.014a	183.5±77.41ab	174.1±70.81ab
PF13	13	0.6	196.5±42.31a	0.95±0.017a	0.80±0.018a	157.2±31.93ab	148.9±32.48ab
PF20	20	0.2	178.8±27.57a	0.95±0.043a	0.82±0.032a	147.0±23.62ab	139.4±21.45ab
PF40	40	0.4	252.0±21.15a	0.93±0.039a	0.83±0.024a	208.0±14.03a	192.7±19.78a
PF50	50	0.38	127.8±08.18a	0.96±0.001a	0.82±0.014a	104.5±8.41b	100.2±8.03ab
PF60	60	0.8	137.6±20.10a	0.92±0.028a	0.77±0.027a	106.1±12.62b	097.9±11.29b
ANOVA	Pr>F		0.0424	0.564	0.0723	0.026	0.029
	F value		3.29	0.81	2.72	3.84	3.72

[α] Means for the same variable (column) followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test $\alpha = 0.05$
[β] PF = Wt % peanut flour replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients.

Dimensions: Twirl factor of thawed fresh frozen pasta is calculated by dividing flat length by twirled length. All pasta treatments including the control (1.6±0.23), PF13 (1.5±0.11), PF20 (1.5±0.07), PF40 (1.3±0.16), PF50 (1.5±0.03), and PF60 (1.3±0.14) had similar twirl factors, (Table 4), indicating that levels of PF and CMC did not significantly ($P>0.05$) affect the degree of twirl of the pasta. In comparing these results to a previous study by Hardy and Hinds (2002), the PF60 formulation differed between the two studies and was shown in this study to be similar to the control where it had previously differed.

Color: All three color dimensions (hue, chroma, and L value) of uncooked and cooked pasta were significantly affected ($P\leq0.05$) by the different formulations (Tables 2 and 3). Tables 2 and 3 show the effects of PF and CMC on the mean color of uncooked and cooked pasta. Hue is a color descriptor where 0 = red and 90 = yellow. As peanut flour increased, the hue of both uncooked (71.9±0.20 to 81.9±1.35) and cooked (74.2±0.35 to 82.9±0.25) pasta became significantly ($P\leq0.05$) more brown than the uncooked (93.5±0.57) and cooked (96.9±0.53) controls. The hue of the uncooked PF13 treatment (81.9±1.35) was significantly ($P\leq0.05$) less brown than the uncooked PF20 (78.0±0.95) and uncooked PF40 (78.1±1.95) treatments. Similarly, the cooked PF13 treatment (82.9±0.25) was more yellow than the cooked PF20 (79.8±0.80) treatment. Uncooked treatments PF50 (71.9±0.20) and PF60 (72.5±1.87), and cooked treatments PF40 (76.4±1.66), PF50 (74.2±0.35) and PF60 (75.1±1.24) were significantly more ($P\leq0.05$) brown than all their other uncooked (78.0±0.95 to 93.5±0.58) and cooked (79.8±0.80 to 96.9±0.53) counterparts. Chroma is defined as the intensity of a color. There was no significant difference ($P>0.05$) in chroma between any of the uncooked treatments. All cooked experimental formulations were similar to the cooked control

(26.6±1.15) in intensity except PF20 (30.0±1.65) which was more intense. Additionally, the cooked PF20 (30.0±1.65) had a significantly ($P \leq 0.05$) more intense chroma than the PF60 treatment (26.7±0.57). L-value is the lightness and darkness of a color (0 = black, 100 = white). In general, as peanut flour increased, the L-value of both uncooked and cooked pasta decreased and the pasta became darker. The L-value of all experimental uncooked (58.5±0.72 to 70.1±2.55) and cooked (58.9±1.96 to 68.0±0.10) treatments were significantly ($P \leq 0.05$) darker than their respective uncooked (74.7±1.16) and cooked (75.7±1.12) controls. Uncooked formulations PF20 (65.2±1.20) and PF40 (66.2±1.82) were significantly ($P \leq 0.05$) darker than PF13 (70.1±2.55) and significantly ($P \leq 0.05$) lighter than PF50 (58.5±0.72) and PF60 (59.2±2.06) formulations. Cooked formulations PF40 (61.7±1.98), PF50 (61.1±0.57), and PF60 (58.9±1.96) were significantly ($P \leq 0.05$) darker than cooked formulations PF 13 (68.0±0.10) and PF20 (65.1±0.88). The trends seen in the color profile in this validation study are similar to those predicted in the previous study using RSM (Hardy and Hinds, 2002).

Table 2
Effect of Formulation on Color (means$^{\alpha}$ ± sd) of Uncooked Pasta

Formula Code	Formulation$^{\beta}$ PF %	CMC %	Color* (uncooked pasta) Hue angle(°)	Chroma	L-value
Control	0	0	93.5±0.58a	28.6±2.27a	74.7±1.16a
PF13	13	0.6	81.9±1.35b	27.1±2.83a	70.1±2.55b
PF20	20	0.2	78.0±0.95c	29.3±1.30a	65.2±1.20c
PF40	40	0.4	78.1±1.95c	29.0±1.15a	66.2±1.82c
PF50	50	0.38	71.9±0.20d	29.3±0.17a	58.5±0.72d
PF60	60	0.8	72.5±1.87d	25.8±1.34a	59.2±2.06d
ANOVA		Pr>F	<.0001	0.01	<.0001
		F value	161.23	4.04	65.52

$^{\alpha}$ Means for the same variable (column) followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test $\alpha = 0.05$.
$^{\beta}$ PF = Wt percent peanut flour replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients.
*Hue angle (color descriptor): 0° = red, 90° = yellow; Chroma = intensity of hue; L Value (lightness scale): 0 = black, 100 = white.

Table 3
Effect of Formulation on Color (means$^{\alpha}$ ± sd) of Cooked Pasta

Formula Code	Formulation$^{\beta}$ PF %	CMC %	Color* (cooked pasta) Hue angle (°)	Chroma	L-value
Control	0	0	96.9±0.53a	26.6±1.15b	75.7±1.12a
PF13	13	0.6	82.9±0.25b	28.3±0.48ab	68.0±0.10b
PF20	20	0.2	79.8±0.80c	30.0±1.65a	65.1±0.88b
PF40	40	0.4	76.4±1.66d	28.0±2.38ab	61.7±1.98c
PF50	50	0.38	74.2±0.35d	28.7±0.15ab	61.1±0.57c
PF60	60	0.8	75.1±1.24d	26.7±0.57b	58.9±1.96c
ANOVA		Pr>F	<.0001	0.0173	<.0001
		F value	343.69	3.56	93.37

$^{\alpha}$ Means for the same variable (column) followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test $\alpha = 0.05$.
$^{\beta}$ PF = Wt percent peanut flour replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients.
*Hue angle (color descriptor): 0° = red, 90° = yellow; Chroma = intensity of hue; L Value (lightness scale): 0 = black, 100 = white.

Cooked Yield: Cooked yield is calculated as a percentage of the weight of boiled noodles to that of raw noodles (Anon, 1985). No significant difference (P>0.05) was identified among all six treatments of pasta (Table 4). Cooked yield ranged from 138.0±2.25 percent (PF40) to 149.4±1.46 percent (PF50) with the control having a cooked yield of 142.2±8.86 percent.

Table 4
Effect of Formulation on Cooked Yield and Twirl Factor (means$^{\alpha}$ ± sd) of Pasta

Formula Code	PF %	CMC %		Cooked Yield %	Twirl Factor$^{\delta}$
Control	0	0		142.2±8.86	1.6±0.23a
PF13	13	0.6		142.7±0.46	1.5±0.11a
PF20	20	0.2		146.7±0.48	1.5±0.07a
PF40	40	0.4		138.0±2.25	1.3±0.16a
PF50	50	0.38		149.4±1.46	1.5±0.03a
PF60	60	0.8		140.7±0.62	1.3±0.14a
ANOVA			Pr>F	0.1606	0.0429
			F value	2.38	2.81

$^{\alpha}$ Means for the same variable (column) followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test ($\alpha = 0.05$).
$^{\beta}$ PF = Wt percent peanut flour replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients.
$^{\delta}$ Twirl factor: Flat length/Twirl length.

Sensory Analysis

Sensory attributes: Table 5 and Figure 2 show the effects of peanut flour (PF) and carboxymethylcellulose (CMC) on the sensory attributes of pasta. All sensory attributes (appearance, aroma, taste, texture, and aftertaste) were significantly affected (P≤0.05) by the different formulations (Table 5).

Appearance scores for pasta treatments containing all levels of peanut flour: PF13 (6.7±1.34), PF20 (6.6±1.34), PF40 (5.5±1.80), PF50 (4.8±1.96) and PF60 (5.1±1.98) were significantly different (P≤0.05) from the control (7.8±1.07) (Table 5). Treatments PF13 (6.7±1.34) and PF20 (6.6+1.34) were also significantly different (P≤0.05) from treatments containing ≥ 40% PF (4.8±1.96 to 5.5±1.80) (Table 5). The control pasta and experimental formulations PF13 and PF20 were considered acceptable in appearance with mean hedonic scores >6.0 (Table 5).

Aroma of formulations PF40 (5.4±2.09), PF50 (5.3±2.17), and PF60 (5.2±2.15) was significantly different (P≤0.05) from the control (7.4±1.38) and formula PF20 (6.4±1.5), Table 5. Formula PF13 (6.0±1.52) and PF20 (6.4±1.45) were similar in aroma to each other (Table 5). Panelists indicated that the control and treatments PF13 and PF20 had acceptable aroma (mean scores >6.0) (Table 5).

Pasta treatments PF13 and PF20 were not significantly different (P>0.05) in taste (6.6±1.53 and 6.7±1.47, respectively) from the control (6.8±1.70), and were considered acceptable (mean scores > 6.0) (Table 5). Additionally, treatments containing ≤20% PF (6.6±1.53 to 6.8±1.70) were significantly different (P≤0.05) in taste compared with treatments containing ≥40% PF (4.9±1.96 to 5.4±2.12). PF40 was considered marginally acceptable in taste with a score of 5.5±1.86, (Table 5).

Acceptability of texture significantly decreased (P≤0.05) in treatments containing >20 PF (4.9±1.96 to 5.5±1.86) when compared with treatments containing ≤ 20% PF (6.5±1.75 to 6.9±1.66) (Table 5). Formulations PF13 and PF20 and the control were given acceptable mean scores (>6.0) during the sensory evaluation (Table 5). Showing a similar trend to taste, PF40 was only marginally acceptable in texture.

Hedonic scores for aftertaste of pasta treatments PF40 were similar to those for taste and texture (Table 5). Pasta treatments containing ≤ 20% PF were alike in aftertaste (6.3±1.59 to 6.6±1.72) and were significantly different ($P \leq 0.05$) from the treatments containing ≥40% which were also alike in aftertaste (4.7±1.83 to 5.3±1.83). Treatments with acceptable aftertaste were the control, PF13 and PF20 (Table 5).

Table 5
Effect of Formulation on Sensory Attributes (means$^{\alpha}$ ± sd) of Cooked Pasta

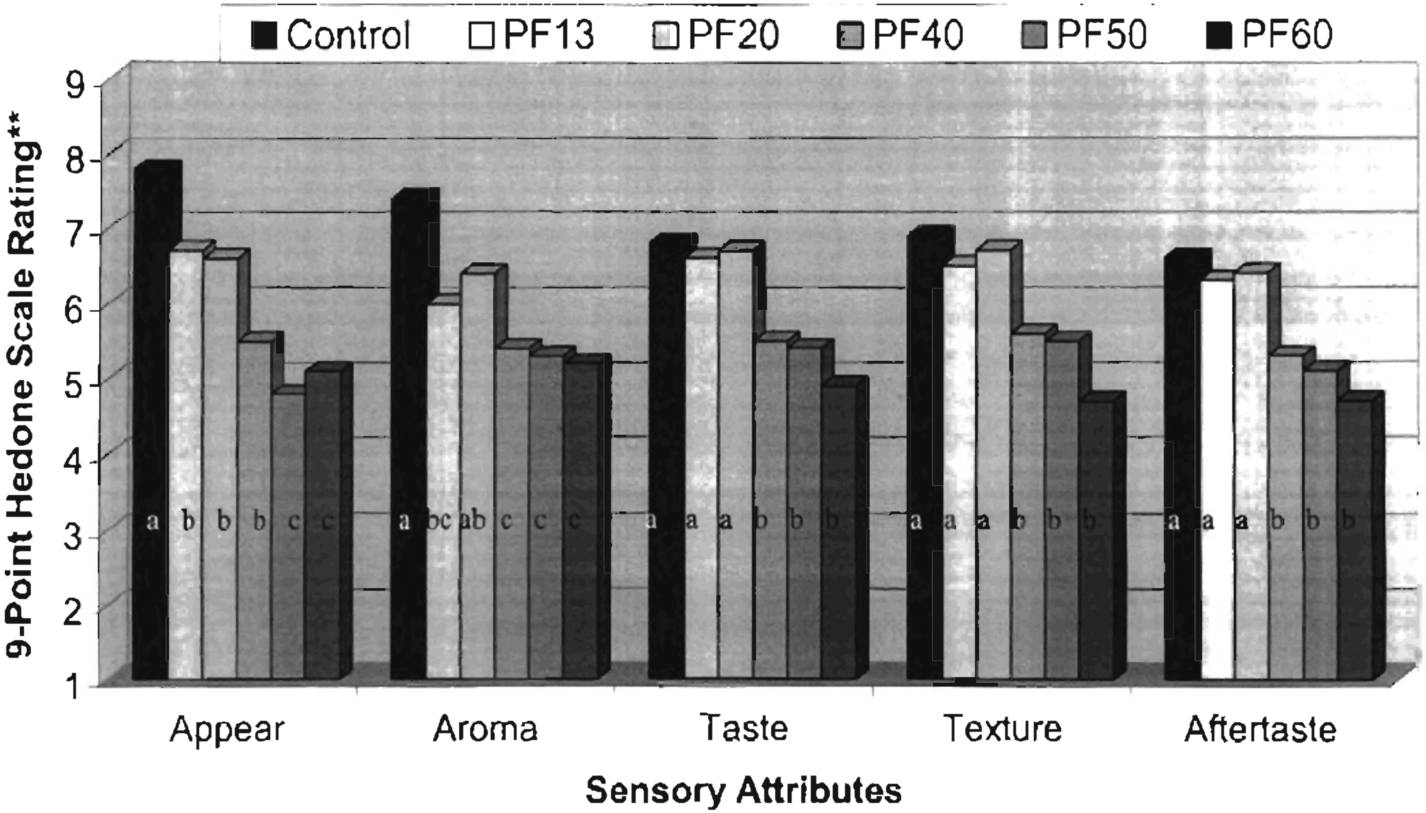
Formula Formulations$^{\beta}$			Sensory Attributes$^{\delta}$				
Code	PF %	CMC %	Appearance	Aroma	Taste	Texture	Aftertaste
Control	0	0	7.8±1.07a	7.4±1.38a	6.8±1.70a	6.9±1.66a	6.6±1.72a
PF13	13	0.6	6.7±1.34b	6.0±1.52bc	6.6±1.53a	6.5±1.75a	6.3±1.59a
PF20	20	0.2	6.6±1.34b	6.4±1.45ab	6.7±1.47a	6.7±1.54a	6.4±1.54a
PF40	40	0.4	5.5±1.80c	5.4±2.09c	5.5±1.86b	5.6±1.76b	5.3±1.83b
PF50	50	0.38	4.8±1.96c	5.3±2.17c	5.4±2.12b	5.5±1.94b	5.1±1.66b
PF60	60	0.8	5.1±1.98c	5.2±2.15c	4.9±1.96b	4.7±1.92b	4.7±1.83b
ANOVA		Pr>F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
		F value	29.6	12.5	13.02	14.66	12.55

$^{\alpha}$ Means for the same variable (column) followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test α = 0.05

$^{\beta}$ PF = Wt % peanut flour replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients

$^{\delta}$ Sensory attributes scored using Hedonic Scale where 1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, 9=like extremely.

Figure 2
Effect of Peanut Flour and Carboxymethylcellulose on Sensory Attributes (mean scores[α]) of Calcium-Fortified Pasta



[α]Means for the same attribute with the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test $\alpha = 0.05$.

**9-Point Hedonic Scale: 1=Dislike extremely, 2=Dislike very much, 3=Dislike moderately, 4=Dislike slightly, 5=Neither like nor dislike, 6=Like slightly, 7=Like moderately, 8=Like very much, 9=Like extremely.

Comparison of Physical and Sensory Properties: Color is one component of the sensory attribute, appearance. Experimental pasta treatments that were considered acceptable in appearance were a lighter tan color ($h° = 79.8\pm0.80$ to 96.9 ± 0.52, L Value $= 65.1\pm0.87$ to 75.7 ± 1.12) than those treatments which were unacceptable ($h° = 75.1\pm1.24$ to 76.4 ± 1.66, L Value $= 58.9\pm1.96$ to 61.7 ± 1.98), Tables 3 and 5.

Texture profile scores (hardness, springiness, cohesiveness, gumminess, and chewiness) of the experimental pasta formulations PF13 (196.5±42.31, 0.95±0.0017, 0.80±0.018, 157.2±31.93, 148.9±32.48), PF20 (178.8±27.57, 0.95±0.043, 0.82±0.032, 147.0±23.62, 139.4±21.45), and the control (221.5±95.56, 0.95±0.018, 0.83±0.014, 183.5±77.41, 174.1±70.81) shown in Table 1 were considered acceptable (>6.0) in the texture (Table 5 and Figure 2) by the sensory panel. Formulation PF40 was marginally acceptable (5.6±1.76) by the sensory panel, and its texture profile scores were 252.0±21.15, 0.93±0.039, 0.83±0.024, 208.0±14.03 and 192.7±19.78 for hardness, springiness, cohesiveness, gumminess, and chewiness respectively (Table 1). Pf40 was harder than the control but displayed similar secondary textural properties to the latter. These results suggest that hardness might be the most important textural attribute for determining acceptability of pasta texture by the sensory panelists in this study.

Purchase Intent: Purchase intent was evaluated using a 5-point scale where 1=definitely would buy, 2=probably would buy, 3=may or may not buy, 4=probably would not buy, and 5=definitely would not buy (Table 6 and Figure 3). Table 6 indicates that there was a significant difference ($P\leq0.05$) among pasta treatments. Formulations PF13, PF20 and the control were scored similarly for purchase intent (2.1±1.05 to 2.4±1.01) and would probably be bought by the panelists (Table 6 and Fig 3).

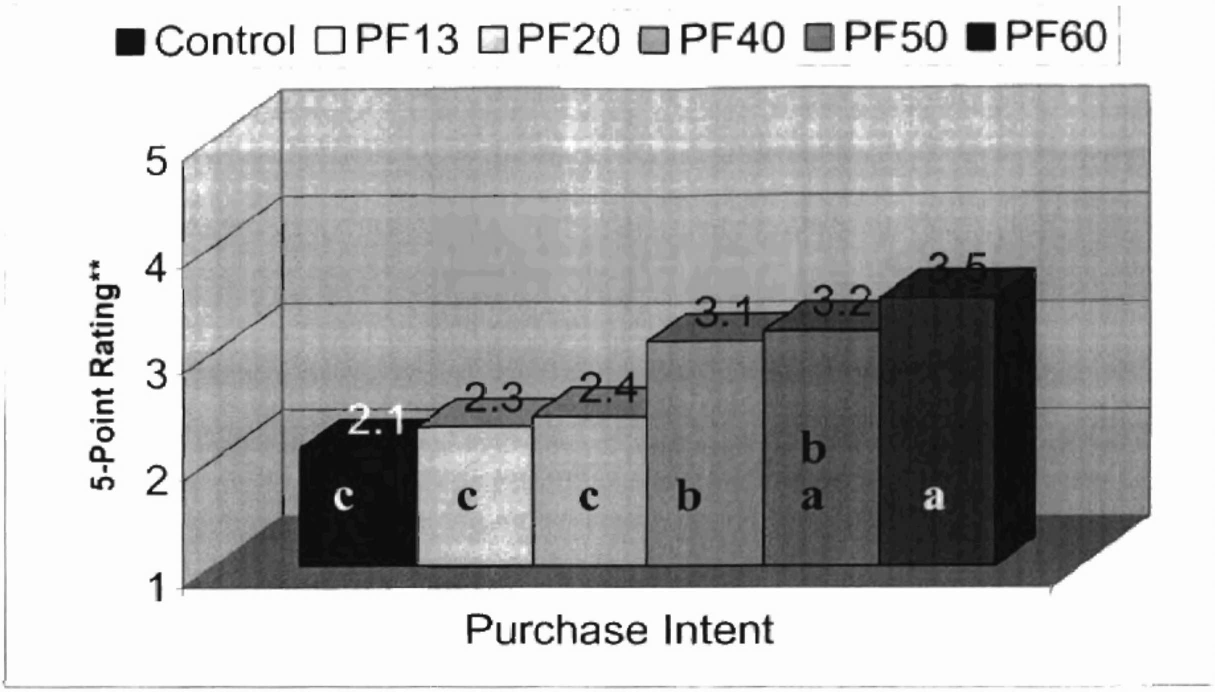
Treatments containing ≥ 40% PF (3.1±1.20 to 3.5±1.13) were scored less positively ($P<0.05$) than those containing < 20% PF, and panelists were undecided about purchasing them (Table 6). There is a positive correlation in acceptability scores and purchase intent scores for experimental pasta formulations PF13 and PF20 and the control. Sensory panelists indicated that they would probably purchase these formulations, which all had acceptable sensory scores.

Table 6
Effect of Formulation on Purchase Intent (means$^{\alpha}$± sd) of Pasta

Formula Code	**Formulation$^{\beta}$** **PF** %		**CMC** %	**Purchase Intent$^{\delta}$**
Control	0	6	0	2.1±1.05b
PF13	13	1	0.6	2.4±1.01b
PF20	20	4	0.2	2.3±1.02b
PF40	40	5	0.4	3.1±1.20a
PF50	50	3	0.38	3.2±1.13a
PF60	60	2	0.8	3.5±1.13a
ANOVA		Pr>F		<0.0001
		F value		15.56

$^{\alpha}$Means for purchase intent followed by the same letter are not significantly different according to Tukey's Studentized Range (HSD) Test ($\alpha = 0.05$).
$^{\beta}$ PF = Wt% peanut flour replacing semolina, CMC = carboxymethylcellulose as wt (%) of dry ingredients.
$^{\delta}$ Purchase intent scored using 5-point scale where 1=Definitely would buy, 2=Probably would buy, 3=May or may not buy, 4=Probably would not buy, 5=Definitely would not buy.

Figure 3
Effect of Peanut Flour and Carboxymethylcellulose on Purchase Intent (mean scores[α]) of Calcium-Fortified Pasta**



[α]Means with the same letter are not significantly different according to Tukey's Studentized Range (HSD) $\alpha = 0.05$.

**5-Point Rating: 1=Definitely would buy, 2=Probably would buy, 3=May or may not buy, 4=Probably would not buy, 5=Definitely would not buy.

Demographic Information: Demographic information obtained from the 60 panelists involved in sensory evaluation included gender, age-range, and frequency of consumption. The majority (83.3%) of the panelists were females. One-hundred percent of the panelists were between the ages of 18 and 55, and 75% of these panelists were between the ages of 18 and 25. Regarding frequency of consumption, 86.6% of the panelists consumed pasta 12 or less times per month. Twenty-five percent of the panelists consumed pasta 9-12 times per month, 38.3% consumed pasta 5-8 times per month, and 23.3% consumed pasta less than 5 times per month (Table 7).

Table 7
Demographic Characteristics of Sensory Panelists

Gender	Percent
Male	16.7 (n=10)
Female	83.3 (n=50)

Age	Percent
18-25	75.0 (n=45)
26-39	13.3 (n=8)
40-55	11.7 (n=7)
>55	0

Frequency of Pasta Consumption	Percent
<5 times/month	23.3 (n=14)
5-8 times/month	38.3 (n=23)
9-12 times/month	25.0 (n=15)
13-16 times/month	8.3 (n=5)
>17 times/month	5.0 (n=3)

CONCLUSION

This study was performed to validate the findings of a previous optimization study which evaluated physical properties of frozen peanut-based pasta (Hardy and Hinds, 2002). The predicted optimum treatments of experimental pasta containing defatted peanut flour (≤60% replacement) and carboxymethylcellulose (≤0.8%) fortified with tri-calcium phosphate (250-300 mg/56 g serving) were significantly similar ($P>0.05$) to the calcium-fortified control pasta (100% semolina) in their textural characteristics, dimensions, and cooked yield. There was a significant difference ($P\leq0.05$) seen in the acceptability of sensory attributes, purchase intent, as well as CIE physical color dimensions. Sensory evaluation provides information on potential acceptability of a product. Formulations containing up to 20% PF were shown to be acceptable in all sensory parameters tested, namely appearance, aroma, taste, texture, and aftertaste. For the 40% PF replacement formulation, panelists were undecided as to whether they disliked or liked its appearance, aroma, and aftertaste. Panelists either disliked slightly or were undecided about liking the appearance, aroma, taste, texture and aftertaste of formulations containing ≥50% PF replacement. When sensory panelists were asked whether or not they would purchase a product, formulations containing up to 20% PF were identified as those products which would likely be purchased.

Utilizing the information from this study it is estimated that a calcium-fortified pasta made with up to 20% defatted peanut flour and 0.2-0.4% CMC would likely produce an acceptable value-added pasta type product. These acceptable formulations demonstrated the following physical characteristics: hardness, springiness, cohesiveness, gumminess, and chewiness were 178.8±27.57 to 221.5±95.5 g shear force, 0.95±0.017 to 0.95±0.043, 0.80±0.18 to 0.83±0.014, 147.0±23.62 to 183.5±77.41, and 139.4±21.45 to 174.1±70.81, respectively. Hue angle, chroma and L value of these formulations were 78.0±0.95 to 93.5±0.58, 27.1±2.83 to 29.3±1.30, and 65.2±1.20 to 74.7±1.16, respectively when uncooked, and 79.8±0.80 to 96.9±0.53, 26.6±1.15 to 30.0±1.65 and 65.1±0.88 to 75.7±1.12, respectively when cooked. The acceptable formulations had twirl factors and cooked yields of 1.5±0.07 to 1.6±0.23 and 142.2±8.86 to 146.7±0.48, respectively.

In this study, formulations containing13% PF with 0.6% CMC, 20% PF with 0.2% CMC, 40% PF with 0.4% CMC, 50% PF with 0.38% CMC and 60% PF with 0.8%

CMC were chosen for validation purposes. Similar results were obtained in this validation study compared with those in the optimization study (Hardy and Hinds, 2002) regarding the physical characteristics of pasta formulations containing up to 60% PF. In choosing the formulations from the optimization study using the mean values from the control parameters to indicate optima, the five formulations listed above appeared to provide a good representation of those physical characteristics that would be similar to the control. After completing the validation portion of this study, however, it is evident that a gap existed between the formulations containing 20% PF and 40% PF. Choosing a formulation between these two values may have assisted with establishing a higher percentage of peanut flour that could be used to make a frozen pasta-type product with acceptable sensory attributes comparable to a control containing 100% semolina .

Results from previous work with peanut flour in pasta done by Chompreeda et al. (1988) indicate that up to 15% PF could be used in a Chinese-type noodle without significantly reducing the sensory quality of the noodles. This current study indicates that up to 20% PF could be used in a short pasta without significantly reducing the sensory quality of the pasta, which is a marginal increase compared with the previous study. It is however, important to recognize that while the peanut flour replacement is only 5% higher, the types of pasta differ. In addition, because of the gap that existed between the 20% PF replacement and the 40% PF replacement, a true cutoff value for percentage of peanut flour that could be used in a short pasta-type product was not fully established. Pasta and noodle type products are staple food items in many cultures around the world, and use of alternative flours provides for diversity in preparation of these products, which can offer benefits from an availability and economic standpoint.

Findings from this study indicate that there is potential for commercial production of a pasta-type product containing 20% PF (as wheat flour replacement) and fortified with approximately 50% of the AI for calcium needs in the general population per 56 g serving of pasta.

FURTHER RESEARCH

To further explore utilization of defatted peanut flour in pasta type products, the following suggestions are proposed:

- Evaluation of frozen pasta-type products containing 21-39% PF replacement to more accurately assess the cutoff point where physical and sensory attributes are within the range of the control pasta containing 100% semolina.
- Evaluation of a dried pasta containing defatted peanut flour which would be more shelf stable and not require refrigeration, thus reducing the cost and availability to the consumer.
- Evaluation of gums other than carboxymethylcellulose in an effort to increase the amount of peanut flour, which could be used in a pasta-type product and still produce acceptable sensory qualities.
- Various flavor combinations with herbs and spices in an effort to increase flavor and increase the amount of PF which could be used to produce a pasta-type product with acceptable sensory qualities.

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APPENDIXES

APPENDIX 1-A

A 5 X 5 COMPLETE FACTORIAL ARRANGEMENT OF PEANUT FLOUR AND CMC 2500

PEANUT FLOUR	CMC 2500 0%	0.4%	0.8%	1.2%	1.6%
20%	20:0	20:0.4	20:0.8	20:1.2	20:1.6
40%	40:0	40:0.4	40:0.8	40:1.2	40:1.6
60%	60:0	60:0.4	60:0.8	60:1.2	60:1.6
80%	80:0	80:0.4	80:0.8	80:1.2	80:1.6
100%	100:0	100:0.4	100:0.8	100:1.2	100:1.6

APPENDIX 1-B

BOX-BEHNKEN 5X5 INCOMPLETE CENTRAL COMPOSITE DESIGN* USED FOR PEANUT FLOUR AND CMC 2500

	PEANUT FLOUR (%)		CMC%	
TRTMT	CODED VALUE	UNCODED VALUE	CODED VALUE	UNCODED VALUE
A	-1	40%	-1	0.4%
B	+1	80%	-1	0.4%
C	-1	40%	+1	1.2%
D	+1	80%	+1	1.2%
E	-2	20%	0	0.8%
F	+2	100%	0	0.8%
G	0	60%	-2	0%
H	0	60%	+2	1.6%
I	0	60%	0	0.8%

*Box and Draper, 1997
Trmt = treatment

APPENDIX 2-A

Pasta Formulations

Random Code	Trtmt	Proc Rep	PF g	Semolina g	CMC g	TCP g	Water ml
307	H	1	1200	800	32	32	933
379	D	1	1600	400	24	32	950
505	B	1	1600	400	8	32	950
613	E	1	400	1600	16	32	700
629	C	1	800	1200	24	32	830
700	A	1	800	1200	8	32	860
880	F	1	2000	0	16	32	970
941	I	1	1200	800	16	32	900
952	G	1	1200	800	0	32	900
999	Control	1	0	2000	0	32	650
59	G	2	1200	800	0	32	832
256	H	2	1200	800	32	32	862
285	E	2	400	1600	16	32	680
299	D	2	1600	400	24	32	900
306	C	2	800	1200	24	32	813
337	B	2	1600	400	8	32	900
351	I	2	1200	800	16	32	834
756	F	2	2000	0	16	32	950
916	A	2	800	1200	8	32	890
927	Control	2	0	2000	0	32	655

Trtmt = Treatment
Proc Rep = Process Replicate
PF = Peanut Flour
CMC = Carboxymethylcellulose
TCP = Tri-Calcium Phosphate

APPENDIX 2-B

Pasta Preparation Conditions

Random	Trtmt	Proc Rep	Ext Yield	Waste	Freeze Temp	Rel Humid	Room Temp
Code			g	g	°C	%	°C
307	H	1	2139.65	356.86	-17	51	22
379	D	1	2237.04	258.21	-22	47	22
505	B	1	2225.79	367.93	-25	36	22
613	E	1	2066	206	-22	60	24
629	C	1	2109.27	426.45	-20	55	22
700	A	1	2073.81	263.91	-22	52	22
880	F	1	2362.42	216.09	-23	53	22
941	I	1	2215.95	202.08	-23	58	22
952	G	1	2148.5	295.26	-22	53	22
999	Control	1	2030.64	213.97	-18	43	22
59	G	2	2128.67	207.77	-23	47	22
256	H	2	1959.43	186.6	-18	49	22
285	E	2	2001	174.02	-24	50	22
299	D	2	2231.48	177.98	-24	54	22
306	C	2	2072.83	153.98	-25	59	22
337	B	2	2250.59	154.55	-17	60	22
351	I	2	2143.6	198.99	-18	60	22
756	F	2	2222.23	88.46	-20	60	22
916	A	2	2062.84	386.75	-17	60	22
927	Control	2	1914.88	235.49	-23	54	24

Trtmt = Treatment
Proc Rep = Process Replicate
Ext yield = Extruded Yield
Rel Humidity = Relative Humidity
Temp = Temperature

APPENDIX 3

Balanced-Block Design for a Six-Product Test with Assigned Three-Digit Random Codes

Serving Order of Samples						
Panelist	**First**	**Second**	**Third**	**Fourth**	**Fifth**	**Sixth**
718 1	320 4	601 6	598 2	911 3	820 5	392 1
072 2	790 2	266 5	399 1	124 6	958 4	978 3
502 3	070 3	709 4	876 2	893 5	569 6	177 1
046 4	605 4	639 2	167 6	042 1	075 3	413 5
953 5	364 5	374 3	034 1	977 2	639 6	245 4
501 6	382 6	074 1	065 4	314 3	128 2	811 5
242 7	727 2	526 3	679 5	363 4	833 1	737 6
650 8	762 5	854 6	480 2	037 1	772 4	853 3
468 9	569 3	079 4	279 1	386 5	891 6	704 2
494 10	644 6	480 3	802 4	281 2	542 1	857 5
268 11	160 5	937 2	562 3	038 4	444 6	795 1
734 12	050 6	681 5	487 2	599 3	178 1	281 4
723 13	562 1	195 6	773 3	917 4	827 2	312 5
053 14	036 2	730 5	124 6	751 1	508 4	652 3
177 15	499 3	435 4	445 1	663 5	615 6	184 2
182 16	461 4	115 1	482 6	457 2	211 3	965 5
197 17	273 1	473 2	726 3	918 6	678 5	741 4
974 18	467 6	487 5	842 4	402 3	653 1	834 2
668 19	452 1	860 6	354 3	734 4	304 2	394 5
225 20	361 2	933 5	326 6	779 1	713 4	610 3
635 21	163 3	191 4	543 1	312 6	511 5	888 2
783 22	583 4	085 1	239 5	654 2	488 3	246 6
617 23	520 5	678 2	818 3	590 4	342 6	369 1

APPENDIX 3
(Cont'd)

Serving Order of Samples						
Panelist	First	Second	Third	Fourth	Fifth	Sixth
297 24	537 6	283 1	166 4	285 5	564 3	337 2
615 25	757 5	751 3	330 6	664 4	413 2	167 1
319 26	112 3	865 5	697 2	331 1	494 4	855 6
601 27	932 2	315 4	264 1	294 6	056 5	889 3
134 28	400 4	365 1	176 6	141 2	720 3	611 5
079 29	091 3	933 2	244 5	478 6	668 1	971 4
406 30	394 6	352 5	929 4	354 3	028 2	093 1
773 31	072 1	972 6	480 5	789 4	298 3	752 2
764 32	406 3	906 5	488 2	011 1	963 4	917 6
185 33	998 2	364 4	157 1	965 5	845 6	879 3
121 34	494 6	379 3	654 4	513 2	398 5	165 1
931 35	035 1	425 2	186 5	031 6	504 3	540 4
908 36	357 6	734 1	831 4	979 3	350 2	577 5
480 37	996 2	293 6	877 5	871 4	630 3	520 1
612 38	927 5	066 3	570 2	637 1	464 4	759 6
359 39	166 1	019 2	847 4	240 5	419 6	388 3
024 40	245 4	013 1	259 6	369 2	493 3	610 5
778 41	618 2	058 3	181 5	744 6	841 4	497 1
404 42	682 4	407 1	294 6	967 3	815 2	341 5
860 43	218 5	255 6	626 3	007 4	642 1	919 2
220 44	030 3	316 5	412 2	245 1	347 4	843 6
242 45	313 2	781 3	342 1	101 5	847 6	490 4
082 46	537 4	602 1	176 5	064 2	612 3	855 6
104 47	367 1	165 2	350 3	586 6	531 5	997 4

APPENDIX 3
(Cont'd)

Serving Order of Samples						
Panelist	**First**	**Second**	**Third**	**Fourth**	**Fifth**	**Sixth**
037 48	124 5	585 4	812 6	549 3	427 2	941 1
075 49	364 1	844 6	517 3	592 4	871 5	949 2
810 50	727 5	908 3	952 2	158 1	663 4	666 6
989 51	783 3	514 4	848 1	392 5	637 6	719 2
140 52	697 4	014 6	834 5	624 2	984 1	047 3
103 53	618 1	696 2	116 3	035 6	222 5	564 4
824 54	509 6	625 5	058 4	450 3	398 1	295 2
011 55	684 1	054 4	506 3	815 5	574 2	916 6
847 56	485 3	458 6	601 2	589 1	182 5	145 4
587 57	192 2	413 4	940 6	041 5	725 1	169 3
974 58	491 4	897 3	582 1	127 2	142 5	571 6
574 59	389 5	471 2	749 4	453 6	927 1	982 3
271 60	764 6	345 1	057 5	250 3	967 2	963 4

APPENDIX 4

Institutional Review Board Form

Oklahoma State University
Institutional Review Board

Protocol Expires: 9/8/2003

Date: Tuesday, September 10, 2002 IRB Application No HE0310

Proposal Title: PHYSICAL AND SENSORY CHARACTERISTICS OF A CALCIUM-FORTIFIEID PASTA-TYPE PRODUCT MADE WITH DEFATTED PEANUT FLOUR

Principal
Investigator(s):

Deborah Hardy	Margaret J. Hinds
425 HES	309 HES
Stillwater, OK 74078	Stillwater, OK 74078

Reviewed and
Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

Dear PI :

Your IRB application referenced above has been approved for one calendar year. Please make note of the expiration date indicated above. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved projects are subject to monitoring by the IRB. If you have questions about the IRB procedures or need any assistance from the Board, please contact Sharon Bacher, the Executive Secretary to the IRB, in 415 Whitehurst (phone: 405-744-5700, sbacher@okstate.edu).

Sincerely,

Carol Olson

Carol Olson, Chair
Institutional Review Board

APPENDIX 5

SOLICITATION FORM

Invitation to Participate in Sensory Evaluation of a Calcium-Fortified Pasta-Type Product Made with Defatted Peanut Flour

You are cordially invited to participate as a sensory panelist in the evaluation of an innovative food product that could potentially be on the market in the near future. The product is a calcium-fortified pasta-type product made with defatted peanut flour.

As a sensory panelist you would be asked to spend approximately 45 minutes evaluating five different pasta samples and completing corresponding questionnaires. Individuals who do not eat pasta and those who are allergic to peanuts and food items containing peanuts or wheat are asked not to volunteer their participation.

The sensory evaluation will take place in the Sensory Lab, Room 149, located at the Food & Agricultural Products Research & Technology Center, corner of Farm and Monroe, Oklahoma State University, Stillwater, OK 74078. Ten panelists will be needed for each of the eight sessions scheduled during September 26 and September 27 with times listed below.

Thursday, September 26, 2002	Friday, September 27, 2002
10:30 a.m.	10:30 a.m.
12:00 p.m.	12:00 p.m.
1:30 p.m.	1:30 p.m.
3:00 p.m.	3:00 p.m.

If you would like to participate in this sensory evaluation, please complete the following information:

NAME: ______________________________

PHONE NUMBER: ______________________________

EMAIL ADDRESS: ______________________________

TIMES AND DATES YOU ARE AVAILABLE TO PARTICIPATE: ______________________________

(NOTE: If possible, please choose two slots in case your first choice is not available)

Please return this form to Deborah Hardy, 425 HES, Oklahoma State University, Stillwater, OK 74078 or call (405) 377-7141 or (405) 410-5898 to sign up. You may also send an email to Tmsdhardy@aol.com with the above listed sign up information.

APPENDIX 6

Consent to Participate in Sensory Evaluation of a Calcium-Fortified Pasta-Type Product Made with Defatted Peanut Flour

I, ____________________________, voluntarily agree to participate in the above titled research that is sponsored by the College of Human Environmental Sciences at Oklahoma State University.

I understand that

1. I will be participating in research at the Food & Agricultural Products Research & Technology Center at Oklahoma State University. The purpose of the research is to test the sensory qualities of a calcium-fortified pasta-type product made with defatted peanut flour.
2. The sensory panel will be drawn from faculty, staff, and students of Oklahoma State University.
3. The study will take place during the 2002 school year.
4. Participation or non-participation in this study will in no way affect my grade or performance rating; but by participating in this research I will see how sensory evaluation can contribute to scientific research in food product development as well as encourage economic development within the peanut industry.
5. I will be informed of all foods and ingredients that I will be asked to evaluate. If I know or suspect that I am allergic to any of them, I will withdraw myself from testing this product.
6. A code number will record all results obtained from my participation in this research. My identity will be kept confidential, and I will not be identified as an individual or by response in any presentation of the results.
7. My participation is voluntary, and I have the right to withdraw from this study at any time with no penalty by contacting the principal investigators.
8. I have not waived any of my legal rights or released this institution from liability or negligence.

I may contact Dr. Margaret Hinds at (405)744-5043 or Deborah Hardy (405)377-7141 should I need further information. I may contact Sharon Bacher, IRB Executive Secretary, Oklahoma State University, 415 Whitehurst, Stillwater, OK 74078 at (405) 744-5700.

I have read and fully understand this consent form. I sign it voluntarily. A copy has been given to me.

Date:____________________________ Time:____________________________(am/pm)

Signed____

I certify that I have personally explained all elements of this form to the subject before requesting the subject to sign it.

Signed____
(Project director of authorized representative)

Printed Name____
(Project director of authorized representative)

APPENDIX 7 – SURVEY

PANELIST ___________ SAMPLE# ___________ DATE ___________

PLEAST RINSE YOUR MOUTH WITH WATER.

FOR EACH OF THE FOLLOWING, PLEASE CHECK ONE APPROPRIATE BOX.

1. GENDER: [ ] MALE [ ] FEMALE

2. AGE (YEARS): [ ] 18-25 [ ] 26-39 [ ] 40-55 [ ] 56+

3. HOW MANY TIMES PER MONTH DO YOU CONSUME PASTA PRODUCTS?

   [ ] ≤4 [ ] 5-8 [ ] 9-12 [ ] 13-16 [ ] ≥17

4. OBSERVE THE SAMPLE AND CHECK THE BOX WHICH BEST DESCRIBES YOUR FEELINGS ABOUT ITS **APPEARANCE**

Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

5. SNIFF/SMELL THE SAMPLE AND CHECK THE BOX WHICH BEST DESCRIBES YOUR FEELINGS ABOUT ITS **AROMA**.

Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

6. CHEW ONE OR MORE BITES AND CHECK THE BOX WHICH BEST DESCRIBES YOUR FEELINGS ABOUT

EACH OF THE FOLLOWING ATTRIBUTES OF THE SAMPLE.

A) **TASTE**:

Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

B) **TEXTURE**:

Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

C) **AFTERTASTE**:

Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

7. WHAT WOULD BE YOUR **PURCHASE INTENT** REGARDING THIS PRODUCT.

Definitely would buy	Probably would buy	May or May not buy	Probably would not buy	Definitely would not buy
[ ]	[ ]	[ ]	[ ]	[ ]

2

VITA

Deborah Hardy

Candidate for the Degree of

Master of Science

Thesis: OPTIMIZATION AND SENSORY QUALITY OF A PEANUT-BASED CALCIUM FORTIFIED PASTA

Major Field: Nutritional Sciences

Biographical:

Personal Data: Born in Mesa, Arizona, on August 6, 1964, the daughter of Paul and Barbara Hardy.

Education: Graduated from Stillwater High School, Stillwater, Oklahoma in May 1982; received Bachelor of Science degree in Nutritional Sciences from Oklahoma State University, Stillwater, Oklahoma in December 2000. Completed the requirements for the Master of Science degree with a major in Nutritional Sciences at Oklahoma State University in August, 2003.

Experience: Medical transcriptionist at Warren Clinic Incorporated and Stillwater Medical Center from 1991 to 2001; Dietetic Intern at Marriott/United States Postal Convention Center, Norman Oklahoma 2000; Dietetic Intern at St. Francis Medical Center, Tulsa, Oklahoma 2002; Graduate Research/Teaching Assistant, Department of Nutritional Sciences, Oklahoma State University, June 2000-December 2002.

Professional Memberships: American Dietetic Association; Oklahoma Dietetic Association; Institute of Food Technologists; American Peanut Research and Education Society.