OPTIMIZATION AND ACCEPTABILITY OF MEATLESS CHICKEN NUGGET ANALOGS PREPARED FROM TEXTURED PEANUT

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Chapter 1 Introduction

Peanuts (*Arachis hypogaea L.*), members of the legume family, contain approximately 26% protein and 48% of fat (USDA, 2006). However, peanuts contain no cholesterol and are high in monounsaturated fat which might play a role in reducing the risk of cardiovascular disease (American Peanut Council, 2006b; Deshpande, *et al.*, 2005; Alper and Mattess, 2003; Kris-Etherton *et al.*, 1999). Additionally, peanuts contain six dietary vitamins and seven dietary minerals necessary for our body to function (American Peanut Council, 2006).

The United States (US) is the third largest producer of peanuts in the world after India and China. In the US, the peanut crop is mainly consumed as peanuts, peanut butter and peanut candy (American Peanut Council, 2006a). Other kinds of peanut fortified foods have also been developed in bakery, beverage and confectionery sectors throughout the years (American Peanut Council, 2006a; Hinds, 2003; Anderson and Jones, 1999; Prinyawiwatkul *et al.*, 1993; Holt *et al.*; 1992a, b; Chompreeda *et al.*, 1988; McWatters, 1986).

Many consumers throughout the world, especially in developing countries, have traditionally consumed vegetable protein as a replacement for animal protein (Mogelonsky, 2005; Merli, 1999; Chompreeda *et al.*, 1988). The peanut is a protein-rich

food which can be a good meat substitute for human consumption and would be more economical for persons who cannot afford expensive animal forms of protein.

1.1 Problem Statement

Most of the harvested peanuts in United State (US) are used as edible foods (peanuts, peanut butter, peanut candy and etc) and about 12% of harvested peanuts are utilized to manufacture peanut oil (American Peanut Council, 2006a). However, about 60% of harvested peanut outside of the US are used for oil extraction (Lusas, 1979). The processing of peanut oil extraction yields a protein rich co-product which could be used for human consumption. Food fortified with defatted peanut flour has been studied widely to improve nutritional value in food products (Hinds, 2003; Anderson and Jones, 1999; Prinyawiwatkul *et al.*, 1993; Holt *et al.*; 1992a,b; Chompreeda *et al.*, 1988; McWatters, 1986). Furthermore, textured peanut produced from twin screw extrusion processing has a meat like appearance and bland flavor that would facilitate its value-added utilization as a meat analog (Hinds *et al.*, 2003).Therefore, chicken nugget meat analogs prepared from textured peanut can provide protein rich, low saturated fat and nutrient dense meat alternative products for consumers.

1.2 Objectives

The main aim of this study is to investigate the formulation to develop meatless chicken nugget analog from textured peanut that would be acceptable to consumers. The specific objectives are as follows:

- Investigate the kinds and levels of chicken flavor, dried plum puree and coating to be incorporated in the meatless chicken nugget analog.
- Evaluate physical properties (color, texture, water activity and moisture) of the meatless chicken nugget analog made from textured peanut as affected by chicken flavor, dried plum puree and coating.
- Evaluate sensory acceptability of the meatless chicken nugget analog prepared from textured peanut.
- Predict the optimum level of chicken flavor, dried plum puree and coating mix to be used to produce acceptable meatless chicken nugget analogs.

1.3 Hypotheses

The null hypotheses proposed for this study are as follows:

- The physical properties of the meatless chicken nugget analog prepared from textured peanut will not be significantly affected by chicken flavor, dried plum puree and coating mixture.
- There will be no significant difference in sensory acceptability between the meatless chicken nugget analogs prepared from textured peanut and a commercial soy–based nugget.

Chapter 2 Review of Literature

2.1 Review of Peanuts

2.1.1 Overview of peanuts

Peanuts (*Arachis hypogaea L.*) also known as groundnuts and ground peas belong to the legume family and not the nuts family. The peanut plant is a shrub with flowers above the ground but the pods matures underground. There are many varieties of peanuts in the world; however, the common types of peanuts available in US market are Runner, Virginia, Spanish and Valencia (American Peanut Council, 2006a). Since peanuts are plants, they contain no cholesterol, are low in saturated fat but high in unsaturated fat. Peanuts contain six dietary vitamins (vitamin E, niacin, folate, B1, B2 and B6) and seven dietary minerals (magnesium, copper, phosphorous, potassium, zinc, iron and calcium) necessary for our body to function (American Peanut Council, 2006b).

Peanut is a protein rich food. Peanut seed contains 22% to 30% crude protein. The main protein fractions in peanut seed are arachin and conarachin. Additionally, the amino acid composition of peanut proteins are Aspartic Acid, Serine, Glutamic Acid, Proline, Tyrosine, Phenylalanine, Glycine, Alanine, ½-Cystine, Methionine, Arginine, Threonine,

Isoleucine, Leucine, Lysine, Valine, Histidine and Tryptophan (Ahmed and Young, 1982). Twenty common amino acids are required for protein synthesis and eight of them are considered essential because they cannot be synthesized in adequate quantities by human cells to meet metabolic requirements. Those eight essential amino acids are Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan and Valine (Rasco and Zhong, 2000). Vegetable proteins are considered to be lower quality than meat proteins because they contain one or more of the essential amino acids in unfavorable quantity. Peanut is limited in Lysine, Methionine and Threonine (Freeland-Graves and Peckham, 1995). However, the peanut protein is less expensive compared with other protein-rich foods such as red meat, milk and cheese (Lusas, 1979). As a result, USDA Food Guide Pyramid includes peanuts as one of the foods in its meat and beans categories. Hence, peanut products are good meat substitutes for vegetarians to consume and are more economical for persons who cannot afford expensive animal forms of protein (FNIC, 1996).

2.1.2 Health Benefits of Peanuts

Some consumers believe that eating peanuts will lead to weight gain, and avoid eating peanuts (Jolly *et al.*, 2001). However, research studies have shown that consumption of peanuts provides many positive health benefits. Peanuts consist of a combination of saturated and unsaturated fatty acids. Approximately 80% of the fat in peanuts consists of unsaturated fatty acids, mainly monounsaturated fatty acids, whereas only 20% is saturated fatty acids (American Peanut Council, 2006b). Kris-Etherton *et al.* (1999) conducted a study comparing high monounsaturated (MUFA), cholesterol

lowering diets with the American Heart Association/National Cholesterol Education Program Step II diets. Step II diet is a low saturated fat (< 7% of the day's total calories from saturated fat) and low cholesterol (< 200mg of dietary cholesterol a day) diet. The results of the study showed that both high MUFA and Step II diets lowered total cholesterol and low density lipoprotein (LDL) cholesterol. However, high MUFA diets did not lower high density lipoprotein (HDL) cholesterol, the beneficial cholesterol, whereas the step II diet did. Hence, they suggested that diets high in MUFA, such as peanuts, might potentially decrease the risk of cardiovascular disease (CVD). Compared with other high MUFA foods, peanuts are also rich in other beneficial nutrients that contribute to maintain a healthy diet (Kris-Etherton *et al.*, 1999).

Another study (Alper and Mattess, 2003) also provided evidence regarding regular peanut consumption and decreased risk of CVD. The results of that study also indicated that regular peanut consumption lowers serum triacyglycerols, augments consumption of nutrients associated with reduced CVD risk, and increases serum magnesium concentration (Alper and Mattess, 2003). Additional studies (Hu *et al.*, 1998; Fraser *et al.*, 1992) have also shown the relationship between peanut consumption and potential for reduced CVD risk. The Food and Drug Administration (FDA) has affirmed the claim that nuts including peanuts when consumed regularly may reduce the risk of heart disease (Virginia-Carolina Peanuts, 2003).

Peanuts contain six essential vitamins such as vitamin E, niacin, folate, B1, B2 and B6 (American Peanut Council, 2006b). Vitamin E is a well known antioxidant to defend against the harmful free radicals. Research findings have indicated that vitamin E found in peanuts may reduce the risk of heart and lung disease as well as cancer by

preventing LDL oxidation (Forcinio, 2000). Also, consumption of vitamin E from natural food sources versus from supplements appears to be as effective in terms of protecting against coronary heart disease (Kushi *et al.*, 1996).

Peanuts are considered a good source of folate and research has shown that diets with peanuts help increase the dietary folate intakes in subjects (Alper and Mattes, 2003). Selhub *et al*. (1995) indicated that folate plays a role in breaking down homocysteine which consequently can decrease the risk of atherosclerosis (Selhub *et al.*, 1995). Also, pregnant women with adequate intakes of folate have been discovered to have lower risk of neural tube defects in the fetus (Morrison *et al.*, 1996).

A research study directed by Dr. Stephen T Talcott (2005) indicated that peanuts are a good source of antioxidants such as p-coumaric acid. Also, the antioxidant capacity in roasted peanuts was higher than in raw peanuts (Talcott *et al.*, 2005). The results of a previous study by Zang *et al.* (2000) with male rats indicated that p-coumaric acid is a powerful ·OH (hydroxyl radical) scavenger. Therefore, p-coumaric acid may contribute to preventing LDL oxidation and reducing serum cholesterol levels. However, further research regarding the mechanisms of p-coumaric acid acting as an antioxidant needs to be carried out (Zang *et al.*, 2000).

Peanuts are a good source of fiber (American Peanut Council, 2006b). Fiber is known to lower blood cholesterol by binding with bile acids, and enable liver to use cholesterol to make new bile acids. Thus, fiber may help reduce the risk of heart disease (Anderson *et al.*, 1994; Arjmandi *et al.*, 1992). Furthermore, fiber also plays a role in controlling blood sugar levels and reducing the risk of diabetes. The results of a cohort study (Jiang *et al.*, 2002) of 83818 healthy women indicated that women who consumed

nuts or peanut butter have lower tendency of getting diabetes. In addition, women who consumed peanut butter five times or more per week decreased their risk of diabetes by 21% more than women who never consumed peanut butter. Thus, it was concluded that higher consumption of nuts and peanut butter has potential to decrease the risk of diabetes in women. Furthermore, the cohort study found that frequent nut consumption, including peanuts did not contribute to weight gain (Jiang *et al.*, 2002).

2.1.3 Usage of Peanut Flour in Food Products

Peanuts are important for oil extraction and peanut butter manufacture (American Peanut Council, 2006a; Lusas, 1979). Peanut oil extraction produces a protein-rich by-product (called peanut press cake) which could be used for human consumption. Most of this peanut press cake from oil extraction is used as animal feed or discarded (Hinds *et al.*, 2003). Many researchers are trying to utilize this protein dense by-product by incorporating it into human diets as defatted peanut flour or extruded peanut grit. In 1974, J.L Ayres directed a study using a modified prepress solvent extraction plant to manufacture edible peanut flour and grits from peanut press cake (Ayers *et al.*, 1974). The edible peanut flour and grits were used to make a sugar frosted cereal, and incorporated into beef patties. The peanut flour was considered as a good ingredient for cereal and snack food because of its high expansibility. Besides, the bland flavor and light tan color of peanut flour and grits facilitate their use in a wide variety of foods (Ayres *et al.*, 1974).

Peanut flour has been used as a substitute in several fried and baked foods such as muffins, chips, cookies, and doughnuts (Hinds, 2003; Holt *et al.*, 1992a; McWatters,

1986). Partially defatted peanut flours, roasted at 160°C for 15 minutes were able to produce peanut chips with good cohesiveness (McWatters, 1986). High temperature roasting of defatted peanut flours would destroy the flours' cohesiveness. Furthermore, wheat flour cookies made with at least 30% of peanut flours have similar physical and sensory characteristics to the 100% wheat flour cookies. Moreover, cookies with 30% peanut flours have 4.5% more total protein content than 100% wheat flour cookies (McWatters, 1986). Dr. M.J. Hinds (2003) conducted a study of wheat flour muffins containing peanut flour and peanut butter. The results of the study showed that muffins with optimum texture and volume contained 0% peanut flour and 32% peanut butter or 30% peanut flour and 15% peanut butter or 61% peanut flour and 0% peanut butter (Hinds, 2003). Also, quality of muffins prepared from combinations of wheat, cowpea, peanut, sorghum and cassava flours indicate the potential of using composite flours for bakery (Holt *et al.*, 1992a).

Peanut flours are also used as an ingredient to make extruded snacks, short pasta, meal bar, tortillas and Chinese-type noodles (Asare *et al.*, 2004; Hardy, 2003; Anderson and Jones, 1999; Prinyawiwatkul *et al.*, 1993; Holt *et al.*, 1992b; Chompreeda *et al.*, 1988). Anderson and Jones (1999) recommended use of peanut flour as an ingredient to make a meal bar because peanut is a nutritious and energy rich food (Anderson and Jones, 1999). Holt *et al.* (1992b) concluded that tortillas with up to 24% cowpea, 46% defatted peanut flour and 30% wheat flour have similar characteristics to 100% wheat flour tortillas (Holt *et al.*, 1992b). Furthermore, Chinese-type noodles were produced with an optimum formulation of 15% defatted peanut flour, 8% cowpea flour and 77% wheat flour (Chompreeda *et al.*, 1988). These noodles have an increased protein content

of approximately 21%. Besides, the results from a contour plot of protein content showed that the increase in protein content in noodles was greatly influenced by the level of peanut flour (Chompreeda *et al.*, 1988). The study of peanut-based calcium-fortified pasta (Hardy, 2003) suggested that a pasta-type product containing 20% peanut flour and fortified with approximately 25% of the RDA for calcium per 56g serving has the potential for commercial production (Hardy, 2003). Additionally, sensory evaluation of an extruded peanut-cornstarch snack showed that this snack has high potential for sale due to higher nutritive value in the product than most snacks (Prinyawiwatkul *et al.*, 1993).

2.2 Extrusion Processing in the Food Industry

Extrusion processing has been used extensively in many industries ranging from food to medical tubings and to plastics because several functions such as mixing, forming, cooking, puffing and drying may be performed inside the extruder machine. It is easier and more economically for a manufacturer to produce quality products using extrusion than other processes. Besides, the extruder machine has the ability to incorporate a variety of ingredients into the final product with different shapes and sizes (Eastman *et al.*, 2001). However, an extruder is more appropriate for materials which exhibit complex responses to temperature, pressure and shear forces (Smith, 1979).

The extrusion process includes an ingredient feeding system and extruder. The ingredient feeding system is important to control the feed rate, and for pre-treating ingredients when necessary. The extruder is the main body in an extrusion process and its barrel has various designs. However, the two most popular kinds of extruder used in the

food industry are single-screw and twin-screw extruders, the barrels of which contain one or two screws, respectively. They are used in making ready-to-eat cereals, snacks, confectionery products, texturized vegetable protein, macaroni and pet foods (Harper, 1989). Robert Straka (1985), research associate in extrusion technology for Nabisco Brands, Inc., mentioned in Cereal Foods World that single-screw extruders cost less but have some limitations in accomplish and maintain steady conditions for extrusion process in breakfast cereal and snack items. He recommended using twin screw extruders in state of single-screw for their ability in controlling screw speed, material distribution, temperature and product output. However, the choice of whether to use single or twin screw extruder still depends on individual circumstances (Straka, 1985).

The functions of the screw inside the extruder barrel are to mix, push and press continuously the materials fed into the extruder. Single screw extruders are more likely to cause material blocking inside the extruder barrel, but this can be prevented when using twin screw extruder. The interaction of both screws enhances mixing, pushing and prevents sticking of material to the screw (Senanayake and Clarke, 1999). Therefore, twin screw extruders can be use to process formulations with low moisture content and gummy material.

The Uni-Tex extrusion process can successfully produce meat analogs using defatted flours or concentrates of soy, peanut and seeds. These meat analogs have the structure, appearance and mouthfeel of meat. Besides, one pound of rehydrated meat analog yields 2.5 lb of meatlike food with similar moisture and protein content as meat (Smith, 1979). Suknark *et al.* (1999) developed snack foods by combining tapioca with catfish and tapioca with partially defatted peanut flour using a twin screw extruder. The

results of the research concluded that tapioca-fish and tapioca-peanut snacks can be successfully made using a twin screw extrusion process (Suknark *et al.*, 1999).

Neil H. Mermelstein (2000) has reported on two extruder manufacturers regarding their special extrusion process in making textured protein. The Specialty Proteins, L.L.C. Company uses a high temperature/short time single screw extrusion process to product textured soy protein. The company claims that the process eliminates the beany flavor of the soy protein because the lipoxygenase is being destroyed in the high temperature environment. However, the high temperature process does not denature the protein itself due to short residence time. Furthermore, the textured soy protein can be made into various particle sizes, flavors, and colors and used as a meat substitute or meat alternatives. In addition, Clextral, Inc., Tampa, Fla., uses a high-moisture extrusion cooking process twin screw extruder to make meat and fish analogs. The company claims that the process can produce textured protein in various shapes including fibers with real meat texture, taste and mouthfeel (Mermelstein, 2000). Extrusion processing has a bright future due to its ability to produce wide variety of food products.

2.3 Extrusion Processing of Peanuts

High-shear extrusion processing imparts a textured or fibrous structure to proteinaceous materials of plant origin such as peanuts (Pham and Rosario, 1984). A research study by Ayres *et al*. (1974) revealed that edible defatted peanut flour could be a potential ingredient used in cereal and snack foods because it has excellent extrusion-expansion characteristics. Furthermore, edible defatted peanut flour and grits have light

tan color, bland and no beany flavor that facilitates them to be used at high levels in a wide range of food products (Ayer *et al.*, 1974).

Texturized products were successfully produced by thermoplastically extruding defatted peanut flour using twin screw extruders (Aboagye & Standley, 1987); and the textured peanut had sub-threshold flavor compounds (Hinds *et al.,* 2005a). Moreover, texturization of defatted peanut flour by using thermoplastic extrusion (Wenger X-25 extruder) did not have any significant effect on the peanut protein. Proximate analysis of texturized peanut made from defatted peanut flour (53.1% protein) contained approximately 52.5% protein (Alid *et al.*, 1981). Hence, texturized peanut made from defatted peanut flour could be a valuable source of vegetable protein.

Extruded peanut snacks made from combination of tapioca and partially defatted peanut flour has pale yellow to light brown color and high shear strength. In addition, these peanut snacks extruded by a twin screw extruder were liked moderately in overall acceptance by Asian and American consumers (Suknark *et al.*, 1998). On the other hand, a baked meat analog product formulated with 60% ground textured peanut protein, 40% wheat gluten, 50% water and 1.75% liquid pork flavor was found to be accepted by consumers in Thailand (Chompreeda *et al.*, 1995).

Textured peanut protein has also been used to make beef patties. Hinds *et al.* (2003) conducted a study of beef patties extended with texturized peanut protein. The results of the study indicated that texturized peanut protein extruded by a twin screw extruder (Wenger TX-52) has the potential to be used as a meat extender. Beef patties formulated with up to 80% textured peanut had light brown color, higher moisture contents and similar textural attributes to 100% beef patties (Hinds *et al.*, 2003). In

another study (Hinds *et al.,* 2005b) binders were incorporated in 100% textured peanut patties to improve texture of the patties. The optimum formulation for 100% textured peanut patties was 2:3 ratio of texturized peanut protein and water, 1.13% to1.27% Carrabind 80A and 1.25% to 1.46% Colloid Bind I-96 (Hinds *et al.,* 2005b). Furthermore, textured peanut of 60% protein, 55% moisture produced at extrusion conditions of 165°C and 90rpm screw speed could be used as beef replacement (Rehrah *et al.*, 2005). This research study indicated that the peanut based ground beef made from the textured peanut was acceptable by panelists and was compatible with a commercial meat product (Rehrah *et al.*, 2005).

2.4 Meat Alternative Market Potential

True vegetarians in United States only represent 1-2% of the population (Egbert and Borders, 2006). However, the meat alternative market has been growing tremendously for the past few years and more meat alternative products are available in the market in different forms including chili, hotdogs, nuggets and burgers. In 1999, Frozen Food Age Magazine reported that Gardenburger Inc. had an 82% dollar sales increase for its flagship vegetable burgers compared with the sales in 1998 (Merli, 1999). Subsequently, Kraft Foods meat alternative category grew by 12% in 2001-2002 (Wishnow, 2002). Marcia Mogelonsky, analyst with Mintel International, reported that frozen meat substitutes had $273.8 millions sales in 2003 through food, drug and mass merchandisers (Mogelonsky, 2005). Increase in demand and sales indicated that the meat alternative category is more ordinary than before. In today's world, meat alternative products are not just limited to vegetarians. Occasional vegetarians are also potential

customers for the meat alternative industries to target. Don Lodemann, previous marketing manager for Green Giant Harvest Burgers, says that "Some companies have been producing meat alternative since the 1930s. But, their marketing has always been directed towards vegetarians only." Another research showed that 53% of American revealed that they were eating less red meat than before (Frozen Food Age, 1996). Therefore, meat alternative industries should really target on worldwide market instead of just vegetarians.

People are more likely to eat healthier foods which offer a great opportunity for the growth of meat alternative category. As people get older, they tend to avoid high fat diets or even choose meat free diets. However, people other than baby boomers are also paying more attention to their health condition (Merli, 1999). Consumers have started to replace some of the meat with meat alternative because many research studies show that diets high in fat increase the risk of coronary artery disease. Nonetheless, some of the consumers would just want to take a break from meat products or just like the taste of vegetarian foods (Mogelonsky, 2005).

2.5 Plum – as an Ingredient in Meat Products

Dried plum has been used as an ingredient in bakery to substitute fat for years. Recently, several research studies incorporated dried plum into precooked meat products such as turkey breast rolls, beef roast, sausage, hamburger, hotdog, cured ham, and pizza meat topping (Lee and Ahn, 2005; Keeton *et al.*, 2002; Kreuzer, 2001; Keeton *et al.*, 2001; Pszczola, 1999). Research studies showed that precooked meat products with plum mixture turned out to have lower moisture loss, less warm over flavor and less lipid

oxidation throughout long period of warming time. Additionally, dried plum mixture was able to help control food born pathogens in uncooked ground beef and pork sausage and help prevent recontamination in those cooked meat products (Kreuzer, 2001).

Precooked, frozen hamburger patties made with 3% dried plum puree were tested by student panelists as school-lunch foods in a study. The result of the study showed that hamburger patties with 3% dried plum puree were acceptable by students (Keeton *et al.*, 2001). Another research study showed that the optimum usage of dried plum puree in ground beef product was 3% to 5% levels. Meat products within these optimum levels of plum mixture have the best antimicrobial action, best moisture retention, best texture and flavor enhancement (Kreuzer, 2001). Malic acid present in plum mimics the function of fat in food, acts as a flavor enhancer, and improves mouthfeel (Kreuzer, 2001). Therefore, plum might be an important ingredient to be included in a reduced fat product.

Other than beef product, a research study that made precooked pork sausage with 3% and 6% levels of dried plum puree was conducted at the Texas A&M University. The results of the study showed that precooked pork sausage with 3% and 6% levels of dried plum puree have higher moisture content, lower fat content and less lipid oxidation than the sausage without dried plum puree. Besides, trained panelists revealed that plum puree helps in decreasing salt and bitter taste in the cooked sausage. Consumer panelists rated the pork sausage with 6% dried plum puree as less acceptable; but, pork sausage with 3% level of dried plum puree was as acceptable as the control (Keeton *et al.*, 2001).

Additional study incorporating plum in meat products was also done at Texas A&M University. Dried plum juice concentrate, fresh plum juice concentrate and spray dried plum powder at 2.5% to 5% levels were injected into roast beef and cured ham. The

results of the study concluded that plum ingredients at any levels were not recommended to be used in making cured ham. Roast beef with fresh and dried plum juice concentrate were acceptable; however, incorporation of spray dried plum powder into roast beef at any level was not recommended (Keeton *et al.*, 2002). Since plum can contribute several benefits to improve the quality of the meat product, it would be nice to add plum as an ingredient in meat product.

2.6 Review of Sensory Evaluation

2.6.1 Importance of Sensory Evaluation

Consumers make their food choices in the market based on personal preference and previous experience with particular kinds of foods. Therefore, it is very important to incorporate sensory evaluation in the process of inventing, improving and maintaining food product quality. Sensory evaluation is 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, 1985). The results of sensory evaluation give food manufacturers valuable information regarding consumer preference of similar food items and leads to more acceptable formulation and higher quality products (Moskowitz, 1995).

Conducting consumer evaluation of new or improved food products in the market not very effective and is very expensive. Usually, preliminary research creating new or improving existing products would be carried under the guidance of food specialists. Prior to market testing, food specialists conduct in-house testing which they have

conscientiously planned and eliminated substandard product formulations. In-house testing is an evaluation conducted within a research center or company. This kind of testing can include as little as 4 to 12 participants or as many as 200 to 500 participants at a specific location (McWilliams, 2001). However, the results of in-house testing can not be assumed to represent the opinions of the entire general public. Instead, in-house testing measures the acceptability of the product by persons who are involved in the evaluation. Hence, narrowing down product formulations prior market testing is more cost efficient.

2.6.2 Types of Sensory Evaluation Tests

There are considerable numbers of different sensory evaluation methods and new methods continue to be developed. However, three common types of sensory evaluation are descriptive testing, preference testing and difference testing. According to Margaret McWilliams (2001), "Descriptive testing is a sensory testing designed to provide information on selected characteristics of food samples"; "Preference testing is a sensory testing to determine acceptability or preference between products"; "Difference testing is a sensory testing designed to determine whether detectable differences exist between products" such as paired comparison, duo-trio and triangle tests. Among these three types of tests, preference testing is more useable in developing new food product and predicting new food product markets.

Consumer preferences determine successfulness of food products in the market. Therefore, consumer panels are usually used in preference testing. Consumer panels are people who are willing to participate in the testing and happen to be available at a test site

(McWilliams, 2001). Panelists who participate in sensory evaluation can be either trained or untrained. Usually, consumer panels are untrained panels that do not go through any training regarding the testing.

2.6.3 Hedonic Scale

There are considerable numbers of scales to be used in sensory evaluation. Depending on the information researchers would like to gather, scales with different styles need to be constructed for a specific research. Generally there are four basic categories of scales; Nominal scales, Ordinary scales, Interval scales and Ratio scales. The differences between these scales are that their measurements are based on classification, ranking and magnitude with either equal distance or ratio, respectively. Usage and limitation of each type of scales is discussed by Stone and Sidel (1985).

Hedonic scale is a special kind of interval rating scale with numbers and wording. It is suitable for use with panelists without prior experience in food testing due to its simplicity and ease to understand. Peryam and Pilgrim (1957) developed a nine-point hedonic scale for preference testing. Several research studies have been conducted to evaluate the usefulness of this nine-point hedonic scale in assessing products in term of like and dislike (Elper *et al.*, 1998; Pangborn and Guinard, 1989; Moskowitz and Sidel, 1971). Those studies concluded that the nine-point hedonic scale can provide reliable and valid results. Hence, the nine-point hedonic scale are most commonly used in food research, especially to obtain information about product acceptance and product preference (Deshpande *et al.*, 2005; Park *et al.*, 2005; O'Mahony *et al.*, 2004).

2.7 Experimental Design

Experimental design in sensory evaluation is a plan that indicates the serving order of products to panelists. Good experimental design with appropriate statistical analysis will yield meaningful research conclusions. However, poor experimental design with appropriate statistical analysis will generate research conclusions that can be misleading (Huang and Anderson, 2003).

Different types of experimental designs that can be use in food research such as completely randomized design, randomized-complete-block design, randomized-balanced-incomplete-block design and nested-incomplete-block design (Deshpande *et al.*, 2005; Huang and Anderson, 2003; Deppe *et al.*, 2001; Stone and Sidel, 1985; Ball, 1997). The fundamental principle of a good experimental design is randomization. A randomized design has the tendency to reduce the risk of bias. Of all the different experimental designs, randomized-complete-block design is preferred because it allows all products to be served equally often in all positions across panelists and with an arrangement that requires the least number of panelists (Deshpande *et al.*, 2005; Stone and Sidel, 1985). However, there are some situations when it is impractical to use randomized-complete-block designs such as evaluating five or more products. In this case, randomized-balanced-incomplete-block design would be more preferable to shorten the amount of time required for evaluation and limit the number of products a panelist needs to evaluate to prevent sensory fatigue (Ball, 1997; Moskowitz and Krieger, 1995). For a randomized-balanced-incomplete-block design, each panelist will not evaluate all of the products. However, each product will appear equal number of times in each section and will be evaluated an equal number of times overall. More information regarding

experimental design considerations and criteria for food research can be found in Stone and Sidel (1985) and Huang and Anderson (2003).

2.8 Response Surface Methodology

Response Surface Methodology (RSM) is a statistical procedure used in optimization studies to determine and solve multivariate problems (Madamba, 2002). It comprises a group of statistical techniques for empirical model building and model exploitation. By careful design and analysis of experiments, it seeks to relate a response variable to the levels of a number of predictors that affect it (Box and Draper, 1987). RSM generates equations that describe the effects of the independent or test variables on the responses, determine the relationship among the test variables and represents the combined effect of all test variables in the response (Madamba, 2002). Quantitative data collected from experimental design are analyzed using multiple regressions to determine unknown model parameters and create a predicted response function (Osborne and Armacost, 1996). If model adequacy is assured, the surface is mapped and optimum factor settings are identified (Osborne and Armacost, 1996).

Chapter 3 Methodology

3.1 Preliminary Study

3.1.1 Nugget Materials and Formulations

The ingredients used to prepare the nugget formulations were either donated or acquired from manufacturers and local grocery stores. Table 1 below shows the ingredients source for each ingredient used to make nuggets. The textured peanut used in this study was prepared by twin-screw extrusion (Wenger TX-52 twin screw extruder, Wenger Manufacturing Inc., Sabetha, Kansas) of defatted peanut flour (Hinds *et al.,* 2005a).

Three independent variables selected in this study were meat flavor, dried plum puree and coating mix. In addition to the three variables, the level of textured peanut, the amount of binders and rehydrated parameters were fixed based on the previous study (Hinds *et al.,* 2005b). The nugget formulation which includes the ingredients and seasonings are shown in Table 2 below.

Table 1: Preliminary Ingredients Sources

Ingredient	Source
Textured Peanut (containing ~6% peanut oil)	Texas A&M University (Collaborator)
Colloid Binder (TIC Pretested® Colloid Bind I-96)	TIC Gums, Belcamp, Maryland (Donor)
Carrageenan Binder (CarraBind 80A Carrageenan)	Carrageenan Company, Santa Ana, California (Donor)
Asian Chicken Powder	JMH International, INC, Park City, Utah (Donor)
Powdered Chicken Base	JMH International, INC, Park City, Utah (Donor)
Powdered Beef Base	JMH International, INC, Park City, Utah (Donor)
Dried Plum Puree	California Dried Plum Board, CA (Donor)
Great Value Drinking Water, Dextrose, Great Value Garlic Powder, 5th Season Onion Powder, McCormick Paprika, 5th Season Italian Seasoning, Great Value Noniodized Salt, Kitchen Bouquet Browning & Seasoning Sauce, Lea & Perrins Worcestershire Sauce	Local Grocery Stores (Sellers)

Table 2: Preliminary Nugget Formulation

Ingredients	Ratio (%)
Textured Peanut	1
Water	1.5
Carrageenan Binder	1.25
Colloid Binder	1.35
Dextrose	1
Garlic	0.17
Onion Powder	0.13
Paprika	0.04
Italian Seasoning	0.014
Salt	0.052
Browning	2
Lea & Perrins	1
Meat Flavor	Vary
Plum	Vary
Coating	Vary

Initially, ten experimental nugget formulations were made according to the formulation in Table 2 with different levels of dried plum puree and meat flavor which consists of Asian chicken powder (CA), powdered chicken base (CB) and powdered beef base (CB). Table 3 below shows the variation in the amount of meat flavor and dried plum puree for the initial ten nugget formulations. The percentage of meat flavor and dried plum puree in Table 3 is equivalent to the percentage of the total weight for the textured peanut and water used in the formulation. Different levels of coating types are applied for each nugget formulation as described in Section 3.1.4.

Table 3: Level of Meat Flavor and Dried Plum Puree for Experimental Nugget Formulations in Preliminary Study

Formulation Code	Meat Flavor	Dried Plum Puree
CA1	2.5% Chicken Powder	0%
CA2	5.0% Chicken Powder	0%
CB1	2.5% Chicken Base	0%
CB2	5.0% Chicken Base	0%
BB1	2.5% Beef Base	0%
BB2	5.0% Beef Base	0%
CA3	3.0% Chicken Powder	0%
CA4	4.0% Chicken Powder	0%
CA5	5.0% Chicken Powder	0%
4MCAP2	4.0% Chicken Powder	1%

3.1.2 Nugget Preparation

The nuggets were prepared according to the steps outlined in Figure 1. Textured peanut (TP), colloid and carrageenan binders were mixed for 2 minutes using either home style double action mixer (Kitchen Aid Stand Mixer, Model KS45SS, St. Joseph, MI) or single best double action mixer (Leland Southwest Double Action™ Mixer, Model D-100 DA70, Fort Worth, TX). Dextrose, garlic powder, onion powder, paprika, noniodized salt, Italian seasoning and meat flavor were then added and mixed for 3 minutes. If dried plum puree (plum) was being used, it was stirred and dissolved in pre-weighed water for 3 minutes before added into the TP mixture. Together with the remaining pre-weighed drinking water, dissolved plum, Browning & Seasoning Sauce and Worcestershire Sauce were added into the TP mixture. The rehydrated TP and other ingredients were then mixed for 2 minutes and 45 seconds. During the 2 minutes and 45 seconds mixing period, the mixer was stopped at 1 minute intervals to scrape off any TP mixture that was stuck to the wall of the mixing bowl. This action was to ensure all ingredients were uniformly mixed. Well mixed TP mixture was stuffed into presoaked casings (88mm diameter cellulose casing) either by hand or using manual stuffer. Finally, the casings were tied with string, labeled and refrigerated at 4°C (40°F) for later used.

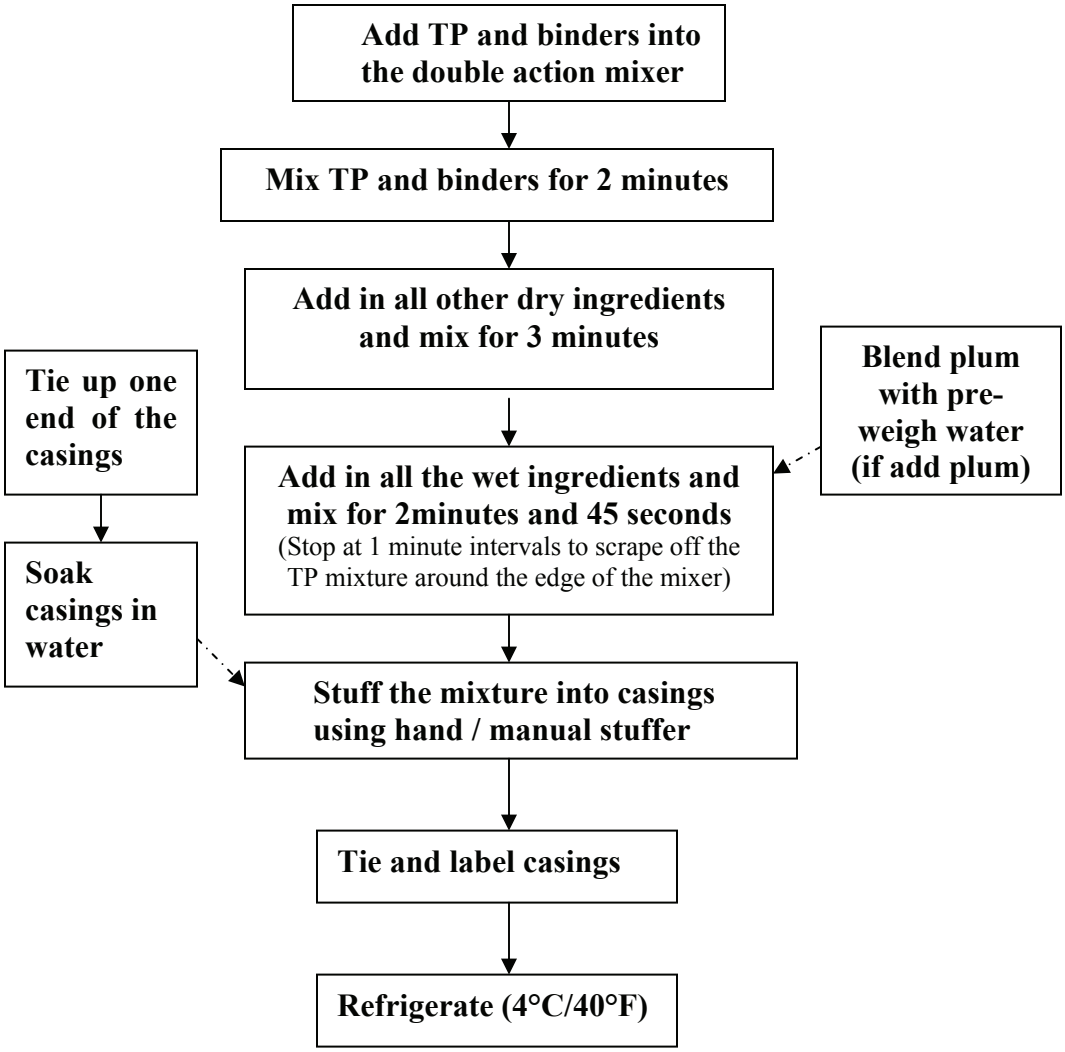


Figure 1: Preliminary Nugget Preparation

3.1.3 Precook Methods

(a) Smoke House Cook

Encased treatments were precooked using a smoke house (Alkar Inc., Series No. 62260399GN1E073, Lodi, Wisconsin) in the pilot plant located at Oklahoma Food and Agricultural Products Research and Technology Center, Oklahoma State University,

Stillwater. The smoke house (Alkar Inc) was set to have steaming cook at 100% relative humidity with 77°C (170°F) oven temperature. Casings were suspended from a stainless steel shelf placed inside the smoke house. A thermometer was inserted into one of the casings to a depth of 10cm, centrally from one end, to measure internal temperature of the products. Once the internal temperature reached 74°C (165°F), the cooking process was stopped, and the encased products were then removed from the smoke house. Precooked encased treatments were kept refrigerated (4°C / 40°F) or frozen (-10°C / 14°F) for at least 1 day before cutting and cooking.

(b) Kettle Cook

Encased formulations were precooked with water cook method in stainless steel kettle (Crown Food Service Equipt. LTD, Series No. AP-1016245-2T-1063, ON, Canada) at pilot plant, Oklahoma Food and Agricultural Products Research and Technology Center, Oklahoma State University, Stillwater. Encased treatments were submerged into preheated water (water temperature about 77°C / 170°F). A digital thermometer (Cox Technologies, Type K) was inserted into one of the casing to a depth of 10cm, centrally from one end, to measure its internal temperature. Water temperature was monitored throughout the cooking process to ensure it stayed at ~77°C (170°F). Once the casings internal temperature reached 74°C (165°F), casings were taken out and kept refrigerated (at 4°C / 40°F) or frozen (at -10°C / 14°F)for later use. Precooked encased formulations were kept refrigerated or frozen for at least 1 day before cutting. Figure 2 illustrates the step-by-step procedure of the kettle cooked nuggets.

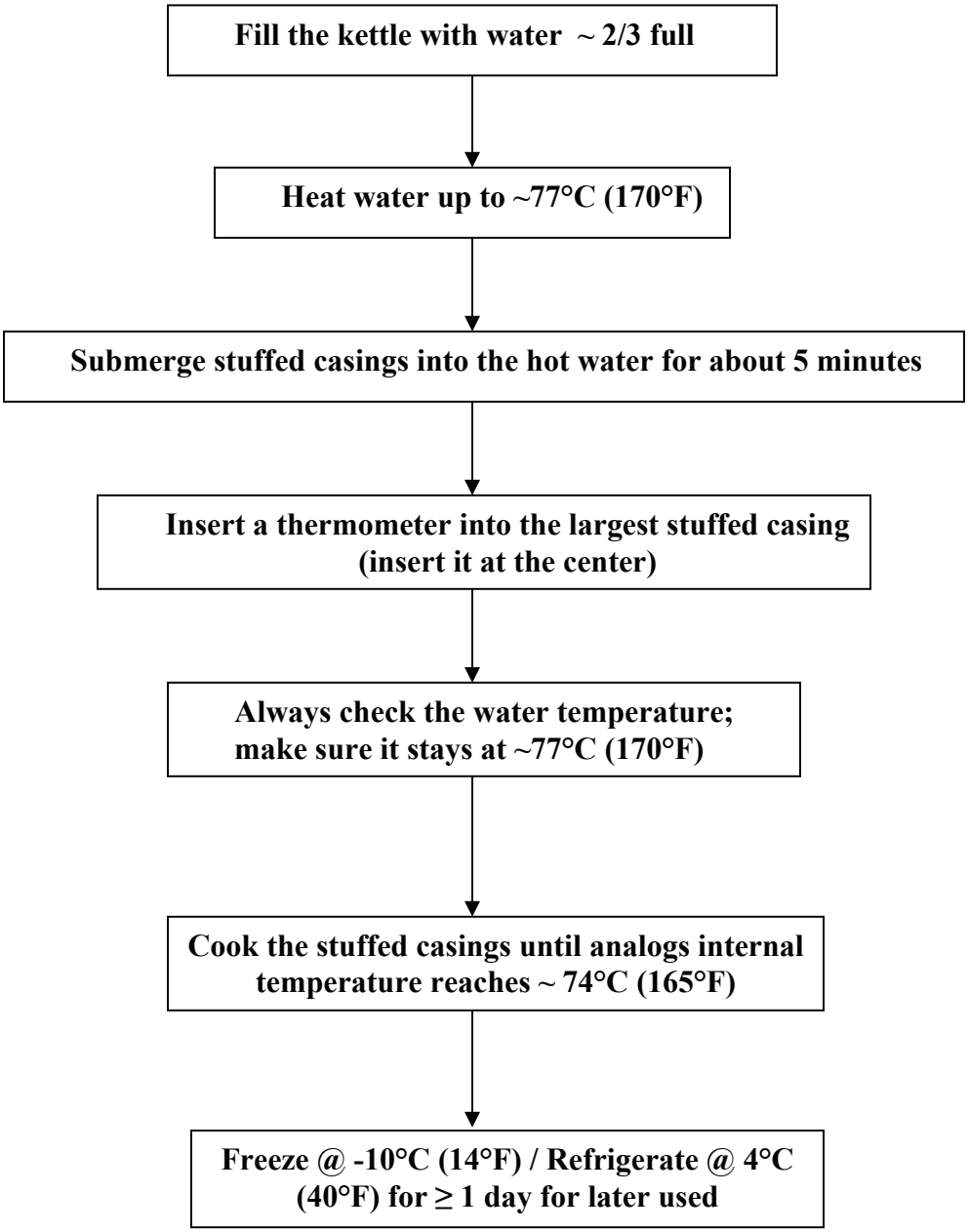


Figure 2*:* Step-by-step Procedure of the Kettle Cooked Nuggets in Preliminary Study

3.1.4 Coating Materials and Cook Methods

As described in Section 3.1.1, the kind and level of coatings for each nugget formulation were varied in the preliminary study to select three optimum levels of coatings that were later used for the main study. Criteria used for selecting the optimum coatings were based on the appearance, flavor and texture that mimic the commercial chicken nuggets. The coating ingredients used in the preliminary study were dextrose, sucrose, buttermilk powder, whey powder, Kraft Shake'N Bake Seasoned Coating Mix Herbs & Garlic, Best Choice Seasoned Coating Mix Chicken, Best Choice Seasoned Coating Mix Pork, Kraft Shake'N Bake Seasoned Coating Mix Original Chicken, Kraft Shake'N Bake Seasoned Coating Mix Original Pork, Kraft Shake'N Bake Seasoned Coating Mix Barbecue Glaze, Don's Chuck Wagon All Purpose Batter Mix, McCormick Golden Dipt Fry Easy Fry Mix All Purpose Batter, Louisiana Fish Fry Products Seasoned Shrimp Fry, vegetable oil, Pam, drinking water, buttermilk and paprika. All of the coating ingredients were purchased from local grocery stores.

Twenty seven coating treatments were tested in the preliminary study and the summary of the coating, cooking method and ingredients for each treatment is shown in Table 4. Precooked encased treatments were cut into ½ inch thick pieces, casings were removed, and then dipped into either buttermilk or water before coating. The nuggets were then cooked based on the manufacturer's instructions for the particular coating. Detailed cooking method for each type and level of coating are showed in Appendix A. After the cooking process was completed, the nuggets were then wrapped in heavy duty foil and held under heating lamps prior to evaluation.

Table 4: Preliminary Coating Treatments (page 40-page 41)

Code	Coating and Cooking Method	Ingredients
P1	Panfry	Pam spray
N2	Bake at 400°F	None
D10	Shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Herbs & Garlic, 10% Dextrose
WN	Paste with water and bake at 400°F	Water
WD10	Paste with water, shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Herbs & Garlic, 10% Dextrose, Water
SN	Bake at 400°F	None
S10	Shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Herbs & Garlic, 10% Sucrose
SB10	Paste with solution, shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Herbs & Garlic, 10% Sucrose solution, 10% Buttermilk powder
SB20	Paste with solution , shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Herbs & Garlic, 10% Sucrose solution, 20% Buttermilk powder
SW10	Paste with solution, shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Herbs & Garlic, 10% Sucrose solution, 10% Whey powder
SW20	Paste with solution, shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Herbs & Garlic, 10% Sucrose solution, 20% Whey powder
4.1B	Dip in buttermilk, shake and bake at 400°F	Best Choice Seasoned Coating Mix Chicken, Buttermilk
4.2B	Dip in buttermilk, shake and bake at 400°F	Best Choice Seasoned Coating Mix Pork, Buttermilk
4.3B	Dip in buttermilk, shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Original Chicken, Buttermilk
4.4B	Dip in buttermilk, shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Pork, Buttermilk

4.5B	Dip in buttermilk, shake and bake at 350°F	Kraft Shake'N Bake Seasoned Coating Mix Barbecue Glaze, Buttermilk
4.6B	Dip in buttermilk, shake and bake at 400°F	Don's Chuck Wagon All Purpose Batter Mix, Buttermilk, Butter, Pam
4.7W	Deep fry at 375°F	Don's Chuck Wagon All Purpose Batter Mix, Water, Vegetable oil
4.8W	Deep fry at 375°F	McCormick Golden Dipt Fry Easy Fry Mix All Purpose Batter, Water, Vegetable oil
4.9W	Panfry at 375F	McCormick Golden Dipt Fry Easy Fry Mix All Purpose Batter, Water, Vegetable oil
4.10	Deep fry at 350°F	Louisiana Fish Fry Products Seasoned Shrimp Fry, Water, Vegetable oil
4.1P	Dip in water, shake and bake at 400°F	Best Choice Seasoned Coating Mix Chicken, 10% paprika, Water
4.1	Dip in water, shake and bake at 400°F	Best Choice Seasoned Coating Mix Chicken, Water
4.3	Dip in water, shake and bake at 400°F	Kraft Shake'N Bake Seasoned Coating Mix Original Chicken, Water
4143A	Dip in water, shake and bake at 400°F	33.3% Kraft Shake'N Bake Seasoned Coating Mix Original Chicken, 66.7% Best Choice Seasoned Coating Mix Chicken, Water
4143B	Dip in water, shake and bake at 400°F	50% Kraft Shake'N Bake Seasoned Coating Mix Original Chicken, 50% Best Choice Seasoned Coating Mix Chicken, Water
4143C	Dip in water, shake and bake at 400°F	66.7% Kraft Shake'N Bake Seasoned Coating Mix Original Chicken, 33.3% Best Choice Seasoned Coating Mix Chicken, Water

3.1.5 Sensory Evaluation

Sensory screening sections were conducted to evaluate nuggets from each treatment. In house panelists were asked to describe the following attributes of the nuggets: appearance, flavor and texture. The references used in preliminary study were Tyson Quick'N Easy Chicken Nuggets, Tyson Quick'N Easy South Style Chicken Nuggets, Morningstar Farms Honey Mustard Chick'n Tenders and Morningstar Farms Chick'n Nuggets.

3.2 Main Study

3.2.1 Experimental Design

Initial screening of the three independent variables --- meat flavor, dried plum puree and coating mix in the preliminary study provided information for establishing the levels and types of ingredients that could be used to create nuggets that might be acceptable to consumers. It was predicted that Asian Chicken Powder (chicken flavor/chicken powder), Dried Plum Puree (plum), Kraft Shake'N Bake Seasoned Coating Mix Chicken (Kraft-mix) and Best Choice Seasoned Coating Mix Chicken (BestC) could be used to produce chicken nugget analogs that mimic commercial soy-based chicken nugget. Two percent, 3% and 4% levels of Asian Chicken Powder, 0%, 0.5% and 1.0% levels of Dried Plum Puree and a mixture of Kraft-mix and BestC at the following percentage; 33.3%/66.7%, 66.7%/33.3% and 100%/0% were used to formulate treatment combinations according to a design suggested by Madamba (2002). The results on coating are presented in terms of the percent Kraft coating in the coating mixture.

Overall, there were thirteen nugget formulations being made, and Table 5 shows the coded and uncoded experimental designs for each formulation.

Table 5: Coded and Uncoded 3 Level 3 Factor Randomized Incomplete Block Design of Asian Chicken Powder, Dried Plum Puree and Kraft Coating Mix

Formulation Code	CA		DPP		Kraft	
	Coded	*Uncoded*	*Coded*	*Uncoded*	*Coded*	*Uncoded*
128	+1	4%	-1	0%	0	66.7%
219	-1	2%	0	0.5%	-1	33.3%
332	-1	2%	+1	1.0%	0	66.7%
383	0	3%	-1	0%	+1	100.0%
443	+1	4%	0	0.5%	-1	33.3%
461	0	3%	+1	1.0%	-1	33.3%
567	+1	4%	+1	1.0%	0	66.7%
634	0	3%	-1	0%	-1	33.3%
696	+1	4%	0	0.5%	+1	100.0%
781	-1	2%	0	0.5%	+1	100.0%
828	0	3%	0	0.5%	0	66.7%
855	0	3%	+1	1.0%	+1	100.0%
974	-1	2%	-1	0%	0	66.7%

CA = Asian Chicken Powder
DPP = Dried Plum Puree
Kraft = Kraft Shake'n Bake Seasoned Coating Mix Original Chicken

3.2.2 Nugget Ingredients and Coating Formulations

The independent variables which are Asian chicken powder, dried plum puree and mixture of Kraft and BestC coating mix were added according to the experimental design in Table 5. The amount of other ingredients and seasonings were used in levels discussed in the preliminary study (Table 2). Appendix B shows in detail the ingredients and seasonings used for each of the thirteen nugget formulations.

Ingredients and seasonings used for the nugget formulations were either donated or acquired from manufacturers and local grocery stores. The textured peanut used in this

study was prepared by twin-screw extrusion of defatted peanut flour (Hinds *et al.,* 2005a). Table 6 lists the sources of the ingredients used in this main study.

Table 6: Main Study Ingredients sources

Ingredient	Source
Textured Peanut (containing 10% peanut oil)	Texas A&M University (Collaborator)
Colloid Binder (TIC Pretested® Colloid Bind I-96)	TIC Gums, Belcamp, Maryland (Donor)
Carrageenan binder (CarraBind 80A Carrageenan)	Carrageenan Company, Santa Ana, California (Donor)
Asian chicken powder	JMH International, INC, Park City, Utah (Donor)
Dried plum puree	California Dried Plum Board, CA (Donor)
Great Value Drinking Water, Dextrose, Great Value Garlic Powder, 5th Season Onion Powder, McCormick Paprika, 5th Season Italian Seasoning, Great Value Noniodized Salt, Kitchen Bouquet Browning & Seasoning Sauce, Lea & Perrins Worcestershire Sauce	Local Grocery Stores (Sellers)

3.2.3 Nugget Preparation

Textured peanut (TP), colloid and carrageenan binders were mixed for 2 minutes using a single best double action mixer (Leland Southwest Double Action™ Mixer, Model D-100 DA70, Fort Worth, TX). Dextrose, garlic powder, onion powder, paprika, noniodized salt, italian seasoning and Asian chicken powder were then added and mixed for 3 minutes. If dried plum puree (plum) was being used, it was stirred and blended in pre-weighed water for 3 minutes before adding to the TP mixture. Together with the remaining pre-weighed drinking water, dissolved plum, Browning & Seasoning Sauce

and Worcestershire Sauce were added into the TP mixture. The rehydrated TP and other ingredients were then mixed for 2 minutes and 45 seconds. During the 2 minutes and 45 seconds mixing period, the mixer was stopped at 1 minute intervals to scrape off any TP mixture was stuck to the wall of the mixing bowl. This action was to ensure all ingredients were uniformly mixed. Well mixed TP mixture was stuffed into presoaked casings (88mm diameter cellulose casing) using a manual stuffer. Finally, the casings were tied with string, labeled and refrigerated at 4°C (40°F) for later used. Three stuffed casings (each 45cm long x 8.8 cm diameter) were prepared for each formulation. Figure 3 illustrates the step-by-step procedure for the initial nugget preparation.

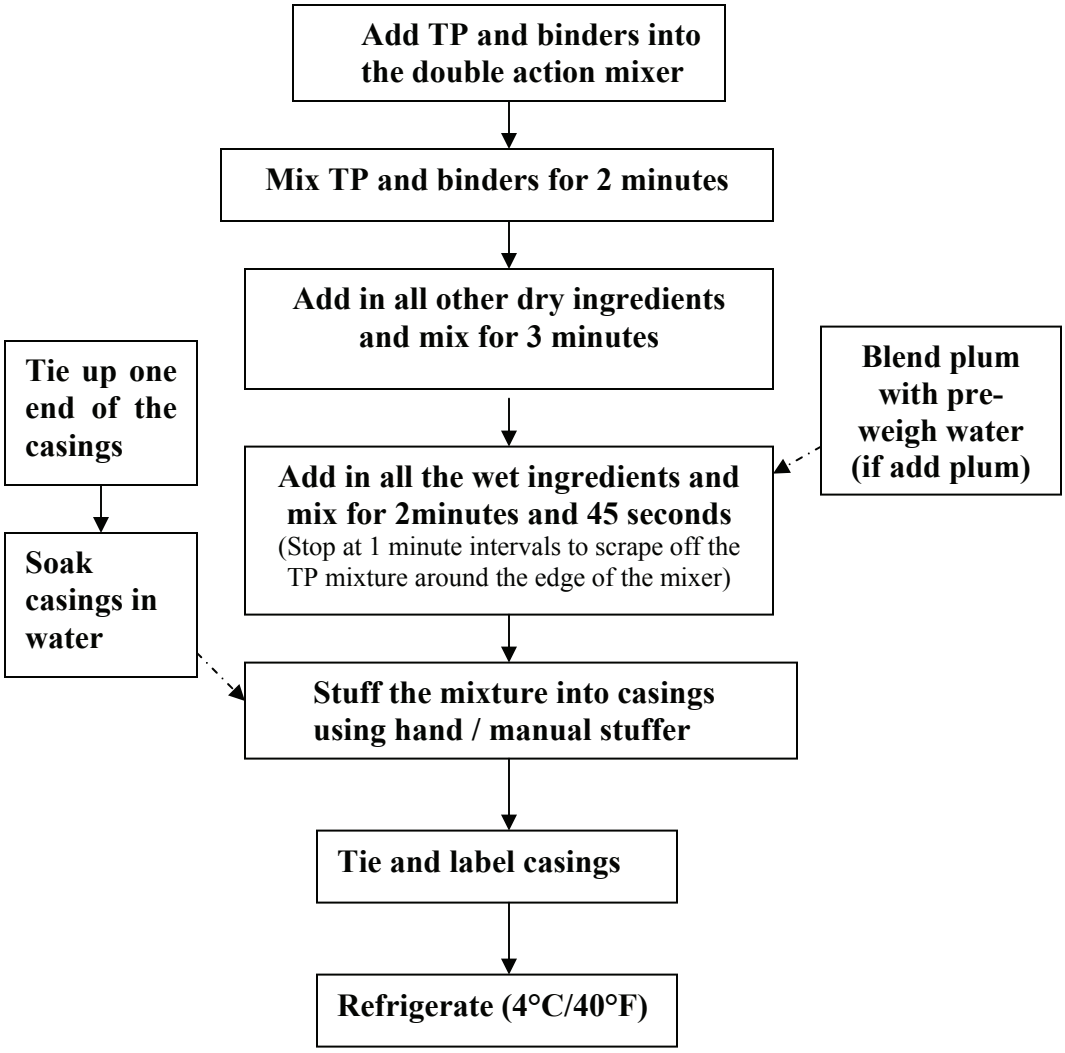


Figure 3*:* Nugget Preparation in Main Study

3.2.4 Kettle Precook of Nuggets

Encased formulations were precooked in water using a stainless steel kettle (Crown Food Service Equipt. LTD, Series No.: AP-1016245-2T-1063, ON, Canada) at the pilot plant, Oklahoma Food and Agricultural Products Research and Technology Center, Oklahoma State University, Stillwater. Casings were submerged into preheated water (water temperature about 77°C / 170°F). A digital thermometer (Cox Technologies,

Type K) was inserted into the end of one of the casings, centrally to a depth of 10 cm, to measure its internal temperature. Water temperature was monitored throughout the cooking process to make sure it stayed at ~77°C (170°F). Once the casings internal temperature reached 74°C (165°F), casings were removed and cooled (at 4°C / 40°F) for 1 hour, then vacuum packed (UltraVac) and kept refrigerated (at 4°C / 40°F) for later use. Precooked encased formulations were kept refrigerated for at least 1 day before cutting. Figure 4 illustrates the step-by-step procedure of kettle cooked nuggets.

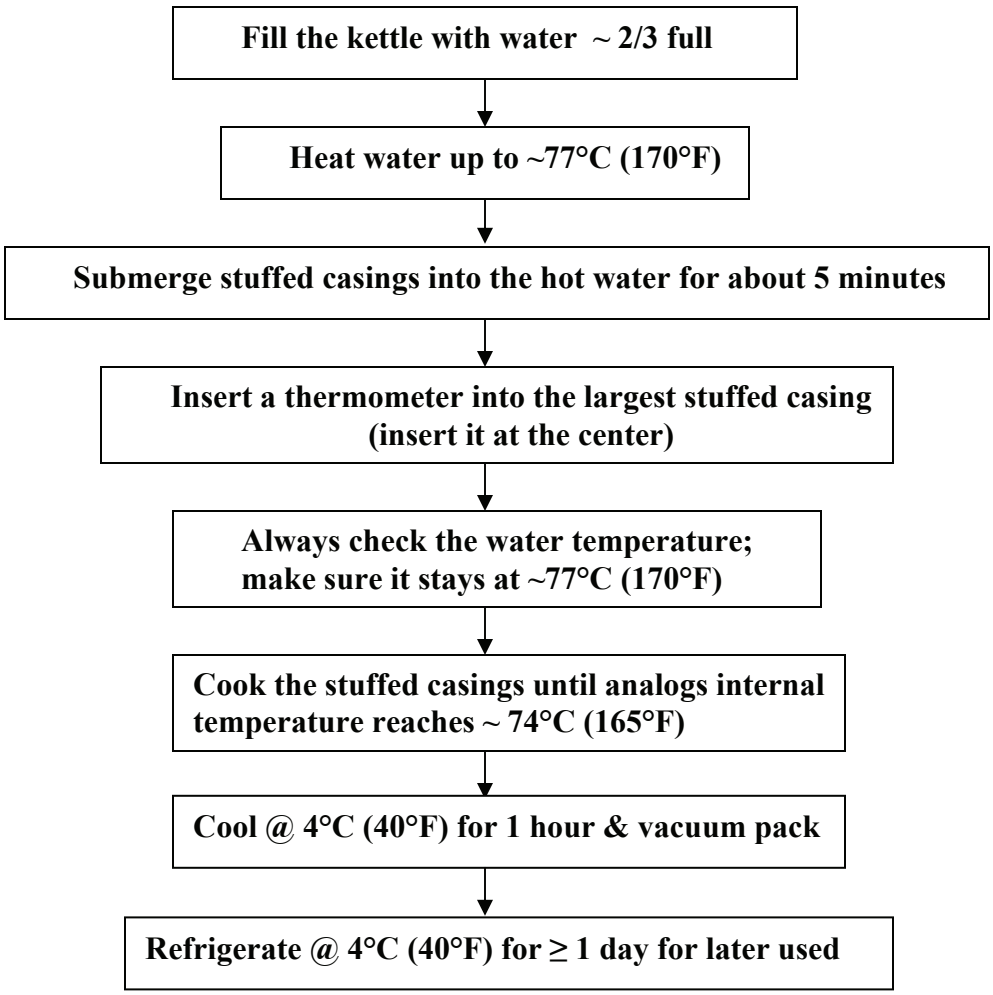


Figure 4*:* Step-by-step Procedure of the Kettle Cooked Nuggets in Main Study

3.2.5 Baking Methods

As mentioned in section 3.2.1, Kraft Shake'n Bake Seasoned Coating Mix Chicken (Kraft) and Best Choice Seasoned Coating Mix Chicken (BestC) were the coating mixes used to coat all thirteen nugget formulations. Precooked encased formulations were cut into ½ inch thick pieces. Casings around the cut nuggets were removed, and the nuggets were then coated with Kraft and BestC coating mixture at different ratio according to the experimental design (Table 5). A total amount of 21g of the combination coating mixture was used to coat every 2 pieces of nuggets. Figure 5 illustrates the step-by-step procedure for baking nuggets. For sensory evaluation, nuggets were held at ≥ 140°C for less than 30 minutes prior to serving; whereas nuggets were cooled to room temperature prior to physical analyses.

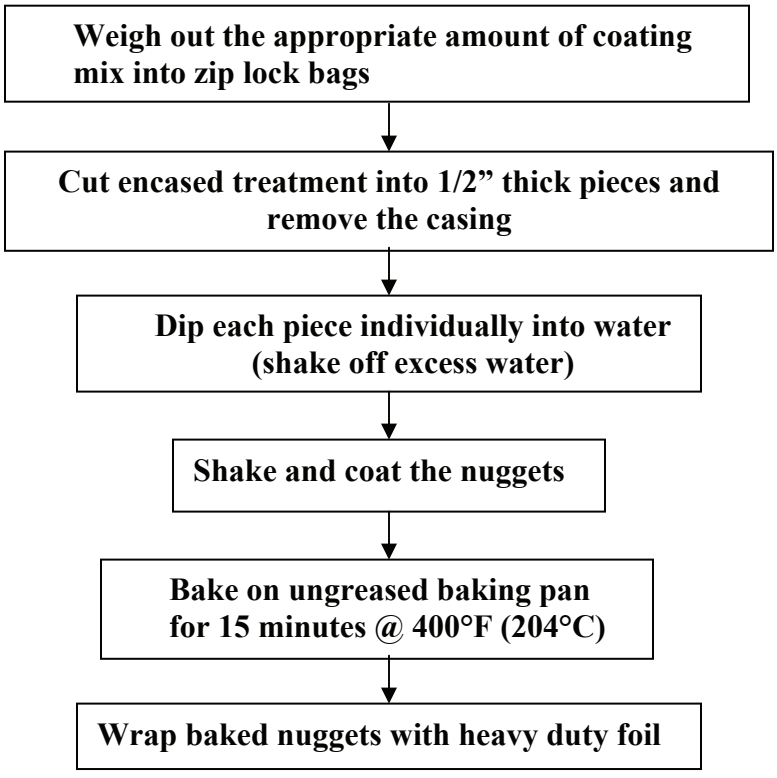


Figure 5*:* Step-by-step Procedure for Baking Nuggets in Main Study

3.2.6 Physical Tests

(a) Color

Color of baked nugget was measured using a Minolta Chroma Meter Reflectance System (6mm Diameter Aperture, Model CR-2000, Minolta, Japan) set in the CIE L*C*h° mode with illuminant C at 2° observer angle. In the CIE system, L-value (L) reflects the degree of lightness and darkness on a gray scale where 0 represents black and 100 represents white. Hue (h°) is a color descriptor. Color of the nugget was measured in a 360 degree angle where 0-90 degrees represents red to yellow, 90-180 degree represents yellow to green, 180-270 degree represents green to blue and 270-360 degree represents blue to red. Chroma (C) evaluates the intensity of the hue. The chroma meter was calibrated before being used to evaluate the color of the nuggets. The calibration was based on a standard tile with Y = 94.3, x = 0.3134 and y = 0.3207 (L* = 97.75, a* = -0.58 and b* = +2.31) chromaticity coordinates. Three pieces of nuggets per formulation were selected for color evaluation randomly. Three measurements were randomly taken from the front side of one piece of nugget, and the mean was used to obtain one data point. Tests were replicated on three nuggets.

(b) Moisture

Moisture of baked nuggets was measured using an IR-30 Moisture Analyzer (Denver Instrument Company, Ltd, Denver, Colorado). The moisture analyzer was set at the following conditions: 95°C of heat temperature, auto start, and result mode of 0-100% moisture. Each nugget formulation was analyzed in triplicate. About 2.00gram of sample was spread evenly into a moisture disposable dish for each analysis.

(c) Water Activity

Water activity of baked nuggets was measured using Rotronic Water Activity Meter (Model A2101, Rotronic Instrument Corp., Huntington, NY). Each nugget formulation was analyzed in triplicate to determine the availability of water in nugget for microorganism to growth.

(d) Texture Analysis

TA-XT2i Texture Analyzer (Texture Technologies Corp, Scarsdale, New York) was used in this study. A TA-25 cylinder probe (50 mm diameter) with 25kg load cell fitted to the analyzer and Texture Expert Exceed Software were used to measure the texture of the baked nuggets. Each piece of nugget sample was placed directly underneath the probe of the texture analyzer. Each piece of sample was compressed twice with a probe traveled at 2 mm/sec and with a compression distance of 5mm. A 5 second rest period was allowed between the two compressions. Six texture attributes obtained from each formulation were hardness, springiness, cohesiveness, adhesiveness, resilience and chewiness. Defined by the Texture Techonologies Corp, hardness is the peak force of the first compression of the sample. Cohesiveness reflects how well the sample withstands a second deformation relative to how it behaved under the first deformation. Springiness measures how well the sample springs back after it has been deformed during the second compression. Chewiness is the interaction between springiness and gumminess. Resilience is corresponding to the area of the first withdrawal divided by the compression. Each nugget formulation was measured in triplicate. Appendix I show a typical texture profile of chicken nugget analog prepared from textured peanut.

3.2.7 Sensory Analysis

(a) Experimental Design

Thirteen formulations and one reference (Morningstar Farms Chick'n Nuggets) were evaluated by untrained panelists. A balanced randomized incomplete block design generated by PROC OPTEX of Statistical Analysis Software (SAS, Version 9.1) was used in this study. Each panelist was requested to evaluate 8 nugget formulations out of 14 formulations in one session. Each nugget formulation was assigned with a three digit code and each panelist was assigned with a number for identification purposes. Appendix C shows the code for the serving samples and Appendix D shows the serving order of samples for untrained panelists' sensory evaluation with assigned code.

(b) Sensory Evaluation

Acceptance testing method was used to investigate the acceptability of the chicken nugget analog by consumers. A total of 116 untrained panelists recruited at Oklahoma State University campus participated in evaluating the nuggets. Briefing regarding the evaluation was given at the beginning of each session and each panelist was required to sign a consent form (Appendix F) approved by the Institute of Review Board, Oklahoma State University prior to participate in the study. The sensory evaluation of nuggets was conducted in the sensory evaluation laboratory located at Oklahoma Food and Agricultural Products Research and Technology Center, Oklahoma State University, Stillwater.

Each panelist was assigned a number for identification purposes and he/she was responsible to evaluate 8 different samples. Panelists were asked to fill out a score sheet

for each sample they evaluated in term of appearance, aroma, taste, texture and purchase intention. Each sample attribute except the purchase intention was rated using a 9-point Hedonic Scale. The 9 points on the Hedonic Scale were: dislike extremely = 1, dislike very much = 2, dislike moderately = 3, dislike slightly = 4, neither like nor dislike = 5, like slightly = 6, like moderately = 7, like very much = 8 and like extremely = 9. On the other hand, purchase intention was rated on a 5 point scale where definitely would not buy = 1, probably would not buy = 2, may or may not buy = 3, probably would buy = 4 and definitely would buy = 5. Also, panelists were asked to answer voluntarily some demographic questions on the score sheet including gender, age range and consumption frequency of nugget. A copy of the score sheet is in Appendix G.

3.2.8 Statistical Analysis

(a) Objective Evaluation

Statistical analysis Software (SAS Version 9.1) was used to conduct response surface regression (RSREG) to determine the effects of independent variables on physical properties of the chicken nugget analogs. A polynomial equation was fit for each response variable:

$$Y = b_0+b_1x_1+b_2x_2+b_3x_3+b_4x_1^2+b_5x_2^2+b_6x_3^2+b_7x_1x_2+b_8x_2x_3+b_9x_1x_3+b_{10}x_1x_2x_3 \quad (1)$$

where, Y = dependent variable; x_1 = chicken flavor; x_2 = plum; x_3 = Kraft-mix in %; b_0 = intercept; $b_{1\text{-}10}$ = regression coefficients

The adopted regression models were used to generate contours and 3-dimensional surfaces plots to illustrate the effects of chicken flavor, plum and Kraft-mix (%) on the dependent variables.

For water activity and color (hue angle, chroma, L value), the predicted values showed lack of fit. Therefore, mathematical transformations were performed to improve the fit of the model. Arcsine transformation was used for water activity and L value; Log transformation was used for hue angle and chroma. The data from the equations were then inversed transformed to plot the graphs.

(b) Sensory Evaluation

Statistical analysis Software (SAS, Version 9.1) was used to evaluate consumers' responses to the chicken nugget analogs. Response Surface Regression (RSREG) for each attribute was carried out to determine the consumers' acceptable level of chicken flavor, plum and Kraft-mix (%). Contour and 3-dimensional surface plots were generated to illustrate the effects of chicken flavor, plum and Kraft-mix on the sensory attributes (appearance, smell, taste and texture).

Chapter 4 Results and Discussion

4.1 Preliminary Study Sensory Screening

Treatments prepared in the preliminary study were screened for appearance, smell, taste and texture. References used in the preliminary study include Tyson Quick'N Easy Nuggets, Tyson Quick'n Easy Southern style Nuggets, Morningstar Farms Honey Mustard Chick'n Tender, and Morningstar Farms Chick'n Nuggets. Formulations with sensory attributes close to the reference were chosen to be included in the main study. Beef base (BB) was eliminated due to its bland flavor compared with both of the chicken flavors (CA and CB). However, the flavor of chicken base (CB) was not strong and tasty enough compared with the flavor of chicken powder (CA). Therefore, Asian chicken powder was selected as the flavoring ingredient used in the main study. CA level from 2% to 5% were used in the preliminary study, and nuggets formulated with 5% CA level were consider too salty. Hence, CA levels of 2%, 3% and 4% were used in main study.

All of the coating mixtures and cooking methods listed in (Table 4) Section 3.1.4 did not produce acceptable nuggets except coating and cooking methods with the code 4.1 and 4.2. Kraft Shake'N Bake Seasoned Coating Mix Original Chicken (Kraft-mix) and Best Choice Seasoned Coating Mix Chicken (BestC) were used in codes 4.2 and 4.1,

respectively. Nuggets baked with BestC only were more yellowish-red in color compared to the nuggets baked with Kraft-mix. However, nuggets baked with Kraft had better taste than nuggets baked with BestC. Therefore, combination of both BestC and Kraft-mix coating mixture was chosen to be one of the independent variables in main study. Additionally, research studies (Keeton et al, 2002; Keeton et al, 2001) showed that plum puree has the ability to help retain moisture in hamburger or processed meat products. Since textured peanut (main ingredient) has less fat content compared with meat, including plum puree in the formulation might enhance texture of the nuggets.

4.2 Main Study

4.2.1 Objective Evaluation

(a) Response Surface Regression

Response surface analysis was carried out to determine the effects of independent variables which were chicken flavor, plum and Kraft-mix on physical characteristics (dependent variables) of nugget samples. The measured physical characteristics of nugget samples were color including hue, chroma and L-value; moisture; water activity and texture including hardness, springiness, cohesiveness, adhesiveness, resilience and chewiness. As mentioned in section 3.2.8 part (a), the RSREG is based on a second order polynomial equation, and RSREG procedure of Statistical analysis Software (SAS, Version 9.1) was used to obtain the regression coefficients for each physical characteristic.

The regression models from RSREG for moisture, hardness, springiness, cohesiveness, adhesiveness, resilience and chewiness showed no significant lack of fit. Therefore, the regression coefficients for those physical characteristics were used to generate contour and 3-dimensional surface plots for the response variables. The regression model from RSREG for water activity and color of the samples showed significant lack of fit. Hence, mathematical transformations were performed on these variables to improve the fit of the models. Arcsine was performed on L value and water activity while hue angle and chroma were log transformed. Predicted values were inverse transformed, and these latter values were used to produce the surface and contour plots.The graphs of the response variables from the sensory study were used to determine optimum level of chicken flavor, plum and Kraft-mix to be used to make acceptable chicken nugget analog.

(b) Surface Plots for Moisture

Contour and surface plots were generated for moisture with each independent variable fixed at constant levels. Figures 6-8 showed the surface plots for moisture with constant chicken flavor, plum and Kraft coating in coating mix. At high levels of chicken flavor, the moisture content of the nuggets increased with increased of Kraft-mix and decreased plum (Figure 6). But at low chicken flavor levels, moisture also increased with low Kraft-mix. Nuggets that contained 2%, 3% and 4% chicken flavor had maximum moisture content when they contained 0% plum and approximately 100% Kraft-mix. The higher the chicken flavor level present in the nuggets, the smaller the increment of moisture content would be at the lower level of Kraft-mix and plum.

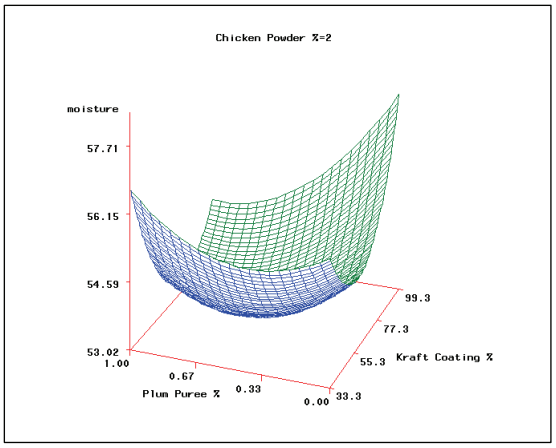
Nuggets containing all three levels of plum have maximum moisture content when the amount of Kraft-mix was approximately 100% and chicken flavor was 4% (Figure 7). The increment of moisture content was small with lower levels of plum and lower levels of Kraft-mix. Similar trends were observed in the plots generated from data on nuggets with Kraft-mix fixed at constant levels (Figure 8).

(c) Surface Plots for Water Activity.

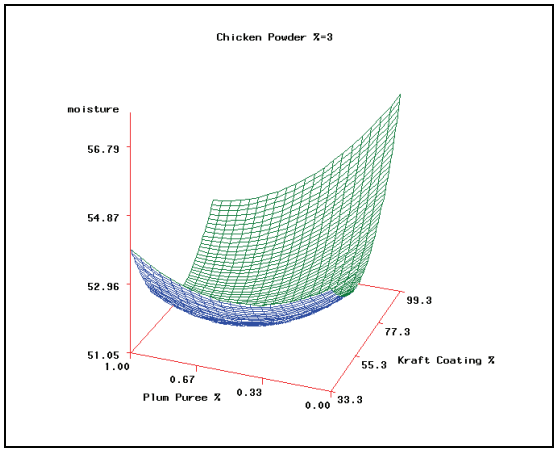
Water activity of nuggets with high and low levels of chicken flavor increased as the levels of Kraft-mix increased. Figures 9-11 showed the surface plots for water activity with different levels of chicken flavor, plum and Kraft-mix. However, water activity for treatments at the middle level of chicken flavor remained fairly constant regardless of the levels of Kraft-mix (Figure 9). At lower levels of chicken flavor, the water activity of nuggets decreased at high and low levels of plum. Nonetheless, water activity of nuggets increased with increased plum at middle levels of chicken flavor. These results indicate that formulations containing 4% chicken powder, 0.5% plum and 100% Kraft-mix; and 2% chicken powder, 0.5% plum and 100% Kraft-mix might impart the juiciest mouthfeel.

Furthermore, water activity is a crucial parameter to correlate with microbial growth and shelf-life stability. In general, a low acid food with water activity in the range of 0.90 to 1.0 is highly perishable and requires refrigeration (Chinachoti, 2000). Water activity of all treatments were above 0.9 indicating that these products would need to be held refrigerated or frozen to prolong shelf-life because they are low acid foods.

(a)



(b)



(c)

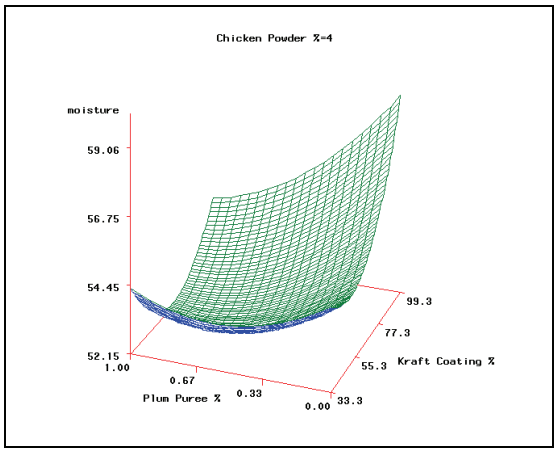
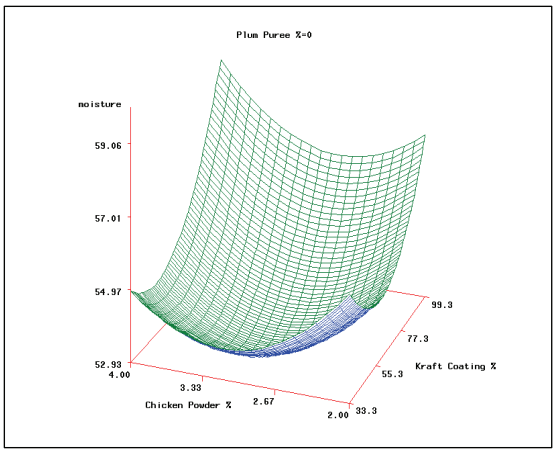


Figure 6: Surface Plots of Moisture with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



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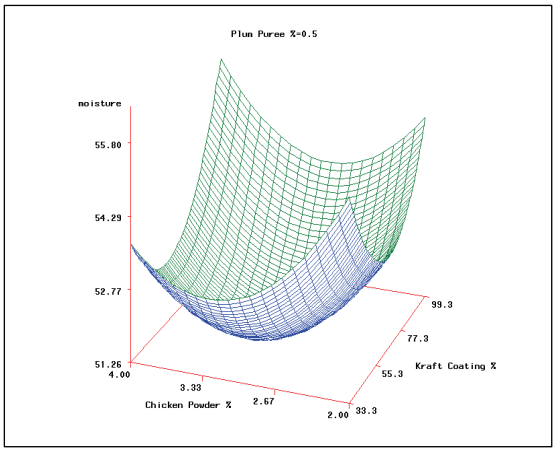

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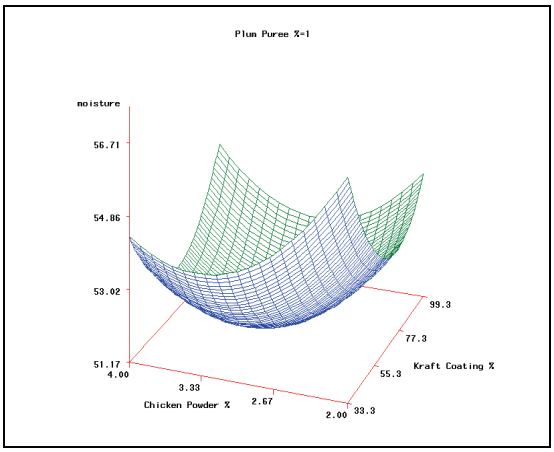
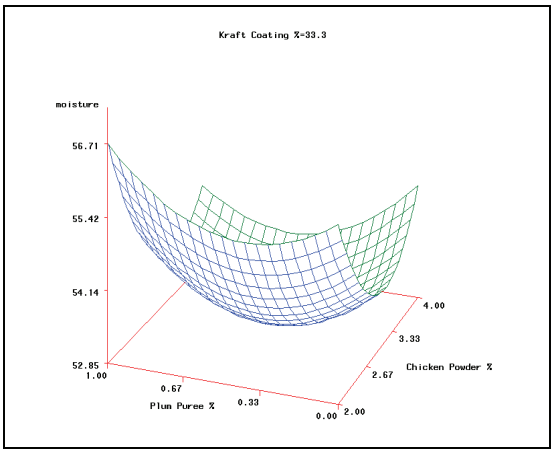
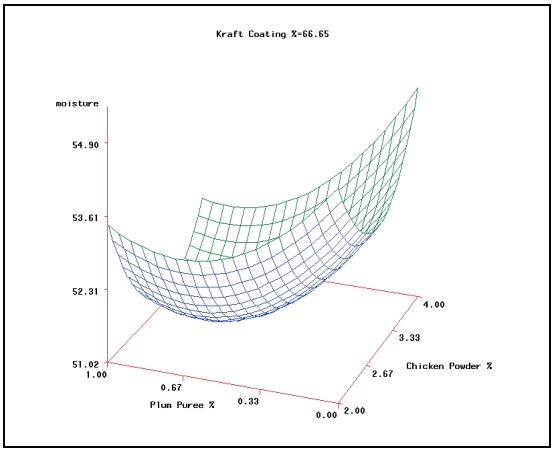


Figure 7: Surface Plots of Moisture with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



(b)



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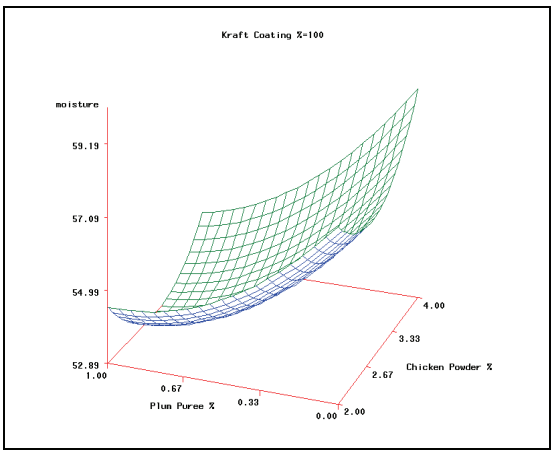
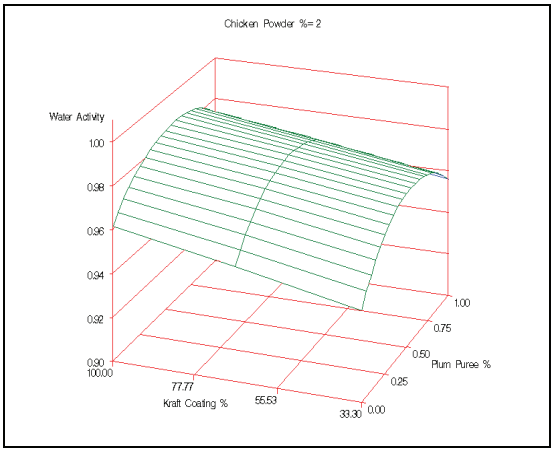


Figure 8: Surface Plots of Moisture with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

(a)



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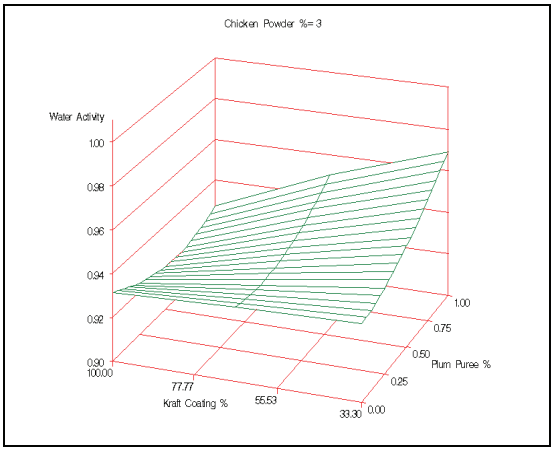

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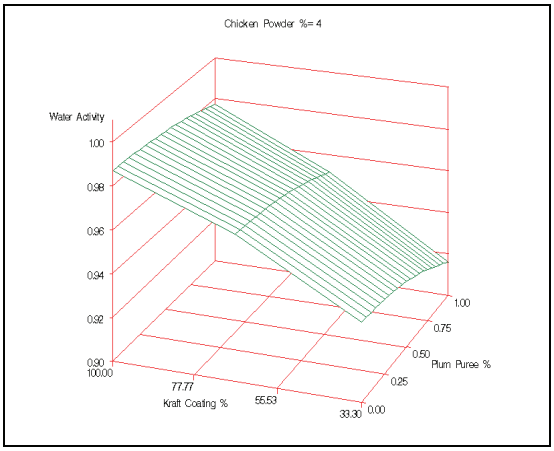
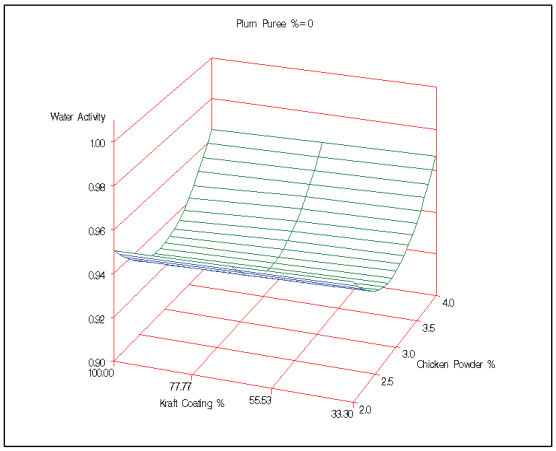
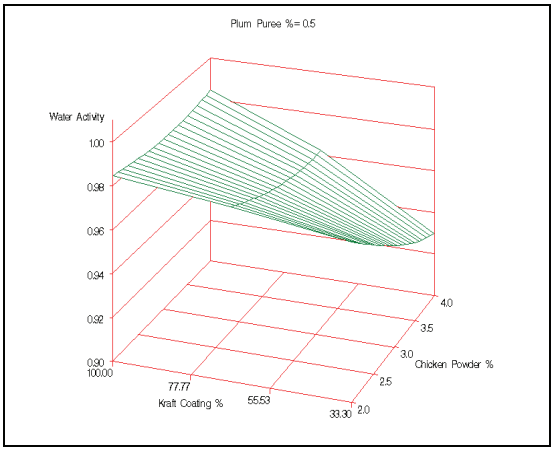


Figure 9: Surface Plots of Water Activity with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



(b)



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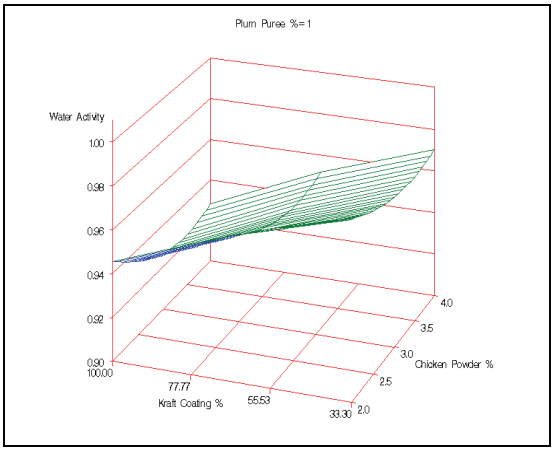
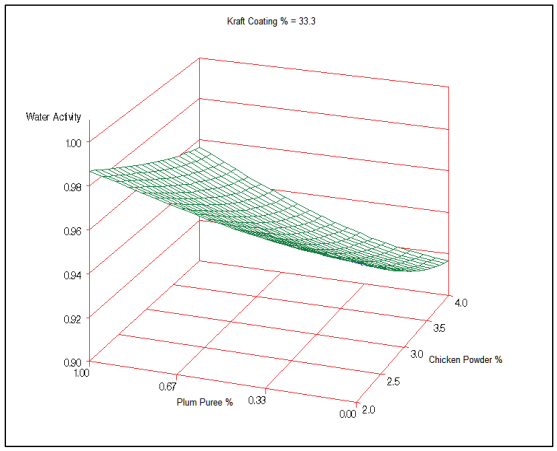
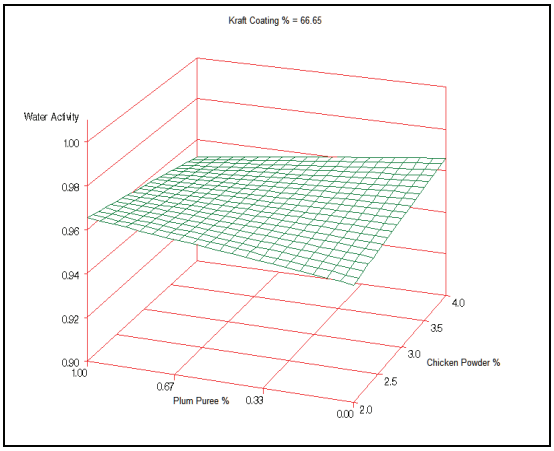


Figure 10: Surface Plots of Water Activity with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



(b)



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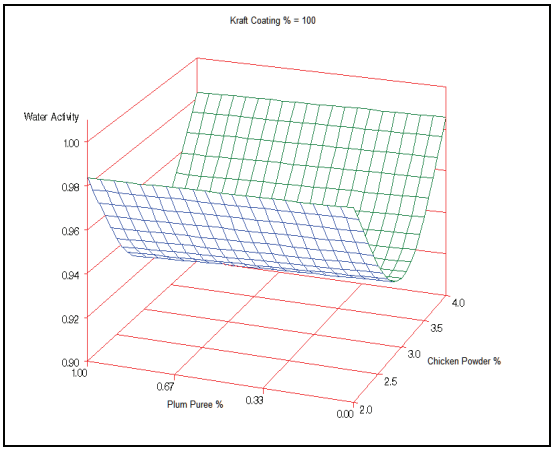


Figure 11: Surface Plots of Water Activity with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

(d) Surface Plots for Texture

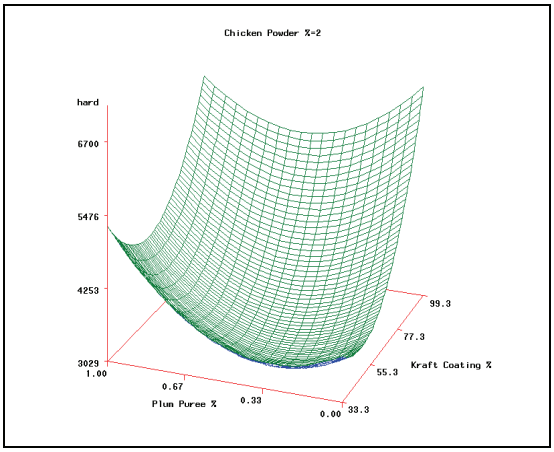
Contour and surface plots for each texture attribute such as hardness, adhesiveness, cohesiveness, springiness, chewiness and resilience were generated (Figures 12-29).

Generally, for constant levels of chicken flavor, hardness of nuggets increased as the levels of plum and Kraft-mix were increased (Figure 12). However, at higher chicken powder levels, hardness of the nugget also increased when the level of plum and Kraft were low. The turning points of hardness were approximately 53% Kraft-mix and 0.38% plum for 2% chicken flavor, 61% Kraft-mix and 0.38% plum for 3% chicken flavor, 68% Kraft-mix and 0.38% plum for 4% chicken flavor.

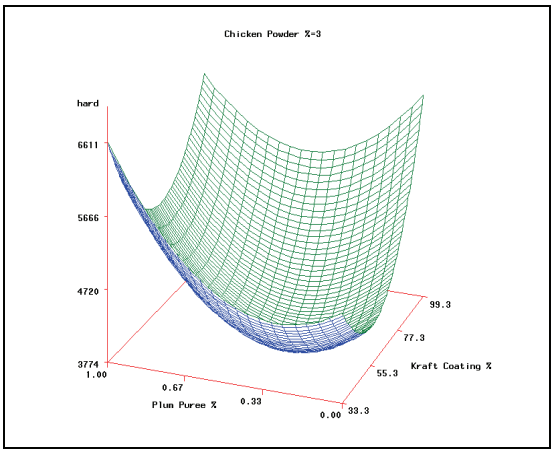
The surface plots of hardness for all levels of plum (Figure 13) reflected similar trends as the chicken flavor described above. When plum was at 0.5%, hardness increased as the level of chicken flavor was more than 3% and the level of Kraft-mix was less than 55%. Hardness increased as the level of plum was at 1% with more than or less than 3% chicken flavor and with more than or less than 68% Kraft.

For different levels of Kraft-mix, hardness decreased as the levels of chicken flavor decreased or increased (Figure 14). However, at low to middle levels of Kraft-mix, hardness increased as plum was increased. But, at high levels of Kraft-mix, hardness increased with low and high plum. The turning points of hardness were approximately 0.33% plum and 3% chicken flavor for 33% Kraft-mix, 0.4% plum and 3.3% chicken flavor for 66% Kraft-mix, 0.55% plum and 2.7% chicken flavor for 100% Kraft-mix.

(a)



(b)



(c)

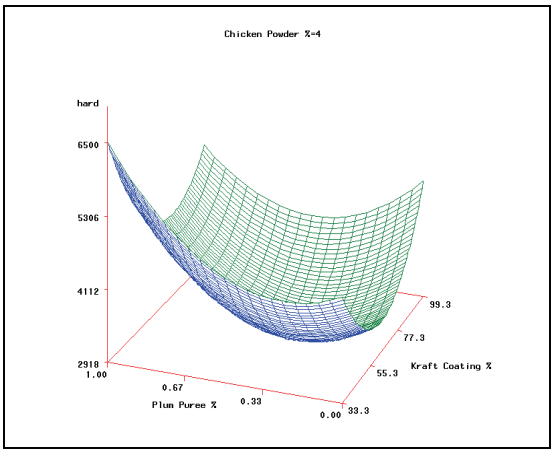
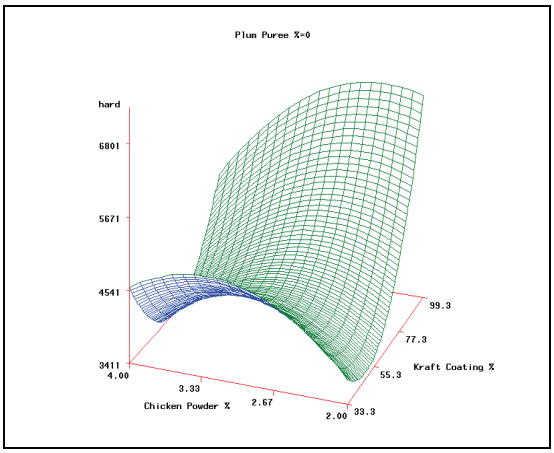


Figure 12: Surface Plots of Hardness with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



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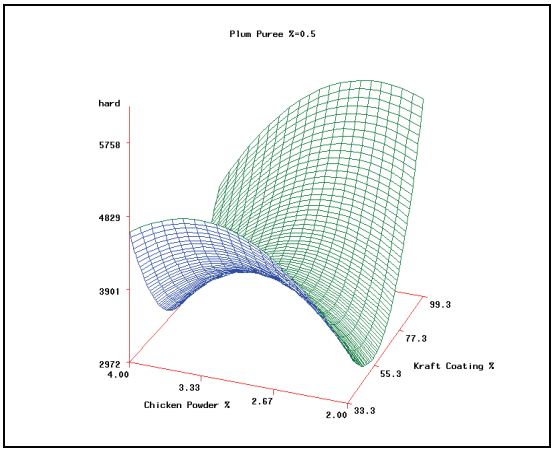


(c)

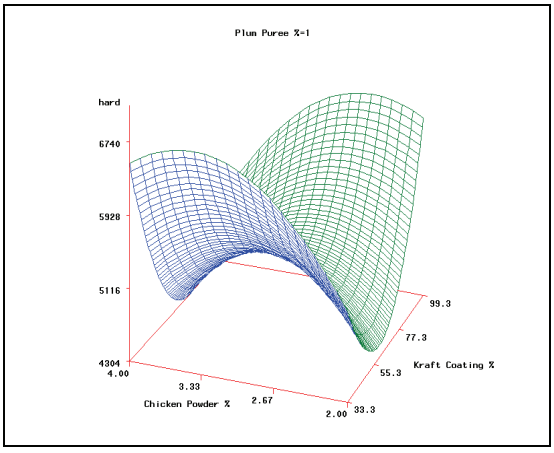
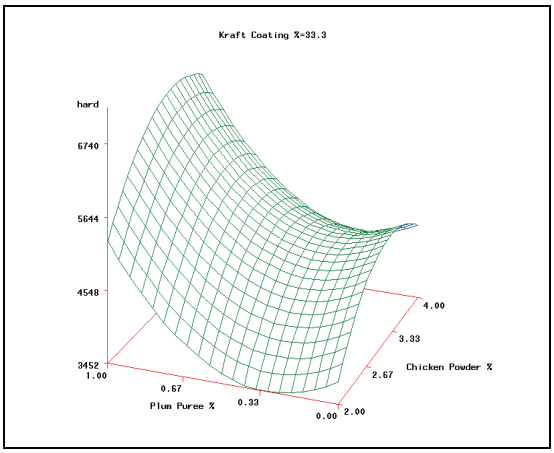
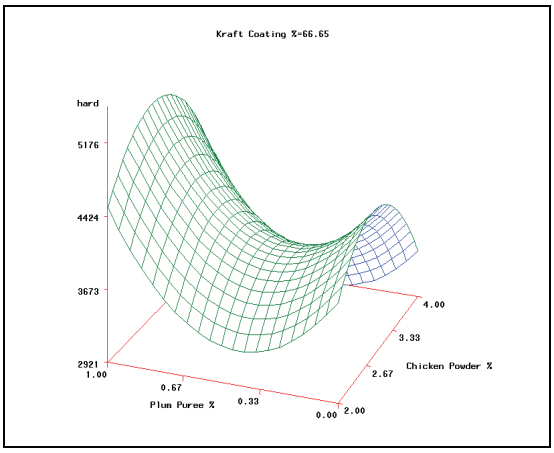


Figure 13: Surface Plots of Hardness with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



(b)



(c)

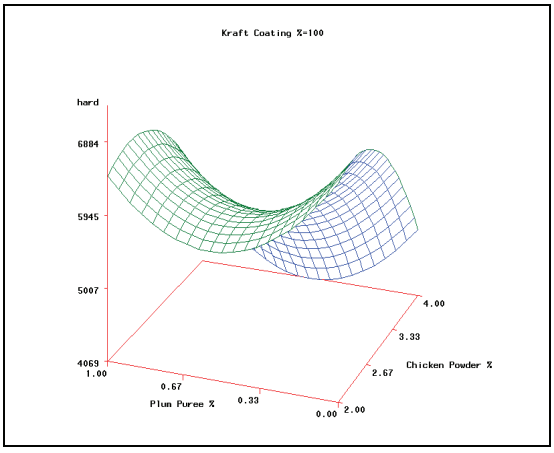


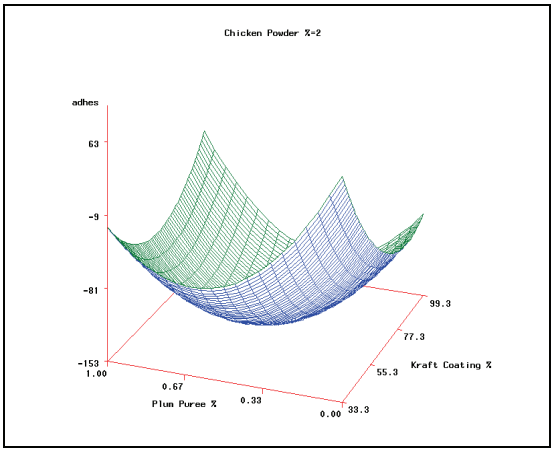
Figure 14: Surface Plots of Hardness with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

Adhesiveness of nuggets with 2% or 3% or 4% chicken levels increased at higher levels and lower levels of Kraft-mix and plum (Figure 15). The turning point for 2% chicken flavor was at approximately 75% Kraft-mix and 0.5% plum, for 3% chicken flavor was at approximately 71% Kraft-mix and 0.5% plum, for 4% chicken flavor was at approximately 68% Kraft-mix and 0.5% plum.

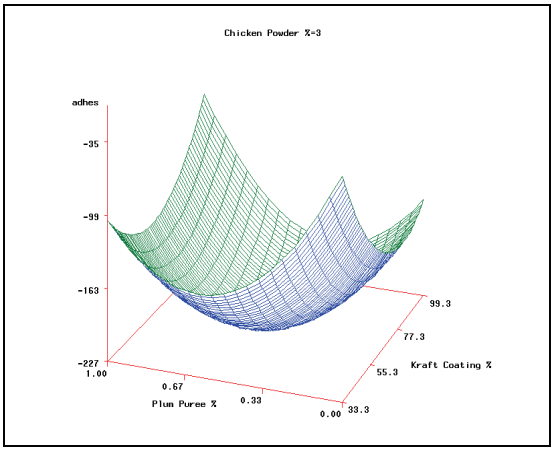
Similar situations were found with different levels of plum (Figure 16). At 0% plum, adhesiveness of nuggets increased when the levels of Kraft-mix and chicken flavor were more than or less than approximately 83% and approximately 3%, respectively. Furthermore, adhesiveness of nuggets increased as Kraft-mix was more than or less than 73%, and chicken flavor was more than or less than 3% when plum was at 0.5%. While the levels of Kraft-mix was more than or less than 61% and the levels of chicken flavor was more than or less than 3%, adhesiveness of nuggets with 1% plum was increased.

The surface plots of adhesiveness for all levels of Kraft-mix were reflected the same trend as the chicken flavor and plum mentioned above (Figure 17). When Kraft-mix at 33%, adhesiveness increased as chicken flavor was either more than or less than 3% and plum was either more than or less than 0.63%. While Kraft-mix at 66%, adhesiveness increased as chicken flavor was either more than or less than 3% and plum was either more than or less than 0.5%. Adhesiveness increased as chicken flavor was either more than or less than 3% and plum was either more than or less than 0.38% at 100% Kraft-mix.

(a)



(b)



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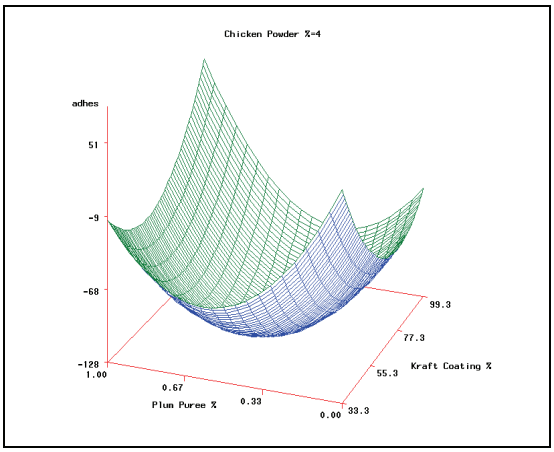
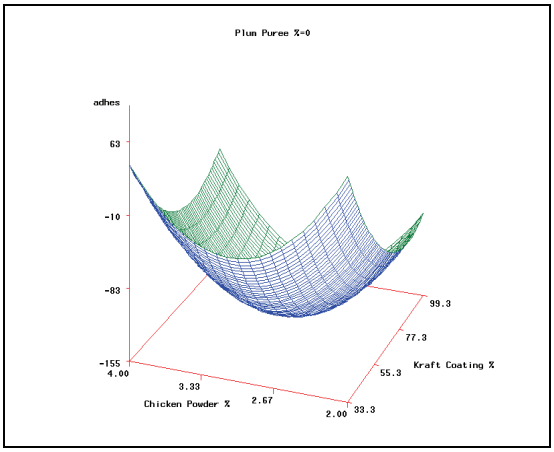
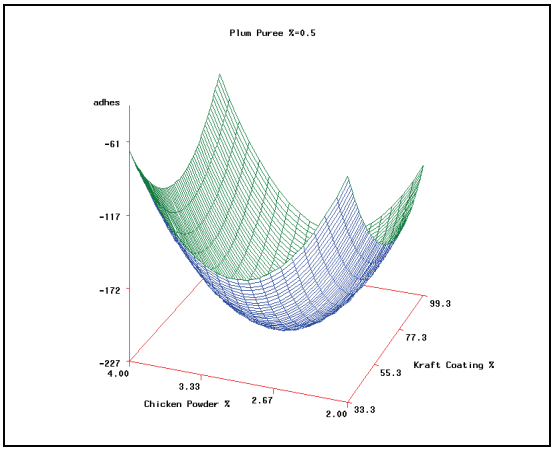


Figure 15: Surface Plots of Adhesiveness with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



(b)



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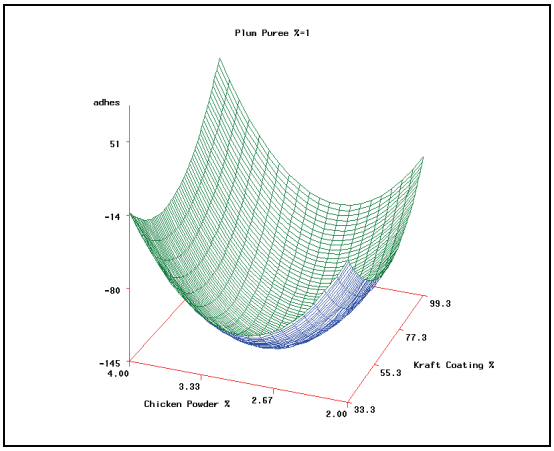
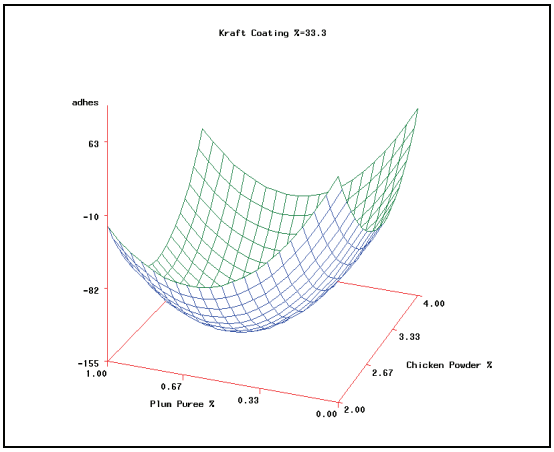


Figure 16: Surface Plots of Adhesiveness with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



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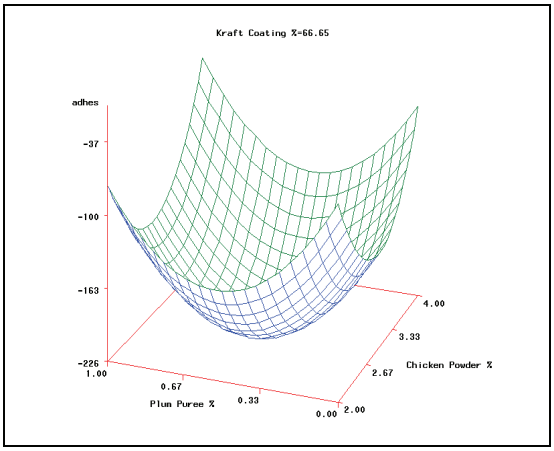

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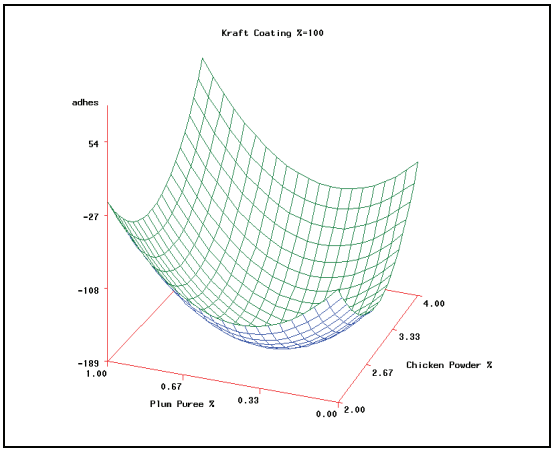


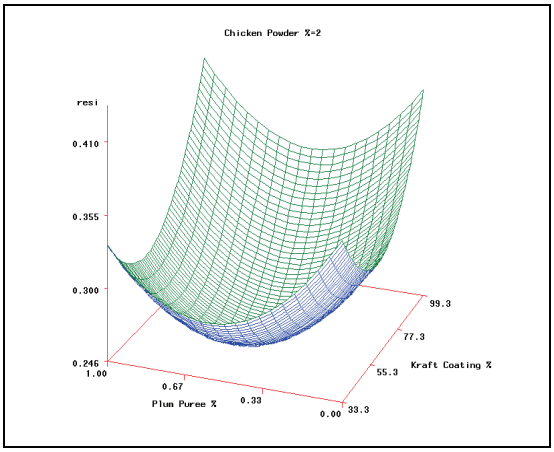
Figure 17: Surface Plots of Adhesiveness with (a) 33.3%, (b) 66.7%, (c) 100 % Kraft Coating Mix

Resilience of nuggets increased when the levels of chicken flavor, plum and Kraft-mix increased (Figure18). Additionally, resilience increased as well when the levels of chicken flavor, plum and Kraft-mix decreased. The turning point for 2% chicken flavor was at approximately 0.55% plum and 59.7% Kraft-mix, for 3% chicken flavor was at approximately 0.5% plum and 63% Kraft-mix, for 4% chicken flavor was at approximately 0.45% plum and 68% Kraft-mix.

In addition, resilience of nuggets with 1% plum increased when more than or less than 3% chicken flavor and more than or less than 61% chicken flavor were present in the nuggets (Figure 19). While plum was at 0.5%, resilience increased as chicken flavor was either more than or less than 3.2% chicken flavor and Kraft-mix was either more than or less than 63%. Resilience increased as chicken flavor was either more than or less than 3.3% and Kraft-mix was either more than or less than 66.3%.

The surface plots of resilience for all levels of Kraft-mix were reflected the same trend as the chicken flavor and plum mentioned above (Figure 20). The least resilience nugget formulations were 0.5% plum and 2.9% chicken flavor at 33.3% Kraft-mix, 0.5% plum and 3.2% chicken flavor at 66.65% Kraft-mix, 0.4% plum and 3.4% chicken flavor at 100% Kraft-mix.

(a)



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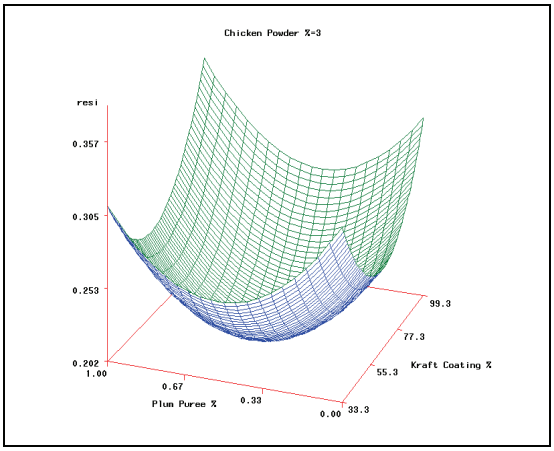

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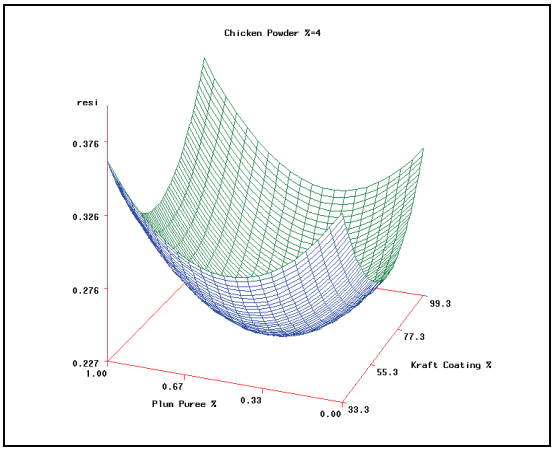
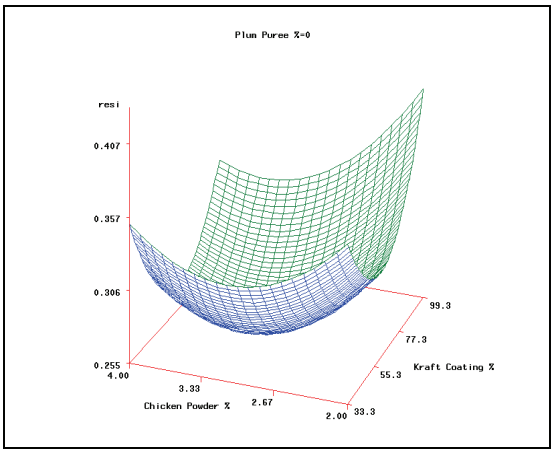


Figure 18: Surface Plots of Resilience with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



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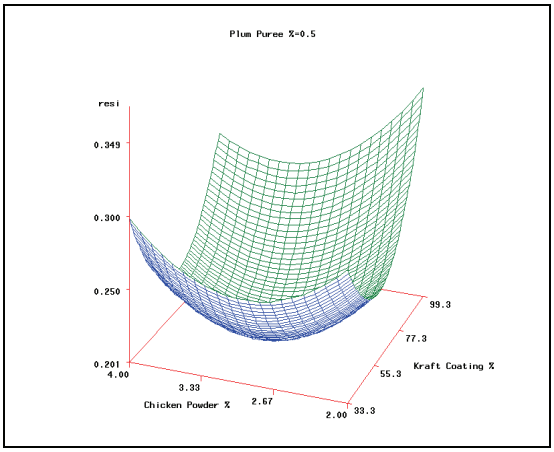


(c)

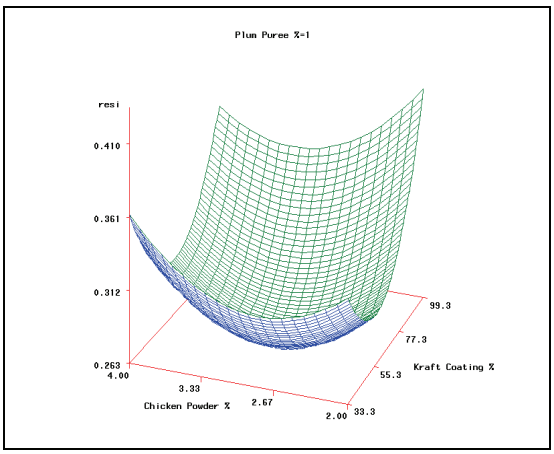
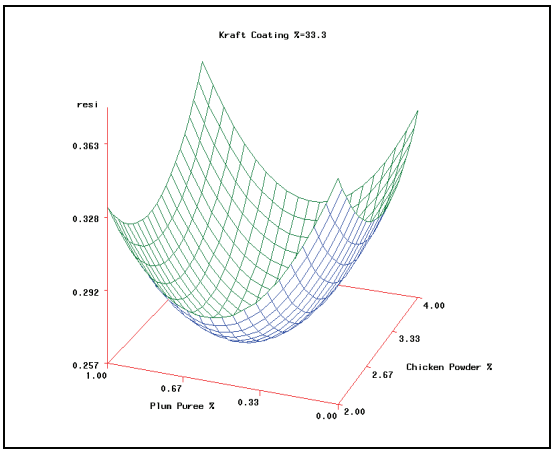
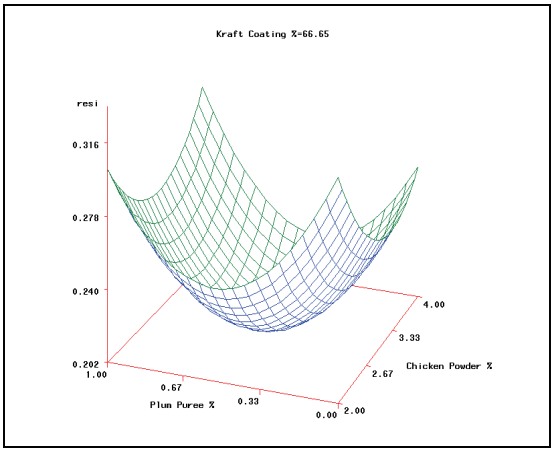


Figure 19: Surface Plots of Resilience with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



(b)



(c)

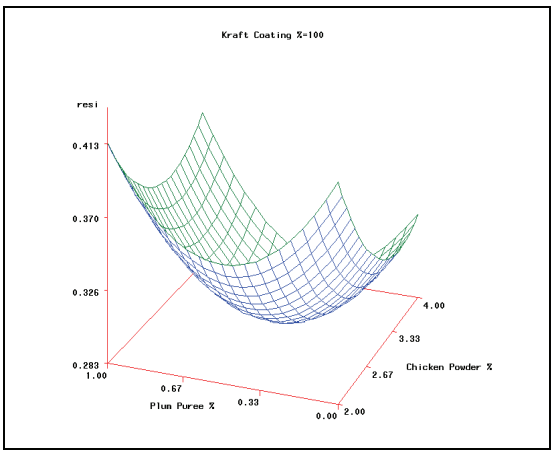


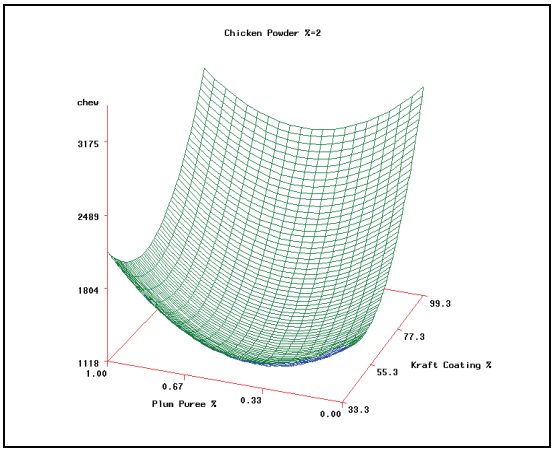
Figure 20: Surface Plots of Resilience with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

Chicken flavor, plum and Kraft-mix had different effects on chewiness of nuggets. For different levels of chicken powder, chewiness increased at higher and lower levels of Kraft-mix as well as at higher and lower levels of plum (Figure 21). The turning points were 0.43% plum and 51.5% Kraft-mix at 2% chicken flavor, 0.4% plum and 59.7% Kraft-mix at 3% chicken flavor, 0.38% plum and 69.9% Kraft-mix at 4% chicken flavor.

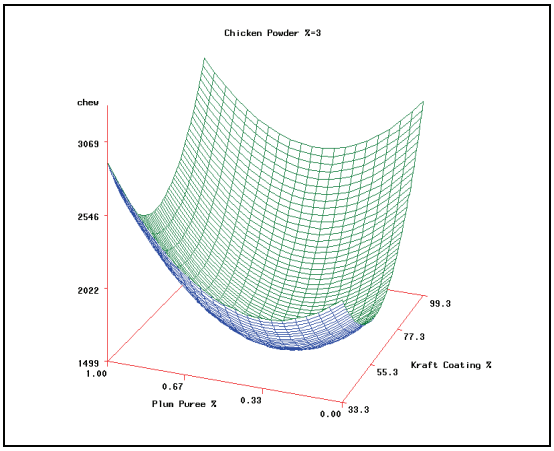
At different levels of plum, chewiness increased at high levels and low levels of Kraft-mix (Figure 22). However, chewiness decreased at high levels and low levels of chicken flavor. At 0% plum and lower Kraft-mix levels, chewiness decreased as chicken flavor was either more than or less than 3.33%. However, chewiness increased as Kraft-mix was either more than or less than 55% when plum was 0%. The turning point of chewiness at 0.5% plum was 3.33% chicken flavor and 55% Kraft-mix.

At various levels of Kraft-mix, chicken flavor and plum had different effects on chewiness. At 33.3% Kraft-mix, chewiness increased as the levels of plum was more than or less than 0.38%, and chewiness decreased dramatically as the levels of chicken flavor was less than 3.4%. When Kraft coating in coating mix was at 66.7%, chewiness increased as the levels of plum was more than or less than 0.43%, and chewiness decreased as the levels of chicken flavor was more than or less than 3%. (Figure 23) Furthermore, at 100% Kraft-mix, chewiness increased as the levels of plum was more than or less than 0.5%, and chewiness decreased as the levels of chicken flavor was more than or less than 2.4% to 2.6%.

(a)



(b)



(c)

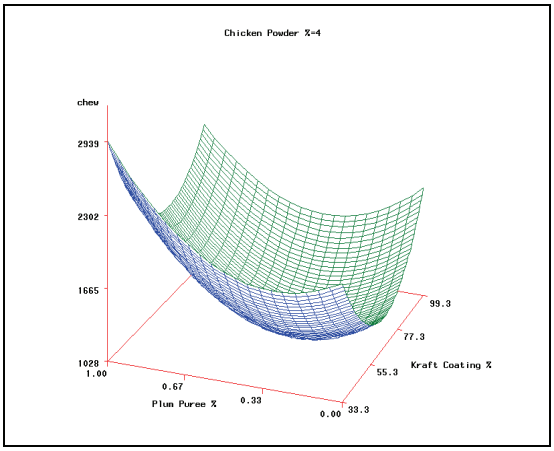
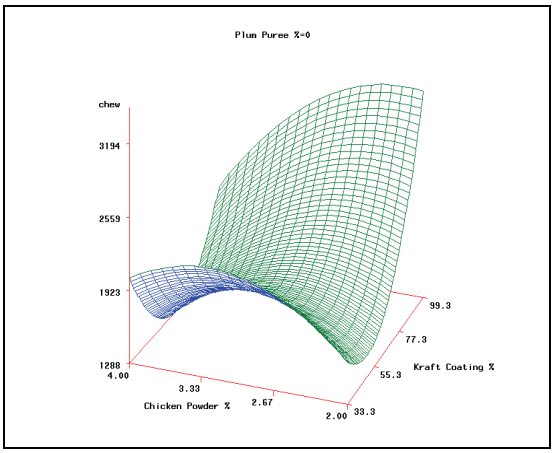
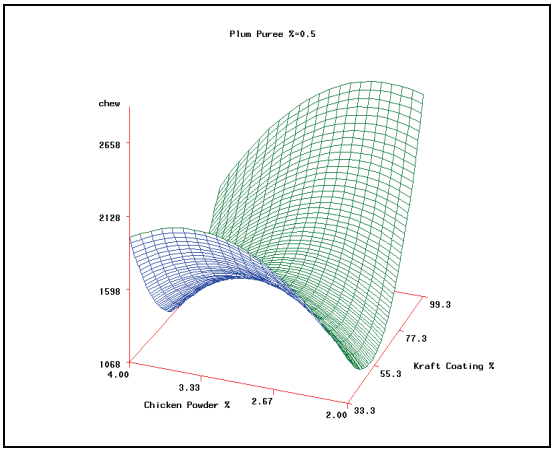


Figure 21: Surface Plots of Chewiness with (a) 2%, (b) 3%, (c) 4% Asian Chicken Flavor

(a)



(b)



(c)

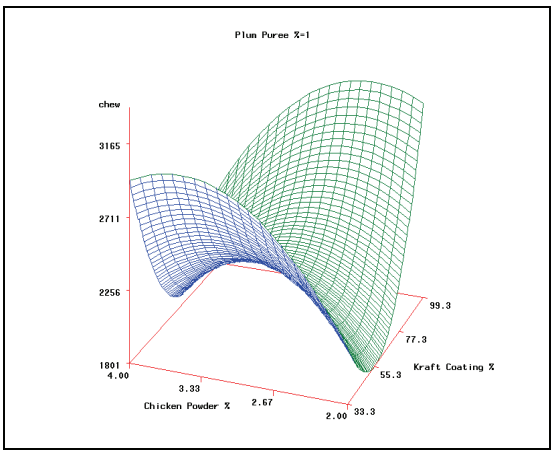
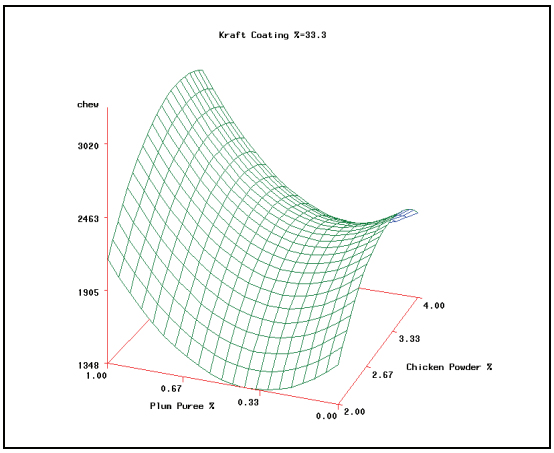
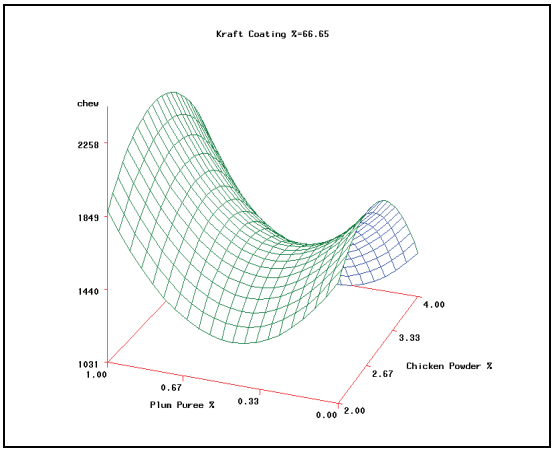


Figure 22: Surface Plots of Chewiness with (a) 0%, (b) 2%, (c) 1% Dried Plum Puree

(a)



(b)



(c)

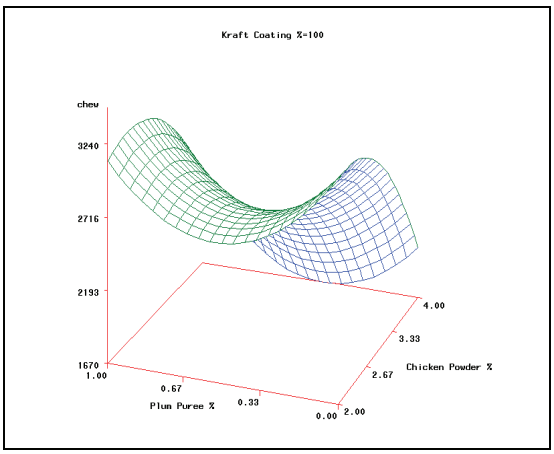


Figure 23: Surface Plots of Chewiness with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

Chicken flavor, plum and Kraft-mix had different effects on springiness of nuggets at the various levels of chicken flavor. At 2% chicken flavor, springiness increased as Kraft-mix increased and plum decreased (Figure 24). Springiness decreased at high and low levels of plum and Kraft-mix for 3% chicken flavor and 4% levels, but decreased for low and high levels of Kraft-mix and low levels of plum only.

For all levels of plum, springiness increased as the level of Kraft-mix increased (Figure 25). However, springiness decreased at high level and low level of chicken flavor. Springiness of nuggets with different level of Kraft-mix decreased as the level of chicken flavor and plum increased and decreased (Figure 26). Yet, the effect of plum on springiness is small compared with the effect of chicken flavor on springiness.

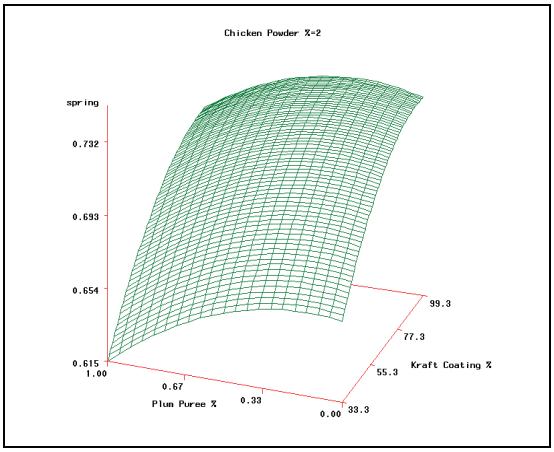
Additionally, cohesiveness of nuggets increased at high levels and low levels of chicken flavor, plum and Kraft-mix. The turning point of cohesiveness for 2% chicken flavor was with 0.58% plum and 5634% Kraft-mix, for 3% chicken flavor was with 0.5% plum and 61.4% Kraft-mix, for 4% chicken flavor was with 0.43% plum and 66.3% Kraft-mix (Figure 27). In term of different levels of plum, nuggets had least cohesiveness when formulations were 0% plum, 3.3% chicken flavor and 65% Kraft-mix; 0.5% plum, 3% chicken flavor and 61% Kraft-mix; 1% plum, 2.8% chicken flavor and 58.1% Kraft-mix (Figure 28).

Similar situations were found with different levels of Kraft-mix. At 33.3% Kraft-mix, cohesiveness of nuggets increased when the levels of plum and chicken flavor were more than or less than approximately 0.55% and approximately 2.8%, respectively (Figure 29). Furthermore, cohesiveness of nuggets increased as plum was more than or less than 0.5% and chicken flavor was more than or less than 3.1% when Kraft-mix was

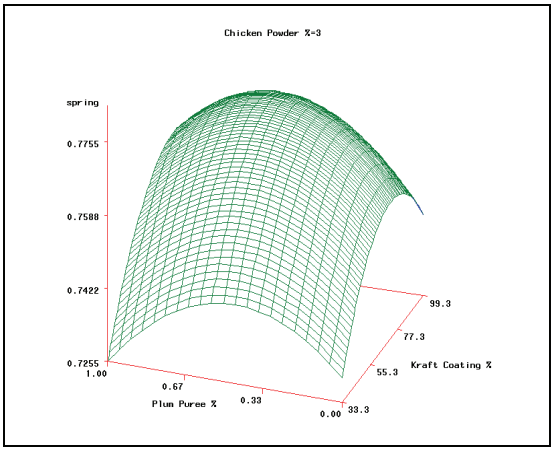
at 66.65%. While the levels of plum was more than or less than 0.4% and the levels of chicken flavor was more than or less than 3.5%, cohesiveness of nuggets with 100% Kraft-mix increased.

The texture results indicated that all three independent variables (chicken powder, plum and Kraft-mix) might have affected texture profiles of treatments. The salt content in the treatments increased at higher levels of chicken powder. Hence, this might have increased moisture absorption during water-cook and affected the texture of the nuggets. Furthermore, coating might be another factor that affected texture profile of the nuggets. Kraft Shake'N Bake Seasoned Coating Mix contains wheat flour whereas Best Choice Seasoned Coating MGix contains bread crumb. Since wheat flour did not gone through additional process as bread crumb; therefore, treatments with higher levels of Kraft-mix might bind more moisture during baking and influenced the texture of the nuggets. Additionally, cooling method of encased treatments after kettle cook might also affected the texture profile of the nuggets.

(a)



(b)



(c)

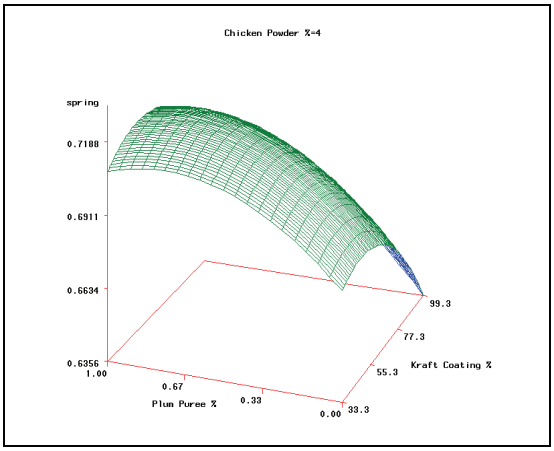
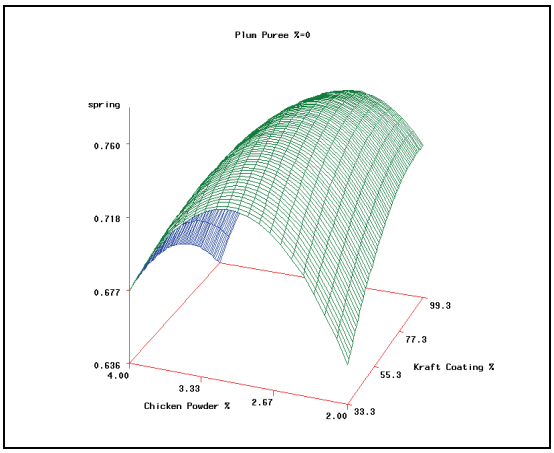
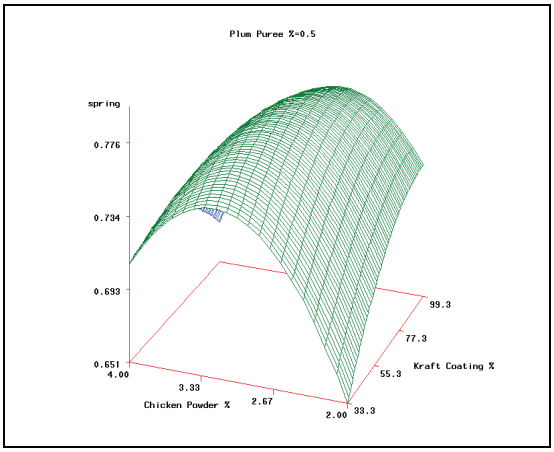


Figure 24: Surface Plots of Springiness with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



(b)



(c)

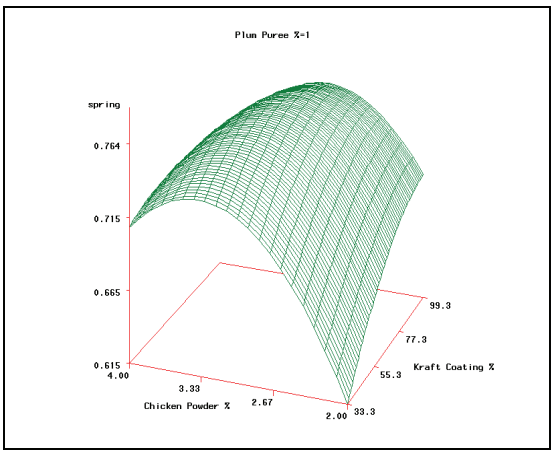
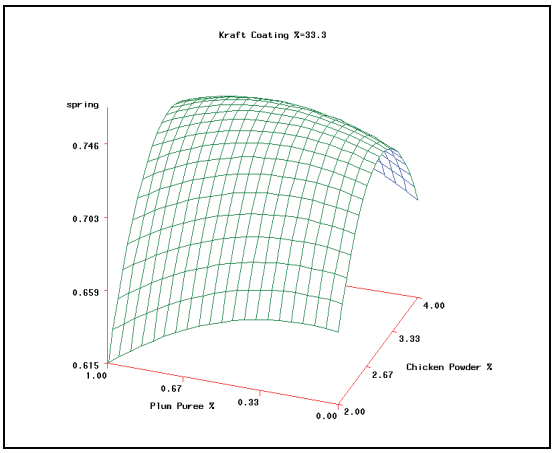
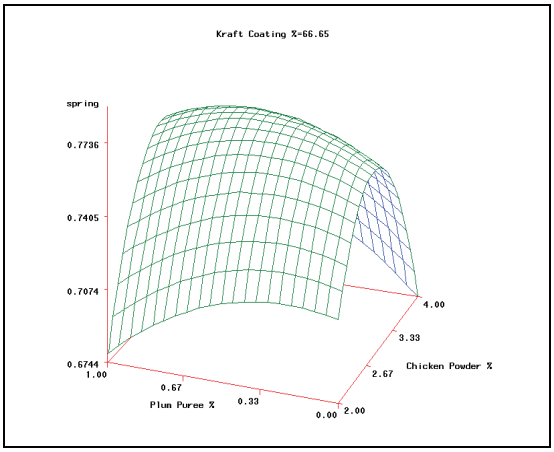


Figure 25: Surface Plots of Springiness with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



(b)



(c)

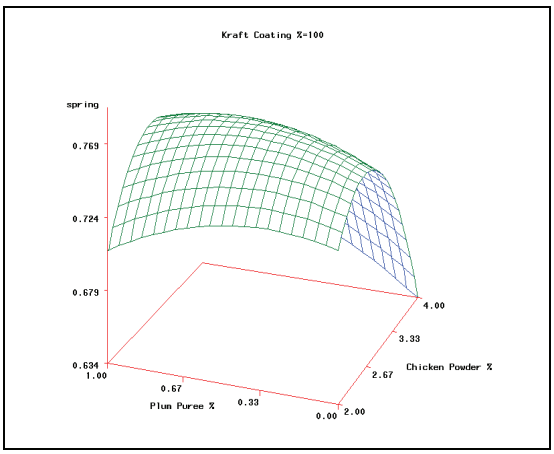
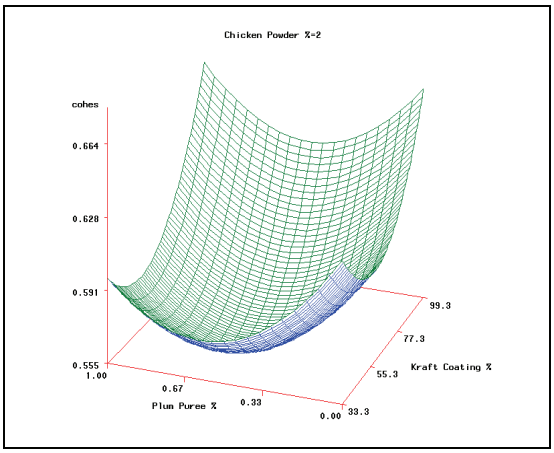
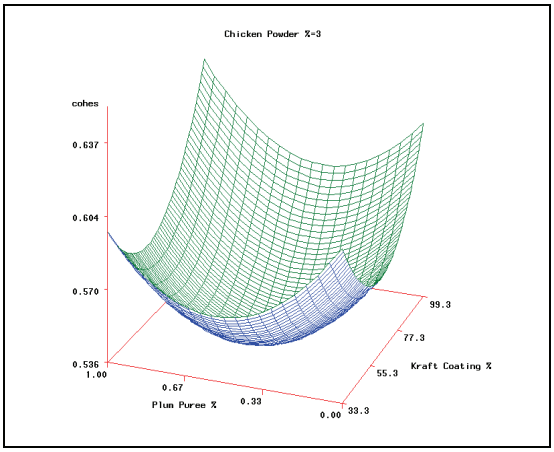


Figure 26: Surface Plots of Springiness with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

(a)



(b)



(c)

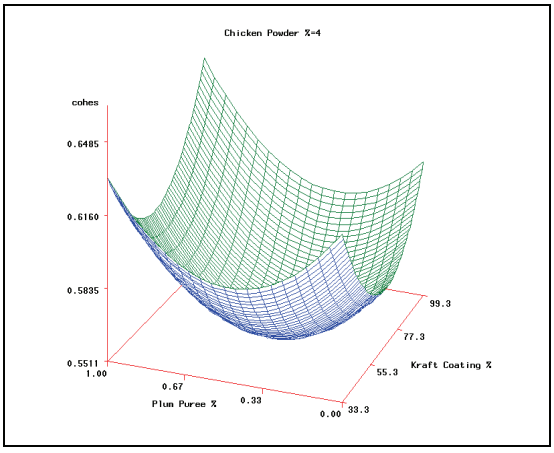
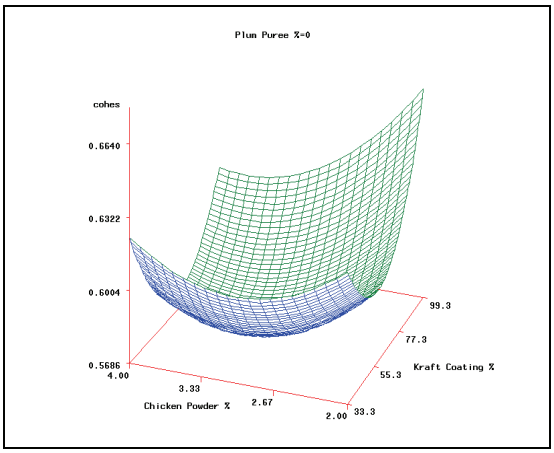
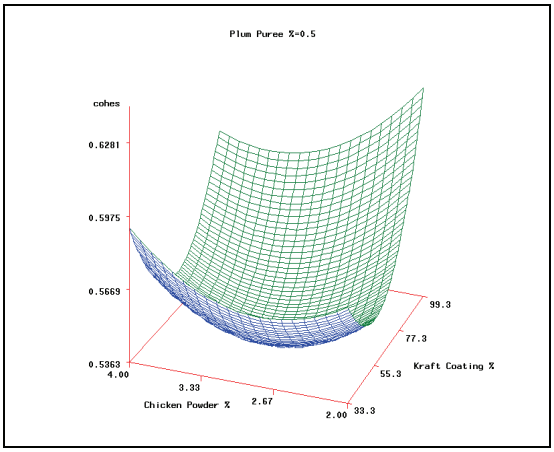


Figure 27: Surface Plots of Cohesiveness with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



(b)



(c)

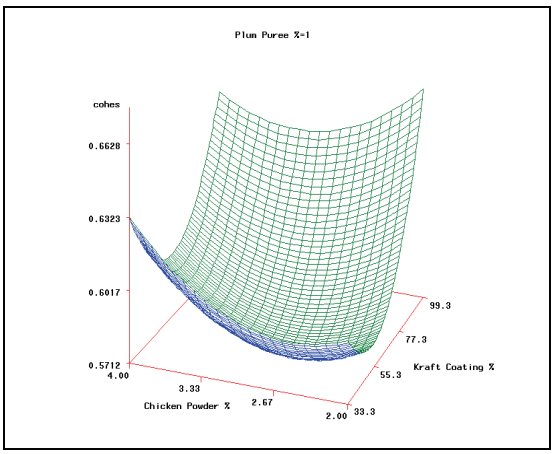
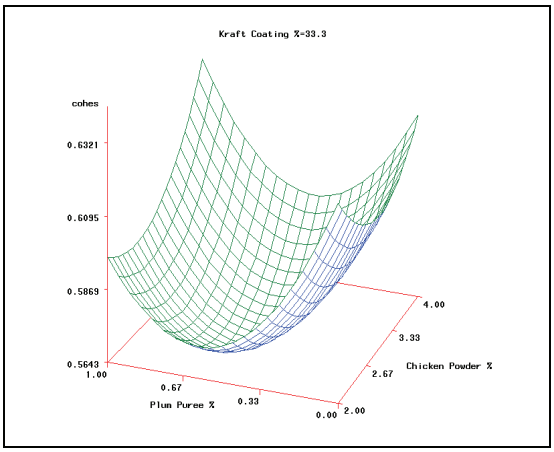
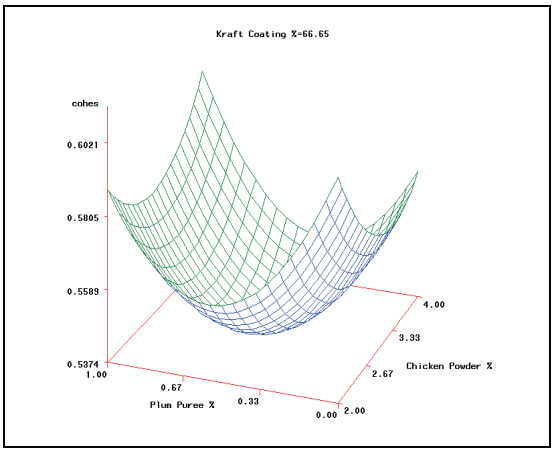


Figure 28: Surface Plots of Cohesiveness with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



(b)



(c)

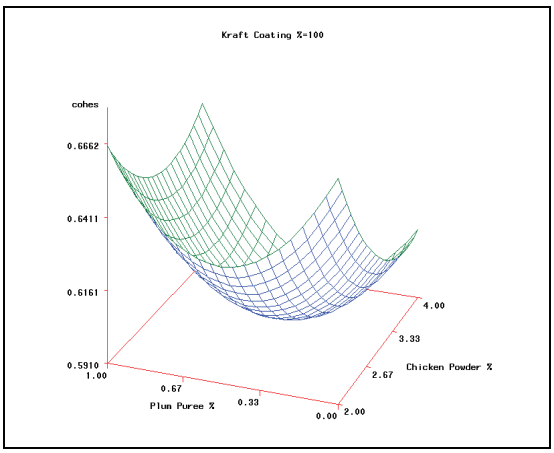


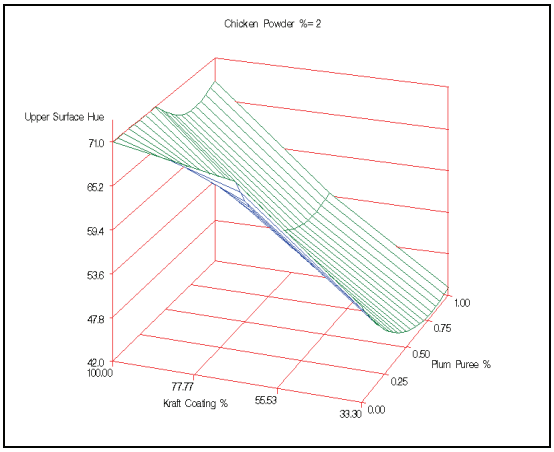
Figure 29: Surface Plots of Cohesiveness with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

(e) Surface Plots for Color

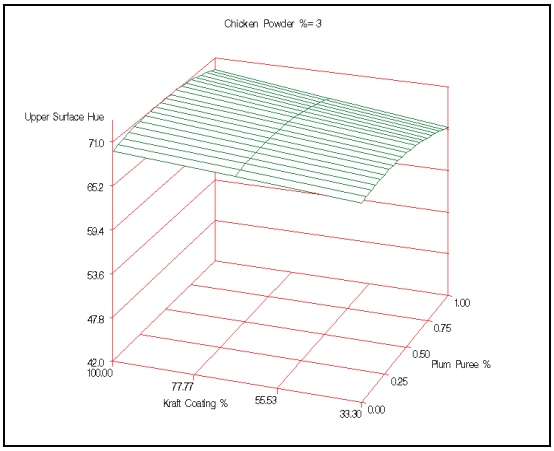
All three color dimensions (L value, hue angle and chroma) of meatless chicken nugget analogs were measured. At low levels of chicken powder, hue increased mainly as the levels of Kraft-mix increased (Figure 30a). However, hue peaked at 0% plum and middle levels of chicken powder (Figure 31a). Hue was fairly constant at middle to higher levels of chicken powder at all levels for plum and Kraft-mix. At high chicken levels, hue was increased as the levels of plum increased (Figure 30c). Similar trends were found in the contour and surface plots when Kraft-mix and plum were held constant. Furthermore, chicken powder, plum and Kraft-mix showed the similar effects on chroma (Figures 33-35). Nonetheless, the independent variables have different effect on L value (Figures 36-38). At low levels of chicken, L value increased at high levels of plum but low levels of Kraft-mix (Figure 36). L value was not affected much by Kraft-mix and plum at middle levels of chicken powder. However, as the chicken powder increased, L value increased for low and high levels of plum (Figure 36).

Kraft Shake'N Bake Seasoned Coating Mix (Kraft-mix) has a hue angle of 104.0°, chroma of 2.38 and L value of 97.75; whereas, Best Choice Seasoned Coating Mix (BestC) has a hue angle of 90.2°, chroma of 11.62 and L value of 89.60. Therefore, nuggets with higher level of Kraft-mix tend to be lighter and less intense yellowish-green-brown color. However, BestC caused the nuggets to be darker and more intense yellowish-brown color. Furthermore, BestC contained a higher amount of sugar than Kraft-mix which might contribute to darkening the nugget caused by Maillard browning reaction during baking.

(a)



(b)



(c)

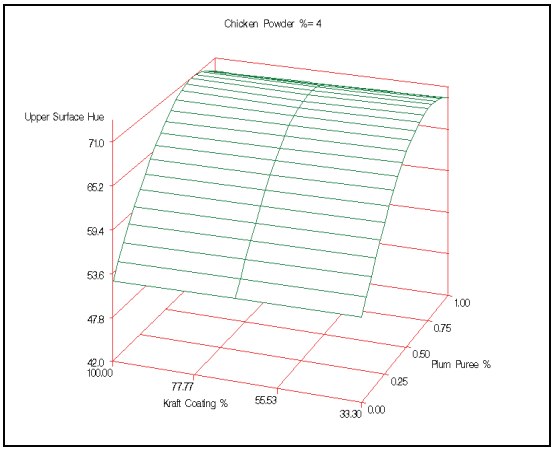
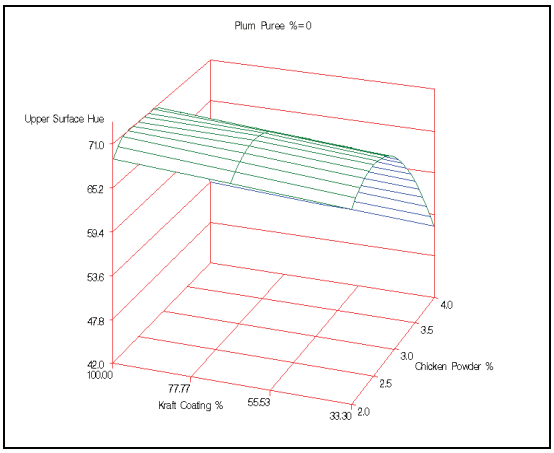
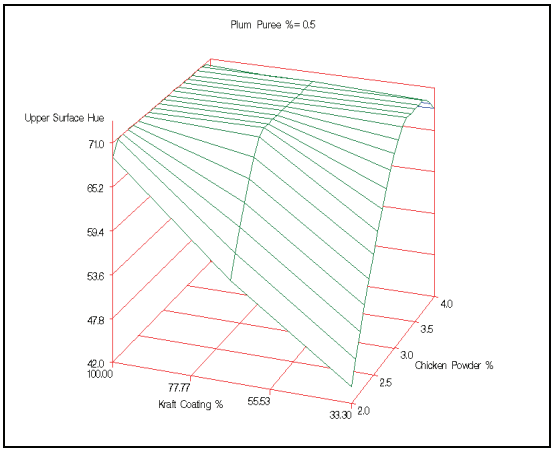


Figure 30: Surface Plots of Hue with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



(b)



(c)

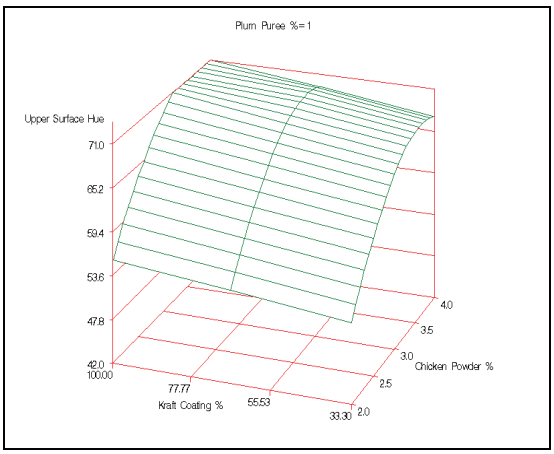
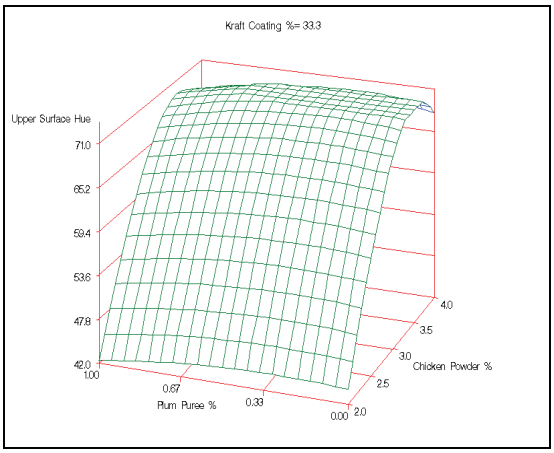
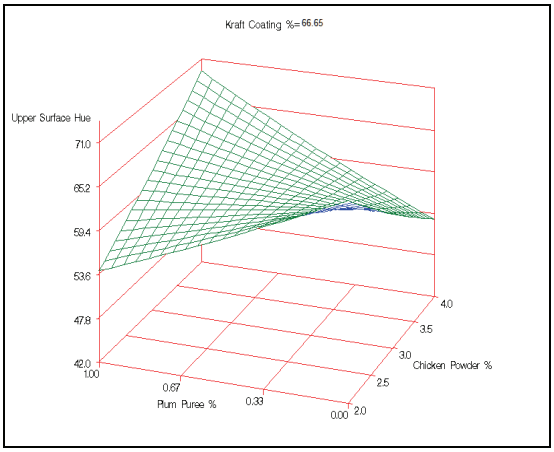


Figure 31: Surface Plots of Hue with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



(b)



(c)

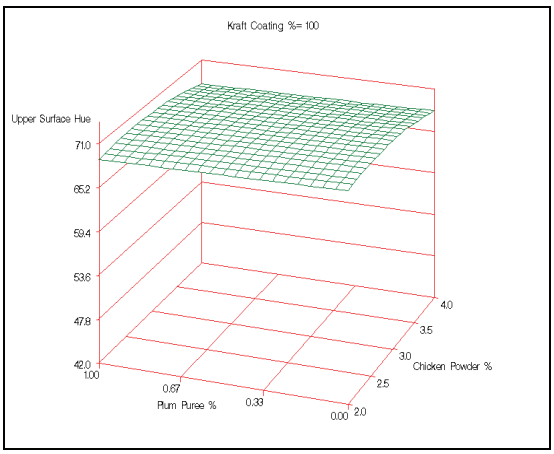
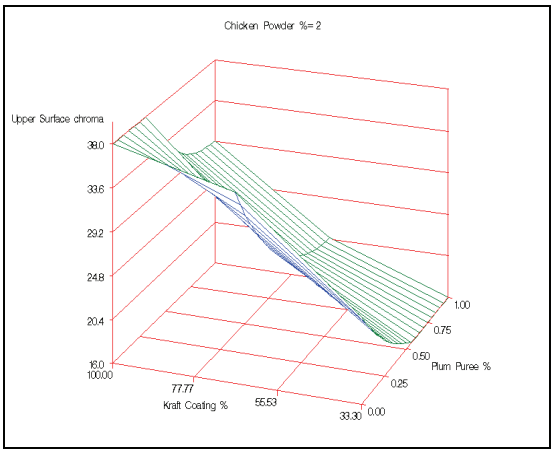
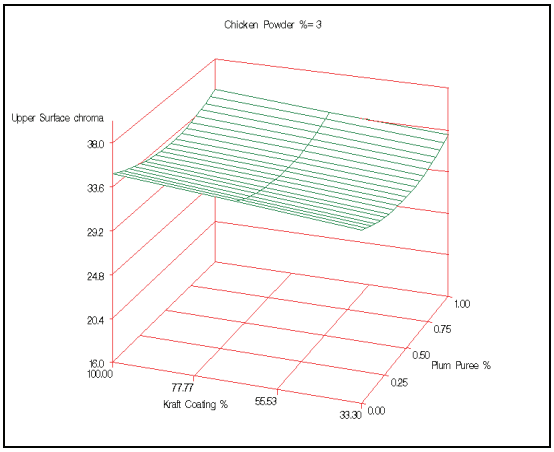


Figure 32: Surface Plots of Hue with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

(a)



(b)



(c)

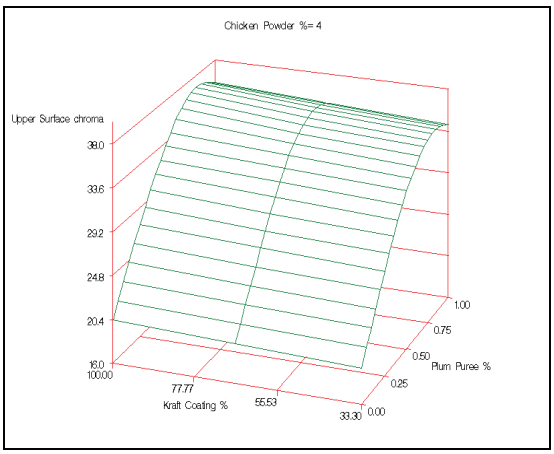
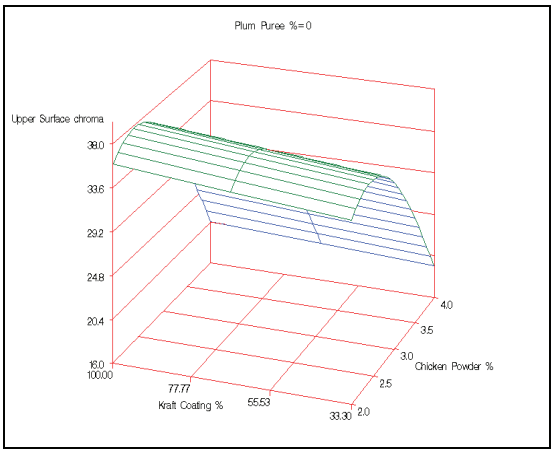
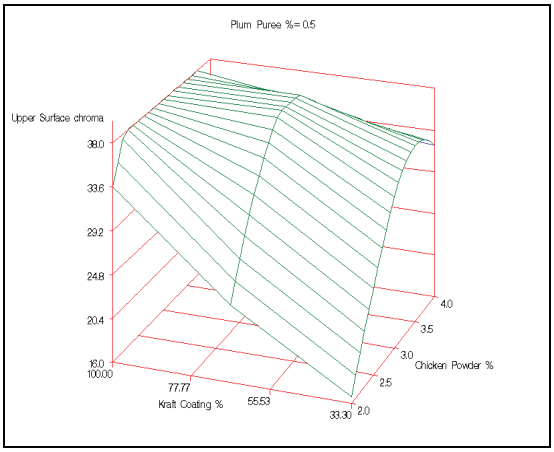


Figure 33: Surface Plots of Chroma with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



(b)



(c)

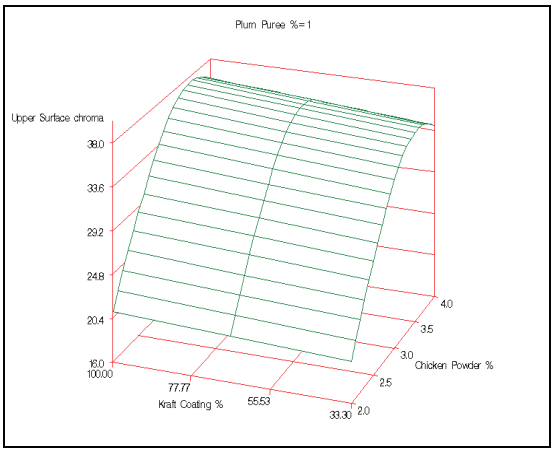
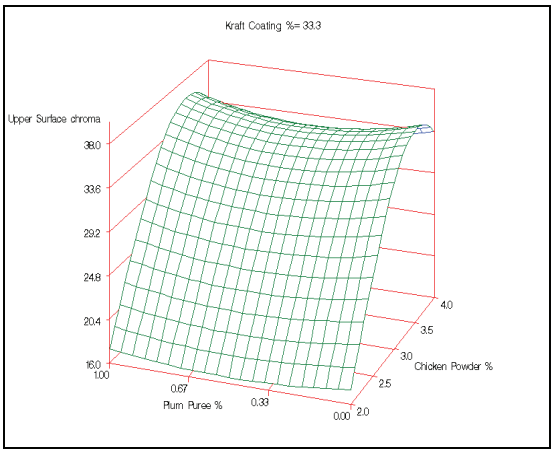
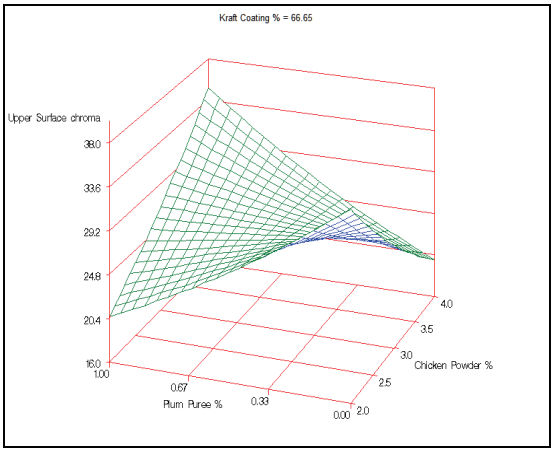


Figure 34: Surface Plots of Chroma with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



(b)



(c)

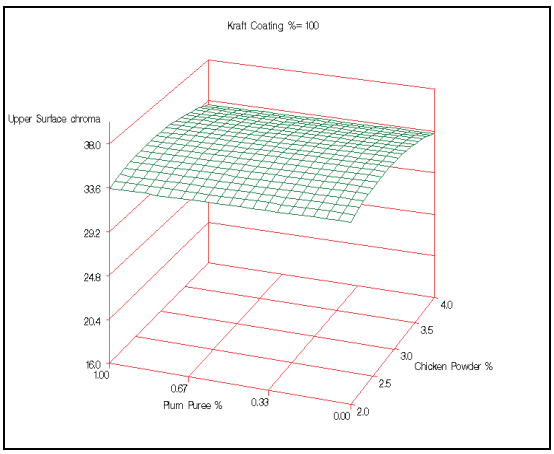
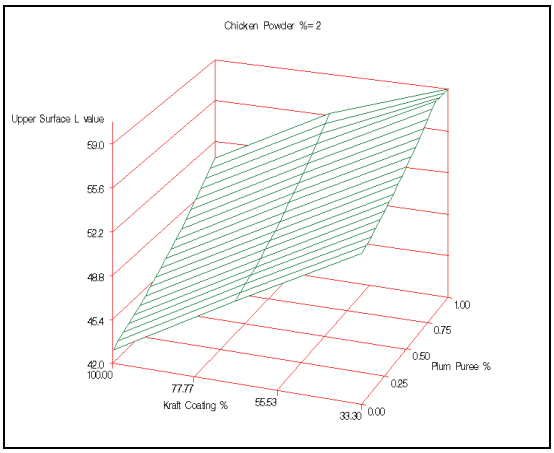
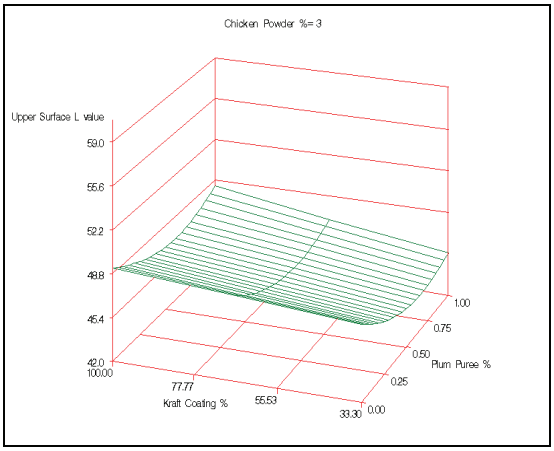


Figure 35: Surface Plots of Chroma with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

(a)



(b)



(c)

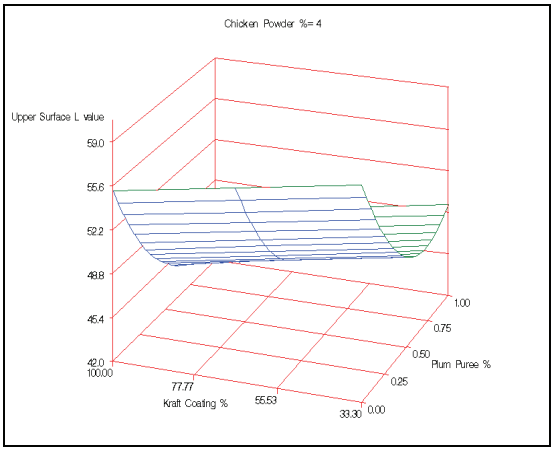
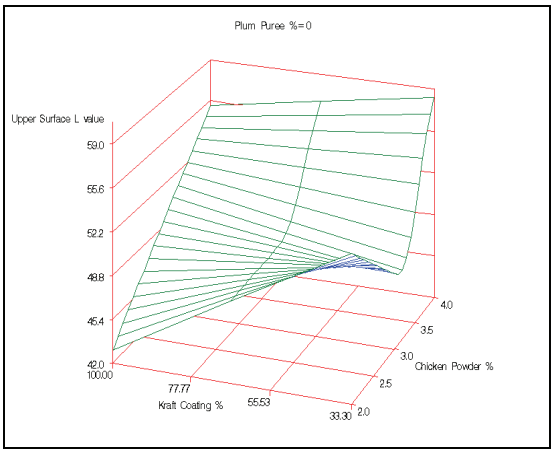
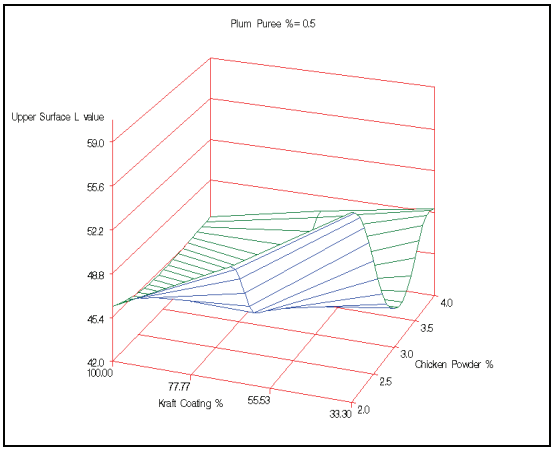


Figure 36: Surface Plots of L Value with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

(a)



(b)



(c)

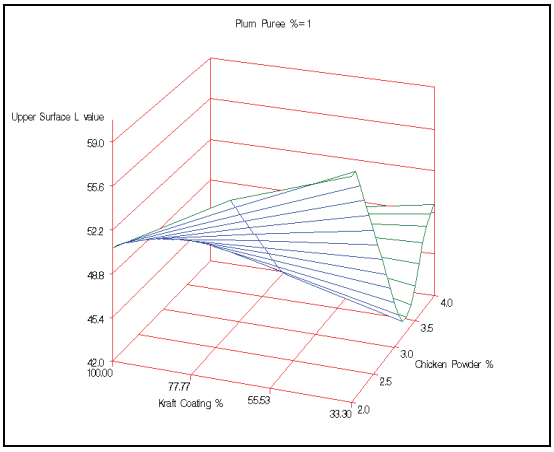
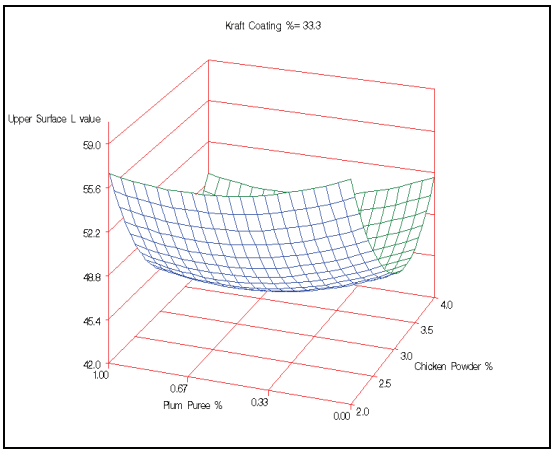
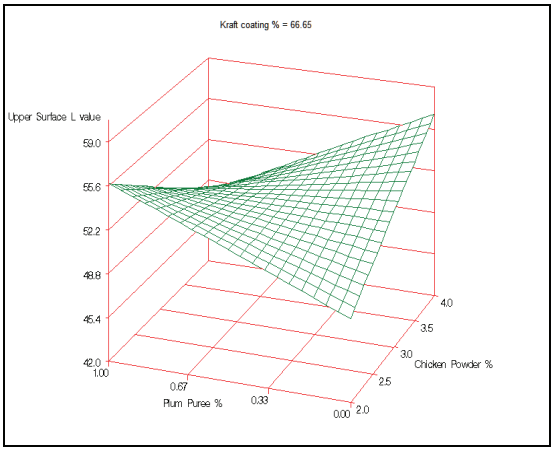


Figure 37: Surface Plots of L Value with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

(a)



(b)



(c)

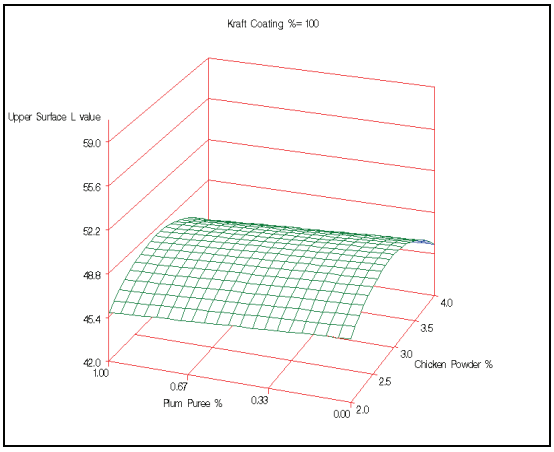


Figure 38: Surface Plots of L Value with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

4.2.2 Sensory Evaluation

Sensory evaluation was conducted in the Sensory Lab facilities, Oklahoma Food and Agricultural Products Research and Technology Center, Oklahoma State University, Stillwater. Approval to conduct sensory evaluation of the samples was obtained from the Institutional Review Board (IRB), Oklahoma State University (Appendix E). A total of 116 panelists participated in the sensory part of this research and completed consent forms (Appendix F). Each panelist was responsible to evaluate eight different nugget samples. Panelists were asked to fill out a score sheet (Appendix G) with a 9-point Hedonic Scale based on the appearance, smell, taste, and texture of the samples. The 9 points on the Hedonic Scale were: dislike extremely = 1, dislike very much = 2, dislike moderately = 3, dislike slightly = 4, neither like nor dislike = 5, like slightly = 6, like moderately = 7, like very much = 8 and like extremely = 9.

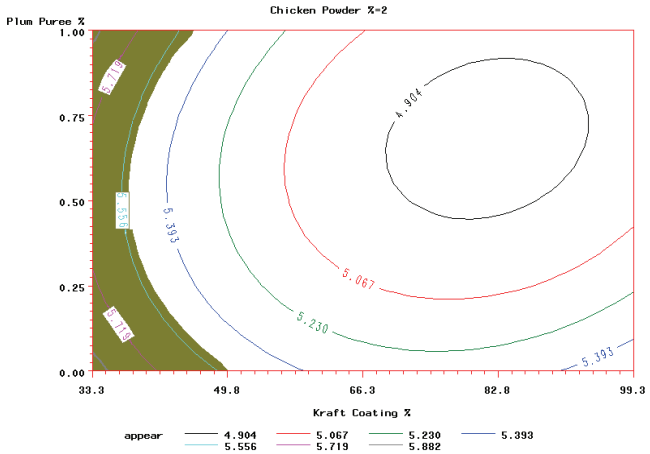
(a) Response Surface Regression

Response surface regression (RSREG) was done to determine the effects of independents variables which were chicken flavor, plum and Kraft-mix on sensory attributes of nugget samples. The measured sensory attributes of nugget samples were appearance, smell, taste and texture. The regression models for appearance, smell taste and texture showed no significant lack of fit. Therefore, the regression coefficients for those sensory attributes were used to generate contour (Figures 39-50) and surface plots (Appendix H) for the response variables.

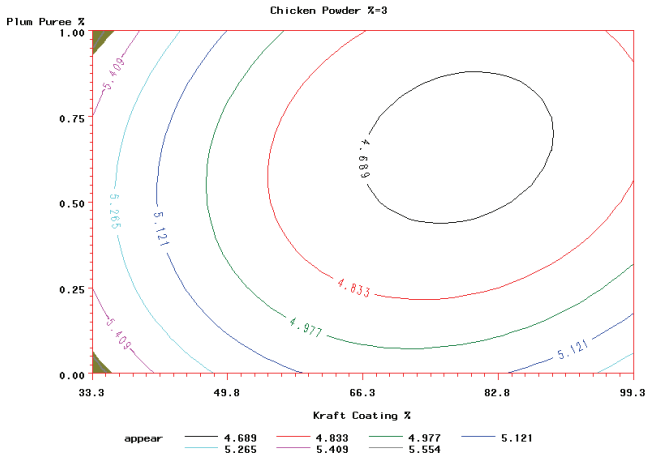
(b) Contour Plots

Experimental treatments with sensory attribute score above 5.5 were considered as acceptable. The influence of chicken flavor, plum and Kraft-mix on acceptability of nugget appearance is shown in Figures 39-41. Nuggets were most acceptable in appearance when Kraft-mix was low at approximately 33.3% to 37.4%. The acceptability of smell decreased as the percent of plum and the percent of Kraft-mix in the formulation were increased (Figures42-44). Smell was acceptable for all levels of chicken flavor when Kraft-mix was approximately 33.3% to 53.1% and plum was around 0% to 0.3%. In addition, taste of nuggets was acceptable to panelists at low levels of Kraft-mix, approximately 33.3% to 36.6%, when chicken flavor was approximately 2.0% to 3.7% and plum was approximately 0% to 0.1%. Figures 45-47 showed the contour plots for taste with different levels of chicken flavor, plum and Kraft-mix. Furthermore, acceptability of texture was highest at low levels of Kraft-mix (approximately 33.3% to 44.8%) and plum (approximately 0% to 0.23%). Panelists considered nuggets to have the most acceptable texture when plum was less than 0.2% and Kraft-mix was less than 44.8% for all levels of chicken flavor. Figures 48-50 showed the contour plots for texture with different levels of chicken flavor, plum and Kraft-mix.

(a)



(b)



(c)

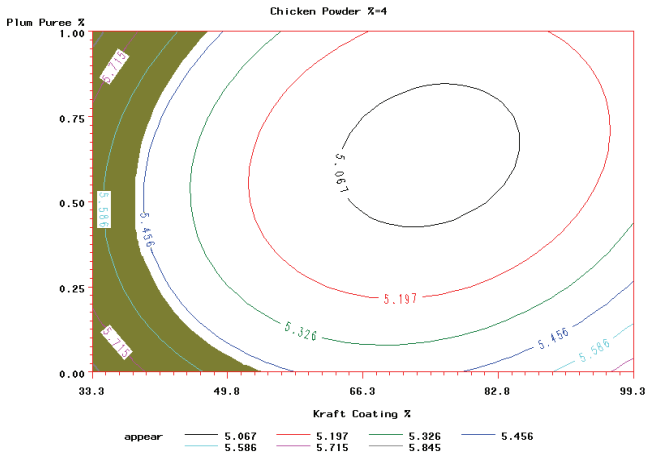
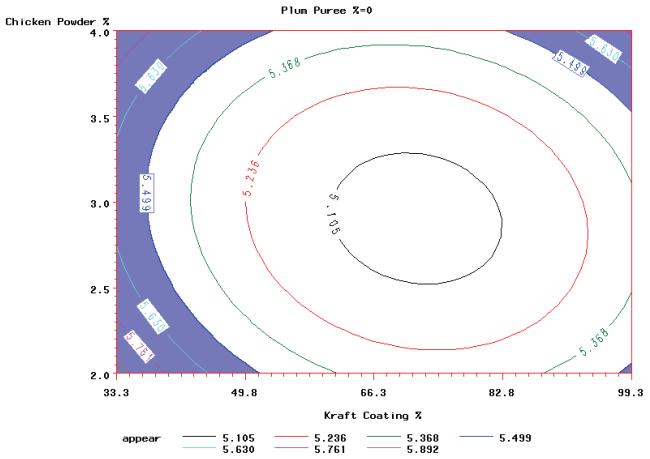


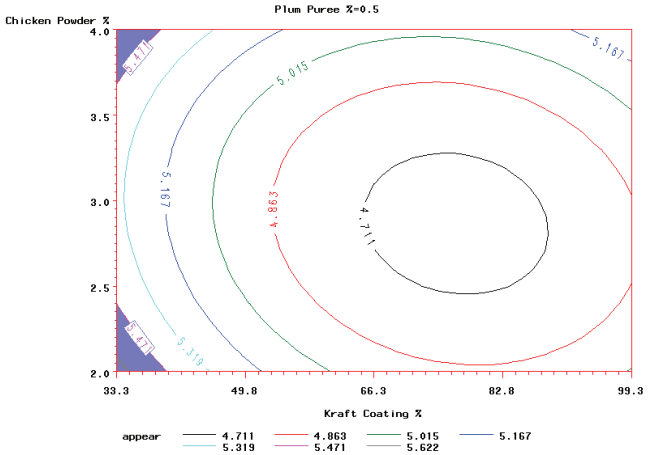
Figure 39: Contour Plot of Sensory Scores for Appearance with (a) 2%, (b) 3%, (c) 4% Chicken Powder

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

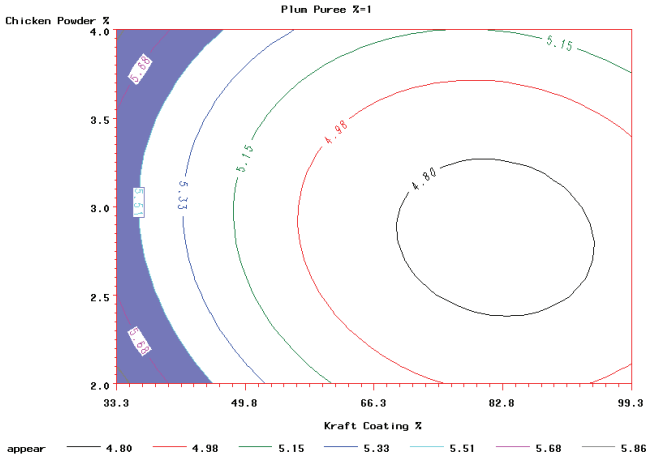
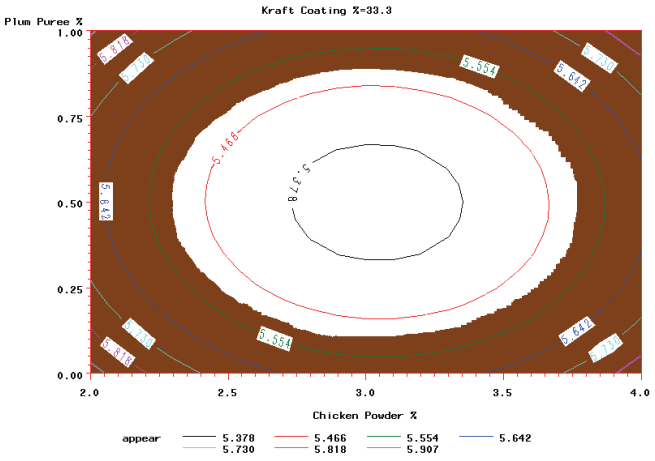


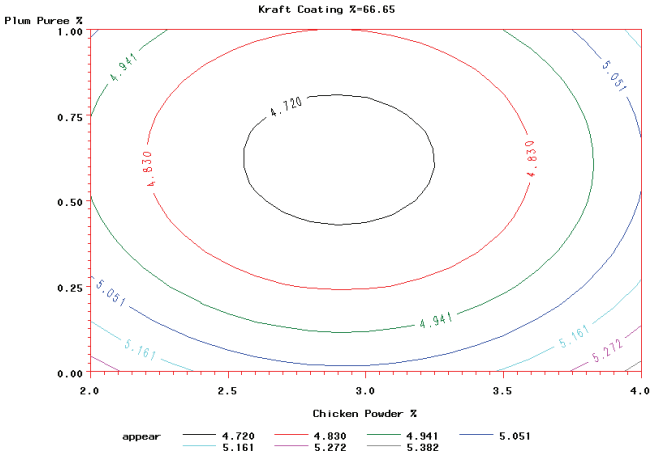
Figure 40: Contour Plot of Sensory Scores for Appearance with (a) 0%, (b) 0.5%, (c) 1% Plum Puree

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

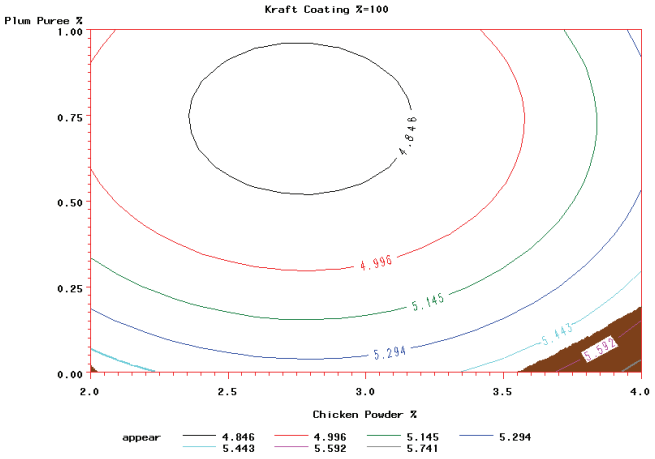
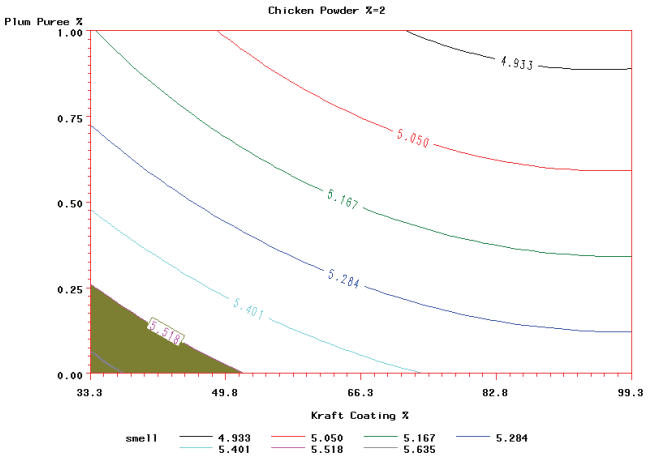


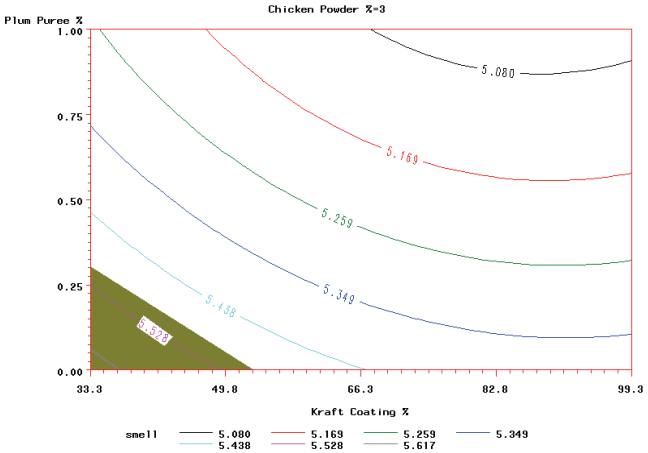
Figure 41: Contour Plot of Sensory Scores for Appearance with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

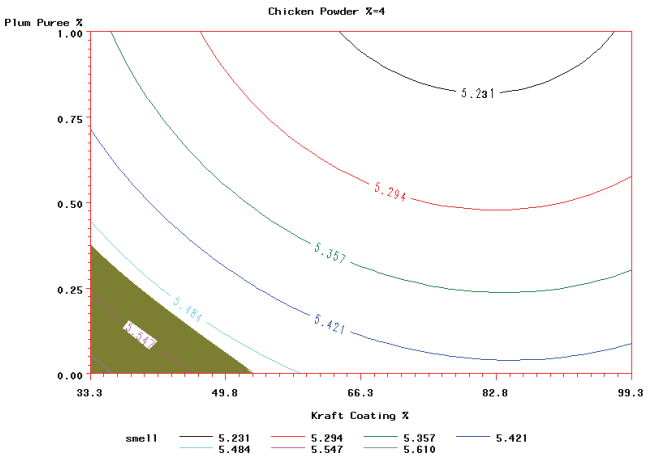
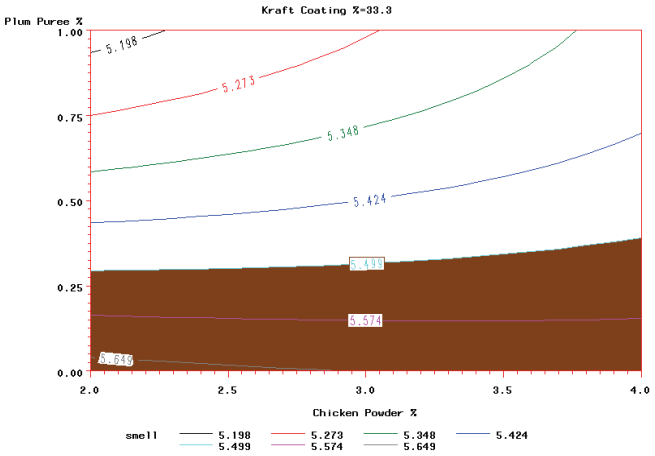


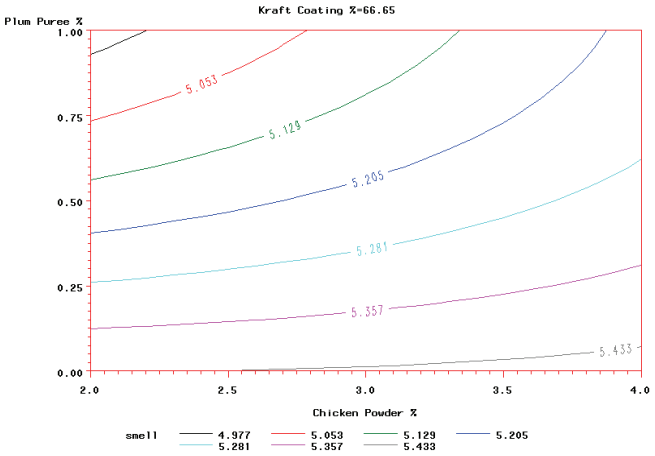
Figure 42: Contour Plot of Sensory Scores for Smell with (a) 2%, (b) 3%, (c) 4% Chicken Powder

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

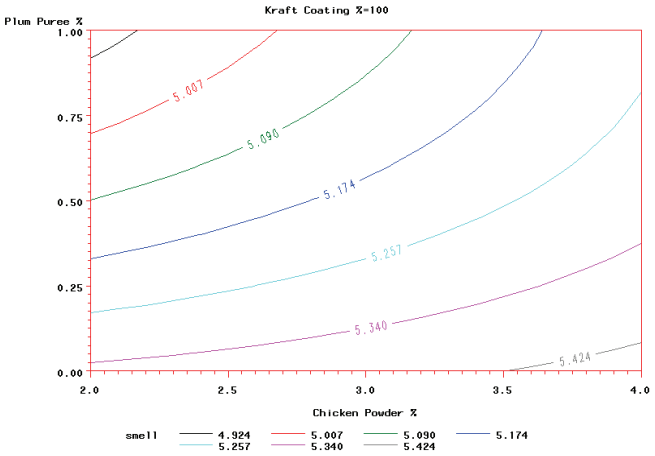
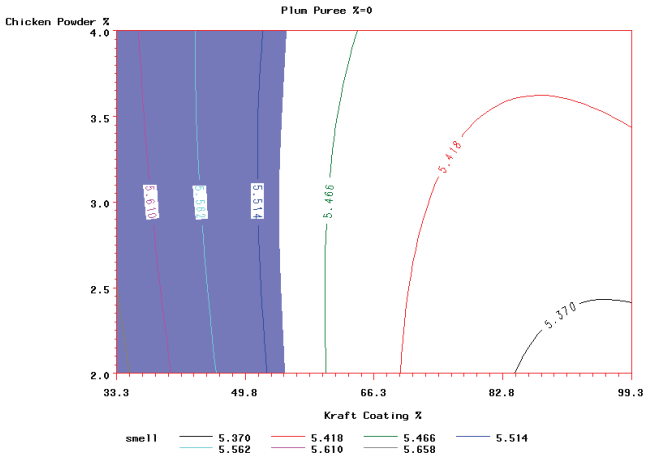


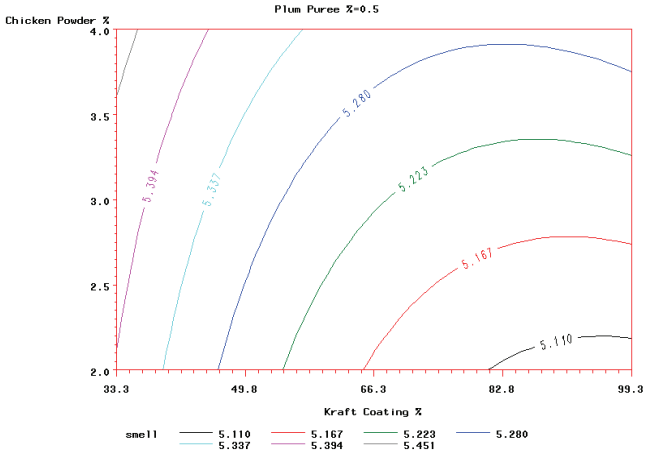
Figure 43: Contour Plot of Sensory Scores for Smell with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

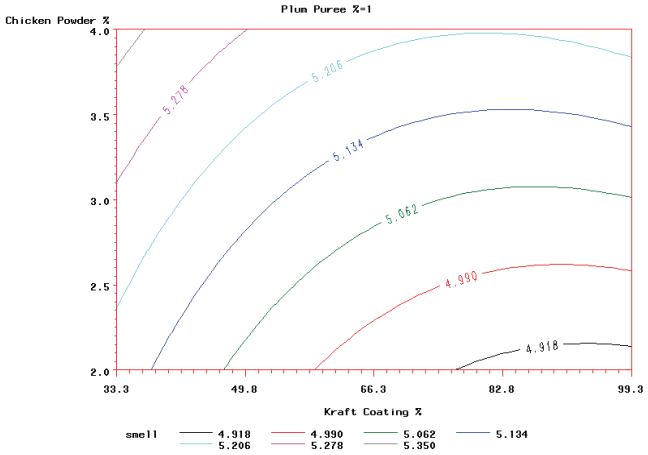
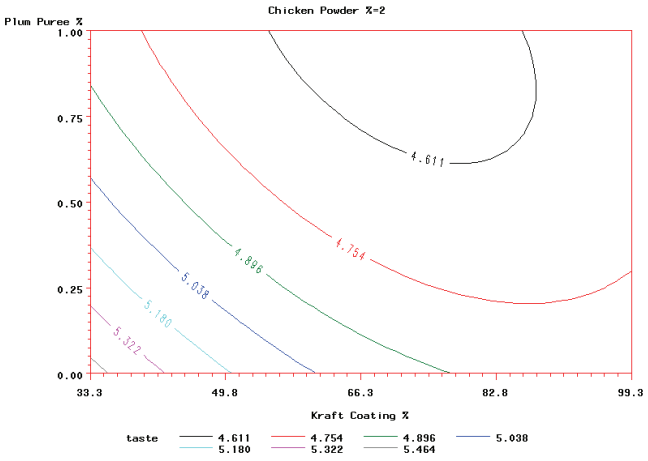


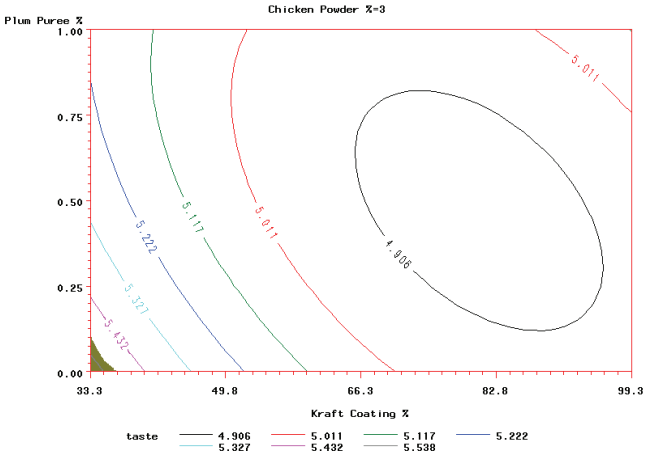
Figure 44: Contour Plot of Sensory Scores for Smell with (a) 0%, (b) 0.5%, (c) 1% Plum Puree

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

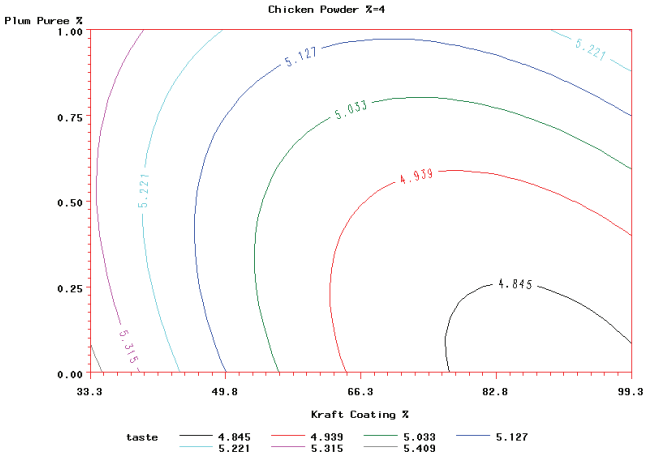
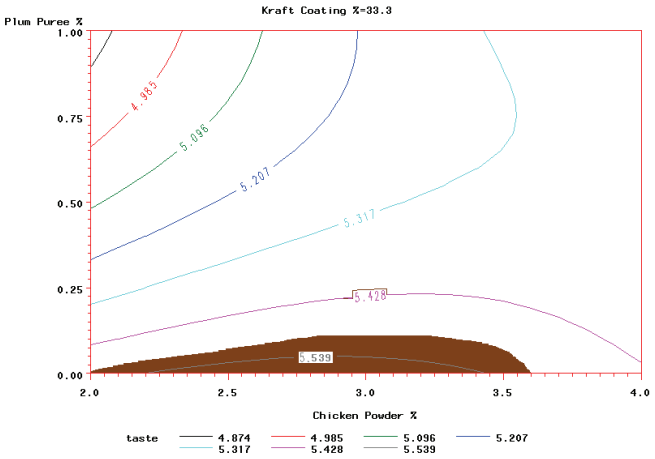


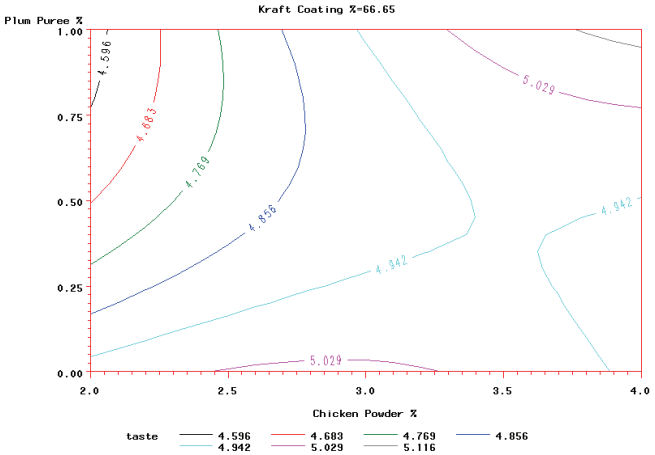
Figure 45: Contour Plot of Sensory Scores for Taste with (a) 2%, (b) 3%, (c) 4% Chicken Powder

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

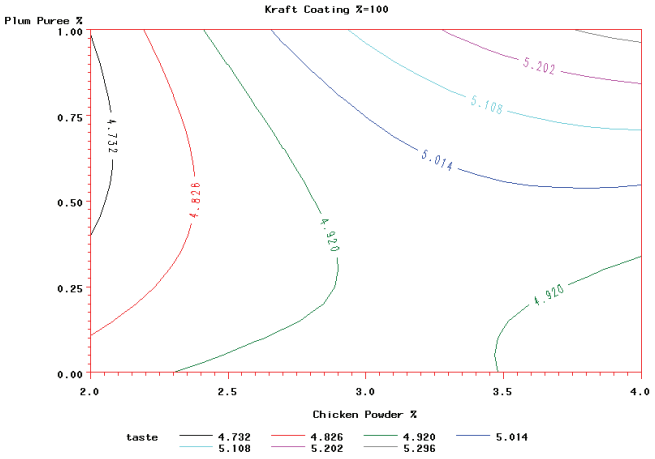
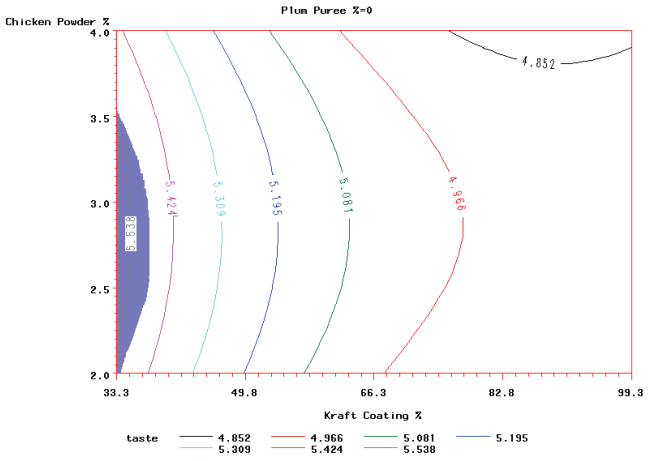


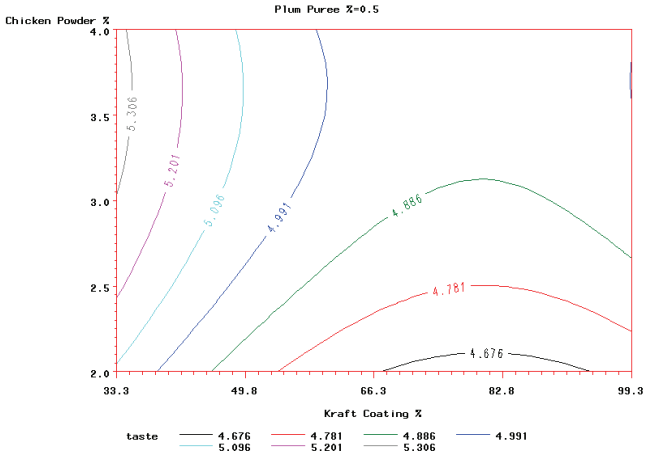
Figure 46: Contour Plot of Sensory Scores for Taste with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

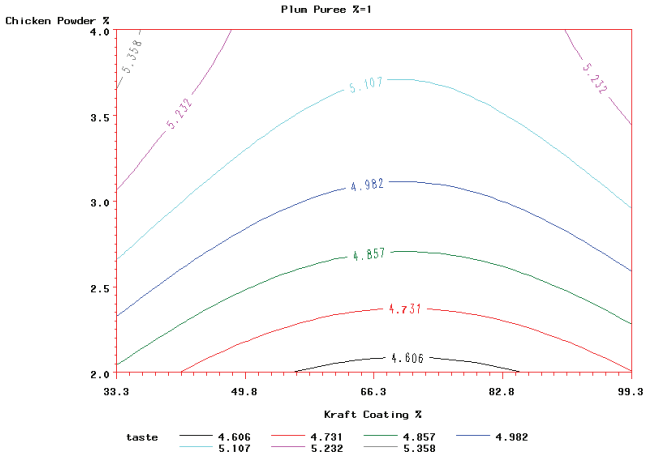
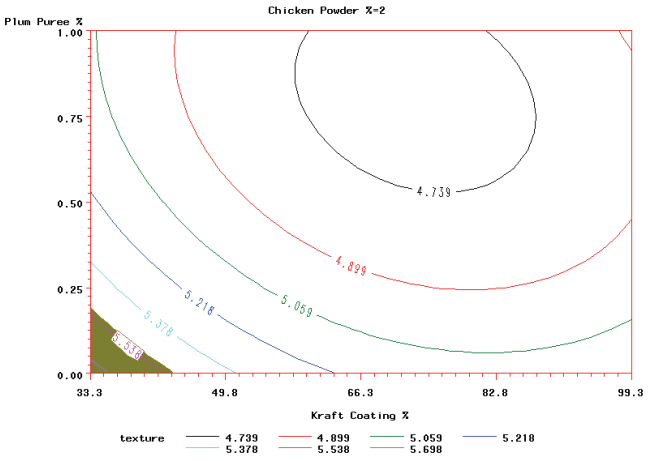


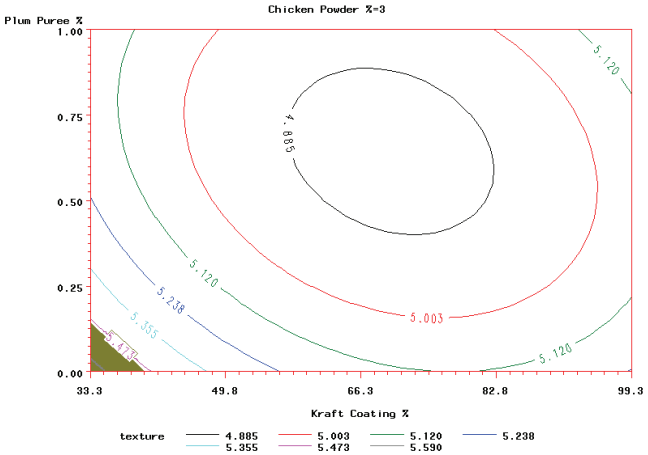
Figure 47: Contour Plot of Sensory Scores for Taste with (a) 0%, (b) 0.5%, (c) 1% Plum Puree

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

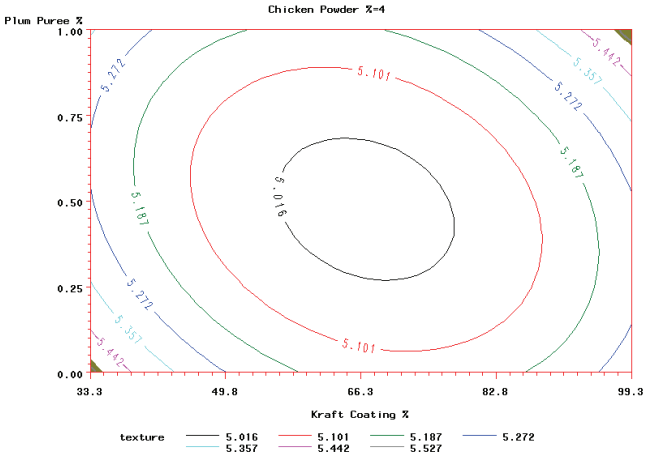
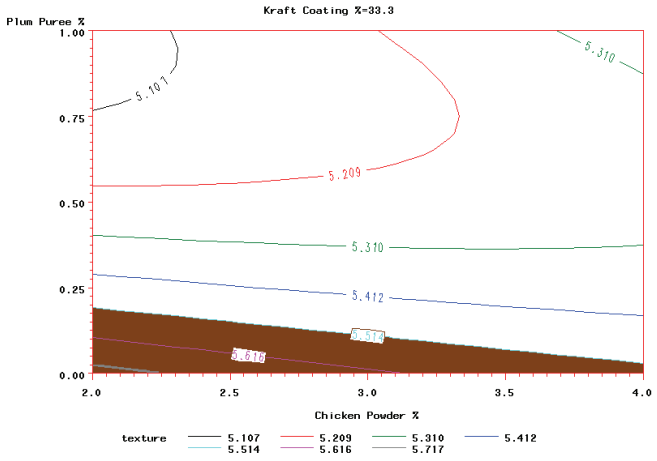


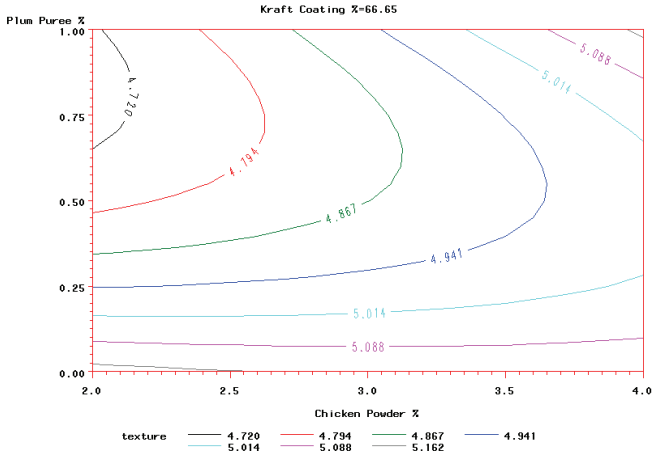
Figure 48: Contour Plot of Sensory Scores for Texture with (a) 2%, (b) 3%, (c) 4% Chicken Powder

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

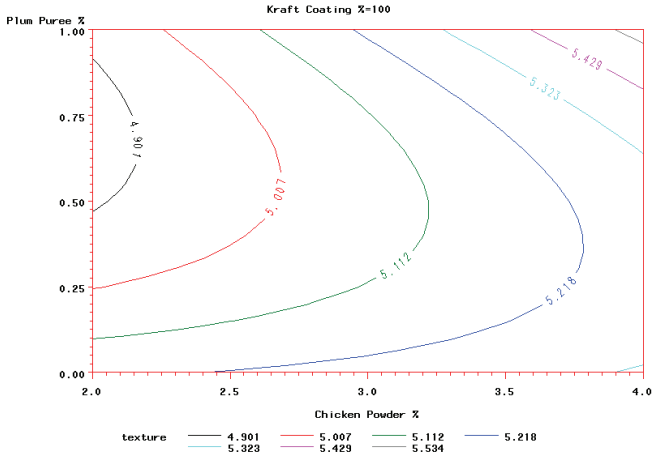
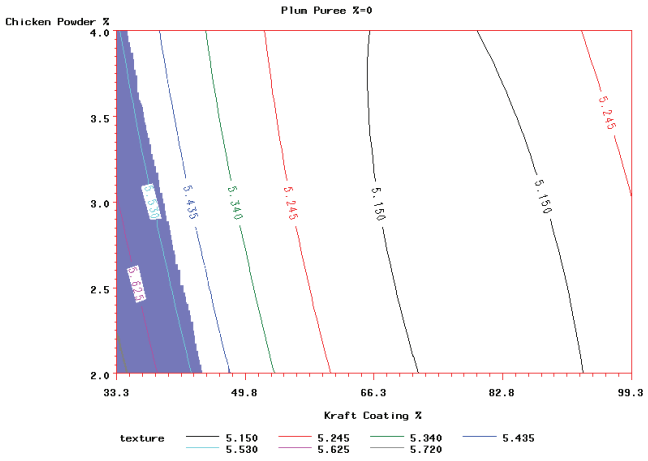


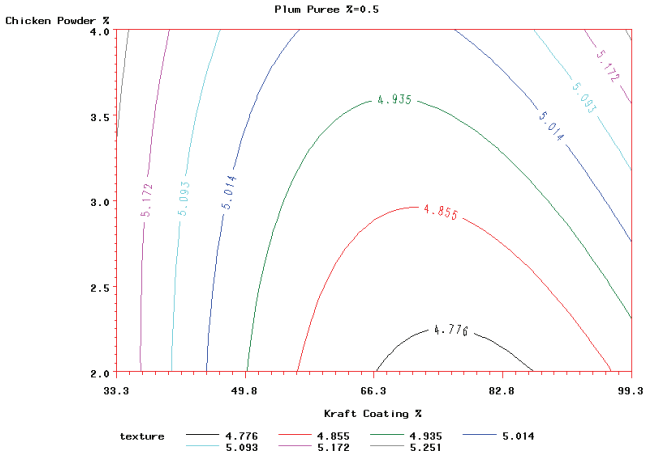
Figure 49: Contour Plot of Sensory Scores for Texture with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating

(Shaded area indicates acceptable treatments)

(a)



(b)



(c)

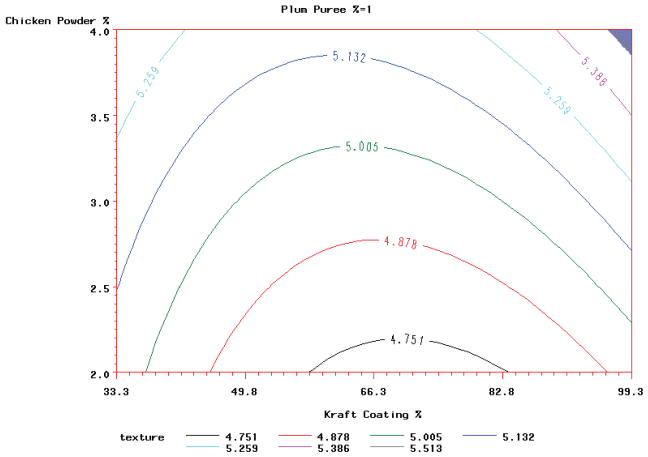


Figure 50: Contour Plot of Sensory Scores for Texture with (a) 0%, (b) 0.5%, (c) 1% Plum Puree

(Shaded area indicates acceptable treatments)

4.2.3 Comparison of Physical and Sensory Attributes

Panelists preferred to have harder, chewier and more yellowish-red nuggets. In general, panelists preferred nuggets containing low Kraft-mix, low plum and medium range of chicken flavor. Nuggets with high amount of chicken flavor were less hard than nuggets with lower amount of chicken flavor. It might be assumed that the higher the amount of chicken flavor (higher salt) in the nuggets might have caused flavor leaching out and water leaching into the permeable casing during water cooking stage causing the higher-chicken flavor nuggets to be softer. However, nuggets might be bland and will not be acceptable to panelists if only lower amounts of chicken flavor were incorporated. Best Choice Seasoning Coating Mix gave nuggets more yellowish-red color while Kraft Seasoning Coating Mix gave nuggets more yellowish-green color. Since most of the commercial nuggets have golden brown color, nuggets with more intense yellowish-red color might attract panelists' attention.

Nugget formulations with 2% to 3.7% of chicken flavor, 0% to 0.1% dried plum puree and 33.3% to 37.4% Kraft coating in coating mix were acceptable to consumers. Based on the contour and surface plots, nuggets with formulations within the acceptable range have color with Hue angle about 55° to 71°, Chroma ~ 24.8 to 35.8 and L value ~ 44 to 53. Furthermore, nuggets with low Kraft-mix, low plum and chicken flavor (2% to 3.7%) have acceptable moisture content (53% to 55%) and acceptable water activity content (0.93 to 0.96). Nuggets within the predicted consumer acceptability range had texture profile of 1570 to 2133 chewiness, 0.643 to 0.723 springiness, 0.30 to 0.33 resilience, 3662 to 4411g hardness, 0.57 to 0.62 cohesiveness and maximum adhesiveness of -59. Table 7 shows the physical properties of the reference (Morningstar

Farms Chick'n Nuggets) and the meatless chicken nugget analogs (TP analogs) with acceptable sensory attributes.

Table 7: Physical Properties of Acceptable TP Analogs and Reference

Variables	TP Analogs	Reference
Hue angle	55 -- 71	74
Chroma	24 -- 35.8	39
L value	44 -- 53	53
Moisture	53 -- 55	46.4
Water activity	0.93 -- 0.96	1.0
Hardness	3662g -- 4411g	5152g
Springiness	0.643 -- 0.723	0.85
Chewiness	1570 -- 2133	2880
Resilience	0.30 -- 0.33	0.4
Cohesiveness	0.57 -- 0.62	0.65
Adhesiveness	-59 (max)	-0.4

Chapter 5 Conclusions and Recommendations

Asian chicken powder, dried plum puree and Kraft Shake'N Bake Seasoned Coating Mix (chicken flavor) significantly affected the physical properties of the meatless chicken nugget analogs. Color of all treatments was affected by all three independent variables. However, chicken flavor had predominant effect on L value. Water activity of nuggets was affected by chicken flavor and Kraft-mix. Water activity increased with the increased of Kraft-mix and chicken powder. Moisture of the nuggets was only affected slightly by plum; but was affected mainly by Kraft-mix. Moisture increased with the increase of Kraft-mix. Additionally, Kraft-mix was the main variable that affected hardness and chewiness of the nuggets. When the amount of Kraft-mix in the formulation increased, the nuggets became harder and chewier. Nuggets were springier at middle levels of chicken powder and middle levels of plum. Nuggets were also springier as the levels of Kraft-mix increased. Furthermore, all three independent variables affected resilience, cohesiveness and adhesiveness of the nuggets in similar manners. Nuggets had minimum resilience, cohesiveness and adhesiveness at middle levels of plum, chicken powder and Kraft-mix.

Findings from this study also indicate that consumers prefer to have meatless textured peanut types of chicken nugget analogs with mid-yellow to more reddish color

(55° to 71° hue angle; 24.8 to 35.8 chroma; 44 to 53 L value). Nuggets within the predicted consumer acceptability range had texture profile of 1570 to 2133 chewiness, 0.643 to 0.723 springiness, 0.30 to 0.33 resilience, 3662 to 4411g hardness, 0.57 to 0.62 cohesiveness and maximum adhesiveness of -59. Furthermore, the predicted acceptable nugget analogs had similar cohesiveness, were less hard, chewy and springly, and slightly less resilient but more tender and more adhesive than the commercial soy-based nugget (Morningstar Farms Chick'n Nuggets). RSM predicted that optimum levels of 2% to 3.7% of Asian Chicken Powder, 0% to 0.1% Dried Plum Puree, 33.3% to 37.4% Kraft Shake'N Bake Seasoned Coating Mix (chicken flavor) and 66.7% to 62.6% Best Choice Seasoned Coating Mix (chicken flavor) would be present in acceptable textured peanut chicken-nugget analogs.

To further explore utilization of textured peanut in nugget analog type products, the following suggestions are proposed:

- Evaluate meatless chicken nugget analog type product with higher ratio of Best Choice Seasoned Coating Mix chicken than Kraft Shake'N Bake Seasoned Coating Mix (chicken flavor).
- Conduct sensory evaluation using the optimum level of Asian Chicken Flavor, Dried Plum Puree, Best Choice Seasoned Coating Mix chicken and Kraft Shake'N Bake Seasoned Coating Mix (chicken flavor).
- Investigate possible cooling parameters after kettle cooking that could affect texture profile of nuggets.

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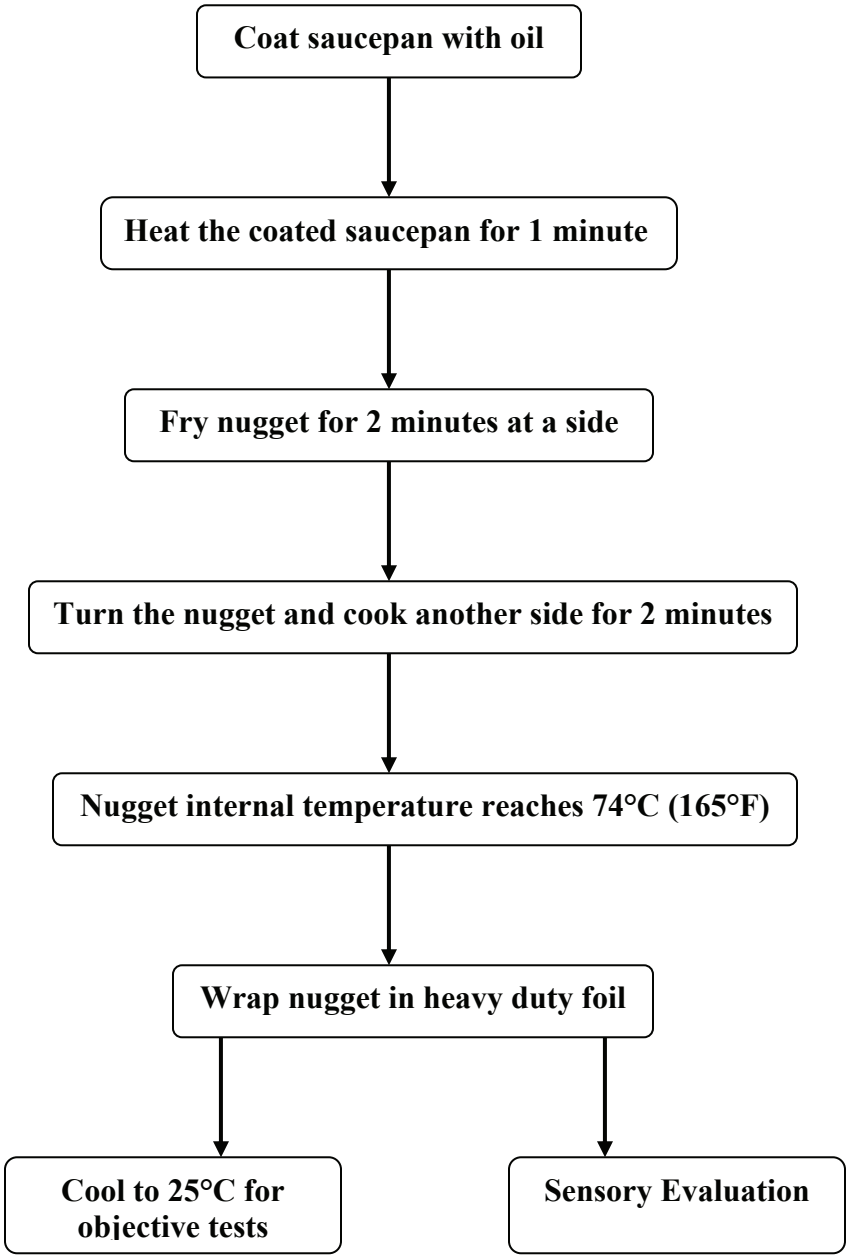
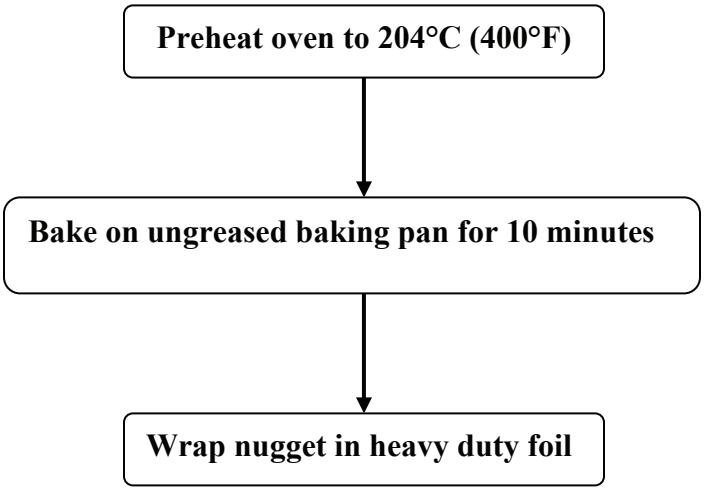
Appendices

Appendix A: Cooking Method of Different Coating Formulation

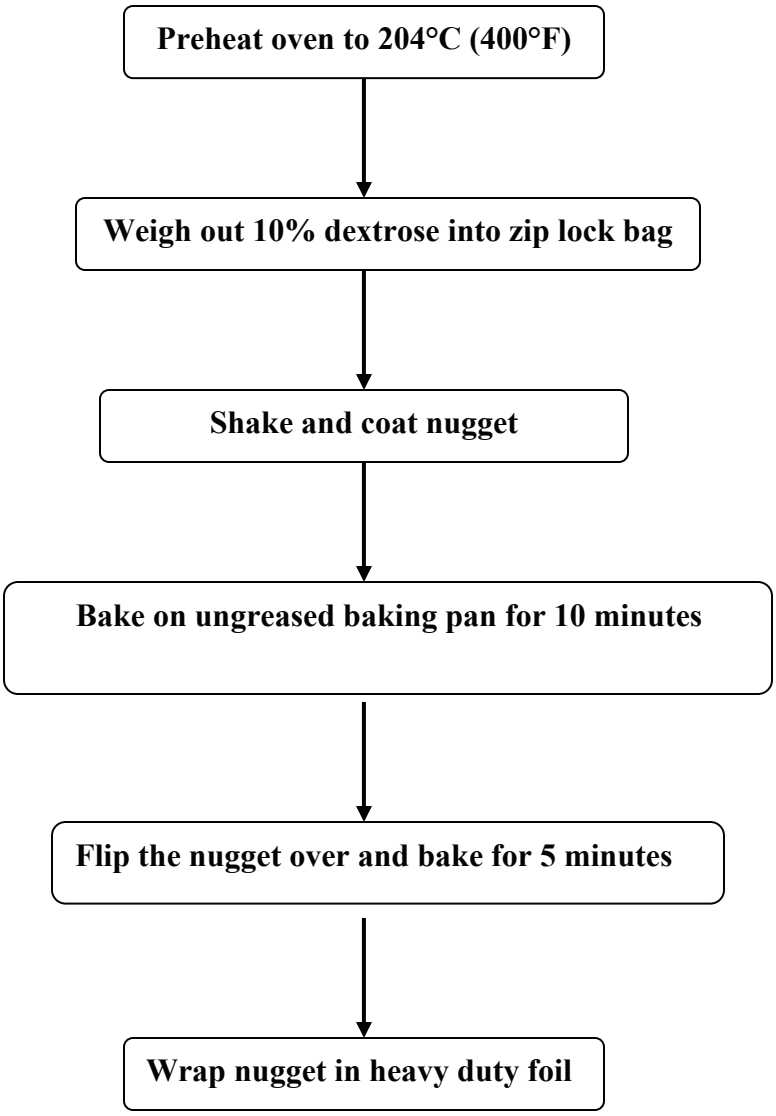
A.1 Code P1 Panfry Method



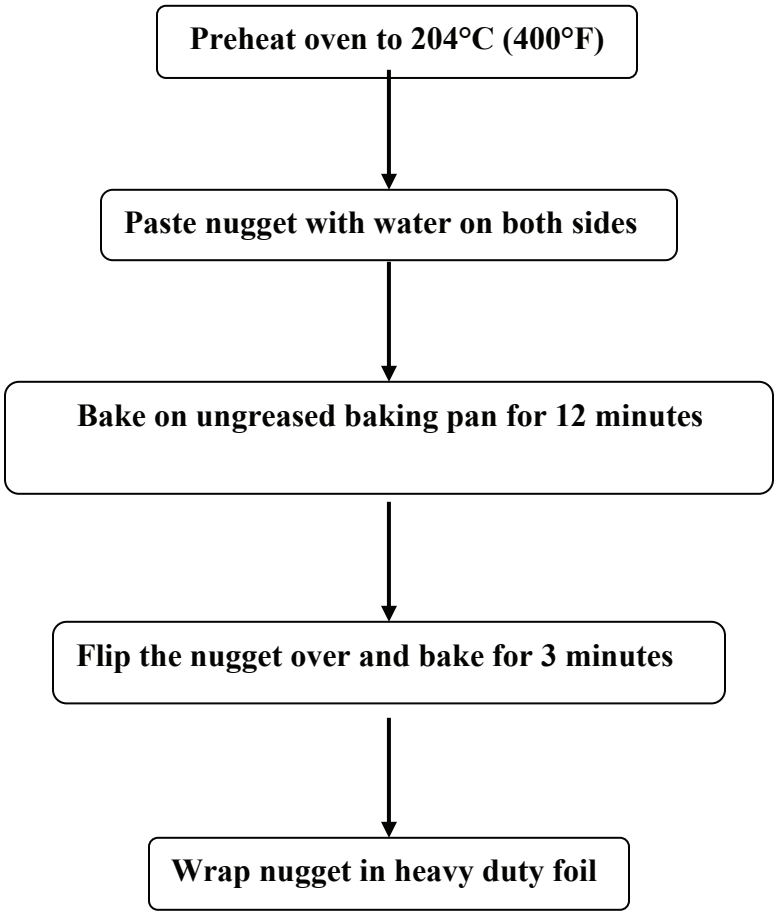
A.2 Code N2 Bake Method



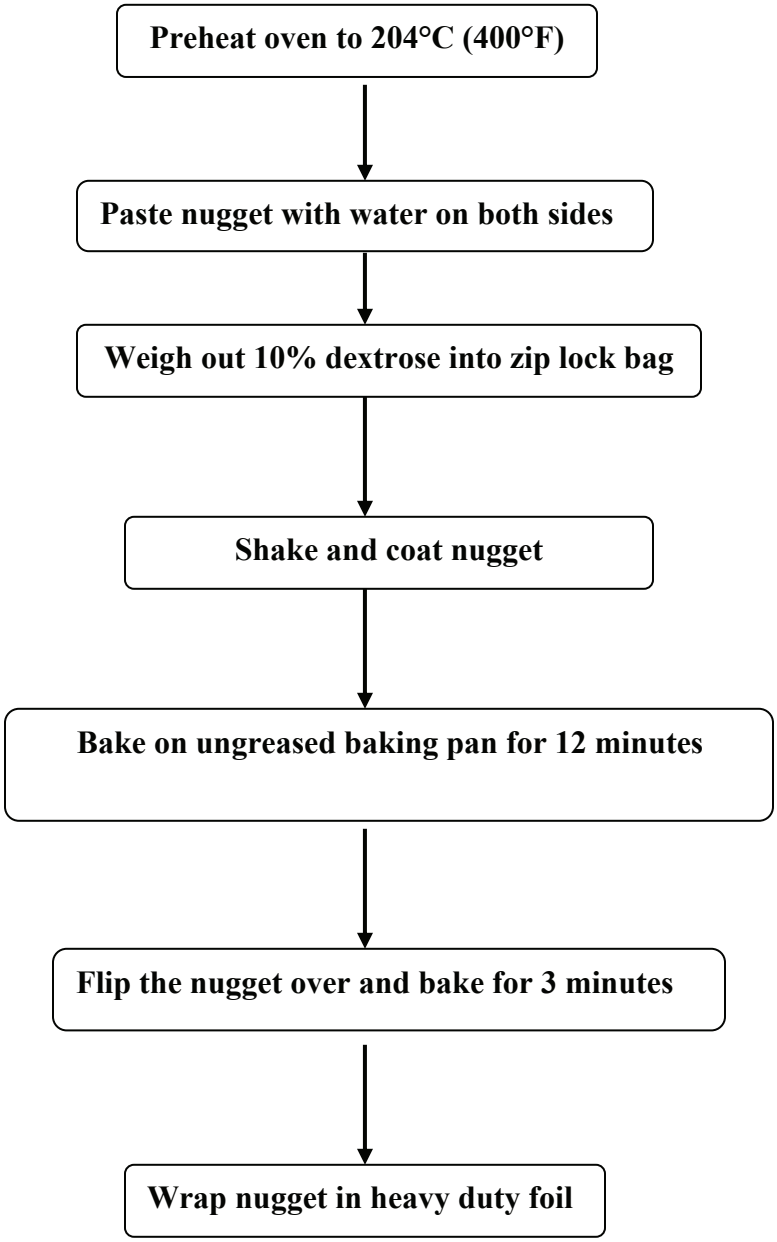
A.3 Code D10 Bake Method



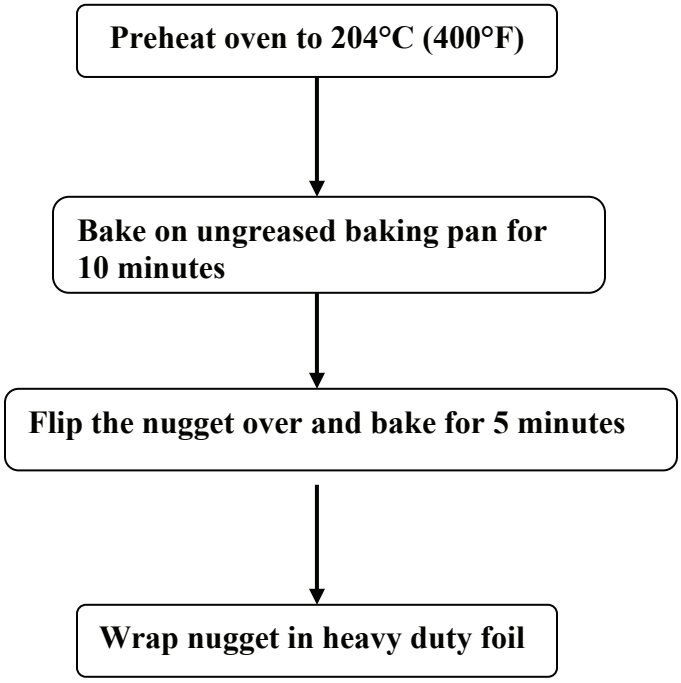
A.4 Code WN Bake Method



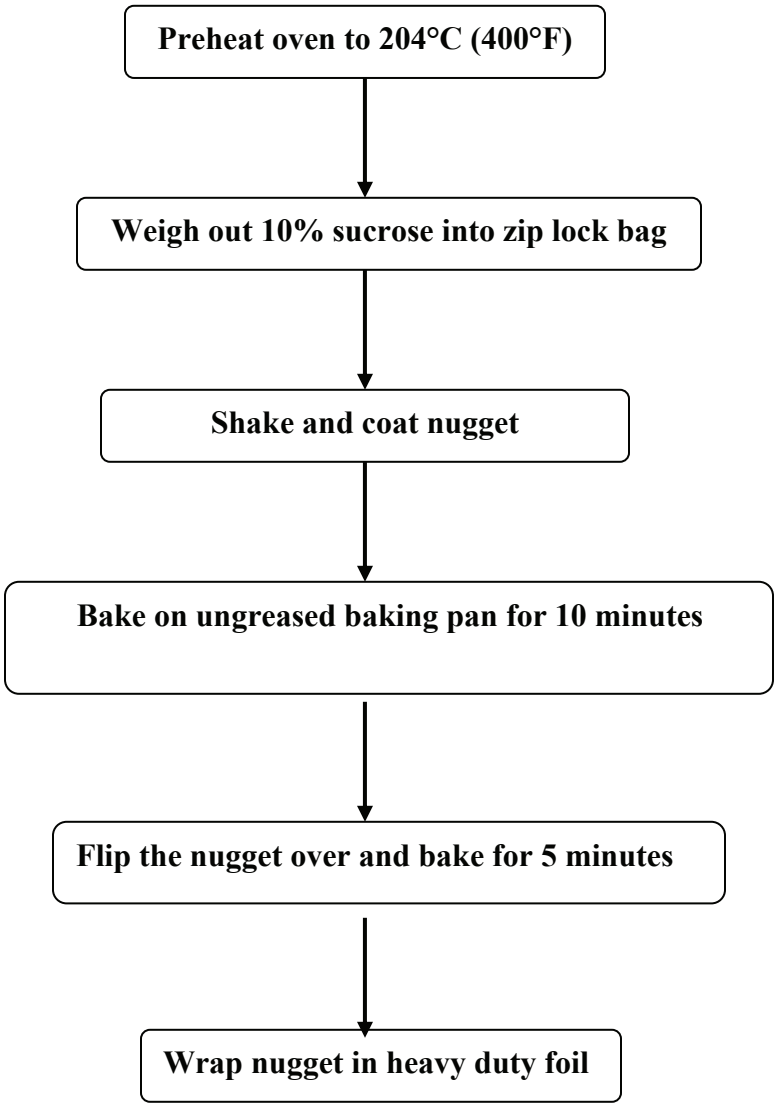
A.5 Code WD10 Bake Method



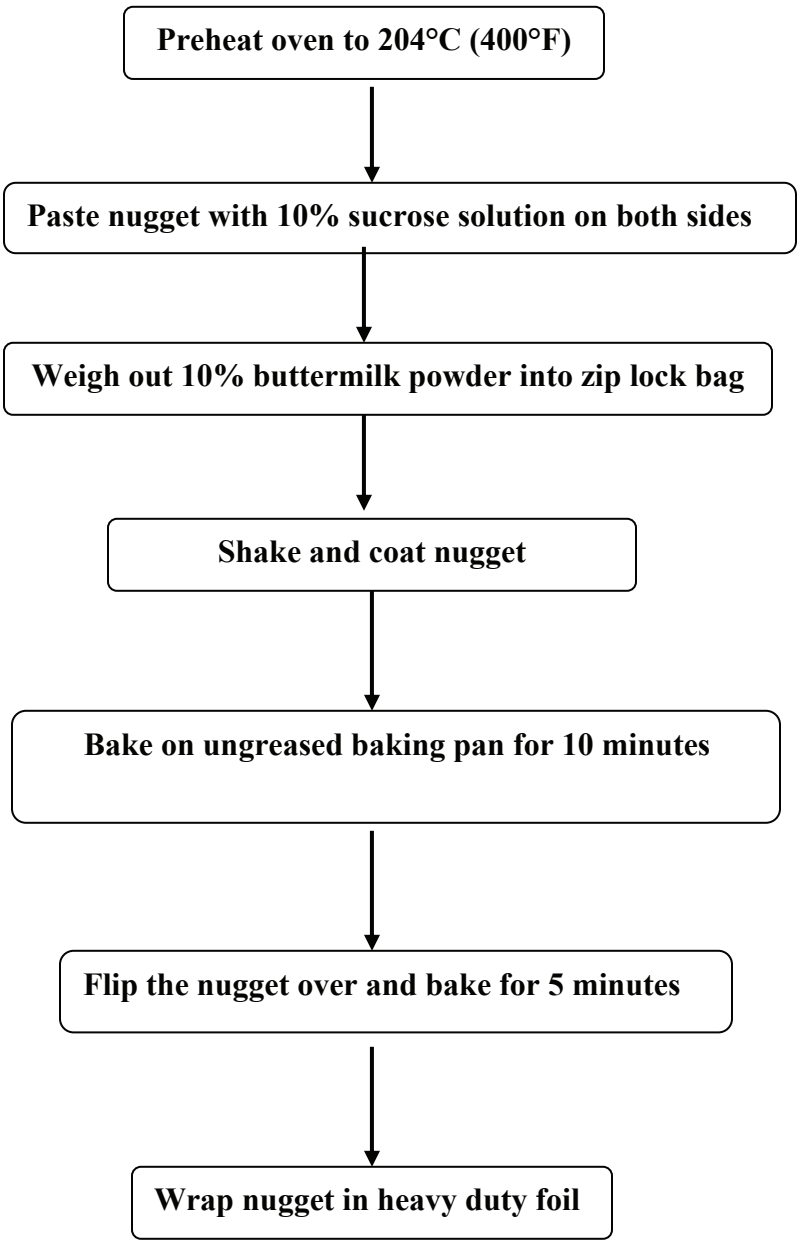
A.6 Code SN Bake Method



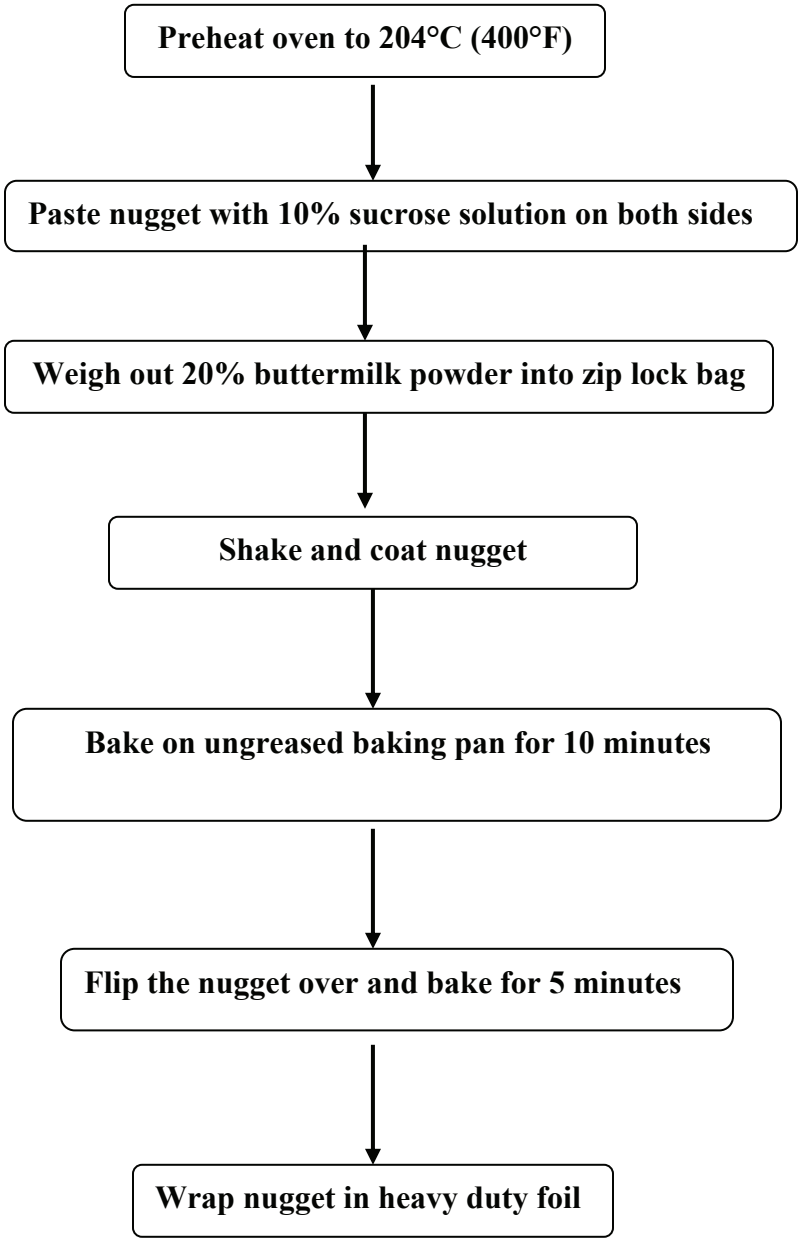
A.7 Code S10 Bake Method



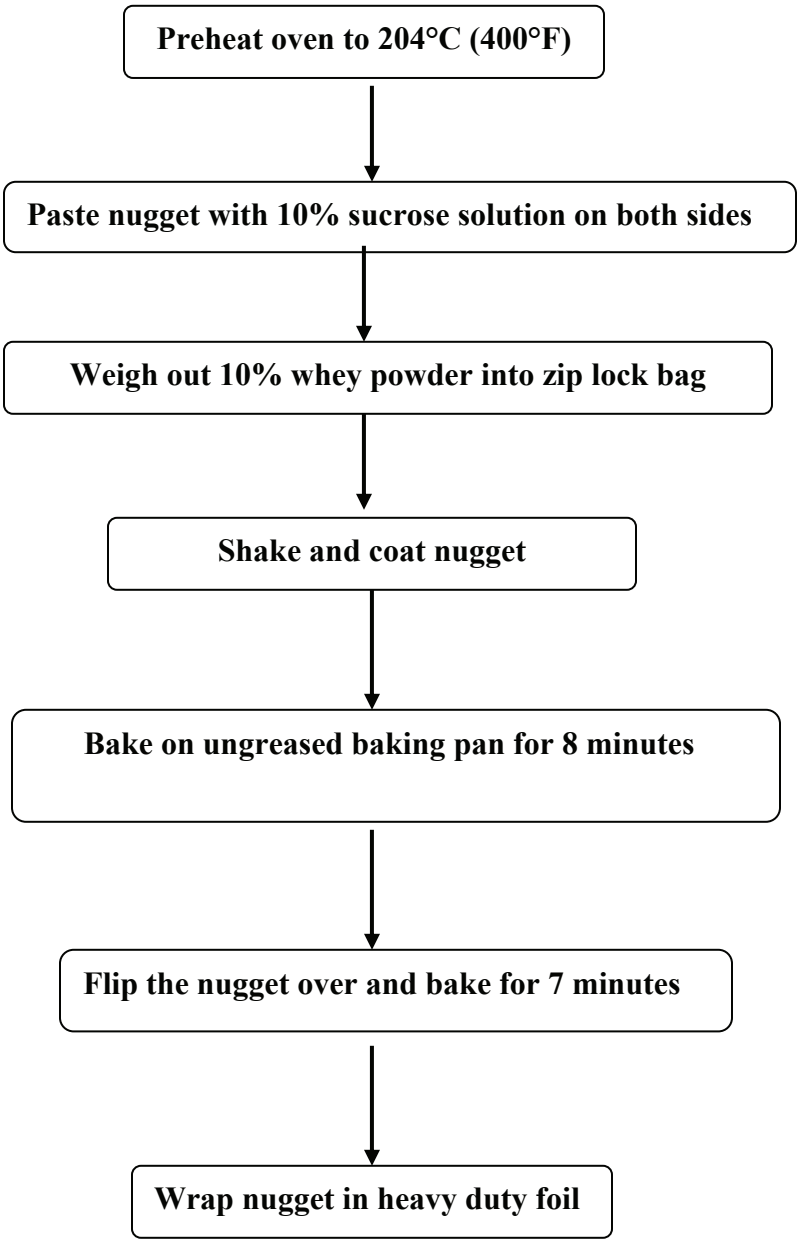
A.8 Code SB10 Bake Method



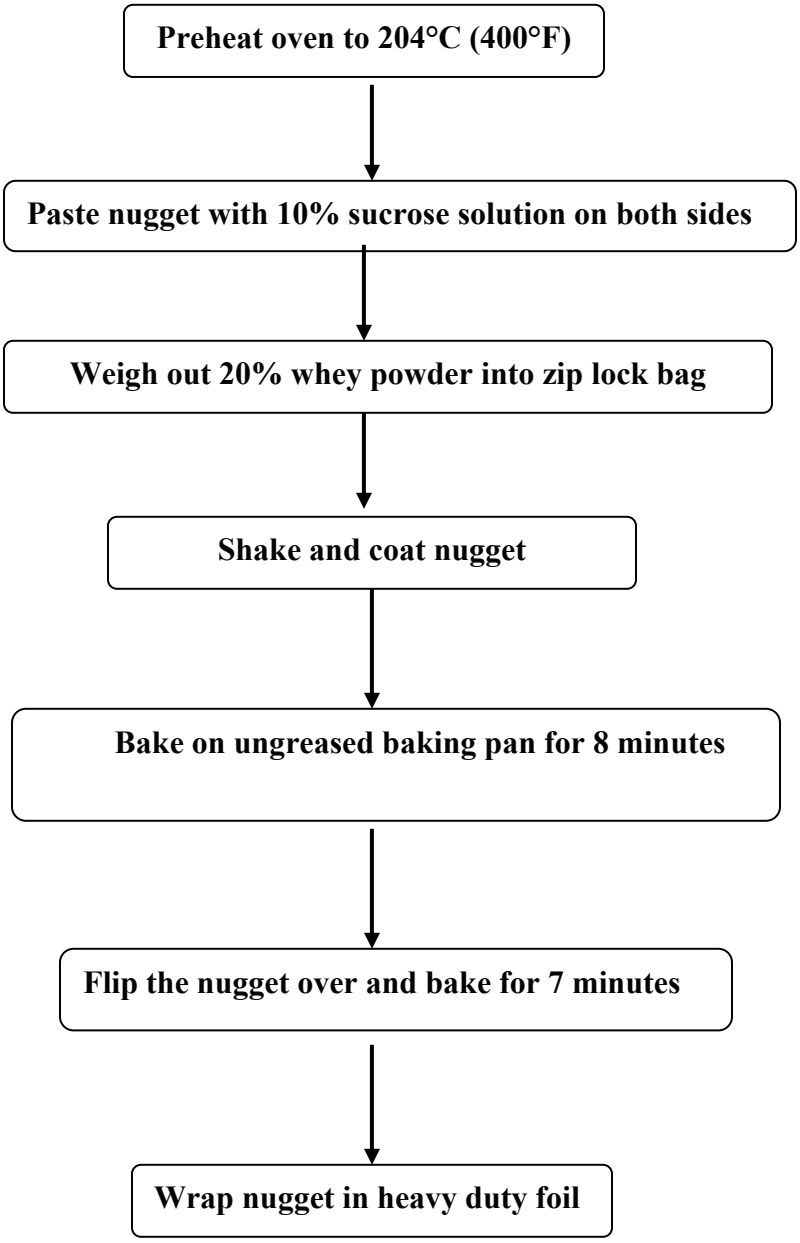
A.9 Code SB20 Bake Method



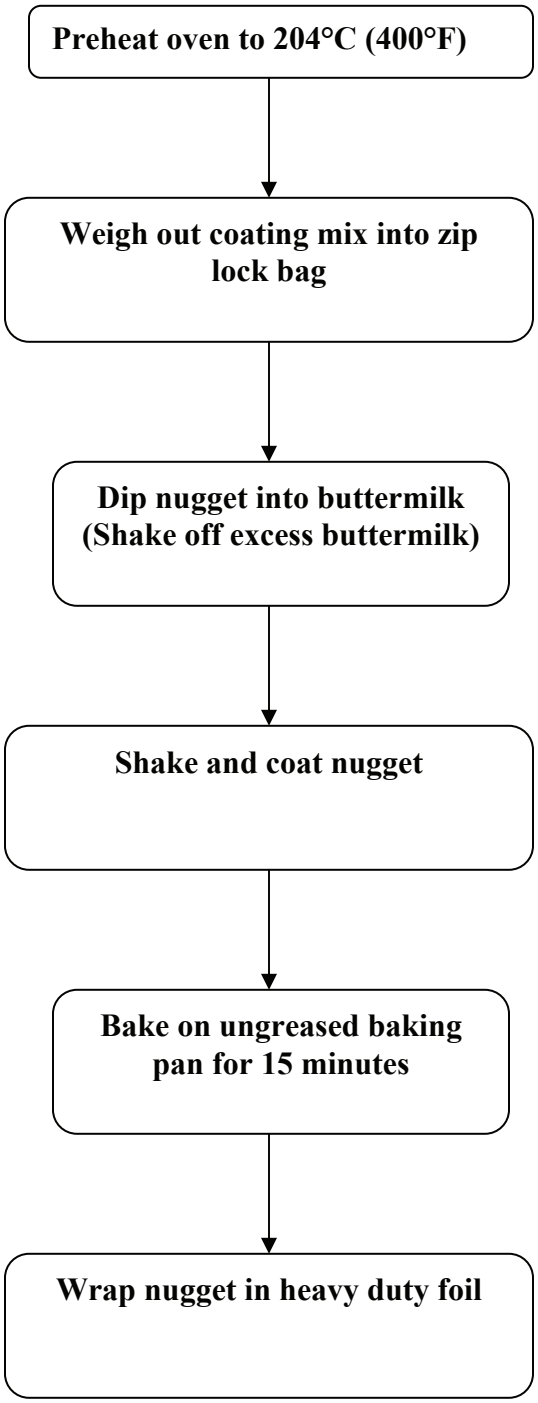
A.10 Code SW10 Bake Method



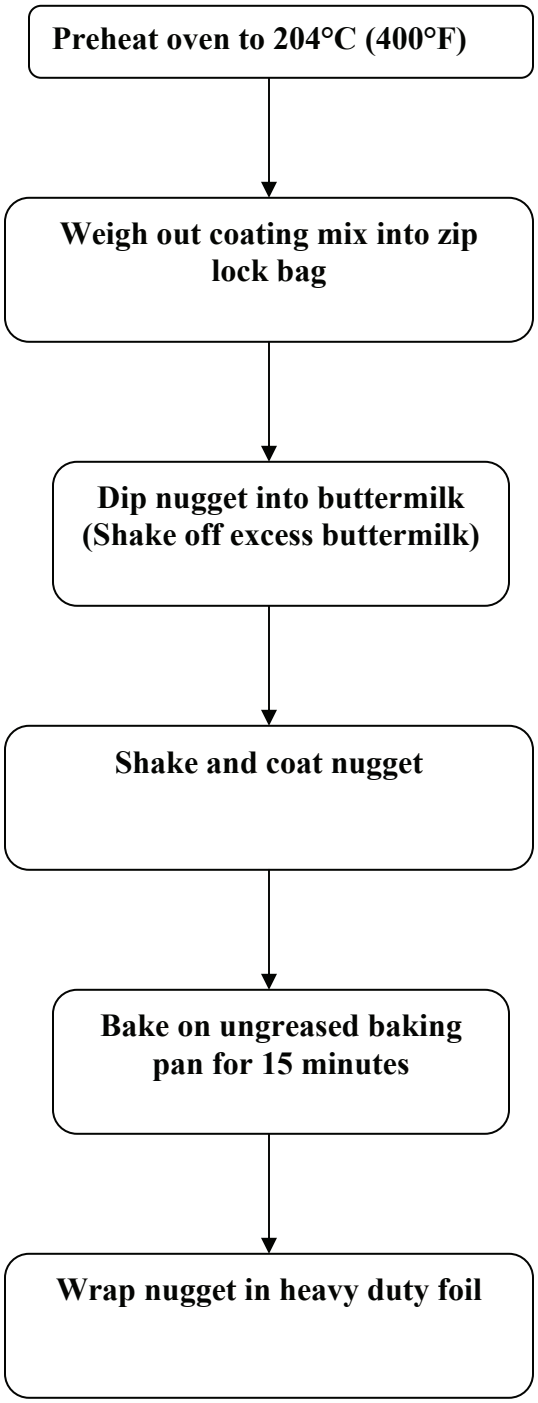
A.11 Code SW20 Bake Method



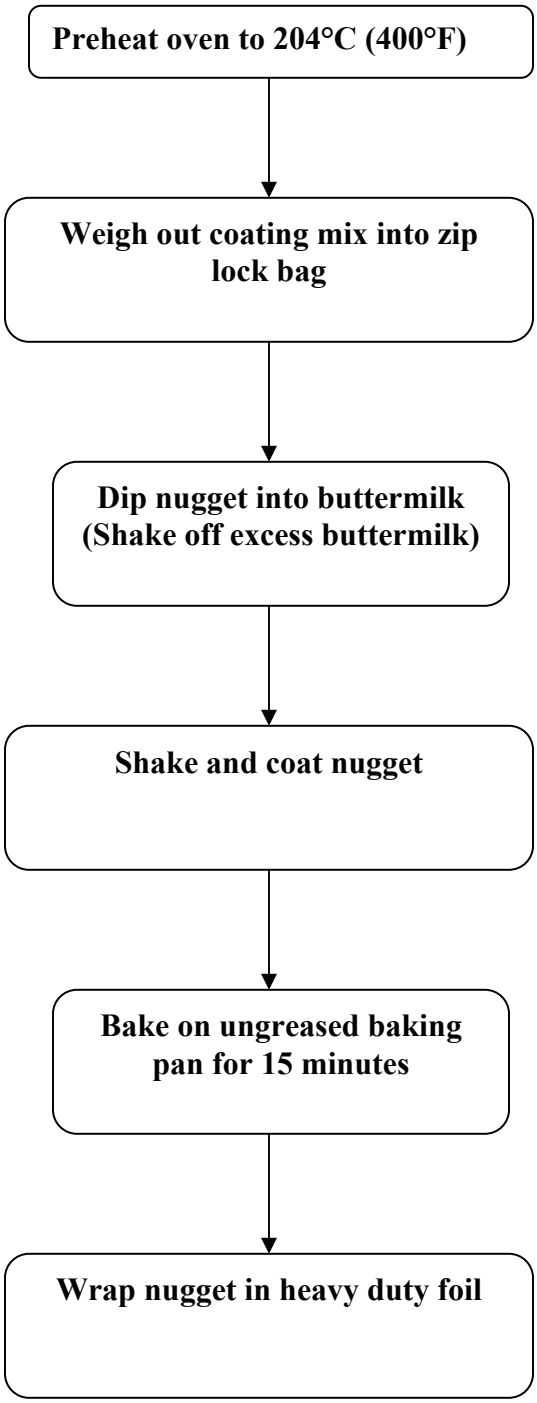
A.12 Code 4.1B Bake Method



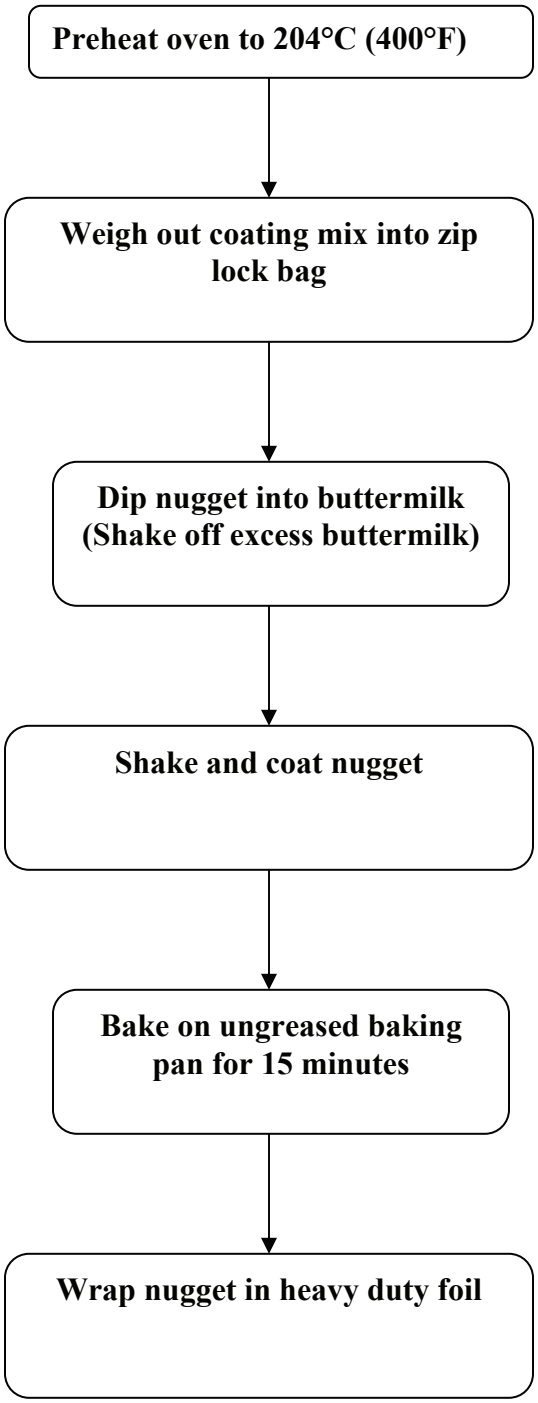
A.13 Code 4.2B Bake Method



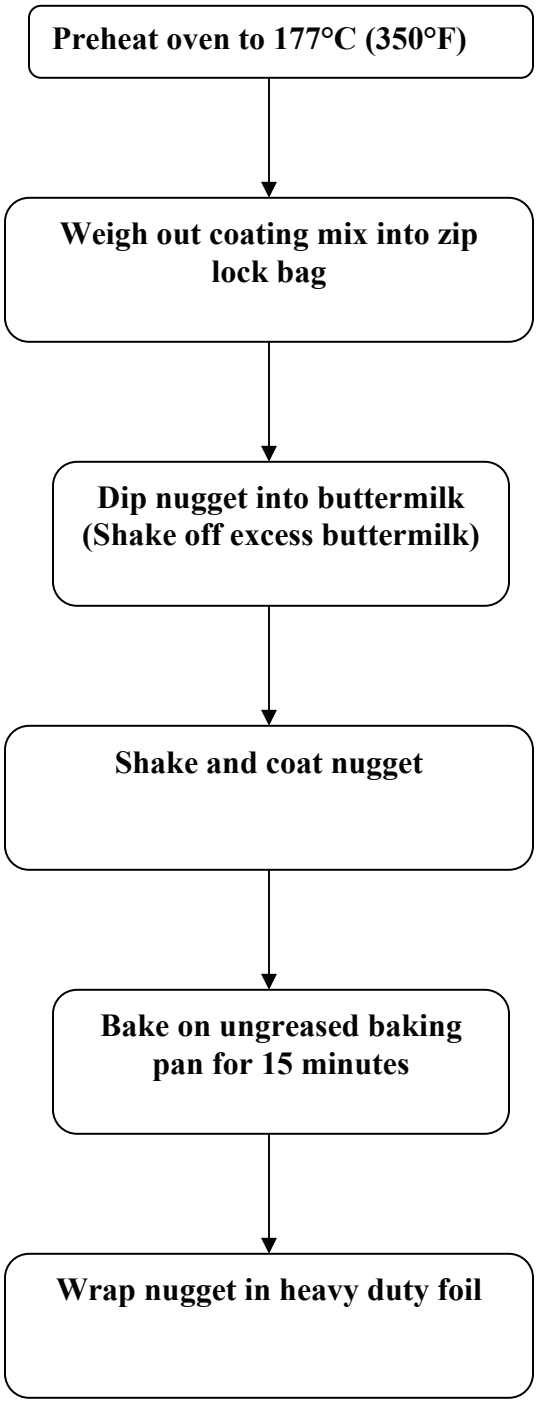
A.14 Code 4.3B Bake Method



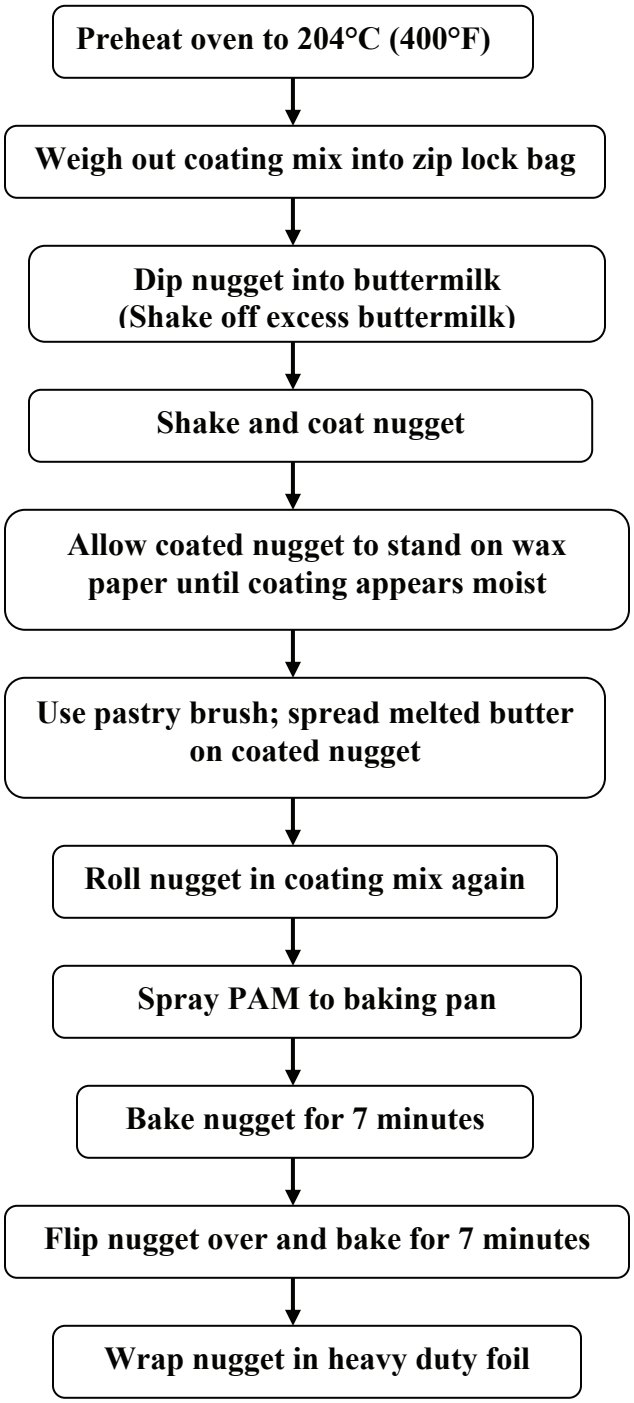
A.15 Code 4.4B Bake Method



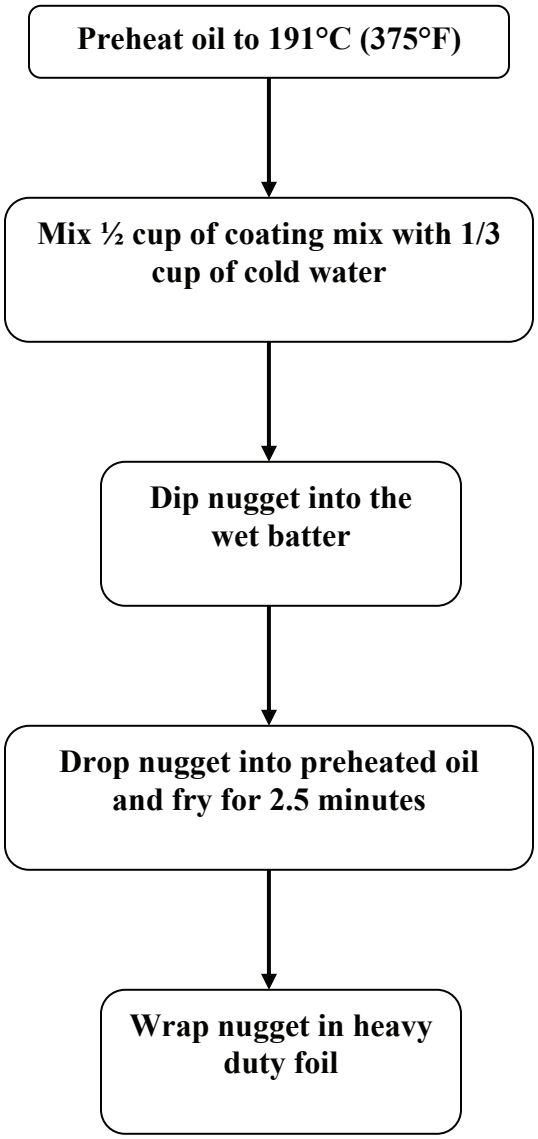
A.16 Code 4.5B Bake Method



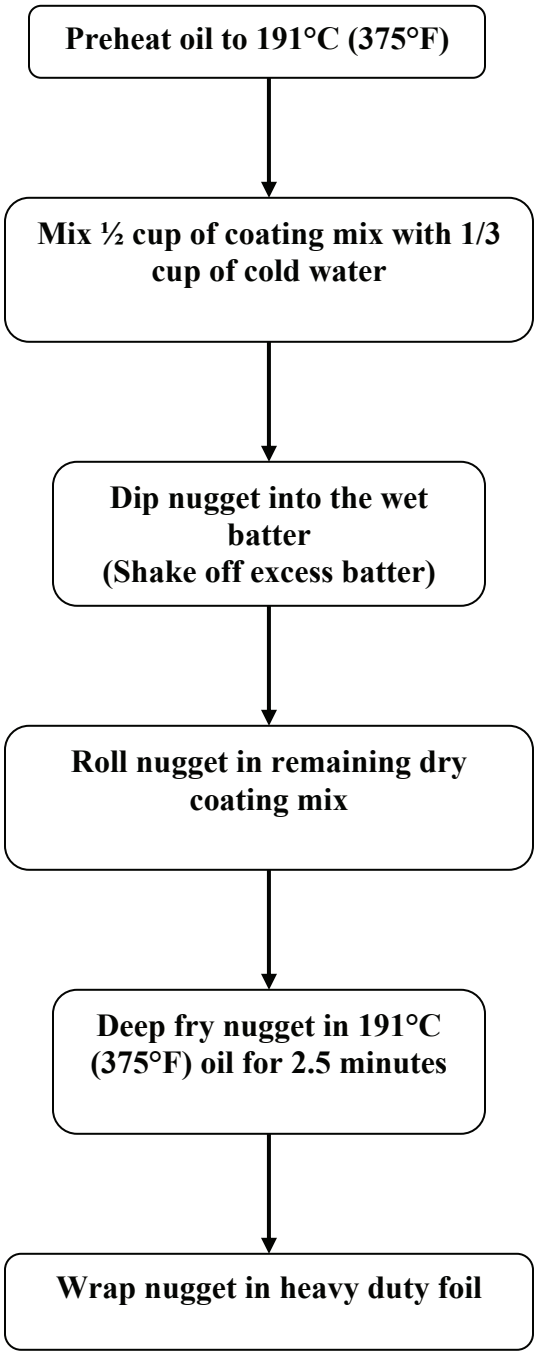
A.17 Code 4.6B Bake Method



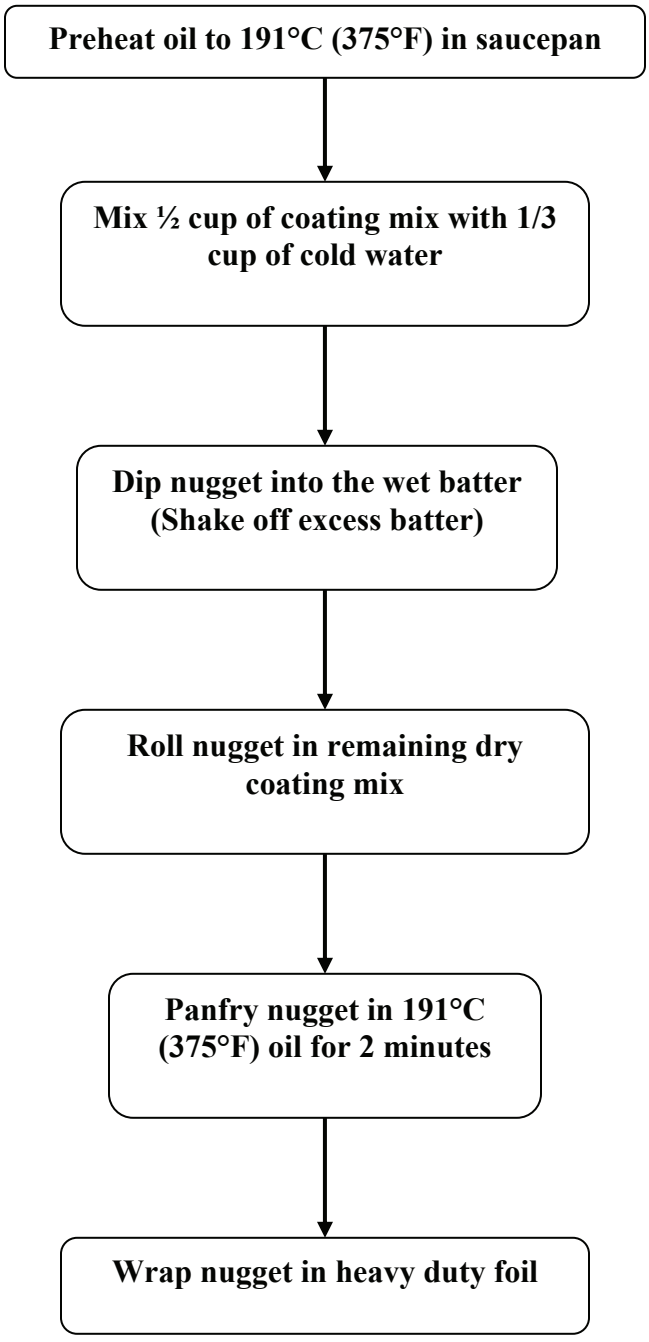
A.18 Code 4.7W Deep Fry Method



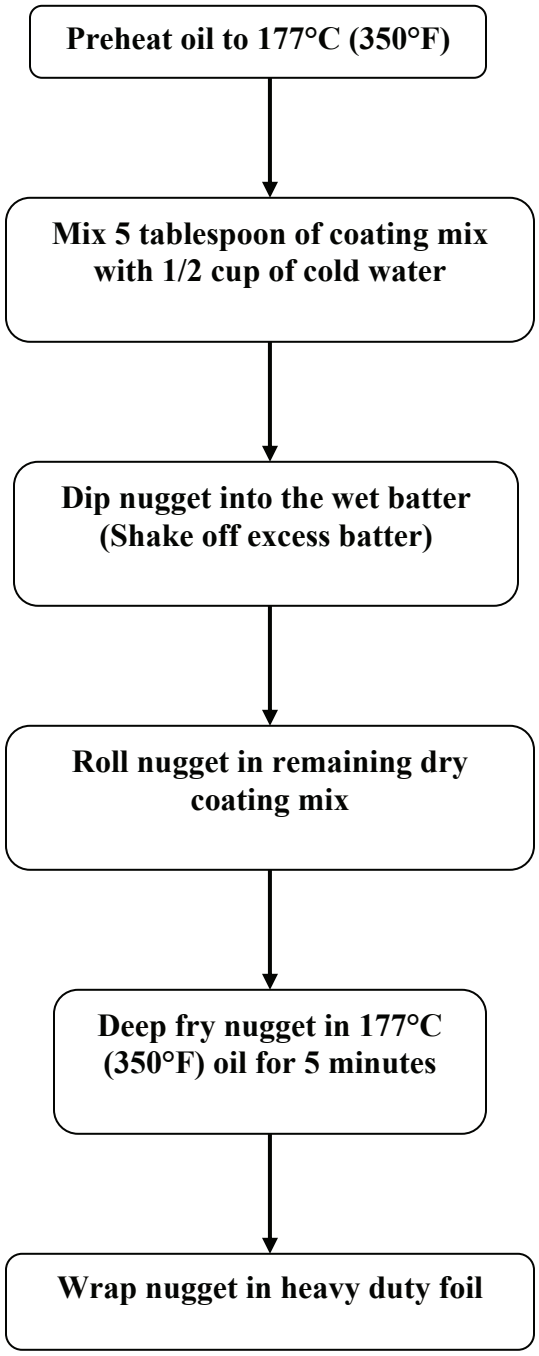
A.19 Code 4.8W Deep Fry Method



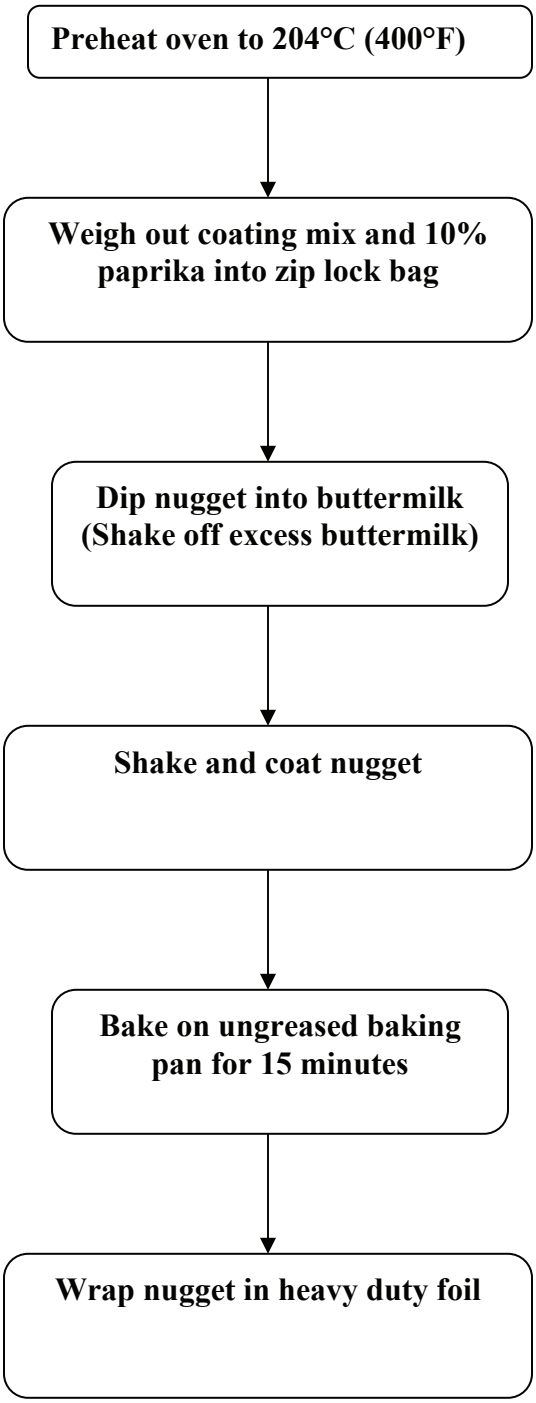
A.20 Code 4.9W Panfry Method



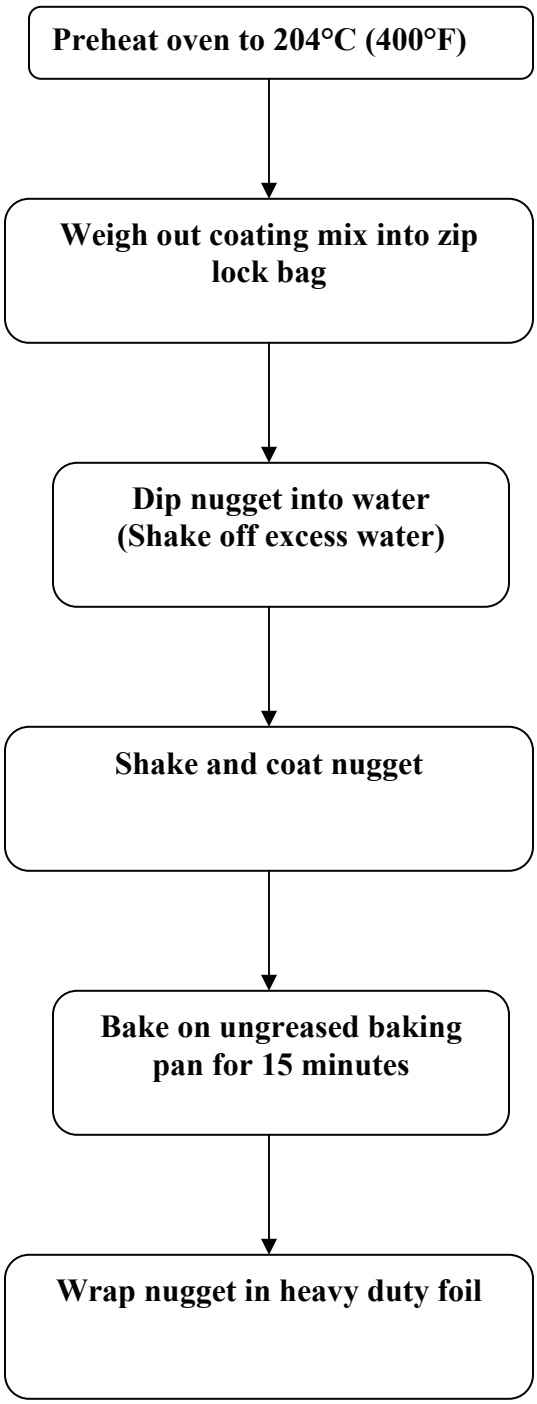
A.21 Code 4.10 Deep Fry Method



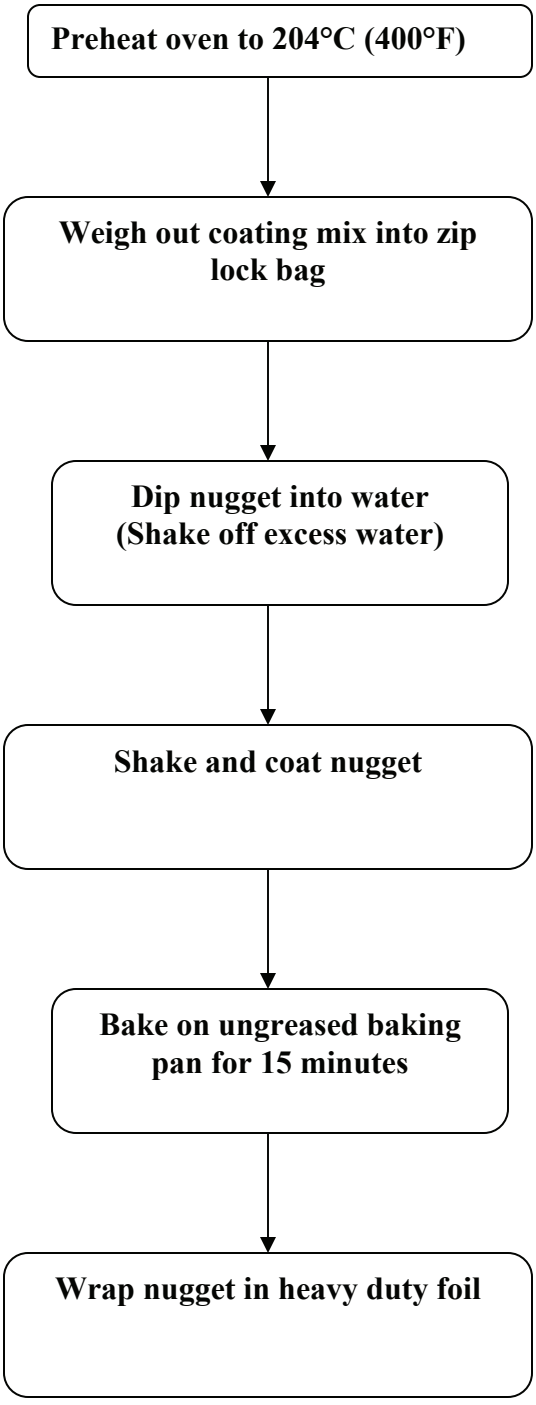
A.22 Code 4.1P Bake Method



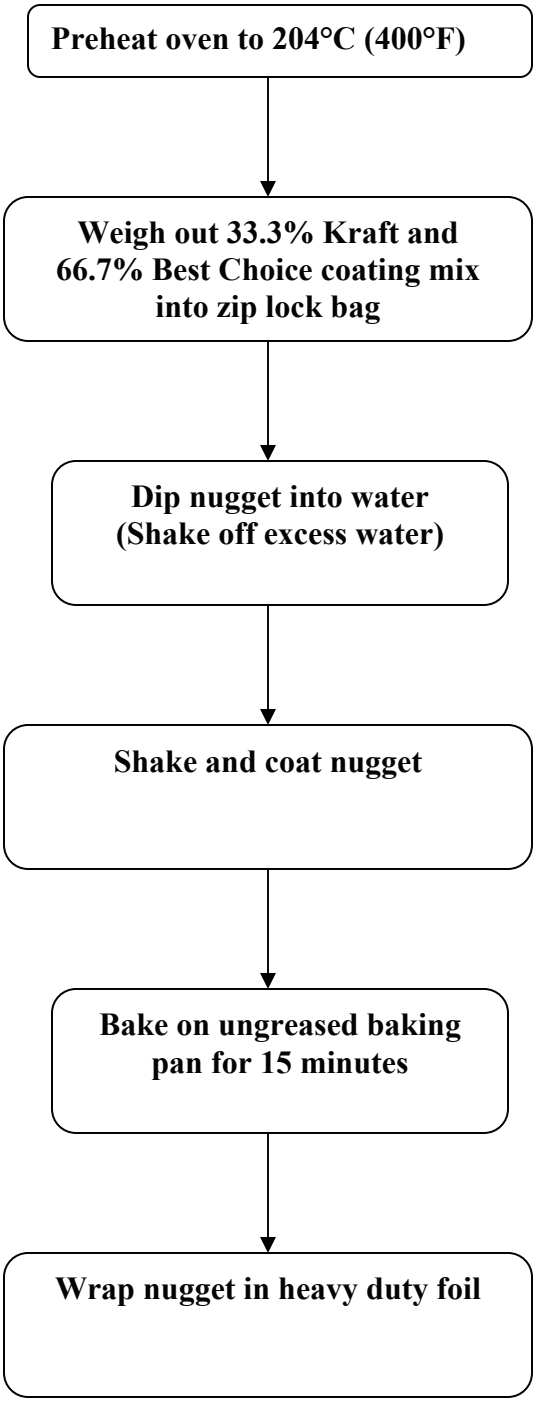
A.23 Code 4.1 Bake Method



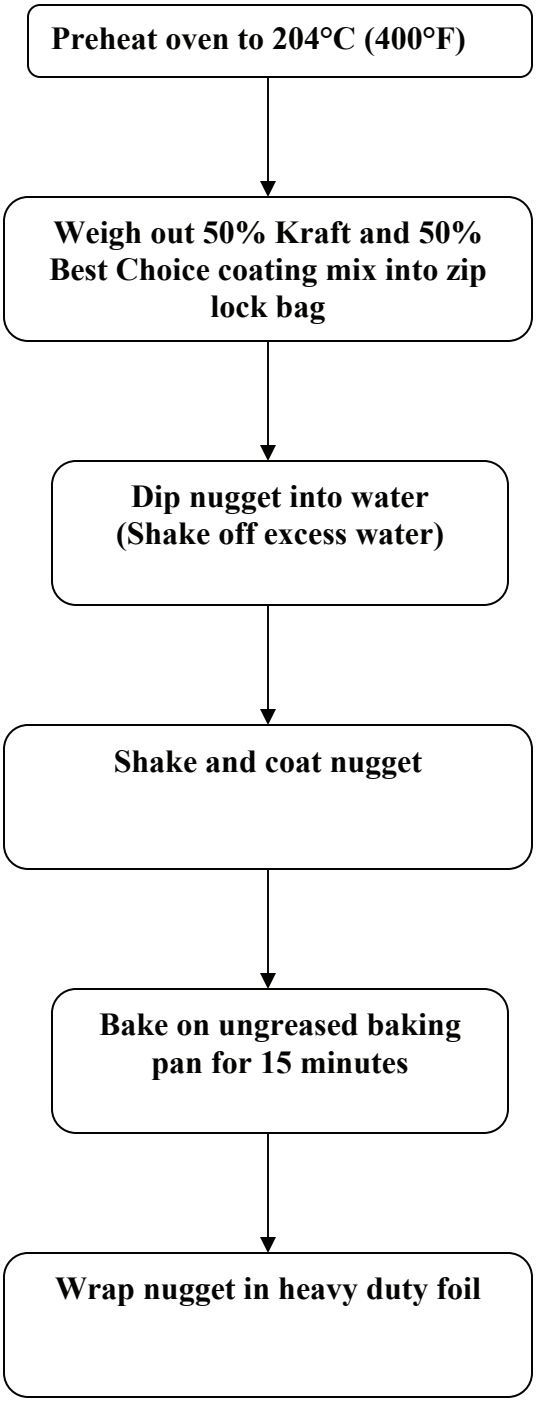
A.24 Code 4.3 Bake Method



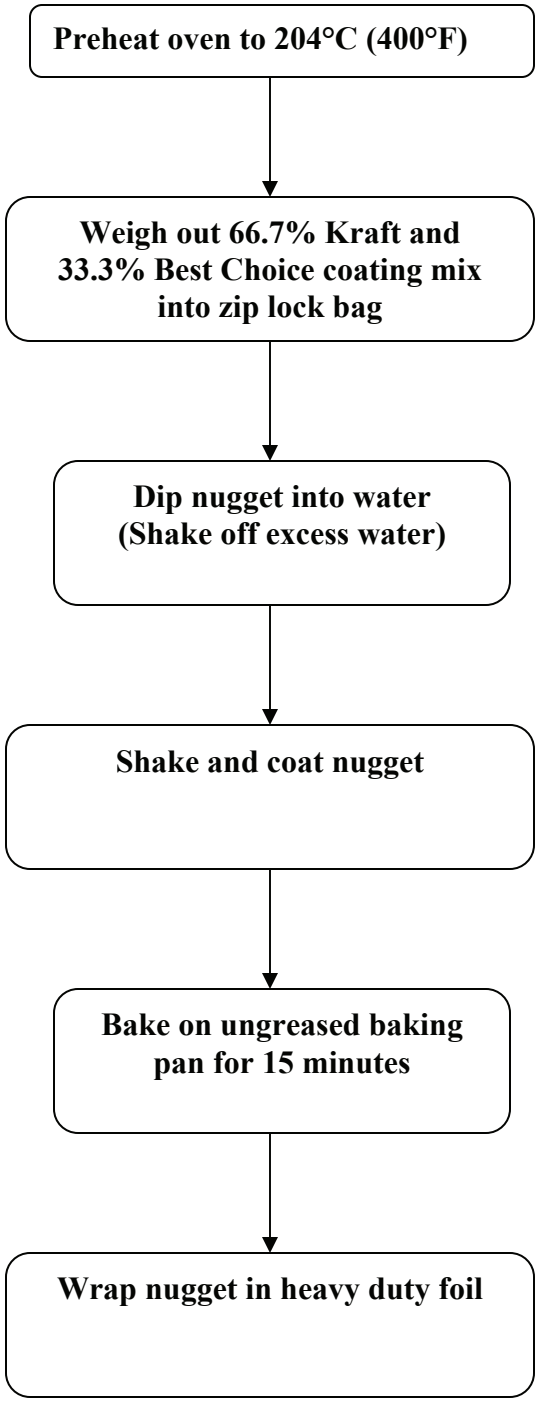
A.25 Code 4143A Bake Method



A.26 Code 4143B Bake Method



A.27 Code 4143C Bake Method



Appendix B: Main Study Nugget Formulations

	Formulation Code						
	128	219	332	383	443	461	567
Ing	Ratio (%)	Ratio (%)	Ratio (%)	Ratio (%)	Ratio (%)	Ratio (%)	Ratio (%)
TP	1	1	1	1	1	1	1
Water	1.5	1.5	1.5	1.5	1.5	1.5	1.5
CarraB	1.25	1.25	1.25	1.25	1.25	1.25	1.25
CollB	1.35	1.35	1.35	1.35	1.35	1.35	1.35
Dex	1	1	1	1	1	1	1
Garlic	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Onion	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Pap	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Ita	0.014	0.014	0.014	0.014	0.014	0.014	0.014
Salt	0.052	0.052	0.052	0.052	0.052	0.052	0.052
Brown	2	2	2	2	2	2	2
L&P	1	1	1	1	1	1	1
CA	4	2	2	3	4	3	4
DPP	0	0.5	1	0	0.5	1	1
Kraft	66.7	33.3	66.7	100	33.3	33.3	66.7
BestC	33.3	66.7	33.3	0	66.7	66.7	33.3

	Formulation Code					
	634	696	781	828	855	974
Ing	Ratio (%)	Ratio (%)	Ratio (%)	Ratio (%)	Ratio (%)	Ratio (%)
TP	1	1	1	1	1	1
Water	1.5	1.5	1.5	1.5	1.5	1.5
CarraB	1.25	1.25	1.25	1.25	1.25	1.25
CollB	1.35	1.35	1.35	1.35	1.35	1.35
Dex	1	1	1	1	1	1
Garlic	0.17	0.17	0.17	0.17	0.17	0.17
Onion	0.13	0.13	0.13	0.13	0.13	0.13
Pap	0.04	0.04	0.04	0.04	0.04	0.04
Ita	0.014	0.014	0.014	0.014	0.014	0.014
Salt	0.052	0.052	0.052	0.052	0.052	0.052
Brown	2	2	2	2	2	2
L&P	1	1	1	1	1	1
CA	3	4	2	3	3	2
DPP	0	0.5	0.5	0.5	1	0
[α]Kraft	33.3	100	100	66.7	100	66.7
[α]BestC	66.7	0	0	33.3	0	33.3

[α]Kraft and BestC % ratio was based on the total of 21g, not based on the amount of TP and water.

TP = Textured Peanut
CarraB = Carrageenan Binder
Water = Drinking Water
CollB = Colloid Binder
Dex = Dextrose
Garlic = Garlic Powder
Onion = Onion Powder
Pap = Paprika Powder
Ita = Italian Seasoning
Salt = Noniodide Salt
Brown = Browning & Seasoning sauce
L&P = Lea & Perrins Worcestershire Sauce
CA = Asian Chicken Powder
DPP = Dried Plum Puree
Kraft = Kraft Shake'n Bake Seasoned Coating Mix Original Chicken
BestC = Best Choice Seasoned Coating Mix Chicken

Appendix C: Sensory Master Table Code

Sample No.	Sample Random No. (Code)	Letter Code
1	128	AZ
2	219	BY
3	332	CE
4	383	FG
5	443	KU
6	461	WL
7	567	TZ
8	634	SP
9	696	PV
10	781	HJ
11	828	ER
12	855	QA
13	974	DX
14	999 (REFERENCE)	MP

Appendix D: Serving Order of Samples for Untrained Panelist's Sensory Evaluation with Assigned Code (page 154-164)

Panelist #	A	B	C	D	E	F	G	H
1	471 QA	869 TZ	922 CE	511 FG	563 BY	196 MP	526 AZ	857 ER
2	097 PV	165 MP	827 WL	088 HJ	569 SP	952 AZ	732 CE	221 QA
3	733 WL	364 BY	125 DX	134 ER	913 AZ	538 MP	344 KU	168 FG
4	439 QA	321 SP	917 BY	204 MP	254 TZ	585 CE	055 HJ	671 WL
5	125 CE	452 SP	222 WL	292 DX	571 PV	975 AZ	473 ER	890 KU
6	910 QA	320 BY	641 FG	609 PV	876 SP	202 MP	214 DX	648 AZ
7	429 MP	068 AZ	383 KU	316 HJ	548 TZ	652 CE	993 QA	828 ER
8	774 DX	073 ER	565 KU	595 FG	376 CE	089 WL	835 TZ	826 HJ
9	892 BY	069 SP	307 FG	241 PV	322 QA	916 DX	405 KU	888 CE
10	870 BY	352 KU	078 DX	903 WL	993 HJ	576 MP	990 ER	883 TZ
11	972 AZ	755 CE	712 ER	119 PV	378 FG	271 WL	704 TZ	912 SP

1

Panelist#	A	B	C	D	E	F	G	H
12	109 FG	493 WL	691 PV	878 SP	865 HJ	108 CE	555 AZ	940 BY
13	339 QA	377 ER	793 KU	656 DX	762 CE	783 FG	218 PV	293 BY
14	949 TZ	347 FG	297 QA	794 SP	239 HJ	199 AZ	644 ER	906 DX
15	470 HJ	262 SP	731 QA	770 AZ	841 WL	112 MP	272 KU	767 ER
16	357 AZ	115 PV	706 HJ	750 TZ	081 ER	700 DX	118 QA	865 BY
17	558 AZ	869 HJ	613 BY	196 QA	712 KU	141 SP	954 TZ	602 MP
18	987 DX	461 TZ	754 BY	307 PV	870 CE	847 HJ	052 FG	658 MP
19	525 WL	371 SP	717 DX	937 KU	452 FG	637 PV	059 ER	192 TZ
20	187 DX	912 ER	231 FG	295 QA	340 TZ	491 AZ	810 PV	346 KU
21	639 MP	682 DX	890 HJ	256 WL	273 SP	181 BY	769 CE	572 QA
22	154 WL	987 KU	453 AZ	836 BY	268 PV	344 SP	410 MP	419 CE

Panelist #	A	B	C	D	E	F	G	H
23	051 HJ	815 MP	466 ER	340 WL	304 KU	663 FG	252 QA	246 CE
24	870 TZ	089 QA	756 HJ	238 DX	267 BY	285 ER	296 SP	864 PV
25	790 DX	735 BY	727 AZ	498 CE	286 TZ	843 HJ	575 FG	302 KU
26	944 WL	836 TZ	088 FG	148 DX	368 QA	856 ER	570 MP	175 SP
27	322 PV	097 HJ	545 SP	411 ER	213 WL	343 CE	110 FG	596 QA
28	900 AZ	050 KU	675 BY	266 DX	351 QA	793 PV	739 ER	522 MP
29	683 KU	867 CE	177 QA	431 AZ	65 HJ	785 BY	917 DX	158 MP
30	392 PV	815 AZ	895 TZ	761 KU	497 SP	139 QA	626 WL	949 FG
31	745 BY	840 DX	955 HJ	931 TZ	867 AZ	165 MP	390 PV	507 ER
32	580 CE	128 MP	931 HJ	667 SP	728 ER	510 BY	268 TZ	167 WL
33	405 ER	966 MP	988 CE	167 DX	435 KU	249 SP	301 TZ	665 WL

Panelist #	A	B	C	D	E	F	G	H
34	771	170	979	958	822	438	723	795
	FG	PV	AZ	WL	TZ	QA	BY	SP
35	972	219	740	166	579	899	690	158
	FG	PV	WL	CE	HJ	KU	DX	BY
36	811	327	551	275	726	811	917	064
	QA	TZ	SP	KU	PV	FG	AZ	MP
37	058	874	538	173	198	319	488	897
	ER	CE	HJ	WL	QA	DX	FG	KU
38	109	817	565	738	120	593	490	291
	SP	ER	FG	AZ	BY	WL	HJ	MP
39	540	612	510	589	333	257	952	238
	PV	HJ	TZ	CE	KU	AZ	BY	QA
40	959	486	105	559	894	361	321	435
	WL	MP	HJ	PV	DX	ER	QA	TZ
41	659	421	904	749	656	523	405	506
	MP	SP	QA	CE	AZ	TZ	DX	PV
42	256	804	509	298	545	122	199	444
	ER	TZ	WL	AZ	FG	KU	BY	SP
43	382	203	137	258	156	836	915	427
	BY	TZ	SP	HJ	MP	ER	FG	PV
44	134	525	116	447	82	319	429	514
	DX	MP	KU	CE	QA	WL	ER	AZ

Panelist #	A	B	C	D	E	F	G	H
45	299	839	702	843	382	403	153	845
	HJ	QA	FG	BY	CE	PV	SP	WL
46	469	059	847	556	313	837	544	298
	MP	DX	AZ	QA	FG	CE	KU	TZ
47	215	524	189	425	449	328	982	377
	KU	SP	PV	CE	ER	HJ	MP	DX
48	562	835	524	722	169	963	948	373
	FG	PV	KU	BY	MP	DX	AZ	HJ
49	177	928	786	357	225	949	207	409
	TZ	DX	BY	CE	ER	SP	PV	AZ
50	368	306	208	797	639	898	580	338
	WL	SP	AZ	BY	QA	FG	KU	ER
51	644	932	096	641	605	214	933	710
	WL	MP	TZ	SP	DX	HJ	KU	CE
52	993	670	399	443	290	553	121	909
	BY	PV	DX	TZ	FG	CE	MP	ER
53	610	067	384	258	172	498	539	437
	WL	HJ	TZ	QA	PV	AZ	MP	SP
54	831	978	681	739	894	781	880	612
	KU	BY	QA	HJ	AZ	WL	FG	DX
55	753	398	256	136	521	663	490	600
	PV	ER	TZ	AZ	FG	CE	WL	BY

Panelist #	A	B	C	D	E	F	G	H
56	774 CE	320 MP	269 ER	534 SP	881 TZ	919 KU	109 HJ	613 FG
57	907 DX	720 ER	725 PV	97 CE	659 WL	228 TZ	222 MP	903 QA
58	051 KU	601 FG	885 AZ	191 QA	706 SP	852 HJ	996 DX	596 BY
59	377 ER	761 BY	469 HJ	858 CE	543 AZ	150 KU	412 SP	270 MP
60	076 PV	556 WL	933 QA	212 TZ	724 CE	518 KU	969 FG	121 ER
61	347 FG	696 WL	370 SP	610 AZ	461 DX	576 HJ	367 MP	854 TZ
62	236 BY	989 ER	180 KU	96 HJ	364 QA	799 SP	457 DX	485 PV
63	865 PV	640 WL	216 CE	716 TZ	906 BY	996 MP	741 FG	392 AZ
64	454 PV	119 TZ	876 SP	173 KU	357 DX	120 CE	198 BY	525 QA
65	714 AZ	952 ER	121 TZ	406 MP	762 WL	710 PV	341 HJ	315 QA
66	907 ER	554 DX	231 WL	608 AZ	790 HJ	222 CE	592 SP	120 BY

Panelist #	A	B	C	D	E	F	G	H
67	238 MP	769 FG	785 PV	962 QA	956 CE	353 KU	571 BY	107 WL
68	751 DX	897 SP	412 FG	152 AZ	794 HJ	930 ER	875 BY	761 WL
69	646 SP	818 WL	444 QA	741 DX	551 MP	148 TZ	285 KU	296 FG
70	857 ER	636 KU	157 HJ	898 BY	068 CE	120 MP	190 AZ	852 PV
71	137 WL	289 HJ	310 PV	844 TZ	949 BY	951 SP	540 QA	676 KU
72	481 MP	989 ER	739 TZ	315 DX	748 SP	656 AZ	053 CE	347 FG
73	775 FG	224 HJ	241 WL	249 BY	64 MP	840 TZ	324 QA	453 DX
74	164 CE	911 ER	230 KU	364 PV	393 DX	979 HJ	571 MP	155 AZ
75	160 FG	603 AZ	413 SP	287 KU	672 PV	818 WL	678 QA	907 ER
76	598 ER	184 PV	964 TZ	435 QA	966 KU	285 BY	993 SP	100 CE
77	679 AZ	112 PV	134 HJ	557 ER	547 MP	519 DX	243 SP	740 FG

Wordlist #	A	B	C	D	E	F	G	H
78	147	725	447	769	130	607	304	967
	FG	DX	TZ	ER	KU	QA	SP	BY
79	259	558	727	322	942	520	930	383
	TZ	WL	CE	BY	QA	PV	HJ	DX
80	433	848	245	583	759	411	866	391
	WL	MP	AZ	CE	KU	QA	TZ	BY
81	073	739	182	937	993	457	599	998
	ER	FG	CE	MP	PV	BY	SP	QA
82	123	342	246	286	898	596	728	726
	FG	SP	PV	DX	HJ	MP	KU	WL
83	355	763	222	390	592	683	88	659
	ER	TZ	KU	WL	FG	CE	AZ	HJ
84	948	511	762	374	334	141	659	312
	DX	AZ	MP	CE	FG	PV	ER	QA
85	394	378	840	954	967	298	395	923
	HJ	MP	WL	DX	SP	PV	AZ	KU
86	448	105	115	91	730	956	776	327
	ER	SP	TZ	BY	CE	QA	HJ	KU
87	798	859	717	380	766	850	520	573
	FG	QA	TZ	CE	BY	DX	HJ	AZ
88	331	572	219	132	302	808	865	725
	QA	CE	KU	ER	MP	PV	FG	WL

Panelists #	A	B	C	D	E	F	G	H
89	865 PV	535 AZ	589 TZ	418 BY	398 WL	940 QA	587 ER	770 HJ
90	701 SP	547 DX	443 TZ	669 FG	836 KU	834 ER	831 HJ	326 CE
91	316 KU	807 QA	942 DX	712 WL	452 AZ	844 BY	63 SP	436 MP
92	552 TZ	701 FG	863 HJ	903 CE	449 PV	787 DX	112 QA	182 WL
93	948 AZ	724 CE	543 SP	886 ER	281 BY	51 MP	514 TZ	984 KU
94	422 MP	290 TZ	64 SP	683 BY	660 FG	841 PV	594 DX	671 KU
95	514 ER	171 WL	986 AZ	431 DX	515 FG	177 MP	988 TZ	500 BY
96	624 WL	720 PV	149 AZ	228 CE	758 QA	970 SP	479 MP	235 TZ
97	740 HJ	667 AZ	277 QA	265 TZ	233 CE	586 BY	638 ER	508 FG
98	875 PV	604 DX	432 BY	428 KU	290 SP	290 ER	328 HJ	878 WL
99	728 MP	286 CE	270 DX	417 AZ	633 QA	993 ER	787 FG	425 SP

Passlist #	A	B	C	D	E	F	G	H
100	470	932	066	138	621	092	989	102
	BY	HJ	PV	KU	MP	WL	QA	ER
101	912	722	090	142	823	893	778	675
	TZ	CE	HJ	KU	AZ	WL	PV	DX
102	433	555	201	286	549	504	388	216
	DX	TZ	SP	FG	BY	WL	QA	MP
103	212	745	617	581	992	858	693	614
	BY	AZ	KU	HJ	CE	SP	FG	PV
104	486	684	073	328	957	243	955	838
	TZ	ER	WL	AZ	BY	SP	DX	CE
105	400	338	595	248	903	991	524	141
	TZ	KU	FG	HJ	ER	PV	MP	AZ
106	860	888	190	723	565	570	562	290
	HJ	KU	SP	QA	AZ	TZ	PV	FG
107	150	931	556	164	885	985	621	893
	CE	DX	QA	MP	WL	BY	KU	FG
108	861	525	353	754	588	971	521	112
	HJ	PV	CE	FG	SP	AZ	WL	ER
109	841	325	374	432	481	093	329	890
	QA	FG	SP	PV	HJ	MP	ER	DX
110	950	618	693	958	312	585	819	132
	DX	WL	MP	KU	PV	AZ	BY	TZ

Panelist	A	B	C	D	E	F	G	H
111	541	838	932	446	328	954	221	206
	CE	MP	HJ	SP	AZ	FG	QA	DX
112	468	574	758	342	577	841	536	994
	PV	BY	KU	MP	FG	WL	ER	TZ
113	380	778	292	349	926	546	088	878
	HJ	CE	ER	AZ	PV	QA	DX	WL
114	861	073	058	342	672	062	601	793
	ER	MP	QA	SP	KU	BY	TZ	PV
115	409	248	121	655	388	522	169	153
	AZ	KU	CE	SP	DX	QA	WL	BY
116	110	260	986	621	996	795	299	443
	MP	QA	FG	HJ	BY	KU	WL	ER
117	500	832	377	507	105	316	743	401
	MP	AZ	QA	PV	DX	HJ	FG	CE
118	914	725	921	227	590	522	806	691
	CE	SP	HJ	KU	FG	PV	MP	TZ
119	708	577	420	265	334	100	182	447
	QA	AZ	CE	SP	BY	DX	ER	WL
120	523	680	800	128	133	708	168	956
	SP	CE	DX	PV	TZ	KU	WL	AZ
121	148	853	947	810	144	823	242	818
	QA	ER	BY	CE	MP	HJ	SP	FG

Appendix E: IRB Approval Form

Oklahoma State University Institutional Review Board

Date	Tuesday, November 08, 2005	Protocol Expires:	8/29/2006
IRB Application	HE011		
Proposal Title:	MEAT ANALOGS MADE FROM TEXTURIZED VEGETABLE MATERIALS		
Reviewed and Processed as:	Exempt **Modification**		

Status Recommended by Reviewer(s) **Approved**

Principal Investigator(s) :

Margaret J. Hinds
309 HES
Stillwater, OK 74078

Yee shyen Yong
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The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB

The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

Signature :

Sue C. Jacobs, Chair, OSU Institutional Review Board

Tuesday, November 08, 2005
Date

Appendix F: Consent Form

(Front page)

MEAT ANALOGS MADE FROM TEXTURIZED VEGETABLE MATERIALS
CONSENT FORM C

1. I have been asked to participate as a panelist in a research project entitled "meat analogs made from texturized vegetable materials".

2. The purpose of the project is to develop and evaluate meat analogs made primarily from vegetable materials that are grown in Oklahoma.

3. The project is under the direction of Dr. Margaret J. Hinds, a faculty member in the Department of Nutritional Sciences, College of Human Environmental Sciences, Oklahoma State University, and is being funded by the Oklahoma Agricultural Experiment Station.

4. If I choose to participate in the project, I understand that I will be asked to evaluate various samples of burgers and sausage, and burger and sausage-type products containing mainly soy, peanut, wheat, and prune puree. I will be required to spend about half-hour to evaluate samples at the Sensory Evaluation Laboratory, Food and Agricultural Processing Center, OSU. I will visually inspect, smell, taste, and chew (swallowing is optional) cooked samples, and indicate my feelings on acceptability of the samples. I understand that all the products and materials used in this project have been obtained from USDA-inspected facilities, and that the soy-peanut-wheat samples have been prepared according to rules and regulations governing food preparation and service in Oklahoma. However, I have been advised that if I am allergic to or do not consume any of the following that I should NOT participate in the project: beef, soy, peanuts, wheat, prunes, garlic, onion, caramel flavor, natural meat flavor, and salt.

5. I understand that information gathered from me will not be reported to anyone outside the research project in any manner which personally identifies me. A report of general and combined results from all participants in the project will be prepared for the OK Agricultural Experiment Station, and will be submitted to a professional publication or conference at a later time.

6. I understand that participation is voluntary, that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty after notifying the project director.

7. I understand that a signed statement of informed consent is required of all participants in this project.

8. I may contact Dr. Margaret J. Hinds, Nutritional Sciences Department, at telephone number (405) 744-5043. I may also contact Dr. Sue C. Jacobs, 415 Whitehurst, Oklahoma State University, Stillwater, OK 74078; telephone number: (405) 744-1676.

9. **My signature on page 2 indicates that I understand and voluntarily agree to the conditions of participation in the project as described above. If I do not wish to or have doubts about participating in this project, I will not sign this form or participate in any more activities connected with this project.**

1

(Consent Form back page)

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

Date: _____ Time: _____(a.m./p.m.)

Signed: _____
Signature of Subject

Printed Name of Subject: _____

Signed: _____
Signature of Witness

"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 or his/her authorized representative

2

1. PLEASE RINSE YOUR MOUTH WITH WATER. ***Panelist Code*** ***Sample Code***

FOR EACH OF THE FOLLOWING, PLEASE CHECK ONE APPROPRIATE BOX

2. YOUR GENDER: [] MALE [] FEMALE

3. YOUR AGE RANGE (years): [] 22 Or less [] 23-35 [] 36-50 [] 51 or more

4. YOUR ANNUAL HOUSEHOLD INCOME: [] $20,000 or less [] $21,001-$35,000 []$35,001-$55,000 []$55,001 or more

5. NUMBER OF TIMES PER MONTH YOU EAT BURGERS OR SAUSAGE: [] 1 or less [] 2-5 [] 6-9 [] 10 or more

6. 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
[]	[]	[]	[]	[]	[]	[]	[]	[]

7. Chew one or more bites, and check the box that best describes your feelings about each of the following attributes of the sample:

A) AROMA (SMELL):

Like Extremely	like very much	like moderately	like slightly	neither like nor dislike	dislike slightly	dislike moderately	dislike very much	dislike extremely
[]	[]	[]	[]	[]	[]	[]	[]	[]

B) TASTE:

Like Extremely	like very much	like moderately	like slightly	neither like nor dislike	dislike slightly	dislike moderately	dislike very much	dislike extremely
[]	[]	[]	[]	[]	[]	[]	[]	[]

C) TEXTURE:

Like Extremely	like very much	like moderately	like slightly	neither like nor dislike	dislike slightly	dislike moderately	dislike very much	dislike extremely
[]	[]	[]	[]	[]	[]	[]	[]	[]

8. Please indicate your feelings about purchasing this product if it were sold at a reasonable price:

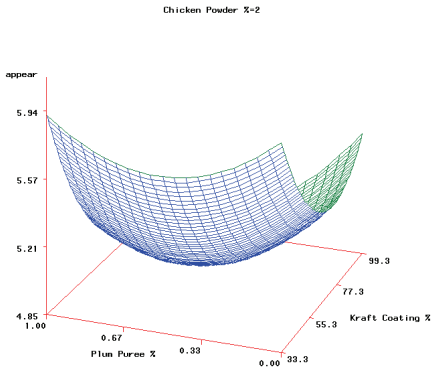
Definitely would buy	probably would buy	may or may not buy	probably would not buy	definitely would not buy
[]	[]	[]	[]	[]

PLEASE CHEW A CRACKER, AND RINSE YOUR MOUTH WITH WATER.

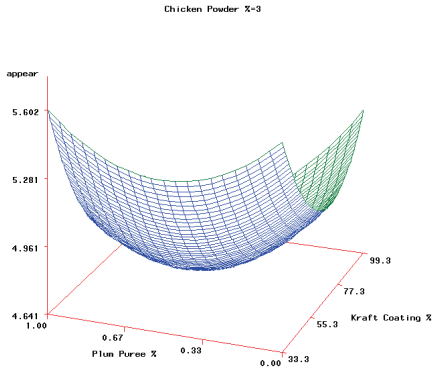
Appendix H: Surface Plots of Sensory Scores for Sensory Attributes

h1: Surface Plot of Sensory Scores for Appearance with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

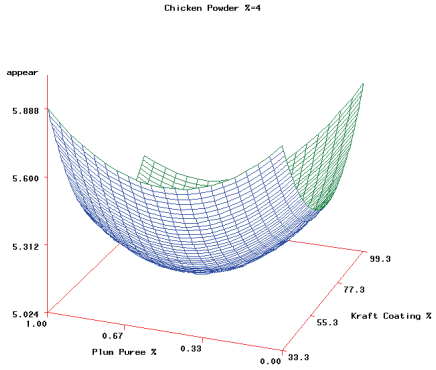
(a)



(b)

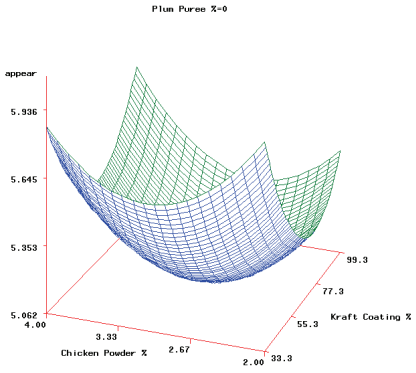


(c)

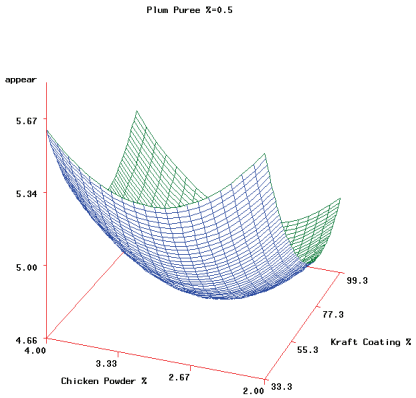


H2: Surface Plot of Sensory Scores for Appearance with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

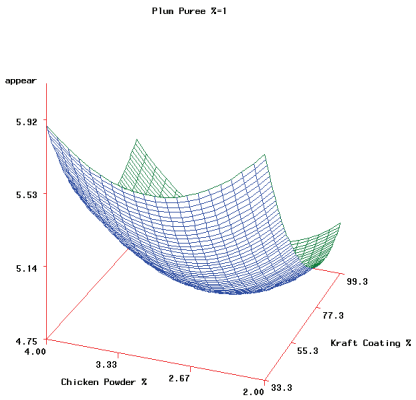
(a)



(b)

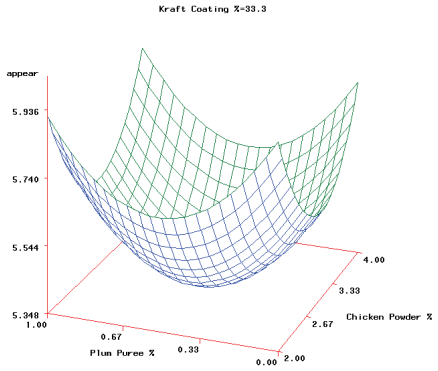


(c)

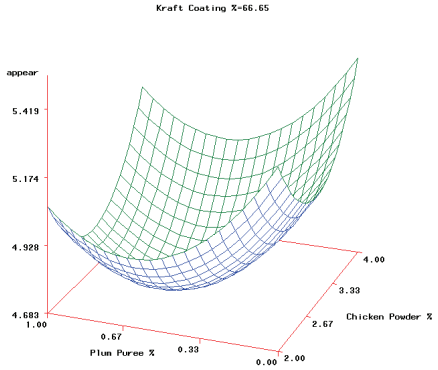


H3: Surface Plot of Sensory Scores for Appearance with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

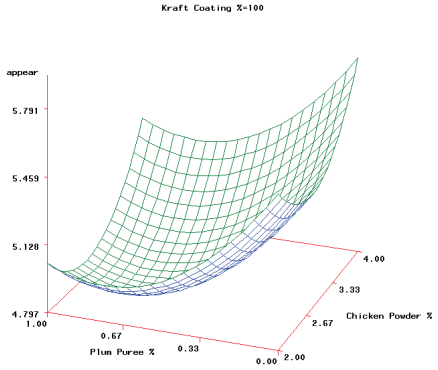
(a)



(b)

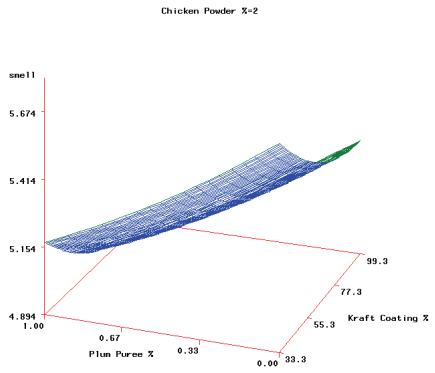


(c)

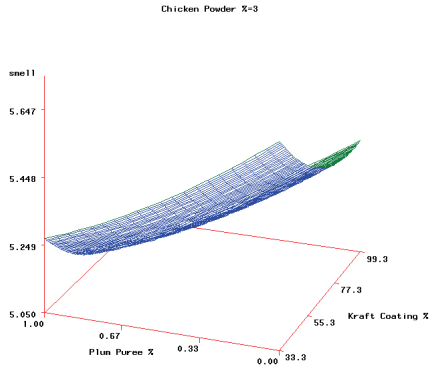


H4: Surface Plot of Sensory Scores for Smell with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

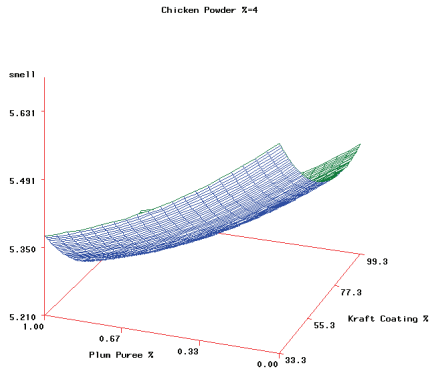
(a)



(b)

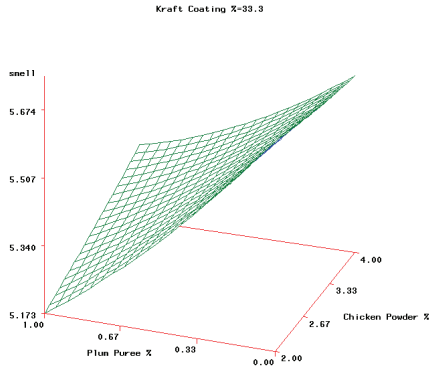


(c)

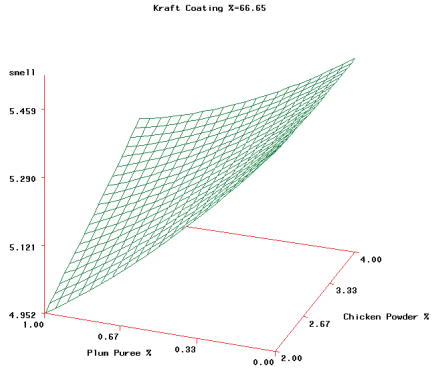


H5: Surface Plot of Sensory Scores for Smell with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

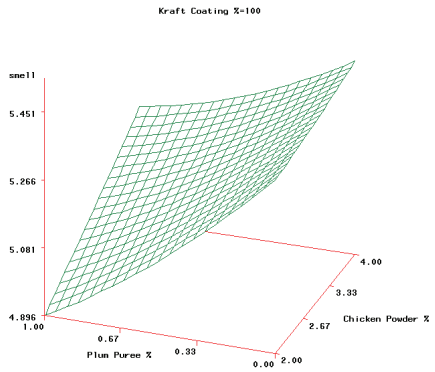
(a)



(b)

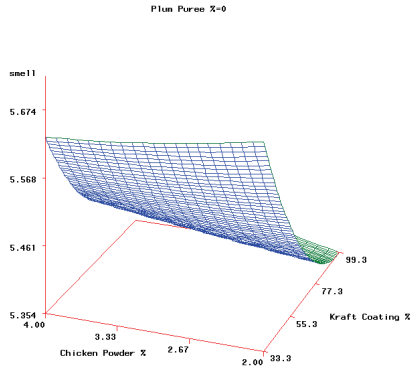


(c)

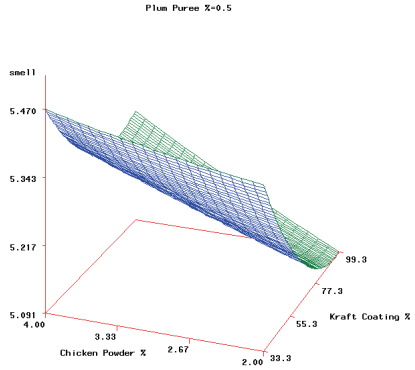


H6: Surface Plot of Sensory Scores for Smell with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

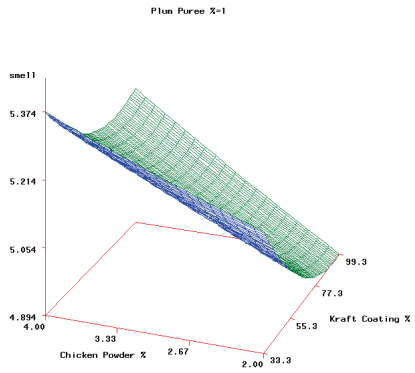
(a)



(b)

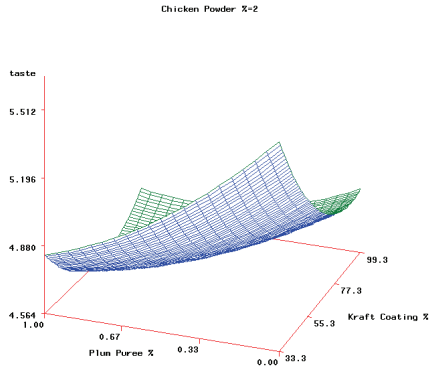


(c)

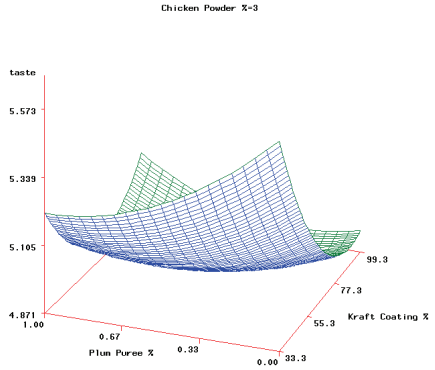


H7: Surface Plot of Sensory Scores for Taste with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

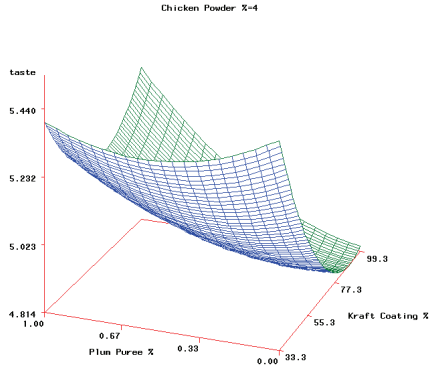
(a)



(b)

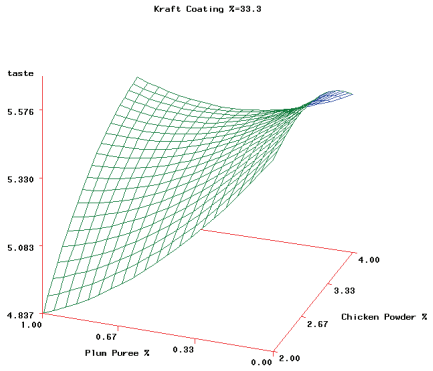


(c)

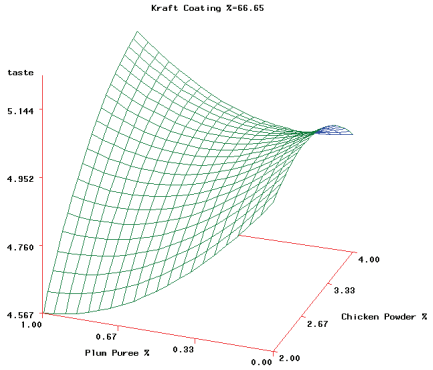


H8: Surface Plot of Sensory Scores for Taste with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

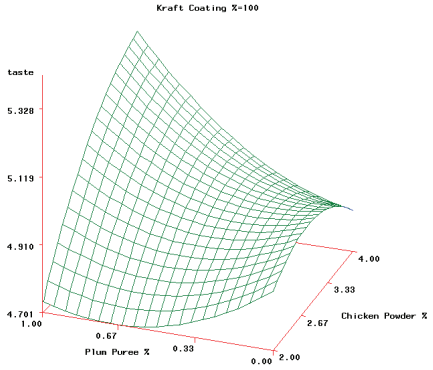
(a)



(b)

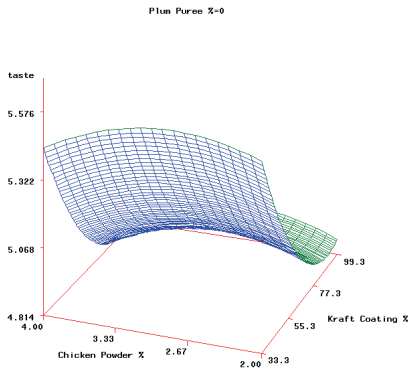


(c)

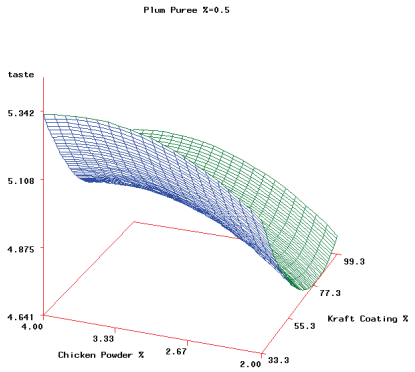


H9: Surface Plot of Sensory Scores for Taste with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

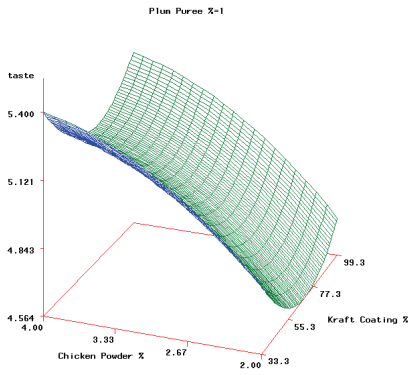
(a)



(b)

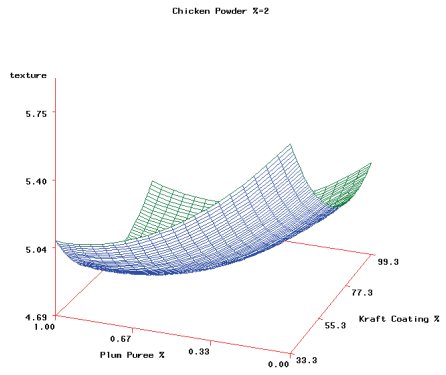


(c)

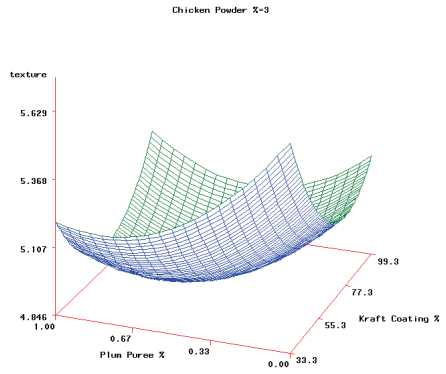


H10: Surface Plot of Sensory Scores for Texture with (a) 2%, (b) 3%, (c) 4% Asian Chicken Powder

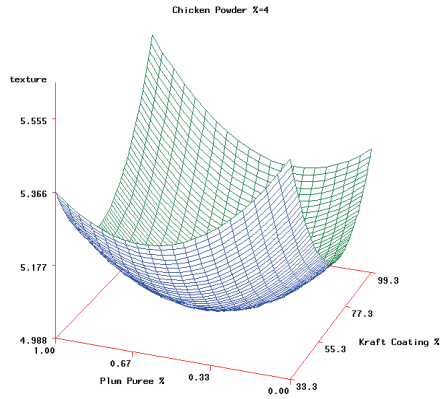
(a)



(b)

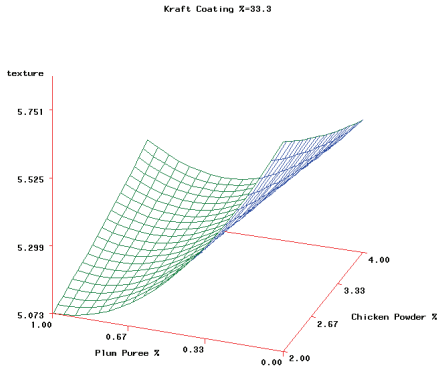


(c)

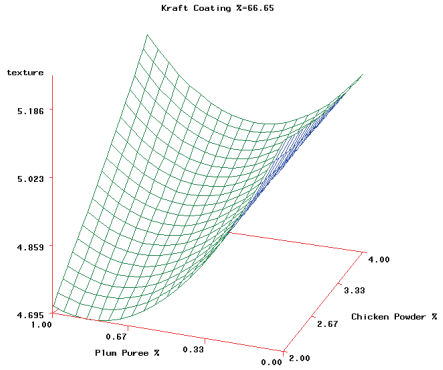


H11: Surface Plot of Sensory Scores for Appearance with (a) 33.3%, (b) 66.7%, (c) 100% Kraft Coating Mix

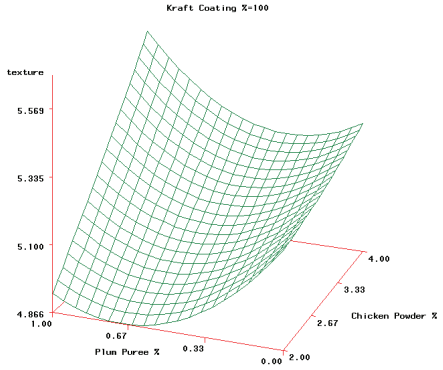
(a)



(b)

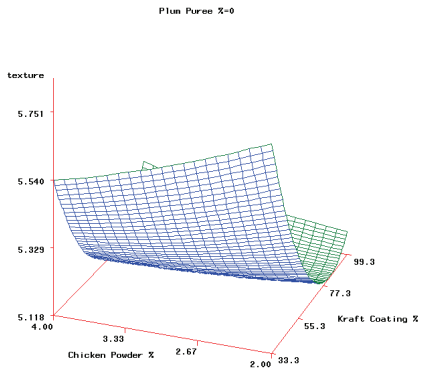


(c)

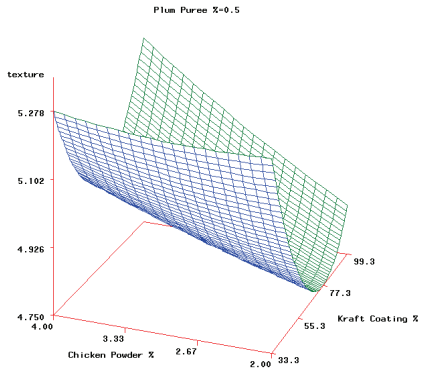


H12: Surface Plot of Sensory Scores for Appearance with (a) 0%, (b) 0.5%, (c) 1% Dried Plum Puree

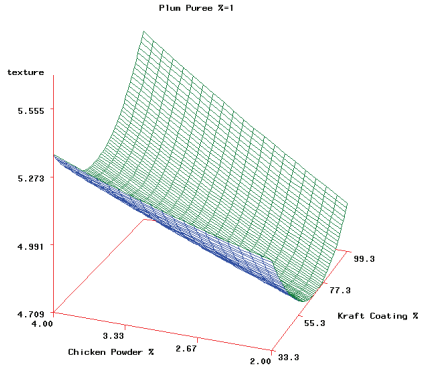
(a)



(b)

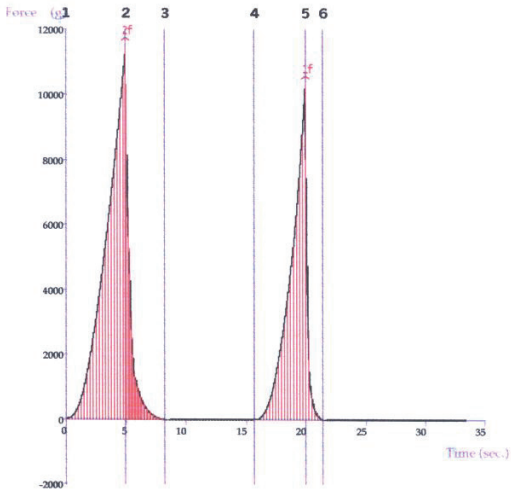


(c)



Appendix I: Typical Texture Profile of Textured Peanut Chicken Nugget

Typical Texture Profile of TP Nugget Analogs



Hardness = 11391 g force (force 2f)

Appendix J: IRB Online Certification

(CITI course front page)

CITI Course in The Protection of Human Research Subjects

Monday, June 12, 2006

CITI Course Completion Record
for Yee Shyen Yong

To whom it may concern:

On *5/31/2006*, *Yee Shyen Yong* (username=yeey) completed all *CITI Program* requirements for the *Basic CITI* Course in The Protection of Human Research Subjects.

Learner Institution: *Oklahoma State University*

Learner Group: *Social/Behavioral Research Investigator Faculty/Staff/Student*

Learner Group Description:

Contact Information:

Gender: Female
Department: Food Science
Which course do you plan to take?: Social & Behavioral Investigator Course Only
Role in human subjects research: Student Researcher
Mailing Address:
S37 University Place Apt 6
Stillwater
Oklahoma
74075
USA
Email: yee.yong@okstate.edu
Office Phone: 405-332-2106

The Required Modules for *Social/Behavioral Research Investigator Faculty/Staff/Student* are:	**Date completed**
Introduction	04/17/06
History and Ethical Principles - SBR	04/03/06
Defining Research with Human Subjects - SBR	04/03/06
The Regulations and The Social and Behavioral Sciences - SBR	04/17/06
Assessing Risk in Social and Behavioral Sciences - SBR	04/17/06

(CITI course back page)

Informed Consent - SBR	05/31/06
Privacy and Confidentiality - SBR	05/31/06
Internet Research - SBR	05/31/06
Research With Protected Populations - Vulnerable Subjects: An Overview	05/31/06
Conflicts of Interest in Research Involving Human Subjects	05/31/06
Oklahoma State University module	05/31/06
Additional optional modules completed:	**Date completed**

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator

VITA

Yee Shyen Yong

Candidate for the Degree of

Master of Science

Thesis: OPTIMIZATION AND ACCEPTABILITY OF MEATLESS CHICKEN NUGGET ANALOGS PREPARED FROM TEXTURED PEANUT

Major Field: Food Science

Biographical:

Personal Data: Born in Malaysia, on September 19, 1979, the daughter of Yoke Ann Yong and Swee Eng Kuang

Education: Graduated from Hin Hua High School, Negeri Selangor, Malaysia, received Bachelor of Science degree in Chemical Engineering from Oklahoma State University in December 2003. Completed the requirements for the Master of Science degree in Food Science at Oklahoma State University in July, 2006.

Experience: Employed by Oklahoma State University, Department of Nutritional Sciences as a graduate research assistant, August 2004 to May 2006.

Professional Memberships: Institute of Food Technologists, Kappa Omicron Nu National Honor Society.

Name: Yee Shyen Yong Date of Degree: July, 2006

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: OPTIMIZATION AND ACCEPTABILITY OF MEATLESS CHICKEN NUGGET ANALOGS PREPARED FROM TEXTURED PEANUT

Pages in Study: 183 Candidate for the Degree of Master of Science

Major Field: Food Science

Scope and Method of Study: The effects of commercial chicken flavor, dried plum puree, and coating mixture on physical properties and sensory acceptability of meatless chicken nugget analogs prepared from textured peanut were evaluated.

Findings and Conclusions: Physical properties of the meatless chicken nugget analogs were significantly affected by chicken flavor and plum levels in the formulation, as well as the Kraft coating (%) in the coating mix. Meatless chicken nugget analogs that contained 2%-3.7% chicken flavor, 0%-0.1% dried plum puree, and coated with commercial coating mix containing 33.3%-37.4% Kraft Shake'N Bake Seasoned Coating Mix (chicken) replacing Best Choice Seasoned Coating Mix (chicken) were the most acceptable to sensory panelists. Nuggets within the predicted consumer acceptability range had color of 55°-71° Hue, 24.8-35.8 Chroma, 44-53 L value; 53%-55% moisture; 0.93-0.96 water activity; texture profile of 3662-4411g hardness, 1570-2133 chewiness, 0.643-0.723 springiness, 0.30-0.33 resilience, 0.57-0.62 cohesiveness, and maximum adhesiveness of -59.

ADVISER'S APPROVAL: Dr. Margaret J. Hinds