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I am submitting herewith a thesis written by Noor Aziah Bt Abd. Aziz entitled "Evaluation of cake doughnut with sweet potato as ingredient." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

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Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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To the Graduate Council:

I am submitting herewith a thesis written by Noor Aziah Bt. Abd. Aziz entitled "Evaluation of Cake Doughnut With Sweet Potato As Ingredient." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

J. L. Collins, Major Professor

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and recommend its acceptance:

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EVALUATION OF CAKE DOUGHNUT WITH SWEET POTATO AS INGREDIENT

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Noor Aziah Bt. Abd. Aziz

June 1980

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ABSTRACT

The purpose of this study was to develop a product (cake doughnut) utilizing sweet potato as an ingredient and to evaluate certain quality factors including chemical composition, physical and sensory attributes, and caloric content of the product.

Three types of sweet potato were prepared: sweet potato flour, baked, and steam cooked sweet potato. Four levels of each type were substituted at 0, 7, 14 and 21% for equal amounts of wheat flour of the doughnut recipe.

Consistency of the dough prepared with sweet potato was adjusted to that of the control dough (0% sweet potato). Reducing the amount of water permitted a change in consistency of the dough. Doughs of similar consistency for all treatments were used to prepare doughnuts for evaluation.

Proximate composition of raw, cured sweet potato flesh and cooked doughnuts was determined. Generally, the amount of crude fat in the doughnuts increased as the level of steam cooked sweet potato was increased. Crude protein decreased as the level of sweet potato was increased due to lower crude protein content in sweet potato than in wheat flour. Other changes were due to the level of sweet potato.

Highest caloric content was found in doughnuts with steam cooked potato.

Doughnuts prepared from steam cooked sweet potato were softer and higher in volume than doughnuts prepared with sweet potato flour or baked sweet potato.

Type and level of sweet potato had no effect on Hunter L values (lightness) for the crust. The crumb became darker as the level of baked

and steam cooked sweet potato was increased. Steam cooked sweet potato produced the darkest crumb in doughnuts, while sweet potato flour produced the lightest crumb.

The presence of sweet potato had little or no effect on degree of redness of the crust, but the crumb became more red as the level of sweet potato was increased. Small differences in degree of redness were determined for crust and crumb among types of sweet potato.

Yellow coloration of crust was not affected by type or level of sweet potato. Yellowness of the crumb was affected by type and level of sweet potato. Doughnuts with steam cooked sweet potato were more yellow than doughnuts with baked sweet potatoes since baking destroys some of the carotenoid pigments.

The doughnuts were evaluated by a sensory panel for 13 attributes: 6 for flavor, 4 for texture, and 3 for surface appearance and color.

Type of sweet potato affected the sweet, bready, oily, spicy and sweet potato flavor while level of sweet potato affected all of the flavor attributes except salty and oily. As the level of sweet potato was increased, the doughnuts became sweeter. Increasing the level of the three types of sweet potato produced a progressively greater sweet potato flavor in doughnuts. Doughnuts with steam cooked sweet potato were more oily than the control doughnuts. Increased levels of baked sweet potato made the doughnuts sweeter; increased levels of sweet potato flour, more bready and spicy; increased levels of steam cooked, more oily; and increased levels of flour and baked, exhibit a greater sweet potato flavor.

All textural attributes were affected by type and level of sweet potato. Elasticity decreased with increasing levels of baked sweet potato; tenderness decreased with increasing levels of steam cooked sweet potato; and adhesiveness increased with increased levels of sweet potato flour and baked sweet potato. Doughnuts with steam cooked potato were more elastic; with steam cooked sweet potato flavor, most tender; with sweet potato flour and baked sweet potato, more sticky; and with baked sweet potato, more gummy.

The sweet potato in the doughnuts affected crumb color, and level of sweet potato affected surface appearance and crumb color. With increasing levels of all types of sweet potato, the yellowness of the crumb increased. Baked sweet potato produced doughnuts with darker crust and steam cooked sweet potato produced doughnuts with more yellow crumb.

While doughnuts with sweet potato flour had many desirable attributes, the production cost may make the use of flour uneconomical. Baked or steam cooked sweet potato may be used to produce doughnuts of satisfactory quality. However, a blend of baked and steam cooked sweet potato may be used to take advantage of the higher sweet flavor of the baked and the higher volume development of the steam cooked sweet potato. Since doughnuts with baked sweet potato alone were relatively hard, use of steam cooked sweet potato would counteract this effect, producing a more desirably soft doughnut.

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CHAPTER I

INTRODUCTION

The sweet potato (Ipomoea batatas Lam.) is a popular food crop in the southern and eastern United States and is grown over large areas (15, 16, 71). Consumption of the roots in this country is much less than that in other countries. The higher consumption in other countries is due to the fact that the root is an inexpensive source of concentrated energy (15). The roots provide an excellent source of vitamins A, C, and niacin, calcium, and energy. Yet, per capita consumption of the roots in the United States has declined at a steady rate from 13.29 kg. in 1919 to 2.54 kg in 1974 (11, 12, 13, 18, 34).

Many factors are responsible for the decrease in the consumption of the roots. The list of factors include: (a) the American population can afford to purchase more expansive proteinacious foods (16); (b) there is an increasing awareness among consumers of the caloric content of foods consumed (21, 24); (c) there are problems in preparing, storing, and pricing of the roots (11, 12, 21), and (d) for many people, the roots are regarded as "low status country food" (21).

Attention should be given by research organizations and growers to the declining usage of sweet potatoes. Being highly nutritious, a greater number of processed sweet potato products should be made available to consumers. The new products should meet the consumers needs. One approach to meeting these needs will be that of incorporating sweet potato as an ingredient into different food products. One example of such a food product is the cake doughnut--a popular food item.

The purpose of this study was to develop a product (cake doughnut) utilizing sweet potato as an ingredient and to evaluate certain quality factors including chemical composition, physical and sensory attributes, and caloric content of the product.

CHAPTER II

REVIEW OF THE LITERATURE

I. SWEET POTATO ROOT

The sweet potato (Ipomoea batatas Lam.) belongs to the Convolvulaceae family (71). The root originated in the North-western part of South America. Columbus, on a return voyage from America, took roots of the sweet potato to Spain and the Spanish later introduced the roots to Europe, China, Japan, Malaysia, and the Moluccas region (54). In 1650 A.D., English Colonists introduced the roots into an area which is the present state of Virginia (13, 15, 18).

Sweet potatoes have been grouped into two major classes on the basis of textural properties (71). When baked, the "moist" type has a soft, syrupy texture and a bright, orange colored flesh which is high in carotene (16, 18, 75). This type is often referred to as "yam" which is technically incorrect since the true yam belongs to a different family (15, 40). The "dry" type has a firm, mealy texture and yellow or white flesh when baked (16, 18, 75).

Although sweet potatoes are of tropical origin, they have been grown successfully over a considerable range of climatic conditions (13). In the United States, production of this crop extends from the sub-tropical climate of the Gulf Coast to the mid-temperate region of Maryland and New Jersey (13). Commercially, the roots are produced in the South-eastern states including Virginia, North and South Carolina, Georgia, Florida, Alabama, Louisiana, and Mississippi (13, 16, 40) and in California. Currently, the major sweet potato producing areas in descending order of production are North Carolina, Louisiana, and California.

Sweet potatoes have been an important food crop in the tropical region for a long time (13, 14, 21). In the United States, sweet potatoes are popular, particularly in the southern states (13, 15). Although the roots are an excellent source of energy (114 cal per 100g) and vitamin A (8,800 I.U. per 100g), consumption of the root is still declining (11, 12, 13, 48). Annual consumption of fresh sweet potatoes has declined from approximately 6.80 kg in the mid-1940's to about 1.36 kg per capita in 1975 (48).

Economic and social characteristics of consumers are important in explaining the downward trend in sweet potato consumption. Among white households, family income, season of the year, and section of the country where people live are important determinants of weekly consumption of the roots. For each percentage increase in family income, a decline of 0.11% in consumption of sweet potatoes has been reported. Greater consumption of sweet potatoes occurs in the Fall season than in Winter or Spring. Rural farm families consume more roots than urban and rural non-farm families. Southern families consume more sweet potatoes than North-Western, North Central and Western families (48).

Among non-white households, age and size of family affect significantly the consumption of the roots. These families tend to consume more roots as the members become older. For each additional member of the household, there is an increase in family consumption by almost 0.09 kg weekly (48).

II. CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF SWEET POTATO

The average composition of the root is 5.8% crude protein, 1.4% crude fat, 2.4% crude fiber, 3.4% ash, 89.5% carbohydrate, 0.1% calcium and 8,800 International Units of vitamin A per 100g (24, 78). The root is a concentrated source of certain nutrients and energy because the moisture content is low compared to other common vegetables (15).

Foods prepared from sweet potatoes provide many important vitamins to the diet. The roots provide an excellent source of vitamin C (22 mg/100g). Baked sweet potatoes were two-thirds as rich in vitamin C content as raw or boiled roots (30). Cooking the root by accepted methods retained about 69 to 83% of the original vitamin C value. Losses of the vitamin to the cooking water were significantly higher than losses caused by heat used to boil the roots (30).

The roots have an appreciable amount of thiamine, riboflavin, niacin, and panthothenic acid (15, 16). Pearson and Luecke (56) found that the sweet potato cooked by baking retained 75.5% of the thiamine, 88.6% of the riboflavin, and 76.8% of the panthothenic acid. However, boiled roots were found to retain 92.3% of the thiamine, 103.2% of the riboflavin and 99.9% of the panthothenic acid (42, 56).

B-carotene, a precursor of vitamin A, is responsible for the orange color in the roots (47). Therefore, the orange-fleshed sweet potatoes are a major source of vitamin A (16, 21). B-carotene comprised between 80-90% of the total pigment, but in some varieties (excluding the white potatoes) the percentage may be as low as 22 (17).

Some varieties of sweet potatoes contain more than 9.0% crude protein (dry weight basis). The major portion of the protein is represented by a specific globulin, "ipomoein," which is converted by the action of proteolytic enzymes to a polypeptide upon aging of the roots (39).

Calcium and iron are found in appreciable amounts of about 32 mg and 0.7 mg/100 g, respectively, in the roots (78).

Glucose, maltose, sucrose, dextrin, and starch comprise the principal carbohydrates (16, 24, 38, 41, 78). Baking converts the starch into maltose and dextrins (29, 65, 66, 76). Gore (25) indicated that diastase converts large amounts of starch into soluble carbohydrates during slow cooking (60 - 100°C). Hoover (34) found that in sweet potato puree, starch was not converted into maltose and dextrin until the temperature was increased above that for starch gelation. A high dextrin content is associated with high maltose content (29). Dextrins were found in significant amounts only in baked roots which had been cured (29). Sistrunk and co-workers (65) found that the content of the reducing sugars increased from 1% in the raw state to as much as 14% in baked roots (38, 64). Scott and Matthews (63) indicated that dry matter loss after six months storage was 18% of the amount present at harvest. This loss was accounted for largely in the change in the amount of reserve carbohydrates or starch. Baking converts more starch to sugar than boiling (65).

III. DEVELOPMENT OF SWEET POTATO PRODUCTS

Numerous investigations have been conducted to develop new products from sweet potatoes. Sweet potato flour has been made for a long time (36, 58). Use of the flour can save the consumer time and labor of preparation. The dehydrated product contains a higher proportion of minerals due to lower water content. Therefore, the dehydrated product can be used as fortifying agents for diets, particularly in carotene, the precursor for Vitamin A (58). Bread can be made from sweet potato flour with up to 50% substitution for wheat flour (36). It was found that sweet potato flour could be used in place of mashed fresh sweet potatoes in pies or in puddings (36).

One per cent sweet potato flour was recommended as a stabilizing agent in all-cream ice cream.

Attempts have been made to make starch and sugars from the roots (36, 58).

Investigations were conducted on frozen, peeled cured sweet potatoes and on baked roots (11, 12, 32). In both cases, panel evaluations indicated that the products were acceptable.

Many efforts have been made to produce high quality sweet potato chips (35, 64). Blanching raw chips in sodium acid pyrophosphate and partially dehydrating prior to deep-frying prevent discoloration and development of a leathery texture (35).

Dehydrated sweet potatoes were used by the United States Armed Services during World War II (16). Enzymatic conversion of starch to sugar or addition of sugar in sweet potatoes can result in acceptable flakes. These products are being used in the school lunch program and by the Armed Forces (51).

Deep-fried juiliene strips, dices, and frozen french fries have been prepared also from sweet potatoes (41).

Canning sweet potatoes has been practiced for a long time. However, it is difficult to retain certain quality attributes of the roots in the canned product (33)

Discoloration and textural problems have been encountered in the production of high quality sweet potato products. Discoloration may be due to enzymatic, non-enzymatic or caramelization reactions (5, 9, 33, 50). Blanching or use of citric acid (16), a mixture of sodium acid pyrophosphate and tetrosodium pyrophosphate (33), or sodium bisulfite are two of the methods used to control discoloration. Textural problems in sweet potato chips result from the absorption of fat which is influenced by the type of raw sweet potato used (62).

IV. GENERAL ASPECTS OF DOUGHNUTS

Snack foods play an increasingly important role in the American diet. Estimates indicate that 20 to 25% of the calories consumed by adolescents are provided by snack foods (45). Fried products, whether chemically leavened or yeast-raised, have long ranked among the most popular confections produced by the baking industry (59). Popularity of fried products is related to the flavor and textural characteristics imparted by the frying method.

The doughnut is a popular snack food item. Pyler (59) reported on three major areas of concern in cake doughnuts; these are: (a) the outer surface of which the color should be a rich, golden brown as this color has been synonymous with an eye-appealing doughnut; (b) the outer zone which, in freshly fried doughnuts, is a crisp exterior skin or crust formed by the dehydration of the outer portion of the doughnut; and (c) the inner zone or core of the doughnut which resembles a baked product more than a fried one.

Robertson (60) indicated that 25 to 30% of the moisture may be retained by the inner core and this will eventually migrate and destroy the nature of the crust. Time and temperature of frying influence the degree of color development on the outer surface of doughnuts (60). Fat usage has little to do with color development.

A. Deep-frying

Production of deep-fried food products is a multi-billion dollar industry. Deep-frying is practiced widely as a method of cooking food in the United States (60). Three reasons have been given for the wide consumption of deep-fried foods. Deep-fried foods (a) are accepted by people of all ages (9), (b) provide convenience to the consumer (60), and (c) are the major items of the American diet (9).

Deep-frying is the process whereby the prepared food is cooked in heated edible fat (59, 73). Studies indicate that during deep-frying, heat from the fat (above 155.6^{o}C) drives out water from the outer portion of the fried food. At a moisture content of 3% or less, the crust is formed and the food is considered cooked (59). The fats react with the protein and carbohydrate components of the food which result in unique flavors and odors (79).

B. Frying Fats

Frying fats should possess the following characteristics during use: (59) (a) a light or fairly light color, (b) a surface free of foam and smoke, (c) a clean, clear appearance free of burnt particles, and (d) blandness in flavor so that it will enhance the eating quality of the fried foods.

Frying fats comprise about 25% of the finished product. The viscosity, ability to transfer heat, and the content of the free fatty acids of the fat have a pronounced effect on the quality of the finished product (20).

C. Fat Absorption

In deep-frying of foods, high fat absorption is frequently a problem (59). Two phenomena imparted in usage of fat are: (59, 60) (a) absorption where fat seeps into the product to become part of the crust and (b) adsorption where fat merely adheres to the surface of the crust rather than becoming an integral part of it.

Fat absorption results in the tenderization of the crust and wetting of the fried food. Both factors within limits add richness of flavor, improve mouthfeel and eating quality, and lengthen keeping quality of the product (59, 58, 80).

Doughnuts in which there has been an inadequate amount of absorbed fat acquire a pasty eating character. However, too high a fat content will leave a greasy film in the mouth and bring out a distinctive greasy flavor (59, 80).

Variation in humidity is an uncontrollable condition which influences absorption of fat by doughnuts and quality of the fried item. Moisture leaves the doughnut more readily when humidity is low and, therefore, a slight change in formulation is sometimes desirable under extreme humidity conditions (80).

Frying fats containing a high concentration of free fatty acids cause high fat absorption in addition to its contribution to development of off-flavors (80).

Formulation of the doughnut mix influences fat absorption. A balance between the structural building components and tenderizing ingredients of the mix controls the absorption of fats, the symmetry character of the crust, volume, and tenderness. Changes in the procedure of mixing the dough alters the function of any of the components of mix, thus affecting the finished doughnut (80).

Undermixed doughnut dough does not offer the necessary resistance to the expanding gases and the cells become over extended. Also, undermixing prevents development of protein which normally aids in formation of a barrier against the absorption of fat (80).

Amount of added moisture has a dramatic effect on absorption of fat (53). Under varying moisture conditions, the proteins of the flour dehydrate and function differently. With the moisture content increased above a normal level, protein develops and hydrates well, but the leavening reacts more readily and softens the batter. This allows the leavening gases to move freely in the dough, resulting in high fat absorption. A decrease in moisture content results in less toughening action in the protein and increases fat absorption (53, 80).

Temperature of frying fat is important in sealing the surface of the doughnut, thus channeling the movement of gas which shapes the doughnut. The heat from the frying fat triggers the leavening action. A low frying temperature results in slowing coagulation of the protein and gelatinization of the starches. Therefore, the leavening is not retained by the cooked surface of the doughnut. This results in a fat-soaked doughnut. High frying temperatures result in a too rapid and complete sealing of the surface which yields small, misshapen doughnuts with a low amount of fat absorbed (80). Recommended frying temperatures range from 185^o to 193.3^o C (59).

D. Fat Deterioration

Frying fats are subjected to three primary environmental conditions in the frying process. The conditions are (a) frying period, (b) standby period, and (c) storage period. Each condition plays a role in the chemistry of deterioration during frying operations by causing hydrolysis, oxidation, and polymerization (22, 52, 59, 61, 62, 80).

Decomposition products formed during the frying operation range from volatile to non-volatile compounds. Many of the volatile compounds identified can impart off-flavors to fried foods. On the other hand, at very low levels of oxidation, some of the decomposition products make up the characteristics "deep-fat fried flavor" (61, 62, 79). Accumulation of polymeric materials with prolonged fat use increases the viscosity of the oil which results in formation of gums on the coils and sides of the fryer. As a side reaction, the fat darkens in color and there is an increased tendency for the fat to smoke and foam during the frying operation (52, 59, 61, 62).

Fat of different degrees of unsaturation exhibit different rates of oxidation. Thompson and co-workers (73) found that fat deterioration during frying is less dependent on degree of unsaturation than on how the fats are used.

V. MAJOR INGREDIENTS IN CAKE DOUGHNUT

A. Wheat Flour

Protein in wheat flour consists of glutenin and gliadin together with about 20% of albumin, globulin, and a small amount of proteose (31, 44, 55). Protein, when treated with water, tends to hydrate and form a coherent mass, the gluten. Halton and Scott-Blair (28) stated that the elastic behavior of wheat flour dough is due to protein chains that act like coiled springs. The linkages between chains are not of the same strength. So, when the dough is extended some of them break almost immediately while others remain intact and maintain the rigid structure of the dough.

Swanson and Andrews (70) reported that glutenin formation in wheat flour dough is related to the hydration of the molecules in the gluten. When flour is mixed with water, the proteins are arranged in a heterogeneous manner. Mixing action results in the gluten particles becoming oriented in a parallel position. High speed mixers cause a pulling action on the dough which results in a rather parallel arrangement of protein strands. Thus, the dough becomes smooth and shows greatest resistance to pulling action and to elasticity. Mixing beyond this stage breaks the dough down and causes it to become soft and sticky.

Mixing conditions required to develop different flours vary due to variation in the rates of combination of flour with the gluten, and to a difference in molecular structure of the proteins and to the manner in which the proteins are bound together in the gluten strands (46).

Starch, together with small amounts of dextrins, sugars, and cellulose, make up the carbohydrates of wheat flour (46).

Wheat flour contains 0.5 to 3.0% lipid material. Deterioration of the lipid materials results in the decline of flavor quality in wheat flour (46).

Mecham and Weinstein (49) studied the lipid binding capacity in doughs. They found that wheat flours when treated with water or when they are made into a dough, bind a considerable amount of water extractable lipids.

Addition of other types of flours with wheat flour can induce adverse effects on dough properties, including (a) altered absorption and mixing properties, (b) poor color and flavor, (c) changed fermentation rates, and (d) a modified gluten complex (74).

B. Dough Conditioners

Swanson and Andrews (70) stated that certain surface active materials could modify the mixing characteristics of wheat flour doughs. A surfactant alters conditions prevailing at interfaces of dough systems (70). Surfactant-based dough conditioners will (a) modify mixing properties of dough and increase tolerance of non-wheat flour, (b) improve quality of products through stabilization of higher loaf-volumes, by development of excellent crust textures and cell structure, and by increasing greater resistance to staling (27, 74, 75).

Sodium-stearoyl-2-lactylate (SSL) acts as a dough conditioner and emulsifier in high-fat, yeast-leavened products (71, 74). SSL is a friable solid and is supplied commercially as a free-flowing powder (6, 71).

The Food Additive Regulation 121.1048 (23) specifies that SSL may be used in an amount not greater than that required to produce the desired internal physical or technical effects of the product. SSL can be incorporated into a food system as a powder, as an admixture with fats, or as a water-gel (71).

SSL permits the production of uniform, high quality, baked products over a wide range of processing and ingredients variations (71). SSL imparts strength to the dough, giving it tolerance to withstand production and ingredient variations (70, 71). It also permits the manufacture of yeast-leavened sweet goods with excellent shelf-life, volume, and tenderness (70, 74, 75). The usage level of SSL is not a critical factor. Optimum usage generally falls in the range of 0.5 to 1% of the flour weight (71).

CHAPTER III

MATERIALS AND METHODS

I. SOURCE AND TYPE OF SWEET POTATO

The Jewel cultivar of sweet potatoes was used in the experiment. The roots were grown on the Plant Science Farm, University of Tennessee, in 1979 by personnel of the Plant and Soil Science Department, University of Tennessee. The roots were cured for a month prior to use.

The roots possessed an orange-colored flesh and are classified as a "moist" type (76).

II. PREPARATION OF THE SWEET POTATOES

The roots were prepared into the following forms:

A. Flour

The roots were washed and lye-peeled in a 10% lye solution for five minutes at 103° C. The roots were removed from the lye, washed with water to remove hydrolyzed flesh and lye, and placed in a 0.5% citric acid solution to neutralize the lye (16). The roots were sliced to approximately 0.6 cm with a Hobart Food Chopper (Model 84142). The slices were steam blanched 6 minutes and dried in a forced-air dehydrator at 45° C for 84 hours. The dried slices were ground in a Viking Hammer Mill to pass a screen with 1 mm openings. This process was followed by grinding the material in a colloid mill to pass a 100-mesh screen. The flour was stored in jars over desiccant at room temperature until used.

B. Baked Sweet Potato

The roots were washed with water, wiped dry, and baked for 1.5 hours at 191°C in a preheated "Despatch" oven. The baked roots were allowed to cool to room temperature before being peeled by hand and pureed for 6 minutes with a Hobart Food Chopper (Model 84142). The puree was filled into plastic bags and stored at -17° C until used.

C. Steam Cooked

Initially, the roots were prepared in a manner similar to that used to produce flour. The raw slices were cooked for 17 to 20 minutes in an atmospheric steam cooker. After cooling to room temperature, the flesh was pureed with a Hobart Food Chopper for 6 to 10 minutes. Samples were placed in plastic bags and stored at -17° C until used.

III. PREPARATION OF CAKE DOUGHNUTS USED FOR A CONTROL SAMPLE

The ingredients used in the preparation of a control sample of cake doughnuts are listed below (69):

Ingredients	Amount
Flour	425.40g
Sugar	56.80g
Salt	7.10g
Nonfat-dry milk	21.30g
Shortening	42.60g
Water	180.00ml
Egg	46.40g
Vanilla extract	2.00g
Mace	1.77g
Active dry-yeast	28.35g
Sodium stearoyl-2-lactylate	3.80g

Salt, sugar, nonfat-dry milk, and margarine were combined and blended for 3 minutes in a Hobart mixer equipped with a dough hook and at a speed setting of 2. Egg and vanilla extract were added to the mixture and mixed for 2 additional minutes. Following this, active dry-yeast (dissolved in water) was blended into the mixture for another 2 minute period. Mace and sodium stearoyl-2-lactylate (SSL, dough conditioner) were added to the mixture and mixed for an additional minute. All purpose plain flour and sweet potato were added and mixed for 8 minutes.

IV. PREPARATION OF CAKE DOUGHNUTS WITH SWEET POTATO

The recipe used for preparing doughnuts with sweet potato was similarly to the one presented for making cake doughnuts of the control (Section III) with two exceptions. The recipe contained sweet potato which had been prepared by drying as a flour, baked and steam cooked at four levels and the amount of water was varied with type and level of sweet potato. Sweet potato of each type (flour, baked and steam cooked) was substituted for 0, 7, 14, and 21% wheat flour. The amount of sweet potato solids replaced an equivalent amount of wheat flour. Table I presents the amount of sweet potato used in the recipes.

Consistency of the doughs prepared with sweet potato and used to prepare doughnuts for analysis and evaluation was manipulated so that doughs had a consistency similar to that of the control. To accomplish this, three levels of water were added in a given recipe containing sweet potato of a specific type (Section II) and levels at 7, 14, and 21%. The amounts of water added was such that the consistency of at least one of the doughs was greater than that of the control dough. One dough was prepared to yield a consistency lower that that of the control. The third sample was prepared with an amount of water to produce a dough with an intermediate consistency. For each treatment (type - level of sweet potato) samples were prepared in two replications at each level of water. From individual samples, three subsamples were taken and five measurements were made on each subsample. Therefore, the mean value for

TABLE I

AMOUNT OF SWEET POTATO USED AT FOUR LEVELS
FOR PREPARATION OF CAKE DOUGHNUTS

Proportion of S.P. and[1] Wheat Flour	Flour(g)	Baked(g)	Steam Cooked(g)
0% S.P. solids	---	---	---
100% wheat flour	425.40	425.40	425.40
7% S.P. solids	31.65	79.52	113.93
93% wheat flour	395.62	395.62	395.62
14% S.P. solids	63.30	159.04	227.85
86% wheat flour	365.84	365.84	365.84
21% S.P. solids	94.95	238.53	341.74
79% wheat flour	336.07	336.07	336.07

S.P. = Sweet potato

[1]S.P. was calculated on a moisture free basis; wheat flour, on a weight basis with approximately 12% moisture.

consistency consisted of 30 measurements. Linear regression analysis of the data for consistency and amount of water was used.

V. PREPARATION OF DOUGH TO DETERMINE DOUGH CONSISTENCY

The dough for the control sample (with wheat flour only) was prepared as previously stated (section III), however, only one-half batches of the ingredients were used. The ingredients were mixed in a Kitchen-Aid mixer (Model K-5, speed No. 4) using a dough hook. After the addition of flour, the dough was mixed for 10 minutes. The method used for preparing dough with sweet potato was similar to that used to prepare dough for the control (section III), but the amount of water was adjusted as discussed in Section IV.

VI. MEASUREMENT OF DOUGH CONSISTENCY

The consistency measurement of samples of doughs was made with the Instron Food Testing Machine (model 1132). The machine was equipped with a 5 kg. capacity load cell and a probe attachment of 1 cm. diameter. The crosshead-and chart speeds were set at 10 cm. per minute.

Three 70 g samples were taken from the dough of each treatment (type of sweet potato - level of sweet potato combination). Each sample was wrapped in aluminum foil to prevent loss of moisture. For testing, the dough, while wrapped in foil, was rolled to 1.5 cm thickness with a rolling pin. The foil was removed and the samples of dough was placed onto a wooden support covered with plastic for measurement.

Measurements of consistency were made by allowing the probe to penetrate to a depth of 6 mm. The peak force value recorded on the chart at this depth was used as the measurement of consistency. Samples were prepared from two replicates. Three subsamples were taken from each replicate and 5 measurements were made per subsample. Therefore, each value for consistency is the mean of 30 measurements.

VII. PREPARATION OF DOUGH AFTER MIXING

The dough was prepared by procedures presented in Section III and IV. After mixing the ingredients together, the dough was placed in a greased bowl and proofed for 1 hour at 38 to 40^{o}C and 98% relative humidity in a proofing cabinet. After proofing, the dough was rolled on a floured board to a thickness of approximately 1.2 cm. A doughnut cutter of 6.7 cm diameter was used to cut the dough. The cut dough was placed in a greased pan and held under a towel at room temperature for 10 minutes. Proofing was continued in a cabinet for 30 minutes at 27^{o} C prior to frying.

VIII. COOKING METHOD

A small, commercial-type deep-fryer was used for frying the doughnuts. Six liters of soybean oil were filled into the fryer and heated to 191^{o} to 193^{o} C (45, 69). The doughnuts were cooked in hot oil for 50 seconds on each side. Four doughnuts were cooked at one time. The cooked doughnuts were placed on paper towels to absorb surface oil (45). The doughnuts were always prepared just prior to use for testing.

IX. CHEMICAL ANALYSIS OF SWEET POTATO AND CAKE DOUGHNUT

Samples of cured, raw sweet potato flesh and doughnuts from each treatment were analyzed for the components presented below. Two replications were prepared from the sweet potato flesh and doughnuts and three analyses were made on samples from each replicate.

A. Moisture

Moisture content was determined by the Vacuum Oven Method (4). Triplicate samples of 5g were dried to a constant weight at 70° C for 19 hours at 163 torr. Moisture content for sweet potato prepared as flour, baking and steam cooked, was determined also.

B. Crude Fat

Three grams of oven-dried samples were extracted for 16 hours with petroleum ether in a Goldfisch Apparatus according to AOAC (4). Results were expressed as percentage of crude fat.

C. Ash

The percentage of ash was determined according to AOAC (4). Five grams of sample were ashed in a Muffle Furnace at 525° C until the sample reached constant weight. The amount of ash was presented as percentage of ash.

D. Crude Fiber

Crude fiber content was analyzed only on the raw sweet potato flesh according to AOAC (4). Two grams of samples were analyzed and values were presented as percentage of crude fiber.

E. Crude Protein

Two grams of air-dried samples were analyzed for protein content (% N x 6.25) by the modified Kjeldahl method according to AOAC (4). Values of crude protein were presented in percentage.

F. Carbohydrate

Percentage of carbohydrate was calculated by subtracting the percentage of moisture, crude fat, ash, crude fiber, and crude protein from 100%.

X. GROSS ENERGY VALUE

Gross energy value was determined with an Oxygen Bomb Calorimeter (Parr Instrument Co., Moline, Ill.) (1). Approximately 0.7g of air-dried sample was analyzed for doughnut samples. Two replications were prepared from doughnut samples of each treatment and 3 observations were made for each replication.

XI. COLOR MEASUREMENT OF COOKED DOUGHNUT

Color determinations were made on doughnuts from each treatment by using the Hunter Calorimeter (Model D25 2M). L, "a," and "b" values were recorded for the surface (crust) and crumb of the doughnuts. The instrument was standardized against a white tile (Hunter C2-136). Samples were placed in an optical glass bottom cuvette (6.4 cm diameter x 5.7 cm height) for color determination. Two replications were prepared and three observations were measured in each replication.

XII. TEXTURE OF COOKED DOUGHNUTS

The Instron Food Testing Machine (Model 1132) was used to measure the force (kg) required to compress the cooked doughnut (2). The 50 kg. load cell was used; the crosshead - and chart speeds were set at 10 cm and 25 cm per minute, respectively. Three measurements were made on each of three replications of samples. Each sample was compressed between surfaces having diameters (15 cm) greater than that of the doughnuts. The doughnuts were compressed 20% of their average thickness and a value for hardness was determined.

XIII. VOLUME OF COOKED DOUGHNUTS

Four doughnuts per treatment were used to determine the volume by using a cake volumeter (3, 8). Volume was determined by rapeseed displacement. The specific volume (cc/g) of each doughnut was calculated by dividing the volume by the weight.

XIV. SENSORY EVALUATION

A. Preliminary Study

The Quantitative Descriptive Analysis (QDA) method of sensory evaluation was used to evaluate the cooked doughnuts. Ten panelists were used during the training period. The panel consisted of faculty members and graduate students in Food Technology and Science. They were trained using the scale consistent with that designated by QDA (43, 67).

Each sample was evaluated for 19 attributes of quality considered pertinent by individuals who were familiar with cake doughnuts. These attributes and reference standards chosen for each end of the QDA scale are listed in Appendix A.

During training, the panel members evaluated cake doughnuts prepared with sweet potato flour at 0, 5, 10, 15, and 20%. At each level, sweet potato flour was substituted for wheat flour on the basis as presented in Section IV.

Evaluation of samples was conducted in a laboratory designed for sensory evaluation. One-half doughnut was given to each panelist at a time. The sample was placed in a transparent plastic cup and covered with transparent plastic wrap. Samples were coded with a randomized series of three numbers and presented to the panelists in a randomized arrangement. Samples were evaluated under fluorescent light.

Data were subjected to factor analysis by utilizing the Statistical Analysis System of the University of Tennessee Computer Center (7, 67).

B. Sensory Evaluation of Cake Doughnuts Prepared from Different Types of Sweet Potato Materials

Ten trained panelists evaluated cake doughnuts containing 0, 7, 14, and 21% (based on solids content as presented in Section IV) sweet potato of the three types. The reference standard chosen for each end of QDA scale is listed in Table II. Testing except for surface appearance, and crust and crumb color was conducted under conditions similar to those used during the training period.

Samples evaluated for crust and crumb color were cut horizontally into half sections. For panel viewing, an uncut doughnut and one-half of a cut doughnut were placed separately on a white plastic plate and covered with transparent plastic wrap. Testing was conducted under white fluorescent light between 2:30 and 4:30 p.m. Samples representing each type and level of sweet potato were evaluated for 13 attributes as presented in Appendix B.

XV. STATISTICAL ANALYSIS

Proximate analysis data is of the cooked doughnuts were analyzed by analysis of variance as a factorial of a complete block (3X4; type of sweet potato X level of sweet potato).

Data for volume, color, and texture were analyzed by analysis of variance as a factorial of a completely randomized block (3X4X2; type of sweet potato X level of sweet potato X replication). Data for the sensory evaluation were analyzed as a factorial of a completely randomized block (3X4X2X10; type of sweet potato X level of sweet potato X

TABLE II

REFERENCE STANDARDS USED BY THE SENSORY PANELS TO EVALUATE 13 ORGANOLEPTIC ATTRIBUTES OF CAKE DOUGHNUTS PREPARED WITH SWEET POTATO

Factors Evaluated	Ends for scale used to evaluate the factors: Left-weak sensation	Right-extreme sensation
Flavor		
Sweet	2% sugar solution	5% sugar solution
Salty	0.05% salt solution	0.20% salt solution
Bready	Raw canned biscuit dough	Canned biscuit baked for 8 minutes at 246° C.
Oily	White potatoes sliced to 0.3 cm in thickness, fried 3 minutes in soybean oil and blotted with paper towels.	Preparation was similar for weak except they were fried 5 minutes and were not blotted with paper towels.
Spicy	0.024% mace in water.	0.05% mace in water.
Sweet potato	Sweet potatoes were boiled 30 minutes and mashed. 150 g of the mashed tissue was mixed with 100 g of dehydrated white potatoes and 300 mls of water.	Only mashed, boiled sweet potato was used as described for the weak sensation.
Texture		
Elasticity	Raw canned biscuit dough rolled in wheat flour.	Household sponge
Tenderness	Stale commercially prepared unglazed cake doughnuts.	Commercially prepared unglazed cake doughnut
Adhesiveness	Sugarless peppermint gum	Taffy candy.
Gumminess	Overcooked canned biscuits baked at 246° C for 12-15 minutes.	Baked canned biscuits for 6 minutes at 246° C.

TABLE II (Continued)

Factors Evaluated	Ends for scale used to evaluate the factors	
	Left-weak sensation	Right-extreme sensation
Appearance and Color		
Surface Appearance	Smooth sensation. Prepared doughnut was fried 40 seconds at 191^{o}C.	Rough sensation. Over-proofed doughnut was fried 1 minute at 191^{o}C.
Crust	Brown (light) Light brown sugar	Brown (dark). 1¼ oz. cup of light brown sugar mixed with 1¼ tbsp. cocoa.
Crumb	Light creamy yellow. 5Y 9/2 Munsell color chip.	Yellow-orange. 7.5 YR 7/10 Munsell color chip.

replication X panelist). Duncan's Multiple Range Test was used to determine significance among the means (57). The Statistical Analysis System program referred to previously was used to compute the data.

CHAPTER IV

RESULTS AND DISCUSSION

I. FIRMNESS OF DOUGH FOR THE CAKE DOUGHNUTS

Firmness values of cake doughnut dough prepared with wheat flour, sweet potato, and different amounts of water are presented in Table III. Values apply to use of one-half formulation of ingredients. The control dough prepared with 213 g of wheat flour and 90 mls. of water had a firmness of 163 g force. The firmness values for doughs of each wheat flour-sweet potato combination are presented for each of the three levels of water. Obviously, the firmness decreased as the amount of water was increased. Also, firmness decreased as the proportion of sweet potato of each type was increased and when the amount of water was held constant.

Within each wheat flour-sweet potato-water treatment combination, the correlation coefficient between firmness and water level demonstrated that a very close linear relationship existed. The linear regression equation for each treatment was used to calculate the amount of water needed to produce a dough similar in firmness to the control doughs. The calculated amounts of water are presented in Table IV. These amounts of water were used to formulate doughs from which doughnuts were prepared for analysis.

II. PROXIMATE COMPOSITION OF RAW, CURED SWEET POTATO FLESH

The proximate composition of raw sweet potatoes used in this study is shown in Table V. Cured flesh of the Jewel variety had a mean

TABLE III

EFFECTS OF DIFFERENT AMOUNTS OF WATER ON THE CONSISTENCY OF CAKE DOUGHNUT DOUGHS PREPARED FROM ONE-HALF RECIPE WHICH CONTAINS THREE TYPES OF SWEET POTATO

Treatment				
Wheat flour, %	Sweet potato, %	Water (ml)	Consistency,[1] grams force	Correlation coefficients
100 (control)	0	90	163	---
	Flour			
93	7	80	278+6.7	
		90	125±6.5	-0.9273
		100	97±5.6	
86	14	75	192±3.7	
		85	150±1.8	-0.9829
		95	128±3.6	
79	21	75	181±8.0	
		85	140±8.2	-0.9985
		95	107±8.4	
	Baked			
93	7	45	284±13.7	
		55	176±4.4	-0.9961
		65	96±5.2	
86	14	10	293±11.5	
		20	201±12.0	-0.9970
		30	127±3.6	
79	21	0	180±10.1	
		10	118±3.1	-0.9879
		20	63±3.5	
	Steam Cooked			
93	7	35	355±5.9	
		50	213+3.2	-0.9989
		65	91±3.4	

TABLE III (Continued)

Treatment				
Wheat flour, %	Sweet potato, %	Water (ml)	Consistency,[1] grams force	Correlation coefficients
86	14	20	267±8.9	
		35	163±4.6	-0.9989
		50	93±0.9	
79	21	0	247±2.4	
		15	166±2.7	-0.9939
		35	94±5.9	

[1]Mean of 30 observations ± one standard deviation.

TABLE IV

AMOUNT OF WATER USED TO PREPARE A RECIPE FOR CAKE DOUGHNUT DOUGH WITH SWEET POTATO TO POSSESS A CONSISTENCY SIMILAR TO THAT OF CONTROL DOUGH

	Type of Sweet Potato		
Level of Flour	Flour	Baked	Steam Cooked
		ml	
0% sweet potato 100% wheat	180 (control)	180 (control)	180 (control)
7% sweet potato 93% wheat	181	115	113
14% sweet potato 86% wheat	166	51	74
21% sweet potato 79% wheat	159	6	36

TABLE V

PROXIMATE COMPOSITION[1] OF RAW, CURED SWEET POTATO FLESH OF JEWEL VARIETY USED IN PREPARATION OF CAKE DOUGHNUT

Moisture	Crude Fat[2]	Ash[2]	Crude Fiber[2]	Crude Protein[2]	Carbody-drate[2]
66.11±0.25	1.11±0.12	3.35±0.01	2.44±0.04	4.51±0.05	88.59

[1]Mean of 6 observations with ± one standard deviation of means for measured components.

[2]Mean of 6 observations on dry matter basis.

66.11% moisture; on the dry weight basis, the flesh had a mean 1.11% crude fat, 3.35% ash, 2.44% crude fiber, 4.51% crude protein, and 88.59% carbohydrates. These values are in close agreement with published values (77) except for moisture content which is slightly lower than published values.

Table VI presents the moisture content of sweet potatoes as prepared into flour, baked, and steam cooked forms. The results were used as the basis for calculation of total solids to determine amounts of sweet potato to substitute for 7, 14, and 21% flour.

III. PROXIMATE COMPOSITION OF COOKED CAKE DOUGHNUT WITH DIFFERENT TYPES OF SWEET POTATO

Table VII presents the F-ratios for the analysis of variance for proximate analysis of cooked cake doughnuts prepared with sweet potato. Type, level, and interactions between type and level were significant for moisture, crude fat, crude protein and carbohydrate values (0.01 level). However, level of sweet potato affected ash value at 0.01 level; type and interaction of type X level affected ash content at the 0.05 level.

Type and level of sweet potato added to the doughnuts affected the water retaining capacity (Table VII). A greater amount of moisture was retained in doughnuts with steam cooked sweet potato; the least amount of moisture was retained in doughnuts with baked sweet potato. The difference in moisture content in doughnuts with increased levels of sweet potato depended upon the type of sweet potato used. Generally, as the amount of sweet potato flour was increased, there was no change

TABLE VI

MOISTURE CONTENT[1] (%) IN EACH TYPE OF SWEET POTATO USED IN PREPARING CAKE DOUGHNUT

Type of Sweet Potato		
Flour	Baked	Steam Cooked
5.91 ± 0.01	62.55 ± 0.22	73.85 ± 0.14

[1]Mean of 6 observations with ± one standard deviation.

TABLE VII

F-RATIOS FOR THE ANALYSIS OF VARIANCE FOR PROXIMATE ANALYSIS OF COOKED CAKE DOUGHNUTS PREPARED WITH SWEET POTATO

Source	D.F.	Moisture	Crude Fat	Ash	Crude Protein	Carbohydrates
Total	71	--	--	--	--	--
A. Type	2	313.93**	328.52**	4.42*	8.81**	111.28**
B. Level	3	11.06**	137.07**	17.82**	66.63**	4.64**
A X B	6	76.05**	83.90**	3.06*	3.96**	15.60**
Residual error (Mean square)	60	0.09	0.14	0.02	0.30	0.65

*Significant at 0.05 level.

**Significant at 0.01 level.

in moisture content. When increasing amounts of baked sweet potato were used, the percentage of moisture lost during deep-frying was increased. Contrariwise, as the level of steam cooked sweet potato was increased, the moisture retention was increased.

Doughnuts with steam cooked sweet potato had a greater amount of fat than doughnuts with the other two types of sweet potato, between which there was no difference (Table VIII). As the level of sweet potato flour and steam cooked sweet potato was increased, the level of fat increased. However, the increase of fat for doughnuts with steam cooked sweet potato was greater. Level of baked sweet potato had no effect on fat content of the doughnuts. Practically, all of the fat was absorbed from the deep-fryer.

Sweet potato had 7 times more ash than the wheat flour used to prepare the doughnuts (78). Therefore, addition of sweet potato increased the ash content of the doughnuts. The increase in ash content was significant, however, only to doughnuts with steam cooked sweet potato.

Wheat flour has 12% crude protein content (69). Replacing wheat flour with sweet potato decreased the protein content of the doughnuts. For all types, there was an inverse relationship between percentage of crude protein and level of sweet potato in the doughnuts. Overall, doughnuts with steam cooked sweet potato had a higher crude protein content than doughnuts with the two other types, between which there was no difference (Table VIII).

Carbohydrate content was decreased as the level of sweet potato was increased in doughnuts with steam cooked sweet potato. Doughnuts exhibited an increase in carbohydrate content as the level of baked sweet

TABLE VIII

MEAN VALUES FOR PROXIMATE ANALYSIS OF COOKED CAKE DOUGHNUTS PREPARED WITH SWEET POTATO

Level %	Type of sweet potato: Flour[1]	Baked[1]	Steam Cooked[1]
		Moisture	
0	23.40[fg]	23.63[ef]	23.85[ef]
7	24.43[cd]	23.04[g]	24.70[bc]
14	23.98[de]	23.03[g]	25.12[b]
21	22.93[gh]	22.50[h]	27.07[a]
Mean[2]	23.69[j]	23.05[k]	25.19[i]
		Crude fat	
0	23.61[g]	24.17[efg]	24.41[def]
7	23.71[g]	24.60[de]	24.79[d]
14	23.30[gh]	23.04[h]	27.60[b]
21	26.16[c]	23.91[fg]	29.14[a]
Mean[2]	24.19[j]	23.93[j]	26.49[i]
		Ash	
0	2.87[c-f]	2.81[def]	2.78[ef]
7	2.95[cde]	2.72[f]	2.87[c-f]
14	3.19[ab]	3.03[bc]	3.04[bc]
21	3.01[c]	2.98[cd]	3.28[a]
Mean[2]	3.00[i]	2.89[j]	2.99[i]
		Crude protein	
0	15.32[ab]	15.44[ab]	15.80[a]
7	14.83[bc]	13.95[d]	15.51[ab]
14	13.83[d]	14.12[cd]	13.74[d]
21	12.73[e]	12.84[e]	13.75[d]
Mean[2]	14.18[j]	14.09[j]	14.70[i]

TABLE VIII (Continued)

Level %	Type of sweet potato Flour[1]	Baked[1]	Steam Cooked[1]
		Carbohydrate	
0	58.51[bc]	57.61[cd]	50.05[g]
7	58.51[bc]	58.72[bc]	56.83[d]
14	59.69[ab]	59.81[ab]	55.62[e]
21	58.09[cd]	60.28[a]	54.00[f]
Mean[2]	58.62[i]	59.10[i]	55.87[j]

[1]Interaction means were derived from 6 observations.

[2]Level means were derived from 24 observations.

[a-h]Type X Level interaction means within moisture, crude fat, crude protein, and carbohydrate followed by the same letter are not different at 0.01 level; for ash, at 0.05 level.

[ijk]Means for type within moisture, crude fat, crude protein, and carbohydrate followed by the same letter are not different at 0.01 level; for ash, at 0.05 level.

potato was increased. Overall, doughnuts with steam cooked sweet potato had a lower carbohydrate content than doughnuts with the two other types.

IV. CALORIC CONTENT OF COOKED CAKE DOUGHNUTS

Table IX presents the mean gross energy values (caloric content) of cake doughnuts prepared with the different types of sweet potato.

Addition of sweet potato affected the resultant caloric content of the cooked doughnuts. Sweet potato flour at 21% caused a 0.36 kcal decrease in caloric content of the doughnuts; baked sweet potato at 21%, a 0.40 kcal decrease; and steam cooked sweet potato at 21%, a 0.42 kcal increase.

The relatively high caloric content of the samples is due to the crude fat content of approximately 23 to 29%. Definite relationships are apparent between the levels of baked and steam cooked sweet potato added to the doughnuts and the caloric content of doughnuts. Doughnuts with baked sweet potato exhibited a slight decrease in crude fat content (Table VII) and caloric content as the amount of sweet potato was increased to 21%. Increased levels of steam cooked sweet potato in the doughnuts caused an increase in the caloric content which resulted from the increased crude fat content in these samples absorbed during the frying operation.

From the commercial standpoint, the processor may not want to add steam cooked sweet potato in preparation of cake doughnut due to the higher absorption of fat. Cake doughnuts with steam cooked sweet potato might be objectionable to the consumer because of the oily nature and higher caloric content. Thus, sweet potato flour and baked sweet potato might be a more desirable choice from the standpoint of a lower

TABLE IX

MEAN[1] CALORIC CONTENT[2] OF COOKED DOUGHNUTS PREPARED WITH SWEET POTATO

Level of sweet potato, %	Type of sweet potato		
	Flour	Baked	Steam Cooked
		Kcal/g	
0	6.86±0.17	6.72±0.12	6.61±0.04
7	6.66±0.03	6.67±0.18	6.68±0.17
14	6.50±0.13	6.35±0.27	6.78±0.44
21	6.50±0.05	6.32±0.60	7.03±0.10
Mean of type	6.63	6.52	6.78

[1]Mean of 6 observations with ± one standard deviation.

[2]Kcalories per gram on the dry matter basis.

fat absorption by the doughnut. On the other hand, the higher cost of producing sweet potato flour might discourage its use. Thus, doughnuts with baked sweet potato might be considered most acceptable to the processor and to the consumer since the doughnuts absorb less oil, are less oily in appearance, are lower in caloric content than doughnuts with steam cooked sweet potato, and should be less costly to formulate than doughnuts with the apparently more costly sweet potato flour.

There are numerous other factors to consider regarding the type of sweet potato to use. These include: ease in which flour can be shipped and stored, and increased difficulty and cost of handling high-moisture sweet potato material.

V. TEXTURE OF COOKED CAKE DOUGHNUTS

F-ratios for the analysis of variance for the effect of the three types of sweet potatoes on hardness of cooked cake doughnuts are presented in Table X. The type of sweet potato and the type X level of sweet potato had significant effects (0.01 level) on hardness of the cooked cake doughnuts.

Doughnuts prepared with steam cooked sweet potato were less hard (softer) (0.01 level) than doughnuts prepared with sweet potato flour or baked sweet potatoes, among which no difference existed (Table XI). Use of sweet potato flour and baked sweet potato did not cause a significant change in hardness from that of the control doughnuts, but there was no difference in hardness of doughnuts with 7, 14, and 21% steam cooked sweet potatoes from that of control doughnuts.

The higher level of fat absorption in doughnuts with steam cooked sweet potato during frying probably had a definite influence toward making the doughnuts softer than doughnuts with the other types of sweet potato.

TABLE X

F-RATIOS FOR THE ANALYSIS OF VARIANCE FOR THE EFFECT OF SWEET POTATO ON HARDNESS OF CAKE DOUGHNUTS

Source	D.F.	F-ratio
Total	71	---
A. Type	2	39.16**
B. Level	3	2.33$^{n.s.}$
A X B	6	5.90**
Replicate	1	0.01$^{n.s.}$
Residual error (Mean square)	59	0.09

**Significant at 0.01 level.

$^{n.s.}$Not significant at 0.05 level.

TABLE XI

MEAN HARDNESS VALUE OF CAKE DOUGHNUTS
PREPARED WITH SWEET POTATO

Level of Sweet Potato, %	Types of Sweet Potato Flour[1]	Baked[1]	Steam Cooked[1]
		Kilogram force	
0	1.21[a]	1.21[a]	1.21[a]
7	1.20[a]	1.10[a]	0.56[b]
14	1.53[a]	1.47[a]	0.46[b]
21	1.28[a]	1.60[a]	0.36[b]
Mean[2]	1.30[c]	1.35[c]	0.65[d]

[1]Interaction means were derived from 6 observations.

[2]Level means were derived from 24 observations.

[ab]Type X level interaction means followed by the same letter are not different at 0.01 level.

[cd]Means for type followed by the same letter are not different at 0.01 level.

VI. VOLUME OF COOKED CAKE DOUGHNUTS

The F-ratio for the analysis of variance for the effect of sweet potato on the volume of cake doughnuts are presented in Table XII. Types of sweet potatoes affected the volume (0.01 level). Overall level of sweet potato had no significant effect on volume of the doughnuts, but the interaction between type and level of sweet potato affected volume (0.05 level). Replication affected the volume of doughnuts (0.05 level).

The mean volume for all doughnuts prepared with steam cooked sweet potato was higher (0.01 level) than the mean volume values for all doughnuts prepared with sweet potato flour or baked sweet potato, among which there was no difference (Table XIII). Steam cooked sweet potato was the only type which caused an increase in volume at the different levels. Doughnuts containing all three levels of steam cooked sweet potato had a higher volume than doughnuts with 0% sweet potato.

Previous findings by Gore (26) show that mixtures of sweet potato flour and hard wheat flour in bread produced an average volume of 2425 cc. But when the bread was prepared without sweet potato, the volume obtained was 2250 cc. In doughnuts, sweet potato flour did not produce an increase in volume. Failure to produce an increase in volume might be due to several factors. Gore had used hard wheat flour and in this study, all-purpose flour was used. The type of product in which the sweet potato flour was utilized might influence the volume of the respective products.

In spite of the fact that doughnuts with steam cooked sweet potatoes had excellent volume; this product might be objectionable to consumers. This is because the doughnuts were more oily and had a

TABLE XII

F-RATIOS FOR THE ANALYSIS OF VARIANCE FOR THE EFFECT OF SWEET POTATO ON VOLUME OF CAKE DOUGHNUTS

Source	D.F.	F-ratio
Total	23	---
A. Type	2	19.61**
B. Level	3	1.39$^{n.s.}$
A X B	6	4.06*
Replicate	1	5.87*
Residual Error (Mean Square)	11	0.03

*Significant at 0.05

**Significant at 0.01 level.

$^{n.s.}$Not significant at 0.05 level.

TABLE XIII

MEAN VOLUME (CC/G) OF CAKE DOUGHNUTS PREPARED WITH SWEET POTATO

Level of sweet potato, %	Types of Sweet Potato		
	Flour[1]	Baked[1]	Steam cooked[1]
0	3.20[cd]	3.20[cd]	3.20[cd]
7	3.30[c]	3.00[cd]	3.70[ab]
14	3.10[cd]	3.30[bc]	3.70[a]
21	2.80[d]	3.30[c]	3.90[a]
Mean[2]	3.10[f]	3.20[f]	3.60[e]

[1]Interactions means were derived from 2 observations.

[2]Level means were derived from 8 observations.

[a-d]Type X level interaction means followed by the same letter are not different at 0.05 level.

[e-f]Means for type followed by the same letter are not different at 0.01 level.

higher caloric content than doughnuts prepared with the other types of sweet potato. From a practical standpoint, one might use a mixture of steam cooked and baked sweet potatoes to take advantage of the excellent volume produced by steam cooked sweet potato and the lower caloric content (Table IX, p. 39) resulting from the use of baked sweet potatoes.

VII. COLOR MEASUREMENT OF COOKED CAKE DOUGHNUTS

A. The External Crust

The F-ratios for the analysis of variance for the effect of type and level of sweet potato on Hunter L, "a," and "b" color values of the external crust of cake doughnuts are presented in Table XIV. The Hunter L value was affected (0.01 level) by level of sweet potatoes in the doughnuts, but not by the type of sweet potato or by interaction between level and type. All factors had an effect (0.05 level) on Hunter "a" values. Yellowness (Hunter "b") of the crust was affected (0.05 level) only by level of sweet potato.

The mean L value for all samples of doughnuts was 37.03 (Table XV). The L values ranged from 35.00 to 39.47.

Baked sweet potato had a redder crust than the other two types of sweet potato (Table XV). Increasing the level of sweet potato flour or steam cooked potato to 14% tended to produce doughnuts with crusts which became more red as the level of sweet potato was raised. The mean Hunter "a" value was 9.16 for all samples.

The Hunter "b" value (yellowness) for crust was not affected by type or by the type X level interaction; however, level of sweet potato affected yellowness at the 0.05 level (Table XIV). The mean Hunter "b" value for all samples of doughnuts was 20.73.

TABLE XIV

F-RATIOS FOR THE ANALYSIS OF VARIANCE FOR THE EFFECT OF SWEET POTATO ON HUNTER L, "a," AND "b" COLOR VALUES FOR CRUST OF CAKE DOUGHNUTS PREPARED WITH SWEET POTATO

Source	D.F.	L	"a"	"b"
Total	71	---	---	---
A. Type	2	$2.63^{n.s.}$	4.19*	$0.33^{n.s.}$
B. Level	3	4.61**	3.88*	4.07*
A X B	6	$0.42^{n.s.}$	2.86*	$1.79^{n.s.}$
Replicate	1	$0.45^{n.s.}$	6.07*	$0.37^{n.s.}$
Residual Error (Mean Square)	59	5.76	5.72	2.84

*Significant at 0.05 level.

**Significant at 0.01 level.

$^{n.s.}$Not significant at 0.05 level.

TABLE XV

MEAN[1] HUNTER L, "a," AND "b" COLOR VALUES FOR EXTERNAL CRUST OF CAKE DOUGHNUTS PREPARED WITH SWEET POTATO

Level %	Type of Sweet Potato		
	Flour[1]	Baked[1]	Steam Cooked[1]
		Hunter L	
0	38.70[a]	37.90[a]	36.12[a]
7	38.20[a]	39.47[a]	37.22[a]
14	35.10[a]	36.27[a]	35.00[a]
21	36.77[a]	37.28[a]	36.33[a]
Mean[2]	37.19[b]	37.73[b]	36.17[b]
		Hunter "a"	
0	6.46[g]	10.55[cde]	7.33[fg]
7	7.16[fg]	10.52[cde]	7.55[efg]
14	10.51[cde]	9.13[c-g]	11.93[c]
21	9.68[c-f]	11.00[cd]	8.03[d-g]
Mean[2]	8.45[i]	10.30[h]	8.71[i]
		Hunter "b"	
0	21.25[j]	19.97[j]	19.03[j]
7	21.68[j]	21.93[j]	21.48[j]
14	19.95[j]	20.78[j]	19.43[j]
21	20.17[j]	20.93[j]	22.10[j]
Mean[2]	20.51[k]	20.90[k]	20.51[k]

[1]Interaction means were derived from 6 observations.

[2]Level means were derived from 24 observations.

[a,j]Type X level interaction means within L and "b" notations followed by the same letter are not different at 0.05 level.

[c-g]Type X level interaction means for "a" notation followed by the same letter are not different at 0.05 level.

[b,k]Means for type within L and "b" notations followed by the same letter are not different at 0.05 level.

[h,i]Means for type followed by the same letter are not different at 0.05 level.

Apparently, the heat of the hot oil in which the doughnuts were cooked, not the ingredient, was the primary factor contributing the color of the crust.

B. The Crumb

The F-ratios for the analysis of variance for the effect of type and level of sweet potato on Hunter L, "a," and "b" color values of the crumb of cake doughnuts are presented in Table XVI. Hunter L, "a," and "b" values were affected (0.01 level) by types and level of sweet potato (0.05 level). Hunter L and "a" values were affected at the 0.01 level by interaction between type and level of sweet potato.

Mean Hunter L, "a," and "b" values are shown in Table XVII. Addition of baked or steam cooked sweet potato to the doughnuts decreased the L value as the percentage of sweet potato was increased. The L value was not affected by increasing the amount of sweet potato flour. The mean L value was 69.94 for the doughnuts without sweet potato (control). At the 21% level, the mean L value for doughnuts with sweet potato flour, baked, and steam cooked sweet potato was 68.62, 64.07, and 62.90, respectively.

Differences among the mean L values were found for doughnuts containing the three types of sweet potato. Doughnuts with steam cooked sweet potato had the lowest L value, indicating a darker product. Samples with sweet potato flour had the higher "L" value and were the lightest in color.

Addition of the sweet potato to the doughnuts caused a shifting of the color from greenness to redness ("a" values). The greatest change occurred for doughnuts with baked sweet potato.The increased degree of redness was significant at the 0.01 level. The small change in "a"

TABLE XVI

F-RATIOS FOR THE ANALYSIS OF VARIANCE FOR THE EFFECT OF SWEET POTATO ON HUNTER L, "a," AND "b" COLOR VALUES FOR THE CRUMB OF CAKE DOUGHNUTS

Source	D.F.	L	"a"	"b"
Total	71	---	---	---
A. Type	2	26.06**	49.94**	6.89**
B. Level	3	39.69**	107.22**	474.51**
A X B	6	8.69**	15.63**	0.93$^{n.s.}$
Replicate	1	7.01*	2.15$^{n.s.}$	0.17$^{n.s.}$
Residual Error (Mean Square)	59	2.04	0.69	0.62

*Significant at 0.05 level.

**Significant at 0.01 level.

$^{n.s.}$Not significant at 0.05 level.

TABLE XVII

MEAN HUNTER L, "a," AND "b" COLOR VALUES FOR CRUMB OF CAKE DOUGHNUTS PREPARED WITH SWEET POTATO

Level %	Type of Sweet Potato: Flour[1]	Baked[1]	Steam Cooked[1]
		Hunter L	
0	70.23[a]	69.88[a]	69.78[a]
7	68.38[ab]	70.75[a]	66.83[bc]
14	69.00[ab]	65.98[cd]	64.82[cde]
21	68.62[ab]	64.07[de]	62.90[e]
Mean[2]	69.06[f]	67.67[g]	66.08[h]
		Hunter "a"	
0	-3.78[lm]	-3.93[m]	-3.33[lm]
7	-2.80[klm]	-3.21[lm]	-1.50[k]
14	-2.08[k]	1.28[ij]	1.06[j]
21	-2.41[kl]	2.45[i]	1.45[ij]
Mean[2]	-2.77[o]	-0.85[n]	-0.58[n]
		Hunter "b"	
0	21.20[p]	21.08[p]	21.12[p]
7	26.90[p]	26.40[p]	27.47[p]
14	26.68[p]	28.85[p]	30.23[p]
21	29.67[p]	29.51[p]	30.41[p]
Mean[2]	26.86[qr]	26.46[r]	27.31[q]

[1]Interaction means were derived from 6 observations.

[2]Level means were derived from 24 observations.

[a-e, i-m]Type X level interaction means for L and "a" notations followed by the same letter are not different at 0.01 level.

[p]Type X level interaction means for "b" notation followed by the same letter are not different at 0.05 level.

[f-h,no,qr]Means for type within L, "a," and "b" notations followed by the same letter are not different at 0.01 level.

values for doughnuts with sweet potato flour was significant. The shift from a green coloration ("-a") to red coloration ("a") was significant as the level of steam cooked sweet potato was increased. Overall means for type of sweet potato indicated that the crumb of doughnuts containing sweet potato flour was more green than the other types of sweet potato, between which there was no difference.

Increasing the level of sweet potato for each type did not change the "b" (yellowness) values significantly. However, there was a trend for increased yellowness as the level of sweet potato of all types was raised. Overall effects for level of sweet potato showed that increasing the level of all types of sweet potato caused the doughnut to become more yellow. Overall, doughnuts with steam cooked sweet potato were more yellow (0.01 level) than doughnuts with baked sweet potato. Yellowness of doughnuts with sweet potato flour was not different from that of doughnuts containing the other two types of sweet potato.

The apparently greater yellowness in the crumb of the doughnuts with sweet potato flour was due to the presence of carotenoid pigments in the sweet potato tissue.

The additional yellow color in doughnuts containing sweet potato could be detected by visual observation. The more intense yellow color should not distract from the appearance qualities. Actually, the color was considered very pleasing by all the panel members who evaluated the samples.

VIII. SENSORY EVALUATION

A. <u>Results of Preliminary Study</u>

Data from the preliminary evaluation of doughnuts by the sensory panel were analyzed by factor analysis. Factor analysis was the tool used to determine which variables of the 19 studied tended to "map" together in a plot of one factor versus another factor. Variables which mapped together were considered to be redundant variables.

The results obtained showed that the aroma attributes of bready, oily, spicy, and sweet potato tended to map with the flavor by mouth attributes of bready, oily, spicy, and sweet potato. Consequently, the flavor by mouth attributes of the four factors were selected instead of those for aroma since aroma is a component of flavor as is taste. The factors of sweet and salty were selected instead of those of bitter and sour because the mean scores indicated that the scores for sweet and salty were higher in value along the evaluation scale than the scores for bitter and sour. Actually, the samples received very low scores for these two latter factors. The remaining 13 attributes were used for the final sensory evaluation of cake doughnuts.

B. Results of Sensory Evaluation of Cake Doughnuts Prepared with Sweet Potato

F-ratios for the analysis of variance for the effect of sweet potato on certain flavor attributes of cake doughnuts are presented in Table XVIII. Type of sweet potato affected the sweet, bready, oily, spicy, and sweet potato flavor in doughnuts. Salty taste was not affected by type of sweet potato. Overall, the level of sweet potato affected the sweet, bready, spicy and sweet potato flavor of the doughnut at the 0.01 level. Significant effects for interaction between type and level of sweet potato were found for the sweet, bready, oily, spicy, and sweet potato flavor in doughnuts. A significant effect (0.05 level) for replication occurred only for the spicy attribute. A significant difference (0.01 level) among the scores of the panelists was found for

TABLE XVIII

F-RATIOS FOR THE ANALYSIS OF VARIANCE FOR THE EFFECT OF SWEET POTATO ON CERTAIN FLAVOR ATTRIBUTES OF CAKE DOUGHNUTS AS DETERMINED BY SENSORY PANEL

Source	D.F.	Sweet	Salty	Bready	Oily	Spicy	Sweet Potato
Total	239	---	---	---	---	---	---
A. Type	2	30.78**	2.26$^{n.s.}$	6.28**	8.19**	8.34**	4.28*
B. Level	3	26.05**	1.77$^{n.s.}$	8.59**	0.78$^{n.s.}$	3.91**	140.75**
A X B	6	10.56**	1.67$^{n.s.}$	2.23*	3.96**	3.18**	3.65**
Replicate	1	0.05$^{n.s.}$	0.03$^{n.s.}$	0.05$^{n.s.}$	0.00$^{n.s.}$	4.02*	0.00$^{n.s.}$
Panelists	9	4.28**	9.57**	6.29**	6.98**	5.95**	3.24**
Residual Error (Mean Square)	218	0.40	0.19	3.76	3.54	1.20	0.84

*Significant at the 0.05 level.

**Significant at the 0.01 level.

$^{n.s.}$Not significant at the 0.05 level.

all attributes tested. The significant difference for the panelists indicated that the panelists differed among themselves as to the score to be assigned for a particular attribute of a sample.

Table XIX presents the means for panel scores of cake doughnuts for flavor attributes. The doughnuts became increasingly more sweet when sweet potato flour and baked sweet potato were added in increasing amounts. A positive relationship between oiliness and level of steam cooked sweet potato was found. Likewise, the amount of oil absorbed by the doughnuts during cooking increased as the level of steam cooked sweet potato was increased (Table VII, p. 34). With all three types of sweet potato, the sweet potato flavor increased as the level of sweet potato was increased. The bready taste decreased when sweet potato flour and baked sweet potato were added in increasing amounts.

The interaction between type and level of sweet potato for spiciness was significant (0.01 level), however, within each type of sweet potato, with two exception, there was no significant difference in spicy flavor of doughnuts having 0 to 21% sweet potato. When sweet potato flour and baked sweet potato were added at the 14% level, spicy flavor tended to be more pronounced.

Doughnuts with baked sweet potato had the highest value for sweetness, with steam cooked sweet potato having the lowest value. The higher sweetening effect of baked sweet potato is due to a greater conversion of starch to sugar (primarily maltose) during the baking process. The highest scores for bready and spicy flavor were determined for doughnuts with sweet potato flour and the lowest scores for bready and spicy flavor were determined for doughnuts with steam cooked sweet potato. Doughnuts with steam cooked sweet potato had a more oily taste

TABLE XIX

MEAN SCORES FOR CERTAIN TASTE ATTRIBUTES OF CAKE DOUGHNUTS PREPARED WITH SWEET POTATO AS DETERMINED BY SENSORY PANEL[1]

Level of Sweet Potato %	Sweet[2]	Salty[2]	Bready[2]	Oily[2]	Spicy[2]	Sweet Potato[2]
			Flour			
0	1.91[g]	1.97[a]	9.81[a]	7.30[ab]	2.38[bc]	0.09[f]
7	2.53[c-f]	2.18[a]	9.17[abc]	6.69[b]	3.04[abc]	1.85[e]
14	2.75[bcd]	1.86[a]	8.58[a-d]	6.48[b]	3.85[a]	3.64[a]
21	3.01[bc]	2.03[a]	8.33[bcd]	6.11[b]	2.69[bc]	3.53[ab]
Mean[3]	2.55[i]	2.01[h]	8.97[h]	6.64[i]	2.99[h]	2.28[h]
			Baked			
0	1.99[fg]	2.07[a]	9.72[a]	7.52[ab]	2.59[bc]	0.55[f]
7	2.63[cde]	1.84[a]	9.37[ab]	6.52[b]	2.71[bc]	1.80[e]
14	3.26[b]	1.82[a]	8.24[bcd]	6.08[b]	3.14[ab]	3.20[abc]
21	3.96[a]	1.76[a]	6.82[e]	6.78[b]	2.09[c]	3.93[a]
Mean[3]	2.96[h]	1.87[h]	8.54[hi]	6.72[i]	2.63[hi]	2.37[h]
			Steam Cooked			
0	2.26[d-g]	1.99[a]	7.89[cde]	6.67[b]	2.42[bc]	0.46[f]
7	2.17[efg]	1.88[a]	8.58[a-d]	7.16[ab]	2.31[bc]	1.94[de]
14	2.17[efg]	1.98[a]	7.23[de]	8.58[a]	2.04[c]	2.68[cd]
21	2.12[efg]	1.75[a]	7.87[cde]	8.50[a]	2.37[bc]	2.78[bc]
Mean[3]	2.18[j]	1.90[h]	7.89[i]	7.72[h]	2.28[i]	1.96[i]

[1]Scale used is presented in Appendix B.

[2]Interaction means were derived from 20 observations.

[3]Level means were derived from 80 observations.

[a-g]Means for sweet, salty, oily, spicy and sweet potato resulting from type X level interaction followed by the same letter are not different at 0.01 level; means for bready, at 0.05 level.

[h,i,j]Means for level within sweet, salty, bready, oily and spicy followed by the same letter are not different at 0.01 level; for sweet potato, at 0.01 level.

than doughnuts with the other types of sweet potato. The sweet potato flavor of steam cooked sweet potato was less prounounced in doughnuts than was the flavor in sweet potato flour and baked sweet potato. The lower scores for flavor from steam cooked sweet potato is probably due to loss of flavor during the longer time of cooking the raw sweet potato. The intensity of sweet potato flavor was relatively low, for all samples.

Table XX presents the F-ratios for the analysis of variance for the effect of sweet potato on textural attributes-elasticity, tenderness, adhesiveness, and gumminess of cake doughnuts. The type and level of sweet potato effected each textural attribute at the 0.01 level except for effect of level on gumminess which was affected at the 0.05 level. The interaction between type and level of sweet potato was significant for elasticity and tenderness at the 0.01 level; and for adhesiveness, the 0.05 level. The effect of differences among panelists scores was significant (0.01 level).

Table XXI presents the mean panel scores for textural attributes of doughnuts with sweet potatoes. Elasticity decreased significantly only when the level of baked sweet potato was increased. The lower elasticity occurred in doughnuts at the 21% level. Tenderness was reduced significantly in doughnuts in which increased amounts of steam cooked sweet potato were added. Adhesiveness increased generally as the level of sweet potato flour and baked sweet potato were increased.

Steam cooked sweet potato produced doughnuts with the highest scores for elasticity and lowest scores for tenderness, adhesiveness, and gumminess. Sweet potato flour and baked sweet potato caused doughnuts to exhibit the highest degree of adhesiveness and gumminess and the lowest degree of elasticity. All these differences were not significantly different. The degradative products of starch in the baked sweet potato

TABLE XX

F-RATIOS FOR THE ANALYSIS OF VARIANCE FOR THE EFFECT OF SWEET POTATO ON CERTAIN TEXTURAL ATTRIBUTES OF CAKE DOUGHNUTS AS DETERMINED BY SENSORY PANEL

Source	D.F.	Elasticity	Tenderness	Adhesiveness	Gummi-ness
Total	239	---	---	---	---
A. Type	2	9.55**	12.26**	6.85**	7.73**
B. Level	3	5.66**	13.40**	4.42**	3.56*
A X B	6	4.49**	3.59**	2.50*	1.33$^{n.s.}$
Replicate	1	0.07$^{n.s.}$	0.38$^{n.s.}$	2.20$^{n.s.}$	2.69$^{n.s.}$
Panelist	9	3.32**	5.39**	17.79**	12.15**
Residual error (Mean square)	218	5.47	3.86	2.95	3.40

*Significant at the 0.05 level.

**Significant at the 0.01 level.

$^{n.s.}$Not significant at the 0.05 level.

TABLE XXI

MEAN SCORES FOR CERTAIN TEXTURAL ATTRIBUTES OF CAKE DOUGHNUTS PREPARED WITH SWEET POTATO AS DETERMINED BY SENSORY PANEL[1]

Level of Sweet Potato %	Elasticity[2]	Tenderness[2]	Adhesiveness[2]	Gumminess[2]
		Flour		
0	9.13[a]	5.66[ab]	4.06[c]	5.09[a]
7	9.62[a]	5.62[ab]	4.37[c]	5.37[a]
14	9.17[a]	5.57[ab]	5.75[ab]	6.36[a]
21	8.67[a]	4.99[ab]	5.77[ab]	5.76[a]
Mean[3]	9.14[de]	5.46[d]	4.99[d]	5.65[de]
		Baked		
0	9.41[a]	6.06[ab]	4.80[bc]	5.79[a]
7	9.69[a]	4.43[ab]	5.06[abc]	6.07[a]
14	8.31[a]	4.13[bc]	4.63[bc]	5.80[a]
21	5.42[b]	4.27[b]	6.13[a]	7.17[a]
Mean[3]	8.21[e]	4.72[de]	5.16[d]	6.21[d]
		Steam Cooked		
0	9.51[a]	6.14[a]	3.91[c]	4.42[a]
7	9.30[a]	4.52[ab]	4.70[bc]	5.40[a]
14	9.91[a]	2.55[c]	3.97[c]	4.77[a]
21	10.02[a]	2.50[c]	4.28[c]	5.67[a]
Mean[3]	9.81[d]	3.92[e]	4.21[e]	5.06[e]

[1]Scale used is presented in Appendix B.

[2]Interaction means were derived from 20 observations.

[3]Level means were derived from 80 observations.

[abc]Means for elasticity, tenderness, and gumminess resulting from type X level interaction followed by the same letter are not different at 0.01 level; mean for adhesiveness, at 0.05 level.

[de]Level means within all attributes followed by the same letter are not different at 0.01 level.

material, no doubt, were responsible for influencing these attributes. Doughnuts with sweet potato flour were the least tender (hardest); with steam cooked sweet potato the most tender (softest).

Table XXII presents the F-ratios for the analysis of variance for the effect of sweet potato on surface appearance, crust color, and crumb color of cake doughnuts. Type of sweet potato affected crust color (0.01 level) and crumb color (0.05 level), but not surface appearance. Level of sweet potato, and the interaction between type and level affected surface appearance and crumb color (0.01 level), but not crust color. Replication was significant (0.01 level) for surface appearance and crust color. The effect among panelists was significant (0.01 level) for crumb and crust color and (0.05 level) for surface appearance.

Table XXIII presents the mean scores for panel evaluation of surface appearance, and crust and crumb color of cake doughnuts prepared with sweet potato. The significant trend for effect of level of sweet potato on surface appearance occurred with doughnuts containing steam cooked sweet potato. Doughnuts at the 14% level had a less desirable surface appearance than doughnut at the other levels. Crumb color scores increased as the level of sweet potato from all types was increased. The increased values for crumb color are due to increasing levels of carotenoids being supplied with increased levels of sweet potato.

The panel indicated that doughnuts with baked sweet potato had a darker crust than doughnuts with steam cooked sweet potato. The crust color for doughnuts with sweet potato flour was not different from the color of doughnuts containing the other two types of sweet potato. This conclusion is in contrast with the Hunter L readings which showed no difference in crust darkness for doughnuts containing the three types

TABLE XXII

F-RATIOS FOR THE ANALYSIS OF VARIANCE FOR THE EFFECT OF SWEET POTATO ON SURFACE APPEARANCE, CRUST COLOR, AND CRUMB COLOR OF CAKE DOUGHNUTS AS DETERMINED BY SENSORY PANEL

Source	D.F.	Surface Appearance	Crust Color	Crumb Color
Total	239	---	---	---
A. Type	2	1.96$^{n.s.}$	5.35**	3.72**
B. Level	3	5.14**	1.15$^{n.s.}$	165.40**
A X B	6	2.99**	1.77$^{n.s.}$	4.85**
Replicate	1	7.69**	6.99**	0.30$^{n.s.}$
Panelists	9	18.78*	14.10**	10.44**
Residual Error (Mean square)	218	1.74	1.80	2.15

*Significant at the 0.05 level.

**Significant at the 0.01 level.

$^{n.s.}$Not significant at the 0.05 level.

TABLE XXIII

MEAN SCORES FOR SURFACE APPEARANCE, CRUST COLOR, AND CRUMB COLOR OF CAKE DOUGHNUTS PREPARED WITH SWEET POTATO AS DETERMINED BY SENSORY PANEL[1]

Level of Sweet Potato %	Surface Appearance[2]	Crust Color[2]	Crumb Color[2]
		Flour	
0	4.10^{abc}	4.54^{a}	1.20^{e}
7	3.30^{bc}	4.91^{a}	3.68^{d}
14	3.15^{c}	4.75^{a}	5.51^{c}
21	3.40^{bc}	4.96^{a}	6.19^{bc}
Mean[3]	3.73^{f}	4.79^{fg}	4.14^{g}
		Baked	
0	3.51^{bc}	4.88^{a}	1.34^{e}
7	3.56^{bc}	4.63^{a}	3.18^{d}
14	3.97^{abc}	5.57^{a}	5.14^{c}
21	4.42^{ab}	5.81^{a}	7.19^{ab}
Mean[3]	3.86^{f}	5.22^{f}	4.21^{g}
		Steam Cooked	
0	3.28^{bc}	4.44^{a}	1.48^{e}
7	3.91^{bc}	4.79^{a}	3.52^{d}
14	5.11^{a}	4.72^{a}	7.49^{a}
21	4.26^{abc}	4.20^{a}	6.41^{abc}
Mean[3]	4.14^{f}	4.54^{cg}	4.72^{f}

[1]Scale used is presented in Appendix B.

[2]Interaction means were derived from 20 observations.

[3]Level means were derived from 80 observations.

[a-e]Means for surface appearance and crumb color resulting from type X level interaction followed by the same letter are not different at 0.01 level.

[fgh]Means among types for crust color and crumb color followed by the same letter are not different at 0.01.

of sweet potato. Hunter "a" values (redness) were significantly higher for the crust of doughnuts with baked sweet potato, however. Obviously, the conflict between the sensory scores and Hunter readings is more apparent than real. The discrepancy between the two measurements is due to the probability that the panelists perceived darkness as the sensation which resulted from the combined effect of darkness and redness.

CHAPTER V

SUMMARY

This study was undertaken to develop a product (cake doughnut) utilizing sweet potato as an ingredient and to evaluate quality factors of the doughnuts including chemical composition, physical and sensory attributes, and caloric content.

Three types of sweet potato were prepared: sweet potato flour, and baked and steam cooked sweet potato. Four levels of each type were substituted at 0, 7, 14, and 21% for equal amounts of wheat flour of the doughnut recipe.

Consistency of the dough prepared with sweet potato was adjusted to that of the control dough (0% sweet potato). Reducing the amount of water permitted a change in consistency of the dough. Doughs of similar consistency of all treatments were used to prepare doughnuts for evaluation.

Proximate composition of raw, cured sweet potato flesh and cooked doughnuts was determined. Generally, the amount of crude fat in the doughnuts increased as the level of steam cooked sweet was increased. Crude protein decreased as the level of sweet potato was increased due to lower crude protein content in sweet potato than in wheat flour. Other changes were due to level of sweet potato.

Caloric content of doughnuts with sweet potato flour and baked sweet potato decreased with increasing levels of sweet potato; however, caloric content increased when the level of steam cooked sweet potato was raised. The mean caloric content for doughnuts of the control was 6.73 kcal/g, while the mean caloric content of doughnuts with 21% steam cooked sweet potato was 7.03 kcal/g.

Doughnuts with steam cooked sweet potato were softer than doughnuts with sweet potato flour or baked sweet potato, between which there was no difference.

The mean volume for doughnuts with steam cooked sweet potato was higher than that for doughnuts with sweet potato flour or baked sweet potato. As level of steam cooked sweet potato was raised to 21%, there was a trend of increased volume in doughnuts.

Type and level of sweet potato had no effect on Hunter L values (lightness) for the crust. The crumb became darker as the level of baked and steam cooked was increased. Steam cooked sweet potato produced the darkest doughnuts, while sweet potato flour produced the lightest doughnuts.

The presence of sweet potato had little or no effect on degree of redness of the crust, but the crumb became more red as the level of sweet potato was increased. Small differences in degree of redness were determined for crust and crumb among types of sweet potato.

Yellow coloration of crust was not affected by type or level of sweet potato. Yellowness of the crumb was affected by type and level of sweet potato. A trend exists for increasing yellowness with increased levels of sweet potato. Doughnuts with steam cooked sweet potato were more yellow than doughnuts with baked sweet potatoes since baking destroys some of the carotenoid pigments.

The doughnuts were evaluated by a sensory panel for 13 attributes: 6 for flavor, 4 for texture and 3 for appearance and color.

Type of sweet potato affected the sweet, bready, oily, spicy, and sweet potato flavor, while level of sweet potato affected all of the flavor attributes except salty and oily. As the level of sweet potato flour and baked sweet potato was raised, the doughnuts became sweeter. Increasing the level of sweet potato of the three types, produced a progressively greater sweet potato flavor in the doughnuts. All doughnuts with steam cooked potato were more oily than the control doughnuts. Use of baked sweet potato made the doughnuts sweeter; use of flour, more bready and spicy; use of steam cooked, more oily; and use of flour and baked, exhibit a greater sweet potato flavor.

All textural attributes were affected by type and level of sweet potato. Elasticity decreased with increasing levels of baked sweet potato; tenderness decreased with increasing levels of steam cooked sweet potato; and adhesiveness increased with increased levels of sweet potato flour and baked sweet potato. Doughnuts with steam cooked sweet potato were more elastic; with steam cooked sweet potato, most tender; with sweet potato flour and baked sweet potato, more sticky (greater adhesiveness); and with baked sweet potato, more gummy.

The type of sweet potato in the doughnuts affected crust and crumb color, and level of sweet potato affected surface appearance and crumb color. With increasing levels of all types of sweet potato, the yellowness of the crumb increased. Baked sweet potato produced doughnuts with darker crust and steam cooked potato produced doughnuts with more yellow crumb.

While doughnuts with sweet potato flour had many desirable attributes, the production cost may make the use of flour uneconomical. Baked or steam cooked sweet potato may be used to produce doughnuts of satisfactory quality. However, a blend of baked and steam cooked sweet potato may be used to take advantage of the higher sweet flavor of the baked and the higher volume development of the steam cooked sweet potato. Since doughnuts with baked sweet potato alone were relatively hard, use of steam cooked sweet potato would counteract this effect, producing a more desirably soft doughnut.

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APPENDICES

APPENDIX A

TABLE XXIV

REFERENCE STANDARDS USED BY THE SENSORY PANELS TO EVALUATE 19 ORGANOLEPTIC ATTRIBUTES OF COOKED CAKE DOUGHNUTS PREPARED WITH SWEET POTATO--PRELIMINARY TESTS

Factors Evaluated	Ends for scale to evaluate factors Left-weak sensation	 Right-extreme sensation
Aroma		
Bready	Uncooked canned biscuit dough.	Canned biscuits baked for 8 minutes at 246^{o} C.
Oily	White potatoes sliced to 0.3 cm. in thickness, fried 3 minutes in soybean oil and blotted with paper towels.	Preparation was similar for weak except they were fried 5 minutes and were not blotted with paper towels.
Spicy	0.024% mace in water.	0.05% mace in water.
Sweet Potato	Sweet potatoes sliced to 0.3 cm in thickness, fried for 4 minutes in soybean oil.	Preparation was similar for weak except they were fried for 8 minutes.
Flavor		
Sweet	2% sugar solution.	5% sugar solution.
Salty	0.05% salt solution.	0.20% salt solution.
Sour	0.048% citric acid in water.	0.20% citric acid in water.
Bitter	0.024% caffeine in water.	0.20% caffeine in water.
Bready	Similar for bready aroma.	Similar for bready aroma.
Oily	Similar for oily aroma.	Similar for oily aroma.
Spicy	Similar for spicy aroma.	Similar for spicy aroma.
Sweet Potato	Similar for sweet potato aroma.	Similar for sweet potato aroma.

TABLE XXIV (CONTINUED)

Factors Evaluated	Ends for scale to evaluate factors: Left-weak sensation	Right-extreme sensation
Texture	Smooth sensation	Rough sensation
Surface appearance	Prepared doughnuts fried 40 seconds at 191° C.	Overproofed doughnut was fried 1 minute at 191° C.
Tenderness	Stale commercially prepared unglazed cake doughnuts.	Commercially prepared unglazed cake doughnuts.
Elasticity	Raw canned biscuit dough rolled in wheat flour.	Household sponge.
Adhesiveness	Sugarless peppermint gum.	Taffy candy.
Gumminess	Overcooked canned biscuits baked at 246° C for 12-15 minutes.	Baked canned biscuits at 246° C for 6 minutes.
Color		
Crust	Brown (light) Light brown sugar.	Brown (dark) 1¼ oz cup of light brown sugar mixed with 1¼ tbsp. cocoa.
Crumb	Light-creamy yellow. A drop of yellow food color in 275 mls of water.	Yellow-orange. Mixture of 2 and 10 drops of red and yellow food color respectively in 275 mls of water.

APPENDIX B

SCALE USED BY SENSORY PANELS

Sample Code #   Name: Date:

Please evaluate each sample and answer each question in sequence, placing a vertical line across the horizontal line at the point that best describes that property in the sample. Take sufficient sample and time to evaluate each characteristic.

1. Flavor - Sniff and taste one of the two samples given and evaluate for:

a) Sweet

Weak ———————————————————— Strong

b) Salty

Weak ———————————————————— Strong

c) Bready

Weak ———————————————————— Strong

d) Oily

Weak ———————————————————— Strong

e) Spicy

Weak ———————————————————— Strong

f) Sweet potato

Weak ———————————————————— Strong

II. Texture - Compress cross-section partially between fingers, remove force, and evaluate for:

a) Elasticity - the degree and quickness of recovery to original shape

Slight ———————————————————— Extreme

Place cross-section between molar teeth, bite through, and evaluate for tenderness, then chew and evaluate for stickiness and gumminess.

b) Tenderness - force required to bite through sample

Soft — Hard

c) Adhesiveness - degree to which samples stick to teeth and to the roof of the mouth (after 5-6 chews)

Slight — Extreme

d) Gumminess - degree to which the mass holds together (after 5-7 chews)

Slight — Extreme

The following tests will be performed on outer area.

III. Surface Appearance

Smooth — Rough

Iv. Color

Crust

a)brown

light — dark

Crumb

b) yellowness

light creamy yellow — yellow-orange

Thank you for your participation.

VITA

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She is a member of the Food Technology Club of the University of Tennessee, Knoxville, the Institute of Food Technologists, Phi Tau Sigma (the national honor society of Food Science), and Gamma Sigma Delta (the international honor society of Agriculture).

She is married to Zainol Che Mamat.