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THE EFFECT OF STORAGE CONDITIONS ON SELECTED QUALITY ATTRIBUTES OF SWEET POTATO FLOUR

A Thesis

Presented for the

Master of Science

Degree

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Susan Ulm Gurkin

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DEDICATION

The author wishes to dedicate this work to those who have given her love, support and encouragement throughout her studies

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ABSTRACT

This study was undertaken to gain additional knowledge of the effect of storage conditions on selected quality attributes of sweet potato flour and of the effect of stored flour on the quality of a food system (muffin).

The percentage of oxygen present, number of weeks of storage, and increases in temperature had no effect on the proximate composition of the sweet potato flour. The apparent beta-carotene content decreased significantly at the higher oxygen content (2% vs. 0%) but increased significantly with increased storage time. The storage period-temperature and atmosphere-temperature interactions also affected the apparent beta-carotene content.

Storage variables had no effect on the Hunter L and "a" color measurements; however, the Hunter "b" measurement decreased due to storage period, temperature, and their interaction.

Headspace oxygen content was not changed throughout the experiment.

Storage treatment had a significant effect on the hardness, gumminess, crumbliness, and moistness of muffins made with sweet potato as compared to an ideal breakfast muffin concept.

Color, crumbliness, gumminess, moistness, appearance acceptability, texture acceptability, and overall acceptability were significantly affected by the storage treatment. Treatment also had significant effects on the Hunter L, "a", and "b" measurements and compression and cohesion measurements. Muffins made with sweet potato flour were rated higher in overall acceptabiltiy than muffins made with sweet potato puree.

Gender of the panelists, their preference for sweet potatoes, and the frequency at which they consumed breakfast muffins had significant effects on the scores given by the panel.

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CHAPTER I

INTRODUCTION

Sweet potatoes are an excellent source of many nutrients and are well adapted to climatic conditions of Tennessee. However, misconceptions and biases toward sweet potatoes have led to consumer avoidance. The serious decline in sweet potato consumption has resulted in the scientific community determining the need for new, high quality products made with sweet potatoes.

Acceptance can be increased by incorporating sweet potato into different products. A storage stable sweet potato flour could be a source of nutrients, natural sugar, color, and flavor in baked goods.

One of the major concerns with a sweet potato flour is the prevention of deteriorative changes during storage. Beta-carotene, a vitamin A precursor, is vulnerable to oxidation in dried products due to the high specific surface. Desirable color, flavor, and biological value are lost when beta-carotene is oxidized (Teixeira Neto et al., 1981).

Additional knowledge of storage variables is essential to establish storage characteristics of the flour so that the potential for sweet potato flour as a food ingredient

can be determined.

The objectives of this study were to determine 1) the effect of storage conditions on selected quality attributes of sweet potato flour and 2) the effect of stored flour on the quality of a food system (muffin).

CHAPTER II

REVIEW OF LITERATURE

I. The Sweet Potato

The sweet potato (Impomoea batatas, Lam.) is a vegetable of the morning glory family Convolvulaceae (Yen, 1982). This plant is cultivated primarily for its roots which are used to provide a tasty and nutritious food source for people throughout the world. It is in the emergent countries of the tropics and subtropics that the sweet potato makes its most valuable contribution as a crop. The reason for the great popularity of the sweet potato in these regions is readily apparent in light of the present food shortages - the sweet potato is behind only epos root and corn in caloric content and high yields are easily produced. Thus, the sweet potato represents an inexpensive, concentrated source of food energy that can be easily grown (Crosby, 1964).

The sweet potato is of American origin. Archaeological remains of the use of sweet potato have been found in Peru, including representations on pottery (Edmond and Ammerman, 1971; Yen, 1982). Researchers have reported the finding of sweet potato remains from a cave in Chilca Canyon, Peru, carbon-dated at between 8,000 and 10,000 B.C (Yen, 1982).

Taken from its American source, the sweet potato was introduced into Europe by Spanish explorers. From Europe, the sweet potato was disseminated in both the easterly and westerly directions (Yen, 1982). It is unclear whether trading parties traveling on land from Mexico or explorers traveling by sea from West Indian ports introduced the plant into North America. Records show, however, that the sweet potato was grown by the Virginia colonists as early as 1648 (Crosby, 1964; Edmond and Ammerman, 1971).

Sweet potatoes are classified as two general types: dry-fleshed cultivars with mealy, light yellow or white flesh and moist type cultivars with soft, gelatinous, bright orange flesh. The moist type is higher in sugar content and is the more popular type in the United States. Here, the term "yam" has become synonymous with the sweet moist type potato. However, true yams are a member of the family Dioscoreaceae and are not even closely related to the sweet potato (Crosby, 1964; Edmond and Ammerman, 1971).

The ease with which high yields of the sweet potato root are produced in warm, humid areas has led to its world-wide cultivation. Annual world-wide production of sweet potato in the early 1980's ranged between 133.9 and 135.9 million metric tons. Food and Agriculture Organization figures indicate that China produces almost 85% of the

world's sweet potato crop, followed by Indonesia which produces 2.2%. North American production is less than 1%. Thus, the relative importance of this crop can be shown by comparing China with the United States - China with only 20% more land area produces 200 times more sweet potatoes than the United States (Anon., 1983).

The optimum growing condition for the sweet potato plant is a warm tropical climate (Bouwkamp, 1984; Edmond and Ammerman, 1971). During the last several decades, however, the development of special cultivars that grow in colder climates no longer restricts the plant to warm regions. In North America, the sweet potato is grown commercially as far north as New Jersey and Long Island, New York, and in home gardens as far north as Canada. North Carolina, Louisiana, and California are currently the top three producing states (in descending order) while Tennessee ranks about tenth in production (Edmond and Ammerman, 1971; Anon., 1983).

II. Effects of Storage

Fresh sweet potato roots are cured to maintain good market quality during the winter. Cold storage conditions maintain roots in an edible condition for up to a year.

Cooley et al. (1954) determined the optimum temperature range for sweet potato storage to be 12.8 to 15.6 C. He further determined this range to be quite critical in

maintaining root quality. Storage temperatures of 10 C lowered the baking quality of the cultivars tested while temperatures of 18.3 C and above allowed excessive sprouting. Studies by Arthur et al. (1955) agreed with Cooley's findings that a storage temperature of 15.6 C was superior for maintaining raw sweet potatoes and the properties of derived dehydrated products. Chilling temperatures (4.4 to 12.8C) reduce or entirely stop the flow of latex from the cut surface, induce internal breakdown of the flesh, and impair even drying of the flesh (Edmond and Ammerman, 1971).

Sensory studies by Lambou (1956) concluded that storage of the raw sweet potato at 10 C had an undesirable effect on odor and flavor of dehydrated, reconstituted samples. Off flavors were reported for products made from raw sweet potatoes stored at 18.3 to 23.9 C. Of the variables, time and temperature, the latter exerted the greater effect.

Carbohydrates, the main constituents of the dry matter portion of baked sweet potatoes, influence a number of textural and organoleptic attributes (Reddy and Sistrunk, 1980; Walter et al., 1975). Picha (1986) determined that sugars increase with extended storage due to starch breakdown, possibly affecting textural and organoleptic qualities. Sensory evaluations were not conducted to support the relationship between increasing sugar content and

consumer preference.

Results obtained from studies on the effects of storage on the carotene content of sweet potatoes have varied widely. Some workers have determined decreasing carotene content as storage time is extended while others have shown an increase in carotene content with storage (Arthur et al., 1955; Ezell and Wilcox, 1948). Ezell and Wilcox (1948) cited several reasons for such discrepancies. The stem end of the sweet potato may contain two or three times as much carotene as the distal end of the root, and, depending on chemical extraction methods used, other pigments may be included in the carotene fraction. Their studies showed an absolute increase in the carotene content during curing and storing; however, the carotene behavior pattern varied widely among cultivars.

III. Nutritional Value of the Sweet Potato

The sweet potato is an excellent source of many dietary nutrients. The root provides many important vitamins and minerals to the diet and is, therefore, a significant source of food and minor chemical constituents (Crosby, 1964). The mean composition of raw sweet potato is reported to be 70-80% water, 1-2% protein, 1% fat, 22-28% carbohydrate, and 1% ash (Goodbody, 1984; Thompson, 1984).

Deep yellow to orange cultivars of sweet potato are an

excellent source of carotene or provitamin A. The standard cultivar, Porto Rico, which was grown in the United States during the 1950's and 1960's, contained the equivalent of 12,000 IU vitamin A for a 150 g serving (Watt and Merrill, 1963). According to Picha (1985a), the major cultivars grown in the United States today contain amounts similar to or considerably higher than those reported by Watt and Merrill.

The carbohydrate fraction of the sweet potato is comprised of approximately 80% starch and 20% simple sugars. Because 98% of these starches and sugars are easily digested, the fleshy roots are considered an excellent source of food energy (Edmond and Ammerman, 1971). Soluble carbohydrates present in the root include maltose, sucrose, glucose, and fructose. Due to metabolic activity, the sugar level increases and the starch level decreases with storage time (Picha, 1985b) .

The sweet potato also supplies a considerable amount of vitamin C (20 - 30 mg/100 g). This is about 1/3 to 1/2 of the recommended daily allowance (RDA) for males 23 - 50 years old. Vitamin B1 (thiamine) is present in adequate amounts when compared to the caloric content, 0.8 - 1.0 mg/4,184 kilojoules. This amount is about twice the level required by humans. Riboflavin, niacin, and pantothenic acid are provided in appreciable amounts. Potassium (200 -

300 mg / 100 g) is the predominant mineral present followed by iron, phosphorous, calcium, and magnesium respectively. (Collins and Walter, 1982; Crosby, 1964; Edmond and Ammerman, 1971; Huang, 1982; Picha, 1985a).

Sweet potato is not a major contributor of protein to the diet. The protein content on a fresh weight basis is only about 2% (Thompson, 1984). Recently, cultivars have been developed to contain greater than 9% protein on the fresh weight basis (Purcell et al., 1976). In comparison to the FAO pattern for protein, the sweet potato protein is of moderately good nutritional quality. Amino acid analyses showed the protein to be deficient in sulfur-containing amino acids and only marginal in lysine content (Collins and Walter, 1982; Purcell and Swaisgood, 1972). Studies by Yang (1982) showed sweet potato to be an excellent supplemental staple food to cereals such as rice and wheat flour. He reported further that substituting 30% of rice and wheat diets with sweet potato increased the biological value of dietary protein.

IV. Beta-carotene (Provitamin A)

Deep yellow to orange cultivars of sweet potato provide generous amounts of carotene or provitamin A to the diet. Beta-carotene is a carotenoid which produces a yellow color. The color is due to a chromophore that consists of a chain

of conjugated double bonds. The molecule is very susceptible to oxidation because of this arrangement of bonds.

Basically, beta-carotene consists of two vitamin A molecules joined together, hence, provitamin A. In the body, the molecule is cleaved to produce two molecules of vitamin A (Klaui and Bauernfiend, 1981; Emodi et al., 1980; Gordon and Bauernfeind, 1983; Metzner, 1978).

Carotenoids in foods are subject to rapid decomposition in the presence of oxygen with concurrent loss of vitamin A activity and color (Chou and Breene 1972; Goldman et al., 1983). The problem of preserving beta-carotene in food products has attracted the attention of many researchers (Villota et al., 1980).

Epidemiological studies indicate that the incidence of cancer may be slightly decreased among individuals with an above average intake of beta-carotene and other carotenoids. The onset and progress of the disease is affected by free radicals in the body. Burton and Ingold (1984) showed that beta-carotene has singlet oxygen quenching capacities. Bushway (1986) reported findings of antiulcer and antiaging effects of carotenoids.

Vitamin A in the body is essential for normal vision and maintanance of the normal condition of mucous membranes. An early symptom of vitamin A deficiency is impaired dark

adaptation (night blindness). Continued deficiency results in damage of the ocular tissues and eventually blindness, particularly in children. Studies show 500 to 600 mcg retinol (preformed vitamin A), or twice as much beta-carotene, is a minimum requirement for adults to prevent deficiency symptoms (Anon., 1985b; Klaui and Bauernfiend, 1981).

V. Development of New Products from Sweet Potato

Decline in sweet potato consumption has prompted investigation into the more effective utilization of sweet potato roots (Mathia, 1975). The sweet potato industry has experienced a steady decline in per capita consumption of sweet potatoes over the last twenty years. This decline has occurred because of the increasing demand for convenience foods, shifts in composition of foods consumed, and shifts in the population from farm to urban areas (sweet potato consumption, historically, has been higher in the areas of production) (Dwoskin et al., 1963). Canned roots have been available on the market for a long time but often lack certain desirable quality attributes (Bouwkamp, 1984; Collins et al., 1976). Thus, each year the industry faces a problem of marketing the total crop.

Collins et al. (1976) developed a convenient sweet potato product made from baked roots, fruits, and raisins.

French fried sweet potatoes were produced by several researchers (Kelly et al., 1958; Walter and Hoover, 1986) as well as sweet potato chips (Kelly and Baum, 1955; Bozorgmehr, 1987). Other products developed include sweet potato pie (Miller, 1977) and sweet potato yogurt (Ebah, 1987).

A study in 1963 by the United States Department of Agriculture (U.S.D.A.), Marketing Economics Division, determined institutional acceptance of instant sweet potato flakes. Chefs, kitchen help, and restaurant operators were favorable to the idea because the flakes were easy to prepare, use of flakes saved time and labor, and products prepared from flakes added variety to menus. More than 50% of the restaurant operators in the cities where tests were conducted said they would serve sweet potatoes if the new product were made available. Customer acceptance was also favorable. When on the menu, 25% of the customers ordered them and approximately 80% rated recipes using the instant flakes "very good" (Dwoskin et al., 1963).

In a related study the U.S.D.A. Statistical Reporting Service showed acceptance of sweet potato flakes by consumers. Over 200 homemakers used the instant sweet potato flakes to prepare one of three recipes: sweet potato pie, sweet potato casserole with marshmallow topping, or sweet potato casserole with orange topping. Convenience was

the major attraction for most of the homemakers. Seventy-five percent volunteered comments such as "time saver" and "very easy and quick to prepare." More than 50% of the homemakers said they would prefer the flakes to fresh sweet potatoes. Eighty-four percent said they would buy the product (Hollon, 1964).

To support these findings, many attempts were made to develop an "instant" dehydrated product for home, institutional, and military use. Molaison et al. (1962) introduced a diced dehydrated product and Sullivan et al. (1963) introduced a quick-cooking dehydrated dice. The latter product took only 2-5 minutes to rehydrate, whereas, the former required 40 minutes. Deobald and McLemore (1964) developed a method for producing storage stable, precooked dehydrated sweet potato flakes, but storage preparation proved to be too costly. In 1966, Hoover introduced an enzymatic process to produce a more stable flake product. More recently, Manlan and coworkers (1985) developed a method for instant drum dried flakes from tropical sweet potatoes.

Numerous recipes in everyday household periodicals provide new ways to use mashed sweet potatoes - pies, breads, cakes, muffins, pancakes, and casseroles (Anon., 1982, 1987; Gorman, 1987). However, these recipes are often overlooked due to time consuming preparation in baking,

cooling and mashing the sweet potato. A storage stable sweet potato flour that could be quickly substituted into such recipes could make sweet potatoes more of a convenience food and increase utilization of the crop.

The preparation and use of sweet potato flour has been studied in India, Israel, Peru, Egypt, and the West Indies (Hamed et al., 1973a, 1973b; El-Samahy et al., 1980; Sammy, 1970) with the intent of partial substitution for wheat flour in baked goods. Many of these countries are dependent on imported wheat for use in baking, and, consequently, a large amount of their foreign exchange is spent on wheat and wheat flour. Sweet potato flour has been substituted successfully for up to 20% of the flour in recipes in an effort to reduce this cost.

CHAPTER III

MATERIALS AND METHODS

I. Source of Sweet Potatoes

The Red Jewel cultivar of sweet potato was obtained from The University of Tennessee Plant Science Field Laboratory, Knoxville. The sweet potatoes were harvested in late October, 1986, and cured in facilities at the field laboratory. After curing, the roots were stored at approximately 16 C and 70% relative humidity until used.

II. Preparation of Sweet Potato Flour

The cured sweet potatoes were washed thoroughly to remove soil and sliced into sections 1.2 cm thick using a band saw (Birro, Model 44). The sections were steamed 15 min. at atmospheric pressure to ensure denaturation of peroxidase and lipoxygenase. The slices were allowed to cool to room temperature, packed in plastic freezer bags, quick frozen at -35 C in an air blast freezer, and stored at 0 C in a still-air freezer until processed.

The slices were freeze-dried and ground in a Fitz Mill homoloid machine (Model J) to pass through an 80 mesh sieve. The flour was vacuum packaged immediately in an oxygen impermeable plastic bag and stored at 0 C until test samples

were prepared.

The vacuum packaged flour was maintained on dry ice and transported to Cryovac, Division of W.R. Grace Co., Duncan, S.C., where it was packaged in multi-layered oxygen barrier d-film bags under two different atmospheres. The atmospheres consisted of 2% (plus or minus 0.05%) oxygen plus 98% nitrogen and 100% nitrogen (plus or minus 0.05% oxygen). Preliminary studies showed the quantity of oxygen had no effect on changes in the flour, but the presence of oxygen did effect the flour. The packaged flour was transported back to the University of Tennessee laboratories, again maintained on dry ice, and once there, stored in the dark at 0 C, 7 C, 14 C, and 21 C. Samples were removed and analyzed after one hour storage (to allow for equilibrium), 2 weeks, 4 weeks and 6 weeks. Flour for the sensory studies was packaged at the University of Tennesse Laboratories using a Cryovac vacuum packaging machine (Model K140) and premixed gases obtained from MG Industries.

III. Methods of Chemical Analysis

Proximate Analysis

All tests performed on the sweet potato flour were conducted in three replications. Protein, fiber, ash, and carbohydrate contents were determined at the beginning (1

hr storage) and at the end (6 weeks) of the experiment.

Moisture. Moisture content was determined by the AOAC vacuum oven method 14.003 (AOAC, 1980). Two gram samples were dried to a constant weight at 100 C for 5 hr at 25mm Hg.

Crude fat. Two gram moisture-free samples were extracted with petroleum ether on the Goldfisch extractor for 4 hr.

Crude protein. Two gram samples were analyzed for crude protein by the Kjeldahl method. Percentage of crude protein was calculated by multiplying percentage of nitrogen x 6.25.

Dietary fiber. Defatted, 2 g samples were analyzed for dietary fiber using an accelerated method (Anon., 1985).

Ash. Three, 3 g samples were ashed in a muffle furnace operated at 550 C for 3 hr according to AOAC (1980) method 14.006.

Carbohydrate. Percentage of carbohydrate was calculated by subtracting the percentages of crude protein, crude fat, and ash from 100%.

IV. Methods of Physical Analysis

Color Analysis

The color of the flour was measured with the Hunter Color Difference Meter (Model D25D2M). The meter was standardized against an orange tile with L, "a," and "b" values of 59.2, 33.5, and 34.4, respectively. The samples

were held in a cuvette with an optical glass bottom for the measurement.

V. Beta-carotene Analysis

Beta-carotene content in the sweet potato flour was determined by the method of Hoffman LaRoche Co. as modified by Bozorgmehr (1987). Two gram samples were extracted with moisture-free petroleum ether for 4 hr. The ether was allowed to evaporate and the residue was dissolved in 25ml high performance liquid chromatography (HPLC) grade hexane. The solution was filtered through a 0.45 micron filter, and 20 mcl of the solution were injected into an HPLC (Waters Assoc., Milford, MA, Model 6000A solvent delivery system with a U6K injector). The beta-carotene was separated with a Waters Micro Bondpak C-18 column with a Z-module and detected on a Waters Lambda Max (Model 480) Spectrophotometer Absorbance detector set at 452 nm. The detector response was printed by a Shimadzu Chromatopac 2-Channel integrator (Model C-R2AX, INP-R2A) that was connected to the HPLC system. The liquid phase consisted of acetone:hexane (15:85) and the flow rate was 2.0 ml per minute.

The standard solution contained 0.05 mg/ml beta-carotene in hexane. Five, 15 and 25 mcl of this solution were injected in triplicate to determine the calibration

curve.

Beta-carotene, a precursor of vitamin A in the human body, was treated as an indirect measurement of the vitamin content (6 mcg beta-carotene = 1 retinol equivalent vitamin A).

VI. Headspace Determination

Measurement of gases in the headspace of the packages of flour was monitored by injecting 1 ml headspace gas sample into a Hewlett Packard Gas Chromatograph (GC) (Model 5890A), using a modification of a method by Cryovac (Queen, 1987). Headspace gas composition was analyzed on an Alltech CTRI column and detected on the thermal conductivity detector at ambient temperature. Detector response was printed by a Hewlett Packard integrator (Model 3393A). The instrument was standardized using Scotty calibration gas 99 from Alltech.

VII. Sensory Evaluation

Sweet potato flour was substituted for the specified amount of mashed sweet potato in a sweet potato muffin recipe (see appendix 1) (Parish and Nugent, 1985); and the moisture level was adjusted. The flours used were those stored at 14 C for zero time (one hour equlilibration) in 100% nitrogen atmosphere, zero time in 2% oxygen and 98%

nitrogen atmosphere, six weeks in 100% nitrogen atmosphere, and six weeks in 2% oxygen and 98% nitrogen atmosphere. Selection of the stored flour was based on previous analyses. A control using mashed sweet potatoes from the same lot was presented along with the substituted flour samples.

Testing was conducted using an experienced but untrained panel consisting of 38 faculty members and students of food-oriented departments. Samples were presented in a laboratory designed for sensory evaluation and illuminated with a cool white fluorescent light. Water of ambient temperature was provided for rinsing between samples. After first describing the "ideal" plain breakfast muffin on a score sheet, panelists were presented with the five samples in random order. A demographic questionnaire was handed out with the fifth sample (Appendix D). Consumer texture profiles (Szczesniak et al., 1975) modified to include appearance and flavor were used to evaluate the muffins. Evaluation took place at mid-afternoon.

VIII. Texture Measurement

Compression and cohesiveness were evaluated using the Instron Universal Testing Machine, Model 1130, equipped with a 50-kg capacity load cell and cage attachment. The crosshead and chart speeds were set at 50cm and 100cm per

min, respectively. A 2.54 cm thick section was cut from the center of the muffin on the horizontal plane and a 3.8cm core was taken from this section. The core was loaded into the cage attachment, and firmness was judged by compressing the core to 50% of its thickness. Results were reported in kilograms of force. Cohesiveness was determined by compressing the sample a second time. Cohesiveness was reported as the ratio of the peak height of the second compression to the peak height of the first compression (Bourne, 1978).

IX. Color Measurement

Color of the muffins was measured according to procedures in Section IV. A 2.54 cm thick slice was taken from the middle of the muffin on the horizontal plane and placed to cover the entire bottom of an optical glass bottom cuvette.

X. Experimental Design

Proximate composition data were analyzed using a Randomized Complete Block design in a factorial arrangement (2 x 2 x 4 x 4 = replication x atmosphere x time x temperature). Color and beta carotene data were analyzed using a Randomized Complete Block design in a factorial arrangement of 2 x 2 x 2 x 4 (replication x atmosphere x

time x temperature). The determination of significant changes among variables was performed by Analysis of variance (SAS, 1982). After the first statistical analysis, all non-significant interactions were dropped from the model. Then, the analysis was performed again. Separation of means was determined using Tukey's test (Linton and Gallo, 1975; SAS, 1982).

Dependent variables in the sensory tests were analyzed statistically as a function of treatment and panelist. Analysis of variance was used to determine significance. Sensory values for color were correlated with Hunter values obtained from the muffins (Linton and Gallo, 1975).

CHAPTER IV

RESULTS AND DISCUSSION

I. Proximate Composition

The F-ratios from the analysis of variance of the proximate composition of sweet potato flour samples are shown in Table 1. Neither atmosphere, storage duration, nor temperature, affected moisture, fat, protein, carbohydrate, and total dietary fiber contents. Ash content was affected by atmosphere (0.01 level), storage duration (0.05 level), and temperature (0.05 level). The storage duration x temperature interaction affected the fat and ash contents at the 0.05 and 0.01 levels, respectively. The atmosphere x temperature interaction affected the ash content at the 0.01 level. Replication had an affect on fat and ash contents at the 0.05 level.

The mean values for the components of the sweet potato flour samples as affected by experimental factors are presented in Table 2. The overall mean values for the contents of moisture (4.36%), fat (1.34%), protein (6.61%), ash (3.11%), carbohydrate (84.58%), and total dietary fiber (TDF)(5.02%), (DWB) are in close agreement with values published for raw sweet potatoes (Anon., 1983). Ash content was 4.7% lower at the higher percentage oxygen and was 2.2%

TABLE 1. F-ratios from the analysis of variance of the proximate composition of sweet potato flour

Source	df	Moisture	Fat	Protein	Ash	Carbohydrate	TDF[1]
Atmosphere	1	0.27	0.09	1.22	36.39**	0.05	1.88
Storage duration	1	0.40	1.57	0.74	6.82*	0.11	2.38
Temperature	3	1.67	1.35	1.31	4.68*	1.56	0.29
Replication	1	0.29	4.52*	1.10	6.77*	0.02	0.00
Storage duration x Temperature	3	2.54	3.93*	0.57	8.32**	2.32	0.59
Atmosphere x Temperature	3	0.98	0.53	1.25	5.71**	0.48	0.75
Error mean square	19	1.15	0.04	0.03	0.01	1.38	0.02

[1] Total dietary fiber.

* Significant at the 0.05 level.

**Significant at the 0.01 level.

TABLE 2. Mean values[1] for proximate composition of sweet potato flour

Source	Moisture,%	Components of Solids, %				
		Fat	Protein	Ash	Carbohydrate	TDF[2]
Atmosphere						
Oxygen,%						
0	4.26[a]	1.35[a]	6.58[a]	3.19[x]	84.63[a]	4.98[a]
2	4.46[a]	1.33[a]	6.64[a]	3.04[y]	84.54[a]	5.05[a]
Storage Period						
Weeks						
0	4.24[a]	1.38[a]	6.58[a]	3.15[a]	84.65[a]	5.05[a]
6	4.48[a]	1.30[a]	6.64[a]	3.08[b]	84.51[a]	4.98[a]
Temperature						
Celsius						
0	3.76[a]	1.33[a]	6.62[a]	3.19[a]	85.10[a]	4.99[a]
7	4.72[a]	1.44[a]	6.71[a]	3.07[b]	84.06[a]	5.05[a]
14	4.80[a]	1.32[a]	6.56[a]	3.10[a,b]	84.22[a]	5.03[a]
21	4.16[a]	1.26[a]	6.56[a]	3.08[a,b]	84.95[a]	5.01[a]

[1] Values reported on dry weight basis.
[2] Total dietary fiber.
[a,b] Means within a factor followed by the same superscripts are not significantly different at the 0.05 level.
[x,y] Means within a factor followed by the same superscripts are not significantly different at the 0.01 level.

lower after six weeks storage. The samples stored at 7 C had 3.8% less ash than the samples stored at 0 C. Samples stored at 14 and 21 C had ash contents that were not different from the contents of samples stored at 0 and 7 C.

The mean values for the crude fat and ash contents as affected by the storage duration x temperature interaction are shown in Table 3. The initial storage period showed differences in the fat content across the four temperatures. The samples stored for zero weeks at 7 C were greater in fat content than those stored at 21 C. All of the other samples were similar in fat content and compared similarly to both the 0 weeks storage 7 C treatment and 0 weeks storage 21 C treatment. Samples stored for six weeks showed no differences across temperatures. Ash content was not affected in the initial storage period by any of the temperatures. At six weeks storage, the samples at 0 C were 8.9% higher in ash content than the samples at 21 C. Again, all other samples compared similarly to the two which differed.

Mean values for the ash content as affected by the atmosphere x temperature interaction are shown in Table 4. Samples in 0% oxygen at 0 C were 7.6% greater in ash content than the samples in 0% oxygen and 7 C. They were also 9.7% to 10.0% greater in ash content than the samples stored in 2% oxygen at 14 and 21 C respectively. Remaining samples

TABLE 3. Mean values[1] for crude fat and ash contents of sweet potato flour as affected by storage duration x temperature interaction

Storage period, weeks	Temperature,C	Fat,%	Ash,%
0	0	1.40[ab]	3.13[ab]
	7	1.64[a]	3.09[ab]
	14	1.35[ab]	3.17[ab]
	21	1.13[b]	3.19[ab]
6	0	1.26[ab]	3.26[a]
	7	1.25[ab]	3.05[ab]
	14	1.29[ab]	3.03[ab]
	21	1.38[ab]	2.97[b]

[1]Values reported on dry weight basis.

[ab]Means within each column followed by the same superscript are not significantly different at the 0.05 level.

TABLE 4. Mean values[1] for the ash content of sweet potato flour as affected by atmosphere x temperature interaction

Atmosphere, % oxygen	Temperature, C	Ash, %
0	0	3.31[a]
	7	3.06[b]
	14	3.21[ab]
	21	3.18[ab]
2	0	3.08[ab]
	7	3.09[ab]
	14	2.99[b]
	21	2.98[b]

[1]Values reported on dry weight basis.

[ab]Means followed by the same superscripts are not significantly different at the 0.05 level.

were similar in ash content to the above mentioned samples.

No explanation can be offered for the differences in ash content; however, the greatest range across the mean values, 0.33%, is relatively small and significance seems to exaggerate the differences (Tables 2, 3, and 4). The same point of discussion holds for the fat content. Loss of minerals and fat in a low moisture food held in an oxygen impermeable environment does not seem likely.

II. Apparent Beta-carotene Content

The F-ratios from the analysis of variance of beta-carotene content of sweet potato flour samples are shown in Table 5. Atmosphere, storage duration, the storage duration x temperature interaction, and the atmosphere x temperature interaction affected the apparent beta-carotene content of the flour at the 0.05, 0.01, 0.05, and 0.05 levels, respectively.

Mean values for the apparent beta-carotene content of the flour as affected by the conditions of storage are presented in Tables 6, 7, and 8. Retinol equivalents are also presented. The overall mean beta-carotene content of 44,288 mcg/100g compared favorably with published values for raw, orange-fleshed, sweet potatoes (Picha, 1985a).

As shown in Table 6, the presence of oxygen in the package caused a 4.4% decrease in the mean apparent beta-

TABLE 5. F-ratios from the analysis of variance of apparent beta-carotene content of sweet potato flour

Source	df	F-ratios
Atmosphere	1	4.75*
Storage duration	3	10.68**
Temperature	3	1.01
Replication	1	0.87
Storage duration x Temperature	9	2.32*
Atmosphere x Temperature	3	3.57*
Error mean square	88	27335476

* Significant at the 0.05 level.

**Significant at the 0.01 level.

TABLE 6. Mean values for the apparent beta-carotene content of sweet potato flour

Source	Beta-carotene mcg/100g[1]	Retinol Equivalents[2]
	Atmosphere	
Oxygen,%		
0	45299[a]	7545
2	43294[b]	7216
	Storage Period	
Weeks		
0	39848[z]	6641
2	43762[y,z]	7294
4	44259[y]	7377
6	48113[x]	8019
	Temperature	
Celsius		
0	44787[a]	7465
7	44943[a]	7491
14	44073[a]	7346
21	43354[a]	7226

[1] Indicates the values are reported on dry weight basis.

[2] Data were not analyzed statistically.

[a-b] Means within a factor followed by the same superscript are not significantly different at the 0.05 level.

[x-z]Means followed by the same superscript are not significantly different at the 0.01 level.

TABLE 7. Mean values for the apparent beta-carotene content of sweet potato flour as affected by storage duration x temperature interaction

Storage duration, weeks	Temperature, C	Beta-carotene mcg/100g[1]	Retinol Equivalents[2]
0	0	39393[bc]	6566
	7	39226[bc]	6538
	14	39962[bc]	6660
	21	40886[abc]	6814
2	0	46541[abc]	7757
	7	44174[abc]	7362
	14	48937[ab]	8156
	21	37652[c]	6275
4	0	42366[abc]	7061
	7	45458[abc]	7576
	14	44436[abc]	7406
	21	44776[abc]	7463
6	0	50832[a]	8472
	7	49198[ab]	8200
	14	44362[abc]	7394
	21	48060[ab]	8010

[1] Indicates the values are reported on dry weight basis.

[2] Data were not analyzed statistically.

[a-c]Means followed by the same superscript are not significantly different at the 0.05 level.

TABLE 8. Mean values for the apparent beta-carotene content of sweet potato flour as affected by atmosphere x temperature interaction

Atmosphere, % oxygen	Temperature, C	Beta-carotene mcg/100g[1]	Retinol Equivalents[2]
0	0	47191[ab]	7865
	7	43195[ab]	7199
	14	47708[a]	7951
	21	43696[ab]	7283
2	0	42703[ab]	7117
	7	46826[ab]	7804
	14	40957[b]	6826
	21	42959[ab]	7160

[1] Indicates values are reported on dry weight basis.

[2] Data were not analyzed statistically.

[ab]Means followed by the same superscripts are not significantly different at the 0.05 level.

carotene content, while storage duration caused an apparent increase in the mean beta-carotene content of 20.7% by the end of six weeks. Temperature showed no affect.

Table 7 presents the mean values of apparent beta-carotene content as affected by the storage duration x temperature interactions and Table 8 presents the mean values for the atmosphere x temperature interactions. Storage of flour for six weeks at 0 C (Table 7) showed an apparent increase in beta-carotene content when compared to flour stored for 0 weeks at 0, 7, and 14 C, and flour stored for two weeks at 21 C. The remainder of the interactions were not different. For samples stored in 0% oxygen at 14 C there was a greater apparent beta-carotene content than for samples stored in 2% oxygen at 14 C.

Many researchers have studied the effect of storage on the carotene content of sweet potatoes. However, little information is available concerning changes of beta-carotene content in low oxygen atmospheres. The literature presents data for beta-carotene content and changes at high oxygen contents only (Teixeira Neto et al., 1981). Adequate information on the carotenoid content of roots of cultivars being grown today and held under different post-harvest conditions is unavailable (Picha, 1985a).

Results regarding changes in the carotene content of the sweet potato root and the factors affecting these

changes are rather confusing. Some researchers have reported an increase in carotene during storage (Ezell and Wilcox, 1952; Picha, 1985a), some researchers have reported a decrease (Chou and Breene, 1972; Mitchell and Lease, 1941; Teixeira Neto et al., 1981; Walter et al., 1970), and some researchers have reported no change (Speirs et al., 1945). Information on the kinetics of the oxidation of beta-carotene is also confusing. Some researchers have reported first order kinetics (Teixeira Neto et al., 1981; Walter et al., 1970), while others have reported an induction period followed by a first-order reaction (Baloch et al., 1977; Chou and Breene, 1972; Goldman et al., 1983). Ezell and Wilcox (1952) determined that cultivar was an important factor to consider regarding changes in the carotenoid content during storage.

The pigment fraction of sweet potatoes is composed of both carotene and non-carotene carotenoids. Beta-carotene, the predominant carotenoid present, constitutes as much as 85% of the carotene content. Other individual carotenoids include zeta carotene, hydroxy-zeta-carotene, beta-carotene furanoxide, gamma carotene, and cis-cryptoxanthin epoxide. The total carotene content can vary more than 400% within a cultivar grown under similar conditons. The non-carotene fraction includes pigments in the intermediate stages of synthesis and decomposition products of the carotene

molecule (Klaui and Bauernfeind, 1981).

Colorless polyenes, namely phytofluene and phytoene, have been found in harvested, cured sweet potatoes. Phytoene is the basic 40-carbon acyclic carotenoid structure from which most carotenes are believed formed (Klaui and Bauernfeind, 1981).

Substantial quantities of carotenoids have been found in very fine physical dispersions in the aqueous phase of plants. This situation may exist in the sweet potato (Walter et al., 1970). Carotenoids are also known to form polymers with proteins. Very little information is known about the nature of these protein-carotenoid polymers. Stabilization of carotenoid against photooxidation and stabilization of the protein against denaturation by complex formation has been demonstrated (Klaui and Bauernfeind, 1981).

Researchers studying oxidative decoloration of beta-carotene in model systems that simulate dehydrated foods found starch to have a protective effect against decoloration (Ramakrishnan and Francis, 1979). Walter et al. (1970) determined with the use of ^{14}C-beta-carotene that a large portion of beta-carotene in dehydrated sweet potato flakes is not available for oxidative attack. The authors suggested this to be due to the formation of autoxidation retarding agents or protection by materials native to the

sweet potato. Deobald and McLemore (1964) found that precooked dehydrated sweet potato flakes stored at 70 F in nitrogen which contained 2% or less oxygen retained beta-carotene with or without antioxidants for 24 months. The lack of beta-carotene decrease in this experiment thus supports the work of Walter et al. (1970) and Deobald and McLemore (1964).

III. Color Analysis

The F-ratios from the analysis of variance of Hunter color measurements of sweet potato flour samples are presented in Table 9. The degree of yellowness ("b" value) was the only color component affected by storage conditions. Storage duration and temperature affected the yellowness of the sweet potato flour at the 0.01 level and their interaction at the 0.05 level.

Mean values for color of the flour as affected by the experimental factors are presented in Tables 10 and 11. Since the storage parameters had no affect on the L and "a" values, luminosity and redness were unchanged in the flour. The "b" value, or the degree of yellowness, was unchanged with different oxygen levels. Samples of flour showed a 2% decrease in the "b" value after storage of six weeks. Samples of flour stored at 21 C showed a 2.8% decrease in "b" value as compared to the mean color values for samples

TABLE 9. F-ratios from the analysis of variance for Hunter color measurements of sweet potato flour

Source	df	L	"a"	"b"
Atmosphere	1	0.02	0.33	1.90
Storage duration	3	1.97	1.56	5.93**
Temperature	3	0.25	0.33	17.88**
Replication	1	2.83	1.29	0.18
Storage duration x Temperature	9	0.94	0.63	2.76*
Error mean square	46	1.41	0.65	0.17

* Significant at the 0.05 level.

**Significant at the 0.01 level.

TABLE 10. Mean values for Hunter color measurements of sweet potato flour

Source	Measurements[1] L	"a"	"b"
	Atmosphere		
Oxygen,%			
0	72.1[a]	10.7[a]	29.5[a]
2	72.1[a]	10.5[a]	29.6[a]
	Storage Duration		
Weeks			
0	71.5[a]	10.7[a]	29.9[x]
2	72.1[a]	10.9[a]	29.5[xy]
4	72.4[a]	10.4[a]	29.4[xy]
6	72.4[a]	10.4[a]	29.3[y]
	Temperature		
Celsius			
0	71.9[a]	10.8[a]	29.9[x]
7	72.1[a]	10.6[a]	29.8[x]
14	72.1[a]	10.5[a]	29.5[x]
21	72.3[a]	10.6[a]	28.9[y]

[1] L = luminosity: 100 = pure white; 0 = black; "a" = redness; "b" = yellowness. The greater the "a" and "b" values, the more intense the color.

[a] Means within each factor are not significantly different at the 0.05 level.

[xy] Means within a factor followed by the same superscript are not significantly different at the 0.01 level.

TABLE 11. Mean values for the Hunter "b" measurement of sweet potato flour as affected by storage duration x temperature interaction

Storage duration, weeks	Temperature, C	"b"[1]
0	0	29.8[a]
	7	30.2[a]
	14	29.9[a]
	21	29.8[a]
2	0	30.1[a]
	7	29.5[ab]
	14	29.4[ab]
	21	29.2[abc]
4	0	29.9[a]
	7	29.9[a]
	14	29.5[ab]
	21	28.5[bc]
6	0	30.0[a]
	7	29.5[ab]
	14	29.5[ab]
	21	28.3[c]

[1] "b" = yellowness; the greater the value, the more intense the color.

[a-c] Means followed by the same superscript are not significantly different at the 0.05 level.

stored at 0, 7, and 14 C, among which no differences were found.

Samples stored at 21 C exhibited a steady decrease in yellownes of 3.0%, 4.7%, and 5.7%, respectively, after two, four and six weeks of storage (Table 11). No similar changes were found at the lower temperature. Increased storage time and increased temperature caused a loss in the yellowness of the flour (Table 11). The "b" value was greater for samples stored at all temperatures for zero weeks, samples stored two weeks at 0 C, samples stored four weeks at 0 and 7 C, and samples stored six weeks at 0 C than samples stored for four and six weeks at 21 C.

The orange color of sweet potatoes is attributed to the presence of carotenoids, predominantly beta-carotene (Klaui and Bauernfeind, 1981). Since the beta-carotene content did not decrease with storage duration at 21 C (Table 7) and since yellowness ("b" value) did decrease with storage duration at 21 C (Table 11), the decrease in yellowness is probably due to the loss of pigments other than beta-carotene.

IV. Headspace Analysis

Changes in the headspace oxygen content were not analyzed statistically because headspace oxygen concentration never measured greater or less than 2 + 0.05%

or 0 + 0.05% oxygen (the initial variation in headspace oxygen content).

V. Sensory Analysis

The F-ratios from the analysis of variance of sensory scores of an "ideal," plain breakfast muffin and muffins made with sweet potato are presented in Table 12. All attributes, except spiciness, were affected by treatment. (See footnote 1, Table 13). All other attributes evaluated, but moistness (0.05 level), were affected at the 0.01 level. Differences at the 0.01 level were found between panelists as they evaluated the samples for the attributes.

The scoring system (Appendices 2 and 3) was a scale of 1-9. One was the low end of the scale and nine was the high end (i.e. for spiciness, 1=weak, 9=intense). Mean scores for the attributes are presented in Table 13. The ideal muffin and all samples of muffins with sweet potato as an ingredient received similar scores for spiciness. The ideal muffin was harder and less gummy than muffins made with sweet potato.

Muffins made with flour stored for six weeks (treatments 3 and 4) were rated similar to the ideal muffin in crumbliness. Muffins made with sweet potato puree and freshly ground flour (treatment 2) were rated less crumbly than the ideal muffin at the 0.01 level. All samples, with

TABLE 12. F-ratios from the analysis of variance for sensory data of muffins with sweet potato and an ideal muffin concept

Source	df	Spiciness	Hardness	Gumminess	Crumbliness	Moistness
Panelist	36	3.94**	2.03**	3.90**	3.50**	3.40**
Treatment	5	0.64	6.47**	25.30**	10.00**	2.90*
Error mean square	178	2.97	1.29	2.24	2.32	1.41

* Significant at the 0.05 level.

**Significant at the 0.01 level.

TABLE 13. Mean sensory scores for attributes of an ideal muffin and of muffins with sweet potato

Attributes	Ideal[2]	Treatments[1]				
		Puree	1	2	3	4
Spiciness	4.5[a]	4.4[a]	3.9[a]	4.4[a]	4.5[a]	4.3[a]
Hardness	3.4[x]	2.2[y]	2.2[y]	2.0[y]	2.4[y]	2.6[y]
Gumminess	3.4[x]	6.8[x]	6.1[xy]	6.7[xy]	6.1[xy]	5.8[y]
Crumbliness	3.9[x]	2.4[y]	3.1[xy]	2.4[y]	3.7[x]	4.2[x]
Moistness	7.1[ab]	7.4[ab]	7.0[ab]	7.8[a]	6.9[b]	7.0[ab]

[1] Puree=muffin made with sweet potato puree.
1=muffin made with flour stored in 0% oxygen for 0 weeks.
2=muffin made with flour stored in 2% oxygen for 0 weeks.
3=muffin made with flour stored in 0% oxygen for 6 weeks.
4=muffin made with flour stored in 2% oxygen for 6 weeks.

[2] Ideal=panelist's concept of an ideal breakfast muffin.

[ab]Means within a row followed by the same superscript are not significantly different at the 0.05 level.

[x-x]Means within a row followed by the same superscript are not significantly different at the 0.01 level.

the exception of treatment 3, and the ideal muffin received similar scores for moistness.

The F-ratios from the analysis of variance of designated attributes and acceptability of muffins made with sweet potato (the "ideal" muffin scores were not included) are presented in Table 14. Differences (0.01 level) were found between panelists for all factors evaluated. Treatment affected color, crumbliness, appearance acceptabilty, texture acceptability, and overall acceptability at the 0.01 level. Gumminess and moistness were affected at the 0.05 level.

Mean sensory scores for the attributes and acceptabilities evaluated for muffins with sweet potato are presented in Table 15. Means for spiciness, hardness, odor acceptability, and taste acceptability of the muffin samples were similar among treatments. One or more of the muffins made with sweet potato flour were rated more desirable in color, appearance, and texture than muffins made with puree, an accepted recipe. Muffins made with flour stored six weeks in the 0% oxygen atmosphere (treatment 3) were scored as more desirable than muffins prepared with the puree. The muffins of (treatment 4) were scored as less gummy (0.05 level) than muffins made with sweet potato puree. Muffins of the four flour treatments received similar scores for gumminess. Muffins made with flour stored for six weeks in

TABLE 14. F-ratios from the analysis of variance of attributes of muffins with sweet potato

	Panelist df = 36	Treatment df = 4	Error mean square df = 144
Color	6.8**	6.0**	1.7
Spiciness	4.0**	0.8	2.9
Hardness	2.2**	1.8	1.2
Gumminess	3.8**	3.5*	2.1
Crumbliness	2.9**	9.9**	2.5
Moistness	2.9**	3.2*	1.6
Appearance acceptability	3.9**	5.4**	2.4
Odor acceptability	2.3**	0.4	2.2
Taste acceptability	3.0**	1.1	3.0
Texture acceptability	3.5**	4.7**	2.4
Overall acceptability	4.3**	3.9**	2.0

* Significant at the 0.05 level.

** Significant at the 0.01 level.

TABLE 15. Mean sensory scores of attributes and acceptabilty of muffins with sweet potato

Attributes	Treatments[1]				
	Puree	1	2	3	4
Color	5.2[xy]	6.2[x]	6.0[xy]	6.0[xy]	6.6[x]
Spiciness	4.4[a]	3.9[a]	4.4[a]	4.5[a]	4.3[a]
Hardness	2.2[a]	2.2[a]	2.0[a]	2.4[a]	2.6[a]
Gumminess	6.8[a]	6.1[ab]	6.7[ab]	6.1[ab]	5.8[b]
Crumbliness	2.4[y]	3.1[xy]	2.4[y]	3.7[x]	4.2[x]
Moistness	7.4[ab]	7.0[ab]	7.8[a]	6.9[b]	7.0[ab]
Appearance acceptability	5.0[y]	6.2[x]	5.8[xy]	6.1[xy]	6.5[x]
Odor acceptability	6.0[a]	6.3[a]	6.3[a]	6.3[a]	6.2[a]
Taste acceptability	5.4[a]	5.7[a]	5.5[a]	6.0[a]	6.1[a]
Texture acceptability	5.0[y]	5.8[xy]	5.4[xy]	5.8[xy]	6.5[x]
Overall acceptability	4.9[y]	5.8[xy]	5.5[xy]	6.1[x]	6.0[xy]

[1] See footnotes, Table 13 for identification.
[ab]Means within a row followed by the same superscript are not significantly different at the 0.05 level.
[xy]Means within a row followed by the same superscript are not significantly different at the 0.01 level.

either atmosphere (treatments 3 and 4) were rated as more crumbly than muffins made with puree and freshly ground flour in 2% oxygen (treatment 2). Muffins made with flour stored six weeks in 0% oxygen (treatment 3) were rated as less moist (0.05 level) than muffins made with freshly ground flour in 2% oxygen (treatment 2). Muffins prepared with the puree, treatments 1 and 4, received scores intermediate of scores of samples of the previously mentioned treatments. Overall acceptability was improved for muffins made with sweet potato flour when compared to muffins made with puree. Muffins made with flour stored for six weeks in 0% oxygen (treatment 3) were more acceptable than muffins made with puree. Scores of all other sample treatments were intermediate of these scores.

Storage of the flour contributed favorably to the quality of muffins prepared with sweet potato. Generally, scores received by the muffins made with flour stored for six weeks (treatments 3 and 4) were higher (or most acceptable) than scores received by the ideal muffin or those prepared from puree, or freshly ground flour.

Dough that contains root flour lacks the strong cohesive and elastic properties of wheat flour doughs. Hamed et al. (1973a) determined that the addition of sweet potato flour in bread making increased absorption, weakened the dough, and decreased dough stabilty. Sweet potato flour

has no gluten and is more acid than wheat flour. Decreasing the pH of flour leads to decreased dough development time and increased dough weakening (Hamed et al., 1973b). Similar findings were indicated by Abdel-Baki et al., El-Samahy et al., and Morad et al. (1980). The increased water absorption with the addition of sweet potato flour in cake mixes affected tenderness and the staling rate of the cakes. These studies support the fact the muffins obtained higher scores in gumminess and lower scores in hardness than an ideal breakfast muffin.

Appendix D presents the information concerning the panelists who participated in the study. The percentage of male panelists was 45.7% and the percentage of female panelists was 54.3%. Forty-six percent of the panelists liked sweet potatoes "very much so" while 11.4% did not like them at all. The frequency with which panelists consumed sweet potatoes was 14.3% never, 74.3% several times a year, 8.6% several times a month, and 2.9% several times a week. The majority of panelists ate sweet potatoes baked or in a pie. The frequency with which panelists consumed breakfast muffins was 2.9% never, 62.9% several times a year, 31.4% several times a month, and 2.9% several times a week.

Table 16 presents the F-ratios from the analysis of variance of scores assigned by the panel based on demography. Gender had a significant effect on scores for

TABLE 16. F-ratios from the analysis of variance of muffins with sweet potato according to panelists

Source	Gender		Preference for Sweet Potatoes		Frequency of Breakfast Muffin Consumption		Error mean Square	
	df	F-ratio	df	F-ratio	df	F-ratio	df	F-ratio
Spiciness			7	4.22**	3	8.96**	164	3.74
Hardness					3	3.93**	171	1.42
Gumminess	1	14.12**			3	4.98**	170	2.99
Crumbliness					3	3.52*	171	3.81
Moistness			7	2.28**	3	4.57*	164	1.93
Color	1	6.70*	7	4.84**	3	5.64**	163	3.03
Appearance acceptability			7	2.03			167	3.90
Odor acceptability	1	2.13			3	1.58	170	2.74
Taste acceptabiltiy			7	4.60**			167	3.61
Texture acceptability			7	1.98			159	3.39
Overall acceptability			7	3.39**			167	3.08

* Significant at the 0.05 level.

** Significant at the 0.01 level.

gumminess and color scores. Males rated the muffins significantly more gummy than females and less desirable in color (Table 17 and 18). Whether the panelist had a preference for sweet potatoes had a significant effect on his/her taste acceptability and overall acceptability score. Panelists who liked sweet potatoes "very much so" gave significantly higher taste and overall acceptability scores than panelists who did not like sweet potatoes at all. Frequency of sweet potato consumption had no significant effect on scores. Frequency of eating breakfast muffins had a significant effect on scores for hardness, gumminess, crumbliness, and moistness.

VI. Color Measurement of the Muffins

The F-ratios from the analysis of variance of Hunter color measurements of muffins made with sweet potato are presented in Table 19. All of the Hunter color measurements were affected by the treatment of the sweet potato (see footnote 1, Table 13) at the 0.01 level.

Mean values for the color measurements of the muffins made with sweet potato are presented in Table 20. The muffins made with flour stored for six weeks (treatments 3 and 4) were lighter (higher L value) in color than muffins made with freshly ground flour stored in 2% oxygen (treatment 2). Luminosity of muffins prepared with flour

TABLE 17. Mean sensory scores[1] of attributes of an ideal muffin and muffins with sweet potato

	No. of Panelists[2]	Spiciness	Hardness	Gumminess	Crumbliness	Moistness
Gender:						
male	16			6.83^{x}		
female	19			5.89^{y}		
Preference for sweet potatoes:						
very much so	16	4.29^{a}				7.38^{a}
not at all	4	4.25^{a}				7.15^{a}
Frequency of breakfast muffin consumption:						
never	1	3.80^{a}	3.00^{ab}	4.00^{y}	3.60^{ab}	7.00^{ab}
several times a year	22	4.30^{a}	2.39^{b}	6.23^{xy}	3.29^{ab}	7.07^{b}
several times a month	11	4.05^{a}	1.82^{a}	6.76^{x}	2.55^{b}	7.75^{a}
once a week	1	7.40^{a}	2.80^{ab}	5.80^{xy}	5.00^{a}	6.20^{ab}

[1] 1=dislike 9=like extremely (See appendix B).
[2] Panelists were asked to identify with one group of each category.
^{ab} Means within a factor followed by the same superscript are not significantly different at the 0.05 level.
^{xy} Means within a factor followed by the same superscript are not significantly different at the 0.01 level.

TABLE 18. Mean sensory scores[1] of muffins with sweet potato according to panelists

	No. of Panelists[2]	Color	Acceptability				
			Appearance	Odor	Taste	Texture	Overall
Gender:							
male	16	5.85[a]		6.01[a]			
female	19	6.21[a]		6.35[a]			
Preference for sweet potatoes:							
very much so	16	6.06[a]	5.89[a]		5.44[x]	5.95[a]	5.86[a]
not at all	4	6.00[a]	5.95[a]		4.90[y]	5.96[a]	4.85[a]
Frequency of breakfast muffin consumption:							
never	1	6.20[a]		6.40[a]			
several times a year	22	6.06[a]		6.15[a]			
several times a month	11	6.16[a]		6.38[a]			
once a week	1	4.20[a]		4.80[a]			

[1] 1=dislike 9=like extremely (See appendix B).
[2] Panelists were asked to identify with one group of each category.
[a,b] Means within a factor followed by the same superscript are not significantly different at the 0.05 level.
[x,y] Means within a factor followed by the same superscript are not significantly different at the 0.01 level.

TABLE 19. F-ratios from the analysis of variance of Hunter color measurements of muffins with sweet potato

Source	df	L	"a"	"b"
Treatment	4	11.11**	9.02**	9.55**
Error mean square	10	0.59	0.49	1.08

** Significant at the 0.01 level.

TABLE 20. Mean values for Hunter color measurements[1] of muffins with sweet potato

Treatment[2]	L	"a"	"b"
Puree	57.6*y	7.7*	28.4y
1	57.3*y	5.7*y	32.2*
2	56.5y	5.1y	30.7*y
3	59.9*	4.6y	28.4y
4	59.5*	5.1y	32.0*y

[1]L=luminosity: 100=pure white; 0=black; "a"= redness; "b"=yellowness. The greater the "a" and "b" values, the more intense the color.

[2]Puree=muffin made with sweet potato puree.
1=muffin made with flour stored in 0% oxygen for 0 weeks.
2=muffin made with flour stored in 2% oxygen for 0 weeks.
3=muffin made with flour stored in 0% oxygen for 6 weeks.
4=muffin made with flour stored in 2% oxygen for 6 weeks.

*y Means within a column followed by the same superscript are not significantly different at the 0.01 level.

was not different from luminosity of muffins prepared with puree. Muffins made with sweet potato puree had more red color ("a" value) than muffins made with flour from three treatments. This increase in redness was correlated negatively ($r = -0.20$) at the 0.01 level with scores of color desirability and appearance acceptabilty scores given by panelists. There was a trend for muffins with the flour to exhibit more yellow color than muffins prepared with puree. Only muffins prepared with freshly ground flour (treatment 1) were significantly more yellow than muffins prepared with puree.

VII. Texture Measurements of the Muffins

Table 21 presents the F-ratios from the analysis of variance of compression (hardness) and cohesiveness measurements of muffins with sweet potato. Treatment affected compression at the 0.01 level and cohesiveness at the 0.05 level.

Hardness (or compressability) is defined as the force necessary to attain a given deformation (Larmond, 1976) or the peak force during the first compression cycle ("first bite")(Bourne, 1978). Cohesiveness is defined as the extent to which a material can be deformed before it ruptures (Larmond, 1976) or the ratio of the positive force area during the second compression to that obtained during the

TABLE 21. F-ratios from the analysis of variance of compression and cohesiveness of muffins with sweet potato

Source	df	Compression	Cohesiveness
Treatment	4	8.58**	4.59*
Error mean square	10	0.02	4.67

* Significant at the 0.05 level.

**Significant at the 0.01 level.

first compression (Bourne, 1978).

Mean values for compression and cohesiveness of the muffins are given in Table 22. The muffins made with flour freshly ground (treatment 2) required more kilogram force to compress than muffins made with puree. The compression values for the remaining treatments were intermediate and similar in compressability to both of the above samples. The muffins made with flour stored six weeks in 2% oxygen (treatment 4) were less cohesive than muffins made with freshly ground flour in 0% oxygen (treatment 1). The remaining treatments (puree, 2 and 3) were comparable to both of the above mentioned treatments.

TABLE 22. Mean values for compression and cohesiveness of muffins with sweet potato

Treatment[1]	Maximum force, kg	Cohesiveness[2]
Puree	0.78[y]	.84[ab]
1	0.90[*y]	.88[a]
2	1.33[*]	.85[ab]
3	0.98[*y]	.86[ab]
4	1.10[*y]	.81[b]

[1]Puree=muffin made with sweet potato puree.
1=muffin made with flour stored in 0% oxygen for 0 weeks.
2=muffin made with flour stored in 2% oxygen for 0 weeks.
3=muffin made with flour stored in 0% oxygen for 6 weeks.
4=muffin made with flour stored in 2% oxygen for 6 weeks.

[2]Cohesiveness = the second of two compressions divided by the first of two compressions.

[*y]Means within a column followed by the same superscript are not significantly different at the 0.01 level.

CHAPTER V

CONCLUSIONS

The objectives of this study were to determine the effect of storage conditions on selected quality attributes of sweet potato flour and to determine the effect of stored flour on the quality of a food system (muffin).

The proximate composition of sweet potato flour remained essentially unchanged over six weeks storage time at temperatures of 0, 7, 14, and 21 C in atmospheres of 0 and 2% oxygen. Apparent beta carotene content decreased as oxygen content was increased from 0 to 2 % oxygen. However, apparent beta carotene content increased as weeks of storage time increased. Storage temperature did not effect the apparent beta carotene level. The intensity of yellowness of the flour (as measured by the Hunter "b" value) decreased with increasing storage time and at a temperature of 21 C.

Muffins made with sweet potato flour were scored close to the "ideal" plain breakfast muffin in all attributes except gumminess. The muffins with sweet potato were scored more gummy. Muffins made with sweet potato flour compared to muffins made with sweet potato puree scored higher in color, appearance acceptability, texture acceptability, and overall acceptability. Males rated muffins more gummy than

females. Panelists with a greater preference for sweet potatoes gave higher scores for taste acceptability. The frequency with which panelists consumed breakfast muffins affected the scores for hardness, gumminess, crumbliness, and moistness.

Optimum storage conditions for sweet potato flour were 0% oxygen at 14 C for up to six weeks. Increasing package atmosphere to 2% oxygen negatively affected apparent beta carotene content and increasing the temperature to 21 C negatively affected the intensity of yellowness. The effect of stored flour on the quality of a food system (muffin) as compared to the panelists ideal concept was detrimental only to gumminess. The remainder of the attributes received more favorable scores as storage time was increased. Package atmosphere had no obvious affect on the quality of the muffins.

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APPENDICES

APPENDIX A

Sweet Potato Muffin Recipe

1/3 cup shortening
1 1/3 cup sugar
2 eggs
2 cups mashed sweet potatoes
1 2/3 cup self-rising flour
1/2 tsp. cinnamon
1/2 tsp. nutmeg

Cream shortening and sugar. Add eggs and cooked mashed sweet potatoes. Beat 5 minutes. Add dry ingredients. Beat 10 minutes and cook at 350 F for 25 minutes.

(Parish and Nugent, 1985)

APPENDIX B

Product: MUFFINS

On the scales below please indicate where you think the "ideal" plain breakfast muffin (not a corn muffin) would be rated. Mark the scorecard by placing a check on the line to represent the degree to which the characteristic should be present in the sample.

Taste

Spicy

weak 1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 9 intense

Texture

Hardness (Force required to bite through on first bite)

very soft 1 : : : : : : : : 9 very hard

Gumminess (degree to which the product forms a mass in the mouth)

not at all 1 : : : : : : : : 9 very much so

Crumbliness

holds together 1 : : : : : : : : 9 crumbles easily

Moistness

very dry 1 : : : : : : : : 9 very moist

APPENDIX C

Product: MUFFINS

You will be given 5 samples. Please evaluate them as presented. Mark the scorecard by placing a check on the line to represent the degree to which the characteristic is present in the sample. Please rinse between samples.

Appearance

Color

very desirable 9 : 8 : 7 : 6 : 5 : 4 : 3 : 2 : 1 very undesirable

Acceptability of appearance

very desirable 9 : : : : : : : : 1 very undesirable

Odor

Acceptability of odor

very desirable 9 : : : : : : : : 1 very undesirable

Taste

Spicy

weak 1 : : : : : : : : 9 intense

Acceptability of taste

very desirable 9 : : : : : : : : 1 very undesirable

Texture

Hardness (Force required to bite through on first bite)

very soft 1 : : : : : : : : 9 very hard

Gumminess (degree to which the product forms a mass in the mouth)

not at all 1 : : : : : : : : 9 very much so

Crumbliness

holds together 1 : : : : : : : : 9 crumbles easily

Moistness

very dry 1 : : : : : : : : 9 very moist

Acceptability of texture

very desirable 9 : : : : : : : : 1 very undesirable

Overall Acceptability

very desirable 9 : : : : : : : : 1 very undesirable

COMMENTS:

APPENDIX D

* Number of panelists

Do you like sweet potatoes?

not at all 4 : 2 : 0 : 2 : 1 : 1 : 5 : 4 : 16 very much so

How often do you consume sweet potatoes?

Never 5

Several times a year 26

Several times a month 3

Once a week 0

Several times a week 1

When you eat sweet potatoes, how are they prepared?

How often do you consume breakfast muffins?

Never 1

Several times a year 22

Several times a month 11

Once a week 1

Several times a week 0

Male 16 Female 19

VITA

Susan Ulm Gurkin was born in Arlington Heights, Illinois on December 12, 1962. She attended Roswell High School, Roswell, Georgia and graduated in 1981. She attended the University of Georgia, Athens and received her Bachelor of Science degree in Agriculture in 1985. In January 1986, she entered the graduate program in Food Technology and Science at the University of Tennessee. She accepted a graduate research assistantship in September 1986 and completed the degree of Master of Science in Food Technology and Science in August 1988.

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