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Effect of cultivar, processing, and storage on the quality characteristics of sweet potato chips

Koorosh. Bozorgmehr

To the Graduate Council:

I am submitting herewith a thesis written by Koorosh. Bozorgmehr entitled "Effect of cultivar, processing, and storage on the quality characteristics of sweet potato chips." 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.

John R. Mount, Major Professor

We have read this thesis and recommend its acceptance:

Jim L. Collins, Sharon L. Melton

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Koorosh Bozorgmehr entitled "Effect of Cultivar, Processing, and Storage on the Quality Characteristics of Sweet Potato Chips." I have examined the final 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 Technology and Science.

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We have read this thesis
and recommend its acceptance:

Sharon S. Melton

J Collins

Accepted for the Council:

Burrinkel
Vice Provost
and Dean of The Graduate School

EFFECT OF CULTIVAR, PROCESSING, AND STORAGE ON THE QUALITY CHARACTERISTICS OF SWEET POTATO CHIPS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Koorosh Bozorgmehr

March 1987

DEDICATED TO

My father, Bozorg Bozorgmehr
Who set the standards of professional excellence, devotion,
and personal integrity which I have strived to match

My mother Zarrin Bozorgmehr
Whose love and affection have given me strength

My brother Kamran Bozorgmehr
Whose love has sustained me

My professors and friends who nurtured my growth

Through this thesis,

The best within me salutes the best within you.

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ABSTRACT

This study was undertaken to compare sweet potato chips utilizing different sweet potato cultivars, and to evaluate the effect of processing and storage on the quality characteristics of the chips. Chips contained an average of 1.7% moisture, 4.6% crude protein, 52% crude fat, 1.9% ash, 4.5% total dietary fiber, and 36% carbohydrate, with an average 2411 kj/100g (155 kcal/oz.).

Proximate composition of the cultivars showed no significant differences, however, total dietary fiber of the "Southern Delite" (SD) chips was significantly higher than either "W-221" (W2) or "Red Jewel" (RJ) chips. Moisture decreased with storage time and reached a plateau after three weeks. Beta-carotene content of chips averaged 2671 R.E. There was a significant difference among the cultivars in beta-carotene content with SD chips having the highest amount (3978 R.E.). Beta-carotene decreased with the presence of salt or air over storage time. Chips required an average force of 357g to break as measured with the Instron Universal Testing Machine. W2 required the highest force (379g) to break. Chip color was analyzed with the Hunter Colorimeter. L and "a" values significantly differed among the cultivars. The "a" value decreased due to atmosphere and time of storage. W2 chips were lighter than the other two cultivars and were more yellow than red with an "a":"b" ratio of 0.6 compared to 0.7 for SD and RJ. An experienced panel found a slightly detectable off-flavor after 9 weeks of storage with no difference due to processing or storage time. They rated chips very crispy with slightly pale-orange yellow to moderately dark-orange yellow in color.

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INTRODUCTION

During recent years, the snack food industry has grown into a multi-million dollar industry. In 1971, an estimated 96% of all households in the United States purchased some type of snack food. With a predicted 6% annual growth rate, this industry will be worth about $8.2 billion by the year 1991 (Anon., 1972).

During the next five years, the public will become more health conscious and people will demand nutritious food products. The food industry is seeking new snack products which will add variety and expand the volume of sales. One source of material for use in making snack food products is the sweet potato which can be utilized in many different types of snack foods. This may help increase the consumption of sweet potato which has been on a decline since the 1940's. In the United States the per capita consumption of the sweet potato root has declined at a steady rate from 13.29 kg in 1919 to 1.9 kg in 1983 (Anon., 1984a).

The serious decline in consumption of sweet potatoes has resulted in the scientific community determining the need for new, high quality products made from sweet potato which could be beneficial to potato producers, snack food processors, and consumers. Such new products should meet the needs of consumers, and hence, increase consumption of sweet potatoes. One such product is sweet potato chips and includes advantages such as ready availability and an excellent source of beta-carotene (vitamin A precursor).

The objectives of this study were to explore possibilities of development of sweet potato chips utilizing different sweet potato cultivars and to evaluate the effect of processing and storage on the quality characteristics of the chips.

Chapter II

REVIEW OF LITERATURE

I. The Sweet Potato Root

Today, millions of people throughout the world consume sweet potatoes (Ipomoea batatas, Lam.). This vegetable, which belongs to the Convolvulaceae family (Yen, 1976), originated in the Central or South American lowlands, growing possibly as a hybrid cross or through karyotypic alterations from an unknown plant of the genus Ipomoea (O'Brien, 1972). The plant's production is known to date back as far as 3000 B.C. (Crosby, 1964; Farris, 1978). The sweet potato was introduced to Europe by the Spanish and was dispersed to Malaysia, China, Japan, and the Moluccas regions. It was spread to India and Africa by the Portuguese (O'Brien, 1972). English colonists introduced the sweet potato to the United States in 1650 (Crosby, 1964; Kane, 1978; Miller, 1977).

Sweet potatoes are of two general types: 1) the dry-fleshed type with a mealy yellow flesh and 2) the moist type with a soft gelatinous flesh. The latter type is higher in sugar content than the dry-fleshed type and has a bright orange colored flesh (Edmond and Ammerman, 1971; Farris, 1978; Mathia, 1975). The moist type is called "yam" in the United States, but this is a misnomer because the "true yam", as regarded by the rest of the world, is Dioscorea alata (Fitzgerald, 1976; Kane, 1978; Kushman, 1967; Miller, 1977). The dry type appears to be more popular in the Carribbean, while the moist type is most popular in the United States (Martin and Rhodes, 1984).

The consumption and popularity of the sweet potato are varied in different parts of the world, including the United States (Edmond and Ammerman, 1971; Yen, 1976). In China and Japan, it has been a highly prized food since introduction. In the United States, the sweet potato is particularly popular in the southern states, where it was first introduced in 1648 (Crosby, 1964). The relative importance of the crop can be noted by comparison of production in China and Japan with production in the United States. China with a land area 20% larger than the United States, produces about 200 times more sweet potatoes as the United States; and, Japan with less than one-tenth the land area of the United States, produces twice as much (Anon., 1983a).

Although the value of this root crop is unquestioned, the consumption has been declining in the United States. Several factors which might have affected this decline include: 1) increase in food item offerings; 2) the idea that the sweet taste makes it "less" nutritious; 3) the association of the sweet potato with certain holidays; and 4) the idea that the potato is associated only with low-income families (Fitzgerald, 1976). Among non-white households, size and age of family members affect the consumption of the sweet potato roots, and consumption tends to increase in the elderly population of this group (Mathia, 1975).

The optimum growing condition for sweet potatoes is a warm tropical climate. However, the roots have been successfully grown under a wide range of climatic conditions. In the United States, production of this crop extends from the sub-tropical climate of the Gulf coast to the mid-temperate regions of Maryland and New Jersey

(Cooley, 1948). Currently, the major sweet potato producing areas in descending order of production are North Carolina, Louisiana, and California (Anon., 1984a).

II. Chemical Composition and Nutritional Value of Sweet Potatoes

The average sweet potato flesh on the fresh weight basis is composed of 1.8% crude protein, 0.7% crude fat, 1% crude fiber, 68.5% water and 28% carbohydrates (Cooley, 1948; Goodbody, 1984; Thompson, 1984). In comparison, the Irish potato has 2.1% crude protein, 0.1% crude fat, 0.5% crude fiber, 79.8% water and 17.5% carbohydrates (Johnson and Peterson, 1974). The moisture content is lower in sweet potatoes than in Irish potatoes, and sweet potatoes are among the few vegetables with such a low moisture content. Crosby (1964) stated that this makes the sweet potato a significant source of food and minor chemical constituents. The total carbohydrate content (dry weight basis) of the sweet potato root is 89.5% which includes the sugars maltose, sucrose, and glucose, and dextrin (Picha, 1985b; 1986b). Picha (1986a) studied the influence of storage duration and temperature on sweet potato sugar content and chip color. He found that storage of roots at 32°C, 15.6°C, or 7°C after harvest resulted in increased sucrose, glucose, and fructose concentration and, therefore, a darker color of chips. An unsuccessful attempt was made to manipulate storage temperatures in order to decrease the reducing sugar content.

Different cultivars of sweet potatoes contain various concentrations of carbohydrate. Length of storage decreases the

amount of starch and increases the sugar level, reflecting root metabolic activity. Depending on the cultivar, the degree of increase in the reducing sugar content varies (Walter and Hoover, 1984).

The roots of the sweet potato crop are an excellent source of energy (114 calories per 100 g) and a good source of pro-vitamin A (880 RE per 100 g) (Mathia, 1975). It may also be used as feed for farm animals, and tests have shown that dehydrated roots in combination with other materials make a nutritious food for all classes of livestock. When comparing feeding values, the sweet potato matches 95% to that of corn, and in some cases, is equal to corn in feeding value. Dehydrated sweet potatoes contain 80%-85% carbohydrate and 4%-5% protein, whereas the best grade of corn contains 70% carbohydrate and 9.6% protein (Cooley, 1948).

The sweet potato provides a wealth of nutrients, adding many important vitamins and minerals to the diet. The roots are an excellent source of vitamin C and provide appreciable amounts of riboflavin, niacin, pantothenic acid (Crosby, 1964; Edmond and Ammerman, 1971) thiamin, calcium, and iron (Elkins, 1979; Fitzgerald, 1976). The sweet potato also provides dietary fiber. Trowell (1976) introduced and secured acceptance of the definition of dietary fiber as "the remnants of the plant cells resistant to hydrolysis by the alimentary enzymes of man" (Alstin, 1985). Plant constituents usually considered as part of dietary fiber include cellulose, hemicellulose, lignin, and pectins (Schneeman, 1986; Eastwood and Passmore, 1984). Burkitt and Trowell (1975) reported that a diet deficient in fiber over an extended period of years can lead to gastrointestinal tract

dysfunctions which may further result in serious disease states. A low dietary fiber intake may be associated with diverticular disease, colon cancer, ischemic heart disease, constipation, diabetes, and other diseases of the gastrointestinal tract (Kelsay, 1978; Vijayagopal et al., 1973). Dietary fiber was once considered an insignificant part of the human diet because it was thought to contribute very little as a source of energy (Burkitt et al., 1974; Eastwood and Passmore, 1984).

The sweet potato provides an appreciable amount of beta-carotene, a precursor of vitamin A in the body. This nutrient is essential for maintenance of epithelial tissue, reproduction, growth, and normal vision (Clemens and Brown, 1986). The characteristic color of the potato results from a high level of beta-carotene (Chichester and Tanner, 1972; Martin, 1983). Recently researchers have demonstrated that some vitamin A active carotenoids have anti-cancer and anti-ulcer properties. An inverse relationship has also been suggested between the risk of cancer and the consumption of foods containing certain carotenoids (Bureau and Bushway, 1986). Picha (1985b) reported a higher level of carotenoid concentration in four different cultivars of sweet potatoes after curing and short term storage than is present at harvest. Eighty to ninety percent of the carotenoids are composed of beta-carotene. The remaining carotenoids which also are precursors of vitamin A may in some cultivars (excluding the white strains) be as high as 22% (Ezell and Wilcox, 1948). Hence, there are both economic and aesthetic reasons for interest in the plant pigment (Francis, 1969; Francis and Clydesdale, 1970; Hoover and Mason, 1961).

The root of the sweet potato is a source of protein, and people of some tropical areas depend on it for a major portion of dietary protein (Thompson, 1984; Walter et al., 1984). Some cultivars of sweet potato contain more than 9% protein (Purcell et al., 1976; Purcell and Swaisgood, 1972). Li and Oba (1985) studied protein changes in the roots after cutting, infection, or storage and identified major soluble proteins of sweet potato (Ipomoea batatas Lam.). Cutting, infection, or storage of root tissue resulted in the production of protein in the form of new isozymes of peroxidase, acid phosphatase, and esterase. They reported some increase in protein concentration in cut and diseased tissues. Picha (1985b) reported that on a fresh weight basis, crude protein in six cultivars after storage treatments ranged from 1.36 to 2.13 g/100g.

Consumed in moderation, sweet potato is not a major contributor of protein to the diet. When vegetable makes up most of the diet, the quantity and quality of protein is barely adequate to meet the minimum recommended dietary allowance (RDA) of protein which is 56g and 44g for adult males and females, respectively (Picha, 1985b).

The relative nutritional importance of this crop can be noted by comparing with Irish pctatoes. Cooked Irish potato contain about the same amount of energy as cooked sweet potatoes, more protein and vitamin C, and much less vitamin A. A one-cup serving (225 g) of mashed cooked sweet potatoes provides 1190 Kilojoules (kj) and 5 g of protein. This is almost double the amount of energy and about equal the amount of protein obtained from a cup of cooked cereal, such as corn or rice (Anon., 1983b).

III. Deep-Fat Frying

Deep-fat frying is the practice of frying foods in fat deeper than the height of food such that moisture continually evolves from the food in the fat during frying. During frying the oil serves to transfer heat and reacts with carbohydrate and protein in the food to give color and flavor to the final product. Therefore, chemical changes, as well as deterioration, occur in the oil and food product.

According to Nawar (1985), deterioration of the oil is one of the major causes of food spoilage. Deterioration causes the oil to become dark, viscous, and burnt in odor and flavor (Bocca et al., 1984; Weiss, 1983).

Dep-fat frying is an extremely popular method of cooking in the United States, where it has grown into a multi-billion dollar industry (Chang, 1967; Robertson, 1967). To realize the popularity of fried food one has to consider the variety of such items that are in the market; sweet potatoes, carrots, peas, and beets (Kelley and Baum, 1955), turnips (Reddy et al., 1971), potato chips, doughnuts, and the list goes on. Fried foods are nutritious, digestable, and might not be so "fattening" as many people think (Robertson, 1967).

Since fat is absorbed and becomes part of the food, it is important to use good quality oil (Jacobson, 1967; Silverman and Kushner, 1985). Many studies have been conducted to determine the chemical changes in heated fats/oils (Carlson and Tabucchi, 1986; Parmanyer et al., 1985; Perrin et al., 1985). Autoxidation, the reaction of oil with molecular oxygen, is the main reaction involved in oxidative deterioration of fats (Kleinert, 1985). During frying,

the food loses moisture through vaporization and then absorbs oil. Oxidation causes production of hydroperoxides and conjugated diens. These products can undergo fission to give alcohols and aldehydes, which react to give acids and hydrocarbons. Hydrocarbons, in turn, yield free radicals that form dimers, epoxides, and other hydrocarbons. Heat can also cause formation of dimers and cyclic compounds (Melton, 1986). Accumulation of polymeric compounds due to prolonged fat use increases the viscosity of the oil, and results in formation of gums on the sides of the kettle. This condition can decrease the smoke point and, in turn, cause the fat to darken. Each type of degradation product formed in frying oil causes deterioration and affects its frying quality. Accumulation of free fatty acids lowers the smoke point of the oil. Aldehydes, ketones, hydrocarbons, and alcohols cause flavor and aroma problems.

It is of great economic concern to the food industry to determine deterioration of fats/oils. Deteriorated oils lead to the development of off-flavors and off-odors in edible oils and fat-containing foods which cause these foods to become unacceptable. In addition, oxidation decreases the nutritional quality of food, and certain oxidation products are potentially toxic (Nawar, 1985).

Factors contributing to rancidity of sweet potato chips are exposure to air, light, and high temperature, contamination of oils with metals, and poor packages. Antioxidants may be added to the oil or to the salt which is applied to chips during processing to delay rancidity and extend shelf-life. A number of antioxidants such as nordihydrogluconic acid (NDGA), propyl gallate, butylated

hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and others have been found suitable in the chip industry (Smith, 1977).

IV. Potato Chip Quality

Chip quality is defined by various parameters. However, the most common and important factor is color (Work et al., 1981). The color of chips is affected by several factors. Those factors are quality of the raw product, reducing sugar content of the sweet potato prior to harvest and during storage, processing, phenols, and additives (Anon., 1980).

Recent research has shown that the major cause of chip discoloration is the Maillard reaction. Reducing sugars are shown to participate in this reaction (Smith, 1977). Formation of a gray discoloration is thought to be caused by the reaction between o-dihydroxyphenols and ferric iron (Hoover, 1963). The rate of this reaction increases at high temperatures attained in deep-fat frying (Walter and Hoover, 1986). When phenolase is activated, the O-quinones of cholorgenic acid are polymerized to yield dark compounds (Arthur and McLemore, 1956). Root discoloration related to phenolase activity occurs in the range of 60°C to 90°C. This enzyme is inactivated at higher temperatures (Scott and Kattan, 1957).

Different cultural and environmental conditions have been found to affect the quality of the raw product (Constantine et al., 1974). Variation in chemical composition of different cultivars is known to be responsible for differences in the quality of products (Miller, 1972; Hoover, 1963). Cultivars respond differently to storage

conditions. In some cultivars concentration of reducing sugars may rise enough within two weeks of storage to cause dark color chips (Singh et al., 1976). On the other hand, other cultivars can withstand low storage temperatures (Murphy and Goven, 1967).

Various studies have shown that cultivars held at various storage conditions have significant differences in the sugar content (Burton, 1965), and the optimum temperature depends on variety, root maturity, and length of storage (Miller et al., 1975; Murphy and Goven, 1967). Research has shown that exposure of the roots to low temperature (4.4°C) initiates rapid increase in reducing sugars along with invertase concentration (Pressey, 1969). Invertase is one of the enzymes involved in the formation of reducing sugars. Starch is converted to sugar at low temperature. One of the sugars in this conversion is sucrose, a non-reducing sugar. This sugar serves as an intermediate product in the formation of reducing sugars from starch (Isherwood, 1976). Sowokinos (1978) found a direct correlation between sucrose content at harvest and resulting chip color following storage at intermediate temperatures (11.7 ℃). In contrast, Hair and Gould (1979) found no statistically significance correlation between color and harvest sucrose content. Sistrunk (1977) found that roots stored at 2 ℃ after harvest followed by two days at 24°C were rated higher in color by a sensory panel after baking or boiling than roots stored at 24 ℃ even though L and "a" values were not significantly different. Roots stored at 2 ℃ showed less discoloration.

V. Development of Products From Sweet Potatoes

Many scientists have investigated the development of new products from sweet potatoes. In this way, some resistance can be provided to the decreasing consumption of the roots, and products may be promoted for their nutritional value or energy content (Edmond and Ammerman, 1971). Expansion of the processing industry may, indeed, aid the rural economy of the regions that produce the roots (Hennessey et al., 1971). These efforts may be successful only when a high quality convenience product is provided. This in turn calls for overcoming the problems that are associated with processed sweet potato products.

Discoloration, a major problem, masks the natural pigmentation of sweet potato products. This problem can be attributed to enzymatic browning, (Olorunda and Kitson, 1977), nonenzymatic browning (Elkins, 1979), or caramelization (Marquez and Anon, 1986; Picha, 1986a, b). Various investigators have explored different means of controlling discoloration in sweet potatoes. Baba et al. (1985) stated that blanching is one effective way to control discoloration along with the addition of disodium dihydrogen pyrophosphate. Olorunda and Kitson (1977) demonstrated that the sugar content can be lowered by storing the roots at 30°C for several weeks before processing. Other methods of preventing discoloration include the use of sodium bisulfite (recently banned for some uses by FDA), citric acid, or a mixture of sodium acid pyrophosphate and tetrasodium pyrophosphate (Spadaro et al., 1967).

Textural problems exist, yet they are not as significant as discoloration problems. Poor texture in sweet potato chips results from the absorption of fat in the chips which is further influenced by the type of raw roots used (Baba and Yamamura, 1981a; Baba et al., 1985). Baba and Yamamura (1981a) described that hardness of chips prepared from sweet potatoes and concluded that hardness was apparently influenced by blisters formed during frying and the final oil content in the chips. Upon subsequent investigation, they noted a 75% decrease in chip hardness, which was dependent upon the root variety used (Baba and Yamamura, 1981b). The chips that were the least hard were the ones that were frozen and thawed. In sensory evaluation of the chips, they found that those with a high starch content received the highest sensory scores for flavor and appearance. Blanching followed by freezing was found to be an effective method to soften the texture of a sugar-coated sweet potato product (Baba et al., 1985).

Numerous attempts have been conducted to develop new products from sweet potato roots. Canned roots have been on the market for some time, yet certain quality attributes of the roots are not retained in the canned product (Hoover, 1963). Even still, the part of the crop not suitable for fresh market sale may be canned to provide the potato growers with a dependable market (Miller, 1977).

Collins et al. (1976) developed a convenient frozen sweet potato product served with fruits and raisins. Deep-fried juiliene strips, dices, and frozen french fries have been prepared from sweet potatoes (Kelly et al., 1958). Other products produced from sweet potatoes

include french fried sweet potato strips (Walter and Hoover, 1986) and instant sweet potato pie (Miller, 1977).

A number of different techniques have been investigated to produce sweet potato flakes. Hoover (1966) introduced an enzymatic process to produce the flake and later improved it (1967). Spadaro et al. (1967) proposed a different processing method for producing instant sweet potato flakes. Dehydrated sweet potatoes found their greatest usage during World War II by the United States Armed Forces. The amount of dried sweet potatoes used by the United States Army was about 52 million pounds in 1944 (Edmond and Ammerman, 1971).

Molaison et al. (1962) introduced methods for production and evaluation of dehydrated diced sweet potatoes. Manlan et al. (1985) developed a method for drum drying of sweet potato roots which resulted in instant drum dried flakes. Hoover et al. (1983) and Walter and Hoover (1984) showed that patties cooked in peanut oil found acceptable quality and could be prepared from either freshly harvested or cured and stored roots.

Over the past several years, many efforts have been made to produce a high quality sweet potato chip (Baba et al., 1985; Hoover and Miller, 1973; Kelly and Baum, 1955). One problem resulting is "hard" chips, but this may be solved by blanching and freezing the slices before chip preparation (Baba and Yamamura, 1981b). Another problem encountered with chips is discoloration which has been attributed to increased levels of maltose in chips. Blanching has been found to inhibit the increase of maltose development and, hence, chip discoloration (Baba and Yamamura, 1981a).

Chapter III

Materials and Methods

I. Source and Type of Sweet Potatoes

One cultivar and two experimental breeding lines (hereafter referred to as cultivar) of sweet potato (Ipomoea batatas) were used to produce chips. The "Red Jewel" (RJ) cultivar was produced in North Carolina by a commercial grower and is used by a local processor to prepare sweet potato chips. The breeding lines "Southern Delite" (SD) and "W-221" (W2), were produced on The University of Tennessee Plant and Soil Science Laboratory at Knoxville. SD and W2 were developed at the USDA Station, Charleston, South Carolina. SD has orange-colored flesh, while W2 has yellow-colored flesh. The sweet potatoes were cured at 30C and relative humidity 85%-90% and stored at approximately 16 C and 70% relative humidity prior to processing.

II. Preparation of Sweet Potato Chips

Sweet potatoes were washed thoroughly with warm water and trimmed. The roots were cut in half around the equatorial area and sliced with an electric, stainless steel slicer along the longitudinal section at approximately 1.6 mm to 0.8 mm in thickness and 2.5 cm to approximately 7.5 cm wide. To minimize oil temperature drop during the frying process, 2.3 kg of strips of each cultivar were weighed and fried in these lots. Sweet potatoes were prepared and processed in stainless steel equipment to produce quality chips.

Partially hydrogenated soybean oil containing BHT, BHA, and an anti-foaming agent was used for frying. The initial temperature of the frying oil was raised to 149-154°C, then sweet potato slices were added. The addition of the slices lowered the temperature of the oil to approximately 125°C. When the oil temperature was increased to 135°C (approximately 5 min), the frying process was considered complete. After frying, the chips were placed into an oven at 66°C for 30 min to dry the chips. Upon removal from the oven, a 1% very fine particle salt (used in peanut butter manufacture) was added by hand to chips. An additional allotment from the same batches remained unsalted. This treatment resulted in treatments of salted and unsalted chips from RJ, SD, and W2. One treatment of each cultivar (salted and unsalted) was flushed with nitrogen after the chips had been packaged but before the package was sealed, leaving the other treatments (salted and unsalted) sealed with occluded air. The chips were placed in glass jars, sealed, and stored at 20°C away from light exposure for 0, 3, 6, and 9 weeks with analysis conducted at each of the periods.

III. Methods of Chemical Analysis

Following storage time at 20°C for the specified weeks, all chips were stored in a still-air freezer at -17 C until analyzed.

Proximate Analysis

Moisture. Moisture content was determined by the vacuum oven method (AOAC Method 22.018, 1980). Two-gram samples were dried to a constant weight at 100°C for 6 hours at 163 torr.

Ash. The samples were ashed in a Muffle Furnace operated at 580 °C The dry ashing method was used on a 2g sample (AOAC Method 32.012, 1980).

Crude Fat. Moisture-free samples (2g) were extracted with anhydrous ethyl ether for 24 hours using the Soxhlet method.

Crude Protein. Protein content was determined by the Kjeldahl method on 2g samples (% nitrogen X 6.25).

Dietary Fiber. Defatted, 2g samples were analyzed using an accelerated method (Prosky et al., 1985).

Nitrogen-Free Extract. Percentage of carbohydrate was calculated by subtracting the percentages of moisture, dietary fiber, crude protein, crude fat, and ash from 100%.

IV. Gross Energy Content

The gross caloric value was determined using a Parr Adiabetic Oxygen Bomb Calorimeter (Model 124). A 0.8g sample was used in the gross energy determination and values were reported in kilojoules (kj) per gram.

V. Methods of Physical Analysis

Texture Analysis

The Instron Universal Testing Machine (Model 1132) connected to a Shimadzu Chromatopac C-R3A integrator was used to determine the force required to break the chips. A 2.5 cm blade with a 3.2 mm thickness operating against an open groove 6.4 mm wide and 7.6 cm long was used. Ten chips were evaluated on each treatment with omission of highest and lowest values and averaged for each replication. A 5000gm capacity load cell was used, and the crosshead and chart speeds were set at 10 cm and 25 cm per minute, respectively. Values were reported as kilograms force to break the chips.

Color Analysis

The chip color was measured on all treatments using the Hunter Color Difference Meter (Model D25M-2). Values L, "a," and "b" were recorded for the chips. The samples were crushed and held in a cuvette with an optical glass bottom for the measurement. The meter was standardized against a white tile No. C2-21125 with L = 91.03, "a" = -1.3, and "b" = 1.6.

VI. 'Beta-Carotene Analysis

Beta-carotene content in the sweet potato chips was determined by a modification of the method of Holden (1985). Beta-carotene is a precursor of Vitamin A in the human body and was treated as an indirect measure of the vitamin.

Two gram samples were extracted with moisture free petroleum ether for 4 hrs. The ether was allowed to evaporate and the residue was dissolved in 25 ml high performance liquid chromatography grade hexane. The solution was filtered through a 0.45 micron filter, and 20 micro liters of the solution were injected into a HPLC. A Waters HPLC instrument (Waters Assoc., Milford, MA, Model 6000A solvent delivery system with a U6K injector) was used and vitamins were separated with a Waters Micro Bondapak C-18 column with a Z module. The detector used was 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 standard solution contained 0.002 mg/ml beta-carotene in hexane. Five micro liters and 25 micro liters of this solution were injected in triplicate to determine the calibration curve. The liquid phase used consisted of acetone-hexane (15:85) and the flow rate was 2.0 ml per minute. The results were reported in mg beta-carotene per 100 g sample.

VII. Sensory Analysis

Samples of sweet potato chips were analyzed by a descriptive analysis method of sensory evaluation to evaluate off-flavor, color, and crispiness of the chips. The panel consisted of faculty members and graduate students of food-oriented departments. The number of panelists evaluating the first and second batches were 7 and 9, respectively. The panelists were experienced and participated in an

orientation session before evaluation. The scale used was consistent with that designated by Larmond (1977) (See Appendix).

Samples of deep-fried sweet potato chips represented the three cultivars. Chips were stored at 22°C in glass jars for 9 weeks, at which time evaluation took place. The chips were coded with three digit random numbers and presented in random order to panelists in individual booths under white light. Panelists were instructed to evaluate off-flavor (any detectable rancidity) (1= No detectable off-flavor, 6= Strong detectable off-flavor), color (5 = Very dark orange, 1 = Very pale orange-yellow), and crispiness (5 = Extremely crispy, 1 = Not crispy) of the chips. The panelists were asked to evaluate chips, rinse with ambient temperature water and expectorate the residue. Evaluation took place at 2:30 P.M.

VIII. Experimental Design

The tests for texture, color, and moisture content of the chips were performed following a Randomized Complete Block design using a 3x2x2x2X4 factorial; three cultivars, two batches, two seasonings, two storage atmospheres, and four storage times. Data for ash, protein, gross energy, fat, beta-carotene, and total dietary fiber were analyzed according to a 3x2x2x2 factorial of a Randomized Incomplete Block design. Sensory evaluation was performed on all treatments of the 9 week storage period only.

The determination of any significant changes among variables was performed by Analysis of Variance (ANOVA). Significant differences among means were determined by the Student Newman-Keul (SNK) technique

at $p < 0.05$. The statistical analysis was performed using the Statistical Analysis System (SAS, 1982) program available through the IBM-CMS main frame computer at the University of Tennessee.

Chapter IV

RESULTS AND DISCUSSIONS

I. Proximate Composition of Raw Sweet Potato Flesh

The proximate components of raw sweet potatoes used in this study are presented in Table 1. Flesh of RJ, SD, and W2 contained 74.74%, 71.97%, and 76.21% moisture, respectively. All three cultivars had higher solids content than Irish potatoes which have a moisture content of 78.96%. On a dry weight basis (DWB) the sweet potato cultivars contained an average of 5.41% crude protein, 1.04% crude fat, 1.99% ash, 4.67% total dietary fiber, and 85.56% carbohydrate. These values compare to 9.83% crude protein, 0.48% crude fat, 4.23% ash, and 85.55% carbohydrate in an Irish potato. The proximate composition for the sweet potatoes is in close agreement with published values (Anon., 1983b).

II. Proximate Composition of Sweet Potato Chips

The average contents of moisture (1.75%), protein (4.56%), and fat (52.28%) were not significantly different ($p > 0.05$) among the three cultivars (Table 2). However, the sweet potatoes did contain approximately 10% more fat than Irish potato chips (Table 3). Factors affecting oil content of chips were: 1) dry matter content of potatoes, 2) thickness of slices, 3) type of fat, 4) temperature of fat during frying, 5) length of frying time, 6) blanching of slices, and 7) partial drying of raw slices. Probably the constituents which

Table 1. Proximate composition of raw, cured sweet potato flesh

Cultivar	Moisture[1]	Protein[2]	Fat[3]	Ash[2]	Fiber[2]	Carbohydrate[4]
Red Jewel	74.74	5.06 (1.28)	1.28 (0.32)	2.15 (0.54)	4.38 (1.11)	87.13 (22.01)
Southern Delite	71.97	5.42 (1.52)	0.90 (0.25)	1.86 (0.52)	5.56 (1.56)	86.26 (24.12)
W-221	76.21	5.74 (1.36)	0.95 (0.23)	1.96 (0.47)	4.05 (0.96)	83.29 (19.81)
Irish[5] potato	78.96	9.83 (2.07)	0.48 (0.10)	4.23 (0.89)	------	85.55 (17.98)

[1]Mean of 2 replications.

[2]Mean of 2 replications; calculated on dry weight basis; means in parentheses are calculated on the wet-basis.

[3]Mean of 3 replications; calculated on dry weight basis; means in parentheses are calculated on the wet-basis.

[4]Means calculated by difference on the dry weight basis; means in parentheses are calculated on the wet-basis.

[5]Anon., 1984b.

TABLE 2. Summary table for analyses of variance of means for the proximate composition of sweet potato chips

Source	d.f.	F-ratios				
		Moisture	Protein	Fat	Ash	Fiber
Cultivar	2	0.77^{ns}	0.63^{ns}	2.35^{ns}	5.17^{**}	4.78^{*}
Batch	1	5.38^{*}	0.04^{ns}	0.02^{ns}	0.20^{ns}	0.06^{ns}
Time	3	6.02^{**}	0.98^{ns}	1.85^{ns}	0.01^{ns}	0.01^{ns}
Error mean square =		0.138	0.555	3.73	0.158	0.221

*Significant at $p < 0.05$ level.

**Significant at $p < 0.01$ level.

^{ns}Not significant at $p > 0.05$ level.

TABLE 3. Proximate composition of sweet potato chips

Cultivar	Moisture[1]	Protein[2]	Fat[3]	Ash[2]	Fiber[2]	Carbohydrate[4]
Red Jewel	1.74[a]	4.52[a] (4.44)	51.53[a] (50.56)	2.25[a] (2.21)	4.38[b] (4.38)	37.32 (36.67)
Southern Delite	1.67[a]	4.27[a] (4.19)	53.20[a] (52.31)	1.76[b] (1.73)	5.18[a] (5.09)	35.59 (34.99)
W-221	1.83[a]	4.88[a] (4.79)	52.10[a] (51.15)	1.94[ab] (1.90)	4.67[b] (4.58)	36.41 (35.74)
Irish[5] potato	1.90	3.82 (3.75)	42.00 (41.20)	3.32 (3.26)	------	50.86 (49.89)

[1]Mean of 2 replications.

[2]Mean of 2 replications; calculated on dry-weight basis; means in parentheses are calculated on the wet-basis.

[3]Mean of 2 replications; calculated on dry-weight basis; means in parentheses are calculated on the wet-basis.

[4]Means calculated by difference on the dry-weight basis.

[5]Means analyzed for a commercial Irish potato chip.

[ab]Means followed by like superscripts within a column are not significantly different at $p > 0.05$ level.

comprised the dry matter content of the potatoes absorbed oil at different rates and amounts during the frying process. This could account, in part, for the differences in oil content of the chips (Smith, 1977). The average ash and fiber contents were significantly different among the cultivars. The RJ chips contained a higher ash content (2.25%) and lower fiber content (4.38%) than SD chips with 1.76% ash and 5.18% fiber, but the RJ chips were similar to W2 with 1.94% ash and 4.67% fiber (Table 3). SD chips were not significantly different from the W2 chips in ash content, but were higher in fiber content.

There were no significant differences in the proximate compositions between the batches or among the storage times except in the average moisture contents (Table 2). The average moisture content for batch 1 was 1.67% and was significantly lower than the 1.97% found in batch 2 (Table 4). The difference between the two batches might be accounted for in the differences in the drying time in the oven following frying. The first batch was dried for a longer period of time (30 min) than the second batch (20 min) which would lead to a reduced moisture content. The moisture content decreased in the chips between the 0 storage time and 3 weeks of storage, and then remained unchanged after 6 or 9 weeks of storage (Table 4). This could be due to loss of moisture from the chips into the atmosphere in the jars. Once the chips and atmosphere reached equilibrium during the first three weeks, there was no significant change in moisture content during the remaining weeks of storage.

TABLE 4. Effect of batch and time of storage on average moisture contents of sweet potato chips

MOISTURE[1] (%)					
Batch		Storage time, weeks			
1	2	0	3	6	9
1.67[a]	1.97[b]	2.35[a]	1.57[b]	1.78[b]	1.63[b]

[1] Means calculated from 48 observations.

[ab] Means within each treatment followed by like superscripts are not significantly different at $P > 0.05$ level.

In comparison to sweet potato chips, commercial Irish potato chips contain 1.90% moisture, 3.82% crude protein, 42.00% crude fat, 3.32% ash, and 50.86% carbohydrate. Means for crude protein, crude fat, and total dietary fiber were not significantly different ($p > 0.05$) due to atmosphere and presence of salt.

III. Gross Energy Content

The average gross energy values of the raw sweet potato flesh, sweet potato chips, and commercially prepared Irish potato chips are presented in Table 5. Raw sweet potato flesh for RJ contained 552 kj/100g, SD contained 481 kj/100g, and W2 contained 451 kj/100g, all on a dry weight basis.

Sweet potato chips from RJ, SD, and W2 contain 2497, 2347, and 2389 kj/100g on the dry basis, respectively. Irish potato chips had 1958 kj/100g on a dry weight basis. This value is lower than that of sweet potato chips. Differences in the gross energy content of samples are due to the variation in the proximate composition of the dry matter (Table 3). Since fat has a higher energy value than carbohydrate and protein, samples that contain higher percentage of fat exhibit a greater gross energy content. The difference of greater than 389 kj/100g in energy content is due to the greater amount of oil absorbed by the flesh of sweet potato. The difference could be due to processing methods of the chips, since Irish potato chips are usually fried at higher temperatures and for shorter times than what was utilized for the sweet potato chips.

TABLE 5. Mean[1] gross energy contents of raw sweet potato flesh, chips, and commercial Irish potato chips

Cultivar	Raw (kj/100g)[2]	Chips (kj/100g)
Red Jewel	552	2498[a]
Southern Delite	481	2347[c]
W-221	452	2389[b]
Irish Potato Chips	---	1958[d]

[1]Mean of 8 observations; mean of 2 observations for Irish potato chips.

[2]Kilojoules per 100 gram on the dry matter basis.

[a-d]Means followed by like superscripts are not significantly different at $p > 0.05$ level.

IV. Beta-Carotene Content

The average values for the beta-carotene content of the raw sweet potatoes and chips are given in Table 6. The beta-carotene content for the raw sweet potatoes compared favorably with published values (Anon., 1982). The beta-carotene in the chips had a mean 28.33% reduction when compared to the raw sweet potatoes. The beta-carotene content of the RJ cultivar dropped 30% from 18.18 mg/100g raw sweet potato to 12.61 mg/100g in the chips during the 5 minutes of deep-fat frying. The beta-carotene content (DWB) of SD cultivar dropped 25% from 31.67 mg/100g in raw to 23.87 mg/100g for chips. A 30% drop was observed in the beta-carotene content of the W2 where the level dropped from 16.71 mg/100g to 11.60 mg/100g. The F-ratios for the analysis of variance of the beta-carotene content of the raw sweet potatoes and the deep-fried chips are presented in Table 7. The beta-carotene content of SD was found to be significantly higher than the RJ and W2 (Table 6).

According to the results shown in Table 8 where mean values for the beta-carotene content of the sweet potato chips are presented, unsalted chips had a 25% higher amount of beta-carotene than salted chips. The value of unsalted chips was 16.63 mg/100g (DWB) and 12.41 mg/100g (DWB) for salted chips. It was also observed that chips kept under nitrogen retained a higher amount of beta-carotene (16.06 mg/100g), while the chips stored under air decreased in beta-carotene content (11.77 mg/100g), resulting in a 26.7% reduction.

The mean values for beta-carotene in batch 1 was lower (2352 R.E.) than batch 2 (2388 R.E.). Collins et al. (1974) reported that

TABLE 6. Mean values of beta-carotene content in raw and sweet potato chips

	RAW			CHIPS		
Cultivar	mg/100g[1]	R.E.[2]	I.U.[3]	mg/100g	R.E.	I.U.
Red Jewel	18.18[b]	3030.62[b]	30,306.17[b]	12.61[b]	2102.90[b]	21,029.00[b]
Southern Delite	31.67[a]	5278.58[a]	52,785.80[a]	23.87[a]	3978.20[a]	39,782.00[a]
W-221	16.71[b]	2785.63[b]	27,856.30[b]	11.60[b]	1933.60[b]	19,336.00[b]

[1]Indicates the values reported to be on a 100% dry weight basis.

[2]R.E. = Retinol Equivalents.

[3]I.U. = International Units.

[4]Stored for 9 weeks at 20°C.

[ab]Means within each column followed by same letter are not significantly different at $p > 0.05$ level.

TABLE 7. F-ratios for the analyses of variance of beta-carotene content of raw sweet potatoes and chips

Source	df	F-values
Cultivar	2	85.60**
Seasoning	2	31.91**
Cultivar*Seasoning	4	5.30*
Error mean square =		78549.60
Cultivar	2	175.52**
Atmosphere	2	83.17**
Cultivar*Atmosphere	4	4.09*
Error mean square =		38307.50
Cultivar	2	16.44**
Batch	2	4.73*
Cultivar*Batch	4	0.10ns
Error mean square =		408990.00

*Significant at $p < 0.05$ level.

**Significant at $p < 0.01$ level.

nsNot significant at $p > 0.05$ level.

TABLE 8. Mean retinol equivalents of the three sweet potato cultivars for beta-carotene content affected by atmosphere and presence of salt

Source	Cultivar		
	RJ	SD	W2
Atmosphere			
Air	1605[a]	2938[b]	1340[b]
Nitrogen	2119[a]	4367[a]	2100[a]
Seasoning			
Salted	1998[a]	2938[b]	1340[b]
Unsalted	1848[a]	4368[a]	2100[a]

[ab]Means within a cultivar treatment block followed by like superscripts are not significantly different at $p > 0.05$ level.

the carotene content of fresh roots increased during storage at 16°C. Ezell and Wilcox (1952) also found an increase in the carotene content in five out of six cultivars during storage. In contrast, Brady (1976) found that for color as determined by a color difference meter the "a" value decreased in the first week of storage, then increased as the storage was extended to five weeks. Carotenes are responsible for the color of sweet potatoes. An interaction between harvest date and changes in beta-carotene levels has been indicated (Anon., 1980).

These results show that the chips under the effect of salt and air loose the beta-carotene content possibly attributable to oxidation. At the same time, the loss of beta-carotene during processing is appreciable but cannot be prevented (28% loss). This loss added to the loss in storage will total an average of 50% which is to be noted since the sweet potato chips could be a prominant source of beta-carotene. Some suggested ways to control this loss may be decreased light exposure, leaving chips unsalted, and storing under nitrogen. DeRitter (1976) stated that carotenes are sensitive to oxidation, and the decomposition is accelerated by increasing temperatures and the presence of mineral ions.

V. Physical Properties

Texture Analysis

The F-ratios for the analysis of variance of the effect of the treatments on the texture of the chips are presented in Table 9. The only significant difference in texture occurred among the different cultivars. As presented in Table 10 the mean force necessary to

TABLE 9. F-ratios for analysis of variance of the effect of the treatments on the crispiness of chips

Source	df	F-values
Cultivar	2	3.70*
Batch	1	0.38ns
Salt	1	0.11ns
Atmosphere	1	0.06ns
Time	3	2.43ns
Error mean square =		5124.87

*Significant at $p < 0.05$ level.

nsNot significant at $p > 0.05$ level.

TABLE 10. Force required to break chips of different cultivars of sweet potatoes

Cultivar	gm force[1]
Red Jewel	327[b]
Southern Delite	367[a]
W-221	379[a]

[1]Mean of 32 observations.

[ab]Means followed by like superscripts are not significantly different at p> 0.05 level.

break a sweet potato chip (fracturability) was 379g for W2, 367g for SD, and 327g for RJ. Sixteen percent more force was required to break W2 chips and 12% more force was required to break SD chips than was required for RJ chips. The difference in the hardness of the cultivars might be explained by the percentage of solids present in the different roots. SD and W2 had higher amounts of solids than RJ.

The fracturability of a regular Irish potato chip was 138g. This shows that compared to the sweet potato chip which requires an average of 358g of force to break, the white chips are much less hard. This hardness has been attributed to the blister formation on the surface of the chips during frying. Blistering of chips is a result of cell separation due to expansion of steam trapped within the slices when the surface becomes dehydrated and sealed (Baba, 1981a, 1981b). Properties of naturally occurring polymers are involved in textural perceptions of foods. These polymers such as starch, pectin, cellulose, and hemicellulose, are present as gels. Textural properties are dependent upon the way in which these structural components are arranged (de Man, 1976). During the frying process, the frying oil replaces some of the water in the tissue. Oil is placed mainly in cell walls, intercellular spaces, and blister areas (Reeve and Neel, 1960). Due to the hardness in the sweet potato chip, research has been focused on reducing the hardness of the chips.

One method to improve textural characteristics of chips is by blanching. Blanching gelatinizes starch and causes some cellular disruption, which results in 1) a more uniform color, 2) reduction in fat absorption when it gelatinizes the surface layer of starch,

3) reduction of frying time, and 4) improved textural properties (Feustel and Kueneman, 1975; Madamba et al., 1975).

Color Analysis

The F-ratios for the analysis of variance of the effect of the treatments and cultivars on the color of the chips are presented in Table 11. Means for the effect of the experimental factors on the Hunter color values of sweet potato chips are presented in Tables 12 and 13. W2 had an L value which was higher than the values for RJ and SD; all values were significantly different ($p < 0.05$) (Table 12). These values indicate that the degree of lightness was higher in W2 than the other two types of chips. The color of chips is attributed to carotenoids. The lighter the color, the lower the content of carotenes. This is also shown in Table 7. The W2 cultivar was more yellow than red with an "a":"b" ratio of 0.6 compared to 0.7 for SD and RJ. The "a" value was significantly lower ($p < 0.05$) in W2 chips than the other two cultivars. W2 had an "a" value of 14.53; SD 16.89, and RJ 16.62. This indicates that W2 had a lower amount of red coloration present in the chips compared to the other two types of chips. In contrast, the "b" value was not significantly different ($p > 0.05$) among the cultivars. A significant difference ($p < 0.05$) also was shown to exist between the batches in color values. Batch one had values of 38.58, 16.83, and 21.96 and batch two had values of 39.89, 15.20, and 28.10 for L, "a", and "b" values respectively (Table 12).

Average values for "a" steadily decreased during storage when under air from 17.90 at 0 weeks to 14.50 after 9 weeks (Table 13). However, "a" values did not show a significant change ($p > 0.05$) after

TABLE 11. F-ratios of the analysis of variance for measurements of color of sweet potato chips

Source	df	L	"a"	"b"
Cultivar	2	14.30**	23.20**	2.66ns
Batch (B)	1	4.47*	27.63**	86.92**
Saltiness (S)	1	1.03ns	0.50ns	3.70ns
Atmosphere (A)	1	0.01ns	13.23**	2.77ns
Time (T)	3	0.47ns	10.27**	2.96ns
S*A	1	0.65ns	0.29ns	3.76*
B*A	1	6.97**	0.07ns	7.17**
A*T	2	0.79ns	8.47**	0.61ns
Error mean square =		7.00	1.91	7.75

*Significant at $p < 0.05$ level.

**Significant at $p < 0.01$ level.

nsNot significant at $p > 0.05$ level.

TABLE 12. Means for the effect of some experimental factors on Hunter color values of sweet potato chips

Source	L	"a"	"b"
Cultivar [1]			
Red Jewel	37.28[c]	16.62[a]	23.96[a]
Southern Delite	39.10[b]	16.89[a]	25.50[a]
W-221	41.33[a]	14.53[b]	25.62[a]
Batch [2]			
1	38.58[b]	16.83[a]	21.96[b]
2	39.89[a]	15.20[b]	28.10[a]
Seasoning [1]			
Salted	39.50[a]	15.97[a]	25.42[a]
Unsalted	38.97[a]	16.06[a]	24.63[a]
Atmosphere [1]			
Air	39.26[a]	15.49[b]	24.52[a]
Nitrogen	39.21[a]	16.62[a]	25.62[a]

[1] Means of 32 observations.

[2] Means of 48 observations.

[ab] Means within each column and treatment followed by like superscripts are not significantly different at $p > 0.05$ level.

TABLE 13. Effect of time of storage and air on Hunter color values of sweet potato chips

Time	L	"a"	"b"
0	39.30[a]	17.90[a]	21.72[a]
3	39.00[a]	16.40[a]	25.70[a]
6	38.80[a]	14.40[b]	25.32[a]
9	39.90[a]	14.50[b]	24.00[a]

[1] Means of 24 observations.

[ab] Means within a column followed by like superscripts are not significantly different at $p > 0.05$ level.

9 weeks when under nitrogen. This finding is in contrast with the reported values by Collins et al. (1974) and Ezell abnd Wilcox (1952) where they found an increase in the "a" value. Brady (1976) found that the "a" value decreased in the first week of storage, then increased as the storage was extended to five weeks.

The findings of this study may be attributed to the oxidation of beta-carotene content. The significant interaction between saltiness of the chips and atmospheric condition (Table 11) was due to the increase in "b" value for unsalted chipe under nitrogen compared to those under air (Table 14). The lower "b" value may be attributed to beta-carotene oxidation under air. The significant interactions seen for the two batches and atmospheric condition seem to be attributed to the differences in the batches (Table 14). The difference in the batches may be due to the compositional changes of the roots before processing. This has been further discussed under proximate composition of roots and chips.

VI. Sensory Analysis

F-ratios of the analysis of variance for sensory evaluation of sweet potato chips based on off-flavor, color, and crispiness are presented in Table 15. Flavor scores of each cultivar show that it was not negatively influenced by the storage atmosphere or differences in salting. In regard to color of the chips, the panel found significant differences ($p < 0.05$) among the cultivars. The mean panel scores for flavor, color, and crispiness are presented in Table 16. W2 was rated as a slightly pale orange-yellow (3.25), SD rated as

TABLE 14. Mean values for the effect of batch and atmosphere on Hunter color value of sweet potato chips

Treatment	L	"a"	"b"
Batch 1			
Air	39.3[a]	16.3[b]	22.3[a]
Nitrogen	37.6[a]	17.4[a]	21.5[a]
Batch 2			
Air	39.1[a]	14.7[b]	26.7[b]
Nitrogen	40.8[a]	15.8[a]	29.7[a]

[ab] Means within each column and treatment followed by like superscripts are not significantly different at $p > 0.05$ level.

TABLE 15. F-ratios for the analysis of variance of the effect of flavor, color, and crispiness of sweet potato chips on sensory scores

Source	df	Off-flavor	Color	Crispiness
Cultivar (C)	2	0.43 ns	20.17 **	1.41 ns
Batch	1	2.14 ns	0.21 ns	1.38 ns
Seasoning (S)	1	2.23 ns	-----	-----
Atmosphere	1	0.05 ns	-----	-----
C*S	2	2.92 ns	-----	-----
Error mean square =		1.03	1.01	0.73

** Significant at $p < 0.01$ level.

ns Not significant at the $p > 0.05$ level.

TABLE 16. Mean[1] sensory scores for the effect of some experimental factors on flavor, color, and crispiness of sweet potato chips

Source	Off-flavor[2]	Color[3]	Crispiness[4]
Cultivar			
Red Jewel	1.92[a]	5.50[a]	4.06[a]
Southern Delite	1.95[a]	4.31[b]	3.75[a]
W-221	1.80[a]	3.25[c]	4.25[a]
Batch			
1	2.01[a]	4.43[a]	3.86[a]
2	1.80[a]	4.30[a]	4.15[a]
Seasoning			
Salted	1.78[a]	-----	-----
Unsalted	2.00[a]	-----	-----
Atmosphere			
Air	1.91[a]	-----	-----
Nitrogen	1.88[a]	-----	-----

[1]Means of 64, 84, 96, and 96 observations for cultivar, batch, seasoning and atmosphere, respectively.

[2]1 = no detectible off-flavor and 2 = slightly detectible off-flavor.

[3]3 = slightly pale orange-yellow and 5 = moderately dark orange-yellow.

[4]3 = moderately crispy and 4 = very crispy.

[ab]Means within the each class and each treatment followed by like superscripts are not significantly different at the $p > 0.05$ level.

slightly dark orange-yellow (4.31) and RJ was moderately dark orange-yellow (5.50) in color. The mean panel scores for crispiness showed no significant difference among the cultivars ($p > 0.05$), and mean scores were from 3.75 to 4.25 which was 'moderately crispy' to 'very crispy.' In regard to off-flavor, salted chips (1.78) showed no difference in detectable off-flavor from unsalted chips (2.00) with both containing a slight off-flavor.

From these findings, it was determined that after a period of 9 weeks, slight off-flavor seemed to be detectable and saltiness appeared to help cover any possible occuring off-flavor. Sweet potato chips showed high crispiness, and only color in chips was significantly different from one another. This study also revealed that atmospheric conditions had no effect on the off-flavor development of the chips in the 9 week storage period.

CHAPTER V

CONCLUSIONS

Sweet potato chips produced from three cultivars showed no significant difference in proximate compositions. The total dietary fiber of "Southern Delite" (SD) was significantly higher than that of "Red Jewel" (RJ) and "W-221" (W2). Moisture content decreased within storage time and reached a constant level. Beta-carotene content was significantly different among cultivars, SD having the highest concentration. Beta-carotene content decreased in chips that were salted and stored under air over storage time, possibly due to oxidation. Fracturability of W2 was least since it required more force to break than the other two cultivars.

L and "a" values were significantly different among cultivars; "a" changed due to atmosphere and time of storage. The color for W2 was lighter than SD and RJ and was more yellow than red with an "a":"b" ratio of 0.6 compared to 0.7 for SD and RJ.

The sensory panel found all chips to be very crispy. They also found a slightly detectable off-flavor in the chips that were stored for 9 weeks with no significant differences due to salting or storage atmosphere. The panel rated the W2 chips as a slightly pale orange-yellow, the SD sweet potato chips were slightly dark orange-yellow, and the RJ chips were moderately dark orange-yellow in color.

In reference to the overall quality of chips, the SD cultivar had potentially better chipping characteristics than the two other cultivars. SD was higher in nutritional value and lighter in color in comparison to RJ, which is commercially used. W2 was lower in nutritional value than the other two cultivars, but produced lighter color chips.

This study showed the potential that exists for production of sweet potato chips. Further research should determine the following:

1) "Poor processing" cultivars;
2) Various thicknesses for high quality chips;
3) Differences of roots grown at one location and under the same cultural practices;
4) Effect of additives to improve color of chips and inhibit randcidity;
5) Reduction of oil in samples by the use of various processing methods;
6) Various oil temperatures in frying with different times of frying;
7) Blanching of slices prior to frying, and
8) Processing at different intervals to document the point that roots become unacceptable for processing.

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APPENDIX

Product: Sweet Potato Chips

You have been presented with three samples of sweet potato chips. Please evaluate the samples on the basis of their color, texture, and flavor in the given order using the scales provided. For each sample, first evaluate color visually, then texture and flavor during mastication.

Texture - a crispy chip is one that fractures readily upon biting

Flavor - an off-flavor is characterized as any dectection of rancidity in the chips.

Make a check ( ) under the appropriate sample column corresponding to the phrase that best matches your judgement. Please take a drink of water in between samples to clear your palate.

COLOR

Scale	Code	Code	Code
Very dark orange-yellow			
Moderately dark orange-yellow			
Slightly dark orange-yellow			
Slightly pale orange-yellow			
Moderately pale orange-yellow			
Very pale orange-yellow			

TEXTURE

Scale	Code	Code	Code
Extremely crispy			
Very crispy			
Moderately crispy			
Slightly crispy			
Not crispy			

FLAVOR

Scale	Code	Code	Code
No detectable off-flavor			
Slightly detectable off-flavor			
Moderately detectable off-flavor			
Strong detectable off-flavor			
Very strong detectable off-flavor			

VITA

Koorosh Bozorgmehr was born in Tehran, Iran, on October 20, 1960. He attended secondary school at Sokhan High School of Tehran where he later entered Melli University. In September of 1979, he enrolled in the Agricultural Engineering Department of the University of Tennessee, Knoxville, as an undergraduate. He received a Bachelor of Science (with honors) in June, 1983. In September 1984, he entered in the graduate program and since then he has been working towards completion of the requirements for the degree of Master of Science in Food Technology and Science.

He is a member of the Food Technology Club of the University of Tennessee, the Institute of Food Technologists and the American Society of Agricultural Engineers..