SWEET POTATO FLAKES: A Study of their Development and Usage with Dried Whey in Pies

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INTRODUCTION

Within recent years, the per capita consumption of sweet potatoes has been drastically reduced. Since this is the second largest vegetable crop in the United States, the drop in consumption has had grave economic consequences, particularly in the South.[1] To aid the industry, the United States Department of Agriculture undertook numerous research projects on the sweet potato itself and its production, processing, marketing and consumption.

Being the second largest producer of sweet potatoes, North Carolina has been immensely interested in this work and has been actively engaged in the research studies.[2] One outcome of the research conducted at North Carolina State University, Raleigh, N. C., was the development of a dehydrated sweet potato flake.

Sweet potatoes have long been valued for their excellent flavor, nutritive content, and their versatility in food preparation. The flake form seems to have eliminated two of the factors, i.e.,poor keeping qualities of the fresh produce and the long preparation time, that has previously limited their use. Therefore, it is expected that the consumption of sweet potatoes will increase once this product gains public acceptance.

This study has had a two-fold purpose: To study the production and properties of dehydrated sweet potato flakes and the possible effects that this new product might have on the sweet potato industry; and to determine

the effects that using the flakes and dried whey would have on the palatability factors of sweet potato pie.

In order to gain an adequate understanding of the implications that this new product can have on sweet potato production, marketing and consumption, it has been necessary to review material in these areas as well as the literature that dealt with the manufacture and utilization of the sweet potato flake itself.

PART I. Development and Properties of Sweet Potato Flakes.

SWEET POTATO PRODUCTION

Sweet potatoes are grown in twenty-two states, but their commercial production is concentrated in the South.[3] According to USDA figures, seventy-nine per cent of the total United States poundage is produced by this region.[4]

Although there are numerous varieties of sweet potatoes grown, all fall into two general classes. The dry or Jersey type is characterized by its retention of a firm flesh after cooking. It is the preferred sweet potato in the North. The moist type, commonly called "yam", is the favorite of the South. After cooking, its flesh becomes soft and juicy.

Despite the fact that varieties with higher nutritive value, greater color, and better yields have been developed, the Porto Rico continues to be the principal variety grown in the South. Jenkins and Giger attribute this practice to the fact that long use has conditioned the consumer and the producer to demand the flavor of the Porto Rico variety in a quality potato.

Sweet potatoes are harvested in the late summer or early fall. They are very easily cut and bruised, and extreme care must be exercised in handling them. Consequently, mechanical means for harvesting have not proven to be very satisfactory, and most of the work must still be done manually.

In 1958, the USDA recommended the following harvesting procedure: Use a 16" to 18" tractor drawn turning plow with a vine colter in front of it for digging. After the roots have been plowed out, "those that remain covered should be scratched out by hand. Gloves should be worn to prevent damage to the sweet potato by fingernails." Then the potatoes should be picked up manually, graded and placed in storage baskets.[6] Obviously, such a method of harvesting is costly, back-breaking, and time consuming.

In order to employ mechanized harvesting, either a digger must be designed which will not cause any damage to the tubers or a means of utilizing sweet potatoes damaged in harvesting must be developed. The dehydrated sweet potato flake, as will be explained later, may partially fulfill the latter need.

The freshly harvested potatoes are placed in storage rooms for curing. Research has revealed that a curing temperature of 85° and relative humidity of 90% are required if the curing is to proceed at an optimum rate and to yield the best potatoes.[5] Hoover recommends that this room be well ventilated in order to avoid an excessive build-up of CO_2.[7]

Several research studies have been conducted to determine the length of time required for curing. There is considerable variance in their findings. Hoover recommends seven to ten days.[7] In their research study, Jenkins and Giger found that most of the desired changes

occur within the first six days. Consequently, they believe that a curing period of six days is adequate.[5] Lutz and Simmons advocate a curing period of four to seven days if the temperature is maintained at 85°. If lower temperatures are used, they suggest correspondingly longer curing periods.[6]

Curing increases the sugar content and improves the keeping qualities of the tubers. When harvested, the sweet potato is composed principally of starch. Through enzymatic hydrolysis, the starch is converted to sugar, mainly maltose and dextrin. Although this conversion occurs at room temperature, the rate is much more rapid at a higher temperature.[8] Because the potato with a high sugar content is more flavorful, it is desirable to secure as much hydrolysis as possible prior to cooking. Consequently, an elevated temperature for a period immediately after harvesting is recommended.

A major problem in sweet potato production has been the high loss of the produce in storage. Sweet potatoes are harvested in the early fall. However, the majority of the crop moves to the market between November and June. As a result, the producer frequently has to store his crop as much as six months before selling it. During this time, a loss of twenty per cent is not uncommon and it sometimes amounts to fifty per cent or more.[6] Most of this loss is due to the development of storage rot. Although there are several forms of rot, Cook and

Hildebrand report that most of them are caused by fungus growth.[9]

The sweet potato has a thin delicate skin that is easily broken and bruised. Even with extreme caution, considerable cutting and bruising occurs during harvesting and subsequent handling. In addition, there are necessarily two small wounds on each tuber where it was disengaged from the mother plant. Each of these breaks in the skin is potentially a spot for the disease producing organisms to enter.

Under the proper conditions, a corky layer of new cells will form under a wound. Research conducted by the USDA has demonstrated that this wound-cork greatly retards infection and actually prevents it to a large degree. Fortunately, the temperature and humidity conditions that promote the development of this layer are approximately the same as those which are optimum for starch hydrolysis.[9]

If the producer properly cures his tubers, he can to a considerable degree control the development of storage rot at wounds produced prior to curing. However, any further wounds incurred after curing are still susceptible to fungi penetration.

Evidently considerable damage to the tubers must occur in marketing and shipping. In his study, Badger found that the average decay loss upon arrival at the store ranged from two to five pounds per bushel. There

was a three pound per bushel loss within the store itself.[10] The major portion of this storage rot must have developed after marketing because a farmer would not be expected to market a damaged product.

CONSUMPTION AND UTILIZATION OF SWEET POTATOES

It was previously noted that the per capita consumption of sweet potatoes has rapidly declined within recent years. The table below indicates that this downward trend began in the 1920's and has rapidly accelerated except for slight rises during the depression years 1930-1935 and the war years 1943-1945. The former rise was probably partially due to the relative inexpensiveness of the food. During the war years sugar was limited, and the sweet potato was an available substitute for desserts and sweets.

Table 1. Per Capita Consumption of Sweet Potatoes, 1910-1960[4]

Year	Pounds
1910	27.7
1915	26.5
1920	30.8
1925	19.0
1930	19.2
1935	26.4
1940	17.0
1943	22.2
1945	19.5
1950	13.4
1955	9.6
1960	7.7

Around 1946-47, there were several marketing surveys made by the USDA. One such study was conducted by Abrahamsen on the consumer preferences for sweet potatoes in selected North Carolina cities.[11] Baker conducted a

marketing survey in certain Louisiana cities and Chicago.[12] Baker made a follow-up survey in Pittsburgh to determine if his original survey's findings were representative of nationwide consumption practices.[13] Because the results of these surveys suggest possible reasons for the continuing consumption decline and indicate what is requisite for the sale of sweet potatoes and sweet potato products, some of their findings will be briefly described.

In all three studies, the data was based on the customers who actually purchased sweet potatoes rather than on the total customer volume during the survey period.

Abrahamsen found that eighty percent of the customers were women. Eighty-five per cent of the 3,032 customers interviewed in Baker's initial study were women. It seems safe to conclude with Baker that it is "chiefly the housewife with her preferences who will determine the kind of sweet potato best suited to retail trade."

Baker found that the housewife in Louisiana and Chicago served sweet potatoes an average of 2.2 days per week. Pittsburgh housewives served them 2.1 days. In North Carolina, the average was 2.6 times per week. Because these figures are nearly twenty years old and the per capita consumption is much less, one is inclined to question their validity today. No recent research has been done in this area. However, the above figures do seem to indicate that if people like sweet potatoes, they do not object to serving them frequently.

Abrahamsen found that the sweet potato purchases tended to decrease as the income increased. The weekly sweet potato purchase in the lowest income group was 45% higher than in the highest income group. This inverse relationship seems to still hold true today. In a 1956 study, Badger observed that the store which had the lowest sales volume of sweet potatoes was located in the highest income residential area, whereas the store with the greatest sales volume was in a fairly low income residential area.[10] The USDA consumption report released in 1961 stated that with the exclusion of canned sweet potatoes, the use per person averaged more in households with less than $4,000 income than in those with incomes of $4,000 or more.[4]

Abrahamsen and Baker attempted to ascertain the methods of cooking most frequently used. Abrahamsen asked the consumers to name, in order of their frequency of use, four ways in which they served sweet potatoes. The majority ranked them in this manner: baking, candying, custards or pies, fried, puddings, boiled and other.

In Louisiana and Chicago Baker found that the order of preference was oven bake, candy, fry with meat and pies, puddings and casseroles. The Pittsburgh study agreed with this order except that cooking with meat was slightly favored over frying.

It seems significant that the easiest method of preparation, i.e., baking, was greatly preferred in each

study. However, it should be noted that these studies were made immediately after World War II. The wartime sugar shortage had no doubt limited the use of such methods as custards, pies, puddings and casseroles and increased the serving of baked sweet potatoes. At the time of the surveys, the housewife was probably still conditioned to thinking in terms of this latter method of preparation.

Abrahamsen noted that consumers generally followed the practice of purchasing sweet potatoes at least once a week. He attributed this practice to limited storage space in the home, uncertainty of quality and the possibility of spoilage.

In bulk displays, Badger reported that the consumer showed a distinct preference for a medium size potato, i.e., one weighing from six to ten ounces. It was observed that "Any sweet potato larger than 3" or 3¼" in diameter is likely to be left in the display."[10]

DEVELOPMENT OF DEHYDRATED SWEET POTATO PRODUCTS

Although the sweet potato flake is a relatively new product, the basic idea of drying cooked sweet potatoes is evidently very, very old. Elizabeth H. Sparks has described a method for drying sweet potatoes that was employed by the early settlers in this region in her cook book, NORTH CAROLINA AND OLD SALEM COOKERY. The women would cook and mash the potatoes. They were then "dropped in little mounds on a cloth and dried in the hot sun."[14]

There seems to have been little interest in the commercial production of dehydrated sweet potatoes until the second World War. At that time, research on dehydration, particularly of vegetables, was greatly accelerated. Various techniques for dehydrating were suggested and attempted.

In DRYING AND DEHYDRATION, published in 1943, von Loesecke has described three different forms of dehydrated sweet potatoes that had been developed at that time: dehydrated slices, cubes and strips; riced sweet potatoes; and sweet potato powder.

The dehydrated slices, cubes, or strips were made by first cutting the peeled raw sweet potato into the desired shape. These pieces were blanched for six minutes to inactivate the peroxidase and then dried at 165° until the moisture content was 7% or less.[15] The resulting products were not cooked. In order to use either the dehydrated slices or cubes, it was necessary to

rehydrate them by soaking in boiling water for about 45 minutes. After rehydration, they were cooked until tender. The slices required approximately 15 minutes to cook and the chips 30 minutes or more.[16] The total preparation time for boiled potatoes ranged from one hour to one hour and fifteen minutes.

That form of dehydrated sweet potato had the advantage that the cooked form retained a definite shape. Consequently, any of the preparation methods for cooked fresh sweet potatoes could be used with the product. However, efficient drying demanded that the pieces not be too massive--(3/16" to 6/10" thick slices with 3/16" to 6/10" sides recommended).[15] There were many who objected to the "small" cubes and "thin" slices.

Riced sweet potatoes were prepared by extruding fully cooked sweet potatoes into thin bands or ribbons and then subsequently dehydrating them by toasting.[17] This method of dehydration was developed at the Alabama Agricultural Experiment Station. Riced sweet potatoes were different from any other sweet potato product and were not designed for use in traditional sweet potato dishes. When it emerged from the oven, the product resembled a candy or cooky. This could be served as a breakfast cereal, snack food, or crumb topping. The riced sweet potatoes were also ground into a flour, called Alamalt. This flour was used successfully in cakes, icings and ice cream.[18, 19, 20]

The sweet potato powder described by von Loesecke

was the forerunner of the sweet potato flake. The method of preparation was very similar to that currently used for the flake. However, von Loesecke believed the sweet potato powder had little potential because it lacked a definite shape.[15]

During the war years, the Armed Services purchased large amounts of the dehydrated sweet potatoes, mainly the sliced and cubed forms, and the industry flourished. However, in 1946, the commercial production ceased because the Armed Service contract was terminated and the civilian market exhibited little interest in the products.[3]

Interest in reactivating the dehydrated sweet potato industry began in the early 50's. At the present time the dehydrated sliced and cubed potatoes are being produced commercially. Sullivan, Cording and Eskew have developed a method of puff drying which cuts down on the preparation time considerably. The partially dried cubes are exploded under pressure from a puffing gun, in a manner similar to that used with breakfast food. When the product is boiled two to five minutes, it regains the original shape and possesses the flavor and color of freshly cooked sweet potatoes.[21]

Dr. Hoover and his associates began working to improve the powdered product. Largely, as a result of their research efforts, the flaking process was perfected and pilot plants were established in North Carolina. In

September, 1964, flakes became available on a nationwide basis.[22]

PRODUCTION OF SWEET POTATO FLAKES[7]

Raw Materials

Almost any of the "yam", or moist type varieties of sweet potatoes can be used in the manufacture of sweet potato flakes, although extra processing techniques are sometimes necessary with certain varieties. A raw potato with good flavor and a high carotene and sugar content is necessary for the production of a quality flake.

The sugar content of the raw potato is especially important. Jenkins and Giger have suggested that flavor differences in sweet potatoes may largely be a function of the amount and kinds of sugars present. Even very minute differences seem to greatly affect the flavor.[5]

The factors that determine the sugar content are variety, curing period, and the length and conditions of storage. Various studies have revealed that the type and particularly the amount of sugar varies with the variety.

Earlier it was stated that the curing process increased the sugar content by accelerating the enzymatic starch hydrolysis. Therefore, one would expect that cured sweet potatoes are preferred for flake manufacture. However, a starch conversion process developed by Hoover will permit the utilization of the uncured potatoes.

Although curing causes more rapid starch hydrolysis, the reaction will occur at lower temperatures. Consequently, sweet potatoes that have been stored for a

considerable period after curing will have an appreciably higher sugar content than they had immediately after curing.[5]

In order to produce a consistent product, the sugar content must be controlled. Sometimes the desired content is attained by blending different varieties or by adding sugar. However, Hoover has developed recently a manufacturing process which can be utilized to control this variable. Alpha amylase is continuously added to the cooked sweet potato until the desired content is obtained. Heating is then employed to inactivate the enzyme and stop the reaction.[23]

Processing

Ideally, the sweet potatoes are washed for the first time immediately prior to their processing. The potatoes are then preheated for 25 to 30 minutes in water at 160° to 170° F. in order to improve the color and increase the sugar content.

The sweet potatoes are peeled either by submerging them in boiling lye for 6 to 7 minutes or by using steam and high pressure. The tubers are then washed, trimmed to remove any remaining peeling or decayed areas, and cut into slices ½ to 1¼" thick.

The sliced potatoes may be cooked in either a screw type steam cooker or a woven belt cooker. The former type is preferred because there is less loss of solids and sugars and the air exposure is less, thereby decreasing

the possibility of discoloration.

Immediately after cooking, the sweet potatoes are forced through a stainless steel screen. The resulting puree is then dried on double drum dryers until the moisture content is 4% or less. The sheets of dried puree are broken into small pieces and packaged in an atmosphere of nitrogen.

For a long time, discoloration was a great problem in the manufacture of processed sweet potato products. Soon after peeling, a gray or greenish color would develop upon the outer surface and become more intense with air exposure during cooking. When the potato was pureed, the off-color was spread throughout the mixture. Hoover has discovered that adding a mixture of sodium acid pyrophosphate and tetrasodium pyrophosphate to the puree will control the amount of discoloration without causing a sacrifice in flavor.[24]

NUTRITIVE CONTENT OF FRESH AND DEHYDRATED SWEET POTATOES

The nutritive content of fresh peeled sweet potatoes is given in Table 2.

Table 2. Nutritive Content of Fresh Sweet Potatoes[25]

Nutrient	Baked (110 g.)	Boiled (147 g.)
Calories	155	170
Protein	2 g.	2 g.
Fat (total lipid)	1 g.	1 g.
Carbohydrate	36 g.	39 g.
Calcium	44 mg.	47 mg.
Iron	1.0 mg.	1.0 mg.
Vitamin A value	8,970 I. U.	11,610 I. U.
Thiamine	.10 mg.	.13 mg.
Riboflavin	.07 mg.	.09 mg.
Niacin	.7 mg.	.9 mg.
Ascorbic acid	24 mg.	24 mg.

A medium size baked sweet potato will supply these percentages of the daily nutritive needs: Calories, 8%; protein, 5%; calcium, 6%; iron, 9%; vitamin A, 228%; thiamine, 10%; riboflavin, 6%; and ascorbic acid, 40%.[26]

Research has established that the carotene and ascorbic acid content of sweet potato is influenced by the variety, type of soil, time of planting and harvesting, curing practice, length of storage, and numerous other variables.[27] Consequently, the nutritive content may vary considerably from one potato to the other and particularly from one variety to another.

However, the information given in Table 2 is generally true. The tuber is particularly valued for its vitamin A and ascorbic acid content. The question then

arises: How does the nutritive content of the dehydrated sweet potato compare with that of the fresh? Arthur and McLemore found that freshly dehydrated products contained about the same amount of ascorbic acid and carotene as was present prior to dehydration. The carotene was found to be relatively stable in products packed in an atmosphere of nitrogen. However, there was a measurable decrease in carotene with increasing time and temperature of storage. The ascorbic acid content of the dehydrated product also decreased with increasing time and temperature of storage.[3]

Ascorbic acid content in the fresh sweet potato also declines with increasing time and temperature of storage.[27] The rate of loss in the dehydrated product is similar to the rate of loss in the fresh product.

The same relationship is not true of the carotene content. The USDA concluded in 1953 that there was no significant change in carotene content of a fresh sweet potato during storage.[27] However, the carotene loss in the dehydrated product does not seem to be alarmingly rapid.

Consequently, Hoover has concluded that "sweet potato flakes sealed in an atmosphere of nitrogen containing less than 2% oxygen retain their flavor and nutritional stability during extended storage."[7]

CONSUMER ACCEPTABILITY OF THE DEHYDRATED SWEET POTATO FLAKES

Although the flakes have been on the market nationwide only since September, 1964, they have been locally available for several years. In an informal survey, it was found that those persons who had used the flakes had been favorably impressed with the product. However, several mentioned that they had observed the flavor varied considerably with different brands. Others thought they were expensive.

There have been two market tests reported in the literature. The 120 members of the "Farm Journal's" Family Test Group were supplied with the products and recipes. The homemakers were enthusiastic about the convenience and they liked the products in the recipes tested. They commented that the potatoes were "smooth, with a fresh buttery flavor" and that they were "excellent emergency meal stretchers."[22]

Forty-five restaurants and seven institutions in New Orleans and Cleveland were supplied with sweet potato flakes and recipes for mashed sweet potatoes, orange casserole, sweet potato pie and marshmallow casserole. Only a few served the latter three. Both the operators' and customers' reactions were observed. In general the operators commented that the flakes were easy to prepare, saved labor and time, were easy to store and added variety to the menus. Over fifty per cent said they would serve them if they were available. Twenty to twenty-five per cent of the customers ordered sweet potatoes when they appeared on

the menu. The majority said they were favorably impressed with the food.[28]

SUMMARY

Sweet potato flakes seem to be a partial solution to many of the problems which have long plagued the sweet potato industry. The product can be manufactured from a freshly harvested tuber, thereby eliminating the need for the costly curing process. Since any size potato can be used for the flakes, there can be a greater utilization of the small and large roots which tend to be rejected by the housewife.

If sweet potatoes are processed immediately, storage rot would not have time to develop in roots damaged during harvesting. Consequently, the need to exercise such great care in handling would be lessened and more extensive employment of mechanized harvesting might be possible.

One pound of dehydrated flakes is equal to seven or eight pounds of fresh sweet potatoes. This tremendous reduction in weight and volume greatly decreases shipping costs. In addition, the amount of space required for storage is reduced and the storage loss is negligible. These latter features should appeal to wholesalers, retailers, and consumers.

Sweet potato flakes offer many desirable features to the consumer. Of prime importance is the year-round availability of the product and the decreased amount of time and labor required for the preparation of mashed sweet potatoes. In addition, the quality is assured and the preparation time is certain.

It is difficult to judge the yield of raw fresh sweet potatoes. Consequently, when a recipe requires an exact amount of cooked mashed sweet potatoes, a shortage or an excess is frequently prepared. The use of flakes eliminates this problem.

PART II. Effects of Sweet Potato Flakes and Dried Whey on the Quality of Sweet Potato Pie.

PURPOSE

Sweet potato pies have long been a favorite in the South. However, a considerable amount of time and labor is required when pies are prepared from the fresh produce. It seems reasonable to assume that the time and labor demands would tend to prevent their being served very frequently either in the home or institutions. Furthermore, the poor keeping qualities of the tubers make this a seasonal dish.

Although one would expect that there would be a market for a commercially prepared frozen pie, the product is not currently being sold. The preparation time and labor demands would make the product very costly to manufacture. In addition, the pies could only be produced in certain seasons.

The use of dehydrated flakes in pies would greatly reduce the preparation time and labor. The flakes would also be available on a year-round basis. If a pie could be prepared from the flakes that compared favorably in quality with a pie prepared from the fresh produce, it is possible that this dessert would be served more often, especially by institutions. There is also a possibility that the use of the flakes would eliminate some of the problems that have previously prevented the commercial production of a frozen sweet potato pie.

The primary aims of this investigation have been to

ascertain the effects that using reconstituted flakes would have on the palatability factors of a sweet potato pie and to develop a recipe using the flakes that produced a high-quality product.

It was hoped that the basic recipe developed would be suitable for use by the homemaker, could be adapted for use in institutions, and commercial production of the frozen pies. A secondary aim was to determine if dried whey might replace fresh milk in the recipe developed without significantly affecting its quality.

Few recipes utilizing sweet potato flakes have been published. No research has been reported on the effects of the flake form on the quality of a sweet potato product. Wilson says that reconstituted flakes can be used in any recipe specifying mashed sweet potatoes.[22] It was hypothesized that the dehydrated flakes could be used in any existing recipe for sweet potato pie without significantly affecting the palatability factors. However, it was recognized that slight alterations of the recipe might be necessary in order to secure a high quality product.

The recipe selected for use in this study specified fresh whole milk as the liquid ingredient. Since dried whey is considerably less expensive than fresh milk, substitution of whey for fresh milk would greatly reduce the production costs and make the recipe more suitable for commercial use.

Dried whey contains about one-half the total solids

of milk. Only the casein and fat are removed in the processing of cheese. Water soluble proteins, vitamins and minerals, and the sugars remain. Webb reported the percentage composition of dried whey as lactose 73.5; protein 13.5; water 4.0; and ash 9.0.[30]

No previous work has been reported on the use of whey in sweet potato products. However, Hanning and de Goumois conducted an extensive study on the effects of whey on the quality of cakes.[31, 32] The quality of starch puddings containing whey and/or nonfat dry milk was studied by Hanning, Bloch and Siemers.[33] In addition, whey has been used successfully by food processors in pie crusts, cake mixes, ice cream, frozen-food sauces, confections, cookies and crackers, breads and instant potatoes.[34]

The results of several studies on the effects that whey has on the flavor of a product do not agree. Webb reported that the "natural rather insipid taste of whey" contributed no desirable character to the taste of punch. He found that the salt content of whey became very noticeable and objectionable when whey was used in concentrated form.[30]

A comparison test of cakes containing whey with those made from fluid milk did not indicate that whey had any detrimental effects on flavor.[31] Certain levels of whey caused an improvement in the flavor of cornstarch puddings.[33]

It was hypothesized that the effect which whey would have on the flavor of the sweet potato pies would be

determined by the level of whey used. Concentrated amounts of whey were expected to have an adverse effect, but small amounts were expected to have little influence on the flavor of the pies.

Hanning, Bloch and Siemers reported that whey increased the tenderness of the gel structure in cornstarch puddings. The use of whey resulted in an increase in syneresis and puddings tended to have a smoother texture. The authors suggested that the smoother consistency of the puddings containing whey and the increased tenderness of their gel structure might be due to the high lactose and low protein content of whey.[33] The use of whey was expected to produce similar changes in the texture of sweet potato pies.

In summary, it was assumed that whey could be used successfully in pies made from sweet potato flakes. Changes in the flavor and texture were anticipated. However, it was hypothesized that these changes would not be objectionable if the amount of whey used was not excessive.

EXPERIMENTAL PROCEDURE

Materials

The fresh sweet potatoes used were purchased from a single lot of tubers at a Greensboro outlet of a national chain store in late February, 1965. They had been produced in North Carolina the previous fall and were of the Porto Rico variety.

The same brand of sweet potato flakes was used throughout the experiment. These flakes had been manufactured in North Carolina. It was not possible to ascertain the variety of these potatoes nor their place of production.

Commercially frozen pie shells were used for all pies as a means of controlling the quality of the pastry. Use of the shells had the added advantage of simplifying the preparation and minimizing the time required.

Dried whey was obtained from a local bakery.

The fresh milk used was whole homogenized milk.

The Basic Recipe

There are numerous recipes for sweet potato pie in existence. Some produce a custard type pie, whereas others yield a chiffon pie. In addition, there are recipes for sliced sweet potato pies; novelty pies, such as sweet potato rum, sweet potato coconut, etc.; and pies that use the grated raw potato. Consequently, there is no general consensus on the qualities of a good sweet

potato pie.

Sweet potato flakes can only be used to prepare the chiffon, custard, and certain of the novelty type pies. It was decided that of the three, the custard type would be the most widely accepted version of sweet potato pie. However, recipes for this type vary considerably. This is especially noticed with regard to the kinds and amounts of spices used. Because the spices greatly influence the flavor, differences in flavor preferences would be expected.

After considerable studying and comparison of recipes, two were selected for possible use as the basic recipe. One had been developed in previous experimental work conducted here at the University of North Carolina at Greensboro.[35] The other appeared in a United States Department of Agriculture publication.[16] A fresh sweet potato pie was made from each recipe. Several faculty members of the School of Home Economics were asked to sample both pies and to state which they liked the better. There was a definite preference for the pie prepared from the USDA recipe. All participants in this informal survey liked the texture and consistency of the USDA pie, but some commented that it was rather spicy.

Before definitely adopting the USDA recipe as the standard in this study, it seemed desirable to test the possibility of altering the spice combination. It also seemed wise to test its suitability for use with sweet

potato flakes since there was a possibility that the dehydrated product could not be used successfully in the recipe.

In the initial laboratory session, three pies were prepared. The USDA recipe and fresh mashed sweet potatoes were used for one pie; the second was prepared from the same recipe and sweet potato flakes; and the spice combination in the third was changed to one teaspoon cinnamon, one-half teaspoon nutmeg, and one-fourth teaspoon ginger. Fresh sweet potatoes were used in the third pie.

The taste panel showed a decided preference for the spice combination used in the USDA recipe. Although it was evident that some adjustment would have to be made in the liquid content, the scores indicated sweet potato flakes could be successfully used in this recipe. Since time was a limiting factor, the recipe was adopted as the standard to be used for the fresh sweet potato pie without any further testing.

The recipe is given in Table 3.

Table 3. Basic Recipe for Fresh Sweet Potato Pie

Ingredient	Household Amount	Weight
Sweet potatoes, mashed	1½ cups	369.9 g.
Eggs	2	88.0 g.
Milk	1 cup	244.0 g.
Margarine	2 T.	28.0 g.
Sugar	½ cup	100.0 g.
Mace	¼ tsp.	--
Cinnamon	1 tsp.	--
Allspice	½ tsp.	--
Salt	½ tsp.	--

Adaptation of Basic Recipe for Use with Sweet Potato Flakes

The preliminary testing of the USDA recipe with sweet potato flakes indicated that either the liquid content was too high when the sweet potatoes were reconstituted on the specified one to one ratio or the total volume of the filling needed to be reduced. The unbaked filling was very thin and watery. Approximately two tablespoons were spilled when the pie was placed in the oven and there was considerable splattering onto the edge of the pie crust during baking.

In the second series of pies prepared, the flakes were used in two pies and fresh sweet potatoes in the third. All were prepared by the USDA recipe. However, the flakes used in one pie had been reconstituted according to the specified proportions, i.e., one and one-half cups of water per one and one-half cups of flakes. In the second pie, only one and one-fourth cups of water were used to reconstitute one and one-half cups of flakes. Reducing the water content proved to be satisfactory. Thereafter, all flakes used were reconstituted with the smaller proportion of water.

Use of Varying Levels of Dried Whey in Sweet Potato Flake Pie

Once standard sweet potato pie recipes for both the flake and fresh forms of the tuber had been established, tests were conducted to determine the effects of replacing fresh whole milk with varying levels of reconstituted

dried whey on the palatability factors.

In the original plans, the practice of preparing a fresh standard was to be discontinued once a standard recipe for using the flakes had been derived. However, it was later decided that employing both the fresh and the flake standard would yield more reliable results.

Measuring

All ingredients except the spices and salt were measured by weighing on a trip balance. The weights given in the AHEA HANDBOOK OF FOOD PREPARATION for one cup of milk, one egg, one cup of water, one cup of sugar, and a tablespoon of fat were used to compute the proper amounts of these ingredients.[36]

No established weight for fresh, mashed sweet potatoes was available. A weighed standard Marianne one-cup measure was packed with mashed sweet potatoes and weighed. The weight was then calculated. This was repeated six times. The average of these weights was considered to be the weight of a cup of mashed sweet potatoes and this figure was used as the basis for calculating the appropos weight of sweet potatoes.

Standard directions for reconstituting sweet potato flakes specify that for each cupful of mashed sweet potatoes desired, add one cupful of hot water to one cupful of sweet potato flakes. Stir for one to two minutes. Initially, these directions were followed.

However, as explained earlier, more satisfactory results were obtained by slightly reducing the water content. The pies prepared from sweet potato flakes contained 153.5 g. of flakes and 295.8 g. water. These weights produced approximately one and one-half cups of reconstituted sweet potato flakes.

The average of six weights obtained for a cup of flakes was used to compute the amount of flakes to be used.

No attempt was made to ascertain if a cup of reconstituted sweet potato flakes would be equal in weight to a cup of fresh sweet potatoes. However, it is doubtful that it would since the combined weight of the water and the flakes is much more than the average weight of a cup of fresh sweet potatoes.

Specific instructions for reconstituting whey could not be obtained. Hanning, Bloch and Siemers used the same proportions for reconstituting whey that are used for reconstituting nonfat dry milk.[33] This practice was followed in this study. For a 100% level of whey, the average weight of 1/3 cup of whey was obtained. The weight of water required to yield a volume of one cup was determined. Although the weight of whey used was varied, the weight of water used for reconstituting it was kept constant.

In the second phase of the investigation, various levels of reconstituted whey were used to replace the fresh milk. As mentioned earlier, the weight of water

used to reconstitute the whey was kept constant. The weights of whey and water used are given in Table 4.

Table 4. Weights of Whey and Water Used in Sweet Potato Flake Pies

Series	Whey	Water
Series One		
150% whey	72.3 g.	221.8 g.
100% whey	48.2 g.	221.8 g.
Series Two		
100% whey	48.2 g.	221.8 g.
50% whey	24.1 g.	221.8 g.
Series Three		
50% whey	24.1 g.	221.8 g.
25% whey	12.1 g.	221.8 g.
Series Four		
25% whey	12.1 g.	221.8 g.
0% whey	-	221.8 g.

Preparation of the Pies

In order to allow an adequate cooling period for the pies before they were scored, it was necessary to do considerable preliminary preparation of the ingredients prior to a baking session. The margarine, sugar, spices, and salt were always measured in advance. Individual weighed portions of margarine were placed on pieces of waxed paper and refrigerated in a covered container until used. For each pie, the amount of sugar, spices, and salt required was mixed in a small bowl and then tightly covered with plastic wrap.

The fresh sweet potatoes were cooked under ten pounds of pressure for twenty minutes or until done. After they

had cooled sufficiently, the potatoes were peeled. An electric mixer was used for mashing. The potatoes were allowed to beat at a moderate speed until no lumps were visible. This required approximately three minutes. In an attempt to eliminate undesirable strings (fibrous material), the sweet potatoes which clung to the beaters were not used.

With one exception, the cooked, fresh sweet potatoes were frozen prior to their use in a pie. The amounts needed for a single pie were frozen in a single container. The potatoes were allowed to thaw overnight in a refrigerator before each baking period.

A standard order of mixing was developed and followed. Initially, the milk, water, or reconstituted whey for each pie was placed in a separate bowl. Then the total number of eggs to be used were beaten with a rotary beater for two minutes. The appropos amount of egg for a single pie was placed in each bowl containing the liquid ingredients. Weighed portions of margarine, melted separately in a double boiler, were added to each. These mixtures were beaten for approximately one minute with a rotary beater.

The sweet potato flakes for all pies were then reconstituted in individual bowls. Afterwards the sweet potatoes and the sugar-spice mixture for the first pie were placed in the bowl of the electric mixer. This was allowed to mix for two minutes at a medium speed. The liquid ingredients were then added and the mixture was beaten for

two more minutes. It was then poured into a frozen, unbaked pie shell and placed in a preheated oven.

The remaining pies were then mixed according to the same procedure. The bowls and beaters were usually washed between pies. However, when only amounts rather than ingredients differed, the practice was not considered necessary.

With each replication of a test, a different order of mixing the pies was followed.

Baking and Cooling

The pies were baked in the aluminum pie tins used for frozen pastry shells for forty minutes at 400° F. A gas and an electric oven were used.

In an effort to control the effect that the type of oven might have on the results, the replicate was always baked in a different oven from that used for the first test. The positions in the oven were also alternated. If, in the original test, the pie had been placed at the front shelf position, it would be placed in the back position when the test was repeated.

Upon their removal from the oven, the pies were placed on individual wire racks to cool. Contrary to the usual procedure, they were not removed from their pans since there was the possibility handling would cause surface cracks to develop.

There was necessarily at least twenty minutes between the time the first and last pies were removed from the

oven. This meant that the pies had to be either scored at different times or the length of the cooling period had to vary. Since the former alternative seemed impractical, the latter practice was followed. In order to minimize the effect of the varying cooling periods, it was decided that the pies would be scored only after all had cooled a minimum of one hour and fifteen minutes. After this interval, the pies were at approximately room temperature.

The order of mixing was changed each time a series was replicated. Consequently, the length of a cooling period for each variation within a series was never duplicated. This served to further reduce any effects that the inability to control the length of cooling might have had on the results.

Scoring

A panel of five judges used the score card shown in Table 5 to score the palatability factors of the pies. Each judge was provided with a tray containing a coded sample from each pie. They were asked to score the color, surface appearance, texture, flavor, and overall acceptability of each sample. For each factor, the maximum score was three and the minimum score was one. In addition, the judges were asked to record comments on the score card. The remaining uncut portions of the pies were available for reference in scoring the color and surface appearance.

Table 5. Score Card for Pies

Factor	1	2	3	Score	Comments
Color	too dark, too light		characteristic, attractive		
Surface	cracked		smooth		
Texture	coarse dry		fine firm, moist		
Flavor	flat too sweet unpleasant too spicy		pleasing well-balanced		
Accept-ability					

Only one judge had had no previous experience on a taste panel.

Griswold reports that in some experiments judges have tended to score the first sample offered higher than the others.[37] Because the pies were heavily spiced, it was expected that masking of flavors would definitely be a problem. In an effort to minimize the effects that this factor might have, each judge scored the pies in a different order. Furthermore, the order of scoring was rotated so that no judge ever repeated a score order within a series.

Due to conflicts in the judges' schedules, it was not possible to have them score at the same time. After all the pies had cooled a minimum of one hour and fifteen minutes, they were cut and the trays were set up. Within

the next two and one-half hour period, the judges scored at their leisure. This practice meant that some judges scored immediately before lunch whereas others did not score until after they had eaten.

DISCUSSION OF RESULTS

Results of the preliminary laboratory tests of the basic recipe are given in Table 6.

Table 6. Preliminary Tests of Basic Recipe

Formula	Judges' Mean Score for				
Type of Sweet Potato	Color	Surface Appearance	Texture	Flavor	Acceptability
USDA Recipe Fresh	2.6	2.4	2.4	3.0	2.6
USDA Recipe Flakes	2.0	1.4	2.8	2.8	2.4
Altered Spices* Fresh	2.6	2.6	2.6	2.4	2.4

*1 tsp. cinnamon, ½ tsp. nutmeg, and ¼ tsp. ginger

The taste panel demonstrated a definite preference for the spice combination specified in the USDA recipe.

Although the pie prepared from the flakes received comparatively low scores on the appearance factors, the taste panel did not seem to object to the taste of the product. Its scores for texture and flavor both compared favorably with those scores given to the pies prepared from the fresh produce.

The fillings of all pies expanded considerably while baking. Within five minutes, after the pies were removed from the oven, all the fillings had relaxed. Large cracks

developed in the pie prepared from the flakes as it settled. Neither of the pies prepared from the fresh produce developed cracks of any consequence.

The unbaked filling of the flake pie had been observed to be much thinner than that of the pies prepared from the fresh sweet potatoes. It was decided that the large amount of cracking in the flake pie might have been due to an excessive liquid content. Data in Table 7 indicate that a reduction in the amount of water used to reconstitute the flakes did decrease the amount of surface cracking to some extent.

Table 7. Effect of Water Content on the Quality of Pies Prepared from Sweet Potato Flakes

Variation	Judges' Mean Score for				
	Color	Surface Appearance	Texture	Flavor	Acceptability
Fresh Control	2.6	2.8	2.4	2.8	2.6
Flakes 354.9 g. water	3.0	2.8	2.4	2.6	2.4
Flakes 295.8 g. water	2.8	2.8	3.0	2.4	2.6

However, surface cracking continued to be a problem in pies prepared from the flakes throughout the study. (Tables 8 and 9). It was decided that a larger reduction in the water content would probably cause the pies to be too dry and a further reduction in the water content was not attempted.

In the processing of sweet potato flakes, corky material and fiber are removed. The absence of this fibrous matter could be partially responsible for the characteristic development of cracks in the flake pies since it would probably permit greater expansion in baking. Although no objective tests of volume were made, it was observed that the flake pies did appear to rise more during baking and relax more quickly.

If the removal of the fibrous material from the flakes does promote surface cracking, the addition of cellulose might aid in reducing the amount of cracking. In an informal experiment, one-fourth cup of cellulose was added to a flake pie. Although the results were inconclusive, there appeared to be slightly less cracking. However, the amount used was too large for a single pie because the resulting product was somewhat dry in texture.

Failure to spread the unbaked filling evenly in the pie shell and overbaking also seemed to promote the development of surface cracks in the pies.

The scores of all the fresh sweet potato pies prepared by the USDA recipe are compared with the scores of all the

flake pies which had a reduced liquid content. (Table 8)

Table 8. Palatability of Pies Prepared from Fresh and Dehydrated Sweet Potatoes

	Palatability Factors				
	Color	Surface Appearance	Texture	Flavor	Acceptability
Total Scores					
Maximum	126	126	126	126	126
Fresh	106	123	111	116	113
Flake	123	108	112	117	113
Mean Scores					
Maximum	3.0	3.0	3.0	3.0	3.0
Fresh	2.3	2.9	2.6	2.8	2.7
Flake	2.9	2.6	2.7	2.8	2.7

The unbaked filling of the fresh sweet potato pies was observed to have a paler yellow color than that of the flake pies. When the fillings were baked, the color difference became even more pronounced. The flake pies had a deep, yellow-orange color whereas the color of the fresh sweet potato pies was a pale yellow with a blue-green cast. The judges considered the color of the flake pies more attractive.

Since the variety of the sweet potatoes used to make the flakes was not known, it is quite likely that the color difference was partially due to a difference in the variety of sweet potatoes. Undoubtedly, this inherent color difference was accentuated by the presence of a color preservative in the flakes.

Although the scores indicate that the judges found the flavor of the pies to be equally pleasing, the comments on the score cards revealed that they did detect a difference in flavor. The comments "most natural flavor" and "most potato flavor" were frequently written on the score cards for the fresh sweet potato pies. Because there was a considerable color difference between the fresh and flake sweet potato pies, the judges soon learned to tell by sight which pie contained the fresh sweet potatoes. This knowledge may have had an influence on their scoring.

Although there was little difference between the total scores of the fresh and flake pies on texture, certain panel members would occasionally object to the presence of "lumps" and "strings" in the fresh pies.

The effects that dried whey has on the quality of sweet potato flake pie are shown in Table 9.

Table 9. Palatability of Sweet Potato Pies Prepared from Sweet Potato Flakes and Dried Whey

Variation in Type of Sweet Potatoes and Liquid Content	Judges' Mean Scores for				
	Color	Surface Appearance	Texture	Flavor	Accept-Ability
Series 1					
Flakes 150% Whey	2.8	2.2	2.1	2.0	2.0
Flakes 100% Whey	2.9	2.1	2.8	2.0	2.2
Fresh Whole Milk	2.4	3.0	2.9	2.9	2.9
Flake Whole Milk	3.0	2.4	2.6	2.8	2.8

(Continued)

Table 9--Continued

Variation in Type of Sweet Potatoes and Liquid Content	Judges' Mean Scores for				
	Color	Surface Appearance	Texture	Flavor	Acceptability
Series 2					
Flakes 100% Whey	2.8	1.8	2.4	2.0	2.0
Flakes 50% Whey	2.9	2.2	2.4	2.2	2.2
Fresh Whole Milk	2.4	2.9	2.6	2.8	2.6
Flakes Whole Milk	2.9	2.2	2.5	2.7	2.4
Series 3					
Flakes 50% Whey	2.9	2.7	2.4	2.2	2.4
Flakes 25% Whey	2.9	2.3	2.7	2.8	2.8
Fresh Whole Milk	2.6	2.9	2.7	2.8	2.8
Flake Whole Milk	2.9	2.7	2.8	3.0	2.7
Series 4					
Flakes 25% Whey	2.8	2.1	2.4	2.3	2.1
Flakes 0% Whey	3.0	2.1	2.7	2.7	2.7
Fresh Whole Milk	2.7	3.0	2.6	2.6	2.6
Flakes Whole Milk	3.0	2.9	2.7	2.9	3.0

The pies that contained whey had an unpleasant, strong flavor which the judges frequently described as "acidic" or "sharp." The taste panel was able to detect the presence of

small quantities of whey. In addition, they could distinguish slight differences in concentration since the pie containing the greatest proportion of whey in a series consistently received the lowest scores on flavor, texture and overall acceptability.

Although the judges considered the flavor of the whey pies "acidic", a pH test indicated that all pies in series two had a pH of approximately 6.0. These readings were made with pH paper. A more exacting test might have revealed differences in the degree of acidity.

In general, the cracking was even more pronounced when whey was used in sweet potato flake pie. This had been anticipated since it was known that the per cent of protein was very low and the sugar content high. Both of these factors would tend to produce a more tender gel structure.

Interestingly, the level of whey used seemed to have little effect on the degree of cracking. Although the pie containing 150% whey had the greatest protein content of any of the whey pies, its mean score on surface was only slightly higher than that of the pies containing 25% and no whey.

The texture of the whey pies was not very pleasing. The judges considered it "pasty", "gummy", and "too smooth." Since the texture of a pie prepared solely from water was very similar to that of the pies containing whey, it seems likely that the unpleasant texture was due not to a property of whey itself, but rather to the absence of protein.

CONCLUSIONS

Sweet potato flakes produced pies which a taste panel rated equally as acceptable as pies made from the fresh product. However, the panel did detect a difference in the flavor. The pies prepared from the flakes tended to have surface cracks. Reducing the amount of water used to reconstitute the flakes helped to control this condition, but was not completely successful.

The flake pies had a deeper, yellow-orange color than those pies prepared from the fresh product. The judges considered the color of the flake pies to be the more attractive.

The substitution of dried whey for fresh milk in sweet potato flake pies did not prove to be very successful in this study. The pies containing whey had large surface cracks, a pasty texture, and an unpleasant, strong flavor.

Although some surface cracks occurred in the flake pies made with fresh milk, the condition was much worse in the whey pies. The increased cracking and objectionable texture was believed to have resulted from the comparatively low protein content of whey. Perhaps the addition of protein to the formula might aid in controlling the development of these conditions. However, further work is needed in this area before any definite conclusion is reached.

No attempt was made to determine the cause of the

objectionable flavor in the whey pies. It might have been a characteristic "whey" flavor or it could have resulted from a reaction between the whey and the sweet potatoes or their color preservative. Further research is needed on this problem.

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