Chemical, Physical, and Sensory Properties of a Sweet Potato French-Fry Type Product During Frozen Storage

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ABSTRACT

Chemical, physical, and sensory properties of a sweet potato French-fry type product were determined after 0, 3, 6, 9, and 12 months frozen storage. Analyses included measurements of dry matter, sugars, alcohol insoluble solids, carotene, vitamin C, color, texture and sensory panel scores for color, flavor and texture. Few changes were observed except for an appreciable loss (58%) in vitamin C and an apparent increase in carotene (27%). A partial drying treatment before freezing increased the rate of ascorbic acid loss. For the fried product, no appreciable storage-induced changes were noted in the sensory scores for color, flavor and texture thus indicating that the product had good stability in frozen storage.

INTRODUCTION

SWEET POTATOES are a good source of provitamin A and vitamin C. They also provide a high quality protein, dietary fiber and calories. Fresh market use accounts for most of the U.S. consumption of this commodity with North Carolina being the leading producer of sweet potatoes in the United States (USDA, 1984). Canned sweet potatoes are also widely distributed and available year round. Recent attempts to expand the marketability of sweet potatoes have focused on processed products such as fries (Walter and Hoover, 1986), chips (Hannigan, 1979; Hoover and Miller, 1973) and patties (Walter and Hoover, 1984).

The sweet potato French-fry type product was judged of good quality and acceptability by consumer panels (Walter and Hoover, 1986). Since roots are harvested seasonally and storage costs are high, continual availability of the French-fry type product would require frozen storage. However, no data are available on the stability of this product in frozen storage.

The objectives of this study were to evaluate chemical, physical, and sensory changes in the sweet potato french-fry type product during frozen storage over a 1-year period.

MATERIALS & METHODS

Raw product

Approximately 240 kg sweet potatoes (Jewel cultivar) were obtained from a local University farm. Half the roots (uncured) were processed into strips immediately and frozen. The remaining roots were cured for one week at 30°C and 85% relative humidity (Wilson et al., 1980) before processing.

Processing conditions

Roots were processed into a French-fry type strip of variable length (1.9 cm wide x 0.64 cm thick) following the procedure described by Walter and Hoover (1986) except half the strips were air-dried at 22°C for 5 min to remove surface moisture after blanching and half were partially dehydrated in a continuous upward flow forced air drier at 121°C for 5.7 min. After partial drying, all strips were individually frozen, packaged in polyethylene bags and stored at −18°C. The partial drying treatment conditions were chosen based on optimal sensory scores of the product found in a previous study (Walter and Hoover, 1986). At 3-month intervals, strips were thawed, analyzed raw and fried in peanut oil at 175°C for 2 min.

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Chemical analyses

Table 1 summarizes the analyses performed on samples of products handled and processed under various conditions. All chemical analyses were performed in duplicate. Dry matter was determined as described by Walter and Hoover (1986). For total sugars, samples were ground in an ethanol-water (80:20) mixture and allowed to equilibrate for 1 week. Aliquots were removed and sugar determined using the phenol-sulfuric acid reagent (Dubois et al., 1956). Alcohol insoluble solids were measured as previously described (Walter and Hoover, 1984). Carotenoids were extracted from 10g diced tissue by homogenizing the sample in petroleum ether (b.p. 36–57°C)-acetone, (1:9 v/v), filtering and diluting to 100 ml with petroleum ether-acetone. Total carotenes were calculated by absorbance readings at 453 nm using the extinction coefficient ($E^{1\%}_{453}$ = 2595; DeRitter and Purcell, 1981). Ascorbic acid was determined using the modified 2,6-dichloroindophenol procedure described by Lanier and Sistrunk (1979). All chemical analyses reported are expressed on a dry weight basis.

Physical measurements

Hunter color values (L, a, b) were determined from reflectance measurements using a Spectrogard color system (Pacific Scientific Silver Spring, MD). Two rows of strips were placed side by side in a 5 cm x 4 cm cell. Color data were collected from two replicate samples.

Shear measurements were made using an Instron Universal Testing Machine. Samples (32 ± 1g) were placed perpendicular to the blades of a Kramer shear cell with a slotted bottom (Model CS-1, Food Technology Corporation, Rockville, MD) and kg shearing force measured. Cross-head speed was set at 200 mm/min.

Sensory analysis

Sensory evaluations were performed on all fried samples following the procedure previously described (Walter and Hoover, 1986). Strips were evaluated at 0, 3, 6, 9, and 12 month intervals frozen storage. Twenty panelists evaluated the product at each interval.

Statistical analyses

The data collected were analyzed by the analysis of variance (ANOVA) and general linear model (GLM) procedures using the Statistical Analysis System (SAS, 1982a, b).

RESULTS & DISCUSSION

STRIPS prepared from cured or uncured sweet potatoes were statistically similar in dry matter, alcohol insoluble solids (AIS), L, a, b color values and shear press measurements. Therefore, the average values shown for these variables in Table 2a do not distinguish between curing treatments. There were differences in cured versus uncured for total sugars ($P < 0.0003$) and vitamin C ($P < 0.04$), and these data are presented in Table 2b.

Alcohol insoluble solids varied during this study; however, no significant trends were observed during one year of frozen

Table 1—Analyses performed at 3 month intervals for 1 year on lots of a frozen sweet potato French-fry type product undergoing various processing treatments

Treatment	Dry Matter	Alcohol in-soluble solids	Sugar	Carotene	Vitamin C	Color (L,a,b)	Shear measurements	Sensory panels
Fried	X	X	X			X	X	X
Raw	X	X	X	X	X	X	X	

Table 2a—Alcohol insoluble solids, dry matter, color values, and shear measurements of sweet-potato French-fry type product subjected to various processing conditions

Measured variables[a]	Alcohol insoluble solids (g/100g dry matter)	Dry matter (5)	Color values L	Color values a	Color values b	Shear force (Newtons)
Processing conditions						
Raw air-dried	52.2	20.3	53.0	14.0	17.1	195
Raw tunnel-dried	53.9	25.9	53.2	14.1	17.0	282
Fried air-dried	51.7	50.9	48.0	12.3	18.2	310
Fried tunnel-dried	56.8	59.1	47.1	12.1	17.1	761
Std. Error of Mean	1.43	1.78	0.87	0.48	0.43	1.73

[a] Values represent an average of 20 sample determinations each analyzed in duplicate.

Table 2b—Total sugar, carotenes and vitamin C content of sweet potato, French fry type product subjected to various processing conditions

Measured variables[a]	Sugars (g/100g)	Carotenes (mg/100g)	Vitamin C (mg/100g)
Cured			
Raw air-dried	32.5	16.0	77.9
Raw tunnel-dried	32.4	12.2	56.5
Fried air-dried	21.8	—	—
Fried tunnel-dried	22.8		
Uncured			
Raw air-dried	36.2	11.9	76.9
Raw tunnel-dried	37.5	13.4	43.8
Fried air-dried	23.4	—	—
Fried tunnel-dried	23.9		
Std. Error of Mean	0.47	0.09	3.13

[a] Values are expressed on a dry weight basis and represent an average of 10 sample determinations each analyzed in duplicate.

Table 3—Interactions of processing treatments on color values, sugars, alcohol insoluble solids, carotene, vitamin C and shear values obtained from a sweet-potato French-fry type product during frozen storage

Variable	Interaction	Level of significance (P<)
Sugars	Cure × Fry	0.003
	Cure × Dry × Time	0.02
Alcohol insoluble solids	Fry × Time	0.006
Vitamin C	Dry × Time	0.05
Shear force	Dry × Fry	0.001
	Dry × Time	0.01
	Fry × Time	0.007

storage. Drying treatment influenced AIS ($P < 0.009$) because of lower moisture loss during air drying. For pooled data, mean AIS values of raw samples were similar to average AIS of fried strips. However, changes in AIS over time differed for raw samples versus fried and are responsible for the observed fry × time interaction (Table 3).

No significant changes were noted in dry matter during frozen storage. As expected, due to greater moisture loss, dry matter was higher in those samples (both raw and fried) which were tunnel-dried as opposed to those which were air-dried. Dry matter of fried strips was greater than that of raw strips due to heat mediated water evaporation and oil uptake.

The L, a, b color values were similar in all raw strips analyzed (Table 2a) and remained constant during storage (data not shown). Frying decreased L ($P < 0.0002$) and a ($P < 0.002$) values as anticipated indicating a change to a darker, less red product. Air drying caused an increase ($P < 0.05$) in b values of fried samples, but a similar increase was not found for tunnel-dried samples. The yellower product (higher b values) which resulted might be attributed to changes in surface carotenes during air drying. However, no difference was detected in total carotenes of air-dried and tunnel-dried raw strips. The changes in color values caused by frying probably reflect

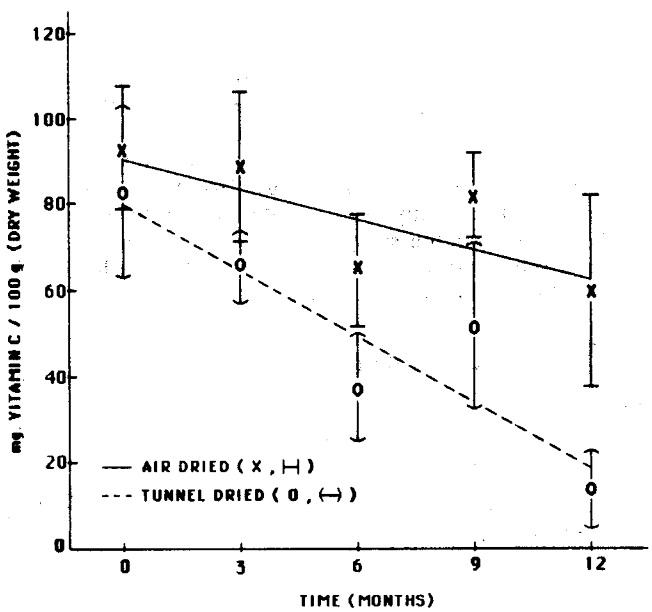

Fig. 1—Linear regression lines for changes in vitamin C as a function of frozen storage time for a sweet-potato French-fry type product produced by various processing conditions. Mean and 95% confidence limits are indicated.

a complex series of physical and chemical changes occurring at the tissue surface.

The data from this study indicated that frozen storage had no effect on sugar levels. However, both fried and raw uncured samples were higher ($P < 0.0003$) in sugar than cured samples. These treatments affected sugar content differently and are re-

Table 4—Sensory panel scores for color, flavor and texture of a sweet-potato French-fry type product

Curing treatment	No. of observations	Sensory scores[a] Color	Flavor	Texture
Cured	194	3.75	3.53	3.22
Uncured	194	3.76	3.30	3.27
F value		NS	7.75*	NS
Time (months)				
0	76	3.96	3.54	3.23
3	68	3.79	3.35	3.46
6	76	3.84	3.51	3.25
9	80	3.75	3.29	3.21
12	88	3.48	3.40	3.13
Average		3.76	3.42	3.25
F value		3.96*	NS	NS

[a] Scores: 5 = excellent, 4 = good, 3 = acceptable, 2 = poor, 1 = unacceptable.
* Significant at P<0.05

sponsible for the significant cure × fry interaction (Table 3). Smaller differences in sugar levels were noted in fried vs raw samples when comparing curing treatments. Hamann et al. (1980) reported that curing for 7 days had no effect on the sugar content of baked sweet potatoes. Perhaps, the blanching process used in the present study extracted more sugar from the cured strips. Sugar on a dry weight basis was less in fried than in raw strips. The major factor involved in this apparent decline was most likely caused by an increase in dry matter due to water vaporization and oil uptake during frying. It is also possible that some sugars were lost in the sugar-amine reaction. This reaction with its resultant browning products may also be responsible for the higher b color values (yellower product) of the air-dried fried samples.

Vitamin C was degraded during frozen storage. A greater loss was observed in those samples which were tunnel-dried vs air-dried. Air-dried samples resulted in an average 36% loss in vitamin C while tunnel-dried samples lost 83% over the one year storage period. A significant dry × time interaction accounts for these findings (Table 3). Figure 1 illustrates the linear regression lines for the loss of ascorbic acid as a function of frozen storage time. The greater susceptibility of ascorbic acid to degradation in the tunnel-dried product may have been caused by the lower water activity of these samples (Labuza, 1971). The stability of ascorbic acid generally increases as the temperature of storage is lowered; however, some studies have shown an accelerated loss during frozen storage (Heid, 1960). There are no reports concerning the stability of ascorbic acid during frozen storage of sweet potatoes. Tunnel drying, in comparison to air drying, caused an average 35% loss in vitamin C (Table 2b). Uncured samples contained lower average vitamin C relative to cured strips. Similar results were reported by Ezell and Wilcox (1952). The largest difference between curing treatments, 22%, was observed in those samples which were tunnel-dried. Fried samples were not suitable for vitamin C analyses due to analytical interferences.

Drying ($P < 0.009$) and curing ($P < 0.004$) conditions were found to influence total carotenes. Cured air-dried samples were higher in carotene than uncured air dried samples (Table 2b). However, the opposite effect was found in tunnel-dried samples. Those which were cured were lower in carotenes relative to uncured.

The storage data indicated that total carotenes apparently increased by an average of 27%. Since no significant change in dry matter was observed during storage, an increase in extraction efficiency of carotene might have occurred as a function of storage time. Therefore, data reflecting changes in carotenes as affected by processing treatment or storage time were not considered valid.

Shear force changed significantly during frozen storage. This change was related to drying treatment ($P < 0.01$) and is reflected in the observed fry × time interaction (Table 3). The shear values obtained for raw strips were different ($P < 0.007$) from those found for fried samples. These values differed during frozen storage as indicated by the significant fry × time interaction (Table 3). Greater variability in shear measurement over time was noted in fried strips vs raw samples. As expected, drying ($P < 0.0003$) and frying ($P < 0.0002$) treatment affected the shear force of strips (Table 2a). Tunnel-dried samples, both raw and-fried, were tougher than air dried strips due to surface hardening and moisture loss of the tunnel-dried product. All fried samples required greater force to shear relative to raw (Table 2a). The combination of drying and frying treatments affected shear measurements differently and accounted for the dry × fry interaction (Table 3). Partial dehydration had a larger influence on shear measurements of fried strips than on shear measurements of raw ones.

Sensory scores

Throughout the one year storage period, panelists rated the product better than acceptable in all sensory categories (Table 4). Flavor of strips prepared from cured potatoes was rated better than that of those prepared from uncured samples ($P < 0.006$). Curing has previously been reported to produce a more acceptable baked sweet potato (Hamann et al., 1980). Drying treatment had no affect on sensory scores for color, flavor or texture. A change ($P < 0.004$) was observed in color scores during the one year storage period (Table 4). A slight trend toward lower acceptability in color ratings as a function of storage period was not considered of primary importance in overall acceptability of the product.

Frozen product prepared from cured roots in a preliminary study initiated 1 year before the present investigation, was judged similar in sensory scores by the panel to fries stored throughout this study. These results indicated that in addition to good stability for 2 years of frozen storage, seasonal variability in the roots did not markedly influence product quality.

CONCLUSIONS

FEW QUALITY CHANGES were observed during frozen storage of a sweet potato french-fry type product for a one year period except for an appreciable loss in vitamin C. Drying treatment significantly affected the magnitude of ascorbic acid loss. Product prepared from curing and air drying treatments is recommended for greater retention of vitamin C. Sensory panels rated the fried product to be of good quality throughout storage. No appreciable changes except for a small but significant change in color scores were noted by panelists during frozen storage. A number of statistically significant interactions were affected by sample treatment; however, most were considered of minimal influence on product quality.

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