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FLAVOR QUALITY AND STABILITY OF POTATO FLAKES

Effects of Raw Material and Processing

INTRODUCTION

PREVIOUS STUDIES of potato flake stability (Sapers et al., 1972) have indicated that the shelflife of this product is limited by the development of hay-like off-flavors associated with oxidative reactions. Under mild storage conditions, nonenzymatic browning appears to play a minimal role; however, large differences in levels of volatile products of the browning reaction may occur in fresh flakes prior to storage.

Large variations in the flavor quality of freshly produced potato flakes and in product shelflife have been observed by the potato processing industry (Sapers, 1970). While this variability is undoubtedly due to differences in raw material, processing conditions and packaging, there is no consensus in industry as to the relative importance or specific effects of these factors. One can speculate that deficiencies in potato flake flavor and stability might arise from sub-optimal commercial practices which, if optimized, might result in significant product improvement.

The present study is part of a research program undertaken at the Eastern Regional Research Laboratory to improve potato flake flavor quality and shelflife. The effects of certain raw material and processing variables are described herein.

EXPERIMENTAL

Materials and standard process

All potato flake samples were processed from Norchip variety tubers, harvested at the Red River Valley Potato Growers Association Research Farm (Grand Forks, N.D.) in September, 1970 and stored at 13°C (except where specified otherwise) until April, 1971. Tubers had a specific gravity of 1.094 and contained 0.14% fructose, 0.36% glucose and 4.24% sucrose (moisture-free basis).

Raw material and processing variables

Potato flake samples were prepared at the Red River Valley Potato Research Center pilot plant to test the effects of the following raw

material and process variables on flavor quality and stability:

Conventional flakes (Product 1). Tubers were abrasion peeled, subdivided to 9.5 mm cross-cuts, precooked in water at 71–77°C for 20 min, cooled in water at 10–13°C, steam blanched for 20 min, and mashed in a Hobart Mixer (Model L-800). Sodium bisulfite was added via the cooking water. An aqueous suspension containing 20g mono- and diglycerides (Durkee EM400E), 15g sodium acid pyrophosphate, and 1.5 ml Tenox 4 (Eastman) was added to 22.7 kg of mashed potatoes in the Hobart Mixer. The mash was dried on a single drum drier, heated with steam at 100 psi, and the sheets of dried mashed potato were broken into flakes and packaged in polyethylene bags.

Cull raw material (Product 2). The raw material was inspected for defects, and cull tubers (subject to sprouting, rot and atypical shapes) were set aside. Flakes were produced from the cull raw material by the same process used for conventional flakes.

High sugar raw material (Product 3). Raw tubers were transferred from storage at 13°C to storage at 4°C 3 wk prior to processing. The sugar content increased to 0.66% fructose, 0.98% glucose and 7.13% sucrose (moisture-free basis). Flakes were prepared by the conventional flake process.

Unpeeled tubers (Product 4). The abrasion peeling step was omitted from the conventional flake process. Peel was in intimate contact with the product through the drying step where it was removed on the drum drier rolls.

Small raw potato pieces (Product 5). Peeled tubers were subdivided to 11.1 × 3.2 mm random length pieces rather than 9.5 mm cross-cuts.

Large raw potato pieces (Product 6). Peeled

tubers were subdivided to 14.3 × 14.3 mm random length pieces.

Potato pieces held before cooking (Product 7). Peeled potatoes were subdivided to 11.1 × 11.1 mm random length pieces and held in water containing 1% sodium bisulfite for 18 hr prior to further processing.

Minimum process water (Product 8). The solids contents of the cooking and cooling waters were permitted to build up by the passage of 136 kg of potato pieces through the processing line with no water turnover. This material was discarded and fresh potato pieces were processed into product using the high solids process waters for cooking and cooling. The solids contents of the cooking and cooling waters were 1.76 and 0.32%, respectively, as compared to 0.85% and 0.02%, respectively, for the conventional flake process with which the process water was continuously replaced.

Maximum process water (Product 9). The solids build-up in the process water was reduced to negligible levels by using the maximum rate of water turnover possible in the cooker and cooler.

Preparation for storage

All products were shipped to ERRL for initial evaluation, canning and storage. Samples were analyzed for moisture (16 hr in 70°C vacuum oven), equilibrium relative humidity (Hygro-dynamics Electric Hygrometer Model 15-3001, Hygro-dynamics, Inc., Silver Spring, Md.) and sulfur dioxide (Nury et al., 1959; West and Ordoveza, 1962). Analytical data are summarized in Table 1.

Products were canned in No. 303 and No. 10 cans in air and under nitrogen (less than 2% oxygen) and were placed in storage at 23° and -18°C.

Table 1—Moisture content, equilibrium relative humidity and sulfur dioxide content of potato flake products

Flake product	Variable tested	Moisture (%)	ERH ^a (%)	SO ₂ (ppm)
1	Conventional process (control)	6.76	31.9	423
2	Cull raw material	6.34	32.1	298
3	High sugar raw material	6.34	36.8	505
4	Unpeeled tubers	5.66	18.5	338
5	Small raw potato pieces	10.10	57.0	1544
6	Large raw potato pieces	6.92	31.0	494
7	Potato pieces held before cooking	7.78	35.6	752
8	Minimum process water	6.31	27.6	689
9	Maximum process water	5.84	22.9	160

^a Equilibrium relative humidity

¹ A center cooperatively operated by the USDA North Central Region, ARS; The Minnesota Agricultural Experiment Station; the North Dakota Agricultural Experiment Station; and the Red River Valley Potato Growers Association.

Sensory evaluation

Products were evaluated for flavor quality initially and at intervals during storage using a trained panel as described by Sapers et al. (1972). Panelists were asked to rate flake samples on an eight-point scale ranging from "much better than standard" (8) to "extreme off-flavor" (1).

The conventional product (Product 1) stored at -18°C under nitrogen was used as a standard and hidden standard. The significance of differences reported by the panel was determined using Duncan's multiple range test (LeClerg, 1957).

Gas chromatographic analyses

Flake samples were analyzed by GLC for volatile components associated with nonenzymatic browning and oxidative rancidity (Table 2). Lower boiling compounds were determined in the headspace vapor; higher boiling components were determined in volatile concen-

trates prepared by steam distillation using procedures described previously (Sapers et al., 1972). Component concentrations were expressed as peak area ratios (component peak area/internal standard peak area). Duplicate analyses were performed initially and at intervals during storage.

RESULTS & DISCUSSION

Initial product flavor quality and volatile composition

The results of sensory evaluations and GLC analyses performed at the beginning of the storage study are summarized in Table 2. Differences between products in flavor score were small and not significant at the 0.05 level. Flakes processed from high sugar raw material (Product 3) were scored slightly lower than the conventional flakes (Product 1), probably be-

cause of their atypical sweet flavor. Likewise, flakes processed from unpeeled tubers (Product 4) were downgraded, probably due to the presence of an atypical peel-like flavor in the product. No other off-flavors were observed.

Major GLC headspace vapor (HV) and volatile concentrate (VC) peaks (Table 3) previously associated with typical storage off-flavors (Sapers et al., 1972) were examined for differences between fresh products. Levels of HV component 14 (2- and 3-methylbutanal), Strecker degradation aldehydes associated with non-enzymatic browning, were slightly elevated in flakes produced from cull raw material (Product 2), high sugar raw material (Product 3), unpeeled tubers (Product 4), potato pieces held before cooking (Product 7) and potato pieces cooked with maximum rate of process water turnover (Product 9). Similar results were obtained with VC components 40 (furfural) and 51 (phenylacetaldehyde) which are also associated with non-enzymatic browning. Presumably, these differences resulted from variations in heat damage to the flakes during processing and/or from different levels of browning reaction precursors.

The extent of oxidation in fresh potato flake samples was determined from levels of the major volatile oxidation products listed in Table 3. The sums of mean peak area ratios were computed for the four HV components and for the eight VC components used as indices of oxidation and are reported in Table 2. Flakes, analyzed within 3 wk of their arrival at our laboratory contained relatively low levels of oxidation products. Samples stored in their original shipping containers (polyethylene bags within closed fiber drums) for more than 3 wk at room temperature before analysis contained elevated levels of hexanal and benzaldehyde in volatile concentrates, as is shown in Table 4. This may have been due to the oxidation of lipids (including potato lipids, added emulsifiers and corn oil, the solvent in Tenox 4) on flake surfaces in contact with polyethylene. The very low levels of other volatile components characteristic of flake oxidation and the absence of hay-like off-flavors in these samples suggests that the reactions which occurred in bulk storage were not typical of potato flake oxidation. Fortunately, this phenomenon did not interfere with the storage study since all products intended for storage were canned within one week after their arrival. Subsequent storage stability was not correlated with the behavior of the products in bulk storage. Volatile concentrate analyses compromised by bulk storage oxidation were later repeated using nitrogen packed cans stored at -18°C . These data indicate that flakes prepared with maximum process water (Product 9), and flakes processed

Table 2—Summary of sensory and gas chromatographic data for potato flake products stored in air and nitrogen at 23°C

Flake product	Variable	Storage time (months)	Flavor score ^a	Sum of major volatile oxidation products ^a		
				Headspace vapor ^b	Volatile Conc. ^c	2- and 3-Methylbutanal ^d
1	Conventional process (control)	0	4.91	0.037	0.69	0.072
		6	—	0.040	2.03	0.052
		12	3.93	0.045	2.87	0.065
2	Cull raw material	0	4.56	0.045	0.73	0.094
		6	3.31 ^e	0.063	3.91	0.082
		12	3.64 ^e	0.098	6.88	0.086
3	High sugar raw material	0	4.44	0.037	0.88	0.089
		6	—	0.045	—	0.082
		12	3.71 ^e	0.042	2.30	0.083
4	Unpeeled tubers	0	4.33	0.038	0.73	0.117
		6	3.54 ^e	0.093	5.66	0.138
		12	3.14 ^e	0.103	10.29	0.118
5	Small raw potato pieces	0	5.06	0.034	1.20 ^g	0.055
		6	—	0.040	—	0.061
		12	4.36 ^f	0.053	4.06	0.047
6	Large raw potato pieces	0	4.75	0.030	1.10 ^g	0.059
		6	—	0.063	1.68	0.062
		12	4.21 ^f	0.064	4.05	0.067
7	Potato pieces held before cooking	0	5.13	0.027	0.67	0.122
		6	4.15 ^e	0.065	2.24	0.107
		12	3.93 ^e	0.084	4.65	0.122
8	Minimum process water	0	5.13	0.025	0.58	0.063
		6	—	0.036	—	0.068
		12	4.54	0.053	3.59	0.068
9	Maximum process water	0	4.62	0.044	1.57 ^g	0.080
		6	3.56 ^e	0.104	4.39	0.091
		12	3.62 ^e	0.135	9.29	0.100

^a Samples stored in air

^b Sum of mean peak area ratios for headspace vapor components 2, 18, 17 and 23 (identified in Table 3)

^c Sum of mean peak area ratios for volatile concentrate components 16, 19, 23, 24, 29, 44, 45 and 47 (identified in Table 3)

^d Samples stored in nitrogen

^e Significantly different from hidden standard at 0.01 level

^f Significantly different from hidden standard at 0.05 level

^g Samples stored 12 months in N_2 at -18°C

from small (Product 5) and large (Product 6) raw potato pieces contained slightly higher levels of volatile oxidation products than the other samples at zero time.

Changes during storage in nitrogen

As in previous studies of potato flake stability (Sapers et al., 1972), nitrogen-

packed potato flakes stored at 23°C showed little evidence of deterioration. After 12 months in storage, the trained taste panel found no significant differences between the products stored in nitrogen at 23°C and the nitrogen packed conventional flakes (Product 1) stored at -18°C.

Levels of 2- and 3-methylbutanal in

the headspace vapor of the nitrogen packed flakes showed little change during storage for one year at 23°C (Table 2).

Changes during storage in air

All nine potato flake products showed evidence of oxidation during 12 months storage in air at 23°C. As is seen in Table 2, the development of hay-like off-flavors was accompanied by increases in the levels of the volatile components previously associated with potato flake oxidation. Typical changes in individual volatile components during storage are shown in Table 5. Increases in the lower boiling oxidation products determined by headspace vapor analysis were not as great as increases in higher boiling oxidation products determined in volatile concentrates. Among the latter, peaks 19, 44, 45 and 47 were especially conspicuous in severely oxidized samples, sometimes exceeding peak 16 (hexanal) in size and rate of increase. Peak 44, an unknown component, was not previously detected in oxidized potato flakes although a component having the same retention time did appear as a major oxidation product in explosion puffed dehydrated potatoes (Sapers et al., 1971).

To determine the degree of association between potato flake flavor and volatile formation during storage, correlation coefficients were computed for the regression of flavor score against levels of individual oxidation products, different combinations of oxidation products and the sums reported in Table 2. All corresponding GLC and sensory data were included in the calculations except those for Product 3 and for Product 2 at 6 months, the former being objectionably sweet and the latter having an atypical off-flavor probably arising from a raw material defect which was carried through the process.

It can be seen in Table 6 that there is a high negative correlation between flavor score and oxidation product level for all peaks except hexanal (HV 23, VC 16) and benzaldehyde (VC 45). Correlation coefficients were slightly higher when flavor scores were correlated with combi-

Table 3—Volatile components of potato flakes indicative of flavor changes during storage

Source	Component no.	Identity ^a	Associated with
Headspace vapor	2	Pentane	Oxidation
	8	Propanal	Oxidation
	14	2- and 3-Methylbutanal	Nonenz. browning
	17	Pentanal	Oxidation
Volatile conc	23	Hexanal	Oxidation
	16	Hexanal	Oxidation
	19	2-Pentenal ^b	Oxidation
	23	2-Pentylfuran & 2-hexenal	Oxidation
	24	Unknown	Oxidation
	29	Unknown	Oxidation
	40	Furfural	Nonenz. browning
	44	Unknown	Oxidation
	45	Benzaldehyde	Oxidation & nonenz. browning
	47	Unknown	Oxidation
	51	Phenylacetaldehyde	Nonenz. browning

^a Sapers et al. (1972)

^b Tentative

Table 4—Levels of hexanal and benzaldehyde in volatile concentrates prepared from new potato flakes stored in bulk at room temperature

Flake product	Variable	Days in bulk storage	Mean peak area ratio	
			Hexanal	Benzaldehyde
3	High sugar raw material	19-22	0.22	0.56
		31	0.40	0.84
7	Potato pieces held before cooking	24	0.22	0.38
		32	0.60	0.91
8	Minimum process water	10-12	0.17	0.32
		30	0.37	0.50

Table 5—Major volatile oxidation products in potato flakes stored in air at 23°C

Flake product	Variable	Storage time (months)	Mean peak area ratio ^a													
			Headspace vapor component					Volatile concentrate component								
			2	8	17	23	Sum	16	19	23	24	29	44	45	47	Sum
1	Conventional process	0	0.012	0.005	0.004	0.016	0.037	0.22	0.02	0.01	0.01	T	T	0.43	T	0.69
		6	0.016	0.005	0.003	0.016	0.040	0.24	0.11	0.12	0.06	0.02	0.14	1.17	0.17	2.03
		12	0.015	0.007	0.005	0.019	0.045	0.29	0.26	0.13	0.13	0.14	0.10	1.56	0.27	2.87
2	Cull raw material	0	0.010	0.004	0.005	0.026	0.045	0.21	0.03	0.02	0.03	T	T	.43	0.01	0.73
		6	0.025	0.012	0.004	0.022	0.063	0.42	0.63	0.17	0.17	0.24	0.70	1.06	0.52	3.91
		12	0.026	0.021	0.010	0.042	0.098	0.76	0.91	0.20	0.23	0.46	1.20	1.92	1.20	6.88

^a Components identified in Table 3; T = Trace.

Table 6—Correlation of flavor score with levels of volatile oxidation products in potato flake samples stored in air at 23°C

Component ^a	Correlation coefficient (—)	
	Flavor score vs. Log peak area ratio	Flavor score vs. Peak area ratio
	HV 23	0.805
HV Sum ^b	0.885	0.917
VC 16	0.763	0.723
VC 19	0.883	0.894
VC 23	0.766	0.836
VC 24	0.812	0.792
VC 29	0.861	0.873
VC 44	0.805	0.879
VC 45	0.532	0.641
VC 47	0.772	0.865
VC 19 + 47	0.824	0.901
VC 29 + 47	0.803	0.892
VC Sum ^c	0.860	0.871

^a Components identified in Table 3

^b HV Peaks 2, 8, 17, 23

^c VC Peaks 16, 19, 23, 24, 29, 44, 45, 47

nations of volatile oxidation products, especially components 19 and 29 with 47; comparable correlation coefficients were obtained when the sums of the major headspace vapor and volatile concentrate oxidation products were substituted for the individual component levels or simple combinations. Some improvement was obtained with most oxidation products and their combinations when flavor scores were correlated with the logarithm of component levels. In view of the similarity of the correlation coefficients for a number of volatile oxidation products, one cannot demonstrate a cause and effect relationship between any single component and the oxidized off-flavor. However, the use of these components (and their sums) as objective indices of flake oxidation is validated by their high degree of correlation with off-flavor level.

Effects of raw material and processing

The extent of oxidation as determined by sensory evaluation and the production of volatile oxidation products (Table 2) varied considerably among the experimental samples.

Potato flakes prepared from cull raw material (Product 2) had slight-moderate off-flavor levels after 6 and 12 months storage in air at 23°C and contained substantially higher levels of volatile oxidation products than did the conventional flakes. The instability of this product may be due to the presence of pro-oxidant substances in the fragments of sprouts, rot and other defects which

were in contact with the mash throughout the process. Such defects should be excluded from the product through careful selection and trimming of the raw material.

Flakes produced from unpeeled tubers (Product 4) were more highly oxidized than the other potato flake products after 6 and 12 months of storage. The instability of Product 4 is noteworthy since peel fragments may be carried through the commercial flake process intentionally (Hollis and Borders, 1965) or as the result of poor peeling and trimming procedures. The original intent of this experiment was to determine whether potato flakes could be stabilized by naturally occurring water soluble antioxidants found in the peel (Pratt and Watts, 1964). It is apparent, however, that this effect, if it occurs, is countered by the pro-oxidant activity of other peel components leached into the mash.

Flakes produced from potato pieces cooked and cooled with the maximum possible rate of process water turnover (Product 9) were similar in stability to the flakes from unpeeled potatoes, having slightly lower levels of higher boiling volatile oxidation products and a slight-moderate off-flavor level. The susceptibility of these flakes to oxidation may be due to the extraction of water soluble antioxidants (e.g., amino acids, quercetin and caffeic acid) during cooking and cooling. In contrast, the flakes produced with a minimum rate of process water turnover (Product 8) were at least as stable as the conventional flakes.

Prolonged holding of the peeled potatoes prior to cooking (Product 7) had a small effect on stability and is probably not a major factor affecting shelflife. The piece size of the subdivided raw potatoes (Products 5 and 6) did not appear to influence potato flake stability. Likewise, the sugar content of the raw material (Product 3) had no effect on the sensitivity of flakes to oxidation. However, the high sugar product was downgraded by the taste panel, possibly because of its conspicuous atypical sweetness.

The extent of oxidation in the potato flake products after storage showed no consistent relationship to the extent of oxidation initially or after brief bulk storage. Oxidation also appeared unrelated to product moisture content or equilibrium relative humidity. The most highly oxidized flakes had somewhat lower levels of SO₂ and higher levels of volatile browning products. Heat damage to these products during drying could have destabilized them through the loss of antioxidants or the formation of pro-oxidants.

It can be concluded that the stability of air-packed potato flakes stored at 23°C is decreased by the presence of peel, by the use of defective raw material and by a high rate of process water turnover during cooking and cooling.

The effects on potato flake stability of the drying operation, moisture content and packaging are under investigation and will be the subject of future publications.

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