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FLAVOR QUALITY AND STABILITY OF POTATO FLAKES: EFFECTS OF DRYING CONDITIONS, MOISTURE CONTENT AND PACKAGING

INTRODUCTION

THE SHELF LIFE of dehydrated instant mashed potatoes produced by the flake process is limited by oxidative reactions which result in the development of hay-like off-flavors during storage (Sapers et al., 1972). A recent study of the effects of raw material and processing variables has demonstrated that storage stability is greatly reduced by the use of defective raw material, by the presence of peel in the mashed potatoes during processing, and by cooking and cooling potatoes in excess water such that solubles losses are high. A small decrease in stability resulted from holding peeled raw material prior to further processing. The raw material sugar content and method of subdividing potatoes prior to cooking had little or no effect on storage stability (Sapers et al., 1973).

This research has been extended to other aspects of the potato flake process. Described herein are studies of the effects of drying conditions, product moisture content and packaging on potato flake stability.

EXPERIMENTAL

Raw material and standard process

Potato flakes were prepared from Norchip variety tubers, harvested in North Dakota in September, 1971 and stored at 10°C until required for processing in January and May, 1972. Raw material used in the January experiments had a specific gravity of 1.078–1.092 and contained 0.07% fructose, 0.14–0.17% glucose and 0.24–0.92% sucrose (moisture-free basis); tubers processed in May had a specific gravity of 1.090–1.096 and contained 0.18–0.25% fructose, 0.18–0.30% glucose and 1.24–1.40% sucrose (moisture-free basis).

All flakes were produced at the Red River Valley Potato Research Center pilot plant (E. Grand Forks, Minn.) using modifications of the standard process described previously (Sapers et al., 1973). Sodium bisulfite was added to the mashed potatoes (5 ml of a 1% aq soln per pound) prior to dehydration. Drying was carried out using a single drum drier, 2 ft in diameter and 3 ft in width, having four 3-1/2 in. diameter applicator rolls separated from the drum by 1/8 in. The drier was operated at a steam pressure of 95 psi and a normal drum speed of 2.0–2.4 rpm depending on the consistency of the mash. Finished flakes were packaged in polyethylene-lined fiber drums and shipped to the Eastern Regional Research Center in Philadelphia for repacking, storage and evaluation.

Packaging study

Potato flakes prepared by the standard process (drum speed of 2.0 rpm) were air packed in No. 10 cans, completely filled with 600g flakes and also half filled with 300g flakes so that the importance of package headspace volume could be determined. In addition, 600g samples of flakes were air-packed in commercial polyethylene bags (0.0025 in. low density polyethylene) designed for potato flake packaging. The flakes had a bulk density of approximately 0.2 kg/liter as packaged and a density of 0.64 kg/liter after grinding to 20 mesh. All samples were stored at 32°C for 1 yr. Controls were nitrogen packed (less than 2% oxygen) in No. 10 cans and stored at −18°C.

Extent of drying and moisture content

Flakes were prepared by the standard process using "slow" drum drying (1.8 rpm) to produce an over-dried product, an intermediate drum speed (2.4 rpm) to produce a normally dried product, and a "high" drum speed (3.5 rpm) to produce an under-dried product. To differentiate between the effects of drying conditions and the resultant flake moisture content, each of these products were divided into subsets which were humidified by exposure to 65–75% RH at 24°C for 7 hr or cabinet dried at 38°C for 30 min to produce comparable moisture contents. The flakes were then air- and nitrogen-packed in No. 303 and No. 10 cans and stored at −18° and 23°C.

Defect accumulation in applicator roll mash

The potentially detrimental effect of defect (fragments of peel, sprouts, rot) accumulation on drum-drier applicator rolls was evaluated in May, 1972 since the incidence of raw material defects is higher at the end of the processing season. Storage potatoes were sorted into two lots, one being relatively free of defects and the other containing numerous defects. Each lot was processed into potato flakes using the standard process with a drum speed of 2.3 rpm. The mash adhering to the applicator rolls during each run was frequently removed and held under ambient conditions until the completion of the run (up to 2 hr). This mash was then processed into flakes. The four products were canned in air and nitrogen and stored at −18° and 23°C.

Product evaluation

Initially, potato flake samples were analyzed for moisture, equilibrium relative humidity (ERH), sulfur dioxide and BHA and BHT (Filipic and Ogg, 1960). Analytical data are summarized in Table 1.

Table 1—Moisture and preservatives in potato flakes

Experiment	Moisture content %	Equilibrium rel. humidity %	Preservatives (ppm) SO_2	BHA	BHT
Packaging study	5.04	16.3	255	23.4	24.0
Under-dried	7.02	33.1	375	20.4	19.5
Under-dried[a]	5.21	18.4	316	20.4	19.5
Normally dried[b]	6.98	36.7	271	23.5	21.5
Normally dried	4.69	16.1	334	23.5	21.5
Normally dried[a]	3.50	8.8	172	23.5	21.5
Over-dried[b]	5.32	20.6	223	20.6	19.6
Over-dried	3.12	6.9	247	20.6	19.6
Good raw material	6.22	31.3	206	21.9	23.8
Good raw material, A.R.M.[c]	6.47	41.2	168	19.8	15.4
Defective raw material	7.10	36.6	168	24.1	23.8
Defective raw material, A.R.M.[c]	6.90	25.6	137	17.9	18.5

[a] Cabinet dried after drum drying
[b] Humidified after drum drying
[c] A.R.M. = applicator roll mash

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

Gas chromatographic (GC) determinations of headspace vapor and volatile concentrate components associated with oxidative reactions and nonenzymatic browning were carried out in duplicate initially and at intervals during storage. GC data were expressed as peak area ratios (component peak area/internal standard peak area) or as sums of peak area ratios for the major oxidation products in sample headspace vapor (4 components) and in volatile concentrates (8 components).

Products were evaluated for flavor quality by a 15-member trained taste panel at the same intervals as the GC determinations. At each session, panelists were asked to rate up to four comparable flake samples from an experiment (including a hidden standard) against a standard, the nitrogen-packed frozen control for the experiment. An 8-point rating scale was used ranging from "much better than standard" (8) to "extreme off-flavor" (1), the flavor rating of the standard being 5 by definition. Results were expressed as mean flavor scores. All procedures and analytical methods employed in the current study have been described previously (Sapers et al., 1973).

RESULTS & DISCUSSION

Effects of packaging

As with previous studies of potato flake stability, samples in the packaging experiment showed a decline in flavor quality accompanied by increases in volatile oxidation products during storage (Table 2). However, differences between samples were small and not significant.

The extent of oxidative deterioration in air-packed potato flakes apparently is not limited by the volume of air in the package headspace. This is consistent with the work of Buttery et al. (1961) on O_2 absorption, fatty acid composition and off-flavor formation in oxidizing potato granules. If one assumes that a moderate oxidized off-flavor level in flakes is comparable to Buttery's "second detectable difference," then this degree of oxidation will correspond to an unsaturation ratio of approx 1.7 or a 40% loss in linoleic and linolenic acids. Using the fatty acid composition of potato flakes (Schwartz et al., 1968) and Buttery's data on O_2 absorption, one can estimate the O_2 uptake of the flakes equivalent to this loss; 600g of flakes would absorb approx 0.0033 moles of O_2. The No. 10 can contains about 0.021 moles of O_2, assuming the density of the flakes to be 1.00. Hence, almost 85% of the original headspace O_2 will remain in a full can containing moderately oxidized potato flakes; the half-full can will retain approx 93% of the headspace O_2. In this experiment then, there is a large excess of O_2 even in the full can. The importance of package headspace volume would be greater in products having a higher bulk density than the flakes used in this study; i.e., if the bulk density were doubled, approx 40% of the oxygen in the full can would be consumed with a moderately oxidized product.

The equivalent performance of metal and polyethylene containers in this study is a logical consequence of the insensitivity of the flakes to headspace volume. If the development of an objectionable oxidized off-flavor in potato flakes is not limited by the O_2 content of the container, then the O_2 permeability of the packaging material will not be limiting. Other differences between metal and polyethylene, i.e., permeability to moisture and to volatiles responsible for off-flavor development, apparently were of secondary importance in this experiment.

Effects of drying and moisture content

Potato flake moisture content and corresponding ERH data from the current experiments and from previously published studies (Sapers et al., 1973) were used to estimate the monolayer moisture content by the graphical BET procedure of Salwin (1959). Our value of 5.51% (as is basis) is in good agreement with monolayer moisture contents reported by Strolle and Cording (1965) for potato flakes and by Salwin (1959) for dehydrated potato dice.

Stability data for the under-dried, normally dried and over-dried flakes at their original moisture contents are summarized on Table 3. The over-dried flakes contained substantially higher levels of volatile oxidation products than the other samples, initially and after 6 and 12 months' storage. The under-dried flakes were slightly lower in volatile content than the normally dried product. Flavor scores for the under-dried and the normally dried flakes were similar and better than those for over-dried flakes initially and after 1 yr of storage.

These data demonstrate the undesirable consequences of over-drying in commercial practice. They represent the combined effects of two variables: the extent of damage to the flakes during drum drying and the influence of moisture content during storage.

The effect of moisture content on potato flake stability was established inde-

Table 2—Effect of packaging on the stability of potato flakes stored in air at 32°C

Package	Storage time (Months)	Mean flavor score	Sum of major volatile oxidation products: Headspace vapor	Volatile concentrate
Fresh flakes	0	4.8	0.062	1.85
Full can	6	3.1[a]	0.109	3.59
	12	2.8[a]	0.178	6.49
Half-full can	6	3.7[a]	0.120	3.07
	12	2.8[a]	0.177	8.14
Polyethylene bag	6	3.5[a]	0.134[b]	3.50
	12	2.5[a]	0.160	7.03

[a] Significantly different from hidden standard at 0.01 level
[b] 8 months

Table 3—Effect of drying and moisture content on potato flake stability in air at 23°C

Drying	Moisture content %	Storage time (Months)	Mean flavor score	Sum of major volatile oxidation products: Headspace vapor	Volatile concentrate
Under	7.02	0	4.9	0.060	1.51
		6	4.3[a]	0.084	3.27
		12	3.9[a]	0.116	5.56
Normal	4.69	0	4.7	0.047	1.04
		6	4.0[b]	0.075	4.27
		12	3.9[a]	0.130	7.06
Over	3.12	0	4.0[b]	0.162	3.67
		6	4.2	0.193	9.18
		12	3.3[a]	0.244	10.60

[a] Significantly different from hidden standard at 0.01 level
[b] Significantly different from hidden standard at 0.05 level

Table 4—Effect of moisture content on the stability of normally dried potato flakes in air at 23°C

Moisture content (%)	Storage time (Months)	Mean flavor score	Sum of major volatile oxidation products	
			Headspace vapor	Volatile concentrate
6.98	0	4.7	0.067	2.87
	6	4.3	0.100	4.29
	12	3.6[a]	0.156	5.86
4.69	0	4.7	0.047	1.04
	6	4.4	0.075	4.27
	12	3.8[a]	0.130	7.06
3.50	0	4.7	0.082	2.12
	6	3.7[a,b]	0.148	6.75
	12	3.7[a]	0.219	10.85

[a] Significantly different from hidden standard at 0.01 level
[b] Significantly different from higher moisture samples at 0.01 level

Table 5—Effect of extent of drying on the stability of potato flakes equilibrated to constant moisture content and stored in air at 23°C

Extent of drying	Moisture content (%)	Storage time (Months)	Mean flavor score	Sum of major volatile oxidation products		2- and 3-Methylbutanal[a]
				Headspace vapor	Volatile concentrate	
Under	5.21	0	4.9	0.086	2.57	0.063
		6	4.4	0.115	4.56	0.110
		12	4.2[b]	0.155	6.97	0.137
Normal	4.69	0	4.7	0.047	1.04	0.154
		6	4.0[b]	0.075	4.27	0.206
		12	3.9[c]	0.130	7.06	0.227
Over	5.32	0	4.0[d]	0.168	5.89	0.227
		6	3.8[c]	0.197	8.68	0.306
		12	3.2[c,d]	0.233	9.00	0.342

[a] Mean peak area ratio, determined by headspace vapor analysis
[b] Significantly different from hidden standard at 0.05 level
[c] Significantly different from hidden standard at 0.01 level
[d] Significantly different from under-dried and normally dried sample at 0.05 level

Table 6—Effect of applicator roll mash and raw material quality on potato flake stability in air at 23°C

Raw material	Mash	Storage time (Months)	Mean flavor score	Sum of major volatile oxidation products		2- and 3-Methylbutanal[b]
				Headspace vapor	Volatile concentrate	
Good	Conv.	0	5.0	0.047	1.69	0.218
		6	3.9[c]	0.075	4.79	0.256
		12	3.6[c]	0.128	6.80	0.312
Good	A.R.[a]	0	4.6	0.062	1.38	0.469
		6	3.3[c,d]	0.122	4.97	0.519
		12	3.2[c]	0.140	6.92	0.577
Defective	Conv.	0	4.5	0.049	1.10	0.502
		6	3.9[c]	0.097	3.36	0.610
		12	2.8[c]	0.096	6.07	0.650
Defective	A.R.	0	3.7[c]	0.048	2.09	0.702
		6	3.2[c,d]	0.126	6.37	0.727
		12	2.5[c]	0.131	8.96	0.810

[a] A.R. = applicator roll
[b] Mean peak area ratio, determined by headspace vapor analysis
[c] Significantly different from hidden standard at 0.01 level
[d] Significantly different from conv. mash at 0.05 level

pendently using products which had been drum dried under constant conditions (normal drying at the intermediate drum speed) and then humidified or cabinet dried under mild conditions to the same moisture contents produced by under-drying and over-drying (Tables 1, 4). Levels of volatile oxidation products were higher in the low moisture flakes than in the other samples after 6 and 12 months at 23°C. Flavor scores indicated that the low moisture sample deteriorated as much in 6 months as did the other samples in 12 months; however, flavor differences between samples at 12 months were not significant.

The protective effect of water on the stability of oxygen-sensitive dehydrated foods has been studied extensively (Labuza et al., 1970) and is attributed to the hydrogen bonding of hydroperoxides, deactivation of trace metal catalysts and free radical destruction. In the current research, the instability of the over-dried potato flakes is due in part to their low moisture content.

Another aspect of the problem, the effect of drum drying per se on potato flake stability, was studied using under-dried, normally dried and over-dried flakes which had been equilibrated to approx 5% moisture prior to storage, thereby eliminating moisture content as a variable (Table 5). The over-dried sample received lower flavor scores and contained higher levels of volatile oxidation products than the normally dried and under-dried flakes, initially and after storage. It appears from these data that extensive oxidation can occur during dehydration when the dry potato mash is exposed to air at an elevated temperature for an extended period of time. These conditions may also result in the destruction of naturally occurring antioxidants, i.e., tocopherols and amino acids, which would further destabilize the flakes during storage.

The loss of amino acids would be a consequence of nonenzymatic browning reactions initiated by drum drying and continuing during storage. Levels of 2- and 3-methylbutanal, Strecker degradation products of isoleucine and leucine, respectively, were directly related to the severity of drying and increased during storage (Table 5). The presence of these and other volatile products of nonenzymatic browning reactions may have contributed to the poor flavor of the over-dried flakes (Sapers et al., 1971).

Effect of defect accumulation in applicator roll mash

Sensory and gas chromatographic data summarized in Table 6 indicate that when good quality raw material was used, flakes prepared from conventional mash and applicator roll mash were similar with respect to oxidation during storage. The slightly lower flavor scores received by the applicator roll mash flakes initially and during storage may be due to nonenzymatic browning reactions. Levels of 2- and 3-methylbutanal were higher in this product than in the conventional mash flakes.

Flakes processed from defective raw material were poorer in flavor quality initially and less stable during storage than were the flakes made from good raw material. The applicator roll mash flakes contained higher levels of volatile oxidation products and 2- and 3-methylbutanal than did the conventional mash flakes. The very low flavor scores received by both products after 12 months' storage probably reflect the combination of oxidized and browning off-flavors.

It would appear from these results that the drum-drier applicator rolls are a potential source of off flavors and product instability, and should be cleaned frequently, especially when the raw material has a high incidence of defects. Willard (1968) has proposed that the applicator rolls be cooled to alleviate this problem. Defects should be removed from the product prior to dehydration by careful inspection and trimming of the raw tubers.

CONCLUSIONS

WE CONCLUDE that package headspace volume and the choice of polyethylene or metal as the packaging material do not affect the storage stability of air-packed potato flakes having a low bulk density.

Over-drying decreases the stability of air-packed potato flakes; this is a consequence of the sensitivity of dehydrated foods to oxidation at low water activities and to the damage done to the product during dehydration.

Potato flake flavor quality and stability may be affected adversely by the build-up of raw material defects in the mash adhering to drum drier applicator rolls.

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