Flavor and Stability of Dehydrated Potato Products

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Cooked potatoes contain a complex mixture of volatile components which vary qualitatively and quantitatively with cooking procedures. The aroma contributions of some potato volatiles have been established. Dehydrated potatoes are low in fresh potato aroma due to losses of volatiles during drying and may develop off-flavors during processing as a consequence of nonenzymatic browning reactions. Such defects may be prevented by reducing the severity of processing conditions and by controlling raw material quality and composition. Similar reactions may occur during storage but normally do not limit product shelf life. Air-packed dehydrated potato products are highly susceptible to oxidative rancidity during storage. Oxidation in potato flakes is affected by raw material quality, peeling, cooking, and drying conditions and product moisture content. The application of principles derived from research on flake stability may result in quality improvement and shelf-life extension.

Dehydrated potato products have become well established in the convenience food market in recent years and currently represent more than 25% of all potatoes used in processing. Much of the rapid growth in this industry is due to the use of dehydrated potatoes in restructured potato chips (Vegetable Situation, August 1974). However, notwithstanding their convenience and economic advantages, dehydrated potato products do not compare favorably with their fresh counterparts in flavor. To the discriminating consumer, dehydrated potato products typically lack fresh potato flavor, often have objectionable off-flavors, and are limited in shelf life (Consumers Union, 1971).

Significant improvements in the flavor quality and storage stability of dehydrated potatoes might be expected to increase consumption of these products. Such improvements could be realized by the potato processing industry through the application of research on the chemical basis of flavor deficiencies and on their causes in terms of raw material composition, processing conditions, and storage changes. In this paper, the current status of research in these areas will be reviewed and additional approaches to flavor improvement and shelf life extension will be explored.

FLAVOR OF FRESH POTATOES

Since dehydrated potatoes are intended as substitutes for fresh cooked potatoes, and ideally should duplicate their flavor, it is appropriate to consider first the chemical basis of fresh potato flavor. This subject was reviewed previously by Burr (1966) and by Self (1967). The following discussion will be limited to the aroma and volatile components of raw, boiled, and baked potatoes.

The aroma of fresh cooked potatoes is due to the contributions of a number of classes of volatile compounds, which vary qualitatively and quantitatively with raw material composition (Self, 1967) and the method of cooking (Buttery et al., 1970, 1973). Volatile components which have been identified in raw, boiled, and baked potato are listed in Table I.

The earthy aroma of raw potatoes has been attributed to 2-methoxy-3-isopropylpyrazine. Tentative evidence was obtained for the presence in raw potato of 2-ethyl-3-methoxypyrazine which also has an earthy aroma (Buttery and Ling, 1973).

Volatile sulfur compounds, arising from the degradation of amino acids and protein during cooking, probably contribute to the aroma of boiled potatoes. Methyl mercaptan, which has an odor threshold of 0.02 ppb, is a major constituent of the volatile sulfur compounds in potato (Gumbmann and Burr, 1964; Self, 1967). Methional, which imparts a potato-like aroma (Burr, 1966), has been identified in boiled and baked potato volatiles (Buttery et al., 1970, 1973).

Guadagni et al. (1971) attempted to enhance the flavor of dehydrated mashed potatoes by the addition of compounds which were considered to be important volatile components of raw and boiled potato. Phenylacetaldehyde, oct-1-en-3-ol, methional, and 2-methoxy-3-isopropylpyrazine were ineffective in increasing the flavor level of the reconstituted mashed potatoes. Flavor enhancement did occur with 2-ethyl-3-methoxypyrazine.

Alkylpyrazines, which arise from amino acid–sugar reactions at elevated temperatures, are major volatile components of baked potatoes. Buttery et al. (1973) considered 2-ethyl-3,6-dimethylpyrazine and possibly 2-ethyl-3,5-dimethylpyrazine to be important to baked potato aroma in addition to methional and deca-*trans,trans*-2,4-dienal. Pareles and Chang (1974) felt that the combination of 2-isobutyl-3-methylpyrazine, 2,3-diethyl-5-methylpyrazine, and 2,6-diethyl-3-methylpyrazine (eluted as a single GLC peak) had a more characteristic baked potato aroma than 2-ethyl-3,6-dimethylpyrazine.

Other volatile components of cooked potatoes include alkanals, 2-alkenals, and dienals which arise from lipid oxidation, Strecker degradation aldehydes, ketones, alcohols, furans, and terpenes (Self, 1967; Buttery et al., 1970, 1973).

FLAVOR OF DEHYDRATED POTATOES

In contrast to fresh cooked potatoes, which have a mild but characteristic aroma, dehydrated potatoes at best are practically devoid of potato aroma. Gas chromatographic analyses of freshly dehydrated potatoes reveal very low levels of most volatile components. This is due primarily to the loss of volatiles by steam distillation during dehydration. Under these circumstances, any chemical change in dehydrated potatoes during processing or storage which entails the formation of volatile compounds is likely to produce an off-flavor.

Explosion Puffed Dehydrated Potatoes. The importance of processing conditions in affecting product flavor is clearly seen with explosion puffed dehydrated potatoes. This experimental product is prepared by heating partially dehydrated potato pieces with superheated steam in a puffing gun and then suddenly releasing the pressure, thereby producing an explosive puffing effect. The puffed potato pieces have a porous structure and are capable of rapid reconstitution (Turkot et al., 1966). However, it was

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Table I. Volatile Components of Fresh Potatoes

	Source[a]	Ref		Source[a]	Ref
Sulfur compounds			Alcohols		
Hydrogen sulfide	B	*b, c*	Methanol	B	*c*
Methyl mercaptan	B	*b, c*	Ethanol	B	*c*
Ethyl mercaptan	B	*b, c*	2-Methylbutanol	B	*d*
Isopropyl mercaptan	B	*b*	3-Methylbutanol	B	*d*
n-Propyl mercaptan	B	*b, c*	Pentanol	B	*d*
Dimethyl sulfide	B	*b, c*	Oct-1-en-3-ol	R, B, BK	*d, e*
Methyl ethyl sulfide	B	*b*	Oct-*trans*-2-en-1-ol	R, B	*d*
Diethyl sulfide	B	*b*	Benzyl alcohol	B	*d*
Dimethyl disulfide	B	*b, c*	α-Terpineol	R, B	*d*
Methyl ethyl disulfide	B	*b*	Nerol	R, B	*d*
Methyl isopropyl disulfide	B	*b*	Geraniol	R, B	*d*
Methional	B, BK	*d, e*	Linalool	B	*d*
3,5-Dimethyl-1,2,4-trithiolane	B	*d*	Furans		
Benzothiazole	B	*d*	2-Pentylfuran	R, B, BK	*d, e*
Aldehydes			2-Acetylfuran	BK	*e*
Acetaldehyde	B	*c*	Pyridine and pyrazines		
Propanal	B	*c*	Pyridine	B, BK	*d, e*
2-Methylpropanal	B, BK	*c, e*	2-Methylpyrazine	BK	*e*
2-Methylbutanal	B, BK	*c, e*	2,5-Dimethylpyrazine	BK	*e, g*
3-Methylbutanal	B, BK	*c, e*	2,6-Dimethylpyrazine	BK	*e, g*
Hexanal	R, B, BK	*d, e*	2-Ethylpyrazine	BK	*e*
Heptanal	R, B, BK	*d, e*	2,3-Dimethylpyrazine	BK	*e*
Nonanal	BK	*e*	2-Ethyl-6-methylpyrazine	BK	*e, g*
Decanal	BK	*e*	2-Ethyl-5-methylpyrazine	BK	*e, g*
2-Propenal	B	*c*	2-Ethyl-3-methylpyrazine	BK	*e, g*
Hex-*trans*-2-en-1-al	BK	*e*	Trimethylpyrazine	BK	*e*
Hept-*trans*-2-en-1-al	B, BK	*d, e*	2-Methyl-5-vinylpyrazine	BK	*e*
Oct-*trans*-2-en-1-al	R, B, BK	*d, e*	2-Ethyl-3,6-dimethylpyrazine	BK	*e, g*
Non-*trans*-2-en-1-al	B, BK	*d, e*	2-Ethyl-3,5-dimethylpyrazine	BK	*e*
Dec-*trans*-2-en-1-al	BK	*e*	2-Isobutyl-3-methylpyrazine	BK	*e, g*
Hepta-*trans,trans*-2,4-dienal	BK	*e*	2,3-Diethyl-5-methylpyrazine	BK	*e, g*
Nona-*trans,trans*-2,4-dienal	BK	*e*	2,6-Diethyl-3-methylpyrazine	BK	*e, g*
Deca-*trans,trans*-2,4-dienal	R, B, BK	*d, e*	2,5-Diethyl-3-methylpyrazine	BK	*e*
Deca-*trans,cis*-2,4-dienal	BK	*e*	2-Isobutyl-3,6-dimethylpyrazine	BK	*e, g*
2-Furaldehyde	B	*d*	2-Methoxy-3-isopropylpyrazine	R	*f*
5-Methyl-2-furaldehyde	BK	*g*	Hydrocarbons		
Benzaldehyde	R, B, BK	*d, e*	Naphthalene	R, B	*d*
Phenylacetaldehyde	B, BK	*d, e*	2-Methylnaphthalene	R, B	*d*
Ketones			Biphenyl	R, B	*d*
2-Propanone	B	*c*	Misc. compounds		
Hexan-2-one	BK	*e*	Methyl salicylate	B	*d*
Heptan-2-one	B, BK	*d, e*	1,1-Diethoxyethane	BK	*g*
Decan-2-one	B	*d*	2-Phenylcrotonic acid	BK	*g*
Oct-1-en-3-one	R, B	*d*			
Non-*trans*-2-en-4-one	B	*d*			

[a] R, raw; B, boiled; BK, baked. [b] Gumbmann and Burr (1964). [c] Self (1967). [d] Buttery et al., 1970. [e] Buttery et al., 1973. [f] Buttery and Ling, 1973. [g] Pareles and Chang, 1974.

found during the development of the process that an objectionable off-flavor developed in the potato pieces during puffing.

Research carried out at the Eastern Regional Research Center, USDA, has indicated that the puffing off-flavor is associated with elevated levels of volatile products of nonenzymatic browning reactions. These include 2-methylpropanal, 2-methylbutanal, and 3-methylbutanal, which were previously associated with browning in potato granules (Buttery and Teranishi, 1963), as well as other Strecker degradation aldehydes, alkylpyrazines, and related compounds (Table II). The headspace vapor concentration of 2- and 3-methylbutanal, determined by GLC (as one peak), has been used as an index of the flavor quality of experimental products (Sapers et al., 1970, 1971; Sapers, 1970).

Engineering studies have demonstrated that modifications of the process which lessen its tendency to induce browning reactions also improve product flavor. For example, reducing the severity of the puffing step by diluting the superheated steam with nitrogen will decrease concentrations of browning volatiles and lower off-flavor levels (Table II and Sullivan et al., 1974). Further improvements may result from the use of raw material having a low reducing sugar content, thereby limiting the extent of nonenzymatic browning reactions during puffing (Table III).

Potato Flakes. The flavor quality of potato flakes, a form of instant mashed potatoes, may be affected by raw material and processing conditions. The potato flake process consists of peeling, slicing, precooking, cooling, cooking, ricing, and drum drying steps (Cording et al., 1957). This process has been reexamined by our laboratory in collaboration with the Red River Valley Potato Research Cen-

Table II. Higher Boiling Compounds Associated with Off-Flavor in Explosion Puffed Potatoes[a]

	Peak height, cm with process		
Component	Steam puffed	Steam/N_2 puffed	Conv. dehyd.
2-Methylpyrazine	5.10	3.10	0.40
2,5-Dimethylpyrazine	3.70	1.85	Trace
2,3- and/or 2,5-methyl-ethylpyrazine[b]	1.05	0.55	Trace
Ethyldimethylpyrazine[b] and furfural	5.10	4.25	0.70
Benzaldehyde	0.80	0.65	0.40
5-Methylfurfural	0.80	0.60	0.35
Phenylacetaldehyde	8.40	6.65	2.65
Off-flavor level	Moderate	Slight	None

[a] Data from Sapers et al. (1971). [b] Tentative.

Table III. Effect of Reducing Sugar Content on 2- and 3-Methylbutanal Level in Explosion Puffed Potatoes[a]

Variety	Reducing sugars, %[b]	2- and 3-Methylbutanal peak area ratio
Kennebec	5.56	0.210
	1.20	0.107
Russet Burbank	6.84	0.513
	2.41	0.230

[a] Data from Sullivan et al. (1974). [b] Moisture-free basis.

Table IV. Effects of Drum Drying and Raw Material Quality on Potato Flake Flavor[a]

Treatment	Moisture content, %	Flavor score	2- and 3-methylbutanal peak area ratio
Underdried (17.1 sec)	7.02	4.9	0.043
Normally dried (25.0 sec)	4.69	4.7	0.154
Overdried (33.3 sec)	3.12	4.0[b]	0.209
Good raw material	6.22	5.0	0.218
Defective raw material	7.10	4.5	0.502
Defective raw material applicator roll mash	6.90	3.7[c]	0.702

[a] Data from Sapers et al. (1974). [b] Significantly different from normally dried sample at 0.05 level. [c] Significantly different from good raw material sample at 0.01 level.

ter, East Grand Forks, Minn., with the intent of improving product flavor and shelf life.

Off-flavor formation may occur during drum drying as a consequence of overheating. This defect is due to nonenzymatic browning and is accompanied by increases in Strecker degradation aldehydes but not by pyrazine formation (Sapers et al., 1972, 1974). Data summarized in Table IV show that flakes which were subjected to increasingly long drying times received lower flavor scores (assigned by a trained taste panel) and contained higher headspace vapor concentrations of 2- and 3-methylbutanal.

Raw material quality may also affect potato flake flavor. Flakes prepared from good quality tubers received higher flavor scores and contained lower levels of 2- and 3-methylbutanal than did flakes prepared from potatoes containing sprouts, rot, and blackspot. Both raw material samples were obtained from the same lot of potatoes by sorting and were similar with respect to reducing sugar and sucrose contents (Sapers et al., 1974).

Mashed potatoes adhering to the drum drier applicator rolls represent another potential source of off-flavors in potato flakes. This mash, which contains particulate raw material defects separated from the product by the applicator rolls, is held at an elevated temperature (ca. 85°), and will continuously contaminate the mash on the drum if not frequently removed (Willard, 1968). In our laboratory, flakes made from applicator roll mash were inferior in flavor and contained high levels of 2- and 3-methylbutanal (Sapers et al., 1974).

Table V. Effect of Storage Conditions on Stability of Nitrogen Packed Explosion Puffed Potatoes[a]

Storage time, months	Flavor score		2- and 3-methylbutanal peak area ratio	
	23°	38°	23°	38°
0	4.00	4.00	0.210	0.210
2	4.15	3.40[b]	0.244	0.646
3		3.36[b]	0.292	0.670
5	4.08	3.14[b]	0.296	0.794

[a] Data from Sullivan et al. (1974). [b] Significantly different from control at 0.05 level.

Table VI. Volatiles in Oxidized Potato Granules[a]

Alkanals	2-Alkenals	Hydrocarbons
Acetaldehyde	2-Pentenal[b]	Methane
Propanal	2-Hexenal[b]	Ethane
Butanal	2-Octenal[b]	Propane
Pentanal		Butane
Hexanal		Pentane
Heptanal[b]		
Octanal[b]		
Nonanal[b]		
2-Methylpropanal		
2-Methylbutanal		
3-Methylbutanal		

[a] Data from Buttery (1961). [b] Tentative.

STORAGE STABILITY OF DEHYDRATED POTATO PRODUCTS

Nonenzymatic Browning. During storage, dehydrated potatoes may undergo nonenzymatic browning reactions which yield volatile products capable of affecting flavor. These include the Strecker degradation aldehydes associated with scorching in potato granules (Buttery and Teranishi, 1963) as well as alkylpyrazines and other higher boiling compounds found in explosion puffed potatoes which increase during storage (Sapers, 1970, unpublished data). The formation of such compounds has been reviewed by Hodge et al. (1972).

In our work with explosion puffed potatoes and potato flakes, we have rarely observed significant changes due to nonenzymatic browning except in samples which were deliberately abused during processing or storage. An example of the latter condition is seen in Table V. In this case, a nitrogen-packed explosion puffed product made from high sugar Kennebec potatoes was stable at 23° but developed

Table VII. Effects of Raw Material, Peeling, and Cooking on Potato Flake Storage Stability in Air at 23°[a]

Treatment	Storage time, months	Flavor score	Sum of volatile oxidation products: Headspace vapor	Sum of volatile oxidation products: Volatile concentrate
Control	0	4.9	0.037	0.69
	6		0.040	2.03
	12	3.9	0.045	2.87
Defective raw material	0	4.6	0.045	0.73
	6	3.3[b]	0.063	3.91
	12	3.6[b]	0.098	6.88
Unpeeled tubers	0	4.3	0.038	0.73
	6	3.5[b]	0.093	5.66
	12	3.1[b]	0.103	10.29
Excess cooking water (trace dissolved solids)	0	4.6	0.044	1.57
	6	3.6[b]	0.104	4.39
	12	3.6[b]	0.135	9.29
No water turnover (1.76% dissolved solids)	0	5.1	0.025	0.58
	6		0.036	
	12	4.5	0.053	3.59

[a] Data from Sapers et al. (1973). [b] Significantly different from hidden standard at 0.01 level.

Table VIII. Effects of Drum Drying and Moisture Content on Potato Flake Storage Stability in Air at 23°[a]

			Sum of volatile oxidation products					
			Headspace vapor after storage, months			Volatile concentrate, after storage, months		
Expt.	Extent of drying	Moisture content	0	6	12	0	6	12
I	Under	7.02	0.060	0.084	0.116	1.51	3.27	5.56
	Normal	4.69	0.047	0.075	0.130	1.04	4.27	7.06
	Over	3.12	0.162	0.193	0.244	3.67	9.18	10.60
II	Normal	6.98	0.067	0.100	0.156	2.87	4.29	5.86
	Normal	3.50	0.082	0.148	0.219	2.12	6.75	10.85
III	Under	5.21	0.086	0.115	0.155	2.57	4.56	6.97
	Over	5.32	0.168	0.197	0.233	5.89	8.68	9.00

[a] Data from Sapers et al. (1974).

an off-flavor and high levels of 2- and 3-methylbutanal during storage at 38° (Sullivan et al., 1974).

Such changes are of little practical significance in air-packed dehydrated potato products since their storage life is limited by flavor changes resulting from oxidative rancidity rather than from nonenzymatic browning (Sapers et al., 1972; Sullivan et al., 1974; Lisberg and Chen, 1973). Browning off-flavors may be a factor in the storage stability of nitrogen-packed products and dehydrated potatoes held at high storage temperatures.

Oxidative Rancidity. During storage in air, dehydrated potatoes rapidly undergo oxidation and develop off-flavors which with explosion puffed potatoes can be described as rancid, and with flakes or granules as hay-like.

Buttery et al. (1961) related off-flavor formation in autoxidizing potato granules to oxygen consumption and the loss of linoleic and linolenic acids during storage. Buttery (1961) found that the oxidized granules contained a number of volatile products of lipid oxidation including hydrocarbons, alkanals, and 2-alkenals (Table VI). Subsequently, Buttery and Teranishi (1963) developed a procedure for the determination of hexanal in the headspace vapor above reconstituted granules. This compound, while not solely responsible for the oxidized off-flavor, could be used as an accurate index of the extent of oxidation and off-flavor formation (Boggs et al., 1964).

The shelf life of air-packed potato flakes is limited by oxidative rancidity to about 6 months. Oxidative changes may be controlled by the addition of antioxidants such as BHA and BHT, which are only partially effective, and by nitrogen packing. The latter approach has not been considered feasible for flakes because of their low bulk density. The optimal moisture content for potato flake storage stability is considered to be between 5.1 and 5.8% which corresponds closely to the monolayer moisture value calculated from water vapor sorption data (Strolle and Cording, 1965).

Off-flavor development in flakes during storage is accompanied by the formation of volatile products of lipid oxidation similar to those found in granules. In our investigations of potato flake stability, we have monitored flake samples by sensory evaluation using a trained taste panel, and by gas chromatographic analyses for major volatile oxidation products. Headspace vapor analysis has been used for lower boiling components including pentane, propanal, pentanal, and hexanal. Higher boiling oxidation products including hexanal, 2-pentenal, 2-pentylfuran, 2-hexenal, benzaldehyde, and four unidentified components were determined in volatile concentrates prepared by steam distillation (Sapers et al., 1972). Comparisons of GLC and sensory data for oxidized flake samples indicated that peak areas for these volatile oxidation products were all correlated with off-flavor levels. The sums of the volatile oxidation

Table IX. Effect of Raw Material Quality and Applicator Roll Mash on Potato Flake Stability in Air at 23°[a]

				Sum of volatile oxidation products		
Raw material	Mash	Storage time, months	Flavor score	Headspace vapor	Volatile concentrate	2- and 3-methylbutanal[c]
Good	Conv.	0	5.0	0.047	1.69	0.218
		6	3.9	0.075	4.79	0.256
		12	3.6	0.128	6.80	0.312
Defective	Conv.	0	4.5	0.049	1.10	0.502
		6	3.9	0.097	3.36	0.610
		12	2.8	0.096	6.07	0.650
Defective	A.R.[b]	0	3.7	0.048	2.09	0.702
		6	3.2	0.126	6.37	0.727
		12	2.5	0.131	8.96	0.810

[a] Data from Sapers et al. (1974). [b] A.R., applicator roll. [c] Peak area ratio.

Table X. Effect of Packaging on the Stability of Potato Flakes Stored in Air at 32°[a]

			Sum of volatile oxidation products		
Package	Storage time, months	Flavor score	Headspace vapor	Volatile concentrate	2- and 3-methylbutanal[c]
Fresh flakes	0	4.8	0.062	1.85	0.286
Can	6	3.1	0.109	3.59	0.473
	12	2.8	0.178	6.49	0.576
Polyethylene bag	6	3.5	0.134[b]	3.50	0.470
	12	2.5	0.160	7.03	0.559

[a] Data from Sapers et al. (1974). [b] Eight months. [c] Peak area ratio.

product peak areas were more highly correlated with flavor scores than were peak areas of the individual peaks. Consequently, we have used the headspace vapor and volatile concentrate peak area sums as indices of the extent of oxidation in flake samples (Sapers et al., 1973).

Effects of Raw Material, Processing, and Packaging. Research on potato flake stability in our laboratories has focused on the influence of raw material quality and composition, processing conditions, and packaging. While the importance of these factors is well known to the potato processing industry, the lack of quantitative information about their effects has been an obstacle to product improvement.

Raw material quality will affect potato flake storage stability as well as initial flavor quality, which was discussed previously. Sensory and GLC data summarized in Table VII show that flakes prepared from raw material containing sprouts, rot, and blackspot received lower flavor scores and contained higher levels of volatile oxidation products after storage than did the control which was processed conventionally using good quality raw material.

We also evaluated the importance of the peeling step, storing flakes prepared from unpeeled tubers; peel fragments were removed from the final product by the drum drier applicator rolls. This product was even less stable than the flakes made from defective raw material. It appears likely that these results are due to the presence in the flakes of pro-oxidant materials which were extracted from the skin and from defects in the skin.

In other experiments, we found that flake stability was not affected by the raw material sugar content or by prolonged holding of the raw potato pieces in bisulfite solution prior to precooking.

Precooking conditions may also affect potato flake storage stability. Flakes were prepared from potatoes cooked in excess water containing a very low concentration of dissolved solids and from potatoes cooked in water having a high dissolved solids content (no water turnover in cooker). The flakes processed from potatoes cooked in excess water received substantially lower flavor scores and contained higher levels of volatile oxidation products. This method of cooking probably extracted a greater quantity of naturally occurring water-soluble antioxidants, i.e., amino acids, peptides, and flavonoids, thereby decreasing product stability; extractive losses would be reduced by cooking in water containing sufficiently high concentrations of dissolved potato solids (Sapers et al., 1973).

Drum drying conditions have a major effect on potato flake storage stability as well as on initial flavor quality. Overdried flakes were found to be more extensively oxidized during storage than were underdried or normally dried flakes (Table VIII, experiment I). This result is due in part to the flake water activity. Normally dried samples were equilibrated under mild conditions to moisture contents corresponding to those obtained by underdrying or overdrying (Table VIII, experiment II). As might be expected, oxidation product levels were higher in the low moisture flakes than in the higher moisture samples. However, overdrying per se has a detrimental effect on flake stability. Even after equilibration to the same moisture content as the normally dried flakes (Table VIII, experiment III), the overdried flakes were more highly oxidized during storage than were the underdried and normally dried samples. This may be due to the destruction of natural antioxidants and the initiation of oxidation during dehydration (Sapers et al., 1974).

The poor flavor of potato flakes after storage may represent the combined effects of nonenzymatic browning during dehydration and oxidative rancidity during storage.

This effect was especially pronounced with flakes made from defective raw material and from mash accumulating on drum drier applicator rolls (Table IX) which contained unusually high levels of 2- and 3-methylbutanal (Sapers et al., 1974).

The selection of packaging materials for air-packed potato flakes has been an area of controversy for the potato processing industry. A comparison of flakes packaged in two widely used containers, the metal can and the polyethylene bag, indicated no differences in storage stability at 32° (Table X). Low flavor scores received by these samples after 12 months probably reflect nonenzymatic browning resulting from the high storage temperature used in this comparison. The equivalent performance of metal and polyethylene containers in this study is a consequence of the low bulk density of potato flakes. At this density, the package headspace contains a large excess of oxygen over that required for flake oxidation; the oxygen permeability of the packaging material is not a limiting factor. Of course, this would not apply to nitrogen packed products or to products having a substantially higher bulk density than flakes, both of which would require an oxygen impermeable package.

CONCLUSIONS AND OUTLOOK

The flavor quality of dehydrated potato products is determined by nonenzymatic browning reactions which occur primarily during processing and by oxidative reactions which take place during storage. The extent to which these reactions affect product flavor depends on raw material quality and composition, processing conditions, packaging, the use of additives, and storage conditions.

What are the prospects for materially improving the flavor quality of dehydrated potatoes? Obviously, processors should avoid those practices which result in flavor problems, overdrying being a prime example. Beyond this, an effort should be made to improve the retention of natural potato flavor through process modification. Precooking, cooling, and cooking conditions might be modified to reduce the leaching and degradation of flavor precursors. The development of new drying procedures which minimize heat damage and improve retention of volatile constituents would be advantageous. The addition of synthetic mixtures of important flavor compounds and precursors might be beneficial. Finally, more effective means to prevent oxidative rancidity during storage are needed. A reduction in the cost of nitrogen packing or the development of more effective antioxidants and synergists might serve this end.

Improvements in these areas might have broad application and would benefit both the food processing industry and the consumer.

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A Review of Thermally Produced Imitation Meat Flavors

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The evolution and current state-of-the-art of thermally produced imitation meat flavors are reviewed and discussed with particular emphasis on the patent literature with respect to flavor precursors and possible routes of formation of flavor components.

Thermally produced imitation meat flavors are often described in the patent literature as "processed meat flavors" because they are the result of the thermal processing of a mixture of food components which possess to varying degrees the organoleptic properties of cooked meat. They arose as a response to a need in the food industry for inexpensive, stable products of consistent, controllable quality which would provide flavors suggestive of cooked meats. These products have enjoyed an increasingly wide application as consumer acceptance and food legislation have per-

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