Vitamin Stability in Fortified Potato Flakes

(Manuscript received January 16, 1961)

James Cording, Jr.,[a]
Roderick K. Eskew,[a]
G. J. Salinard,[b] and
John F. Sullivan [a]
Eastern Regional Research Laboratory [c]
Philadelphia 18, Pennsylvania

1600

SUMMARY

In the flake process, a retention of both natural and added vitamin C during processing is 71–73%. On storage for 28 weeks at 75°F in an air pack, flakes of 5% moisture containing antioxidant, retained 70–76% of the natural and added vitamin C remaining after processing. In a nitrogen pack, substantially all of the vitamin C that survived processing was retained after 28 weeks of storage. Vitamin C, at an initial level of 56 mg per 3 oz of flakes, was less effective as an antioxidant than Tenox IV[c] in 25 weeks storage in air. Under nitrogen at 25 weeks and 18 weeks storage in air, vitamin C at this level was equal to Tenox IV.

Fortification with vitamin B_1 appears uneconomical because of processing losses due to the presence of sulfite.

Based on retention, fortification with vitamins A, B_2, and niacin seems practical. A yellow color in the reconstituted flakes of lots 4 and 5 was attributed to vitamin B_2. However, a small panel did not consider the degree of color undesirable. Flavor of lots 4 and 5 when reconstituted, was considered worse than the standard and was attributed to the multivitamin combination in these lots.

THE VALUE of the potato as a food has long been asserted and the public verdict has been confirmed by scientific analysis. It is low in vitamin C in comparison with "rich" sources (oranges, broccoli, cabbage, tomatoes, etc.), but the potato ranks as a food of major nutritional importance when "consumer appetite" is considered. Research by Dove (1943) comparing the vitamin C content of potatoes with that of cabbage, collards, broccoli, kohlrabi, turnips, and tomatoes, ranked the potato sixth on a unit weight basis. The same values calculated according to "appetite level" showed a striking change in the order of importance, with the potato ranking first. "Appetite level" reflects not only the nutritional value of a food per unit quantity, but the degree of preference of the consumer for that food and the rate of consumption of it. In appetite level, both nutritional and psychological measures of value are combined.

Potatoes offer a good nutrient return for the money spent. One medium-sized potato, boiled in its jacket, supplies about one-quarter of the ascorbic acid recommended as a day's allowance (National Research Council) for a man 25 years old, 8–10% of the iron, thiamine, and niacin; and 4% of the protein, riboflavin, and food energy. Since a medium-sized potato costs 1–2 cents, the nutrients are a bargain.

Because the vitamin C content of raw potatoes varies with variety, growing season, length of storage, etc., the content in processed potatoes will also vary. Addition of C and other vitamins could permit control of nutrient value the year round.

With this in mind, pilot-plant tests on potato flakes were conducted to test the retention of certain vitamins in the potato-flake process, during both drying and subsequent storage. This paper reports the results.

EXPERIMENTAL

Preparation of flakes. Russet Burbank potatoes grown in Idaho and bought in the Philadelphia wholesale market in February, 1959, were used to produce the flakes. They were in good condition but rather low in vitamin C content (12.7 mg per 100 g), as would be expected since some 4 months had elapsed since they were dug. Potato flakes were prepared by methods described earlier (Cording *et al.*, 1954, 1955, 1957, 1959; Eskew *et al.*, 1956).

Potatoes were peeled by immersion at 150°F for 6 min in water containing 20% by weight NaOH. The loosened skins were then removed in a rod-reel-type washer by high-pressure water sprays (100 psi). The peeled potatoes were hand trimmed to remove damaged tissue and then sliced into ⅝-in.-thick slabs in an Urschel Laboratories Model B slicer. The slices were precooked (Cording *et al.*, 1955) 20 min in water at 160°F, cooled 20 min in water at 40°F (Cording *et al.*, 1959), and then cooked 30 min in steam at atmospheric pressure. They were then soft enough to mash. The cooked slices were put through a continuous ricer (Cording *et al.*, 1959). The riced potatoes were collected in 75-lb batches in the bowls of a Hobart Model L-800 mixer. The following additives[d] were incorporated into the mash by mixing 2 min at slow speed in the Hobart mixer:

1) **Emulsion.** Containing 7.5 g glycerol monopalmitate, 15 g nonfat dry milk, 2.7 g Tenox IV, and 225 ml water. This amount was added to each lot except lot 2, from which the antioxidant Tenox IV was omitted to test ascorbic acid as a substitute antioxidant.

2) **Sulfite solution.** Containing 4.5 g Na_2SO_3 and 1.5 g $NaHSO_3$ in 60 ml of solution. This amount was added to all lots, calculated to give about 200 ppm of SO_2 in the dried flakes after losses in dehydration.

3) **Vitamins.** Lot 1) control, none added; lot 2) vitamin C to give 28.1 mg per 3 oz of flakes if none lost in processing; lot 3) vitamin C to give 75 mg per 3 oz of flakes if none lost in processing; lot 4) vitamins C, B_1, and B_2 to give 75, 2.5, and 3.0 mg, respectively, per 3 oz of flakes if none lost in processing; lot 5) vitamins C, B_1, B_2, niacin, and vitamin A to give 75, 2.5, 3.0, 20.0 mg, and 12,000 international units, respectively, per 3 oz of flakes if none lost in processing. The vitamins were dispersed in water before being added to the mash in the mixer.

Each lot was dried separately on a single-drum dryer (Overton Machine Co.) with a drying drum 2 ft in diameter and 3 ft long, where it was dehydrated as a continuous sheet about

---

[a] Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

[b] Hoffmann-La Roche, Inc., Nutley 10, New Jersey.

[c] Reference to certain products or companies does not imply an endorsement by the Department over others not mentioned.

[d] Individual manufacturers should consult the Food and Drug Administration, Washington 25, D. C., and the food and drug officials of the individual states involved, to determine if the use of any proposed additive is permissible, and if so, what limitations are placed on its use.

0.008 in. thick, with a final moisture content of about 5% (Cording *et al.*, 1957). The sheet was cut into flakes about ½-in. square by passing it through a 3-roll cutter attached to the drier. To avoid mixing one lot with another, each lot was followed on the drier by mashed potatoes containing no additives, and the product was discarded 5 min after each new batch of mash was applied to the drier. From lot 3, more flakes were collected than could reasonably be expected from 75 lb of mash, apparently because of inclusion of some flakes from mash containing no additives. This explains the apparent low recovery of vitamin C in that lot.

Flakes from each lot were packed in sealed cans (300 × 509), 100 g in each, packed half in air and half in nitrogen. The cans were stored at 75, 98, and 113°F. Samples were removed at intervals, assayed for vitamin content, and tested organoleptically for flavor and color.

Vitamin assay of flakes. *Vitamin A.* The potato flakes were saponified in alcoholic potassium hydroxide, then blended and extracted by a single shaking with petroleum ether. An aliquot of the petroleum ether was evaporated to dryness and taken up with chloroform, and Carr-Price colorimetry was performed (György, 1951; Methods of vitamin assay, 1951).

Vitamin B_1. The potato flakes were cooked in 0.1*N* hydrochloric acid and digested overnight with enzyme (Clarase). The filtered extract was passed through a Zeolite (Decalso) column and the eluate oxidized via the standard thiochrome procedure (Methods of vitamin assay, 1951).

Vitamin B_2. A portion of the extract from the vitamin B_1 assay was buffered with sodium acetate to pH 4.5–6.0 and read fluorometrically with an internal standard (Methods of vitamin assay, 1951).

Vitamin C. The potato flakes were blended in 3% cold metaphosphoric acid, filtered and/or centrifuged, and assayed by the dye-xylene method, including use of a formaldehyde blank and hydrogen peroxide modification to eliminate interference by sulfite, iron, and tin, which can cause erroneously high values (György, 1951; Methods of vitamin assay, 1951).

Niacin. The potato flakes were autoclaved with 10 parts of 1*N* H_2SO_4 for 30 min at 15 lb pressure. The filtered or centrifuged extract was assayed microbiologically by the method of U. S. Pharmacopoeia XIV, page 737.

Organoleptic testing. Samples were reconstituted by combining 100 g with 2 cups of liquid (1½ cups boiling water + ½ cup cold milk) and adding 1 tablespoon of butter and ½ teaspoon of salt, i.e., as served in the home. In evaluating taste alone, panel members wore red goggles to avoid the influence of the yellow color contributed by the riboflavin in lots 4 and 5. Color was evaluated separately. Samples were ranked 1–5 in the order of least "off" flavor to most "off" flavor. The panel had to be small (8–15 members), so no attempt was made to determine "acceptability." Differences between samples were calculated at the 95% level of reliability.

RESULTS AND DISCUSSION

Retention during processing and storage. Tables 1, 2, 3, and 4 show recovery and retention data for vitamin C. All recovery and retention data are based on 3 oz (85 g) of flakes; this is the normal amount in four servings.

Table 1. Vitamin C content (mg/3 oz) of potato flakes, packed in air and under nitrogen, after storage at different temperatures.[a]

Storage (weeks)	Air pack			N_2 pack		
	75°F	98°F	113°F	75°F	98°F	113°F
0	36	36	36	36	36	36
4	27	....	....	36	....	....
10	....	....	33	....	....	45
12	....	29	....	....	41	....
16	23	26	26	35	40	41
28	30	....	....	53	....	....

[a] Initial value of 36 mg/3 oz represents a 73% recovery on drying of the 49 mg/3 oz calculated on the basis of 12.7 mg/100 g of raw potato.

Table 1 gives data on the natural vitamin C of the potato. Based on 12.7 mg per 100 g found in the raw potatoes before processing, it would be expected that 49 mg would be present in 3 oz of flakes if none were lost in processing. A level of 36 mg per 3 oz of flakes was found just after processing, a recovery of 73%. After 4 months of storage in an air pack, at room temperature (75°F) and at elevated temperatures (98 and 113°F), 23–26 mg per 3 oz remained in the flakes, representing about 70% retention of the vitamin C surviving the processing, or 50% of that in the raw potato. The vitamin assay on the air-pack sample at 28 weeks is anomalous, but it can probably be concluded at least that no further loss occurs. In the nitrogen pack, the data indicate 100% retention on storage of the vitamin C that survived the processing, or an over-all retention of 73.5% of the natural vitamin in the raw potato. It is notable that potato flakes, even in air pack, retain 50% of the natural vitamin C after 7 months storage, whereas fresh potatoes would retain less than 30% (Murphy, 1946).

Table 2 lists vitamin C data for lot 2, to which the vitamin was added at a low level, with no antioxidant, to test not only its retention but its natural antioxidant quality as well. The initial assay showed 56 mg per 3 oz. Subtracting 36 mg per 3 oz contributed by the raw potatoes themselves, 20 mg (71%) was recovered of the 28.1 added to the mash. Of the 56 mg present in flakes initially 29–39 mg (52–69%) were retained in the air pack after 16 weeks at room temperature and elevated temperatures. Again, no further loss is indicated at 28 weeks. In the nitrogen pack, retention was 71–87%.

Table 2. Vitamin C content (mg/3 oz) of fortified potato flakes, packed in air and under nitrogen, after storage at different temperatures.[a]

Storage (weeks)	Air pack			N_2 pack		
	75°F	98°F	113°F	75°F	98°F	113°F
0	56	56	56	56	56	56
4	46	....	....	56	....	....
10	....	....	36	....	....	52
12	....	39	....	....	....	....
16	39	29	33	40	46	49
28	42	....	....	40	....	....

[a] Initial value of 56 mg/3 oz represents a recovery of 20 mg/3 oz; or 71% of 28.1 mg/3 oz added before drying.

Table 3 lists vitamin C data for lot 3. The level of addition in lot 3 as well as in lots 4 and 5 was designed to give sufficient in the flakes after storage to provide 50% of the adult minimum daily requirements

Table 3. Vitamin C content (mg/3 oz) of fortified potato flakes, packed in air and under nitrogen, after storage at different temperatures.[a]

Storage (weeks)	Air pack			N_2 pack		
	75°F	98°F	113°F	75°F	98°F	113°F
0	80	80	80	80	80	80
4	69	....	....	80	....	....
10	....	....	42	....	....	76
12	....	50	....	....	75	....
16	58	54	44	78	81	80
28	60	....	....	70	....	....

[a] Initial value of 80 mg/3 oz represents a recovery of 44 mg/3 oz; or 59% of 75.0 mg/3 oz added before drying.

(15 mg) in each serving, or a minimum of 60 mg per 3 oz (4 servings). As mentioned, more flakes were collected for lot 3 than could reasonably be expected from 75 lb of mash. This explains the apparent low recovery of vitamin C in this lot. However, percentage retention for lot 3 in air and nitrogen compares well with that for lots 4 and 5 (Table 4).

Table 4. Vitamin C content (mg/3 oz) of fortified potato flakes, packed in air and under nitrogen, after storage at different temperatures.[a]

Storage (weeks)	Air pack			N_2 pack		
	75°F	98°F	113°F	75°F	98°F	113°F
0	80	90	90	90	90	90
4	71.5	....	....	90	....	....
10	....	....	46	....	....	80.5
12	....	56.5	....	....	83.5	....
16	74.5	54.5	34	100	92	83
28	68.5	....	....	87	....	....

[a] Initial value of 90 mg/3 oz represents a recovery of 54 mg/3 oz; or 72% of 75.0 mg/3 oz added before drying.

Table 4 shows average vitamin C retentions for lots 4 and 5, wherein this vitamin was added in combination with others. As in lots 1 and 2, retention of the vitamin during processing was over 70%. Retention for 28 weeks in an air pack at 75°F was 76%, safely above the 50% adult minimum daily requirement per serving. In an air pack at 98 and 113°F, the level had dropped below the 60 mg required, indicating a need for higher levels of addition if high storage temperatures are likely. In a nitrogen pack, retention was excellent at all temperatures tested.

Table 5 shows the retention of vitamin A during processing and storage. In lot 5 it was used in combination with vitamins B_1, B_2, and C, and niacin. An assay of the raw potatoes showed only a trace of vitamin A; 12,000 U.S.P. units per 3 oz of flakes were added to the mash before drying; and 10,900 units (91%) were recovered in the flakes. In the air pack after 16 weeks at 75°F, 8000 units remained per 3 oz of flakes, equal to 50% of the adult minimum daily requirement per serving. In 28 weeks at 75°, and in 16 weeks at 98 and at 113°, levels dropped below that required. In the nitrogen pack at 75°, 97% of the vitamin A in the flakes still remained after 28 weeks. At 98° after 16 weeks, vitamin A was sufficient to meet the 50% minimum daily adult requirement. Retention at 113°F had dropped below this level.

Table 5. Vitamin A content (USP units/3 oz) of fortified potato flakes, packed in air and under nitrogen, after storage at different temperatures.[a]

Storage (weeks)	Air pack			N_2 pack		
	75°F	98°F	113°F	75°F	98°F	113°F
0	10,900	......	......	10,900	......	......
4	9,900	......	......	10,900	......	......
7	......	......	7,600	......	......	7,900
10	......	......	7,100	......	......	7,500
12	......	8,350	......	......	9,250	......
16	8,000	7,000	6,050	10,600	8,150	7,400
28	7,420	......	......	10,600	......	......

[a] Initial value of 10,900 USP units/3 oz represents a recovery of 10,900 USP units/3 oz; or 91% of 12,000 USP units/3 oz added before drying.

Flakes of lots 4 and 5 had a pronounced yellow color from riboflavin, and produced a yellow mashed potato.

Flakes from lot 1 (no added vitamins) contained 4.4 mg of niacin per 3 oz, about 11% of minimum daily adult requirement per serving. When niacin was added to mashed potatoes before drying, at 20 mg per 3 oz of flakes produced, 94% was recovered (Table 6). Retention of the niacin initially in the flakes was excellent (more than 90%) after 28 weeks, in both air and nitrogen.

Table 6. Niacin content (mg/3 oz) of fortified potato flakes, packed in air and under nitrogen, after storage at different temperatures.[a]

Storage (weeks)	Air pack			N_2 pack		
	75°F	98°F	113°F	75°F	98°F	113°F
0	23.2	23.2	23.2	23.2	23.2	23.2
4	23.2	......	......	23.2	......	......
8	......	21.8	......	......	21.8	......
16	......	......	22.9	......	......	23.8
28	21.3	......	......	21.3	......	......

[a] Initial value of 23.2 mg/3 oz represents a recovery of 18.8 mg/3 oz; or 94% of 20 mg/3 oz added before drying.

The excellent retention of riboflavin (vitamin B_2) is shown in Table 7. Of the amount added to mashed potato before drying, 86% was found in the flakes initially. In an air pack at 75°F, 93% of the vitamin was still present after 7 months. At higher temperatures, 98 and 113°F, retentions were about 86% after 16 weeks. At 75°F, retention was about the same in nitrogen as in air; at 98° and 113°F, retention in nitrogen pack was slightly, but not significantly, higher.

Table 7. Vitamin B_2 content (mg/3 oz) of fortified potato flakes, packed in air and under nitrogen, after storage at different temperatures.[a]

Storage (weeks)	Air pack			N_2 pack		
	75°F	98°F	113°F	75°F	98°F	113°F
0	2.58	2.58	2.58	2.48	2.48	2.48
4	2.58	......	......	2.48	......	......
7	......	......	2.51	......	......	2.13
10	......	......	2.43	......	......	2.46
12	......	2.36	......	......	2.50	......
16	2.42	2.24	2.22	2.36	2.26	2.26
28	2.41	......	......	2.31	......	......

[a] Initial value of 2.58 mg/3 oz represents a recovery of 2.58 mg/3 oz; or 86% of 3.0 mg/3 oz added before drying.

Loss of vitamin B_1 is high during processing, probably because of the sulfite added to the mashed potatoes before drying. Retention during storage, however, is good, 80% or above at 28 weeks (Table 8).

Organoleptic evaluation of product. Flavor of the various lots of flakes was compared at intervals with that of lot 1, the control sample having no added vitamins but containing Tenox IV.

Experience has shown that flakes made under conditions used for lot 1 will have acceptable flavor for at least 6 months at room temperature in air packing. It was, therefore, assumed that any sample not significantly different from the control at a given time would also be acceptable. It was also assumed

Table 8. Vitamin B_1 content (mg/3 oz) of fortified potato flakes packed in air and under nitrogen, after storage at different temperatures.[a]

Storage (weeks)	Air pack			N_2 pack		
	75°F	98°F	113°F	75°F	98°F	113°F
0	1.52	1.52	1.52	1.52	1.52	1.52
4	1.46	......	......	1.52	......	......
7	......	1.34	1.31	......	1.40	1.34
10	......	......	1.23	......	......	1.26
12	......	1.37	......	......	1.31	......
16	1.40	1.35	1.21	1.50	1.28	1.21
28	1.51	......	......	1.60	......	......

[a] Initial value of 1.52 mg/3 oz represents a recovery of 1.34 mg/3 oz; or 53.5% of 2.5 mg/3 oz added before drying.

that samples worse in flavor than the control at 25 weeks (approx 6 months) were unacceptable.

On this basis, Table 9 shows that flakes fortified with vitamin C to 75 mg per 3 oz (lot 3), alone and in combination with vitamins B_1 and B_2 (lot 4), retain good flavor when they also contain Tenox IV. Vitamin C alone (lot 2), at a low (antioxidant) level, is not as good an antioxidant as Tenox in the air-packed product. When vitamin A and niacin are added (lot 5) in combination with vitamins C, B_1, and B_2, flavor is unacceptable. In the nitrogen pack, however, the flavor, though variable, appeared about the same as the standard after 25 weeks at 75°F (lot 5).

In view of the complications involved in evaluating lot 5, further trials with vitamins A and C only and vitamins A, C and niacin are needed. These additional experiments will determine whether or not vitamin A and niacin are acceptable as to flavor. The work that has been completed indicates that the chemical stability of these vitamins is good.

Table 9. Organoleptic comparisons of vitamin-fortified flakes with standard flakes for off flavor development.

Storage (weeks)	Air pack					N_2 pack				
	Lot 1[a]	Lot 2	Lot 3	Lot 4	Lot 5	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
4	....	W[b]	S	W	W	....	S	W	S	W
9	....	S[c]	S	S	S	....	S	S	S	S
18	....	S	S	S	W	....	S	S	S	W
25	....	W	S	S	W	....	S	S	S	S

[a] Standard.
[b] Worse than standard.
[c] Same as standard.

REFERENCES

Cording, J., Jr., M. J. Willard, Jr., R. K. Eskew, and P. W. Edwards. 1954. Potato flakes. A new form of dehydrated mashed potatoes. I. Pilot-plant process using double-drum drier. *U. S. Dept. Agr., Agr. Research Serv.* ARS-73-2.

Cording, J., Jr., M. J. Willard, Jr., R. K. Eskew, P. W. Edwards, and J. F. Sullivan. 1955. Potato flakes. A new form of dehydrated mashed potatoes. II. Some factors influencing texture. *U. S. Dept. Agr., Agr. Research Serv.* ARS-73-9.

Cording, J. Jr., M. J. Willard, Jr., R. K. Eskew, and J. F. Sullivan. 1957. Advances in the dehydration of mashed potatoes by the flake process. *Food Technol.* **9**, 236.

Cording, J., Jr., J. F. Sullivan, and R. K. Eskew. 1959. Potato flakes. A new form of dehydrated mashed potatoes. IV. Effects of cooling after precooking. *U. S. Dept. Agr., Agr. Research Serv.* ARS-73-25.

Dove, W. F. 1943. Appetite levels of food consumption: a technique for measuring foods in terms of psychological and nutritional values combined. *Human Biology* **15**, 199.

Drummond and Wilbraham. 1939. The Englishman's food, 434. Jonathan Cape, London.

Eskew, R. K., C. S. Redfield, J. Cording, Jr., M. J. Willard, Jr., J. B. Claffey, P. W. Edwards, and J. F. Sullivan. 1956. Potato flakes. A new form of dehydrated mashed potatoes. III. Estimated commercial cost. *U. S. Dept. Agr., Agr. Research Serv.* ARS-73-12.

Györgyi, P. 1951. Vitamin methods (II). Academic Press, Inc., N. Y. Methods of vitamin assay (2nd Edition) (1951). Interscience Publishers, Inc., N. Y.

Murphy, E. 1946. Storage conditions which affect the vitamin C content of Maine-grown potatoes. *Am. Potato J.* **23**, 197.

Salaman, R. N. 1949. The history and social influence of the potato. U. S. Department of Agriculture. 1956. Household food consumption survey, 1955. Report No. 1, 196 pages.