

Loss of Amino Acids and Water Soluble Vitamins During Potato Processing

ABSTRACT

Processing potatoes to potato flakes almost totally eradicated ascorbic acid, but better than 50% of the original amount of riboflavin and niacin was retained. Thiamin content of potato flakes can vary from 0–65% of its amount in the raw potato depending on the amount of sulfite added during processing. If sulfite addition is controlled, a 100g portion of rehydrated potato flakes can supply about 1/6 of the Recommended Dietary Allowance of thiamin. Some losses of arginine, aspartic acid, glutamic acid, and gamma aminobutyric acid occurred during hot water blanching, and a significant loss of methionine occurred during drum drying. However, amino acids can be considered quite stable during potato flake production.

INTRODUCTION

NUTRIENTS are lost during food processing. These losses occur from the time the raw material is harvested until it reaches the consumer's table. Such losses occur during handling, harvesting, processing, storage (in the distribution cycle and at home) and home preparation (Lee, 1978). Generally the greatest losses occur during processing.

Nutrient assessment during processing is part of the study to develop a "Food Process Simulator" (Kozempel et al., 1981, 1982, 1983). Potatoes were used in the study because they are the leading fruit or vegetable processing crop (Salunkhe et al., 1973), and they supply a considerable portion of the Recommended Dietary Allowances (RDA, 1980) of vitamin C. Potatoes also supply many of the B vitamins and proteins which are rated higher in quality than those of soybeans by some nutritionists (Rhoades, 1982).

This study investigated the loss of potato's water soluble vitamins and amino acids during processing and determined methods suitable to give quantitative or qualitative values on nutritional aspects of food processing, and in particular, potato flake processing.

MATERIALS & METHODS

THE EXPERIMENTS were done at Eastern Regional Research Center in the Engineering Science pilot plant with the equipment shown in Fig. 1. Four lots of potatoes from the Maine Agricultural Farm were used over a 2-yr period (1982-83 and 1983-84). In the first year, Russet Burbank and Kennebec potatoes were processed, and in the second, Russet Burbank and Katahdin. Each year the tubers were placed in storage in October at 3.3°C and maintained at this temperature until used. For each experiment 295 kg of potatoes were peeled in a pilot model steam peeler (type DSA45, Paul Kunz and Company, Döttesfeld, West Germany) at a rate of 200 kg/hr, subjected to a steam pressure of 1.3×10^6 Pa for 18 sec, and then passed through a series of high pressure (1×10^6 Pa) water sprays (10–30°C) to remove the peels. The peeling losses (wet basis) averaged 10% or less per run and were determined by weighing before and after peeling. The potatoes were rinsed for 2 sec in a 0.25% NaHSO₃ solution to prevent enzymatic browning, followed by very little hand trimming. The potatoes were cut into nominal 1-cm cubes with a slicer (Model G-A,

Urschel Laboratories, Valparaiso, IN). The starch released during slicing was removed by washing (10–30°C) the cubes on a Vibro-Flo shaker (A.K. Robins, Baltimore, MD). The raw potatoes were sampled upon exiting from the shaker, given the "Philadelphia Cook" (Anon., 1977) by precooking at 80°C in a water blancher (Model TL-36K2210, Rietz Manufacturing Company, Santa Rosa, CA) for 16 min (Cording et al., 1957) and then cooled in a screw conveyor (Abbott Manufacturing Company, Norwood, NJ) at a water temperature of 22°C at a residence time of 8 min (Cording et al., 1959). Samples were taken both from potatoes exiting from the hot water blancher and the Abbott's conveyor. The precooked cubes were further cooked in a continuous atmospheric steam blancher (Model No. 20283, A. K. Robins, Baltimore, MD) until soft enough to rice (residence time ca. 20 min), forced through a continuous ricer (Hyde and Cording, 1962), and collected in 45 kg batches. Samples were taken after exiting both from the steam blancher and the ricer.

The following additives (to make experimental mashes identical to commercial mashes) were incorporated into the mashes (riced potatoes) by mixing at the slowest speed in a mixer (Model 6-800, Hobart Manufacturing Company, Philadelphia, PA) with the flat beater: (1) emulsifier — the emulsifier contained 30g glycerol monopalmitate, 1g milk solids, 3.2g Tenox VII (an antioxidant, Tennessee Eastman, Kingsport, TN), and 1000–5000 mL water added to each 45 kg; (2) sulfite solution — (a) 0.25g NaHSO₃ in 90 mL water was added to each 45 kg to retard nonenzymatic browning during dehydration; and (b) in the thiamin study additional levels of sodium bisulfite were added, 3.0, 5.0, 7.5, and 10g in 90 mL water per 45 kg of mash; Katahdin potatoes were used for these experiments; (3) ascorbic acid study — 1g to 3.6g ascorbic acid per 45 kg mash were added with the above emulsifier; ascorbic acid losses were determined after drum drying; Kennebec potatoes were used for these experiments.

The potato mashes were dried on a single-drum dryer (Overton Machine Company, Dowagiac, MI) drum 0.61 meters in diameter and 0.91 meters long. The operating conditions for the dryer were: (1) speed, 4 or 6 rpm; (2) pressure, 2.4, 3.8, or 5.5×10^5 Pa (gauge); and (3) application rolls used, 3 or 4. The clearance between the application rolls and the dryer (from the top of the dryer) were: 1st roll, 0.63 cm; 2nd roll, 0.63cm; 3rd roll, 0.63 cm; and when the 4th roll was used, 0.32 cm. The flake sample was taken as the sheet was removed from the drum.

Analytical

The potato samples, other than those taken for moisture, were immediately immersed in a bed of powdered dry ice for 15–30 min, then placed into bottles, stored in a freezer at –16°C, and later lyophilized 72 hr. The lyophilized samples were stored in a freezer (–16°C) until analyzed. For the vitamin assay, the freeze-dried potato samples were ground in a Wiley Mill to pass through a 20-mesh screen (8 meshes per 1 cm with 0.0833-cm openings). Replicate determinations were made on all samples for vitamins, amino acids and moistures.

Ascorbic acid

Ascorbic acid was determined using the colorimetric method (Loeffler and Ponting, 1942). One gram lyophilized sample was extracted for 5 min with 20.0 mL extracting solution (0.4% oxalic acid and 20% acetone in water adjusted to pH 1.1 with H₂SO₄); the solution was then analyzed for ascorbic acid. The original method was modified by extending the color reaction to 45 sec before colorimetric measurement. The coefficient of variation of the analysis of potatoes is 4.36%.

Thiamin and riboflavin

For the determination of thiamin and riboflavin a 3.0g-sample of dry potato was suspended in HCl (0.1N) and autoclaved for 30 min

AMINO ACIDS VITAMIN LOSS DURING POTATO PROCESSING...

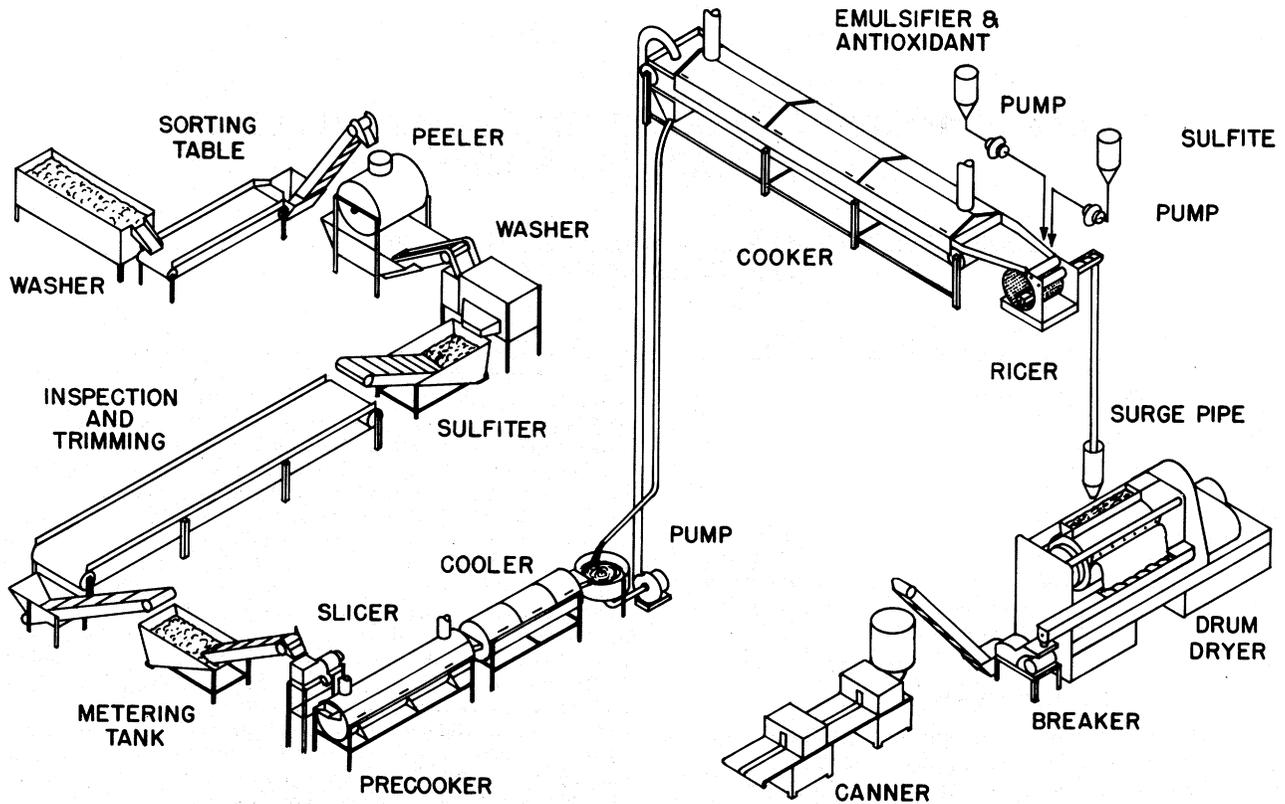


Fig. 1—Potato flake process.

Table 1—Percent retention of vitamins during processing (11 runs)

	Thiamin		Riboflavin		Niacin		Ascorbic acid	
Raw (peeled)	100.0	—	100.0	—	100.0	—	100.0	—
Exit precooker	79.3	± 10.2	72.5	± 20.7	67.6	± 9.8	54.9	± 15.8
Exit cooler	71.9	± 38.2	59.4	± 29.0	57.8	± 11.7	40.5	± 5.1
Exit cooker	67.1	± 17.9	61.2	± 28.1	56.9	± 7.6	25.7	± 13.1
Exit ricer	67.7	± 17.4	63.4	± 24.8	57.4	± 10.5	—	—
Flakes at drum	65.8	± 20.7	54.3	± 28.0	57.1	± 10.5	—	—

Table 2—Ascorbic acid in mash and flakes^a after 1 hr with different amounts of ascorbic acid added

Ascorbic acid added to mash (mg/100g)	Analysis of mash with added ascorbic acid standing 1 hr (mg/100g)	Analysis of flake (mg/100g)
13.3	10.0	4.8
24.6	21.4	19.7
24.7	14.4	10.2
32.4	28.7	22.5
47.8	32.6	28.8
47.8	34.0	38.0

^a Kennebec (1982-83 harvest)

Table 3—Ascorbic acid (after equal additions) of mash on standing and flakes

Ascorbic acid added to mash (mg/100g)	Analysis of ascorbic acid in the mash at			Analysis of ascorbic acid in flakes (mg/100g)
	Zero time (mg/100g)	After 0.5 hr (mg/100g)	After 1.0 hr (mg/100g)	
47.8	52.4	42.6	32.6	28.8
47.8	53.6	44.9	34.0	38.0
47.7	50.0	—	—	—
47.6	57.0	—	—	—
47.7	53.7	—	—	—
47.0	56.2	—	—	—

at 121°C and 17 psi; the samples were adjusted to pH 4.3 with sodium acetate; 5.0 mL of a 5% Takadiastase solution was added and the mixture incubated overnight at 35–37°C. After incubation the samples were made to a final volume of 100 mL with pH 4.3 metaphosphoric acid buffer. Thiamin and riboflavin were determined on the filtered samples with the Technicon Autoanalyzer. The procedures are described in "Technicon's Industrial Methods Manual" as methods No. 479-77A (thiamin) and No. 140-71A procedure (riboflavin). The coefficient of variation for thiamin was ± 0.75% and for riboflavin, ± 1%.

Niacin

Three grams dried potato were treated with 10 mL 1.5N H₂SO₄ plus 40 mL deionized water and autoclaved for 30 min at 121°C and 17

psi. After cooling, 10 mL 1.5N NaOH was added and the mixture made to volume and filtered. Niacin was determined colorimetrically following "Technicon's Industrial Methods Manual" method No. 156-71A. The coefficient of variation for niacin is ± 0.47%.

Amino acids

Preparation of samples. Each dried potato sample (raw, pre-cooked, etc.) was blended separately in isopropyl alcohol for 1.5 min (final slurry is 70% alcohol by weight, taking into account the original moisture of the potatoes (Talley et al., 1970)).

Acid hydrolysis. Approximately 0.05g samples of the accurately weighed isopropyl alcohol slurry were taken using a 1-mL syringe

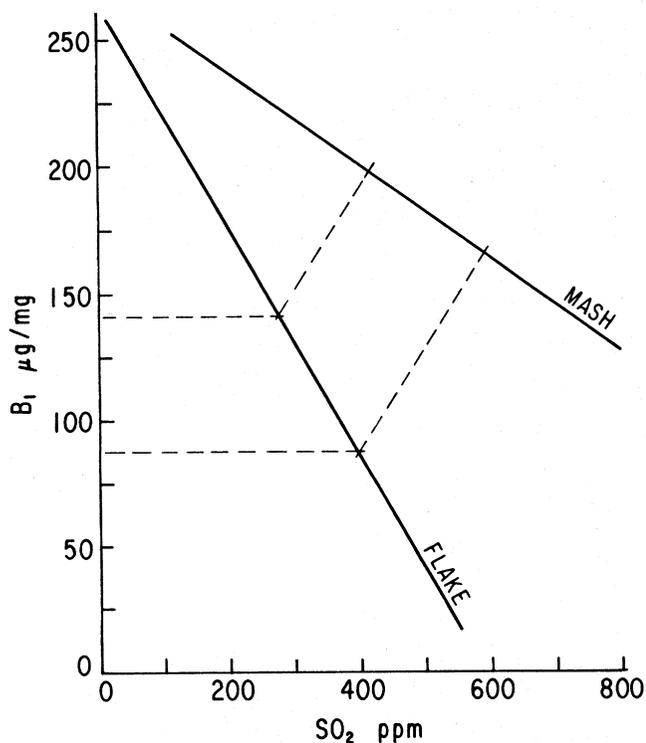


Fig. 2—Effect of sulfite on thiamin in mashed and flaked potatoes.

from the well-mixed slurry. The syringe was fitted with a "needle" of Teflon tubing (3-4 mm i.d.) of sufficient length to hold at least 1 mL. After withdrawing the sample, the outside of the Teflon tubing was wiped off, and the slurry sample carefully added to a weighed test tube covered with an aluminum cap. After weighing, the sample was transferred quantitatively to a 250-mL round-bottomed flask using deionized water and isopropyl alcohol. The solvent was removed on a rotating evaporator under reduced pressure. One hundred milliliters of 6N hydrochloric acid were added to each sample and the flask deaerated on the evaporator. The sample was then refluxed for 24 hr, using a heating mantle and an air condenser. The hydrochloric acid solution was removed on the rotating evaporator under reduced pressure and a few milliliters of water added to aid in the removal of the remaining HCl. The residue was quantitatively transferred to a 5-mL volumetric flask using deionized water, mixed, and the solid material allowed to settle out overnight in the refrigerator. The supernatant was transferred to a dry capped vial and frozen, if not analyzed immediately. A 100- μ L aliquot was used for analysis.

Oxidation and acid hydrolysis. The oxidized samples were prepared in a similar fashion to the acid hydrolysis samples but in test tubes. The slurry was evaporated to dryness under a stream of N_2 gas at room temperature (19–23°C) and then was oxidized overnight with 2 mL performic acid solution (Moore, 1963). After destruction of the excess performic acid with hydrobromic acid, the samples were transferred quantitatively to 250-mL round-bottom flasks, bromine and formic acid were removed by evaporation, and the acid hydrolysis carried out as indicated above.

Tryptophan analyses. Approximately 0.1g samples of isopropyl alcohol slurry, about twice the size listed above, were weighed into clean, dry plastic tubes placed inside dry, capped glass tubes. After weighing, the slurries were evaporated to dryness under a stream of N_2 gas at room temperature (19–23°C). The hydrolysis was carried out as specified by Hugli and Moore (1972) without added starch, using a trace of isopropanol as antifoamer. The evacuated sealed tubes were heated 24 hr in an air oven at 105–110°C. The hydrolyzate was transferred to 5-mL volumetric flasks containing measured quantities of frozen standardized hydrochloric acid. The samples were diluted to volume, mixed thoroughly and allowed to stand overnight in a refrigerator to facilitate removal of suspended solids. The supernatant was subsequently transferred to vials using a syringe. The vials were capped and stored at –20°C until analysis. The procedures for the amino acid analyses of the hydrolyzates and the tryptophan determinations are de-

Table 4—Amino acid values of fresh and cooked potatoes

Amino acid		Mean average (6 runs)	% Reduction of "B"
Alanine	A ^a	2.27	4.0
	B ^b	2.18	
Arginine	A	4.68	10.9
	B	4.17	
Aspartic acid	A	22.9	27.1
	B	16.7	
Cysteine	A	Trace	—
	B	Trace	
Glutamic acid	A	16.2	21.6
	B	12.7	
Glycine	A	2.05	2.4
	B	2.00	
Histidine	A	1.63	—
	B	1.66	
Isoleucine	A	2.92	2.4
	B	2.85	
Leucine	A	4.43	1.1
	B	4.38	
Lysine	A	4.68	4.7
	B	4.46	
Methionine	A	1.18	21.8
	B	0.92	
Proline	A	2.10	–9.5
	B	2.30	
Phenylalanine	A	3.22	7.5
	B	2.98	
Serine	A	2.68	3.7
	B	2.58	
Threonine	A	2.62	–1.2
	B	2.65	
Tryptophan	A	0.74	1.4
	B	0.73	
Tyrosine	A	3.58	5.9
	B	3.37	
Valine	A	4.03	9.4
	B	3.65	
Gamma-amino butyric acid	A	1.53	30.7
	B	1.06	

^a Fresh cut and peeled

^b Cooked (including precook and cool)

scribed in complete detail in a recent publication (Talley et al., 1984). The straight acid hydrolyzates were compared with the oxidized control samples using the sum of the THR, GLU, ALA, VAL, ILE, LEU, GAM, LYS and ARG values. These did not change appreciably upon oxidation. Settling out of humin overnight in the refrigerator and decanting the supernatant with a dry syringe seemed to produce results comparable to micropore filtration and was much easier.

The buffer and timer procedure was capable of separating cysteine acid, methionine sulfoxide, methionine sulfone, glucosamine, gamma-aminobutyric acid and ornithine from the usual standard mixtures containing the 17 amino acids separated by the normal procedure for protein hydrolyzates.

Moisture

Moisture of peeled and cut potatoes was determined using AOAC method 7.003 (1980).

RESULTS & DISCUSSION

Vitamins

In one process study (of 11 runs), Russet Burbank (1983–84 harvest) potatoes were used. Table 1 indicates the various processing steps, the percent retention and the confidence limits of the mean average of vitamins (thiamin, riboflavin, niacin and ascorbic acid). These experiments were run in scaled-up

AMINO ACIDS VITAMIN LOSS DURING POTATO PROCESSING...

Table 5—Amino acid values of riced and flake potatoes

Amino acid		Mean average (11 runs)	% Reduction of "B"
Alanine	A ^a	1.47	12.9
	B ^b	1.28	
Arginine	A	2.65	4.5
	B	2.53	
Aspartic acid	A	9.00	4.9
	B	8.56	
Cysteine	A	—	—
	B	—	
Glutamic acid	A	7.35	4.2
	B	7.04	
Glycine	A	1.19	—
	B	1.19	
Histidine	A	0.86	3.5
	B	0.83	
Isoleucine	A	1.67	7.2
	B	1.55	
Leucine	A	2.46	4.1
	B	2.36	
Lysine	A	2.83	6.4
	B	2.65	
Methionine	A	0.82	29.3
	B	0.58	
Phenylalanine	A	1.86	2.2
	B	1.82	
Proline	A	1.26	2.4
	B	1.23	
Serine	A	1.55	9.0
	B	1.41	
Threonine	A	1.58	6.7
	B	1.47	
Tryptophan	A	0.58	15.5
	B	0.49	
Tyrosine	A	1.95	2.1
	B	1.91	
Valine	A	2.22	—
	B	2.26	
Gamma-amino butyric acid	A	1.03	13.6
	B	0.89	

^a Riced potato samples

^b Potato flake samples

pilot plant equipment in an integrated processing line. The retention of the water soluble vitamins at 80°C for 16 min was about the same as in a previous smaller blancher (Kozempel et al., 1982). Significant ($p < 0.05$) losses of thiamin (B₁), riboflavin (B₂), niacin and ascorbic acid (C) occurred during precooking.

During the cooling step (Table 1), no significant thiamin or riboflavin losses occurred but niacin and ascorbic acid leaching losses were significant ($p < 0.05$). The retention of thiamin after cooling was 71.9%, riboflavin 59.4%, and niacin 57.8%, but ascorbic acid only 40.5%. Cooking in atmospheric steam effected little change in thiamin, riboflavin and niacin; however, ascorbic acid continued to be lost significantly. The ascorbic acid loss during cooking was probably caused by a combination of leaching (by condensing steam), thermal degradation, and oxidation.

Ricing potatoes after steam cooking had a drastic effect on the remaining ascorbic acid, much of which was lost. The ascorbic acid that was retained after ricing (< 10 mg/100g) is within the experimental error of the analysis and undeterminable. The other vitamins, i.e., thiamin, riboflavin and niacin were not significantly changed during ricing.

Drum drying study

Drum drying of potato mash caused no significant loss of thiamin, riboflavin, or niacin during the conversion from mash

to flakes (Table 1). Ascorbic acid could not be measured as it appeared that none was present after ricing. To determine what happens to ascorbic acid during drum drying, the mash to be dried was spiked with ascorbic acid.

Kennebec potatoes (1982-83 harvest) were used in the ascorbic acid study. The amount of ascorbic acid added is shown in Table 2. This Table also shows the ascorbic acid content in the mash just prior to drum drying and the amount in the flakes. As the added ascorbic acid decreased, the ascorbic acid values became less accurate, because of the difficulties encountered in the determination (Jadhav et al., 1975).

It is also noticeable that the ascorbic acid content in the mash prior to drying and that added to the mash did not agree (Table 3). The ascorbic acid of the mash after each addition was higher than the amount added. The difference was probably due to the residual amount of ascorbic acid remaining after ricing. After 1/2 hr and 1 hr standing at room temperature (ca. 70°C), the ascorbic acid had considerable losses (Table 3). This was probably due to oxidation because of the increased surface area of cooked potato where O₂ could react very rapidly with ascorbic acid.

Table 3 also shows six similar ascorbic acid additions to different 45 kg pots of mash. Samples of mash were taken immediately after the additions and analyzed. The ascorbic acid values varied from 50 ppm to 57 ppm. These differences can be attributed to small residual amounts of ascorbic acid retained after ricing.

The data presented in Tables 2 and 3 show the difficulties encountered in ascorbic acid analysis. Table 3 indicates that none or very little ascorbic acid is lost during drum drying.

In the 11 runs with Russet Burbank potatoes a low amount of sodium bisulfite (ca. 0.33% based on solids) was added to the mash. This amount of sulfite had little or no effect on the thiamin content of the mash or the flakes (Table 1). Sulfite additions are used to prevent or retard nonenzymatic browning. Sodium bisulfite as SO₂ and thiamin analysis showed (Fig. 2) that as the sulfite additions increased, thiamin values decreased. Fig. 2 should be interpreted as a nomograph. For example, when 275 ppm of sodium bisulfite was added, the thiamin analysis was 225 µg per 100g. When the flakes from this mash were dried, their analyses (both the flake and mash analyses were on a moisture free basis) were 175 ppm SO₂ and 181 µg of thiamin per 100g. If the mash sulfite and thiamin levels are known, the flake thiamin value can be predicted by drawing parallel lines as shown in Fig. 2.

Concentrations of 200–500 ppm SO₂ in dehydrated potatoes have been regarded by the U.S. Defence Supply as the levels necessary to prevent or retard nonenzymatic browning during drying and storage (U.S. General Service Administration, 1969). Figure 2 shows when 500 ppm of SO₂ were present in the flakes, little or no thiamin was left. However, when 200 ppm were present, 160 µg per 100g of mash or 10% of the RDA was still available. If lower amounts of SO₂ can be used and still hold nonenzymatic browning to a minimum, higher thiamin values will be obtained.

Amino acids

In six experimental runs (Table 4), amino acids of freshly peeled, cut and cooked potatoes were compared. Processing to cooked potatoes included: precooking (hot water blanching), cooling (cold water blanching) and steam cooking. Statistical analysis showed that four amino acids (arginine, aspartic acid, glutamic acid and gamma-aminobutyric acid) were significantly reduced ($p < 0.05$). The losses probably occurred during hot water blanching.

In a later study of 11 experimental runs, the amino acid values were measured before and after drum drying (Table 5). Only methionine changed significantly ($p < 0.05$) during the drum drying of these different mashes. The loss of methionine, the most labile of the free amino acids, is probably due to a

Strecker degradation reaction (Maga and Sizer, 1979). The analytical procedures used however, would not distinguish between free and combined amino acids.

CONCLUSIONS

THE RIBOFLAVIN and niacin values of flakes slightly exceeded 50% of those in the raw potatoes. Their greatest processing loss occurred during precooking (hot water blanching). There were significant thiamin losses during precooking, but an additional loss occurred when sulfite was added to prevent nonenzymatic browning. Greater amounts of thiamin were retained if the addition of sulfite was optimized. If thiamin were not destroyed, a 100g portion could supply about 1/6 of the Required Daily Allowance. Ascorbic acid was almost completely destroyed in the potato flake process. Drum drying was not deleterious to ascorbic acid so the mash could be fortified prior to drying. Five of the 17 amino acids (only a trace of cysteine was found in the raw potato) showed significant losses. Methionine was the only amino acid to drop significantly ($p < 0.05$) during drum drying. In spite of these losses, the potato, raw or processed, is still a good source of amino acids.

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