The ascorbic acid content of dehydrated potatoes
by Patricia Walter Myers

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Home Economics
Montana State University

Abstract:
Two brands of uncooked and cooked dehydrated potato dices, slices, and flakes were analyzed for reduced ascorbic acid.

The mean ascorbic acid content of one serving Brand X cooked dehydrated potatoes was: hash browns, 3.16 mg.; mashed, 0.70 mg.; and fried potatoes, 1.33 mg. Brand Y potatoes were higher in ascorbic acid than Brand X: hash browns, 5.67 mg.; mashed, 3.90 mg.; and fried potatoes, 3.86 mg.

There were significant differences ($P<0.01$) in the vitamin C content between brands, between dices, slices, and flakes, and between uncooked and eooked dehydrated potatoes.

The hash browned, mashed, and fried dehydrated potatoes were significantly lower in ascorbic acid than the same products prepared from fresh potatoes.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

The potato has been an important part of man's diet for around two thousand years. It was cultivated in the mountains of Peru by the Incas in 200 A. D. (55). Spanish and English explorers introduced the potato to Europe in the Sixteenth Century (49). However, one hundred years passed before potatoes were accepted as a food by the Europeans. Now, almost one-half of the world's potato crop is produced in Western Europe (12). It is believed that the Irish Presbyterians planted the first potato in North America in 1719 (49).

Fresh Potato Consumption

The potato is the most commonly used vegetable in the United States and Canada (23,30). The average yearly per capita consumption in the United States was 100 to 102 pounds in 1960 (8). This is approximately one medium-size potato or one-third pound a day (6). The average daily per capita consumption in Canada is six ounces (23).

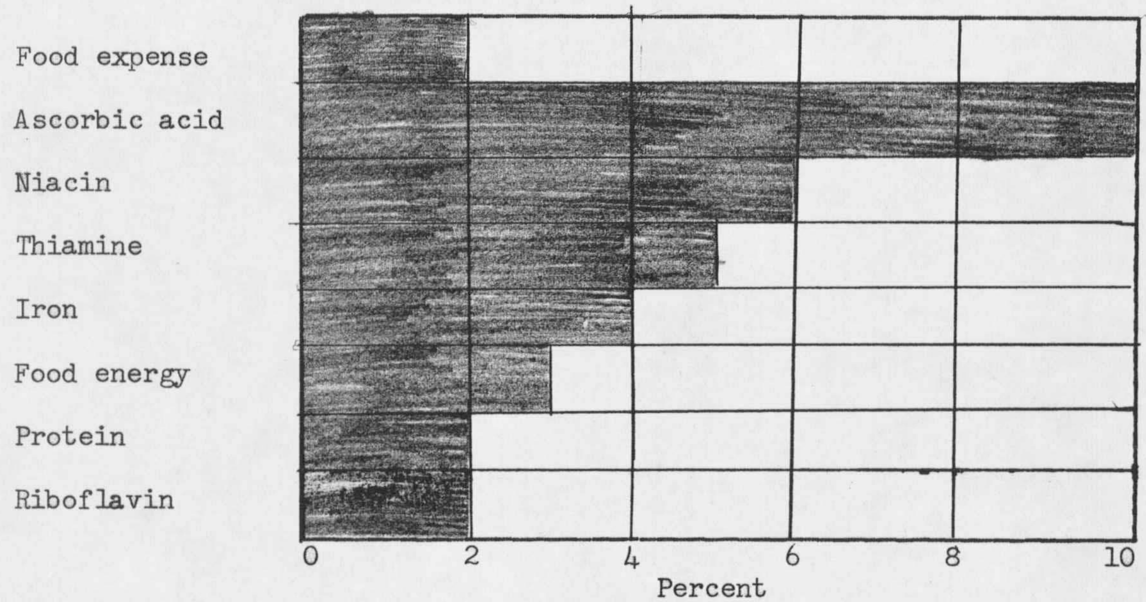
Although the per capita consumption in the United States and Canada is approximately 100 pounds a year, many people in other countries consume 200 pounds or more yearly. The yearly per capita potato consumption for 1956 to 1958 in 14 European countries as reported in _Food, Land, and Manpower in Western Europe_ by Yates (66) follows: Austria, 208.6 pounds; Belgium, 327.8 pounds; Denmark, 283.8 pounds; France, 266.2 pounds; Germany, 338.8 pounds; Greece, 93.1 pounds; Ireland, 396.4 pounds; Italy, 107.1 pounds; Netherlands, 200.2 pounds; Norway, 233.2 pounds; Portugal, 252.1 pounds; Sweden, 222.2 pounds; Switzerland, 179.5 pounds; and the United Kingdom, 209.0 pounds. Yates noticed that the consumption of potatoes in these countries decreased as people moved to a higher income status.

Although Western Europe produces the largest potato crop in the world (12), much of the crop is used in industry or for livestock feed (49). During peacetime, 20 to 60 percent of the potato crop in Europe is used for such purposes. Thirty percent of the crop is used for human consumption in Germany. Sixty percent of the potato crop in Ireland is used for livestock feed. The most important use of potato crops in the United States and England is for human consumption.

Nutritive Value of the Potato

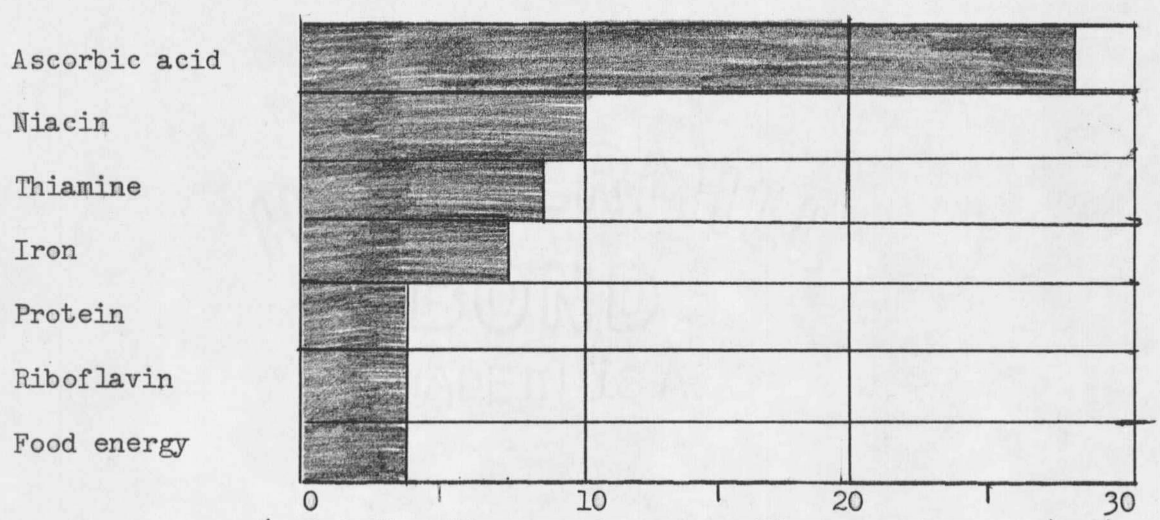
Table I shows the percent of nutrients contributed to the average American diet compared with the percent food dollar spent for potatoes (12). The potatoes were peeled and then boiled. They were served as boiled, mashed, or fried potatoes (61). Table I and Table II show that potatoes are a very inexpensive source of many of the nutrients and that one serving of potato makes a significant contribution to the day's intake of nutrients. The nutritional contribution of one medium-size potato to a day's diet for a 25 year-old man is shown in Table II. The average caloric contribution of the potato is shown to be 3 to 4 percent of the recommended allowance, or 100 calories. One medium-size boiled potato provides 28 percent of the recommended allowance of vitamin C for a man 25 years old.

TABLE I. Percent food dollar spent for potatoes and percent of nutrients contributed in diets.[1]



Estimated cooking losses have been deducted.

TABLE II. Nutritional contribution of one medium-sized potato* to a day's diet.[1]



*Boiled, then peeled.

[1]Fincher, L. S., and Mountjoy, B. M.: Potatoes...facts for consumer education. U. S. Dept. of Agri. AIB No. 178, December, 1957.

Potatoes are used in many therapeutic diets, such as soft, bland, low calorie, and low sodium (42). McCay (33) has reported that potatoes contain an average of 20 mg. of sodium per 100 gms. of raw potato, thus making them an excellent food for the low sodium diets.

Calories. Many people have the misconception that potatoes are "fattening." This is not quite true. It is usually the added seasonings, gravies, fats, and other toppings that add the calories. These toppings usually equal or exceed the caloric value of the potato (5).

To obtain a clearer understanding of the caloric value of the potato, Fincher (12) has reported that one medium-size potato has the same number of calories as the following: 1 fairly large apple, 1 large orange, 1 banana, 1/2 large grapefruit, 2/3 cup cooked lima beans, 3/4 cup cooked fresh corn, and 9/10 cup cooked green peas.

Carbohydrates. Starch, which is the principal constituent of the dry matter of the tuber, constitutes 9.9 to 23.3 percent of the potato on a moist weight basis (33). A potato that is considered high in starch content is mealy, dry, and sloughs extensively during cooking (5). A high-starch potato is considered best for baked potatoes and for general cooking purposes. The starch content of the potato is changed during storage depending upon variety, temperature, season, and locality (5). There is a conversion of sugar to starch during growth.

There is a close correlation between the dry matter or total solids, specific gravity, and starch content of the potato (57). Specific gravity is commonly used to estimate the percent of dry matter in potatoes (5).

The sugar content of the potato varies from trace amounts to 10 percent of the dry weight. Variety and temperature are the most important factors affecting sugar content during storage (51). Total and reducing sugars are increased as the storage temperature is decreased. Other sugars present in the potato include ketoheptose, melibiose, melezitose, and raffinose (5).

Most consumers desire a white potato that is not too sweet. A potato high in total or reducing sugars has a less desirable flavor, but is less mealy and dry, and sloughs less extensively than a potato low in sugars.

Proteins. Proteins constitute 2 percent of the potato on a moist-weight basis. About one-half the nitrogen in potatoes is in the form of protein (33). Potatoes high in nitrogen are less mealy, more moist, slough less extensively, but have less acceptable flavors than potatoes

TABLE III. Essential amino acids supplied by average daily ration of potatoes.[1]

AMINO ACID	AMOUNT IN 130 GMS. WHOLE POTATOES	MIN. DAILY REQUIREMENT	% DAILY MIN. REQUIREMENT
	gms.	gms.	
L-tryptophan	0.020	0.25	8
L-phenylalanine	0.135	1.10	12
L-lysine	0.125	0.80	16
L-threonine	0.093	0.50	18
L-valine	0.120	0.80	15
L-methionine	0.050	1.10	4-5
L-leucine	0.115	1.10	14
L-isoleucine	0.093	0.70	13

[1]Woodward, C. F., and Talley, E. A.: Review of the nitrogenous constituents of the potato. Am. Potato J. 30:205, 1953.

low in nitrogen. It is thought that the non-protein-nitrogen in potatoes may be responsible for off-flavors (5).

In Table III, Woodward and Talley (65) have estimated the essential amino acids supplied by the average daily ration of potatoes. The daily per capita consumption of potatoes in the United States supplies 4 to 18 percent of the minimum daily requirement for the adult man of all the essential amino acids.

Minerals. Fincher (12) and McCay (33) reported that potatoes are an important source of potassium, sulfur, magnesium, chlorine, copper, boron, silicon, fluorine, iodine, aluminum, and manganese. Table IV shows the milligrams of inorganic elements present in 100 gms. of potatoes. The table is a summary by Lampitt and Goldenberg of average inorganic constituent values found by different investigators (29).

TABLE IV. The inorganic constituents of potatoes. Extremes of averages.[1]

INORGANIC ELEMENT	MG./100 GM.	INORGANIC ELEMENT	MG./100 GM.
Phosphorus	116-314	Boron	4.5-8.6
Calcium	32-88	Silicon	5.1-17.3
Magnesium	65-136	Manganese	0.6-8.5
Sodium	26-332	Fluorine	0.6-8.5
Potassium	1811-2430	Iodine	0.02-0.56
Iron	2.6-10.5	Lithium	trace
Sulfur	109-213	Aluminum	2.9-8.8
Chlorine	112-530	Arsenic	0.3
Zinc	1.7-2.2	Molybdeum	0.26
Bromine	4.8-8.5	Cobalt	0.26
Copper	0.4-1.0	Nickel	0.26

[1]Lampitt, L. H., and Goldenberg, N.: The composition of the potato. Chem. Ind. 18:748, 1940.

Ascorbic acid. The disease scurvy is rare wherever potatoes are used in plentiful amounts. Throughout the Middle Ages and the Seventeenth Century in Great Britain the working class was in a state of chronic scurvy. Two hundred years later scurvy had been arrested and the potato was considered mainly responsible for remedying the disease (49).

Ascorbic acid is the most abundant vitamin in the potato and the most variable; investigators have reported 5 to 40 mg. of vitamin C present in 100 gms. of raw potatoes.

Heller *et al* (21) reported the vitamin C content of raw potatoes to vary from 8.7 to 15.0 mg. per 100 gms. and the vitamin C content of steamed cooked potatoes to be 1.0 to 4.8 mg. per 100 gms. They found 56 percent of the vitamin was lost in the cooking process; 21 percent of the loss was found in the cooking water. Much vitamin C was lost by peeling the potatoes in advance, storing them in water in the refrigerator, and draining the water prior to cooking.

Streightoff *et al* (53) also found that much of the vitamin C lost during cooking was in the cooking water. The workers reported 24 to 68 percent of the total ascorbic acid was lost when the potatoes were mashed and 13 percent when the potatoes were boiled. They reported 30.2 mg. total ascorbic acid per 100 gms. of raw potatoes and 16.8 mg. in mashed potatoes.

McCay (33) stated that different investigators have reported 16 to 35 percent of the vitamin C is lost during the french frying of potatoes and 66 percent lost in preparing hash browns.

Richardson, Davis, and Mayfield (44) reported the following values of ascorbic acid per serving (150 gms.) of cooked Netted Gem potatoes grown in Montana: boiled, 19.2 mg.; steamed, 21.2 mg.; baked, 25.5 mg.; fried (boiled and refrigerated overnight), 14.1 mg.; fried raw, 20.6 mg.; mashed, 16.2 mg.; and escalloped potatoes, 14.1 mg. They found that frying potatoes in margarine was less destructive to vitamin C than frying in hydrogenated shortening.

Watt and Merrill in Handbook No. 8 (62) reported the ascorbic acid content of one cup of potatoes prepared in the following ways: hash browns, 14 mg.; mashed with milk added, 14 mg.; and fried raw potatoes, 33 mg. They also reported a year-round average of 17 mg. of ascorbic acid per 100 gms. of raw potato (E.P.) and 23 mg. per 100 gms. of dehydrated potatoes, or 5.75 mg. per 100 gms. on a reconstituted basis (19).

Munsell et al (38) found the total ascorbic acid content of papas (potatoes) in Guatemala to range from 14.4 to 47.6 mg. per 100 gms. of raw potatoes. They reported that potatoes in Costa Rica varied from 27.8 mg. to 34.9 mg. of total ascorbic acid per 100 gms. of raw potatoes (37).

The vitamin C content of potatoes is highest at time of harvest. Karikka and coworkers (27) reported 26 mg. of vitamin C in 100 gms. of raw potatoes harvested in the early fall. This value decreased to 8 mg. by May. Potatoes boiled soon after harvesting yielded 16 mg. vitamin C compared to 5 mg. for potatoes boiled after eight to nine months storage. They found that vitamin C loss was greater when the potatoes were stored at 40°F. then when stored at 50°F.

Mayfield et al (35) reported that Netted Gem potatoes stored six months at 55°F. to 60°F. in a dry room lost little vitamin C. However, potatoes stored at 37°F. to 46°F. in a damp cellar lost one-third of the original vitamin C.

Leichsenring et al (30) reported the relationship of reduced ascorbic to dehydroascorbic acid (biologically active) and diketogulonic acid (biologically inactive) in freshly harvested potatoes was in the ratio of 100 to 1. After several months of storage, much of the dehydroascorbic acid had been lost.

Processed Potatoes

History and development. Dehydration is over 2,000 years old. The South American Indians preserved potatoes by dehydration in 200 A. D.; they called the product chuño (49). The Indians spread the potatoes on the ground and left them to freeze during the night. If they wanted to make white chuño, or tunta, they would cover the potatoes with straw before the sun rose. The following morning the villagers would tread the potatoes to squeeze the water out of the tuber. This process was repeated four or five times. Then the chuño was dried in the sun and stored. If tunta was to be made, the potatoes were next put into a shallow pool of water, left for two months, and later dried in the sun.

The chuño retained the shape of the tuber. The tunta was much lighter in weight than the chuño and very white. Flour was made from these dried products.

Chuño and tunta had an important part in the economy and social life of the Indians. Chuño was found frequently in Pre-Columbian graves on the coast of South America. A thorough history of the potato can be found in The History and Social Influence of the Potato by Salaman (49).

Interest in dehydration of potatoes was renewed during World Wars I and II (11,49). Some dehydration was done commercially in Europe and the United States for military use. Potatoes were processed for retail consumers in 1948 (22).

The production of processed potatoes has increased rapidly each year since 1956. By 1960, 25 percent of the potatoes consumed in the United States were in the processed form. Some members of the potato industry predict that by 1970 50 percent of the potato crop will be in the processed form and that the only fresh potato on the market in 1975 will be potatoes for baking. Twenty-two percent of the processed potatoes in 1959 were dehydrated (11). Production of dehydrated potatoes has tripled in the last three crop years.

Processed potato consumption. Per capita consumption of potatoes has decreased in the past fifty years in almost every European nation and in the United States (8,66). However, this decline reached a plateau in the United States in 1950 and has since remained somewhat constant. It is thought that this halt in the decline may be due to the increased production and consumption of processed potatoes (8).

In twenty years the consumption of processed potatoes has risen from a trace amount to one-fifth of the total potatoes consumed as food. Investigators have found the home use of processed potatoes increased as people moved to a higher income status. Conversely, use of fresh potatoes increased as the income of the household decreased (8).

Reconstituted dehydrated, frozen prepared, and canned potatoes constituted two percent of all the meals served in the United States in 1960. Mr. A. E. Mercker, President of the National Potato Council, predicts that these products will constitute ten percent of all the meals served in the United States by 1965 (36). Table V indicates the consumption of processed and fresh potatoes per person for 1956 through 1960 (9).

TABLE V. Use of potato products per person, crops of 1956-60.[1]

PRODUCTS	1956	1957	1958	1959	1960
	lbs.	lbs.	lbs.	lbs.	lbs.
Fresh	93.0	92.1	90.2	88.0	86.6
Chips	8.7	10.2	9.9	11.5	11.9
Frozen	2.8	2.8	4.8	5.6	8.4
Dehydrated	1.9	2.2	3.4	4.3	5.6
Canned	1.4	1.5	1.6	1.4	1.6
Total	107.8	108.8	109.9	110.8	114.1

[1]Economic Research Service: Market potential for processed potato products. U. S. Dept. of Agri., Marketing Economics Division, Marketing Research Report No. 505, October, 1961.

Results of a study by Walker (60) on fresh and processed potato consumption in Milwaukee, Wisconsin, indicated that few of these people in 1959 used processed potatoes regularly. The average Milwaukee household consumed 8.5 pounds fresh potatoes, 0.82 ounces frozen, 0.05 ounces (dry weight) dehydrated, and 0.43 ounces canned potatoes weekly.

Feustel (11) reported that in 1960 dehydrated potatoes were purchased by one-third of the families in the United States. However, institutional outlets purchased more dehydrated potatoes than retail outlets (9). Dehydrated potatoes were considered advantageous since the consumers made economical savings in storage, transportation, labor, wastes, and cost per serving. The greatest saving made by the use of dehydrated potatoes was in labor costs. The second greatest was in waste costs.

The cost per serving of mashed potatoes prepared from fresh and dehydrated potatoes has been calculated by the Food Quality Laboratory, Human Nutrition Research Division, Agricultural Research Service, United States Department of Agriculture (9):

Potatoes, mashed (3.5 oz. per serving)	Cents
Home Prepared:	
Fresh potatoes (1 pound)	7.68
Milk (2.1 oz. @ 0.74¢/oz.)	1.55
Total cost	9.23
Avg. cost/serving (4.1/pound)	2.25
Instant:	
Dehydrated mashed (7 oz. package)	32.27
Milk (8.2 oz. @ 7.4¢/oz.)	6.07
Total cost	38.34
Avg. cost/serving (11.1/package)	3.45

Processing. Not all varieties of potatoes are suitable for processing; usually the total solids content of the potato must be high (11). A potato with 22 percent solids yields 20 percent more dehydrated vegetable than a potato with 18 percent solids (58).

The Russet Burbank is the most commonly used potato in potato processing. The Russet Burbank, also known as the Netted Gem in Montana (32), is grown extensively in the Pacific Northwest and Maine (59). It is high in dry matter, used for flake and granule processing, and some-times used in chip manufacturing. Most of the dehydrated potatoes are produced in Idaho, where flake manufacture originated. Continuous research is being conducted to produce a potato product which more closely resembles fresh potatoes. A list of processed potatoes, presented by Feustel (11) at the Potato Processing and Storage Conference at Moses Lake, Washington, in 1961, follows.

Sulfur dioxide is usually added to the potatoes after blanching. It is added in the form of sodium sulfite, sodium bisulfite, or sodium metasulfite (28). The sulfite is added in 200 to 500 ppm, based on the percent solids in the mash (10,28). Eskew (10) reported that most of the sulfite is lost during dehydration and only about 20 ppm is retained in the product. The active sulfur dioxide remaining in the potato flakes is 1/10 to 1/30 the amount present in raisins and dried apricots (47). The use of sulfite in potato processing permits use of high dehydration temperatures, which gives a more porous product (28). It also prevents the development of off-flavors and darkening caused by non-enzymatic browning (28,47).

The addition of sulfite to dehydrated potatoes results in a 12 to 40 percent loss of the original thiamine in the potatoes, but has no effect on niacin or ascorbic acid (33).

The sulfite presents problems in the determination of ascorbic acid in dehydrated potatoes. It reacts in much the same manner as ascorbic acid. This results in incorrect ascorbic acid determinations unless the sulfite is inactivated (34).

TABLE VI

PROCESSED POTATO PRODUCTS[1]

<u>Frozen Products</u>

French fries	Creamed
Patties	Boiled
Shredded	Roasted
Hash brown	Cottage fried
Diced	Pancakes
Mashed or whipped	Dumplings
Stuffed baked	Knishes
Rissole	Blintzes
Au Gratin	Soup
Delmonico	Dehydrofrozen mashed
Scalloped	Dehydrofrozen diced
Dutch potato salad	Potatoes and peas in cream sauce

<u>Dehydrated Products</u>

Instant mashed
- Granules
- Flakes

Dice (for preparing hash-brown potatoes, general purpose dishes, and for remanufacture in canned, stews, hash, etc.)
Slices (for preparing salads and general purpose dishes)
Scalloped
Au Gratin
Pancake mixes
Flour (for potato bread, doughnuts, and other specialty baked goods and breading material)

<u>Experimental Products</u>

Sponge-dehydrated potato
Chip bars
Chip confections (candy flavored)
Puffs Dip-sticks Nuts
Instant dehydrated dice and slices

<u>Potato Chips</u>

Regular & crinkle
Barbeque-flavored
Cheese-flavored
Smoke-flavored
"Dip-Chips"

<u>Pre-Peeled Products</u>

(For fresh delivery to restaurants)
Whole potatoes
French fry cuts
Oil-blanched
Hash brown
Salad

<u>Canned Products</u>

Whole potatoes
Sliced potatoes
Shoestring potatoes

Hash	Chowder
Stew	Soup
Pancakes	Salad
Strained (baby food)	Au Gratin

<u>Starch</u>

Regular and chemically modified potato starches for use in paper manufacture, textile sizing and food processing.

[1]Feustel, Irvin C.: Potato dehydration and new products. In Proceedings of the Potato Processing and Storage Conference, Moses Lake, Washington, January, 1961, p. 7.

Eskew (10) reported that other additives in potato processing include small amounts of glycerol monopalmitate to improve texture. The additives help to prevent oxidative rancidity and to stabilize flavor and texture. Often nitrogen packing is used to control the amount of oxygen in the package, giving the product longer storage life. Storage life is around six months at room temperature in a properly sealed package.

Flake manufacturing. Dehydrated potato flakes were developed at the Eastern Utilization Research and Development Division of the Agricultural Research Service in Philadelphia (58). The process was put under public patent in 1956, permitting free entry to all processors. Commercial production of flakes began in 1957. By May, 1961, there were 16 processors of dehydrated mashed potatoes; 12 of these processed flakes (9).

Flakes are manufactured by the direct drum-drying method (11). The steps are carefully controlled to prevent cell rupture, or the release of free starch. Otherwise, the resulting product would be a pasty instead of a fluffy mashed potato (10).

Potatoes with 18 to 24 percent solids are used. First the potatoes are washed and peeled. Then the sulfite is added, followed by inspection, trimming, and metering. The potatoes are sliced into one-half inch slabs and precooked for 20 minutes in water at 160°F. The mash is cooled for 20 minutes. The precooking and cooling stages reduce the solubility of the amylose fraction of the free starch. If the last two steps are omitted, only potatoes with very high solids can be used. Next, the precooked potatoes are cooked in steam for 20 to 50 minutes. The additives