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

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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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Approved:

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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,

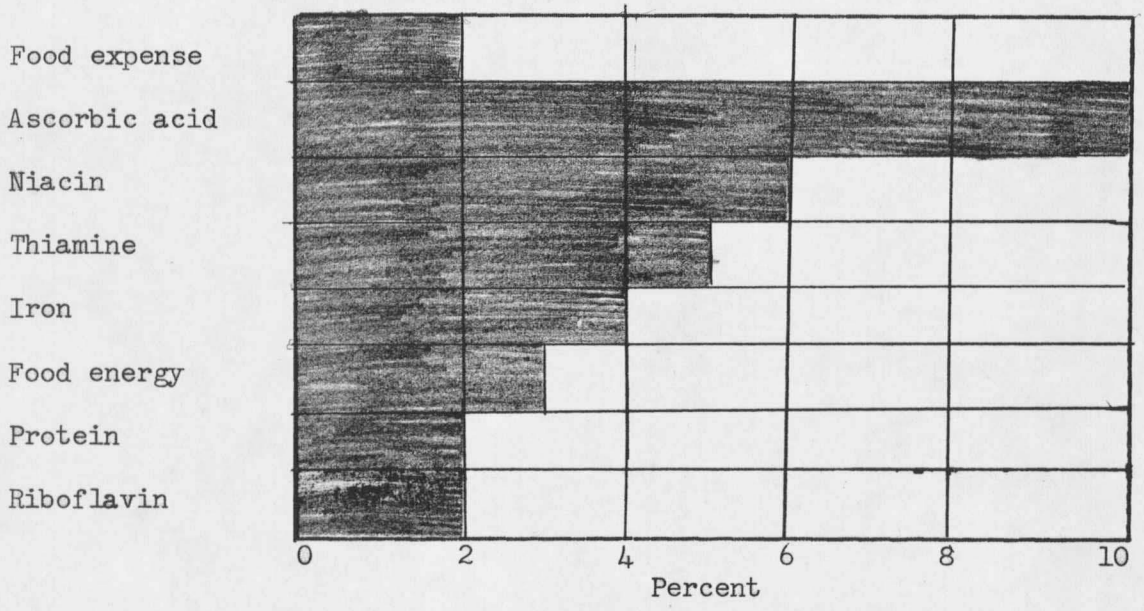
252.1 pounds; Sweden, 222.2 pounds; Switzerland, 179.5 pounds; and the United Kingdom, 209.0 pounds. Yates noticed that the consumption of potatoes in these countries decreased as people moved to a higher income status.

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

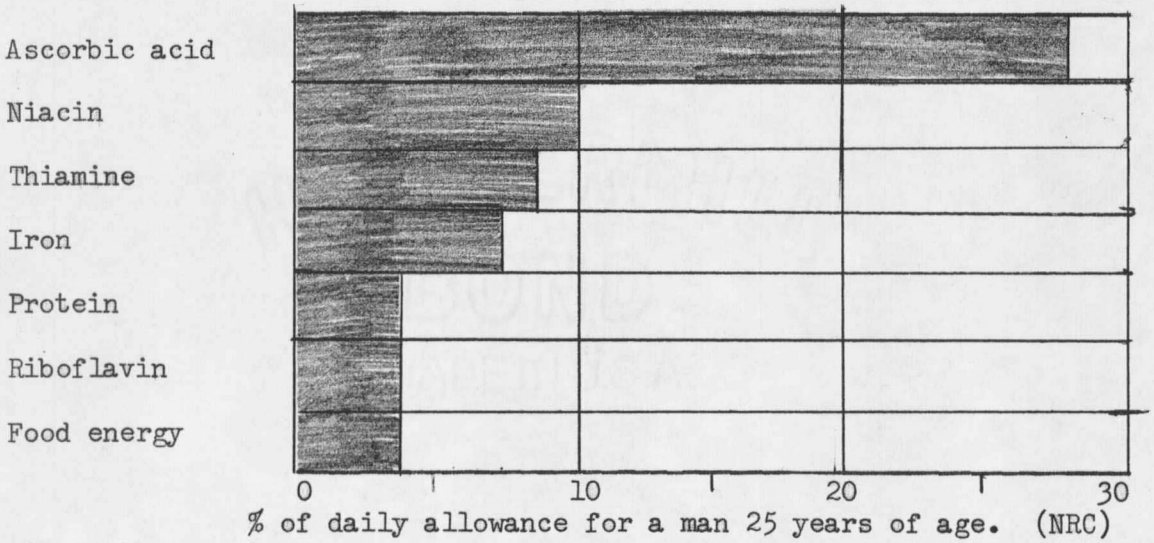
Table I shows the percent of nutrients contributed to the average American diet compared with the percent food dollar spent for potatoes (12). The potatoes were peeled and then boiled. They were served as boiled, mashed, or fried potatoes (61). Table I and Table II show that potatoes are a very inexpensive 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]

Frozen Products

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

Dehydrated Products

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)

Experimental Products

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

Potato Chips

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

Pre-Peeled Products
(For fresh delivery to restaurants)

Whole potatoes
French fry cuts
Oil-blanched
Hash brown
Salad

Canned Products

Whole potatoes
Sliced potatoes
Shoestring potatoes
Hash Chowder
Stew Soup
Pancakes Salad
Strained Au Gratin
(baby food)

Starch

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

are added before ricing, which is the next step. Then the mash is dehydrated on the drum dryer and eventually the thin sheet of potatoes is cut into one-half inch squares. The sheet is usually 0.010 inches thick. In 20 seconds, the moisture content in the potato mash is reduced from near 80 percent to 5 percent (10).

Flakes are more bulky and costly to handle than potato granules (11), but Greig et al (16) found that there is higher consumer acceptance of flakes than of granules.

Slice and dice manufacturing. Potato dices are used principally in canned products as corned beef hash, stew, and soups and frozen meat pies. Scalloped and au gratin potatoes, potato salad, and hash browns show good consumer acceptance (11).

Dehydrated potato dices and slices are usually manufactured from Russet Burbank potatoes in a conveyor-type dryer (28). The potatoes are peeled with steam or lye, washed, inspected, trimmed, and cut. Dices are cut no larger than 3/8 of an inch and the slices are cut 1/8 inch thick and 1 inch in diameter (11). The blanching step, by steam or boiling water, greatly affects the texture, dehydration, and subsequent potato reconstitution (28). Sulfur dioxide and/or calcium salts are added next. Calcium chloride is added before drying to prevent the dices and slices from breaking apart (11).

Ascorbic acid content of dehydrated potatoes. Bring (4) reported the total ascorbic acid in 100 gms. of dehydrated mashed potato flakes to be 1.75 mg. to 11.34 mg. and 0.35 mg. to 9.31 mg. in 100 gms. dehydrated mashed potato granules.

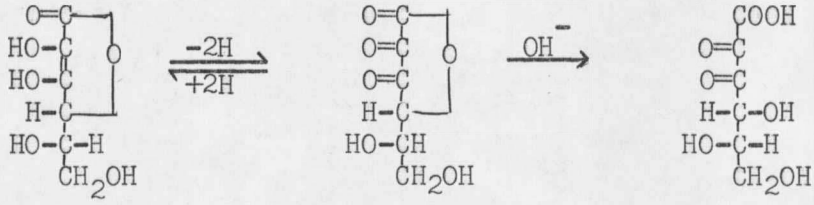
Hanning and Mudambi (19) reported 0.6 to 5.1 mg. of biologically available ascorbic acid in 25 gms. of dehydrated potato flakes and powder.

One food processing company (52) stated that 73 percent of the vitamin C present at the time of processing is retained in the flake and 70 percent is retained after seven months storage. An analysis of their product by Curtis and Tomkins, Ltd., San Francisco, showed that there were 8.8 mg. of ascorbic acid present in 100 gms. of dehydrated mashed potatoes.

Thomas (56) reported that dehydrated potato granules packaged for the United States Army must be fortified with thiamine, ascorbic acid, and vitamin A. Approximately 45 mg. of vitamin C is added to one ounce of dehydrated granules. Thomas reported that vitamin C stability of potato granules stored at 70°F. to 100°F. for one year was not affected.

Ascorbic Acid

Chemistry. Vitamin C is the first vitamin for which the molecular structure was established. It was isolated from lemon juice in 1932 by Charles G. King and William Waugh (63). The substance was identified as ascorbic acid and was the same compound as the reducing substance isolated by Szent-Gyorgyi in 1928. The structure of vitamin C, shown in Figure 1,



L-ascorbic acid (reduced form) — L-dehydroascorbic acid (oxidized form) — L-diketogulonic acid

Figure 1. Vitamin C. (64)

closely resembles that of a monosaccharide. Total ascorbic acid occurs as reduced ascorbic acid, dehydroascorbic acid, and diketogulonic acid.

Ascorbic acid is a white, odorless crystal, stable in the dry form. It dissolves easily in water, ethyl alcohol, and methyl alcohol. However, it is not soluble in ether, xylene, benzene, chloroform, and other fat solvents.

Ascorbic acid is easily oxidized to dehydroascorbic acid in the presence of heat, light, oxygen, metallic ions, enzymes, and alkalies. Above pH 4.0, dehydroascorbic acid is also easily hydrolyzed to diketogulonic acid, which has no biological activity (1).

Ascorbic acid is a strong reducing agent which is the basis for quantitative measurement of the vitamin. It is oxidized by iodine, Benedicts solution, and oxygen in alkaline solution; it reduces Fehling solution, neutral silver nitrate, and neutral potassium permanganate (24). Ascorbic acid and dehydroascorbic acid have properties similar to sugars, forming osazones and converting to furfural (22,24).

Physiological importance. Ascorbic acid is essential for the development and maintenance of intercellular cement, connective tissue, and capillary blood vessels. Development of bone structure and normal calcification depend on ascorbic acid (24).

It is involved in the metabolism of phenylalanine and tyrosine, acting as a coenzyme; but it can also inhibit the action of some enzymes (14,59).

Vitamin C aids in the absorption of iron from the intestinal tract.

The conversion of folic acid to the citrovorum factor depends on the presence of ascorbic acid (14).

It is thought that ascorbic acid may be involved in the synthesis of steroid hormones from cholesterol (42). There is evidence of a reduction of ascorbic acid and cholesterol in the adrenal glands with an increased production of hormones.

The theory that ascorbic acid stimulates antibody production is connected with an increase in the requirement of the vitamin during infections (7).

Ascorbic acid may be involved in the maturation of red blood corpuscles and maintenance of normal blood hemoglobin levels (20). There is also the possibility of a correlation between vitamin A levels in the blood and plasma ascorbic acid levels (20).

Scurvy. Scurvy is a nutritional disease resulting from lack of vitamin C. Symptoms of infantile scurvy include pain, tenderness, swelling of joints and legs, impaired bone and dentine development, anemia, diarrhea, loss of weight, fever, vomiting, and impaired wound healing (42,64).

Adult scurvy shows edema, pain at the joints, anorexia, anemia, hemorrhages of capillaries, gingivitis, infection, thick and scaly skin, impaired wound healing, and changes in structure of the dentine of the teeth (42,59,64).

The breakdown of old wounds that have healed is not uncommon in severe scurvy. The intercellular cement becomes soluble and there is no development of new intercellular cement (64).

White et al (64) stated the underlying cause for all the changes resulting from scurvy, except anemia, is the impaired development of collagen and chondroitin sulfate (a sulfated mucopolysaccharide in cartilage and tendons).

Requirements and recommended allowances. Man, guinea pigs, and monkeys require a dietary source of vitamin C; plants and other animals can synthesize the vitamin from carbohydrates.

Approximately 1 mg. per day per kilogram of body weight is required for normal maintenance of the human body (25). The National Research Council (14) has set recommended dietary allowances for vitamin C. The recommendations provide a safety margin and help to keep blood plasma levels around 1 mg. per 100 ml. of blood plasma. These allowances take the following into consideration: (1) amount of vitamin C needed to prevent frank scurvy, (2) age, (3) sex, and (4) growth. It is known that 10 to 20 mg. daily of vitamin C will prevent frank scurvy (14). The National Research Council has recommended 70 to 75 mg. daily for men and women in the United States.

Sources. Vitamin C is found in all higher plants, especially in the growing parts. Good sources of the vitamin are citrus fruits, strawberries, members of the cabbage family, and tomatoes. Medium to good sources include potatoes and sweetpotatoes. Green and yellow vegetables provide modest amounts (7).

A study by Richardson and Mayfield (43) on the vitamin C content of prepared winter fruits and vegetables purchased in Montana revealed that fruits, especially citrus fruits, were the most economical and best

sources of the vitamin. Cabbage, cauliflower, broccoli, and tomatoes were good sources. Inexpensive and fairly good sources included potatoes, parsnips, squash, and sweetpotatoes.

A list of some common American foods and the ascorbic acid content as reported by Watt and Merrill (62) is shown in Table VII.

TABLE VII. Vitamin C content of common household units of common foods.

FOOD	MG. VIT. C.	FOOD	MG. VIT. C.
Apples, raw, 1 med.	6	Orange jce., 1 C.	122
Apricots, cnd., 1 C.	10	Papayas, raw, 1 C.	7
Asparagus, cnd., 6 spears	19	Parsnips, ckd., 1 C.	19
Beans, cnd., 1 C.	7	Peaches, cnd., 1 C.	11
Broccoli, 1 C.	111	Peas, cnd., green, 1 C.	15
Brussel sprouts, 1 C.	61	Peppers, green, ckd., 1 C.	64
Cabbage, raw, 1 C.	50	Pineapple, cnd., 1 slice	11
Carrots, raw, 1	3	Potatoes, baked, 1 med.	17
Cauliflower, ckd., 1 C.	34	Potatoes, fried raw, 1 C.	33
Corn, ckd., 1 ear	8	Potatoes, hash brown, 1 C.	14
Cranberries, raw, 1 C.	13	Potatoes, mashed, 1 C.	14
Grapefruit, raw, 1/2 med.	76	Potato chips, 10 med.	2
Guavas, raw, 1	212	Raspberries, raw, 1 C.	29
Honeydew melon, 1 wedge	34	Rhubarb, cooked, 1 C.	17
Kale, cooked, 1 C.	56	Rutabagas, cooked, 1 C.	33
Lemon juice, 1 Tb.	7	Spinach, cooked, 1 C.	54
Liver, beef, cooked, 2 oz.	18	Squash, summer, 1 C.	23
Mangos, raw, 1 med.	55	Strawberries, raw, 1 C.	89
Milk, skim, 1 C.	3	Sweetpotatoes, baked, 1 med.	28
Okra, cooked, 8 pods	17	Tomatoes, raw, 1 med.	35
Onions, cooked, 1 C.	13	Turnips, cooked, 1 C.	28
Oranges, whole, 1 med.	77	Watermelon, 1 wedge	26

Chemical assay methods. Since ascorbic acid is such a strong reducing agent, it lends itself easily to quantitative measurement. Most chemical methods of determining ascorbic acid in plant tissue involve the reduction of 2,6-dichlorophenolindophenol dye and iodine or the formation of an osazone with 2,4-dinitrophenylhydrazine (1).

The materials to be tested should be handled carefully and quickly.

The ascorbic acid should be stabilized in acids such as acetic acid, trichloroacetic acid, oxalic acid, and metaphosphoric acid. The acid inactivates ascorbic acid oxidase and inhibits the oxidizing action of metals.

The reduction of 2,6-dichlorophenolindophenol dye by ascorbic acid measures reduced ascorbic acid only. The dye is blue in alkali, red in acid, and colorless when completely reduced (3). The reduction of the dye by ascorbic acid is shown in Figure 2. A buffered sample extract is

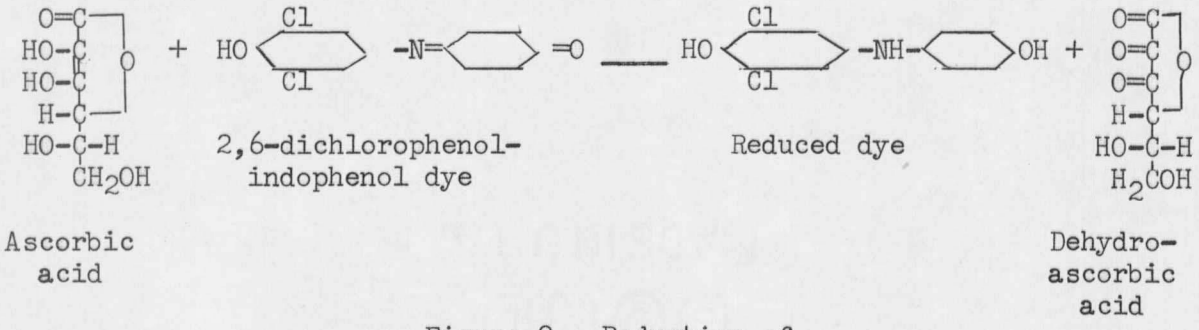


Figure 2. Reduction of 2,6-dichlorophenolindophenol by ascorbic acid. (1)

added to the dye and the reduction is measured photoelectrically by readings made at 10 and 20 seconds and extrapolating to 0 time. Bessey (2) suggested 15 and 30 second readings for dehydrated vegetables as the reducing substances in these foods have been concentrated. The influence of certain reducing agents other than ascorbic acid can be avoided in this method. These substances reduce the dye at a much slower rate than the ascorbic acid. Bessey and King (3) developed the indophenol dye titration method in 1933. Since then, many modifications of the method have been made (2,26,31,34).

Total ascorbic acid (reduced ascorbic acid, dehydroascorbic acid, and

diketogulonic acid) is determined photoelectrically by the formation of bis-2,4-dinitrophenylhydrazone (24,46). Norite oxidizes the ascorbic acid to dehydroascorbic acid which is converted to 2,3-diketogulonic acid. The diketogulonic acid couples with 2,4-dinitrophenylhydrazine to form the red-orange osazone. The osazone is soluble in strong acid. Eighty-five percent sulfuric acid is added to the osazone and the color measured photoelectrically after 10 minutes. The color is stable for several hours after the sulfuric acid is added (50). The sulfuric acid also dissolves interferring substances. Thiourea prevents the interference of oxidants in the final color development. Roe and Kuether (45) developed this method; many modifications have been developed from it (1,18,46,50).

All samples to be tested should be done so immediately to avoid error through loss of ascorbic acid. Some ascorbic acid may be lost in the filtering of starchy vegetable extracts. None appears to be lost if the extract is centrifuged (24).

The presence of sulfur dioxide in dehydrated fruits and vegetables causes an almost instanteous reduction of the indophenol dye. Acetone has been suggested by Mapson (34) to remove the sulfite. The addition of acetone to sulfur dioxide in an acid solution forms acetone bisulfite, which will not reduce the dye or interfere with the reduction by ascorbic acid. The sulfur can be in the form of sulfite, bisulfite, or metasulfite. Mapson used 5 ml. of acetone per 20 ml. of extract in the titration method of the indophenol dye procedure. The extract was then made up to 25 ml. after shaking with the acetone. Mapson obtained good results, even if the

sulfite was forty times greater than the ascorbic acid. The removal of sulfite by evacuation with nitrogen was also suggested, but it was not as successful as the acetone procedure.

Loeffler and Ponting (31) adapted Mapson's acetone method to the indophenol colorimetric method. They found that one part acetone added to ten parts sample extract prevented interference of 500 ppm of sulfur dioxide in ascorbic acid determinations. The dye must be standardized with acid containing the same concentration of acetone (31,34).

Guild et al (17) compared the indophenol dye (2) and 2,4-dinitrophenylhydrazine (46) methods in the ability to measure dehydroascorbic acid and ascorbic acid of fresh and stored solutions. They believed their results showed that the 2,4-dinitrophenylhydrazine method measured more than the biologically active forms of vitamin C as calculations for reduced ascorbic acid in this method were higher than values shown for the dye method. Guild and coworkers also suggested the use of oxalic acid as the extracting acid as it is more effective, very stable, inexpensive, and easily prepared.

CHAPTER II

PURPOSE

Since dehydrated potatoes constitute a measurable and somewhat increasing part of potato consumption in the United States, this investigation was conducted to ascertain the ascorbic acid value of dehydrated potato dices, slices, and flakes.

The objectives of this experiment were the following: (1) to determine the reduced ascorbic acid content of uncooked and cooked dehydrated potato dices, slices, and flakes of two commercial brands; (2) to calculate the ascorbic acid content of one serving cooked dehydrated potatoes; (3) to compare the ascorbic acid content of hash browned, mashed, and fried potatoes prepared from fresh and dehydrated potatoes; and (4) to analyze the results statistically.

CHAPTER III

EXPERIMENTAL PROCEDURE

The potato products from the two commercial food processing companies, designated as Brand X and Brand Y, were received in December, 1961. The dehydrated potatoes were stored in the dark at 23°C. (73°F.) in the Home Economics Research Laboratory of the Agricultural Experiment Station of Montana State College, where the potatoes were analyzed.

Raw Netted Gem potatoes constituted the experimental control. The Netted Gems were purchased from a variety of local food stores. If the potatoes were not analyzed the day purchased, the tubers were stored in a private home at 10°C. to 14°C. (50°F. to 57°F.).

Determinations were made on six packages each of dehydrated potato dices, slices, and flakes of Brand X and Brand Y. There was a total of 36 packages of dehydrated potatoes analyzed for ascorbic acid. Two samples were taken from each package. Three colorimetric determinations were made on the slurry from each sample. One sample was analyzed for reduced ascorbic acid in the uncooked product. The second sample was prepared according to the manufacturer's directions on the package. The dices were prepared as hash browns, the slices as fried potatoes, and the flakes as mashed potatoes.

No reports could be found in the literature in which acetone had been added to the sample extract of the dehydrated potatoes to prevent the interference of sulfite in the 2,4-dinitrophenylhydrazine method of ascorbic acid analysis. A preliminary experiment was conducted to determine if this could be done. The results indicated that acetone could not be added to the extracts of potatoes analyzed by this method.

The reduced ascorbic acid content of the uncooked and cooked dehydrated potatoes was determined by the 2,6-dichlorophenolindophenol colorimetric method as outlined in Methods of Vitamin Assay (1). This method is based on the reduction of the indophenol dye by the ascorbic acid present in the sample extract. Modifications developed by Mapson (34) and Loeffler and Ponting (31) were applied to prevent the interference of the sulfite present in the dehydrated potatoes. The extracting acids used were 0.5 and 0.25 percent oxalic acid. The potato slurries were centrifuged. This was found to be much more satisfactory than filtering.

The modified procedure is described below:

I. Preparation of Potato Samples.

A. Flakes, Brand X, prepared as mashed potatoes. One and one-third cups of tap water containing 2 gms. of salt were brought to a boil. One-hundred six gms. of cold skim milk were added next. Then 70 gms. of dehydrated flakes were added to the liquid and gently stirred. The mashed potatoes were weighed.

Flakes, Brand Y, prepared as mashed potatoes. One and one-half cups of tap water containing 2 gms. of salt were brought to a boil. One-hundred twenty-two gms. of cold skim milk and 90 gms. of potato flakes were added and the mixture gently stirred. Next, the mashed potatoes were weighed.

(1) A 50 gm. sample of mashed potatoes was transferred to a Waring blendor. Then 50 ml. of 0.5% oxalic acid, 300 ml. of 0.25% oxalic acid were added. The slurry was blended for

one minute. An aliquot of slurry was immediately transferred to a centrifuge tube and centrifuged for 10 minutes at 2000 rpm. The supernatant liquid was then decanted into a clean centrifuge tube and again centrifuged for 10 minutes.

(2) Six ml. of the extract, 12.5 ml. of 0.5% oxalic acid, 1 ml. of citrate buffer, and 2.5 ml. of acetone were added to a 25 ml. volumetric flask. Distilled water was added to make up to volume. The procedure was continued as in Part 2, Colorimetric Readings.

B. Slices, Brand X and Brand Y, prepared as fried potatoes. Two and two-thirds cups of tap water containing 4 gms. of salt were brought to a boil. Eighty gms. dehydrated potato slices were added to the water and simmered until tender, about 15 minutes. The reconstituted potatoes were drained and weighed. They were fried in 15 gms. of melted hydrogenated shortening in a cast iron fry pan until golden brown, about 20 minutes. Then the fried potatoes were weighed.

(1) A 25 gm. sample was transferred to a Waring blendor. Twenty-five ml. of 0.5% oxalic acid and 200 ml. of 0.25% oxalic acid were added and the slurry blended for one minute. Then, 250 ml. of 0.25% oxalic acid were added and again blended for one-half minute.

(2) The slurry of fried potatoes was centrifuged as in A(1) and treated as in A(2).

C. Dices, Brand X and Brand Y, prepared as hash browns. Seventy-two gms. dehydrated potato dices and 2 gms. of salt were added to 1-1/2 cups of tap water. The potatoes and water were brought to a boil and simmered until tender, approximately 15 minutes. The reconstituted dices were then drained and weighed. The dices were fried in 15 gms. melted hydrogenated shortening in a cast iron fry pan for 20 to 25 minutes. The hash browns were weighed and treated as in B(1) and B(2).

D. Dehydrated potatoes, uncooked. Two-hundred fifty ml. of 0.25% oxalic acid were added to 10 gms. of dehydrated potatoes and the mixture was left to stand for 30 minutes. Then the dices and slices were blended for two minutes. The flakes were blended for one minute. The slurries were centrifuged as in A(1) and treated as in A(2), using 6 ml. of slurry in the final 25 ml. dilution.

E. Raw potatoes. Netted Gem potatoes were peeled and a 50 gm. sample representing all parts of the potato tuber was transferred to a Waring blendor. Fifty ml. of 0.5% oxalic acid and 150 ml. of 0.25% oxalic acid were added to the potatoes and blended for five minutes. The raw potato slurry was centrifuged as in A(1) and treated as in A(2), except 3 ml. of the raw potato extract was used in the 25 ml. dilution.

2. Colorimetric Readings.

A. Ten ml. of distilled water were added to a cuvette. The cuvette was placed in the Evelyn colorimeter and the galvonometer set at

100% transmission. A 520 mμ filter was used. The center setting was noted.

B. Five ml. of diluted dye solution were added to each cuvette.

C. Five ml. of buffered sample extract were added by means of a rapid delivery pipet to the diluted dye solution. The reaction was timed from the start of the delivery of the sample extract. The cuvette was gently swirled to thoroughly mix the solutions. Then the cuvette was placed in the Evelyn colorimeter. Readings were made at 15 and 30 seconds.

D. A crystal of ascorbic acid was added to the solution to completely reduce the dye. The difference between the optical density of the dye completely reduced and the optical density of the dye reduced by the sample extract was used in calculating the ascorbic acid content of the sample. The galvonometer reading was recorded.

E. Solutions with acetone added to prevent the interference of sulfite and appropriate blanks were processed in a similar manner.

3. Standard Curve.

A. A 100 mg. % standard ascorbic acid solution was prepared. A diluted stock solution was prepared by adding 5 ml. of the standard solution to a 100 ml. volumetric flask and diluting to volume with distilled water.

B. One, two, and three ml. of the diluted stock solution were pipetted into three 25 ml. volumetric flasks. One ml. of citrate buffer, 12.5 ml. of 0.5% oxalic acid, and distilled water added to make up to volume were added to each flask.

C. The standard curve for the sulfited potatoes was prepared in the same manner, with the addition of 2.5 ml. of acetone to each 25 ml. volumetric flask.

D. The solutions were treated as in Part 2 of Procedure.

The ascorbic acid content of the uncooked and cooked dehydrated potatoes was calculated on a dehydrated, or dry, weight basis and on a reconstituted, or fresh, weight basis. Micrograms of ascorbic acid per gram of food =

$$\frac{K(\text{optical density})\text{dilution factor}}{\text{weight of sample}}$$

$K = \frac{C}{D}$

C = concentration of ascorbic acid in μg/ml. of working ascorbic acid standard.

D = optical density = $(\text{Log } G_b - \text{Log } G_o)_{dye} - (\text{Log } G_b - \text{Log } G_o)_{sample}$

G_o = reading at 0 time, calculated by extrapolating to 0 time from readings made at 15 and 30 seconds.

G_b = reading with dye completely reduced.

Three samples of cooked dehydrated mashed potatoes were analyzed for ascorbic acid by the 2,4-dinitrophenylhydrazine method of Schaffert and Kingsley (50) and by the 2,6-dichlorophenolindophenol method (1). This part of the experiment was conducted to determine if results reported by Bring (4) on ascorbic acid in dehydrated potato flakes could be compared with results obtained in this study. Bring determined total ascorbic acid by the Roe and Oesterling method outlined in Vitamin Methods. I. (18). The Schaffert and Kingsley (50) method is a modification of this method. The 2,6-dichlorophenolindophenol dye method measures only reduced

ascorbic acid. Leichsenring et al (30) found dehydroascorbic acid to be one percent or less of the total ascorbic acid in boiled potatoes. Therefore, it was thought that there should be very little differences in ascorbic acid content of the potatoes analyzed by the two methods. Potatoes analyzed by the 2,4-dinitrophenylhydrazine method were prepared according to the method developed by Bring. No acetone was added to the 2,4-dinitrophenylhydrazine method to prevent the interference of the sulfite in the dehydrated potatoes.

CHAPTER IV

RESULTS AND DISCUSSION

The reduced ascorbic acid content of Brand X uncooked and cooked commercial dehydrated potatoes appears in Table VIII. The values for

TABLE VIII. The reduced ascorbic acid content of Brand X dehydrated potatoes.

PHYSICAL FORM	PACK-AGE	REDUCED ASCORBIC ACID UNCOOKED DEHYD.[1] BASIS	UNCOOKED RECONST.[2] BASIS	COOKED DEHYD.[1] BASIS	COOKED RECONST.[2] BASIS	% VIT. LOST DURING COOKING, RECONSTITUTED BASIS
		mg./100 gm.		mg./100 gm.		
Dices or Hash Browns	1	8.65	2.46	5.33	1.52	38.21
	2	9.97	2.76	10.16	2.84	00.00
	3	10.49	2.96	6.83	1.92	35.14
	4	11.12	3.18	5.06	1.45	54.40
	5	9.50	2.66	4.39	1.23	53.76
	6	4.57	1.30	2.74	0.78	40.00
	Avg.	9.05	2.55	5.75	1.62	36.92
Flakes or Mashed Potatoes	1	6.42	0.98	3.00	0.45	54.08
	2	4.64	0.70	3.55	0.54	22.86
	3	4.65	0.72	1.58	0.24	66.67
	4	3.91	0.58	1.55	0.23	60.34
	5	3.12	0.48	2.22	0.34	29.17
	6	4.35	0.65	2.21	0.33	49.23
	Avg.	4.52	0.68	2.35	0.36	47.06
Slices or Fried Potatoes	1	14.16	4.53	3.75	1.20	73.51
	2	8.52	2.59	3.01	0.91	64.86
	3	9.87	3.22	2.30	0.75	76.71
	4	8.67	2.71	2.86	0.89	67.16
	5	8.90	2.81	2.61	0.83	70.46
	6	8.29	2.46	0.38	0.11	95.53
	Avg.	9.74	3.05	2.48	0.78	74.70

[1]Calculated on dehydrated, or dry, weight basis.
[2]Calculated on reconstituted, or fresh, weight basis.

Brand Y potatoes appear in Table IX. The ascorbic acid values given for the uncooked potatoes on the reconstituted basis are calculated from the values obtained by analysis for the uncooked potatoes on the dehydrated

TABLE IX. The reduced ascorbic acid content of Brand Y dehydrated potatoes.

PHYSICAL FORM	PACK-AGE	REDUCED ASCORBIC ACID UNCOOKED DEHYD.[1] BASIS	UNCOOKED RECONST.[2] BASIS	COOKED DEHYD.[1] BASIS	COOKED RECONST.[2] BASIS	% VIT. LOST DURING COOKING, RECONSTITUTED BASIS
		mg./100 gm.		mg./100 gm.		
	1	22.14	5.24	11.44	2.71	48.28
Dices	2	22.13	5.29	14.06	3.36	36.48
or	3	20.65	4.89	12.29	2.91	40.49
Hash	4	21.13	5.05	10.58	2.53	49.90
Browns	5	14.58	3.42	11.83	2.77	19.01
	6	17.29	4.02	13.62	3.16	21.39
	Avg.	19.65	4.65	12.30	2.91	35.92
	1	13.34	2.25	10.05	1.70	24.44
Flakes	2	14.50	2.54	14.11	2.49	1.97
or	3	10.96	1.90	11.22	1.94	00.00
Mashed	4	15.58	2.64	13.55	2.29	13.26
Potatoes	5	11.94	2.00	11.71	1.96	2.00
	6	11.65	1.95	9.79	1.64	15.90
	Avg.	12.30	2.21	11.74	2.00	9.60
	1	24.39	6.75	7.49	2.07	69.33
Slices	2	29.33	7.98	9.26	2.52	68.42
or	3	21.51	6.27	11.26	3.26	48.01
Fried	4	35.43	10.01	7.00	1.98	80.22
Potatoes	5	21.83	5.80	6.20	1.64	71.72
	6	21.38	5.86	7.80	2.14	63.49
	Avg.	25.64	7.11	8.17	2.27	66.86

[1]Calculated on dehydrated, or dry, weight basis.
[2]Calculated on reconstituted, or fresh, weight basis.

basis. The values given for the cooked potatoes on the dehydrated basis are calculated from the values obtained by analysis for the cooked potatoes on the reconstituted basis. Consequently, the tables show the

ascorbic acid content of the uncooked and cooked dehydrated potatoes in mg. per 100 gms. of dry potatoes or mg. per 100 gms. reconstituted potatoes.

It is evident that there is much variation between packages of the same type of potatoes within each brand. This variation may be due to the length and the temperature of storage, the original ascorbic acid content of the processed potatoes, and the method of dehydration.

Brand X dehydrated potatoes lost more ascorbic acid during the cooking processes than Brand Y. Brand Y potato flakes lost very little ascorbic acid during the preparation of mashed potatoes compared to the hash browns and the fried potatoes.

The mean reduced ascorbic acid values for six raw Netted Gem potatoes were 10.10 mg., 8.30 mg., 11.44 mg., 7.86 mg., 7.95 mg., and 11.18 mg. per 100 gms. of potatoes. The average of these means was 9.47 mg. These values are lower than the year-round average of 17 mg. reported by Watt and Merrill (61). However, the values are similar to values reported by other investigators (21,27).

The analysis of variance for the reconstituted dehydrated potatoes is shown in Table X. The differences in ascorbic acid values between the two brands were highly significant. There were also highly significant differences in the ascorbic acid content between the dices, slices, and flakes. The ascorbic acid values for the flakes were much lower than the ascorbic acid values of the dices and slices. The analysis of variance also showed that the differences in ascorbic acid content between uncooked and cooked potatoes were highly significant.

TABLE X. Analysis of variance for reconstituted dehydrated potatoes.

SOURCE OF VARIATION	D.F.[1]	SUMS OF SQS.	MEAN SQS.	F RATIO
Brands	1	73.18	73.18	158.10*
Physical Forms	2	53.77	26.89	58.08*
Flakes vs. dices and slices	1	52.14	52.14	
Slices vs. dices	1	1.63	1.63	
Method of Preparation	1	53.41	53.41	115.37*
Brands/Physical Forms	2	5.18	2.59	5.59*
Brands/Method of Preparation	1	5.32	5.32	11.49*
Physical Forms/Method of Preparation	2	33.74	16.87	36.44*
Brands/Physical Forms/ Method of Preparation	2	5.61	2.80	6.06*
Experimental Error	60	27.77	0.46	
Total	71	257.98		

[1]D.F. = degrees of freedom.
*($P < 0.01$)

Table XI shows the mean ascorbic acid content of the packages of Brand X and Brand Y dehydrated potatoes prepared as hash browned, mashed, and fried potatoes. It is evident that Brand Y potatoes contained more ascorbic acid than Brand X. A "t" test showed the odds are 99 to 1 that

TABLE XI. The mean ascorbic acid content of two brands of cooked dehydrated potatoes.

DEHYDRATED POTATOES	BRAND X MG. VIT. C IN 100 GM.	STANDARD ERRORS OF THE MEAN	BRAND Y MG. VIT. C IN 100 GM.	STANDARD ERRORS OF THE MEAN
Hash browns	1.62	± .23*	2.91	± .23*
Mashed	0.36	± .23*	2.00	± .23*
Fried	0.78	± .23*	2.27	± .23*

*($P < 0.05$)

the ascorbic acid differences between the two brands are not due to chance alone.

The ascorbic acid content of one serving of dehydrated hash browns, mashed, and fried potatoes was calculated and compared with the ascorbic acid content of fresh potatoes prepared the same way as reported by Watt and Merrill in Handbook No. 8 (61). This is shown in Table XII. The

TABLE XII. The mean ascorbic acid content of one serving of hash browns, mashed, and fried potatoes prepared from dehydrated and fresh potatoes.

POTATOES	BRAND X DEHYDRATED	BRAND Y DEHYDRATED	FRESH POTATOES[1]
	mg.	mg.	mg.
Hash browns[2]	3.16	5.67	14.00
Mashed[2]	0.70	3.90	14.00
Fried[3]	1.33	3.86	33.00

[1]Watt, Bernice K., and Merrill, Annabel L.: Composition of foods...raw, processed, prepared. U. S. Dept. of Agri. Handbook No. 8, June, 1950.
[2]Avg. serving = 1 cup = 195 gms.
[3]Avg. serving = 1 cup = 170 gms.

fresh potato products contain more than twice the ascorbic acid present in the cooked dehydrated potatoes. Two-tailed "t" tests for differences in the ascorbic acid content between products prepared from fresh and dehydrated potatoes showed the odds are 99 to 1 that these differences are not due to chance alone.

Table XIII shows the milligrams of ascorbic acid that would be available in the daily per capita consumption of cooked dehydrated and fresh potatoes in four countries. This table is based on the assumption that the potatoes would be consumed as mashed potatoes. It may be noted that the mashed potatoes prepared from fresh potatoes would contribute much

TABLE XIII. The ascorbic acid available in the daily per capita consumption of mashed potatoes, prepared from fresh and two brands of dehydrated potatoes.

COUNTRY	APPROX. DAILY PER CAPITA CONSUMPTION[1]		ASCORBIC ACID IN MASHED POTATOES BRAND X	BRAND Y	FRESH[2]
	lbs.	gms.	mg.	mg.	mg.
Canada	2/5	170	0.61	3.40	12.21
Ireland	1	493	1.77	9.86	35.40
United Kingdom	1/2	259	0.93	5.18	18.60
United States	1/3	151	0.54	3.02	10.84

[1]Yates, P. Lamartine: Food, Land, and Manpower in Western Europe. London: Macmillan and Co., Ltd., 1960.
[2]Watt, Bernice K., and Merrill, Annabel L.: Composition of foods...raw, processed, prepared. U. S. Dept. of Agri. Handbook No. 8, June, 1950.

more ascorbic acid than either Brand X or Brand Y mashed potatoes. The only country that would receive an appreciable amount of ascorbic acid from fresh cooked potatoes is Ireland because of the greater per capita consumption. The daily per capita consumption of fresh potatoes, mashed, in Ireland would provide 35.40 mg. of ascorbic acid whereas the better of the two dehydrated mashed potatoes would provide only 9.86 mg. of ascorbic acid. The 35.40 mg. would be sufficient to prevent symptoms of frank scurvy. It would be doubtful if the milligrams of ascorbic acid provided by the dehydrated potatoes would prevent frank scurvy, if the potatoes were the only source of ascorbic acid.

In order to compare the results of this investigation with results of the method reported by Bring (4) on total ascorbic acid in dehydrated mashed potatoes, the same sample of mashed potatoes was analyzed for ascorbic acid by the 2,4-dinitrophenylhydrazine method (50) and the 2,6-dichlorophenolindophenol method (1). Table XIV shows the ascorbic

acid values obtained by the two methods on the same sample of dehydrated mashed potatoes. Three colorimetric determinations were made on each

TABLE XIV. The ascorbic acid content of Brand X dehydrated mashed potatoes as determined by two methods of analysis.

SAMPLE	METHOD OF ASCORBIC ACID ANALYSIS			
	2,4-DINITROPHENYLHYDRAZINE		2,6-DICHLOROPHENOLINDOPHENOL	
	DEHYDRATED BASIS	RECONSTITUTED BASIS	DEHYDRATED BASIS	RECONSTITUTED BASIS
	mg. total vit. C/100 gms.		mg. reduced vit. C/100 gms.	
1	16.74	3.01	5.34	0.79
2	15.94	2.80	5.57	0.96
3	11.98	2.09	5.03	0.88

sample. It was observed that the ascorbic acid values obtained by the 2,4-dinitrophenylhydrazine method were much higher that the ascorbic acid values obtained by the 2,6-dichlorophenolindophenol method. Results of a paired-"t" test showed these differences were significant ($P < 0.05$). The 2,4-dinitrophenylhydrazine method measures total ascorbic acid and the 2,6-dichlorophenolindophenol method measures only reduced ascorbic acid. However, Leichsenring et al (30) found dehydroascorbic acid to be only one percent or less of the total ascorbic acid in boiled potatoes. It was, therefore, thought that there would be some differences in the ascorbic acid measured by the two methods, but not such great differences as were observed.

There was a statistically significant difference ($P < 0.05$) in the variation of results between methods. The variance for the Schaffert and Kingsley 2,4-dinitrophenylhydrazine method was 3.36 compared to a variance of 0.04 for the indophenol dye method. Since there was such a large

difference in the variances, coefficients of variation (relative standard deviation) were also calculated: 38.41% for the 2,4-dinitrophenylhydrazine method and 1.30% for the dye method. These results indicated that the ascorbic acid values obtained by the 2,4-dinitrophenylhydrazine method varied from the mean a great deal more than the values obtained by the 2,6-dichlorophenolindophenol method varied from the mean. The coefficients of variation indicated that the 2,6-dichlorophenolindophenol method is much more reliable in determining reduced ascorbic acid than the other method is in determing the total ascorbic acid content of dehydrated mashed potatoes. It was concluded that results obtained by the two methods used by the two different investigators could not be compared.

CHAPTER V

SUMMARY

Thirty-six boxes of two brands of dehydrated potatoes, designated as Brand X and Brand Y, were analyzed for reduced ascorbic acid by the 2,6-dichlorophenolindophenol photoelectric method. Ascorbic acid determinations were made on uncooked and cooked dehydrated potato dices, flakes, and slices.

An analysis of variance of the reconstituted potatoes indicated that there were highly significant ascorbic acid differences ($P < 0.01$) between brands, between methods of preparation, and between forms of the dehydrated potatoes. Brand Y potatoes contained more ascorbic acid than Brand X. Both Brand X and Brand Y potato flakes contained significantly lower amounts of ascorbic acid than the potato dices and slices.

The mean ascorbic acid content of one serving Brand X hash browns was 3.16 mg., mashed potatoes 0.70 mg., and fried potatoes 1.33 mg. The mean ascorbic acid content of Brand Y hash browns was 5.67 mg., mashed potatoes 3.90 mg., and fried potatoes 3.86 mg. A "t" test showed that Brand Y potatoes contained more ascorbic acid than Brand X at the one percent level of significance.

Two-tailed "t" tests showed there were highly significant differences ($P < 0.01$) in the ascorbic acid content of mashed, hash browned, and fried potatoes prepared from fresh and dehydrated potatoes. Cooked fresh potatoes supplied more than twice the ascorbic acid available in the cooked dehydrated potatoes.

The results of this investigation indicate that commercially available dehydrated potatoes, represented by the two brands used, contain considerably less ascorbic acid than an equivalent quantity of fresh potatoes.

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