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THE CHEMICAL COMPOSITION OF WHITE POTATOES

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The literature of the composition of white potatoes is very extensive, but also very much scattered and sometimes somewhat indefinite. Hence an effort is made herein to bring together some of the important data and information and incorporate it with results of our own investigations.

Mineral analysis of potatoes began about 1800, according to Fraser (16). Vitamin determination data on potatoes is relatively recent and becoming very voluminous. Formerly, potatoes generally meant white or Irish potatoes. With an increased interest in sweet potatoes, it is now necessary to specify white or Irish potatoes and sometimes to indicate skin color, and even to indicate if the flesh is white or yellow.

White potatoes must always be regarded as underground stem tubers whereas sweet potatoes are roots. Many of the published analyses of the

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white potato state constituents in the whole raw mature potato. Some refer to the constituents or components of the dry matter or ash. Some refer to the edible portion. Many food authorities regard the skin fully as edible as the fleshy portion and as desirable and it is often eaten.

The white potato *(Solanum tuberosum)* is native to the mountainous part of South America, where it grows wild and forms seed balls and fertile seed. Under cultivation, using potato pieces with potato eyes for propagation, the seed balls are not commonly produced. Migrations since the Spanish conquest of South America caused a spread of the potato to Spain and to other parts of Europe and to Ireland and then to all parts of the temperate and semi-tropical zones of the world. The potato plant is relatively hardy. However, it has many diseases and insect enemies and its large scale cultivation is an applied science and an agricultural industry.

Breeding caused it to develop from a small purple underground stem tuber in Peru to the large Green Mountain, Irish Cobbler, Katahdin, White Rose, Rural Russet, Burbank Russet and many other varieties. As one of the low-cost foods in all countries, it has been widely used.

The potato consists of the skin, the cortex, and the outer and inner medullary layers. Grubb and Guilford (20), Brautlecht (9), Winton and Winton (52), Reed (35), and Artschwager (2) give general or minute details of the structure of the potato.

Maine leads in acreage of potatoes, also in yields per acre and in total production, producing about 14 to 18 per cent of the production of table stock and seed potatoes in the United States. Therefore, the composition of Maine potatoes, such as the Cobbler, Green Mountain, Chippewa and Katahdin varieties, becomes of interest. In Maine, more than 80 per cent of the potatoes are grown in Aroostook County. Some of the other large producing sections in America are Idaho, California, Alabama, Colorado, New York, Pennsylvania, New Jersey, Michigan, North Dakota, Minnesota, Wisconsin, Oregon, Washington, and Virginia.

Matsdorff (28) gives as the composition of German white potatoes the following percentages:

Starch	10 to 30	Insolubles other than starch	1.8 to 2.6
Sugars	0 to 5	Cellulose	0.8 to 1.4
Pentosans	0 to 1	Ash	2.0 to 6.0
Protein	0.6 to 3.5		(in dry matter)
		Acids	0.0 to 0.1

German potatoes, in general, are quite different from the common domestic or American varieties. Jenkins and Winton (24) state the average composition of 12 samples of American potatoes in 1892 as: water 78.89, protein 2.14, fat or ether extract 0.10, nitrogen-free extract 17.36, fiber 0.56 and ash 0.95. The per cent ranges were: water 75.37 to 82.15, protein 1.14 to 2.89, fat or ether extract 0.02 to 0.18, nitrogen-free extract 14.05 to 20.37, fiber 0.28 to 0.85, and ash 0.78 to 0.95. All potatoes, however, differ widely with the same variety because of differences in weather, soil, fertilizer, water and cultivation. Too little or too much rainfall affects relatively normal composition. Starch, for example, may vary two or three per cent for the same variety in successive years under apparently the same conditions other than rainfall and temperature.

The ash is alkaline; the raw tuber juice is acid. The organic acids are present in small amounts and are quickly oxidized in the human body. The raw tuber has an acid interior or low pH, thus tending to preserve vitamin C (ascorbic acid), the antiscorbutic vitamin, during storage. Robertson and Smith (38) observed a pH range for potato juice of 5.5 to 6.2 for varieties grown in the British Isles. Some constituents of the potato are present in only very small quantity. Nevertheless, they are essential to the life and health of the potato.

The size of mature Maine potatoes varies widely. A large number of samples of factory potatoes in 1945 for 5 kilograms contained 22 minimum number or largest size, 41 as a maximum number or minimum size, and an average of 30. Some German varieties grown in Maine yield many very small potatoes, about 90 to 5 kilograms.

The results stated are mostly our own and were obtained during a period of many years. Others, among a very large number published are indicated by a reference. Many varieties were used, both commercial and experimental, domestic and foreign, especially the domestic Green Mountain, Irish Cobbler, Katahdin, Chippewa, and Rural, all maturing about October first. Several tubers from 5-kilogram samples were usually taken, quickly milled in a disk mill, a 200-gram or larger sample taken and dried in large porcelain dishes on steam baths, then to constant weight at 100° in a hot air oven in a stream of air, then milled to 100 mesh. Some were sliced thin, then dried at 60 to 100° and milled. Ashing was done in silica dishes, except for silica, which was done in platinum. Phosphorus produced in the ashing process damages the platinum. Headden (23) found about 4.195 to 5.04 per cent ash in the dry matter of potatoes. All Headden (23) references pertain to Colorado potatoes of the 1921-1922 crop years. Goldthwaite (19) found 16.69 to 28.09 per cent total dry matter in Colorado potatoes.

Our regular analyses were made, in almost all cases, according to the A. O. A. C. (3) methods. The following elements are present in various combinations and are expressed both as the free element and often as the customary oxides.

Nitrogen

The total nitrogen in the whole, raw, mature, white potato in Maine was found to vary from 0.35 to 0.45 per cent; average about 0.40 per cent. Of this, about 63 per cent of the total nitrogen is reported to be in the form of protein, according to Jones and Nelson (26). Rathsack (34), for best flavored German potatoes, found as percentages: total solids, 27.3; starch, 20.8; total nitrogen, 0.259, soluble nitrogen, 0.093, amino nitrogen, 0.065; salt as percentage of dry substance 5.50; and relative amino nitrogen 25.8. Headden (23), examining Colorado potatoes of several varieties, reported nitrogen as follows: total in pulp, 0.224 to 0.545; total in juice, 0.245 to 0.564; albumin nitrogen, 0.069 to 0.1635; proteose nitrogen, 0.006 to 0.059, peptone nitrogen, 0.018 to 0.046; and nitrate nitrogen none to 0.0144.

Appleman and Miller (1) state the percentage range of nitrogen distribution in fresh mature potatoes: total non-protein nitrogen, 17.84 to 35.58; nitrogen, as acid amides 3.40 to 7.24; nitrogen in phosphotungstic precipitate (basic amino nitrogen), 2.11 to 5.49; and mono amino nitrogen, 8.83 to 18.07. Whalley (51) reported a distibution of total nitrogen in Canadian potatoes as follows: non-protein, 32.18; acid amide, 6.58; phosphotungstic precipitate 5.49; and mono amine, 15.05.

Silica

About 0.09 to 0.14 per cent silicon corresponding to 0.20 to 0.30 per cent of silica was found in the carbon-free ash of potatoes. Headden(23) found about 0.23 to 0.85 per cent silica in Colorado potash ash.

Carbon Dioxide

Headden (23) found from about 14.7 to 22.1 per cent carbon dioxide in Colorado potato ash. The potato as a living plant even when dormant, undergoes metabolic changes.

Phosphorus

Phosphorus was found in Maine potatoes to be about 0.03 to 0.11 per cent of the total potato as received, or about 0.15 to 0.55 on a dry-weight basis and about 9.0 per cent of the potato ash. Phosphorus pentoxide equivalents would be 0.07 to 0.115, .345 to 1.26, and 21 per cent, respectively. It is nutritive in potatoes, as in other foods, as a builder of skeletal and

nerve tissues but supplies only a small part of the body needs. Only when potatoes are eaten in large quantity is the intake of elements such as nitrogen and phosphorus sufficient to be important as part of the body needs. Headden (23) found from 8.38 to 14,.724 per cent phosphorus as the pentoxide or phosphoric oxide in Colorado potato ash, which corresponds approximately to from 3.56 to 6.48 per cent as the element.

Sulfur

The element sulfur was found present in the whole white potato in amounts ranging from approximately 0.02 to 0.05 per cent with an average of about 0.025 per cent; and from about 0.10 to 0.17 per cent of the water-free material, corresponding to about 1.0 to 1.7 per cent in potato ash. Such amounts appear insignificant but they are associated with cystine. Headden (23) found 3.35 to 7.14 per cent of sulfur as sulfur trioxide in ash of Colorado potatoes. These figures correspond from approximately 1.34 to 2.86 per cent as sulfur in the ash.

Potassium

Potassium is present in white potatoes in dissolved salt form in the liquid surrounding and in the cellulose-walled cells, some containing the starch. It is the element that is largely responsible for the alkalinity of the ash. The potassium content in the raw fresh potato was found in quantities varying from about 0.42 to 0.54 per cent and represents about 2.0 to 2.6 per cent as the element in the dry potato and about 42.0 to 54.0 in the ash. These figures represent, respectively, about 0.51 to 0.65, 2.40 to 3.12, and 51 to 65 per cent of potassium as the oxide in the total ash. Parow (31) reported 55-60 per cent as the oxide in the total ash. The figures for potassium oxide in the ash were 54.4 to 58.4 as tabulated by Headden (23), and about 59 as reported by Winton and Winton (52). The ash represents approximately 1.0 to 2.5 per cent of the tuber weight as received or harvested. The writers generally found from about 1.5 to 2.7 per cent ash as received in Maine potatoes. This may be due to the relatively large quantities of fertilizer usually used in Maine.

Magnesium

At one time, magnesium was not regarded as important in soils or fertilizer in potato culture. It is more abundant in potatoes than calcium, and soils are depleted of it more rapidly; hence the present practice of indicating magnesium oxide on fertilizer bags as well as nitrogen, phosphate, and potash. It was found to the extent of 0.013 to 0.070 per cent with an average of nearly 0.030 per cent of the whole mature potato of different varieties. The last figure is equivalent to 0.05 as magnesium oxide as an aver-

age. Like calcium, but only to a very slight extent, it appears in the starch granules. Possibly more of the magnesium is present nearer the surface of the tuber. On a water-free basis this represents about 0.10 per cent of the element or 0.16 per cent as the oxide. The tops, leaves, and vines contain about five times as much magnesium as the tubers. This high concentration of magnesium in potato leaves is associated with the chlorophyll and functions probably in the formation of formaldehyde, reacting or polymerizing to form soluble carbohydrates such as sugars and the insoluble carbohydrates such as starch, cellulose, *etc.* Sun-burned potatoes, with a green skin and a green color often extending to a considerable extent into the potato, may possibly involve a lack of conversion of chlorophyll to starch or a change from starch to sugar to chlorophyll. Magnesium was found in potato ash by Headden (23) to be about 2.99 to 4.57 per cent magnesium as the oxide, equal to about 1.80 to 2.75 per cent magnesium.

Calcium

Calcium occurs in small quantity, being found to the extent of nearly 0.005 to 0.008 per cent. In the water-free potato, there is about 0.03 per cent calcium and in the potato ash there is about 0.5 to 2.0 per cent. These figures represent about 0.007 to 0.011, 0.04, and 0.7 to 2.8 per cent calcium as the oxide, respectively. Soil and fertilizer affect the calcium concentration greatly, so that limits of 0.006 to 0.022 have often been reported in the literature. Much of the calcium is present in the starch granules and carries over into the starch ash, especially as calcium phosphate. Artschwager (2) reported crystals of calcium oxalate in immature and germinating tubers. Headden (23) obtained figures of approximately 0.647 to 2.226 for calcium as the oxide in Colorado potato ash. This corresponds to about 0.464 to 1.59 for the element calcium.

Sodium

Sodium was found to be present in Maine potatoes to the extent of 0.02 to 0.05 per cent of the total potato, with an average of about 0.03 per cent, about 0.12 per cent in the water-free material and 2.0 per cent in the ash. The last three figures for sodium correspond to 0.04, 0.16, and 2.7 as sodium oxide, respectively. Most of the sodium is probably present as sodium chloride in the potato juice. Some appears in the starch granules, probably as sodium phosphate. Headden (23) in potato ash, found from 0.00 to 1.493 per cent sodium as the oxide, which corresponds from approximately 0.00 to 1.18 per cent as sodium.

Chlorine

The quantity of chlorine in the fresh potato was found to vary from 0.010 to 0.031, with an average of about 0.02 per cent. On a water-free basis, this is nearly 0.09 per cent. There is about 2.0 to 3.0 per cent chlorine in white potato ash. In general, high chlorine in soil or fertilizer gives a yellowish color to the leaves. Thus, potassium sulfate fertilizer with the same potassium oxide equivalent appears preferable. The vines are darker and more luxuriant and the starch content of tubers of the varieties grown in Maine is usually about two per cent greater, other growth factors being approximately equal. This greater content of starch is also associated with a greater amount of total solids. Headden (23) found about 0.82 to 6.40 per cent chlorine in the ash from Colorado potatoes.

Elements of physiological interest are iodine, iron, copper, aluminum, manganese, zinc, and arsenic (Winton and Winton) (52).

Iodine

Because of iodine in the thyroid gland, many determinations of iodine in the potato as an extensively used food have been made. Figures for iodine in domestic potatoes have varied widely on water-free basis. Canned Food Reference Manual (11) gives a figure of 517 parts per billion of iodine on a dry-weight or water-free basis for potatoes in South Carolina, relatively near the Atlantic Ocean; Fraps and Fudge (15) reported from 54 to 387 parts per billion iodine in potatoes from different parts of the southern United States; and 75 to 309 parts per billion were reported by Heller, Jones, and Pursell (24). Frear (17), using a modified Karns method, examined potatoes grown in all parts of Pennsylvania and found 9 to 216 parts per billion of iodine. Some evidence indicates that soil composition affects the iodine content of the tuber Balks (4); Frear (17). Location of potato fields relative to sea water is a factor.

Iron

Iron was found in white potatoes in quantities of about 0.0009 per cent of the raw potato and with nearly 0.005 per cent in the water-free material and 0.08 in the ash. Winton and Winton (52) reported comparable figures as did Remington and Shiver (36) and Peterson and Elvehjem (32). Sherman (39) and others stated that iron, probably in a few salt combinations, is generally regarded as available for human assimilation. Headden (23) found 0.148 to 0.404 per cent iron as the oxide in potato ash, corresponding from approximately 0.10 to 0.282 per cent iron.

Copper

Copper, in traces, is qualitatively evident in Maine potato ash due probably to absorption from Bordeaux spray mixture or copper compound dusts. In the literature, quantities of copper are mentioned of the order of 0.0001 per cent in raw potatoes, 0.0003 per cent in the dried, and 0.01 per cent in the ash Guerithault (21). Remington and Shiver (36) reported about 0.0007 per cent in potatoes on dry basis. A few parts per million are not harmful.

Zinc

Zinc has been reported present as of the order of 0.0004 per cent in mature raw potatoes, a red skinned variety, and 0.0002 per cent in the immature form (Bertrand and Benzon (5).

Aluminum

Aluminum has been found to the extent of approximately 0.001 per cent in the fresh edible portion (Underhill, Peterman, Gross and Krause (50) and 0.003 per cent in the water-free material (Bertrand and Levy(6). The last two percentages represent respectively,0.019 and 0.057 per cent aluminum oxide. Headden (23) found 0.059 to 0.520 per cent aluminum oxide in ash from Colorado potatoes, corresponding to 0.031 to 0.270 per cent aluminum.

Manganese

Manganese has been reported present to the extent of the order of 0.0006 to 0.0014 per cent by Remington and Shiver (36). Headden (23) found 0.00 to 0.257 per cent manganese as the manganic oxide in potato ash, corresponding from 0.00 to 0.180 per cent manganese.

Common Element Analyses

Analysis for nitrogen, phosphorus, sulfur, potassium, calcium, and magnesium, in 1938 and 1939 Maine potatoes, common varieties, commercial procedure showed for eight samples of four common varieties grown in Maine the following results on a water-free basis, as the oxides, except nitrogen.

	N	P_2O_5	SO_3	K_2O	CaO	MgO
Min.	1.42	0.130	0.090	1.68	0.030	0.120
Max.	1.88	0.220	0.240	2.56	0.071	0.141
Av.	1.70	0.172	0.140	2.05	0.050	0.127

Another large number, during the same period, with the same varieties and conditions, but at different growth periods were harvested from about July 15th to September 15th and yielded the following results.

	N	P_2O_5	SO_3	K_2O	CaO	MgO
Min.	1.65	0.07	0.08	1.70	0.042	0.112
Max.	3.51	0.47	0.22	3.41	0.111	0.251
Av.	2.00	0.19	0.13	2.40	0.065	0.130

Starch

Starch, the principal component of white potatoes, is the insoluble carbohydrate stored in the tuber for future use in sprouting and as food for the young plant. Individual starch granules made of amylose and amylopectin apparently grow periodically with dark and light periods, around a nucleus, in layers. Since the starch granules vary greatly in size from less than one to 120 or more microns, new granules are continually forming during the growth of the plant. Many analyses of raw mature Maine Green Mountain potatoes, grown experimentally or commercially in Aroostook County in Maine, have contained from 13.1 to 20.0 per cent starch with an average of nearly 15 per cent, which is about or a little over that of a good commercial grade. The low figures are associated with high muriate of potash (potassium chloride) in the fertilizer, the higher figures often with pure chemical salts or potasium sulfate. The Cobbler variety contains somewhat less starch and experimental Katahdin and Houma varieties contain about 15.4 per cent starch under conditions of soil and climate when Green Mountains contain 18.5 per cent starch. The Chippewa usually contains about two per cent less starch than does the Katahdin variety.

Some German varieties of potatoes have as much as 30 per cent starch. In terms of starch per acre, these high-starch potatoes are not economical to grow and do not grow as well in Aroostook as in Germany. An average German starch content (10-year period) would be about 18 per cent. Starch in most Maine potatoes, all commercial varieties, has been less than 12 per cent during the past few years with the Katahdin variety predominant. The average of several varieties grown commercially in Maine with 1 ton 4-8-8- or 8-16-16 fertilizer per acre revealed starch content as follows: 1938 (wet season), 12.8 per cent; and in 1939 (dry season), 14 per cent. The starch content is usually about 0.6 of the total solids. Starch in experimental potatoes has varied during the past fifteen years from approximately 10 to 20 per cent. Occasional commercial lots have been tested which contained only about 8 per cent starch. In 1934, with good growing conditions, the Green Mountain variety contained about 17 per cent starch. Stanley P. Freedman (18) working with large quantities of high quality potato starch ash found, as an average of several determinations, the following percentage constituents, reported as the common oxides: silica, 3.91; phosphate, 54.47; carbonate, 0.31; lime (calcium oxide), 36.05; magnesia, 1.82; potash, 2.01; soda (sodium oxide), 1.39; with a total of 99.96 per cent. Computed to the elements, excluding carbonate, the percentages are, respectively: silicon, 1.8; phosphorus, 23.9; calcium, 26.3; magnesium, 1.2; potassium, 1.7; and sodium 1.0.

The starch content of various varieties of Maine potatoes (grown in 1938) by Parow potato starch balance (31) (calibrated by starch extraction and by chemical means) were as follows:

A	B	Difference
Per cent Starch Starch Factory Hopper Potatoes (Culls and Surplus)	Per cent Starch by Acid Hydrolysis. Includes Celluloses and Pentosans, *etc.*	
12.2	12.9	0.7
14.5	15.4	0.9
14.2	15.0	0.8
15.3	16.0	0.7
12.2	13.4	1.2
12.8	13.1	0.3
17.7	18.3	0.6
13.9	14.8	0.9
16.0	16.6	0.6
12.4	13.4	1.0
Experimental Potatoes		
12.7	13.5	0.8
14.3	14.8	0.5
11.5	11.9	0.4
10.2	10.6	0.4
14.9	15.4	0.5

The starch analyses of four potato varieties grown in Maine (Chippewa, Cobbler, Green Mountain, and Smooth Rural), 1938 crop, grown during a relatively low-yield wet season, had a starch content of 10.2, 12.7, 14.9 and 13.4 per cent, respectively, by a calibrated potato starch balance. The Green Mountain variety potatoes yielded the highest quantity of starch and also the highest quality starch. The Green Mountain, usually elongated with relatively deep eyes and netted skin, is also regarded as having the best edible qualities. Sweetman, M. D. (48) in an extensive study of factors affecting cooking qualities gives an excellent summary of her investigation as regards the influence of composition. Many other varieties of potatoes are grown in Maine. The Katahdin, relatively round with shallow eyes and light-colored smooth skin, contains less starch than the Cobbler. The

Sebago and Houma varieties were found, in 1938 experimental lots, to contain from 11.5 to 14.3 per cent starch, respectively. Determinations of starch in the 1939 crop, which was a relatively low-yield, dry season, showed for the Chippewa, Cobbler, Green Mountain, Smooth Rural, Earlaine No. 2, Sebago, Houma, Bliss Triumph, and Spaulding Rose, under similar conditions of cultivation, starch contents of 11.5, 13.6, 15.4, 14.5, 9.6, 14.4, 14.5, 11.5 and 11.5 per cent, respectively. The length of the growing season is also a factor in yield and starch content, and the use of DDT with Bordeaux mixture in sprays or DDT with copper compound dusts has lengthened the growing season. Experimental potatoes usually show a higher starch content than do average commercial potatoes of the same variety.

Samples of cull and surplus potatoes of all varieties bought by starch manufacturers were found to vary, for the 1938 crop, from 10.9 to 14.3 per cent, with an average of 12.7 per cent. The average content of starch in potatoes in 1940, a relatively good potato year, was 13 per cent. For the 1941 crop, a relatively poor potato year, most of the potatoes going into starch factories were unsalable as table stock or seed, and of poorer quality, and the average of more than thirty samples was 11.5 per cent for different times of the year from September to April. Brautlecht (9) has reported the starch content of Maine potatoes for other periods. Headden (23) found 7.95 to 16.78 per cent of starch in Colorado potatoes. The starch granule size varies with length of growing season, variety of potatoes, and culture, longest axis being usually a minimum of 0.1, maximum 120, and the average 37 microns. The 1941 crop average starch granule size was slightly less than that of 1940.

Potato starch is not a pure carbohydrate; it contains a small quantity of elements especially potassium and phosphorus in various combinations.

Starch can be determined by several methods, including those of A. O. A. C. (3), by polariscopic method as described by Scheele and Svensson (43), density of individual potatoes using salt solutions of different specific gravities with a knowledge of the relation of the starch to total solids, and by specific gravity methods using 5 kilogram samples usually comprising about 30 potatoes.

Protein

Langworthy (27) states that 1.8 per cent protein is present in the whole raw potato. This would correspond to approximately 0.288 per cent nitrogen. From nearly one-third to two-thirds of the nitrogen is in the form of amino acids. The immature potato may contain as much as 5 per cent nitrogen on a dry-weight basis but this falls off as the potato matures. Rathsack (34) concluded that the taste and flavor of potatoes becomes less desirable

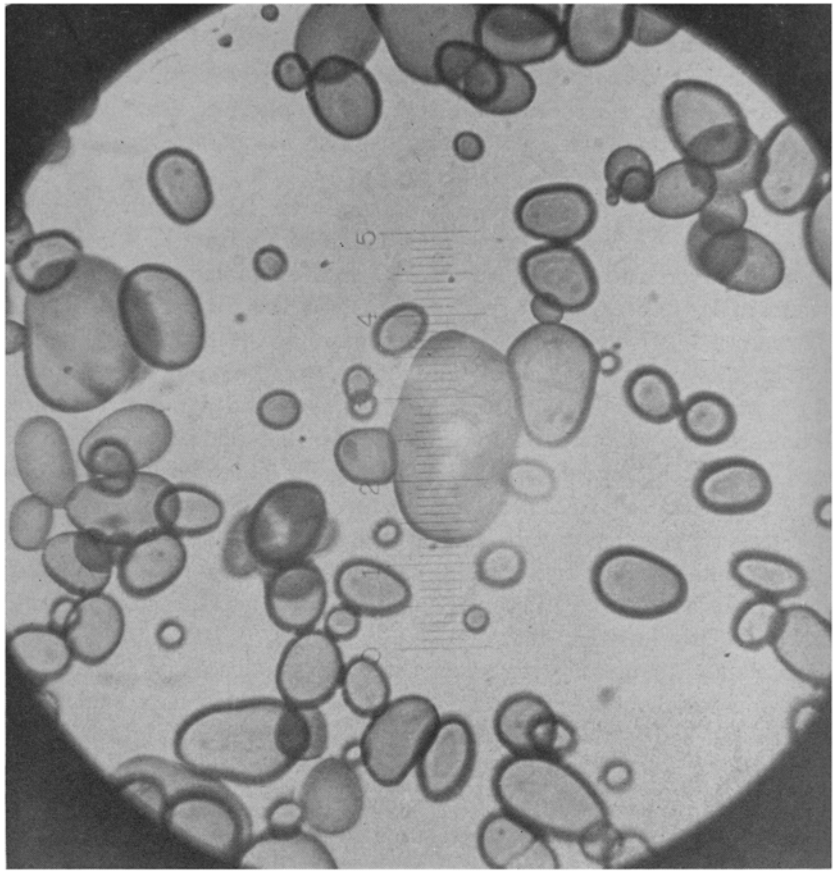

Fig. 1.—Photomicrograph of white-potato starch.

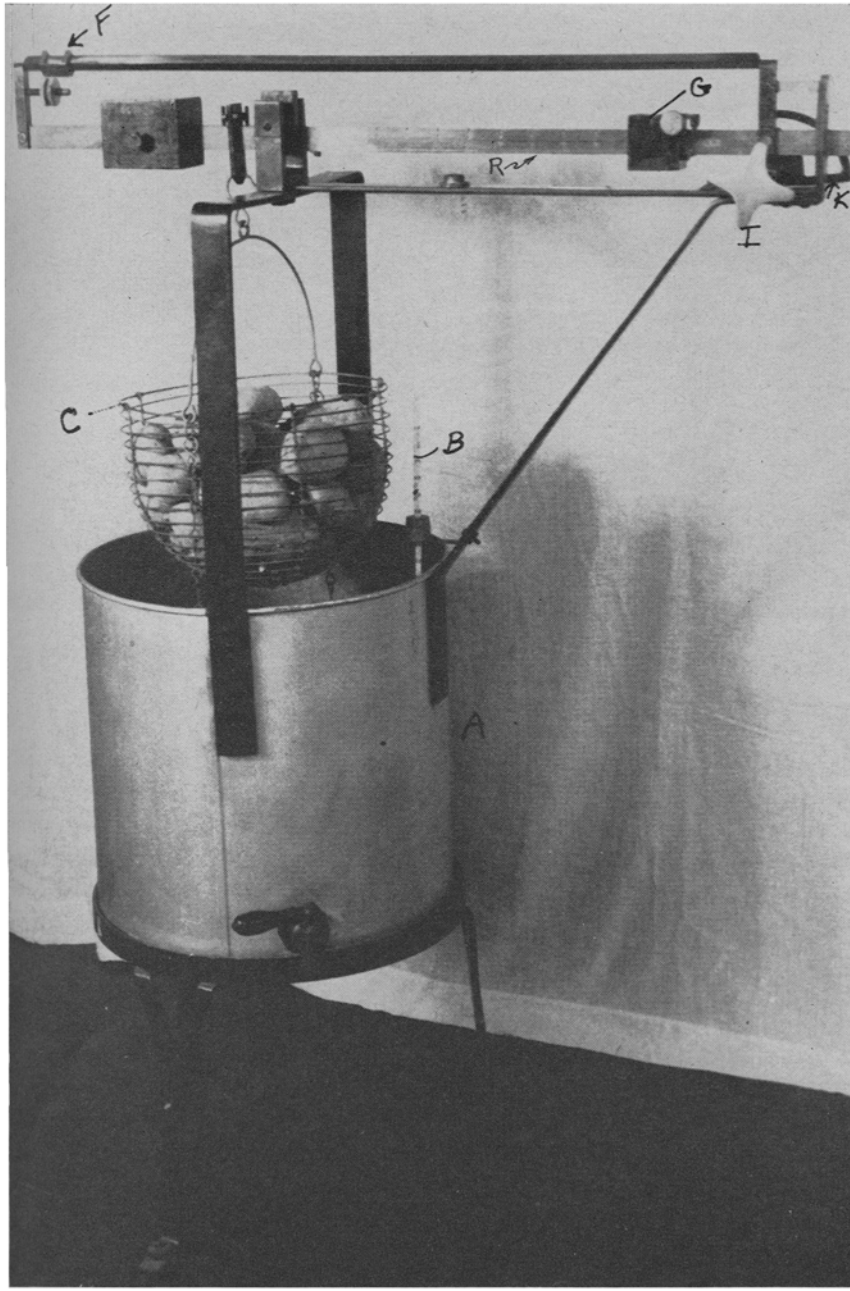

Fig. 2.—Parow Potato Balance. Used for estimating the starch content of potatoes.

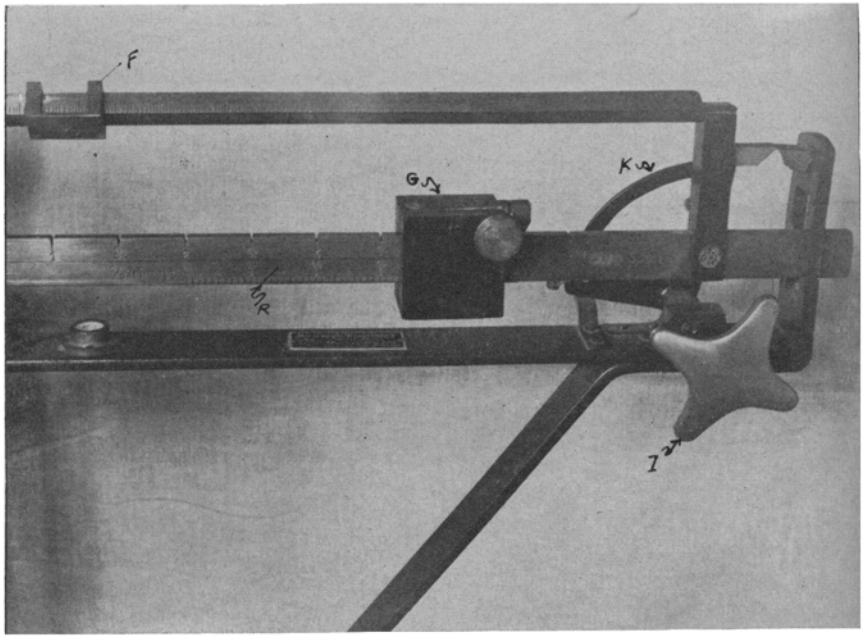

Fig. 3.—Close-up of Parow Potato Balance Beams showing riders, beam release, pointer, and level gauge.

with increase of nitrogen above the normal of about 0.35 per cent. Artschwgaer (2) reported some proteins present as cubic crystals. Jones and Nelson (26) give the partial percentage composition of the potato protein tuberin as: lysine, 3.3; arginine, 4.2; tyrosine, 4.3; cystine, 4.4; and histidine, 2.3; also some tryptophane. Sjollema and Rinkes (45) (46) report the following percentages of amino acids in the nitrogen compound distribution: alanine, 4.9; valine, 1.1; leucine, 12.2; cystine, 4.4; glutamic acid, 4.6; tyrosine, 4.3; phenylalanine 3.9; proline, 3.0; arginine, 4.2; lysine, 3.3; and histidine, 2.3. Ammonia was found to the extent of 1.8 per cent in the hydrolysis products. Yoshimura (54) confirmed the presence of arginine and histidine and found some other organic bases. Other nitrogenous compounds reported are guanine, xanthine, and hypoxanthine as reported by Schweitzer, G. G. (47), and a bluish chromogen by Roach, W. A. (37).

Saare (40) reported 0.6 to 3.7 per cent protein or equivalent nitrogen compounds with an average of 2.0 to 2.2 per cent, based on N x 6.25, this mixture being made up of proteins, crystallizable amides and other nitro-

genous substances. Schulze and Barbieri (44) reported the following percentages of nitrogen distribution in 1878: insoluble protein, 19.2; soluble protein, 40.6; asparagin, 21.6; and unknown amino acids 18.6, and that there was approximately 50 per cent each of proteins and amino acids. The principal protein in potatoes is a globulin or salt-soluble protein named tuberin. Osborne (30A), Morgen (29) studying the distribution of nitrogen in potatoes reported the following:

	Minimum	Maximum	Average
Insoluble protein	3.4	28.9	17.4
Soluble protein	30.1	52.8	43.1
Amino acids (amides)	25.2	51.7	36.6
Unknown forms	0.4	10.2	3.7

Vitamins

The raw, fresh, white potato has vitamins A, B_1 and C (ascorbic acid) and B_2 or G (riboflavin); vitamin C (ascorbic acid) being most abundant. Vitamin B_1 content of fresh white potatoes is reported to be about 30 to 60 units per 100 grams (spectroscopic x factor of 1600) (Fixsen and Roscoe (14). Ascorbic acid limits were found to be 19 to 45 mgs. per 100 grams fresh weight by Murphy, Dove, and Akeley (30).

Vitamin C (Ascorbic Acid)

Ascorbic acid is present in the largest amount and is the vitamin of greatest interest in potatoes. Maine-grown Green Mountain potatoes of the 1939 crop were found by Murphy to have an ascorbic acid content of 16.9 mgs. per 100 grams or a small fraction of one per cent. Human needs for Vitamin C are reported to be about 50 mgs. per 100 grams of raw white potatoes. Losses of Vitamin C occur in cooking and in storage. Heat in cooking and storage are both injurious, although investigations have led to procedures in which the loss of this vitamin is reduced to a minimum (Fixsen and Roscoe (14). Scheunert (42). Woods (53).

Booher and Hartzler (7) (8) in an extensive survey of the literature give figures in milligrams per 100 grams of raw potatoes of approximately 40 for Vitamin A, 20 to 186 for Vitamin B, 5 to 35 for Vitamin C and 10 to 55 for Vitamin G (riboflavin).

Solanine

Solanine, a glucoside and alkaloid, is present in sun-burned potatoes and in potato sprouts and to a very slight extent in normal potatoes. It is never present in toxic quantities according to Thiessen (49), but accounts partly for the bitter taste in sunburned potatoes. The quantity present is

reported as 10 to 58 mgs. per 100 gms. It is reported as concentrated in the outer layer of the tuber by Droste (12). Solanine contains nitrogen, carbon, hydrogen, and oxygen and has the approximate formula $C_{44}H_{71}O_{15}N$. Only when sprouting does the potato contain relatively large amounts of solanine. Schulze and Barbieri (44) reported 0.03 to 0.07 per cent solanine in mature potatoes, present especially in the skin and eyes with a marked increase during sprouting.

Pectins

Von Scheele and Svensson (43) studied pectins of the potato which are present to the extent of 0.1 per cent. The pectins are most difficult to separate from starch because of their colloidal nature.

Pentozans

Pentozans are often determined by the Tollen-Parow method. Saare (40) found 0.74 to 0.95 per cent in ten varieties of potatoes on an as-received basis. This corresponds to approximately 3.25 to 4.0 per cent on a dry-weight basis.

Sugars

The sugar content of potatoes varies very widely. Artschwager (2) states there is none in the mature tuber. The free sugars are in the from of dextrose and sucrose. Levulose, when formed, immediately reacts with some of the dextrose. Saare (41) found that mature green potatoes have usually from 0.0 to 0.4 per cent, varying with variety and climate. Appleman and Miller (1) reported reducing sugars in American potatoes of 0.04 to 0.28 per cent and sucrose of 0.12 to 0.90 per cent. Changes occur in potatoes according to storage conditions. Starch is converted to dextrose, at a temperature of approximately 32°C and some apparently to levulose, a reaction between these monoses, or C_6 sugars yielding sucrose. When the temperature rises, a reconversion of sugar to starch occurs. With some varieties, under certain conditions, 3.0 per cent reducing and 5.0 per cent total sugar may be present. Saare (41) found a variation of 0.4 to 3.4 per cent sugar. Some varieties as the Chippewa are very susceptible to frosting and to this interconversion of starch to sugar. Headden (23) found 0.00 to 3.212 per cent reducing sugars and 0.00 to 4.707 per cent total sugars in the 1921-1922 crops of Colorado potatoes, the larger quantities being after storage.

Organic Acids

Guthrie (22) discovered the organic acids, citric and malic, and confirmed the presence of asparagine in white potatoes. Organic acids such as succinic and tartaric acids have been observed and reported by Artschwager (2), Brautlecht (9), and Whalley (51).

Dextrins

Some investigators have reported dextrin as present in potatoes to a slight extent, about 0.2 per cent. If actually present, dextrins must have been formed by enzymatic changes in a little of the starch.

Enzymes

Pfankuch (33) estimated the phosphatase content of fresh potatoes as 80 to 160 units per gram. A catalase is reported by Bunzell and Kenyon (10). There are undoubtedly many enzymes in the white potato, some acting upon carbohydrates especially to effect changes in starch and sugar to form gums, alcohols, organic acids, *etc.* Other enzymes act on the proteins and amino acids. Some convert dextrose into carbon dioxide, often causing a marked decrease in weight. Oxidase is reported to inactivate ascorbic acid, according to Fixsen and Roscoe (14).

Conclusions and Summary

The percentage of starch in white potatoes has been shown to vary widely with the variety and many climatic and cultural conditions from as low as 9.6 in the Earlaine No. 2 variety, grown only to a slight extent, to 20.0 in Green Mountains. Some samples of commercial potatoes of the Bliss variety have tested as low as 8 per cent. The average starch content of all Maine seed and table stock potatoes is now about 12 per cent (1950 crop). This average can change rapidly because of changes in the per cent grown of relatively low and high starch potatoes. The present trend is apparently toward higher starch potatoes.

Next to starch in order of quality is nitrogenous material as proteins, intermediate hydrolysis products of proteins, and amino acids. The non-starch carbohydrates, as cellulose, pentozans, pectins, *etc.*, then usually follow although they may exceed the nitrogenous compounds. Then come the mineral compounds, especially potassium phosphate. Last is the large number of compounds as the organic acids, enzymes, ether extractives as fat and oil, and enzymes, which are present in very small quantities, and vitamins, present in traces.

The composition of white whole potatoes can be summarized approximately as follows, the analytical data having been collected from much new and old original data from the writer's laboratory and from many published sources.

The average of starch in German potatoes is nearer 18 per cent and maximum near 30 per cent. Maximum starch in Maine potatoes (1934-1950) was 20 per cent. The nitrogen-free extract in some lots was found to be about 23 per cent.

Percentages of alanine approximately 4.9; valine, 1.1; glutamic acid, 4.6; tryosine, 4.3; phenyl alanine, 3.9; proline, 3.6; leucine, 12.2; cystine, 4.4; some tryptophane; arginine, 4.2; histidine, 2.3; and lysine, 3.3 (Sjollema and Rinkes (46).

The data were recorded, for the greater part, from the senior author's records, and from a thesis submitted by A. S. Getchell in partial fulfillment of the requirements for the degree of Master of Science at the University of Maine (1940).

Approximate percentage composition of common, domestic and foreign, varieties of mature white potatoes grown in Maine. Raw and fresh, as received, unless otherwise expressed.

		Av.	Min.	Max.	Av. Per Cent in Total Potato Solids
1	Water (moisture)	79.00	68.00	87.00	
2	Total Solids (by difference)		13.00	32.00	
3	Starch 1/	15.00	8.00	28.00	75.00
	Dextrin			0.20	
	Nitrogen-free Extract			23.00	
4	Ash	1.00	0.60	1.10	3.98

Soluble 0.7: insol. 0.3	as Element	as Oxide	as Element	as Oxide	In Ash as Element	In Ash as Oxide
(a) Phosphorus (P)	0.05	0.114	0.08	0.20	7.2	16.4
(b) Sulfur (S)	0.02	0.05	0.06	0.14	2.0	5.0
(c) Potassium (K)	0.50	0.60	1.70	2.05	47.0	56.5
(d) Magnesium (Mg)	0.03	0.05	0.08	0.13	2.0	3.3
(e) Calcium (Ca)	0.01	0.014	0.03	0.04	1.0	1.4
(f) Chlorine (Cl)	0.02	——	0.09	—	3.0	—
(g) Sodium (Na)	0.03	0.04	0.11	0.15	2.0	2.7
(h) Iron (Fe)	0.0006	0.0009	0.004	0.006	0.08	0.1
(i) Silicon (Si)	0.004	0.009	0.009	0.02	0.12	0.27
(j) Iodine (I)	sl. tr.	sl. tr.	trace	tr.	tr.	tr.
(k) Copper (Cu)	0.0002	0.0003	0.001	0.0012	0.02	0.025
(l) Zinc (Zn)	0.0003	0.0004	0.0012	0.0015	0.03	0.038
(m) Aluminum (Al)	0.001	0.002	0.003	0.005	0.01	0.019
(n) Manganese (Mn)	0.001	0.0014	0.0035	0.005	0.1	0.144

						Av. in potato
5	Sugars — total					
	(a) reducing	0.10	0.0	3.0		
	(b) sucrose	0.20	0.0	5.2*		
6	Fiber (cellulose)	0.60	0.26	1.40		
7	Pentozans	0.80	0.0	1.0	4.0	
8	Pectin, propectin and pectic substances	0.30				
9	Nitrogen					total
	(a) total		0.35	0.45	1.7	0.40
	(b) non-protein					0.17
10	Proteins (mostly tuberin, a globulin) (N x 6.25), *etc.*	0.88	0.06	3.5	10.0	
11	Amino acids 2/	1.22				
12	Solanine (glucoside, alkaloid)	0.05				
13	Enzymes	0.02				
14	Fat (ether extract)	0.10	0.0	0.15		
15	Acids (citric, tartaric, succinic)	0.01				
16	Vitamins, mg. per 100 g.					
	A — 40					
	B — 20 — 186					
	C — 5 — 35					
	G — 10 — 55					
17	Oil (potato odor)	tr.				
TOTAL (many different samples)		99.28				

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