CHEMICAL COMPOSITION OF POTATOES. III.

RELATIONSHIPS BETWEEN SPECIFIC GRAVITY AND THE NITROGENOUS CONSTITUENTS[1]

THOMAS J. FITZPATRICK, EUGENE A. TALLEY, WILLIAM L. PORTER,[2] AND HUGH J. MURPHY[3]

INTRODUCTION

In a previous study by Talley et al (3) on the 1959 crop of Maine Katahdin potatoes, the relationship between specific gravity and the nitrogenous constituents in a given lot of potatoes over a storage period of eight months was demonstrated. In carrying out this work, however, the specific gravity determinations were made on the potatoes as they were removed from storage each month. Whether tubers of different specific gravity reacted differently during these storage periods was not known. Also not known was the effect of the variation in the proportion of the sample making up a given specific gravity lot. To eliminate the possibility of an important variable and to corroborate previous results on potatoes grown in a different year, with the accompanying differences in growing conditions, the present study was carried out.

Immediately after harvest at the growing site (Aroostook Farms, Maine) all of the potatoes to be used for this particular composition study were separated into high, intermediate, and low specific gravity levels. This was carried out in solutions of glycerine and water of decreasing specific gravity levels. Glycerine was used because it was believed to be less injurious to the potatoes than salt solutions since the samples were to be placed in low temperature storage. After separation, the potatoes were washed free of glycerine and air dried. Samples of the tubers were then weighed into wooden boxes and stored at 38 F to be withdrawn periodically and sent to our laboratory in Philadelphia for analysis.

Concurrently, a study was carried out on New York Katahdin potatoes obtained from the El-Ge Potato Chip Company in York, Pennsylvania. These potatoes were initially stored at 60 F and the temperature was lowered gradually over a four-week period to 38 F. Samples were withdrawn at four intervals over the storage period and at this time brine-separated into high, intermediate, and low specific gravity levels, then analyzed as in the previous study (3).

MATERIALS AND METHODS

Katahdin potatoes (9 barrels) grown in 1960 at the University of Maine Agricultural Experiment Station, Presque Isle, Maine, were separated into specific gravity fractions on the site immediately after

---

[1]Accepted for publication November 13, 1963.
[2]Eastern Regional Research Laboratory, Eastern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, Philadelphia, Pennsylvania 19118.
[3]University of Maine Agricultural Experiment Station, Orono, Maine.

harvest. After washing, sufficient specific gravity measurements were made by the P.C.I.I. (Potato Chip Institute International) hydrometer method to arrive at an average specific gravity figure for the entire lot.

Using this average figure, 1.0800, as the median, glycerine-water mixtures, held at 60 F by a water jacket were used to separate the potatoes into five specific gravity levels each separated by increments of 0.0030. These specific gravity fractions were numbered 1 (with the highest specific gravity) through 5 (with the lowest). To amplify the differences, fractions 1, 3, and 5 were taken for analysis while fractions 2 and 4 were not used (see Table 1).

Potatoes to be analyzed were washed in running water to remove residual glycerine, then spread on tables covered with porous paper in a ventilated greenhouse to dry.

The tubers had been placed in rows of equal length graduated in size from the largest to the smallest. Ten samples of each of the three specific gravity fractions were stored for analysis. Each sample consisted of as many graduated rows of tubers as would be contained in the wooden boxes used for storage. The initial net weights (18 to 20 lb) were recorded. The first sample consisting of one box each of high, intermediate, and low solids tubers was sent immediately to our laboratory in Philadelphia to determine the initial composition. This was accomplished ten days after harvest. The remaining samples were stored at 38 F. Samples were then removed from storage and analyzed after 1, 4, 6.2, and 8.4 months.

Concurrently a similar study on New York Katahdin potatoes was carried out. A pallet box of Katahdins grown in New York State was made available by the El-Ge Potato Chip Company, York, Pennsylvania. These tubers were stored at York at 60 F and the storage temperature gradually decreased over a four-week period to 38 F. A 100-pound sample was withdrawn and sent to Philadelphia for analysis after 2, 3, 5, and 7 months of storage. At this time, after determination of the average specific gravity by the P.C.I.I. hydrometer method, the tubers were separated into five levels of specific gravity (fractions 1 through 5) in salt brines differing by increments of 0.0030 specific gravity units. As in the Maine potatoes (fractions 1, 3, and 5) the highest, intermediate, and lowest solids potatoes were selected, while fractions 2 and 4 were not used.

With the exception of the fact that the Maine Katahdins had been separated into high, intermediate, and low specific gravity levels immediately after harvest before subjecting the tubers to cold storage, the analyses on all the potatoes were carried out as previously reported (3). All analytical results are reported as averages of at least two determinations.

Results and Discussion

Table 1 shows, as in the previous study (3), a progressive loss of weight during storage. (Weight losses are based on orignial weight of each fraction). This table also brings out the fact that the overall weight loss during storage is greatest in potatoes having the lowest solids content. The stability of the percent solids content during the same period of storage verifies our previous observation that both solids and water

TABLE 1.—*Weight losses of Maine Katahdins in 38 F. storage.*

Fraction	Sp. gr. designation	Sp. gr. of glycerine[1]	Wt. of frac. lb.	% of total	September No storage		October 1 mo. storage		January 4 mo. storage		March 6.2 mo. storage		May 8.4 mo. storage	
					Sp. gr.[2]	% Wt. loss	Sp. gr.[2]	% Wt. loss	Sp. gr.[2]	% Wt. loss	Sp. gr.[2]	% Wt. loss	Sp. gr.[2]	% Wt. loss
1	High	>1.086	311.6	21.0	1.092	2.65	1.092	2.66	1.095	2.70	1.095	3.42	1.092	4.74
2	Not used	1.083-1.086	349.9	23.6										
3	Intermed.	1.080-1.083	289.9	19.5	1.085	1.85	1.084	3.09	1.086	3.30	1.086	5.58	1.081	5.83
4	Not used	1.077-1.080	301.7	20.3										
5	Low	<1.077	230.2	15.6	1.077	2.40	1.075	1.83	1.076	5.50	1.074	5.48	1.071	6.04

[1]These ranges are the limits of the specific gravities of the glycerine solutions employed.
[2]By the P.C.I.I. hydrometer method.

are lost in the ratio of the original composition and agrees with the findings of Treadway et al (4). It would generally follow, therefore, that tubers with a low solids content would lose a greater weight of solids than high solids potatoes stored under the same conditions.

Tables 2 through 7 show the relationships between solids content and nitrogen values obtained for the three specific gravity levels of both the Maine and the New York Katahdins. The data indicate that no important variables are introduced by separating tubers into specific gravity fractions after storage rather than immediately after harvest since changes in specific gravity during storage are negligible. The principle advantage of specific gravity classification of a large lot of potatoes before storage is the fact that the classification is based on the median specific gravity of the entire batch. This results in a greater homogeneity of the tubers within a given specific gravity level and a more constant distribution of potatoes throughout the various specific gravity levels. These tables also point out the inverse relationship between solids content and nitrogen values (total, soluble, and insoluble nitrogen) when calculated on a moisture free basis. Also within the limits of experimental error, it is apparent that the mg of nitrogen per g of fresh tissue is reasonably constant regardless of the solids content. These results further emphasize our previous findings (3) that this is the result of an increased content of some other dry matter constituent, presumably starch.

TABLE 2.—*The solids and nitrogen composition of the high specific gravity fraction (21.0%) of Maine Katahdins.*

Month	% Solids	% total N (MFB)	mg total N/g fresh wt	% N in extract (MFB)	mg extract. N/G fresh wt	% insol. N (MFB)	mg insol. N/g fresh wt	insol. N / total N (MFB)
Sept.	23.81	1.73	4.12	0.96	2.29	0.77	1.83	0.45
Oct.	23.17	1.76	4.08	0.98	2.26	0.78	1.82	0.44
Jan.	22.57	1.80	4.06	1.03	2.33	0.77	1.83	0.43
Mar.	22.74	1.81	4.11	1.02	2.32	0.79	1.79	0.44
May	22.75	1.84	4.19	1.08	2.45	0.76	1.74	0.41
Avg.		1.79	4.11	1.01	2.33	0.77	1.80	0.43

TABLE 3.—*The solids and nitrogen composition of the high specific gravity fraction of New York Katahdins.*

Month	% Solids	% of Sample	% total N (MFB)	mg total N/g fresh wt	% N in extract (MFB)	mg extract. N/G fresh wt	% insol. N (MFB)	mg insol. N/g fresh wt	insol. N / total N (MFB)
Nov.	21.50	18.90	2.01	4.32	1.17	2.50	0.84	1.82	0.42
Dec.	21.94	24.01	2.07	4.54	1.28	2.81	0.79	1.73	0.38
Feb.	21.36	19.36	2.08	4.44	1.30	2.79	0.78	1.65	0.38
Apr.	22.63	22.77	..	..	..	..	..	..	..
Avg.			2.05	4.43	1.25	2.70	0.80	1.73	0.39

Table 4.—*The solids and nitrogen composition of the intermediate specific gravity fraction (19.5%) of Maine Katahdins.*

Month	% Solids	% total N (MFB)	mg total N/g fresh wt	% N in extract (MFB)	mg extract. N/G fresh wt	% insol. N (MFB)	mg insol. N/g fresh wt	insol. N / total N (MFB)
Sept.	21.81	1.96	4.27	1.15	2.51	0.81	1.76	0.41
Oct.	20.92	2.04	4.26	1.21	2.53	0.83	1.73	0.41
Jan.	20.68	2.12	4.38	1.22	2.53	0.90	1.85	0.42
Mar.	20.77	2.28	4.73	1.25	2.59	1.03	2.14	0.45
May	20.92	2.09	4.37	1.27	2.66	0.82	1.71	0.39
Avg.		2.10	4.40	1.22	2.56	0.88	1.84	0.42

Table 5.—*The solids and nitrogen composition of the intermediate specific gravity fraction of New York Katahdins.*

Month	% Solids	% of Sample	% total N (MFB)	mg total N/g fresh wt	% N in extract (MFB)	mg extract. N/G fresh wt	% insol. N (MFB)	mg insol. N/g fresh wt	insol. N / total N (MFB)
Nov.	19.77	30.39	2.23	4.40	1.31	2.59	0.92	1.81	0.41
Dec.	20.16	23.11	2.04	4.12	1.23	2.48	0.81	1.64	0.40
Feb.	19.93	16.70	2.25	4.69	1.36	2.85	0.89	1.84	0.40
Apr.	20.45	21.25	2.14	4.37	1.32	2.70	0.82	1.67	0.38
Avg.			2.17	4.40	1.31	2.70	0.86	1.74	0.40

Table 6.—*The solids and nitrogen composition of the low specific gravity fraction (15.52%) of Maine Katahdins.*

Month	% Solids	% total N (MFB)	mg total N/g fresh wt	% N in extract (MFB)	mg extract. N/G fresh wt	% insol. N (MFB)	mg insol. N/g fresh wt	insol. N / total N (MFB)
Sept.	20.20	2.13	4.30	1.22	2.46	0.91	1.84	0.43
Oct.	18.74	2.28	4.28	1.32	2.47	0.96	1.81	0.42
Jan.	18.26	2.33	4.26	1.42	2.60	0.91	1.66	0.39
Mar.	18.02	2.81	5.05	1.40	2.53	1.41	2.52	0.50
May	18.18	2.45	4.45	1.41	2.56	1.04	1.89	0.42
Avg.		2.40	4.47	1.35	2.52	1.05	1.94	0.43

Also, irrespective of the solids content, there is the relationship of insoluble nitrogen to total nitrogen which remains fairly constant. This applied to the three specific gravity levels of the Maine Katahdins which in turn correlated well with those grown in New York. The values of 39 to 43% herein presented agree well with those reported by Chick and Slack (1).

TABLE 7.—*The solids and nitrogen composition of the low specific gravity fraction of New York Katahdins.*

Month	% Solids	% of Sample	% total N (MFB)	mg total N/g fresh wt	% N in extract (MFB)	mg extract. N/G fresh wt	% insol. N (MFB)	mg insol. N/g fresh wt	insol. N / total N (MFB)
Nov.	18.08	10.36	2.46	4.45	1.45	2.62	1.01	1.83	0.41
Dec.	18.07	13.29	2.32	4.19	1.34	2.42	0.98	1.77	0.42
Feb.	18.34	30.42	2.40	4.40	1.46	2.69	0.94	1.71	0.39
Apr.	18.22	23.88	2.45	4.46	1.45	2.65	1.00	1.81	0.41
Avg.			2.41	4.38	1.43	2.60	0.98	1.78	0.41

TABLE 8.—*Comparison of the growing conditions of the 1959 and 1960 Katahdin potato crops at Presque Isle, Maine.*[1]

	1959	1960
Planted	May 13	May 17
Vines killed	Sept. 4	Aug. 23
Harvested	Sept. 23	Sept. 9
Fertilization	120-180-180[2]	120-180-180
Rainfall, inches 5/1 to 9/15	14.12	13.20
Temperature (mean) °F		
May	54.6	57.4
June	59.1	57.4
July	69.8	64.0
Aug.	68.5	64.4
Sept.	60.9	56.2
Total heat units	2,967	2,970

[1]From field records of the University of Maine Agricultural Experiment Station, Orono, Maine.
[2]Pounds of N-P_2O_5-K_2O.

With the more refined data, however, obtained on the Maine Katahdins (Tables 2, 4, and 6), there is an indication of a possible trend toward an apparent gain in total nitrogen occurring during the loss of solids and moisture, with the greatest gain occurring in the tubers of greatest weight loss, namely, the low specific gravity fraction. Since these nitrogen increases are, at best, close to the limits of experimental error, the significance of these data could only be determined by more refined and accurate methods of sampling.

Although sampling errors due to variety can be eliminated by working with a single variety of potatoes, the effects of environment, however small, are present in tubers from adjacent plants and possibly between adjacent tubers from the same plant.

Table 8 indicates that environmental differences between potato samples grown in 1959 and 1960 were remarkably small. However, there were considerable differences in the composition of potatoes grown during these two seasons. Comparison of the analytical data reported herein on the 1960 crop with that previously published (3) on the 1959 crop shows a higher solids content in 1960. Also in 1960 there was an increase in mg of total nitrogen per g of fresh weight, but little change in percent extractable nitrogen on a moisture free basis. The insoluble nitrogen, however, was greater in the 1960 tubers, giving a higher ratio of insoluble to total nitrogen for that year. These results would imply that a portion of the higher solids for 1960 tubers could be imparted to a higher level of protein.

The major environmental difference between the 1959 and 1960 samples of Maine Katahdins was the length of the growing season (Table 8). The growing season for the 1960 tubers was 18 days shorter than for those grown in 1959 and consequently 16 days shorter between the dates of planting and vine killing than for the 1959 potatoes. From the results of Murphy and Goven (2) it would appear that the 1959 potato samples, having had the longer growing season should have the highest solids and not the reverse as observed in this study. However, these authors also bring out the fact that lower solids potatoes will result as the date of harvest is delayed beyond the peak of physiological maturity. Vine killing beyond the peak of maturity will also result in low solids potatoes. These two factors may explain the lower solids encountered in the 1959 Katahdins.

Summary

Katahdin potatoes from Maine (1960 crop) were separated into high, intermediate, and low specific gravity levels immediately after harvest, then stored in the cold. Samples were withdrawn periodically for analysis. Concurrently, New York grown Katahdins were placed in cold storage and samples, when withdrawn for analysis, were separated into three specific gravity levels. The pre-separated Maine potatoes permitted more refined analytical data to be compiled. There was a progressive loss of weight during storage which was greatest in potatoes with the lowest solids content. Specific gravity changed very little during storage. The shrinkage therefore is due to a loss of solids and moisture in the ratio of the original composition. With only minor differences in the 1959 and 1960 growing seasons in Maine, there were marked differences in the composition of potatoes grown during these two seasons.

Acknowledgments

The authors express appreciation for help from the following: the Special Plant Investigations group for carrying out the many tedious extractions; Mr. Leslie Ross for total and soluble nitrogen determinations; and also to the El-Ge Potato Chip Company, York, Pennsylvania for their generosity in providing us with the New York grown Katahdins used in this study.

Literature Cited

1. Chick, H., and E. B. Slack. 1949. Distribution and nutritive value of the nitrogenous substances in the potato. Biochem. J. 45: 211-221.
2. Murphy, H. J., and M. J. Goven. 1959. Factors affecting the specific gravity of the white potato in Maine. Maine Agr. Expt. Sta. Bull. 583: 1-24.
3. Talley, E. A., T. J. Fitzpatrick, W. L. Porter, and H. J. Murphy. 1961. Chemical composition of potatoes. I. Preliminary studies on the relationships between specific gravity and the nitrogenous constituents. J. Food Sci. 26: 351-355.
4. Treadway, R. H., M. D. Walsh, and M. F. Osborne. 1949. Effects of storage on starch and sugars contents of Maine potatoes. Am. Potato J. 26: 33-44.