POTATO QUALITY XXV. SPECIFIC GRAVITY AND AFTER-COOKING DARKENING OF KATAHDIN POTATOES AS INFLUENCED BY FERTILIZERS[1]

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INTRODUCTION

Mealiness and whiteness of potatoes are cooking qualities considered most desirable by householders, institution buyers, and processors (2, 7, 12, 21). Of these two physical characteristics, mealiness, which is directly correlated with specific gravity, was considered the most important and whiteness was second in importance. Sogginess was mentioned as a reason for dissatisfaction, together with darkening and hollow heart.

In general, yield and specific gravity of tubers of a given variety depend on the kind and amount of fertilizer and the influence of soil and environmental factors. Of the three major plant nutrients, nitrogen, phosphorus and potassium, nitrogen and potassium are considered more important in determining yield and specific gravity of potatoes. However, it was stated (9) that all three of the major elements in complete fertilizer can influence specific gravity.

Many investigators (3, 5, 11, 14, 18, 22, 23) have shown that the source and rate of potash affect specific gravity of potatoes. In brief, as rate of potash fertilization progressively increases, a corresponding reduction of specific gravity of tubers occurs, and at the same level of potash, potassium chloride (KCl) usually lowers tuber specific gravity more than potassium sulfate (K_2SO_4).

Relatively little is known about the effect of phosphorus on specific gravity of potatoes. It was found (16) that phosphorus rarely has a depressing effect on specific gravity. Some workers (8, 10, 18) have found little or no increase in specific gravity of tubers by application of various levels of phosphorus, while others (3, 5, 6, 13) have found appreciable increase. It was also reported (15) that there is a positive correlation between phosphorus uptake and yield of tuber dry matter on soils low in phosphorus and negative correlation on soils high in phosphorus.

The bluish-gray discoloration, which occurs in certain varieties of potatoes when they have been kept for some time in the air after being boiled is called "after-cooking darkening" (18) and its cause has been reviewed recently (28). Research (4, 25, 26, 27) has indicated that either KCl or K_2SO_4 was beneficial in the prevention of darkening. It was pointed out that the N/K ratio and not either element by itself affects the tendency of tubers to darken. It was also stated (24) that, although frequently a high level of potash noticeably increases the blackening, the response is not uniform even within an experiment.

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In regard to the effect of phosphorus on after-cooking discoloration, it was stated (27) that, in addition to blackening resulting from potash deficiency the condition may be brought about by a deficiency of phosphate and possibly of calcium. However, other workers (19, 20, 24) showed that fertilization with major and minor elements gave no predictable effect upon occurrence of blackening.

It was the objective of this study to determine the effect of level of phosphorus and source and level of potassium, at a constant level of nitrogen, on specific gravity and after-cooking darkening of Katahdin potatoes.

Materials and Methods

Plant growing

Whole, certified "B" size Katahdin seed was planted, with the aid of a two-row assisted feed planter, on May 28 and harvested on October 9, 1961, at Shapley Farm, Ithaca, New York. Soil type was a stony, silty loam; organic matter was 4.3%; soil reaction was 6.2; available phosphorus (P_2O_5) was 25 pounds per acre, and potassium (K_2O) was 50 pounds per acre.

The seed was spaced 8 inches in the row with 34 inches between the rows. The fertilizer belts were adjusted to deliver exactly the prescribed amount for each plot in 23 lineal feet. All fertilizer was applied in two bands, 2 inches below the seed and 2 inches on each side of the seed. The fertilizer nitrogen was applied as NH_4NO_3 (33.5% N) at the rate of 100 pounds per acre of N, phosphorus was applied as superphosphate (20% P_2O_5) at rates of 150 and 300 pounds P_2O_5 per acre and potassium was applied as KCl (60% K_2O) and K_2SO_4 (50% K_2O) both at rates of 100, 300, and 500 pounds K_2O per acre. The 2 x 3 x 2 factorial arrangement was replicated three times in a randomized complete block design.

At harvest, only the two center rows were dug from each 4-row plot with a single row digger. A sample of 70 U.S. No. 1 tubers was collected from each plot and stored at 40 F for three months.

Measurement of after-cooking darkening

The Agtron (1) Model F, reflectance meter was used to measure differences in the degree of grayness due to after-cooking darkening following the procedure worked out by Smith and Davis (17). Each stored sample was reduced to 60 healthy tubers and the specific gravity of individual tubers determined by the weight-in-air: weight-in-water method. Tubers were halved transversely and only the stem end portions used. Two sets at the time, of 12 treatments each, were steamed for 15 minutes at a pressure of 15 psi. Peeled halves were placed in 60 mm petri dishes, with the basal end on the center of the bottom of the container, and they were leveled at the top surface to obain a uniform filling of the dish. It was necessary to remove trapped air from the bottom of the dish to avoid transmittance of light rather than obtaining reflectance. To measure differences in darkening, a scale of 5019.5 = 0 (dark) to 5040 = 100 (white) was used. The samples were placed over the aperture at the top of the Agtron reflectance meter and numerical values were recorded (Table 1).

Specific gravity

Under the conditions of this experiment both source and level of potash exerted a detrimental effect on the specific gravity of Katahdin potatoes, which is in general agreement with the results reported by most workers. At the levels of potash used, KCl reduced specific gravity of tubers to a greater extent than did K_2SO_4 (Table 1).

Results and Discussion

Table 1.—*Effect of two sources and three levels of potash and two levels of phosphorus, at a contsant rate of nitrogen, on specific gravity and after-cooking darkening of Katahdin potatoes.*

Source of K_2O	Lb. of K_2O/A	Lb. of P_2O_5/A	Specific gravity Ave. of 60 readings	After-cooking darkening Average of 60 readings
KCl	100	150	1.077	47.3
	100	300	1.075	45.8
	300	150	1.073	41.6
	300	300	1.073	44.6
	500	150	1.071	38.5
	500	300	1.070	44.9
K_2SO_4	100	150	1.078	40.8
	100	300	1.076	47.4
	300	150	1.076	47.0
	300	300	1.076	46.0
	500	150	1.074	45.7
	500	300	1.074	43.0

Specific gravity: L.S.D. .05 = .00212 and .01 = .00288.
After-cooking darkening: L.S.D. Not significant.

There was a direct relationship between the decreasing specific gravity and the increasing rates of potash within KCl treatments. Differences between 100 pounds per acre and 300 and 500 pounds per acre were highly significant, and the difference between the latter two also was significant.

The detrimental effects of potash within K_2SO_4 treatments were less drastic than with KCl. However, there was a highly significant difference between treatments receiving 100 pounds per acre and those receiving 500 pounds per acre.

Phosphorus had no significant lowering effect on specific gravity of tubers. However, the higher rate (300 pounds per acre) produced tubers of .001 lower specific gravity than the low rate treatments (150 pounds per acre). The specific gravity decreasing effect of phosphorus was about the same between sources of potash as within KCl and K_2SO_4 treatments.

After-cooking darkening

After-cooking darkening of Katahdin potatoes was not significantly influenced by the source and level of potash and level of phosphorus. This also has been shown by early workers (19, 20, 24). Treatments with KCl produced slightly darker potatoes than those receiving K_2SO_4.

There was a trend towards increasing darkening with increasing

rates of KCl. However, there was no such trend within K_2SO_4 treatments. Both the lowest and the highest rates (100 and 500 pounds per acre, respectively) produced about the same color of tubers, while tubers from the middle rate treatments (300 pounds per acre) were slightly lighter in color than those from the lowest and the highest rates (Table 1).

The higher rate of phosphorus produced slightly whiter potatoes than the lower rate. The relative influence of phosphorus rate was about the same between the sources of potash as within KCl and K_2SO_4 treatments.

Correlation between specific gravity and after-cooking darkening

Early in 1939, Smith and Nash (19) stated that there was some relation between specific gravity, mealiness, and after-cooking darkening of potatoes. .Although the calculated correlation coefficient (.38) is not significant in this experiment, it shows a positive correlation between specific gravity and after-cooking darkening of Katahdin potatoes. This indicates that the quantitative expression of after-cooking darkening, in a given variety, is directly proportional to the concentration of the elements or compounds responsible for this undesirable quality factor.

Summary

The effect of two sources and three levels of potash and two levels of phosphorus, at a constant rate of application of nitrogen, on specific gravity and after-cooking darkening of Katahdin potatoes was studied.

Both KCl and K_2SO_4 decreased the specific gravity of tubers. At the same level of potash, KCl lowered specific gravity of tubers more than did K_2SO_4. Some rates of phosphorus may have a decreasing effect on specific gravity of tubers.

Source and level of potash may have some detrimental effect on after-cooking darkening of potatoes. Application of KCl appears to cause more discoloration than K_2SO_4 and its effect is directly related to the increasing rates of application. Increased rates of phosphorus may have some negative relation with tuber discoloration.

The specific gravity and after-cooking darkening of potatoes are positively correlated.

Literature Cited

1. Anonymous. 1960. Model F Agtron operating instructions. Magnuson Engineers Inc., San Jose, California p. 1-8.
2. Cravens, M. E. 1947. Housewives' reactions to Michigan potatoes. Mich. Agr. Exp. Sta. Quar. Bull. 30: 125-130.
3. Dunn, L. E. and R. E. Nylund. 1945. The influence of fertilizers on the specific gravity of potatoes grown in Minnesota. Am. Potato J. 22: 275-288.
4. Findlay, W. M. 1928. Quality in potatoes. Scottish J. Agr. 11: 339-344.
5. Fineman, Z. M. 1947. The influence of fertilizers on yield and specific gravity of potatoes grown in Alaska. Am. Potato J. 24: 82-89.
6. Gericke, S. 1940. The phosphate fertilization of potatoes. Pflanzenbau 16: 302-322.
7. Greig, W. S. and Ora Smith. 1951. Grading potatoes for mealiness and its effect on retail sales. Am. Potato J. 28: 499-520.
8. Haddock, J. L. and P. T. Blood. 1939. Variations in cooking quality of potatoes as influenced by varieties. Am. Potato J. 16: 126-133.

9. Houghland, G.V.C., H. W. Gausman, O. A. Lorenz and L. M. Ware. 1962. Report of the Nutrition (Fertilization) Committee — 1960. Am. Potato J. 39: 288-290.
10. Lorenz, O. A. 1944. Studies on potato nutrition: I. The effects of fertilizer treatment on the yield and composition of Kern County (Calif.) potatoes. Am. Potato J. 21: 179-192.
11. Lucas, R. E., E. J. Wheeler, and J. F. Davis. 1954. Effect of potassium carriers and phosphate-potash ratios on the yield and quality of potatoes grown in organic soils. Am. Potato J. 31: 349-352.
12. Merchant, C. H. and E. E. Gavett. 1957. Consumer acceptance of specific gravity separated potatoes. Maine Agr. Expt. Sta. Bull. 559.
13. Metzger, C. H. 1938. Commercial fertilizers in Colorado in 1937. Am. Potato J. 15: 252-261.
14. Rowberry, R. G., C. G. Sherrell and G. R. Johnston. 1963. Influence of rates of fertilizers and sources of potassium on yield, specific gravity and cooking quality of Katahdin potatoes. Am. Potato J. 40: 177-181.
15. Simpson, K., R. D. Verma and J. Dainty. 1959. Effect of rate of application of superphosphate on growth and yield of potatoes. J. Sci. Food Agr. 10: 588-596.
16. Smith, Ora. 1959. Effect of cultural and environmental conditions on potatoes for processing, Chap. 4, and Potato chips, Chap. 10, *In* Potato processing, Talburt, W. F. and Ora Smith, Avi Publishing Co., Westport, Connecticut.
17. Smith, Ora, and C. O. Davis. 1961. Potato quality XIV. Prevention of greying in dehydrated potato products. Potato Chipper 21: 84-99.
18. Smith, Ora and L. B. Nash. 1940. Potato quality I. Relation of fertilizers and rotation systems to specific gravity and cooking quality. Am. Potato J. 17: 163-169.
19. Smith, Ora and L. B. Nash. 1939. Relation of mineral nutrition to chemical composition and cooking quality of potatoes. Proc. Am. Soc. Hort. Sci. 36: 597-600.
20. Smith, Ora, L. B. Nash and A. L. Dittman. 1942. Potato quality VI. Relation of time of planting, time of harvest and fertilizer treatment to composition and cooking quality. Am. Potato J. 19: 229-254.
21. Stevenson, F. J. 1948. Potato preferences among household consumers. U.S.D.A. Misc. Pub. No. 667.
22. Terman, G. L. 1950. Effect of rate and source of potash on yield and starch content of potatoes. Maine Agr. Expt. Sta. Bull. 481.
23. Timm, H. and F. G. Merkle. 1963. The influence of chlorides on yield and specific gravity of potatoes. Am. Potato J. 40: 1-8.
24. Tottingham, W. E., R. Nagy ,A. F. Ross, J. W. Marek and C. O. Clagett. 1947. Blackening indices of potatoes grown under various conditions of field culture. J. Agr. Research 74: 145-164.
25. Tottingham, W. E., A. F. Ross and R. Nagy. 1937. Potash deficiency only partly explains blackening of potatoes. Farm Sc. Ann. Report (54th). Wis. Agr. Expt. Sta. Bull. 438: 94-95.
26. Wallace, T. 1921. The effects of muriate of potash and sulfate on the cooking and keeping qualities of potatoes. Univ. of Bristol Ann. Rep. Agr. Expt. Sta. p. 136-144.
27. Wallace, T. and R. L. Wain. 1943. The blackening of cooked potatoes. Agriculture (Engl.) 50: 425-428.
28. Wurster, R. T. and Ora Smith. 1963. Potato quality XVIII. The distribution of radioiron in the potato tuber and its significance in after cooking darkening. Am. Potato J. 40: 415-420.