CULTURAL PRACTICES WHICH INFLUENCE THE SPECIFIC GRAVITY OF RUSSET BURBANK POTATOES

by
Thomas R. Owings
Sunspiced, Inc.

The specific gravity of a substance indicates whether it is heavier or lighter than an equal volume of water. It is a measure of how much dry matter is present, but does not differentiate among starch, sugar, protein, cell walls, or other solid material. Specific gravity can be calculated by the following formula:

$$\text{Specific Gravity} = \frac{\text{Weight in Air}}{\text{Weight in air - Weight in Water}}$$

For example: If a sample of potatoes weighs 22 pounds in air and 1.75 pounds under water, the specific gravity would be $\frac{22 \text{ lbs.}}{22 \text{ lbs.} - 1.75 \text{ lbs.}} = 1.086.$

Importance of Specific Gravity

An increase of 0.005 in specific gravity will result in a gain of one pound of potato chips per 100 pounds of potatoes. Potatoes high in solids absorb less cooking oil. Energy savings for dehydrators is significant when processing high specific gravity potatoes because less water needs to be evaporated from the raw product.

For the potato chipper or fryer, the color of the fried product is very important. Dark-colored chips and fries are considered objectionable. The dark color is due primarily to large amounts of reducing sugar which combines with amino acids during cooking. Generally, tubers with high specific gravities also have low levels of reducing sugars in storage and produce fries with firmer texture.

High specific gravity is an indication of overall good quality. We can be fairly sure that high specific gravity potatoes haven't undergone water, temperature, or fertilizer stress during growth and development. High specific gravity caused by dehydration in the field or storage is undesirable. Dehydrated tubers do not process normally, accumulate sugars in storage, and are more susceptible to black spot.

Potatoes with high gravities store with fewer problems. They probably haven't been subjected to overwatering late in the season, which lowers gravities and makes tubers susceptible to water rot. These tubers are probably also more mature when harvested and are not as skinned up going into storage.

Probably most important to the grower -- many grower contracts now contain a specific gravity clause. This incentive program points out the need for every grower to individually reevaluate his own production program. Techniques which work well for one grower may not work at all for someone else. Differences in soil, length of growing season, fertilization, disease, irrigation method, and unknown factors contribute to variations in specific gravities.

Fertilization

Nitrogen stimulates both root and vine growth, which in turn increases the water need and, also, the ability of the plant to obtain water and nutrients from the soil. Excess nitrogen extends the life of the plant and delays tuber maturity. Tubers from plants which receive excess nitrogen are more immature, lower in specific gravity, and develop higher sugars in storage (Iritani 7). Nitrogen is most notably found in protein, enzymes, and nucleic acids where it is associated with photosynthesis, respiration, cell division, and most life processes.

The timing of fertilizer application is very important. Kunkel, Holstad and McNeal (14), Soltanpour (19), and Gardner and Jones (4), found that even though petiole nitrate levels declined as the plant approached maturity, yields were unaffected, if sufficient nitrate was maintained in the petioles through mid-season. If adequate nitrogen isn't present in the vines at mid-season, it probably won't get to the tubers. When Kunkel, et al (14) applied 500 pounds of nitrogen to potatoes planted April 1, they found the maximum nitrogen content of the vines and tubers to be 355 pounds on August 15. The tubers removed 219 pounds of nitrogen at harvest on October 15. The yield was 732 hundredweight. This data indicates that large yields can be obtained with less then 350 units of nitrogen. Petiole sampling should be done early to allow time for correcting any deficiencies.

Excessively high levels of potassium also have a tendency to reduce specific gravity (Kunkel 10, 12). Potassium is involved in the maintenance of osmotic pressure in the plant cells. This osmotic pressure is involved with the opening and closing of the stomata and, also, enables the plant roots to extract water from the soil and resist desication (Kunkel 13). Too much K in the plant could cause excessive water uptake by the roots with subsequent lowering of specific gravity when the water is stored in the tubers (Dubetz 3). Since K is so important in the water relations of a plant, a deficit will give many of the same symptoms as a water deficiency. We would see wilting, dark green foliage, tissue necrosis, and highly blackspot susceptible tubers.

A potassium deficiency could be particularly harmful in a high temperature, low humidity area such as the Columbia Basin. The concentration of K in the tubers expressed as a percentage of the dry matter is relatively constant, regardless of the amount applied in the fertilizer. Approximately 0.44 pounds of K is removed from the soil for each hundredweight of yield. A 600 cwt. yield would remove 260 pounds of K (313lb$K_2$0). A study of the amount of K in the vines and roots could show that additional K would be needed during the growing season.

The amount of phosphate in the soil had no harmful effect on specific gravity and should be maintained at a high level, since it is not leached to any appreciable extent from season to season, (Kunkel 12) and Dubetz 3). Phosphate is involved in root cell division, root growth, and energy metabolism. When phosphate is limiting, its addition will increase yield and specific gravity. A 600 cwt./acre yield would remove 42 pounds P (96 lbs. P_2O_5). Additional phosphate would be required in the stems, leaves, and roots during the growing season. Figure 1 (Bob Kunkel data) shows that as fertilizer rates increase, specific gravity decreases. Presumably, if the growing season were long enough, the highest fertilizer rates would eventually produce potatoes with high specific gravities.

Irrigation

Water management is probably one of the most influential variables affecting the tuber solids and sugar accumulation during growth, development and storage. Kunkel and Holstad (9), report that large quantities of fertilizer can produce maximum yields, without seriously affecting grade or specific gravity. The proper amounts of irrigation water need to be applied for the fertilizer rates used. Extra water must be added to compensate for the increased transpiration rate resulting from more vigorous plant growth. They found that the reduction in specific gravity with excess nitrogen was less with high moisture than with low moisture - even though yield was not affected. When the water deficit in the plant reaches a critical level, the stomata in the leaves close, carbon dioxide is excluded, photosynthesis ceases, and low dry matter potatoes are the result (Kunkel, et al 11). Water deficits cause wilting, death of lower leaves and reduction of dry matter production. Any increase in specific gravity would be due to unwanted tuber dehydration. The production of high yields in the Columbia Basin, using increased fertilization, requires very careful irrigation management.

Any cultural practice which causes tuber growth to stop, and then start again, gives quality and specific gravity problems. Allowing the plant to run completely out of nitrogen

before adding any will produce stressed potatoes. It may not affect yield, but will lower grade and specific gravities.

An experiment performed by Bob Kunkel illustrating the effects of moisture stress on high fertilizer plots is shown in Table 1. Plots were irrigated every second, fourth, or sixth day. Each plot also had fertilizer rates containing 200 pounds or 400 pounds each of N, P_2O_5 and K_2O. 400 pound rates reduced specific gravities from 1.080 to 1.078 when irrigated every second day. Specific gravity was further reduced for the 400 pound fertilizer rates when water was applied every fourth or sixth day. Quality in the form of U.S. No. 1 potatoes also was less with high fertility and diminished water. Quality and specific gravity was not affected as much by water supply when only 200 pounds per acre each of N, P_2O_5, and K_2O were applied. This study indicates the need for careful water management when high fertilizer rates are applied.

Iritani and Weller (5) indicate that moisture stress early in tuber development is implicated in jelly or translucent stem ends. Providing adequate moisture early in the season, especially if high fertilizer rates are banded at planting time, is extremely important to avoid malformed shaped tubers and accumulation of sugars in storage. Bryan (1) and Motes and Greig (15) have shown that quality and yield are optimized when the available soil moisture is maintained above 65%. Plants require much less water late in the season and water should be cut back to avoid potatoes with large lenticels, water rot, and low specific gravities.

Thornton (20) points out that adequate moisture at planting is also important. Seed pieces planted in dry soil often emerge sooner because of warmer soil temperature, but these plants will have undeveloped root systems. Dry soil also causes seed pieces to scab over instead of heal. If rhizoctonia is a major problem, however, it is best not to plant when the soil is cold. The ideal condition for the seed piece would be a warm moist environment.

Motes and Greig (14) found a relationship between high soil temperature and low specific gravity. Shading by vigorous, well fertilized plants could help to keep the soil cooler. The cooler soil temperature would slow down nighttime respiration and allow more carhohydrates to accumulate. An abundance of vegetation is needed to manufacture sugars for translocation to the tubers for conversion to starch.

The effects of under-fertilization are often as harmful as the effects of over-fertilization. Iritani and Weller (7) found that low fertility levels (120 lbs. of N/acre) resulted in significantly higher sugar accumulation in the stem portion of Russet Burbank, as compared to adequate fertility (320 lbs. of N/acre). Iritani and Weller found that vines from plants receiving 100 pounds/acre of nitrogen died prematurely. In such instances, if the tubers are allowed to lie in warm soil for long periods before harvest, they physiologically age and the tendency is for greater sugar accumulation in storage. Tubers lying in moist soil will also decrease in specific gravity by absorbing water (Kunkel 10).

Planting and Harvest Dates

Specific gravities are not significantly affected by planting dates, as shown in Figure 2. Yields do not start to decrease until the latest planting dates. The percent of U.S. No. 1 potatoes is increased by later plantings. When cultural conditions are optimum, the yield and specific gravity is increased by longer growing seasons (Bryan 1).

Iritani and Weller (5) have shown that as tubers grow, develop, and mature, a peak in dry matter is reached shortly after which sugar content declines to a minimum amount. This would be an optimum time to harvest. The setting of the skin or periderm is the external aspect of maturity. Immature, skinned tubers do not store well; they dehydrate easily, tend to sprout sooner, and accumulate more reducing sugars in storage. Dry matter content is inversely correlated with sugar accumulation. Kunkel (10) has shown that the dry matter/acre is at a maximum around the middle of September (Figure 3). The same results were obtained by averaging the weekly solids of 23 Sunspiced, Inc.'s contract growers (Figure 4). Any

further increase in yield is in the form of absorbed water, which decreases specific gravity. Total dry matter per acre was about the same on September 15, as on October 15.

Harvest and storage late in the fall are not recommended. Exposure to 40° F. and 45° F. temperatures can cause field accumulation of sugars and, also, make tubers more black spot susceptible. Tubers which are harvested cold often do not get properly suberized because they are generally never warmed to suberizing temperatures. The longer a tuber is held at 48° F. to 50° F. before being lowered to the holding temperature, the lower is the accumulation of sugar.

The consistant production of high specific gravities is difficult, but not impossible. It is possible to sacrifice other desirable characteristics if too much emphasis is put on specific gravities. Cutting back on N too early can contribute to early dying and low yields. Cutting back too much on K can make tubers very black spot susceptible. Too much water after vine kill produces low specific gravities and may cause enlarged lenticels.

High yields are not incompatible with high specific gravities. Many of the same cultural practices are good for both. The push for higher and higher yields, with a limited growing season, does have a tendency to lower specific gravities.

LITERATURE SOURCES

1. Bryan, J. E. 1962. Specific gravity in potatoes. University of Idaho, Agricultural Extension Service.

2. Dubetz, S. 1975. Effect of two depths of seedbed preparation and fertilizer on Netted Gem potatoes. American Potato Journal, Volume 52, September, P. 263.

3. Dubetz, S. & Bole, J. B. 1975. Effect of nitrogen, phosphorus, and potassium fertilizers on yield components and specific gravity of potatoes. American Potato Journal, Vol. 52, December, P. 399.

4. Gardner, B. R. and J. P. Jones, 1975. Petiole analysis and the nitrogen fertilization of Russet Burbank potatoes. American Potato Journal, Vol. 52, July, P. 195.

5. Iritani, W. M. and L. D. Weller, 1972. Influence of growing conditions on storage and processability of Russet Burbank potatoes. 11th Annual Proceedings of the Washington State Potato Conference and Trade Fair.

6. Iritani, W. M. and L. D. Weller, 1974. Growing conditions and other factors influencing sugar accumulation in storage. 13th Annual Proceedings of the Washington State Potato Conference and Trade Fair.

7. Iritani, W. M. and L. D. Weller, 1976. Relationship of specific gravities to sugar accumulation in stored Norgold and Russet Burbank potatoes. American Potato Journal, Volume 53, February, P. 57.

8. Iritani, W. M. and L. D. Weller, 1977. Changes in sucrose and reducing sugar contents of Kennebec and Russet Burbank tubers during growth and post harvest holding temperatures. American Potato Journal, Vol. 54, September, P. 395.

9. Kunkel, R. and N. Holstad, 1974. Effect of fertility and irrigation on potato quality. 13th Annual Proceedings of the Washington State Potato Conference and Trade Fair.

10. Kunkel, R. and N. Holstad, 1972. Potato chip color, specific gravity and fertilization of potatoes with N-P-K. 1974 American Potato Journal, Vol. 49, February, P. 43-62.

11. Kunkel, R., M. Campbell and R. Thornton, 1972. Potato Fertilizer and Moisture Management - What's Needed? 11th Annual Proceedings of the Washington State Potato Conference and Trade Fair.

12. Kunkel, R., W. H. Gardner, N. M. Holstad, and T. S. Russel. Blackspot and Potato Fertilization in Washington's Columbia Basin - Bulletin 862 - Washington State University, 1978.

13. Kunkel, R., N. M. Holstad and W. H. Gardner. Sources of potassium, 1977. 16th Annual Proceedings of the Washington State Potato Conference and Trade Fair.

14. Kunkel, R., N. M. Holstad and B. L. McNeal, 1977. Comparison of some nitrogen sources for potatoes. 16th Annual Washington State Potato Conference and Trade Fair - P. 31.

15. Motes, J. E., and J. K. Greig, 1970. Specific gravity, potato chip color and tuber mineral content as affected by soil moisture and harvest dates. American Potato Journal, November, Vol. 47, P. 413.

16. Nelson, D. C., and R. E. Nylund, 1969. Effect of planting dates, location in the hill and tuber size on sugar content of Kennebec potatoes. American Potato Journal, Vol. 53, January 1976, P. 15.

18. Painter, C. G., and J. Augustin, 1976. The effect of soil moisture and nitrogen on yield and quality of the Russet Burbank potato, Vol. 53, August, P. 275.

19. Soltanpour, P. N. Accumulation of dry matter and NPK by Russet Burbank, Oromonte, and Red McClure potatoes, 1969. American Potato Journal, Vol. 46, April, P. 111.

20. Thornton, R., 1978. WSU Extension Agent - Fieldmen's Seminar on potato production held at Moses Lake.

Table 1. Effects of 24 hours of irrigation and N, P_2O_5, and K_2O on grade and specific gravity.

Irrigation of Alternate Furrows	Fertilizer in lb/acre	Percent U.S. No. 1's	Specific Gravity
every 2 days	200	67	1.080
	400	74	1.078
every 4 days	200	69	1.080
	400	69	1.076
every 6 days	200	70	1.080
	400	58	1.073

Figure 1. Planted May 15 and Fertilized with N, P_2O_5, and K_2O in lb/acre.

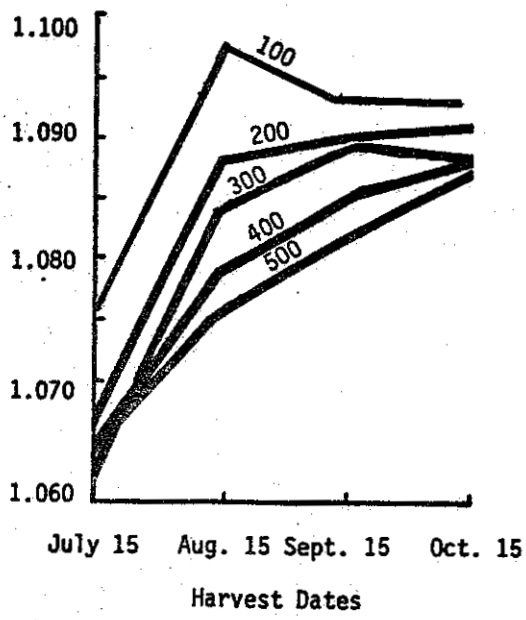

Figure 2. The Effect of Planting Dates on Specific Gravity.

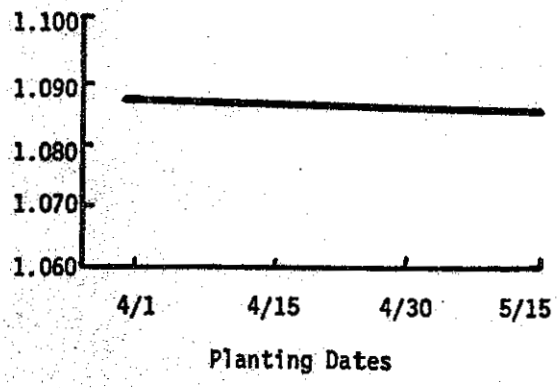

Figure 3. The Effect of Harvest Dates on Specific Gravity.

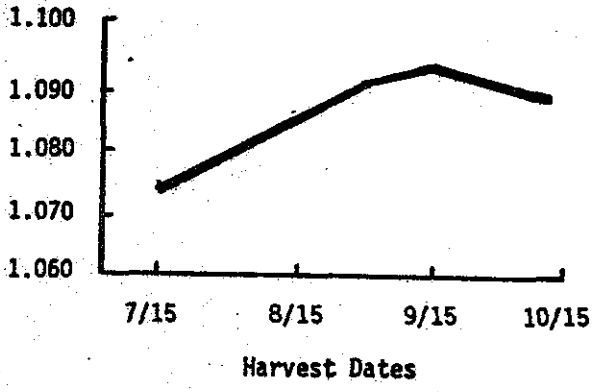

Figure 4. Average Weekly Specific Gravities for 23 Growers.