SOME FACTORS INFLUENCING THE CULINARY QUALITY OF IRISH POTATOES
II. PHYSICAL CHARACTERS[1]

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Surveys (9, 13, 15, 16, 20) have shown that housewives and food processors prefer a mealy, white-fleshed Irish potato for baking and chip manufacture. Tubers which are less mealy are suitable for boiling and salad purposes. However, mealiness in the Irish potato is preferred by most authorities in the United States.

The present study was designed to correlate possible variations in mealiness with the physical characteristics of Irish potatoes. Knowledge of the factors related to mealiness could prove helpful in the breeding, selection, and culture of varieties possessing higher mealiness.

Much of the research on potato-tuber quality has been directed toward determining the factors related to mealiness, which are generally grouped into those of a physical and those of a chemical nature. Many recent studies have been concerned with the relationship between chemical composition and culinary quality of potato tubers (3, 4, 5, 7, 23, 24, 26).

Earlier literature reported considerable variance of opinion as to the physical changes which occurred within a potato tuber during cooking. Atwater (1) and East (12) believed that potato mealiness was due to the starch swelling with cooking, followed by subsequent bursting of the cells. These statements were based on the discovery of broken cells after the potatoes had been mashed. Other workers (8, 10, 11, 17, 25) disagreed and reported that disintegration of the cells was due to the mechanical operation of mashing rather than to the cooking process itself.

Similar results were also found in other research (8, 10, 11, 17, 25). Examination of cooked potatoes, which were mealy in texture, showed no bursting of the cells. Rather, the cells separated from each other, leading to the conclusion that mealiness was due to cellular separation, not cellular disintegration.

Research by Bettelheim and Sterling (4, 5) indicated that cell separation as such was not responsible for mealy texture of potatoes. Starch content of the tubers was believed to be the principal factor determining potato texture by causing a distension of the cell walls during gelatinization, inducing the cells to round off from each other. Barmore (2) reported that starch content was a major factor contributing to mealiness, but found differences in texture ratings by taste panels even between tubers with the same starch content. Starch content was also correlated with mealiness and texture of tubers by Shewfelt (24).

Conflicting data have been presented on the relationship of starch grain size and mealiness. Starch grain size was not correlated with mealiness in some research (25, 26). Briant (7) found a negative correlation between tuber-mealiness and the percentage of starch grains below .02 mm in diameter, indicating that the more of these smaller starch grains in

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a tuber, the less mealy it was likely to be. There was no apparent correlation between potato-mealiness and the percentage of starch grains above .03 mm in diameter.

According to Sharma and Thompson (23) the proportion of various sizes of starch grains in potato tubers was related to specific gravity. Tubers having higher percentage of large starch grains (above 75 microns in diameter) were highest in specific gravity. Tubers containing higher percentage of very small starch grains (below 25 microns in diameter) were of lowest specific gravity. These workers concluded that the percentage of small and large starch grains developed under a common environment might be a varietal characteristic.

The literature contains few reports concerning the effect of cell size on potato quality. Lehmann (18) stated that there was a positive correlation between tuber size and the size of the cells in the tuber. Tubers of several potato varieties, grown under similar conditions, showed cell size differences. Tubers of the same variety, grown in different environments, also varied in cell size.

Bredeman and Schulze (6) found that the size of potato tuber cells was characteristic for each variety, although tuber cell size was affected by environmental conditions. There was no correlation between cell size and size of starch grains in tubers nor between size of cells and time of tuber maturity. Varieties differed in the percentages of cells and starch grains of different sizes found in the tubers. Tubers of several varieties, having approximately the same mean diameter, could be distinguished by the percentage of the various sizes of cells they contained. These results were considered important for potato starch manufacture, since the larger cells yielded more starch.

Materials and Methods

Tubers of 4 Irish potato varieties, Red LaSoda, Sebago, White Rose and Russet Burbank were obtained from the same northern location (Starks Farms, Rhinelander, Wisconsin). A preliminary study was also made with tubers of these 4 varieties which were grown in the same plot at Baton Rouge, Louisiana.

Samples of each variety, consisting of 5 tubers of equal size, weight (200 grams) and predetermined specific gravity, were used for cell and starch grain size measurements. Each tuber was cut in half, one-half was baked and tasted by a taste panel, while the other half was not cooked. Sections were taken from the periderm and cortex of the halves of individual tubers, both cooked and raw. The material was fixed in formalin-propionic acid-alcohol, and dehydrated in tertiary-butyl alcohol. Sections were stained with fast green and iron hematoxylin. A calibrated ocular system was used to measure cell and starch grain sizes. All measurements were made in the parenchymatous tissue of the cortex, 2500 microns beneath the periderm of the tubers. Cell size was expressed as cross-sectional area in square microns.

Starch grains were classified into 2 size groups: (A) Above 50 microns in diameter; (B) Below 50 microns in diameter.

Organoleptic evaluations were made by an 8 member panel. Panel members were asked to rank the tuber samples in an ordinal arrangement of 0 to 4 (mealiest sample = 4; waxiest sample = 0). The criteria used to determine mealiness and waxiness were as described by Sweetman (25). Tubers were baked and served warm without the addition of seasoning.

Total starch determinations were based on the method of Nielson (2), with some modifications (22). The fresh sample was ground in a Waring Blendor, starch extracted with 4.0 to 4.8 molar perchloric acid, and the starch estimated by photoelectric colorimeter readings of the blue color produced with iodine. The percentage of starch was calculated from a standard curve prepared from the colorimeter readings of a known range of starch concentration, based on raw starch extracted from potato tubers.

Amylose and amylopectin percentages were estimated colorimetrically according to the method of Halick and Keneaster (14). This procedure was modified for potatoes and based on the color reaction of amylose with iodine, which has been reported to indicate the amylose content of various starches (19).

Results

A comparison of the cell size in raw and cooked tubers from the 1959 Wisconsin crop showed varietal influences. Red LaSoda tubers were composed of the smallest cells while those of the Russet Burbank variety had the largest cells. Cells of raw tubers of the Russet Burbank variety averaged 89% larger in cross-sectional area than those of Red LaSoda, 53% larger than White Rose, and 32% larger than Sebago tubers (Fig. 1). Baked Russet Burbank tuber cells were 62% larger than uncooked cells from the same tubers. Cells of cooked Sebago tubers were 56% larger than those from the same raw tubers of that variety. Baked Red LaSoda tuber cells were 50% larger and White Rose potato cells were 48% larger when cooked than raw.

Cell size was associated with specific gravity of tubers grown at Wisconsin during 1959 (Table 1). A significant relationship (r = .510) existed between cell size of tubers and their specific gravity.

Total starch content and cell size of tubers were highly correlated (r = .998). Varieties with tubers containing higher amounts of starch were also composed of larger cells (Table 1). Russet Burbank tubers ranked highest in percentage of total starch and had the largest cells. Red LaSoda potatoes were of the lowest total starch content and smallest cell size, while White Rose and Sebago tubers ranked intermediate in both respects.

Mealiness ratings of tubers were also associated with their cell size. There was a significant relationship (r = .939) between cell size and mealiness ratings of cooked tubers. Russet Burbank potatoes were highest in mealiness and contained the largest cells (Table 1). Red LaSoda tubers were of lowest mealiness and composed of the smallest cells.

No correlation was found between cell size and amylose content of tubers.

Inherent varietal differences in tuber starch grain size existed (Figs. 2, 3, 4, 5). Some interrelationships were also observed. Russet Burbank potatoes contained the highest percentage of starch grains above 50 microns in diameter, and Red LaSoda the lowest amount (Table 1).

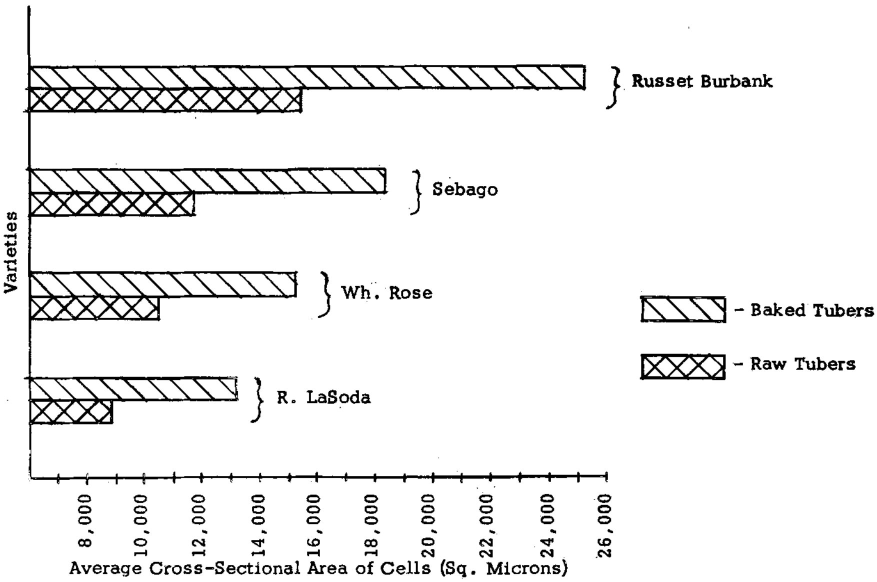

Figure 1. A comparison of cell size in tubers of different varieties and the effect of cooking on cell size.

TABLE 1.—*Effect of variety on quality of northern grown Irish potato tubers.*

Variety	Specific gravity	Mealiness rating[1]	Av. cross-sectional area of cells (Sq. microns)[2]		% Starch[3] grains above 50 Mic. Dia.	Amylose %	Total starch %
			Raw tubers	Baked tubers			
Red LaSoda	1.072	1.14	8,787	13,217	1.5	8.1	10.8
White Rose	1.065	1.31	10,218	15,148	2.3	8.0	12.1
Sebago	1.073	1.61	11,771	18,325	5.6	8.2	14.2
Russet Burbank	1.080	2.68	15,594	25,268	19.4	13.1	18 9

[1]Mealiness Scale: 0 = Waxy
1 = Sl. waxy
2 = Sl. mealy
3 = Mealy
4 = V. mealy

[2]Av. of 10,000 measurements

[3]Av. of 2,000 measurements

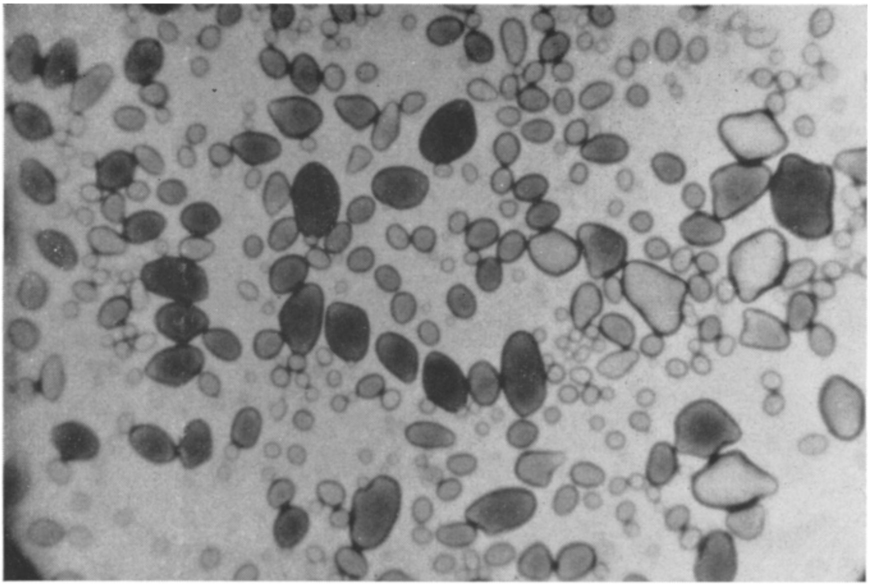

FIG. 2.—Photomicrograph illustrating starch grain size of raw Red LaSoda tubers (X 100).

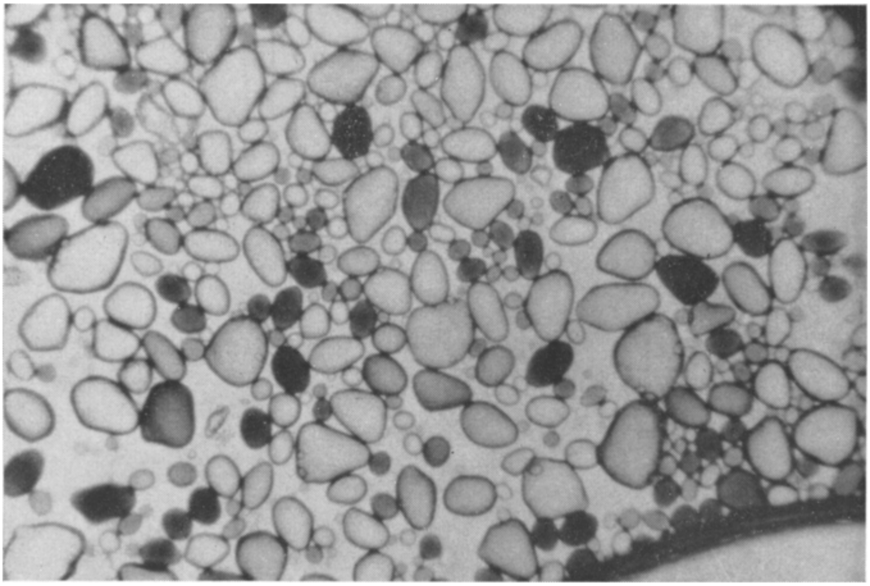

FIG. 3.—Photomicrograph illustrating starch grain size of raw White Rose tubers (X 100).

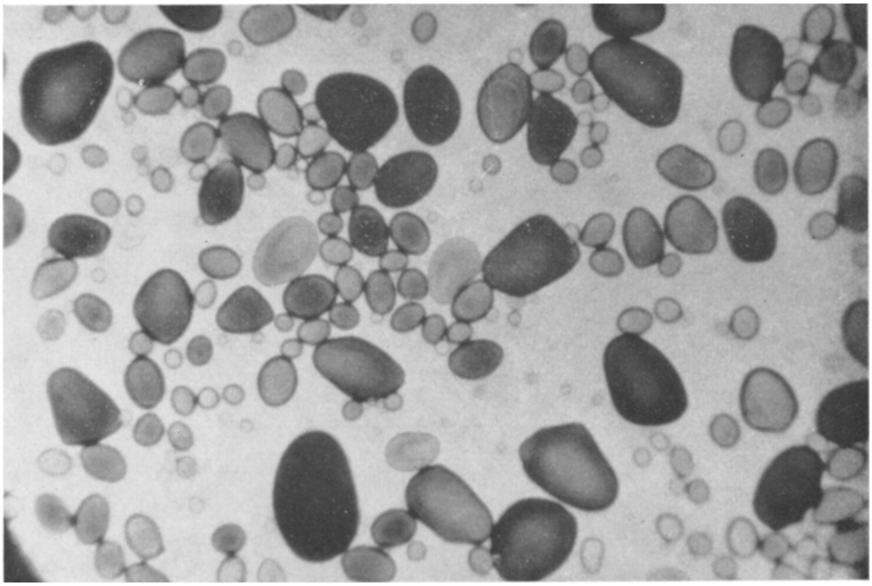

FIG. 4.—Photomicrograph illustrating starch grain size of raw Sebago tubers (X 100).

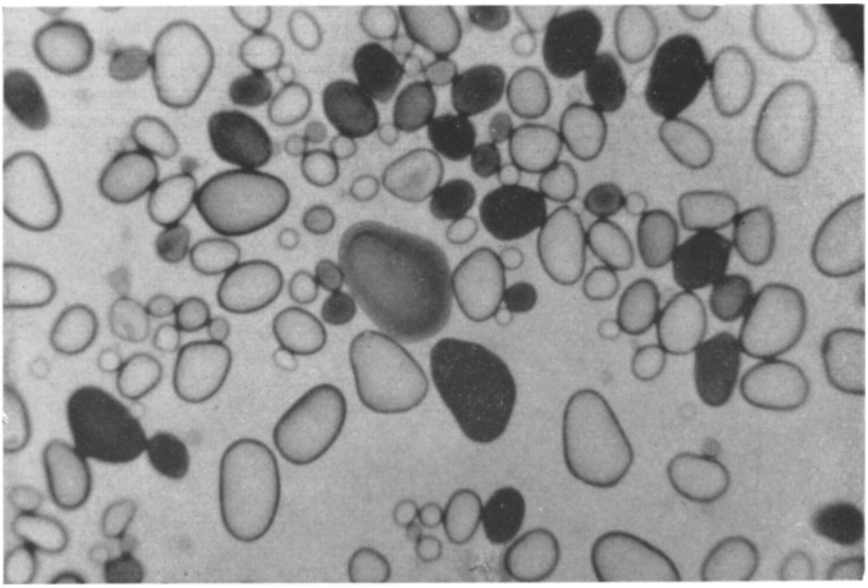

FIG. 5.—Photomicrograph illustrating starch grain size of raw Russet Burbank tubers (X 100).

There was a significant correlation (r = .978) between per cent total starch and per cent of starch grains above 50 microns in diameter. No significant association was found between the percentage of starch grains below 50 microns in diameter and specific gravity, mealiness, cell size, starch and amylose content of the tubers. However, the per cent starch grains above 50 microns in diameter was correlated with some of these tuber factors (Table 1). The per cent amylose was related to the percentage of starch grains above 50 microns in diameter (r = .983). Cell size of the tubers was also associated (r = .972) with the percentage of starch grains above 50 microns in diameter.

No relationship was found between the specific gravity or mealiness ratings of the tubers and the percentage of starch grains above 50 microns in diameter.

Discussion

The cell size-specific gravity relationship of tubers reported earlier in this paper was of interest. Literature reviewed contained no reference to this association. Specific gravity and dry matter content of Irish potato tubers are closely related (16, 20), and starch content has been associated with specific gravity (2, 3, 25).

Research reported herein showed that a significant relationship existed between specific gravity and cell size of the tubers, high specific gravity being correlated with large cell size. Since a similar association was found between starch content and cell size in this study, it would seem that both relationships influenced specific gravity. In other work (3) a correlation was found between total starch, amylose content, and mealiness ratings of tubers, and also between specific gravity and tuber mealiness.

Starch content of tubers was associated with their cell size, since a highly significant relationship existed between these two factors. Russet Burbank potatoes had the largest cells and highest amount of total starch, while the reverse was true of Red LaSoda. White Rose tubers had slightly larger cells than Red LaSoda and a higher percentage of total starch, while Sebago tubers were exceeded only by Russet Burbank in both respects. A varietal association has been reported (6, 18) between the cell size and starch content of tubers grown under a common environment.

Preliminary examination of southern-grown tubers of similar size from these four varieties indicated that they followed a pattern simlar to northern-grown potatoes. The lower starch content of Lousiana-grown tubers was associated with smaller cells than potatoes produced in Wisconsin.

These correlations seem logical, since starch is the principal component of dry matter in potatoes. Larger cells were found in tubers containing higher percentages of starch. The significant association between cell size and specific gravity also indicates that larger cells are present in tubers which contain more dry matter. Such results were based on work with tubers of equal size and weight, as there is some belief (18) that larger tubers are composed of larger cells than smaller potatoes of the same variety.

Tuber cell size was significantly associated with mealiness ratings as assessed by a taste panel. Since total starch percentage and cell size of potatoes were highly correlated, while starch content and mealiness scores of tubers were also significantly related, it would seem reasonable that cell size could also influence potato texture. It is possible that the tubers with larger cells, containing more total starch and amylose but less amylopectin than those of smaller cell size, were ranked higher in mealiness by the panel due to the more granular texture of the larger cells. This possibility seems even more definite if tuber cell size and mealiness are studied more closely. The cell size of tubers from each variety exactly parallels their mealiness ratings. Russet Burbank ranked first in both respects, Sebago second, White Rose third, and Red LaSoda fourth. This relationship also existed in similar size tubers of these potato varieties grown in Louisiana.

The percentage of starch grains above 50 microns in diameter was correlated with cell size, total starch and amylose content of potato tubers.

Starch grain size may also have influenced taste panel ratings, even though no direct association existed between starch grain size and mealiness scores of the tubers. Larger starch grains may confer higher amounts of starch and amylose in a tuber. Larger cells were also associated with larger starch grains. The lack of significance between the percentage of smaller starch grains (below 50 microns in diameter) and other tuber constituents seems to indicate such a relationship, despite the fact that smaller starch grains were more numerous in tuber cells than the larger grains.

Inherent varietal and environmental differences in starch grain size of tubers seemed to exist. Varietal and environmental influences on tuber starch grain size have been reported (6, 24). The present study shows that Russet Burbank tubers, higher in amylose and starch content, invariably contained the largest percentage of starch grains above 50 microns in diameter. The reverse was found in potatoes of the Red LaSoda variety. Preliminary examination of tubers of the 4 varieties studied, that were the same size, indicates the starch grain size of those grown in Louisiana to be smaller than in those produced in Wisconsin.

Summary

Quality comparisons were made with equal size tubers of the Irish potato varieties Red LaSoda, White Rose, Sebago, and Russet Burbank.

Varietal differences in tuber cell size were found. Russet Burbank tubers contained the largest cells, and Red LaSoda the smallest. White Rose tuber cells were slightly larger than those of Red LaSoda while Sebago tuber cell size was exceeded only by that of Russet Burbank.

There was a significant relationship between specific gravity and cell size of the potato tubers.

Tuber cell size and starch content were highly correlated, indicating that starch content was associated with cell size of tubers. Russet Burbank tubers contained the largest percentage of total starch, while Red LaSoda tubers were of lowest total starch content.

Mealiness scores of tubers were significantly associated with their cell size. Tubers of varieties containing the largest cells were rated highest in mealiness by the taste panel.

The percentage of starch grains above 50 microns in diameter was correlated with cell size, total starch and amylose content of the tubers.

Inherent varietal differences and environment also influenced starch grain size of the tubers. Russet Burbank potatoes contained the largest, and Red LaSoda the smallest starch grains.

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