STUDIES ON STARCH GRAIN SIZES AND SPECIFIC GRAVITY IN POTATO VARIETIES

By

KAILASH NARAIN SHARMA

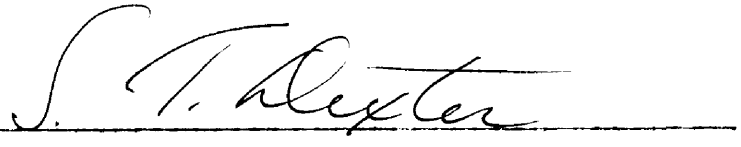
AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Farm Crops

Year 1956

Approved 

KAILASH NARAIN SHARMA

ABSTRACT

In 1955 seventeen varieties of potatoes were grown in four replicated plots at five locations in Michigan. Five tubers of about the same size (U.S. Grade No. 1) were taken from each plot at harvest. These constituted the samples used for the studies on specific gravity, percentage of four sizes of starch grains and chip color rating. By microscopic analyses the starch grains in each tubers were classified as large - above 75 microns, medium - between 75 to 50 microns, small - between 50 to 25 microns, and very small - less than 25 microns.

Approximately 1,700 tubers were analyzed in these investigations.

Although there was a considerable variability between the five tubers in each sample, at the five locations, each variety in general:

1. Assumed a characteristic rank - high, medium, or low in specific gravity;

2. Had a specific pattern of starch grain size;

3. Had a characteristic rank in potato chip color.

KAILASH NARAIN SHARMA ABSTRACT

Even in varieties, tubers:

1. With high specific gravity tended to make lighter colored chips than tubers low in specific gravity;

2. With a high percentage of starch grains larger than 25 microns, were high in specific gravity and made lighter colored chips.

3. With high percentage of very small starch grains, less than 25 microns, were low in specific gravity and made darker chips.

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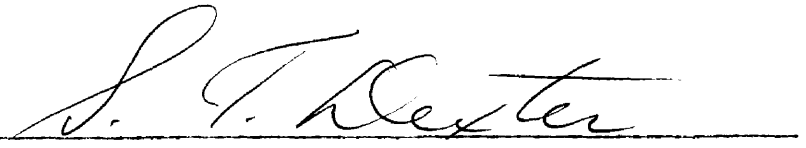
Approved 

ACKNOWLEDGMENTS

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INTRODUCTION

" - - - these roots ought to be exempted from all suspicion of lying heavy on the stomach of those who use them for food, since every pound contains 11 1/2 ounces of water, and the 4 1/2 ounces of solid parts remaining, afford scarce a drachm of earth." ---A. A. Parmentier, 1781. (10)

The potato is one of the most important agricultural products in terms of money value. As well as being used in several forms as one of the staple foods for man it is utilized in industry in various ways. The uses depend on the various qualities of the potato. The kinds of dry matter, such as starch, sugars, and proteins and their proportions, are very important and have a considerable effect on the food value and culinary quality. The composition, as well as the amount of dry matter in a tuber, depends upon several factors, such as variety, climate, soil, fertilizer, culture, etc.

Quality is defined as a combination of factors which relate to the external and internal characters of the tuber and it is mainly considered in three aspects: (1) market quality, (2) culinary or cooking quality and (3) food quality for nutritive and health values. Color, flavor and texture of cooked potatoes are characters for culinary quality. The texture of cooked potatoes is measured by mealiness. A generally accepted index of mealiness of the cooked potato is specific gravity. The major variable fraction of the total solids of the tuber is

starch. Specific gravity may be used as a quantitative measure of starch content, and is commonly used to estimate the yield of potato chips.

A linear relationship of specific gravity and starch content has been established. Other investigations have shown that the starch is in the form of discrete starch grains, with a considerable range of sizes. However, very little information is available concerning the effect of the various sizes of starch grains on the quality characteristics of the potato tuber.

As a consequence, this study was made to explore the effects of varieties and environment on the proportions of the various starch grain sizes found in suspensions made from potato tubers and the relationships of these sizes to specific gravity and chip quality.

REVIEW OF LITERATURE

Varietal Variability

The effects of varieties on measures of culinary quality have been mentioned by many workers.

Within a variety. Gilmore (23) reported a variation in table quality within a potato variety. Goldthwaite (25) concluded from the results of analysis of several hundred individual tubers that no two potatoes, whether of the same variety or from the same hill, have exactly the same composition. Johnson and Boyle (28) found the percentage of dry matter in tubers of the same variety varying from 21.07 to 27.18 and the percentage of starch from 14.65 to 20.76. Vanasse, et al (43) noted that variety and location of production have a statistically significant effect on the specific gravity - dry matter relationship.

Between varieties. Willaman and West (48) stated that American early varieties had lower contents of dry matter than had later varieties, and a similar tendency was shown by the data of Akeley and Stevenson (1). Burton (9) and Whitehead, et al (47) reached the same conclusion in the case of British varieties.

Stevenson and Whiteman (39) showed that inherent differences among the varieties were apparent and that some varieties tend to maintain better quality than others over a wide range of conditions. They also indicated differential varietal adaptation. They said that if comparisons were to be

made between two varieties, it must be known that they were grown under very similar conditions. Akeley and Stevenson (1) also reached the same conclusion.

Akeley and Stevenson (2) discovered that the tendency for the tubers of a potato plant to have a high or low content of dry matter was heritable, and that the character for a high content of dry matter was dominant over that for a low content of dry matter.

Stevenson (38), after examining the varieties Parnasia and Green Mountain, considered starch production to be the expression of a genetic character in the development of which, environment is as important as the genetic factor. Akeley and Stevenson (1) made studies on starch calculated from specific gravity, and found inherent differences between seedlings in the same progeny as well as between progenies and between varieties.

Between locations. Metzer, et al (31) demonstrated statistically significant differences in the composition of potato varieties, and that potatoes from one locality differ in starch and dry matter from those of another locality. Dunn and Nyland (17) stated that the greatest differences in average specific gravity were found between locations. Akeley and Stevenson (1) mentioned that wide differences in the same variety were found when grown in different parts of the country.

Specific Gravity

The specific gravity of the tuber has been used as a rapid measure of the content of dry matter and of starch.

According to Burton (10) Von Scheele et al, gave their results on 560 samples, including a number of varieties and found highly significant correlations and relationships between - specific gravity and dry matter; specific gravity and contents of dry matter and content of starch. They noticed "no differences in the relationships between specific gravity and the content of starch and of dry matter in tubers from different parts of the country or in different years." Further "the relationships between specific gravity and the contents of dry matter and of starch did not differ significantly in different varieties. The coefficients of the correlations between specific gravity and the dry matter and starch contents did, however, differ." Clark et al. (11) pointed out differences in specific gravity of tubers of different sizes.

Glynne and Jackson (24) and Shutt (35) also found a high correlation between the content of dry matter and that of starch. Dry matter and starch were found to be associated with mealiness of potatoes after cooking. Freeman (20) claimed a significant correlation between the specific gravity of a tuber and the mealiness of its texture when baked, as indicated by his "toluene index". Asby (4) and Clark et al. (11) obtained a high correlation between dry matter content and mealiness of the cooked potato and Clark et al (11) suggested that specific gravity was a practical method for making a preliminary selection for mealiness.

Starch

The starch in the potato is in the form of discrete starch grains of a considerable range in sizes. Since it is a major proportion of the total solids, it is an important fraction in quality studies.

Structure and content. Sjostrom (36) noted that potato starch granules vary greatly. Commercially the starch of the highest average granule size is graded best, if other qualities are equal. The largest granules are usually egg-shaped, although granules of oyster shape are not uncommon. As a rule they show concentric striations, which often give them an ornamental appearance. Garner (22) showed that one axis of potato starch particles is longer than the other.

According to Brautlecht (7) Rathsack found that the starch content of the potato is at a maximum in the third layer or zone from outside, when the potato is divided into seven zones. Total solids and starch are present in smaller quantities in the skin than elsewhere in the potato.

Relationship of granule size with varieties. Johnson and Boyle (29) gave the starch grain size of a number of British varieties of potato. Their values for the average size of the largest starch grains in the tuber varied from 116u x 71u (var. Shamrock) to 71u x 51u (var. Royal Kidney); and for the average size of medium starch grains from 71u x 51u (var. Br. Queen) to 39u x 25u (var. Windsor Castle). There was no evidence of starch grain size being a varietal characteristic.

Fitch and Barnnet (21) found from a microscopic examination of different potatoes that the starch granules differ in size with different varieties. They further mentioned that cooking quality differs probably owing to the difference in the size and number of the starch granules. Veselovsky (44) suggested that the qualitative composition of potato starch and the percentage of large and small grains should be considered varietal characteristics.

Barham, et al. (5) observed that varietal and environmental factors affect the structure and size of starch granules. The average size of the granules was either small or large, depending upon the variety. He claimed that five hundred granules seemed to be a sufficient number to measure in order to obtain the average size and the size frequency. Meiss, et al. (30) made a comparison of an average cumulative particle size distribution curve of white potato starch produced in Maine with that produced in Idaho, Minnesota and Oregon and found noticeable differences. Briant, et al. (8) using a hydrometer method, obtained from their starch sample a cumulative distribution of particle size which followed a sigmoid curve.

Relationship of granule size with mealiness. Veselovsky (44) concluded that the size of starch grains for the most part determines the quality of starch. Large-grain potato starch may be readily converted into a soluble starch while small-grain starch gives a more viscous paste. He further established a direct relation between large size of starch grain and hydrolys-

ing capacity, namely, starch grains longer than 60 microns hydrolyze more rapidly than those smaller than 60 microns. Szego (42) and Janieki (26) also stated that the viscosity of a paste is directly related to the average size of the granules, that is, the smaller granules produce a more viscous paste.

Briant, et al (8) presented evidence that there was no correlation between the mealiness of potatoes and the percentage of granules above 30 microns diameter. However, there was a significant negative correlation between the percentage of granules below 20 microns diameter and the mealiness of the cooked potatoes. He concluded that the degree of mealiness of a cooked potato may be associated with some of the physical properties of the starch.

Radley (34) showed a close connection between the granule size and the gelatinization temperature. The larger granules appear to swell at a lower temperature than the smaller ones and require less heat for the conversion of dextrine. Alsberg (3) pointed out that as potato starch grains get bigger, the ratio of volume (or weight) to surface area gets bigger. Therefore, large grains as they take up water, inevitably swell more rapidly than small grains.

Sweetman (41) reported no important correlation between size of starch and mealiness, r being +0.330 $\pm$0.123. Barmore (6), Sweetman (41) and Nash (33) demonstrated a direct significant correlation between the content of starch and the mealiness of cooked tuber.

Relationship of granule size with other factors. Whittenberger and Nutting (49) treating Green Mountain seed potatoes with 63 ppm of either indoleacetic acid or indolbutyric acid found almost no effect on the size of the starch granules in the offspring tubers. According to them this is contrary to Zika and Malcher and Zika (52) who reported that treatment of potato seed piece with indoleacetic acid resulted in a considerably larger average size of the potato starch granules.

Whittenberger and Nutting (49) were of the opinion that the size of starch granule was related in general to the size and probably to the age of the tuber. The average smallest granules were obtained from the smallest of the youngest tubers. The largest granules were found in the largest tubers of full maturity. Johnson and Boyle (27) mentioned that the starch grain size was smaller in small tubers than in large ones. East (18) found that the starch grains were smaller in immature than in mature tubers.

Vilikovski (45) stated that dry seasons reduced the size of the starch grains and that potash fertilizer increased the size.

Potato Chips

Several investigators have presented evidence that the color of potato chips depends mostly on varieties, specific gravity and content of reducing sugars.

Variety. Wright and Whiteman (50) and Wright, et al. (51) stated that the quality of potato chips depends largely on the variety of potato used. Stuart (40) and Denny and Thornton (15) reported that the superiority of the Rural group for the production of good color in potato chips was clearly shown, and that these varieties were low in reducing sugars.

Specific gravity. Cochram, et al. (12) claimed that the reducing sugar content was found to vary inversely with specific gravity. Wheeler and Salunkhe (46) emphasized that early planting produced high specific gravity tubers and in turn made light colored chips. Wright and Whiteman (50) and Kunkel, et al. (29) found that the color of potato chips from high specific-gravity potatoes was lighter than that of chips made from low specific-gravity group. Mikuljskil (32) demonstrated that ripening of potato tuber is characterised by an increase in the content of dry matter and starch and a decrease in the ratio of sucrose to reducing sugars.

Reducing sugar content. Denny and Thornton (14) showed a direct correlation between the amount of reducing sugar in the juice of potato tubers and the extent of browning when chips were made from them. Dexter and Salunkhe (16) concluded that the amount of reducing sugars seems to be one of the causes for the formation of the dark brown color of potato chips. Smith (37) also pointed out that the content of reducing sugars determines the color of potato chips and hence the quality of chips.

MATERIALS AND METHODS

Varieties and Locations

In 1955, seventeen varieties of potatoes were grown at five locations in Michigan for the present investigations. The varieties grown were:

1. Irish Cobbler
2. Early Gem
3. Dazoc
4. Osage
5. Redburt
6. Pungo
7. MS 1363
8. Ia 803-3
9. Redkote
10. Waseca
11. Ia 961-1
12. Red LaSoda
13. Cherokee
14. Sheridan
15. Rushmore
16. Sebago
17. Merrimack

The five locations together with kind of soil and dates of planting and harvesting were as follows:

County	Town	Soil	Date of Planting	Date of Harvesting
Montcalm	Edmore	Mineral	May 7	Oct. 4
Emmet	Levering	Mineral	May 11	Sept. 21
Bay	Bay City	Mineral	May 5	Sept. 16
Arenac	AuGres	Muck	May 20	Sept. 30
Allegan	Plainwell	Muck	May 9	Sept. 29

The design at each location was a simple randomized plot with four replications. Each plot was a single 20 foot row. The distance between rows was 34 inches and between plants in a row, ten inches. Sixteen feet of row was harvested for yield determinations.

Sampling

A fifteen pound sample of U. S. Grade No. 1 tubers from each plot at each location was taken at harvesting time. From each sample, five tubers of approximately the same size were taken and were numbered individually by India Ink to keep the identity for the following tests:

1. Specific gravity.
2. Percentage of starch grains of different sizes.
3. Chip color rating.

Specific Gravity

The specific gravity determinations were made on the individual potato tubers. The weights in air and in water were obtained and the data used in the following formula:

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

These weights were taken on a modified Hanson - "diet scale", a spring balance of 500 gram capacity. The platform of the balance was removed and replaced by an iron rod to the lower end of which a thin wire, 1/32 inch in diameter was attached. The end of the wire was bent in the shape of a hook. Each potato tuber was placed on the hook for weighing. The

balance was supported on a raised, horizontal, five-inch-wide, wooden surface supported on three retort stands for free movement of the potato tuber. The position for the "weight in air" reading is shown in Figure 1. To take weight in water, a deep pan of water was so placed that the tuber was completely immersed as shown in Figure 2. The scale was read to the nearest half gram.

Starch Grain

Percentage of starch grain. Each numbered tuber was cut in half. One half was used for determining the percentages of starch grains of various sizes; the other half was used for making chips. From the half-tuber used for starch percentages fine scrapings from inner and outer medulla were made. The scrapings were placed on a slide with a drop of distilled water, and stained with potassium iodide-iodine solution.

The slide with the stained material was placed on a vertical projection microscope and the image examined on the ground glass back of a camera. (Figure 3). An ocular with an inserted micrometer was used for measuring the sizes of the starch grains. The ocular micrometer was calibrated with the stage micrometer. One division of ocular micrometer was equal to 12.5 microns.

A piece of cardboard with an aperture of two inches by two inches was placed on the ground glass camera view finder to standardize the area observed. The starch grains visible in the 2" by 2" opening were classified into the following four groups.

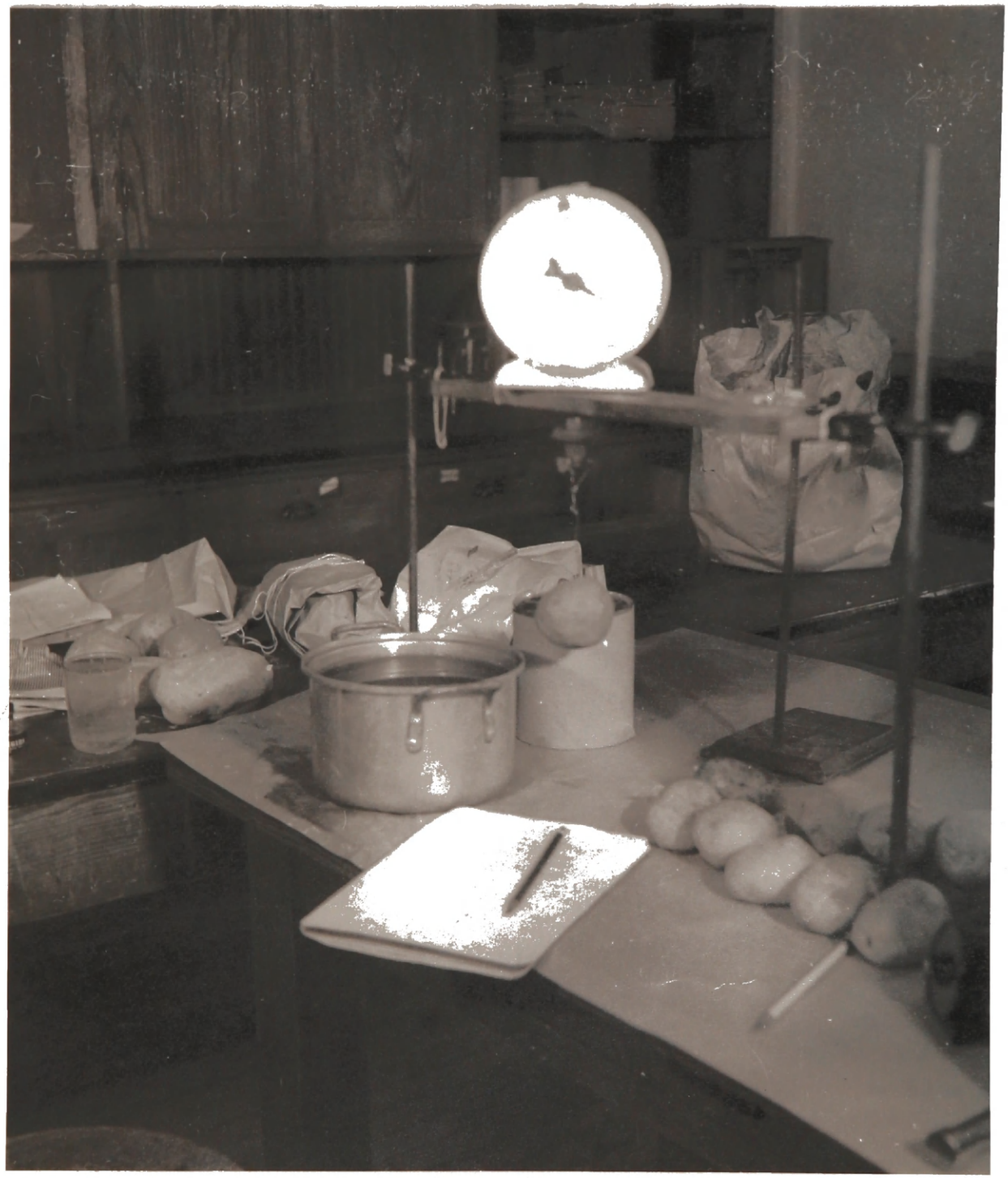


Figure 1. Modified Hanson 'diet scale' a spring balance of 500 gram capacity on a raised horizontal surface supported on retort stands - showing weight of the tuber in air.

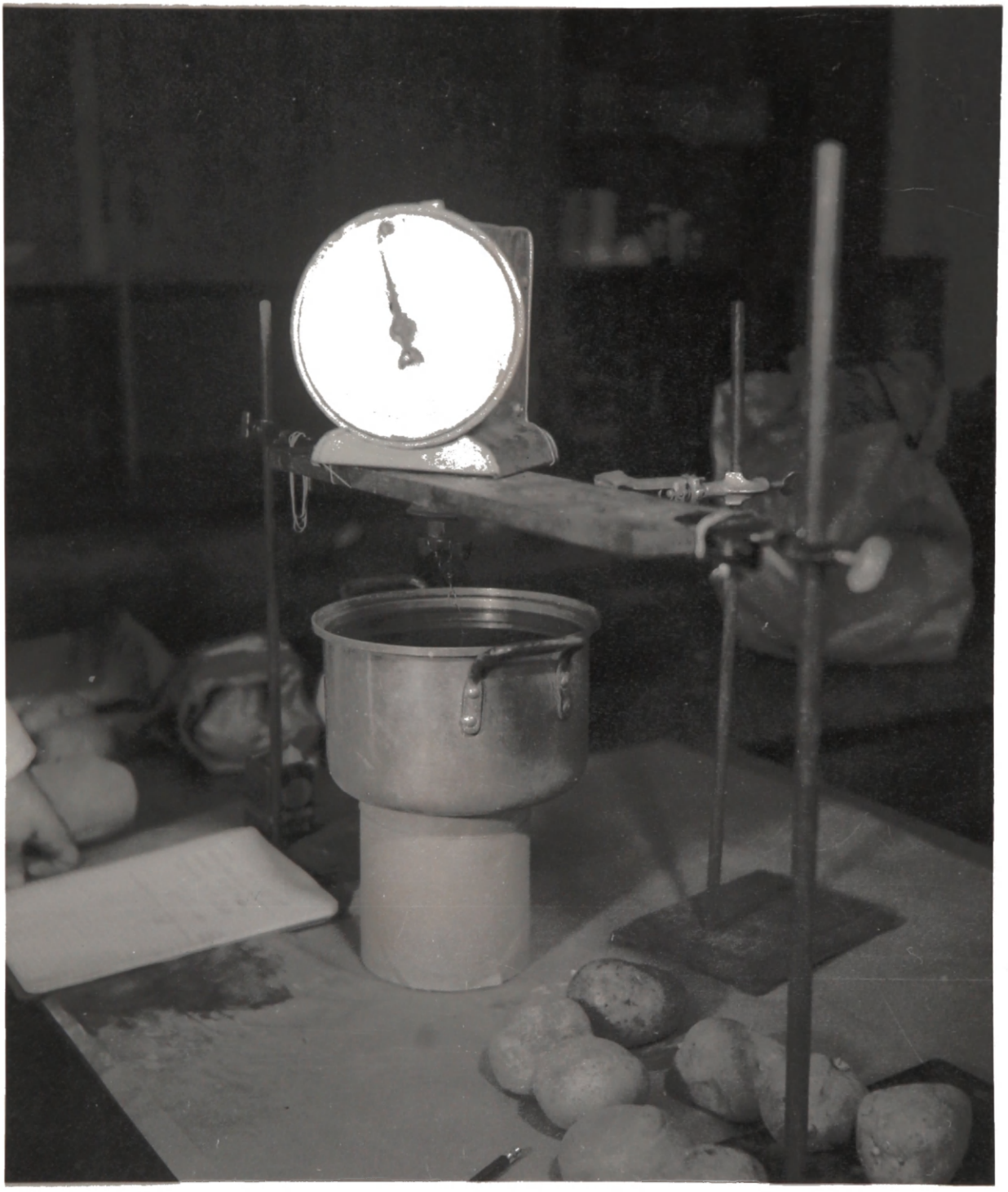


Figure 2. Modified Hanson 'diet scale' showing weight of the tuber in water.

Figure 3. Projection microscope in vertical position with camera fitted on the top.

Group 1	- Large	- above 75 microns	(Fig. 4)
Group 2	- Medium	- 75 to 50 microns	(Fig. 5)
Group 3	- Small	- 50 to 25 microns	(Fig. 6)
Group 4	- Very small	- less than 25 microns	(Fig. 7)

In most instances the entire area under observation was not covered by starch grains. As a result, the total area covered by starch grains was estimated at 100 percent and proportion of this total which was occupied by the starch grains of each of the above four groups of sizes was estimated. This estimated proportion of area is here termed "percentage of starch grain".

Five readings from different fields per slide were taken and the average of these was used for each tuber.

Percentage volume of starch grain. The volume of starch grain was obtained by multiplying the percentage of starch grain of each size group (a) by the mid-point diameter of granule of the same size (b). The percentage of volume for each group was calculated by using $\frac{a \times b}{S(a \times b)}$. The percentage volume of starch grain was calculated for Montcalm County in order to see whether the percentage volume has the same relationship with specific gravity as the percentage of starch grain had with specific gravity. These calculations were made with the assumption that all particles of starch have a spherical shape.

Density of starch grain. Starch was extracted from two samples of the Cherokee variety from Montcalm County. The starch was separated into three group sizes, large - above 60 microns

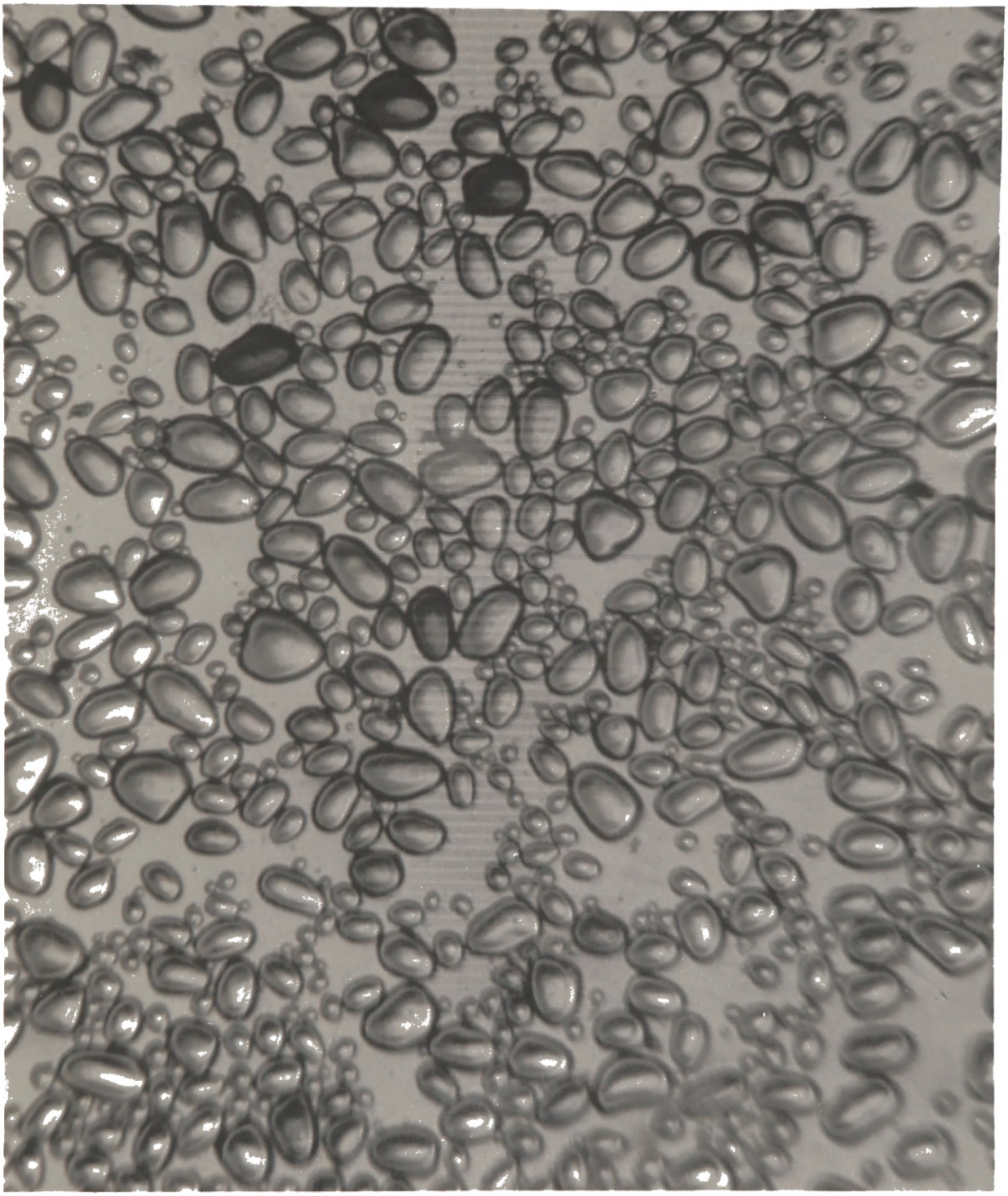


Figure 4. Potato starch grains (Magnification X 140)

A tuber with an unusually high proportion of large starch grains (50% Large, 25% Medium 15% Small, 10% Very Small).

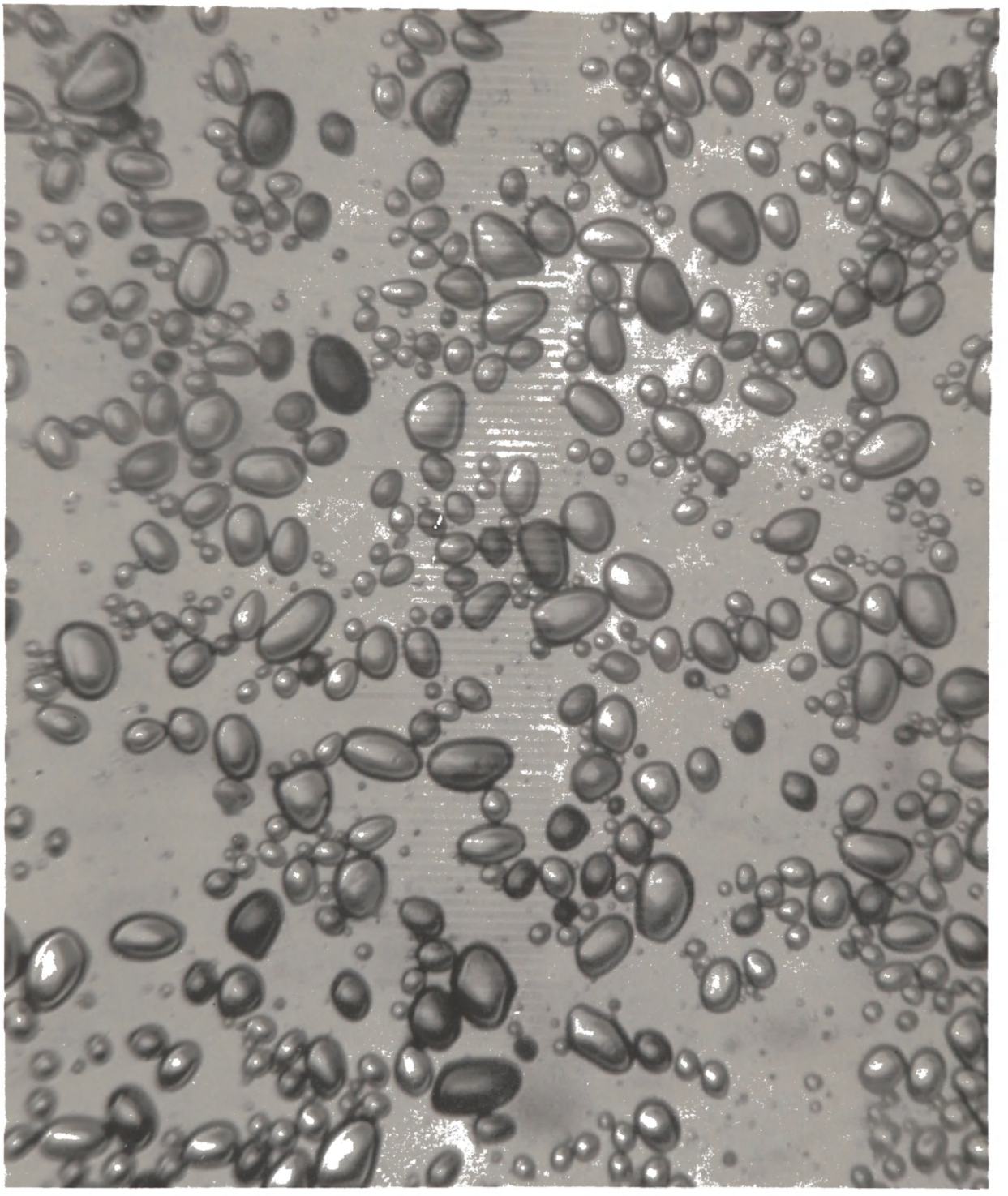


Figure 5. Potato starch grains (Magnification X 140)

A tuber with an unusually high proportion of medium starch grains (15% Large, 45% Medium, 15% Small, 20% Very Small).

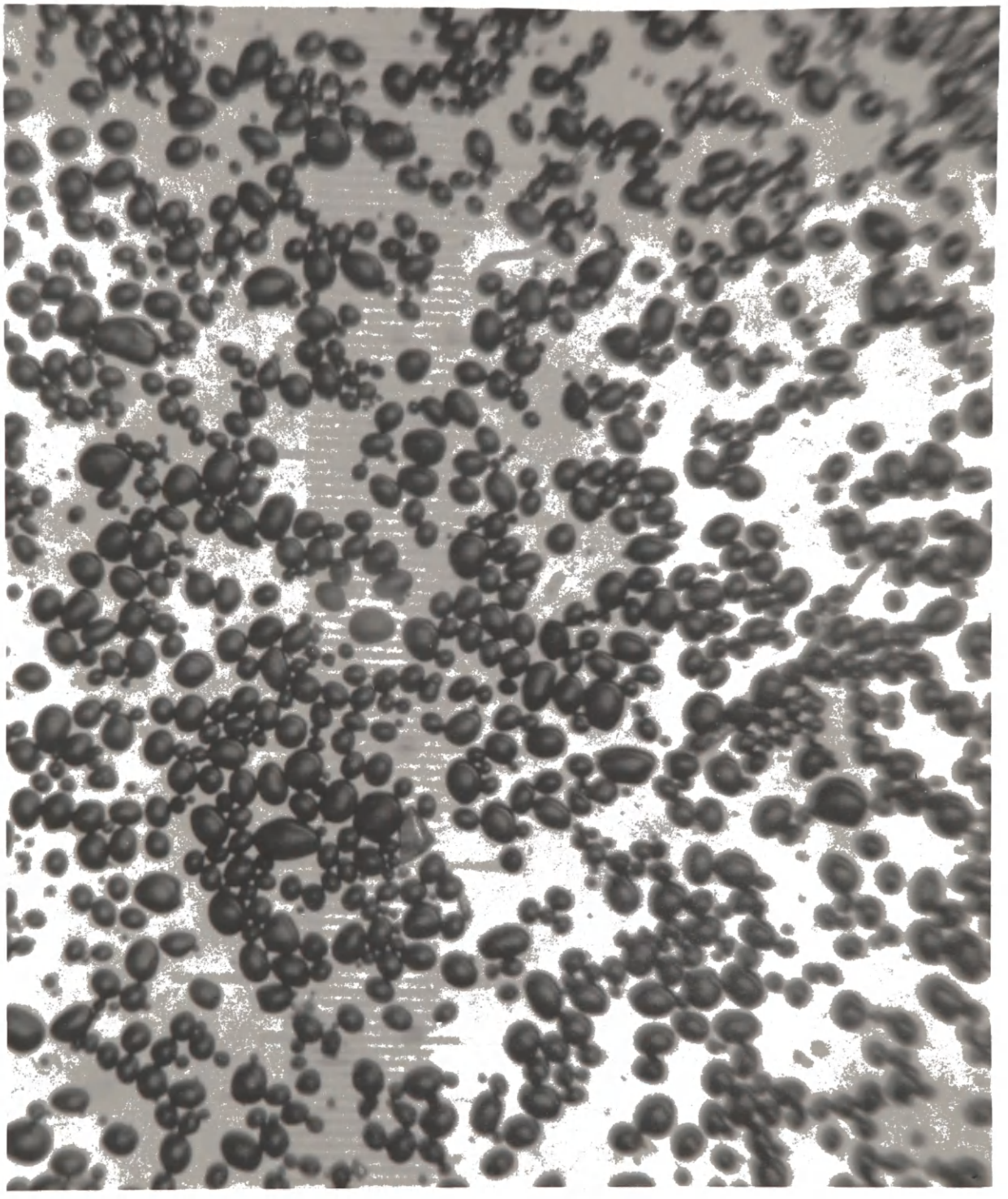


Figure 6. Potato starch grains (Magnification X 140)

A tuber with a high proportion of small starch grains (0% Large, 0% Medium, 60% Small, 40% Very Small).

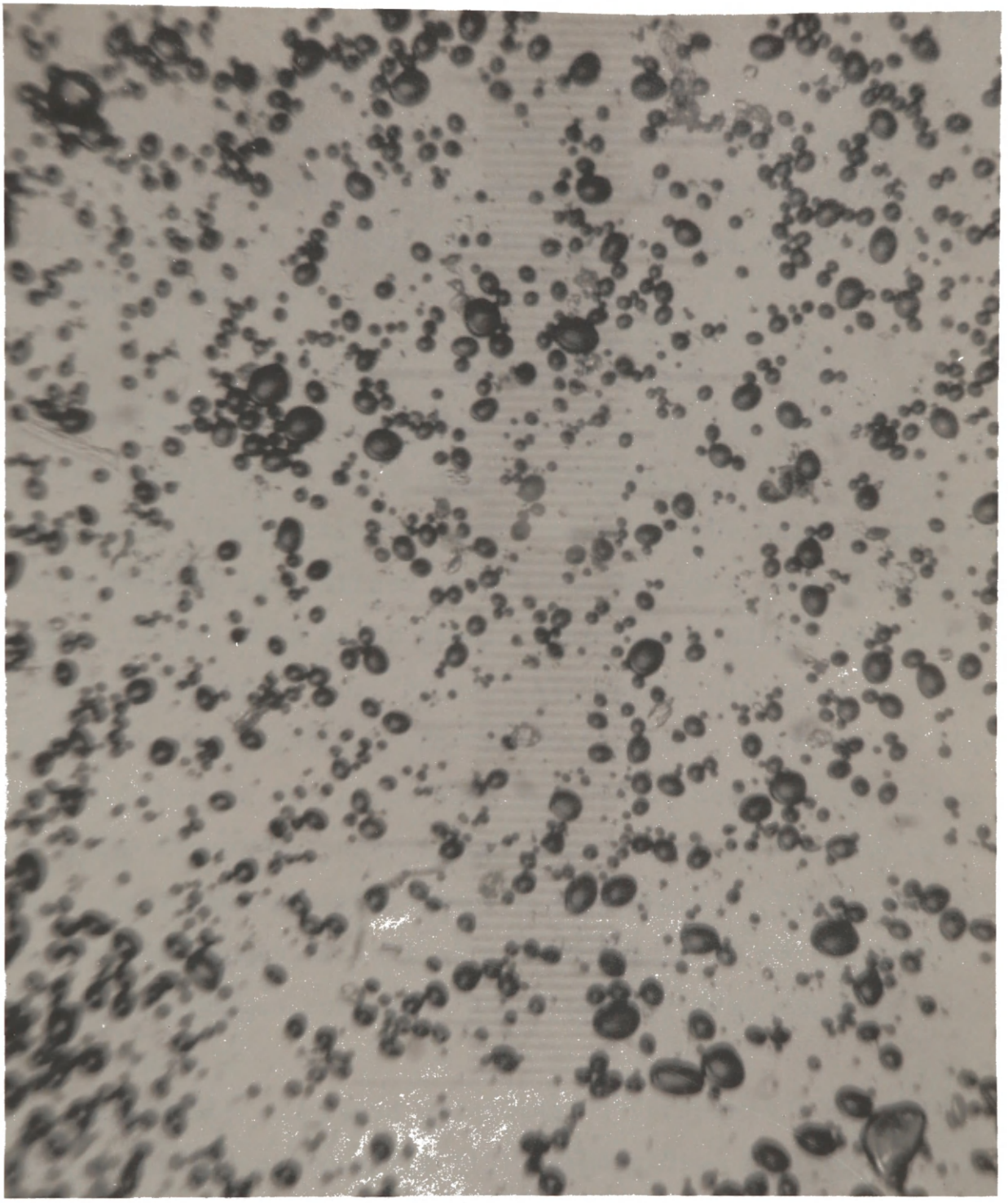


Figure 7. Potato starch grains (Magnification X 140)

A tuber with a high proportion of very small starch grains (0% Large, 0% Medium, 10% Small, 90% Very Small).

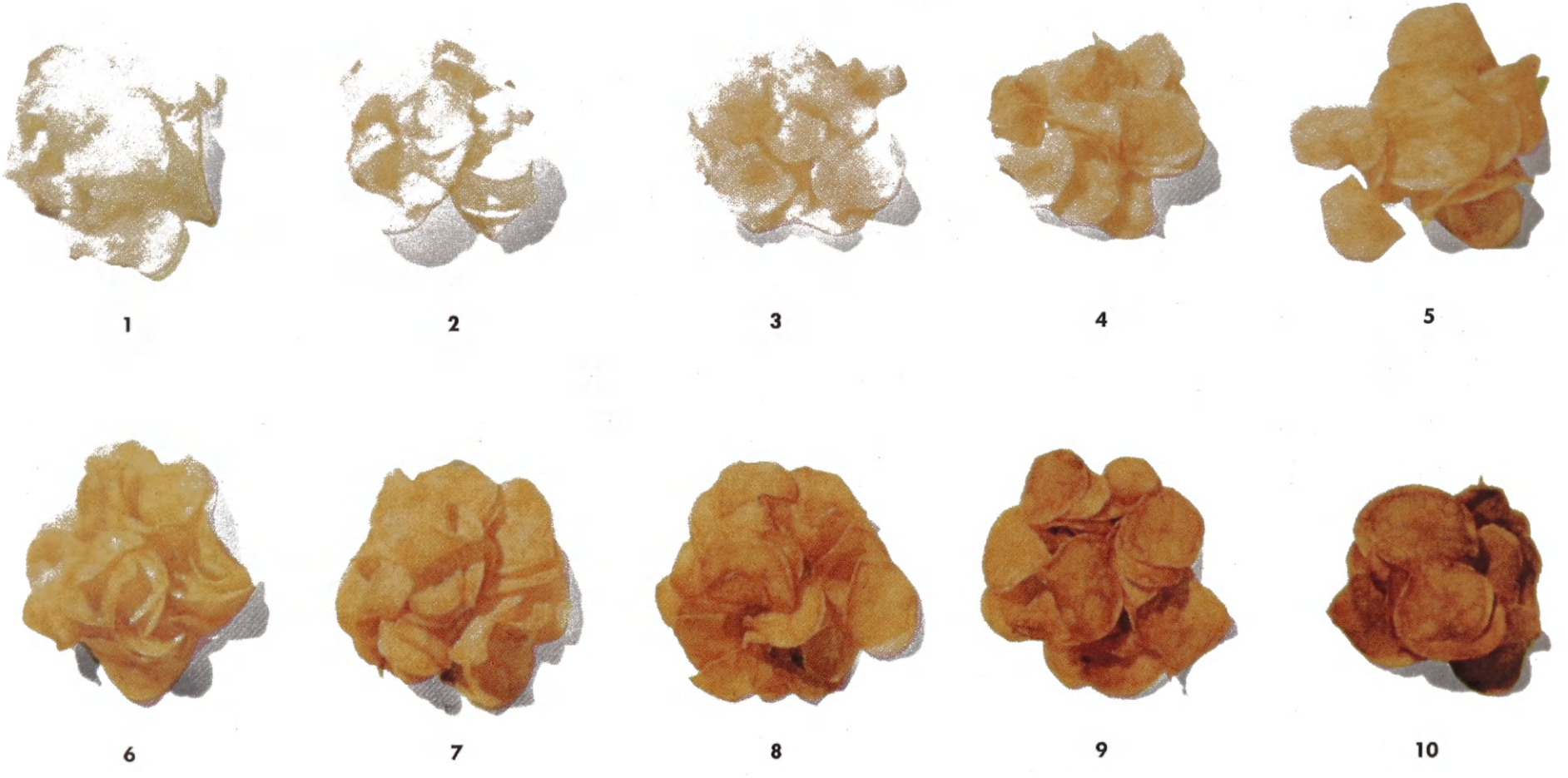
medium-60 to 30 microns and small-less than 30 microns. These sizes were verified by examining the starch samples under the microscope. The density of these three different starch sizes from each of the two samples was obtained by the picnometer method.

Chip Making and Color Rating

The half tuber saved for potato chips was sliced, in a rotating chipper, to a uniform thickness of 3/64 inch to 4/64 inch. Beginning with the outside of the half tuber, the first four or five slices were discarded, the next slice was saved for the chip color test. Thus twenty slices per variety from each location were rated. All twenty slices of a variety were threaded together. For identification, patterns of holes were punched in the slice from the first tuber and the slice from the twentieth tuber. They were washed in running tap water to remove adhering loose starch grains. They were fried in 'Primex' vegetable oil at a temperature of 385° F (196°C). Frying was judged completed when bubbling from chips in the oil stopped.

Each chip was rated according to "Proposed Color Reference Standard" of Coughlin (13) (Figure 8). Ratings are from 1- white to 10- dark. Chips falling within the 3 to 5 color range were considered desirable, those rated 1 and 2 too light and those rated 6 to 10 too dark.

PROPOSED COLOR REFERENCE STANDARD



From a talk,

"QUALITY CONTROL IN POTATO CHIP MANUFACTURING"

presented at the Production and Technical Division Meeting
National Potato Chip Institute
January 25, 1954
F. J. Coughlin, The Procter & Gamble Company

Figure 8

Computations

The readings of five tubers per plot were added and these sums used for calculations. Analyses of variance were calculated. Linear Correlation Coefficients were obtained between

Specific gravity (x) and Percentage of starch grain (y),

Specific gravity (x) and chip ratings (z), and

Percentage of starch grain (y) and chip ratings (z)

By means of covariance the coefficients of correlation between varieties and within varieties were calculated for each county. Two-way tables of variety x location were set up. From these there were obtained by covariance the coefficients of correlation between varieties and within varieties. Scatter diagrams were made to show the relationship.

The three partial correlations, (rxy.z, rxz.y and ryz.x) were calculated by the method suggested by Ezekiel (19).

Correlation coefficients for varieties were calculated between percentage of volume of starch grain sizes and specific gravity and chip rating.

The density of starch grain size readings were examined by the analysis of variance.

EXPERIMENTAL RESULTS

Samples of fifteen pounds of potato tubers were taken at harvest time from each plot of seventeen varieties replicated four times at five locations. From each fifteen-pound sample five tubers of approximately the same size were taken. The data obtained in these studies are given as the averages of specific gravity, the percentages of four groups of starch grains and the chip color rating from these five-tuber samples.

Specific Gravity

The comparative specific gravities of the different potato varieties are shown in the data from the individual counties given in Tables VII to XI. Waseca and Redkote had the lowest specific gravity in two trials each while Merrimack had the highest reading in three counties. The statistical significances of differences exhibited at each location are shown in Table I. All the F-values for "Varieties" were highly significant indicating appreciable varietal differences in specific gravity. The differences between varieties were also significant when the specific gravities from all the five counties were combined (Table I). Early Gem, Redkote and Waseca had the lowest specific gravity (1.056) while Merrimack had the highest (1.073). Table XII.

Differences between specific gravity of potato tubers in different locations were partly indicated by the county

TABLE I

ANALYSIS OF VARIANCE FOR SPECIFIC GRAVITY OF SEVENTEEN POTATO VARIETIES GROWN IN 1955 IN FIVE LOCATIONS

Source	d.f.	Montcalm		Emmet		Bay	
		M.S.	F	M.S.	F	M.S.	F
Rep.	3	262	1.6	65	0.7	39	0.5
Var.	16	1114	9.6**	754	7.6**	401	4.9**
Error	48	117		99		82	

Source	d.f.	Arenac		Allegan	
		M.S.	F	M.S.	F
Rep.	3	971	15.1**	210	3.3*
Var.	16	660	10.3**	707	11.0**
Error	48	64		64	

Source	d.f.	All Locations	
		M.S.	F
Loc.	4	9514	44.1**
Var.	16	2142	9.9**
Error	64	216	

* Exceeds 5% level of significance

** Exceeds 1% level of significance

averages. These ranged from 1.058 for Bay County to 1.071 for Emmet County (Tables VIII to IX). The average for mineral soil trials (Montcalm, Emmet and Bay) was no different from that for the two muck soil trials (Arenac and Allegan).

The magnitude of variation in specific gravity that might occur within a variety was indicated by the F-value for "Replication". (Table I). At two locations, Arenac and Allegan, there were highly significant differences between replications (Tables X to XI). Using five tuber samples of a variety considerable variations in average specific gravity were observed in most of the varieties.

Percentage of Sizes of Starch Grains

The starch suspensions exhibited starch grains of many sizes. These sizes were classified into four groups - large, medium, small and very small, The data on percentages of starch grains are given by size group from tubers of individual county. Tables VII to XII).

Group 1 - large - above 75 microns. Between varieties, the differences in percentage of large starch grains above 75 microns were highly significant in each of five counties or when all were combined (Table II). Early Gem had no large starch grains at any location, while Osage showed the largest average percentage of large starch grains (Table XII). Waseca had no large grains at two locations. Osage produced the highest percentage at three locations. Pungo, 31.5 in Montcalm County, produced the highest single percentage of large starch grains in the entire experiment.

TABLE II

ANALYSIS OF VARIANCE FOR PERCENTAGE OF STARCH GRAIN SIZE GROUP 1-LARGE-ABOVE 75 MICRONS FROM SEVENTEEN POTATO VARIETIES GROWN IN 1955 IN FIVE LOCATIONS

Source	d.f.	Montcalm		Emmet		Bay	
		M.S.	F	M.S.	F	M.S.	F
Rep.	3	192	1.0	7.0	0.2	73	0.8
Var.	16	2071	10.7**	1312	33.8**	1481	15.7**
Error	48	194		39		94	

Source	d.f.	Arenac		Allegan	
		M.S.	F	M.S.	F
Rep.	3	428	3.5*	89	1.8
Var.	16	1003	8.2**	1163	23.3**
Error	48	122		50	

Source	d.f.	All Locations	
		M.S.	F
Loc.	4	1761	4.1*
Var.	16	5289	12.2**
Error	64	435	

* Exceeds 5% level of significance

** Exceeds 1% level of significance

Osage, Pungo, Ia 803-3, Cherokee, and Rushmore produced a higher percentage of large starch grains than did Early Gem, Dazoc, Redburt, Waseca, Red LaSoda and Sheridan at each location (Tables VII to XII).

Location had a statistically significant effect on the percentage of large starch grains as shown by the F-value for "Locations". Average percentage of starch grain at Montcalm was highest, 13.5, while Allegan County was lowest, 7.6 (Table XII). In tubers grown in mineral soil the average percentage of large starch grains was higher than in those grown in muck soils.

The variation in percentage of large starch grains in the tubers of a given variety was noticeable. The F-value for "Replication" at Arenac County was significant (Table II). Group 2 - medium - between 75 to 50 microns. Varietal differences in the percentage of medium sized starch grains were evident from Tables VII to XI for the various counties. The differences between varieties were highly significant at all locations as indicated by the F-values for "varieties" in Table III. Waseca and Early Gem had the lowest percentage of medium starch grains at two counties each while Osage had the highest reading at three counties. When all counties were combined and averaged, Early Gem (6.4) and Osage (27.5) produced the minimum and maximum percentages of medium starch grains respectively (Table XII).

TABLE III

ANALYSIS OF VARIANCE FOR PERCENTAGE OF STARCH GRAIN SIZE GROUP 2-MEDIUM-75 TO 50 MICRONS FROM SEVENTEEN POTATO VARIETIES GROWN IN 1955 IN FIVE LOCATIONS

Source	d.f.	Montcalm		Emmet		Bay	
		M.S.	F	M.S.	F	M.S.	F
Rep.	3	424	5.7**	29	0.5	5	0.1
Var.	16	909	12.3**	628	11.4**	1372	26.7**
Error	48	74		55		51	

Source	d.f.	Arenac		Allegan	
		M.S.	F	M.S.	F
Rep.	3	514	6.9**	286	4.3**
Var.	16	1414	19.0**	884	13.4**
Error	48	75		66	

Source	d.f.	All Locations	
		M.S.	F
Loc.	4	307	0.9
Var.	16	3897	11.9**
Error	64	328	

* Exceeds 5% level of significance

** Exceeds 1% level of significance

Osage, Pungo, Ia 803-3, Ia 961, Cherokee and Merrimack gave comparatively higher percentages of medium starch grains when compared to Early Gem, Dazoc, Redburt, Waseca, Red LaSoda and Sheridan at four locations excepting Emmet County or when all the five locations were combined (Figure 10).

The variability in county averages of percentage of medium sized starch grains was not great. The average of mineral soils, 18.3, was no different from that of two muck soils, 18.2 (Table XII). The differences in percentages of starch grains of this group within varieties were indicated to some extent by the F-values of "Replications" in Table III. At three locations Montcalm, Arenac and Allegan, there were highly significant differences between replications.

Group 3 - Small - Between 50 to 25 microns. The differences in percentage of small starch grains among varieties were apparent from the data of individual counties (Tables VII - XI). These differences were highly significant (Table IV). Waseca produced the smallest percentage of small starch grains in four counties. There was a wide range in percentages from the lowest, Waseca with 10.8% in Bay County, to the highest, Cherokee with 27.5% in Emmet County.

Within a variety, there was no great fluctuation between percentages at the five locations. The analysis of variance Table IV did not show significance for "Replications" and "Locations".

TABLE IV

ANALYSIS OF VARIANCE FOR PERCENTAGE OF STARCH GRAIN SIZE GROUP 3-SMALL-50 TO 25 MICRONS FROM SEVENTEEN POTATO VARIETIES GROWN IN 1955 IN FIVE LOCATIONS

Source	d.f.	Montcalm		Emmet		Bay	
		M.S.	F	M.S.	F	M.S.	F
Rep.	3	50	1.0	5	0.2	15	0.4
Var.	16	209	4.0**	140	6.7**	277	7.7**
Error	48	53		21		36	

Source	d.f.	Arenac		Allegan	
		M.S.	F	M.S.	F
Rep.	3	101	2.8	22	1.2
Var.	16	162	4.5**	87	4.8**
Error	48	36		18	

Source	d.f.	All Locations	
		M.S.	F
Loc.	4	286	1.9
Var.	16	272	1.8*
Error	64	151	

* Exceeds 5% level of significance

** Exceeds 1% level of significance

Group 4 - Very small - less than 25 microns. Varietal differences in the percentage of very small sized starch grains are shown in the data from the individual counties or all combined, Tables VII to XII. Osage tubers had the lowest percentage of very small grains in three counties. The statistical differences between varieties are shown in Table V. The F-values for "Varieties" at all five locations individually or combined were highly significant, indicating large differences between varieties in percentage of very small starch grains. There were wide differences between minimum percentage, Osage, 24.3% at Emmet, and maximum, Waseca, 86.0% at Bay County.

Osage, Fungo, Ia 803-3, Ia 961-1, Cherokee, Rushmore and Merrimack were low in percentage of very small starch grains as compared to Early Gem, Dazoc, Redburt, Waseca, Red LaSoda and Sheridan which have higher percentages as seen from the combined averages of all locations (Table XII).

The differences due to location on the percentage of very small starch grains were not significant. These range from an average of 47.2% for Montcalm County to an average of 53.9% for Allegan County (Table XII). Variation within a variety in the percentage of very small starch grains was evident between replications as indicated by the F-values for "Replications" (Table V). At two muck soil trials, Arenac and Allegan, there were highly significant differences between replications.

TABLE V

ANALYSIS OF VARIANCE FOR PERCENTAGE OF STARCH GRAIN SIZE GROUP 4-VERY SMALL- LESS THAN 25 MICRONS FROM SEVENTEEN POTATO VARIETIES GROWN IN 1955 IN FIVE LOCATIONS

Source	d.f.	Montcalm		Emmet		Bay	
		M.S.	F	M.S.	F	M.S.	F
Rep.	3	304	0.6	55	0.3	14	0.1
Var.	16	5672	11.2**	2938	17.1**	7095	32.6**
Error	48	504		172		218	

Source	d.f.	Arenac		Allegan	
		M.S.	F	M.S.	F
Rep.	3	3344	12.2**	908	4.8**
Var.	16	5926	21.6**	3557	18.8**
Error	48	274		190	

Source	d.f.	All Locations	
		M.S.	F
Loc.	4	2316	1.7
Var.	16	19676	14.3**
Error	64	1378	

* Exceeds 5% level of significance

** Exceeds 1% level of significance

Chip Color Rating

There were marked varietal differences in chip color rating of tubers as seen from the data of all five counties considered individually or combined (Tables VII - XII). These differences were highly significant as is evident from F-values for "varieties" (Table VI). Osage produced the lightest colored chips in three counties while Early Gem made the darkest chips in two counties. When comparing the average of all counties Osage was rated 3.7, the best, and Red LaSoda rated 6.3, the poorest, in chip color (Table XII).

The effect that location had in influencing chip color rating was indicated by the county averages. These range 4.7 for Bay County to 5.4 for Montcalm County. The differences between locations were highly significant (Table VI) although comparatively small. The average chip color from the two muck soil trials was lighter (4.8) than the three mineral soil trials (5.1).

The magnitude of differences of chip color rating between replications was not very great as may be seen from F-values for "Replications". These differences were not statistically significant (Table VI).

The data from Tables VI - XII indicate that in Michigan the varieties could be classified as generally light or dark color for chip production as judged by chip color rating of twenty tubers for each variety from five locations.

TABLE VI

ANALYSIS OF VARIANCE FOR CHIP COLOR RATING FROM SEVENTEEN POTATO VARIETIES GROWN IN 1955 IN FIVE LOCATIONS

Source	d.f.	Montcalm		Emmet		Bay	
		M.S.	F	M.S.	F	M.S.	F
Rep.	3	0.7	0.3	0.7	0.3	1.3	0.7
Var.	16	31.4	12.6**	9.6	4.5**	20.1	11.2**
Error	48	2.5		2.1		1.8	

Source	d.f.	Arenac		Allegan	
		M.S.	F	M.S.	F
Rep.	3	1.0	0.7	1.0	0.8
Var.	16	17.5	11.9**	15.1	11.5**
Error	48	1.5		1.3	

Source	d.f.	All Locations	
		M.S.	F
Loc.	4	39	7.0**
Var.	16	71	12.7**
Error	64	5.6	

* Exceeds 5% level of significance

** Exceeds 1% level of significance

Light colored potato chips were obtained from Irish Cobbler, Osage, Ia 803-3, Ia 961-1, Cherokee, Rushmore, Sebago and Merrimack while Early Gem, Redburt, M.S. 1363, Redkote, Waseca, Red LaSoda and Sheridan produced undesirably dark chips (Tables VII - XII).

Percentages of Volume of Starch Grain Sizes

The data for the four percentages of starch grain sizes for all varieties for the Montcalm County trial were converted into percentages of volume of starch grain sizes, and were given in Table XIII.

The means of the four sizes were in the descending order of medium (31.0), large (26.3) small (22.3) and very small (20.4).

Density of Starch Grain Sizes

Three different sizes of starch grains separated from two Cherokee potato tubers showed that their density or specific gravity varied according to size (Table XIV). The differences in density due to these sizes were highly significant (Table XV). From Table XIV it is evident that as the size of potato starch grain increased, the density also increased. The average density of the different starch sizes was in the descending order of Large - above 60 microns, Medium - 60 to 30 microns, and Small - less than 30 microns, the densities being 1.579, 1.556 and 1.531, respectively.

TABLE VII

AVERAGE SPECIFIC GRAVITY (x), PERCENTAGES OF FOUR STARCH GRAIN SIZES (y) AND CHIP RATINGS (z) OF SEVENTEEN POTATO VARIETIES GROWN IN MONTCALM COUNTY IN 1955, TOGETHER WITH THEIR COEFFICIENTS OF CORRELATION

No.	Varieties	Specific Gravity 'x'	Percentages of Starch Grain Sizes (y)				Chip Rating 'z'
			Large - Above 75 microns	Medium 75-50 microns	Small 50-25 microns	V.Small Below 25 microns	
1	Irish Cobbler	1.062	18.0	26.0	21.8	34.3	5.0
2	Early Gem	1.056	0.0	11.5	21.3	67.3	6.1
3	Dazoc	1.058	4.8	16.3	25.0	54.0	5.7
4	Osage	1.059	24.8	28.5	19.8	27.0	3.2
5	Redburt	1.052	1.0	7.8	16.8	74.5	6.8
6	Pungo	1.068	31.5	22.3	17.3	29.0	6.0
7	M.S. 1363	1.054	11.0	22.5	20.0	46.5	6.9
8	Ia 803-3	1.061	24.3	26.0	21.5	28.3	4.0
9	Redkote	1.055	16.8	19.3	17.5	46.5	5.9
10	Waseca	1.047	0.0	6.3	13.8	80.0	7.0
11	Ia 961-1	1.061	19.0	25.0	22.8	33.3	4.0
12	Red LaSoda	1.059	2.0	20.3	25.8	52.0	7.3
13	Cherokee	1.070	23.3	24.3	21.5	31.0	3.6
14	Sheridan	1.057	2.0	12.0	19.8	66.3	6.0
15	Rushmore	1.054	21.3	17.8	17.3	43.8	5.2
16	Sebago	1.059	15.0	14.0	19.3	51.8	4.8
17	Merrimack	1.079	15.5	23.8	24.8	36.0	4.3
	Average	1.056	13.5	19.0	20.3	47.2	5.4
	r_{xy}		+0.525*	+0.623**	+0.551*	-0.678**	
	r_{yz}		-0.702**	-0.656**	-0.259	+0.732**	
	r_{xz}						-0.571*

* Exceeds 5% level of significance

** Exceeds 1% level of significance

TABLE VIII

AVERAGE SPECIFIC GRAVITY (x), PERCENTAGES OF FOUR STARCH GRAIN SIZES (y) AND CHIP RATINGS (z) OF SEVENTEEN POTATO VARIETIES GROWN IN EMMET COUNTY IN 1955, TOGETHER WITH THEIR COEFFICIENTS OF CORRELATION

No.	Varieties	Specific Gravity 'x'	Percentages of Starch Grain Sizes (y)				Chip Rating 'z'
			Large - Above 75 microns	Medium 75-50 microns	Small 50-25 microns	V.Small Below 25 microns	
1	Irish Cobbler	1.079	7.3	18.0	25.0	49.8	4.8
2	Early Gem	1.064	0.0	5.5	26.8	67.8	5.6
3	Dazoc	1.071	3.8	14.3	25.5	56.5	4.6
4	Osage	1.076	27.5	28.0	20.3	24.3	4.0
5	Redburt	1.063	0.5	15.8	25.0	58.8	5.3
6	Pungo	1.068	14.5	20.3	21.3	44.0	6.0
7	M.S. 1363	1.070	9.0	18.5	19.8	52.8	5.1
8	Ia 803-3	1.083	19.5	23.2	20.2	37.5	3.4
9	Redkote	1.067	17.3	23.8	21.3	37.3	5.2
10	Waseca	1.061	0.0	7.0	18.5	74.5	4.7
11	Ia 961-1	1.069	1.8	13.0	24.0	61.3	4.0
12	Red LaSoda	1.068	4.5	16.0	21.5	58.0	5.7
13	Cherokee	1.074	1.3	13.8	27.5	57.5	4.5
14	Sheridan	1.080	4.8	14.8	22.5	58.0	4.8
15	Rushmore	1.073	18.0	18.0	20.0	44.0	4.2
16	Sebago	1.066	6.8	16.0	22.0	55.3	4.0
17	Merrimack	1.071	7.5	19.8	21.8	51.0	4.6
	Average	1.071	8.5	16.8	22.5	52.2	4.7
	r_{xy}		+0.443	+0.505*	-0.030	-0.532*	
	r_{yz}		-0.296	-0.199	-0.159	+0.261	
	r_{xz}						-0.514*

* Exceeds 5% level of significance

TABLE IX

AVERAGE SPECIFIC GRAVITY (x), PERCENTAGES OF FOUR STARCH GRAIN SIZES (y) AND CHIP RATINGS (z) OF SEVENTEEN POTATO VARIETIES GROWN IN BAY COUNTY IN 1955, TOGETHER WITH THEIR COEFFICIENTS OF CORRELATION

No.	Varieties	Specific Gravity 'x'	Percentages of Starch Grain Sizes (y)				Chip Rating 'z'
			Large - Above 75 microns	Medium 75-50 microns	Small 50-25 microns	V.Small Below 25 microns	
1	Irish Cobbler	1.061	7.0	17.0	17.8	58.3	4.7
2	Early Gem	1.052	0.0	5.8	14.3	80.0	6.9
3	Dazoc	1.059	1.0	10.8	22.8	65.5	4.7
4	Osage	1.055	24.3	28.8	22.3	24.8	3.8
5	Redburt	1.057	0.8	16.8	21.8	60.8	6.2
6	Pungo	1.062	19.0	25.3	22.5	33.3	4.4
7	M.S. 1363	1.057	17.8	27.5	24.0	30.8	5.3
8	Ia 803-3	1.061	20.8	24.0	23.8	31.5	4.3
9	Redkote	1.049	7.5	20.0	24.0	48.5	5.3
10	Waseca	1.051	0.3	3.0	10.8	86.0	6.8
11	Ia 961-1	1.065	12.0	25.5	25.3	37.3	3.7
12	Red LaSoda	1.057	0.0	5.0	21.8	73.3	6.5
13	Cherokee	1.066	21.2	23.3	23.0	32.5	4.5
14	Sheridan	1.059	2.0	17.0	21.8	59.3	5.6
15	Rushmore	1.057	9.5	21.3	21.3	48.0	5.1
16	Sebago	1.058	10.8	26.0	22.5	40.8	5.4
17	Merrimack	1.060	17.3	25.5	22.8	34.5	4.4
	Average	1.058	10.1	19.0	21.3	49.6	5.1
	r_{xy}		+0.435	+0.437	+0.548*	-0.479*	
	r_{yz}		-0.776**	-0.794**	-0.666**	+0.815**	
	r_{xz}						-0.639**

* Exceeds 5% level of significance

** Exceeds 1% level of significance

TABLE X

AVERAGE SPECIFIC GRAVITY (x), PERCENTAGES OF FOUR STARCH GRAIN SIZES (y), AND CHIP RATINGS (z) OF SEVENTEEN POTATO VARIETIES GROWN IN ARENAC COUNTY IN 1955, TOGETHER WITH THEIR COEFFICIENTS OF CORRELATION

No.	Varieties	Specific Gravity 'x'	Percentages of Starch Grain Sizes (y)				Chip Rating 'z'
			Large - Above 75 microns	Medium 75-50 microns	Small 50-25 microns	V.Small Below 25 microns	
1	Irish Cobbler	1.060	6.8	19.3	21.5	52.5	4.1
2	Early Gem	1.051	0.0	3.3	15.3	81.5	5.9
3	Dazoc	1.064	11.8	18.0	19.8	50.5	4.7
4	Osage	1.066	14.5	28.0	23.8	33.8	3.7
5	Redburt	1.054	0.5	4.3	14.0	81.3	5.4
6	Pungo	1.060	19.0	24.5	21.5	35.0	3.9
7	M.S. 1363	1.056	13.3	25.5	21.3	40.0	6.1
8	Ia 803-3	1.065	19.5	28.5	23.0	29.0	3.9
9	Redkote	1.051	7.5	13.5	20.3	58.8	5.4
10	Waseca	1.059	1.3	13.0	23.0	62.8	4.1
11	Ia 961-1	1.066	9.0	24.8	22.0	44.3	3.4
12	Red LaSoda	1.052	0.0	4.8	16.3	79.0	6.3
13	Cherokee	1.065	12.3	27.0	23.5	27.3	3.9
14	Sheridan	1.060	0.0	14.8	19.5	65.8	4.9
15	Rushmore	1.061	18.5	24.5	21.5	30.5	3.7
16	Sebago	1.062	16.3	21.5	18.8	43.5	3.9
17	Merrimack	1.069	11.0	20.8	20.5	47.8	4.5
	Average	1.060	9.5	18.6	20.3	51.6	4.6
	r_{xy}		+0.576*	+0.768**	+0.672**	-0.723**	
	r_{yz}		-0.589*	-0.723**	-0.716**	+0.704**	
	r_{xz}						-0.789**

* Exceeds 5% level of significance

** Exceeds 1% level of significance

TABLE XI

AVERAGE SPECIFIC GRAVITY (x), PERCENTAGES OF FOUR STARCH GRAIN SIZES (y) AND CHIP RATINGS (z) OF SEVENTEEN POTATO VARIETIES GROWN AT ALLEGAN COUNTY IN 1955, TOGETHER WITH THEIR COEFFICIENTS OF CORRELATION

No.	Varieties	Specific Gravity 'x'	Percentages of Starch Grain Sizes (y)				Chip Rating 'z'
			Large - Above 75 microns	Medium 75-50 microns	Small 50-25 microns	V.Small Below 25 microns	
1	Irish Cobbler	1.071	7.8	22.0	21.3	49.0	4.4
2	Early Gem	1.059	0.0	6.0	23.0	71.0	6.0
3	Dazoc	1.062	1.8	13.3	17.0	68.0	5.7
4	Osage	1.070	26.3	24.0	19.3	30.5	3.7
5	Redburt	1.064	0.0	4.5	21.3	74.3	5.7
6	Pungo	1.064	8.0	19.8	19.8	52.5	4.9
7	M.S. 1363	1.062	5.3	18.0	22.0	54.3	6.0
8	Ia 803-3	1.060	6.0	20.3	21.8	52.0	4.4
9	Redkote	1.058	5.0	18.0	20.0	57.0	4.9
10	Waseca	1.060	1.3	10.0	16.5	72.3	5.8
11	Ia 961-1	1.063	6.5	24.8	23.3	45.5	3.9
12	Red LaSoda	1.064	2.3	10.8	20.5	66.5	5.9
13	Cherokee	1.071	15.0	25.3	24.0	35.8	4.6
14	Sheridan	1.063	3.3	17.3	22.3	57.3	5.5
15	Rushmore	1.072	24.0	22.5	18.5	35.0	3.9
16	Sebago	1.067	9.8	18.5	21.0	50.8	4.0
17	Merrimack	1.081	7.3	26.0	21.8	45.0	3.8
	Averages	1.065	7.6	17.7	20.8	53.9	4.9
	r_{xy}		+0.558*	+0.599*	+0.046	-0.635*	
	r_{yz}		-0.725**	-0.828**	-0.045	+0.845**	
	r_{xz}						-0.626**

* Exceeds 5% level of significance

** Exceeds 1% level of significance

TABLE XII

AVERAGE SPECIFIC GRAVITY (x), PERCENTAGES OF FOUR STARCH GRAIN SIZES (y) AND CHIP RATINGS (z) OF SEVENTEEN VARIETIES COMBINED FROM FIVE LOCATIONS GROWN IN 1955, TOGETHER WITH THEIR COEFFICIENTS OF CORRELATION

No.	Varieties	Specific Gravity 'x'	Percentages of Starch Grain Sizes (y)				Chip Rating 'z'
			Large - Above 75 microns	Medium 75-50 microns	Small 50-25 microns	V.Small Below 25 microns	
1.	Irish Cobbler	1.067	9.4	20.5	21.5	48.8	4.6
2.	Early Gem	1.056	0.0	6.4	20.1	73.5	6.1
3.	Dazoc	1.063	4.6	14.5	22.0	58.9	5.0
4.	Osage	1.066	23.5	27.5	21.1	28.1	3.7
5.	Redburt	1.058	0.6	9.8	19.8	69.9	5.9
6.	Pungo	1.065	18.4	22.4	20.5	38.8	5.0
7.	M.S. 1363	1.060	11.3	22.4	21.4	44.9	5.9
8.	Ia 803-3	1.066	18.0	24.4	22.1	35.7	4.0
9.	Redkote	1.056	10.8	18.9	20.6	49.6	5.3
10.	Waseca	1.056	0.6	7.9	16.5	75.1	5.7
11.	Ia 961-1	1.065	9.7	22.6	23.5	44.3	3.8
12.	Red LaSoda	1.060	1.8	11.4	21.2	65.8	6.3
13.	Cherokee	1.069	14.6	22.7	23.9	38.8	4.2
14.	Sheridan	1.064	2.4	15.2	21.2	61.3	5.4
15.	Rushmore	1.063	18.3	20.8	19.7	41.3	4.4
16.	Sebago	1.063	11.7	19.2	20.7	48.4	4.4
17.	Merrimack	1.073	11.7	23.2	22.3	42.9	4.3
	Average	1.063	9.8	18.2	21.1	50.9	4.9
	r_{xy}		+0.566*	+0.719**	+0.679**	-0.692**	
	r_{yz}		-0.756**	-0.802**	-0.502*	+0.799**	
	r_{xz}						-0.744**

* Exceeds 5% level of significance

** Exceeds 1% level of significance

TABLE XIII

AVERAGE SPECIFIC GRAVITY (x), CALCULATED PERCENTAGES OF FOUR VOLUMES OF STARCH GRAINS (y) AND CHIP RATING (z) OF SEVENTEEN POTATO VARIETIES GROWN IN MONTCALM COUNTY IN 1955, TOGETHER WITH THEIR COEFFICIENTS OF CORRELATION

No.	Varieites	Specific Gravity 'x'	Percentages of Starch Grain Sizes (y)				Chip Rating 'z'
			Large - Above 75 microns	Medium 75-50 microns	Small 50-25 microns	V.Small Below 25 microns	
1	Irish Cobbler	1.062	34	37	19	10	5.0
2	Early Gem	1.056	0	30	34	36	6.1
3	Dazoc	1.058	10	32	33	25	5.7
4	Osage	1.059	42	36	15	7	3.2
5	Redburt	1.052	4	20	28	48	6.8
6	Pungo	1.068	53	27	12	8	6.0
7	M.S. 1363	1.054	25	38	21	16	6.9
8	Ia 803-3	1.061	43	33	17	7	4.0
9	Redkote	1.055	34	30	17	19	5.9
10	Waseca	1.047	0	19	26	55	7.0
11	Ia 961-1	1.061	37	35	19	9	4.0
12	Red LaSoda	1.059	5	41	32	22	7.3
13	Cherokee	1.070	42	31	18	9	3.6
14	Sheridan	1.057	7	29	30	34	6.0
15	Rushmore	1.054	43	27	16	14	5.2
16	Sebago	1.059	36	25	20	19	4.8
17	Merrimack	1.079	32	35	22	11	4.3
	Average	1.056	26.3	31.0	22.3	20.4	5.4
	r_{xy}		+0.522*	+0.534*	-0.325	-0.663**	
	r_{yz}		-0.689**	-0.266	+0.564*	+0.681**	
	r_{xz}						-0.571*

* Exceeds 5% level of significance

** Exceeds 1% level of significance

TABLE XIV

DENSITY OF DIFFERENT POTATO STARCH GRAIN SIZES FROM VARIETY CHEROKEE GROWN AT MONTCALM COUNTY IN 1955

Sample No.	Specific Gravity of tuber	Starch Grain Sizes		
		Large Above 60 microns	Medium 60 to 30 microns	Small Below 30 microns
1	1.084	1.579	1.558	1.531
2	1.082	1.579	1.555	1.532
Average	1.083	1.579	1.557	1.531

TABLE XV

ANALYSIS OF VARIANCE FOR DENSITY OF POTATO STARCH GRAIN SIZES

Source	d.f.	M.S.	'F'
Total	5	0.000454	
Between Sizes	2	0.001130	376**
Within Sizes	3	0.000003	

** Exceeds 1% level of significance

Relationship of Percentage of Sizes of Starch Grains To Specific Gravity

Group 1 - large - above 75 microns. The between variety correlation for percentage of large starch grains versus specific gravity was positive at each county, but was statistically significant only at Montcalm, Emmet and Allegan Counties (Table XVI). The variety averages over all locations (Table XII) when correlated also gave a positive significant correlation, r = +0.566. This means that as the percentage of large starch grains increased from one variety to another, the specific gravity also increased (Figure 9).

The correlation within varieties was highly significant and positive between percentage of large starch grains and specific gravity in all five locations. The highest correlation was +0.949 at Emmet County and the lowest was +0.658 at Arenac County (Table XVII). When all locations were put together in a two-way table the correlation within varieties was also highly significant and positive, r being + .523.

Group 2 - medium - between 75 to 50 microns. The between variety correlation between percentage of medium starch grains and specific gravity was positive at all locations and also statistically significant, excepting Bay County. The variety averages over all locations had a highly significant correlation, r +0.719 (Table XVI). This may be seen in Figure 10.

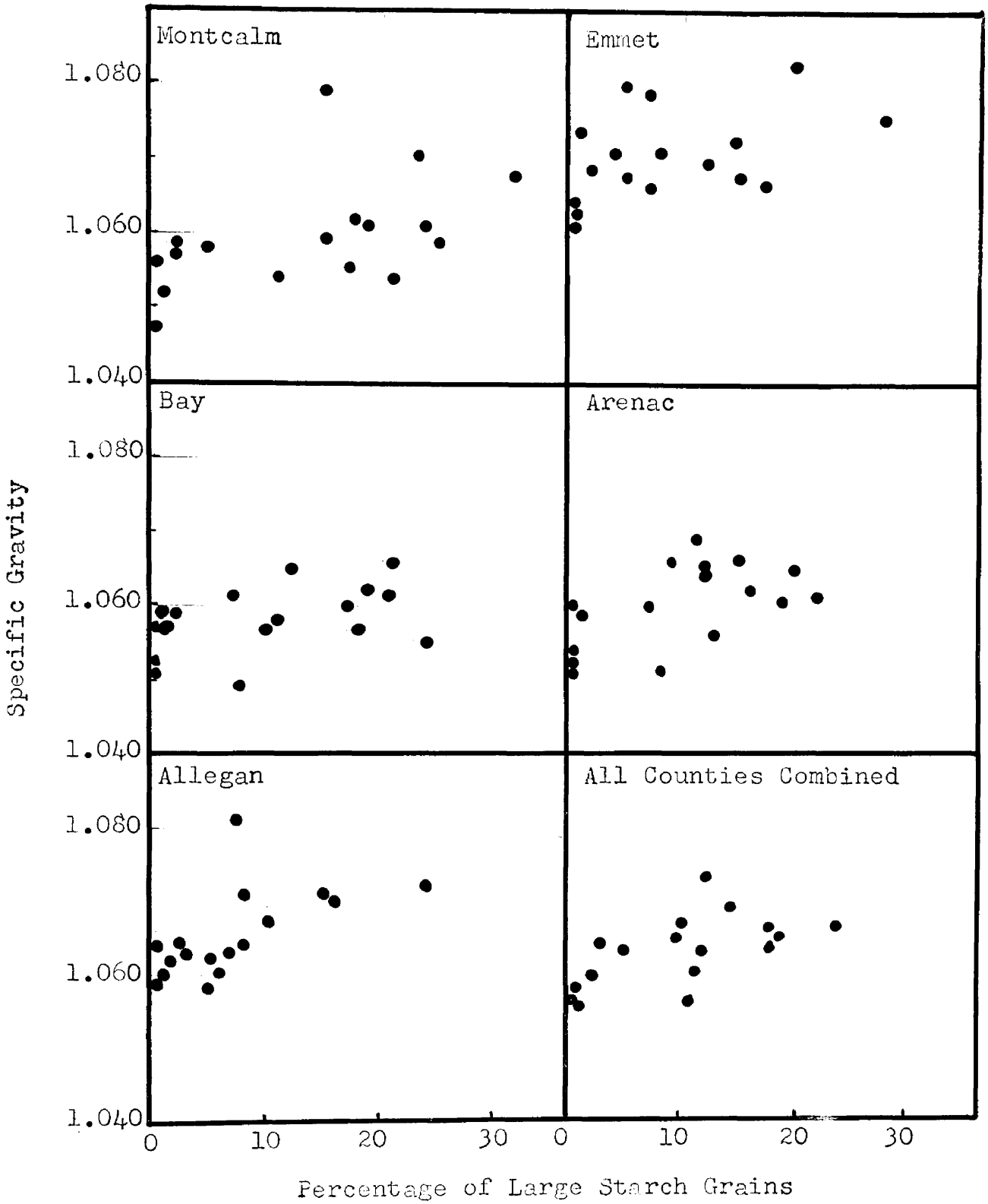


Figure 9: Scatter diagrams of variety means between percentage of large starch grains, above 75 microns size, and specific gravity obtained from potato tubers grown at five counties in Michigan, 1955 crop.

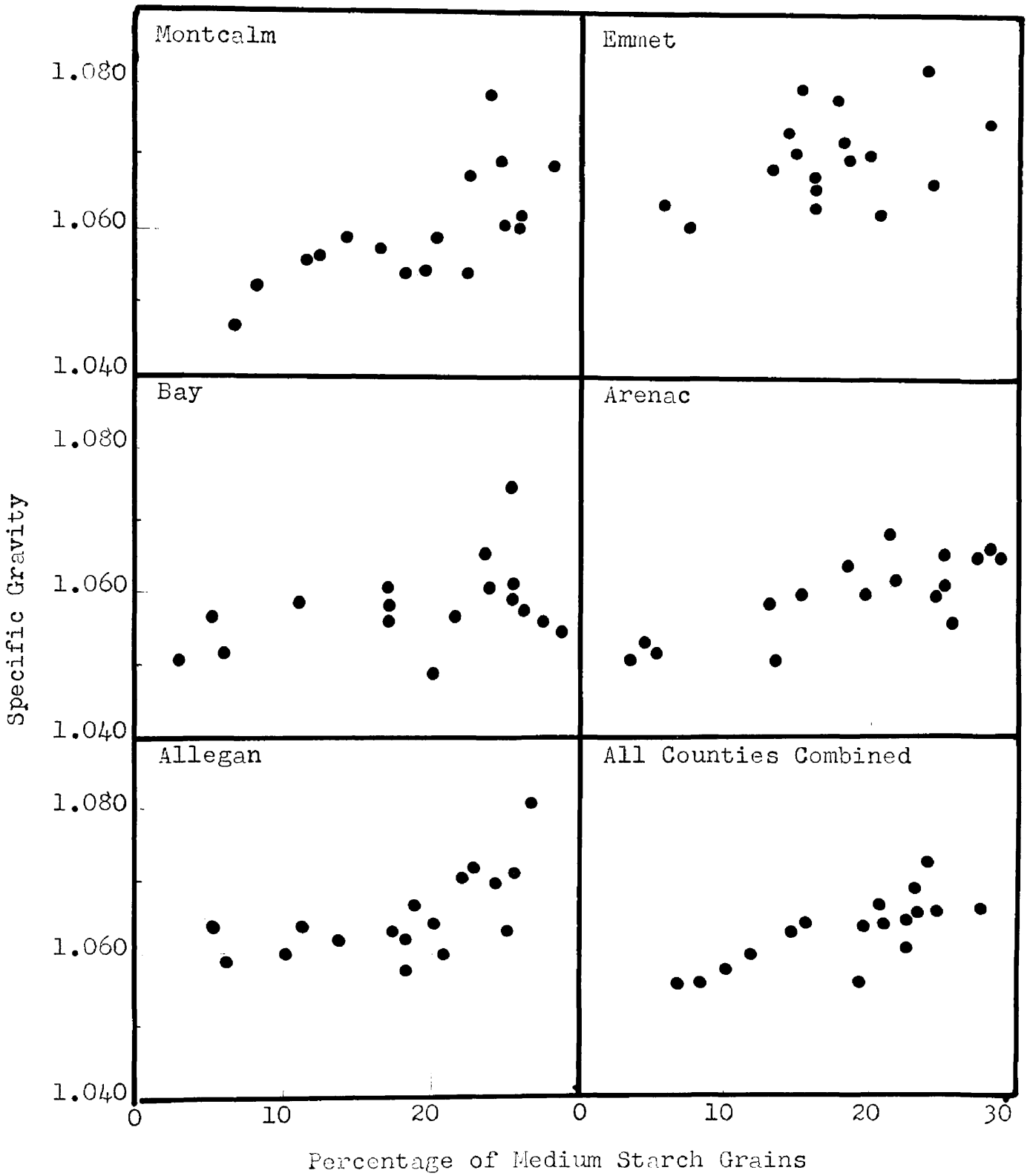


Figure 10: Scatter diagrams of variety means between percentage of medium starch grains, between 75 to 50 microns size, and specific gravity obtained from potato tubers grown at five counties in Michigan, 1955 crop.

The correlation within varieties between percentage of medium starch grains and specific gravity was positive and highly significant at all locations, r ranging from +0.548 at Emmet County to +0.822 at Montcalm County (Table XVII). The correlation within varieties from the two-way table of variety x location also showed a highly significant and positive correlation, r +0.766 (Table XVII).

Group 3 - small - between 50 to 25 microns. The between variety correlation for percentage of small starch grains versus specific gravity was positive and statistically significant at three counties, Montcalm, Bay and Arenac (Table XVI and Figure 11). At the other two counties, Emmet and Allegan, they were not significantly different from zero. This shows that at three locations specific gravity increased with the percentage of small starch grains. The coefficient was positive and highly significant, r +0.679, when the variety averages over all counties were correlated (Table XII).

The correlation within varieties was positive at all locations and significant at Bay, Arenac and Allegan Counties. (Table XVII)

Group 4 - very small - less than 25 microns. The percentage of very small starch grains and specific gravity were negatively correlated between varieties at all the five locations, individually or combined. The coefficients of correlation were statistically significant (Table XVI). This means that as the percentage of very small starch grains increased the specific gravity decreased (Figure 12).

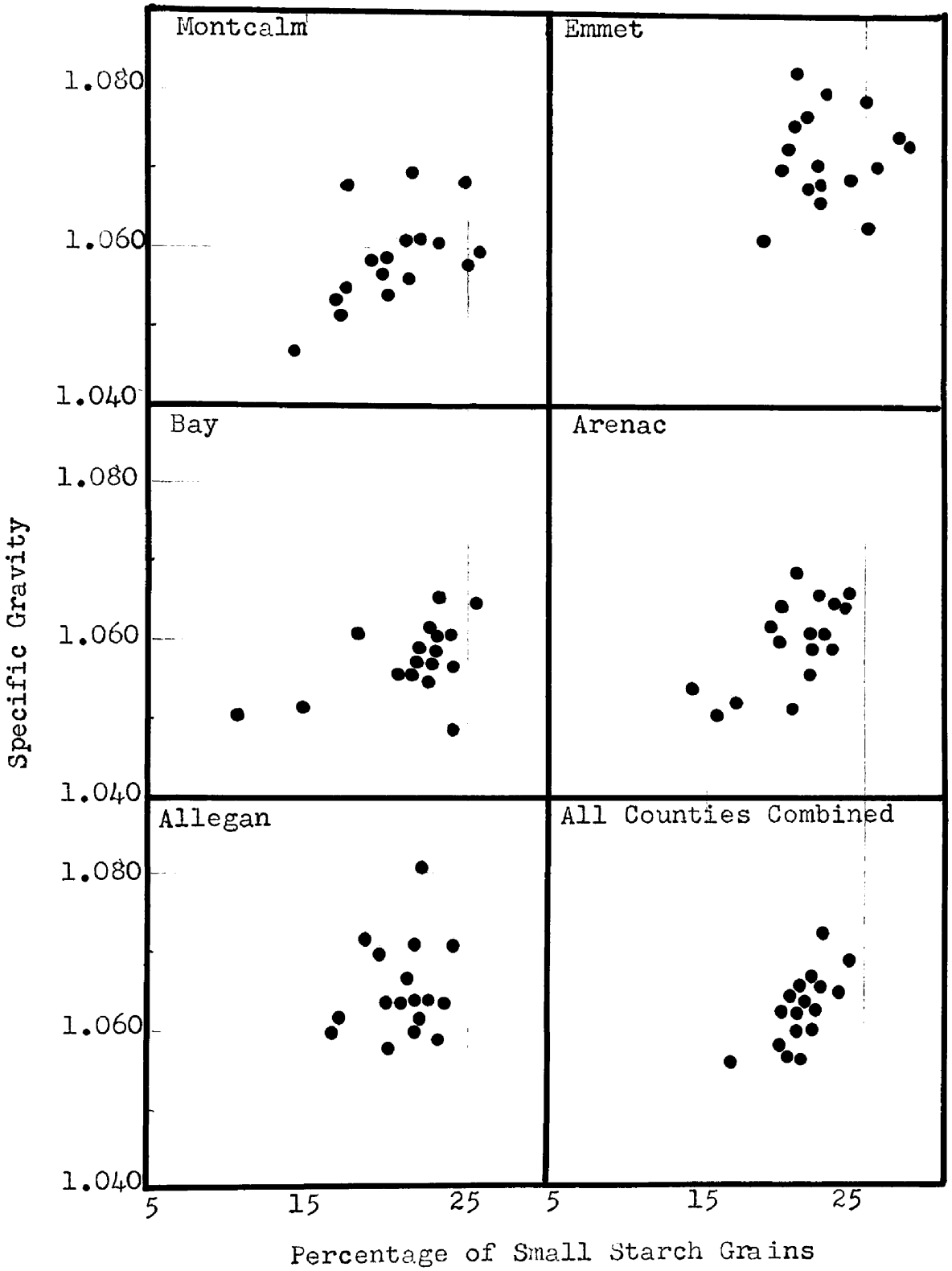


Figure 11: Scatter diagrams of variety means between percentage of small starch grains, between 50 to 25 microns size, and specific gravity obtained from potato tubers grown at five counties in Michigan, 1955 crop.

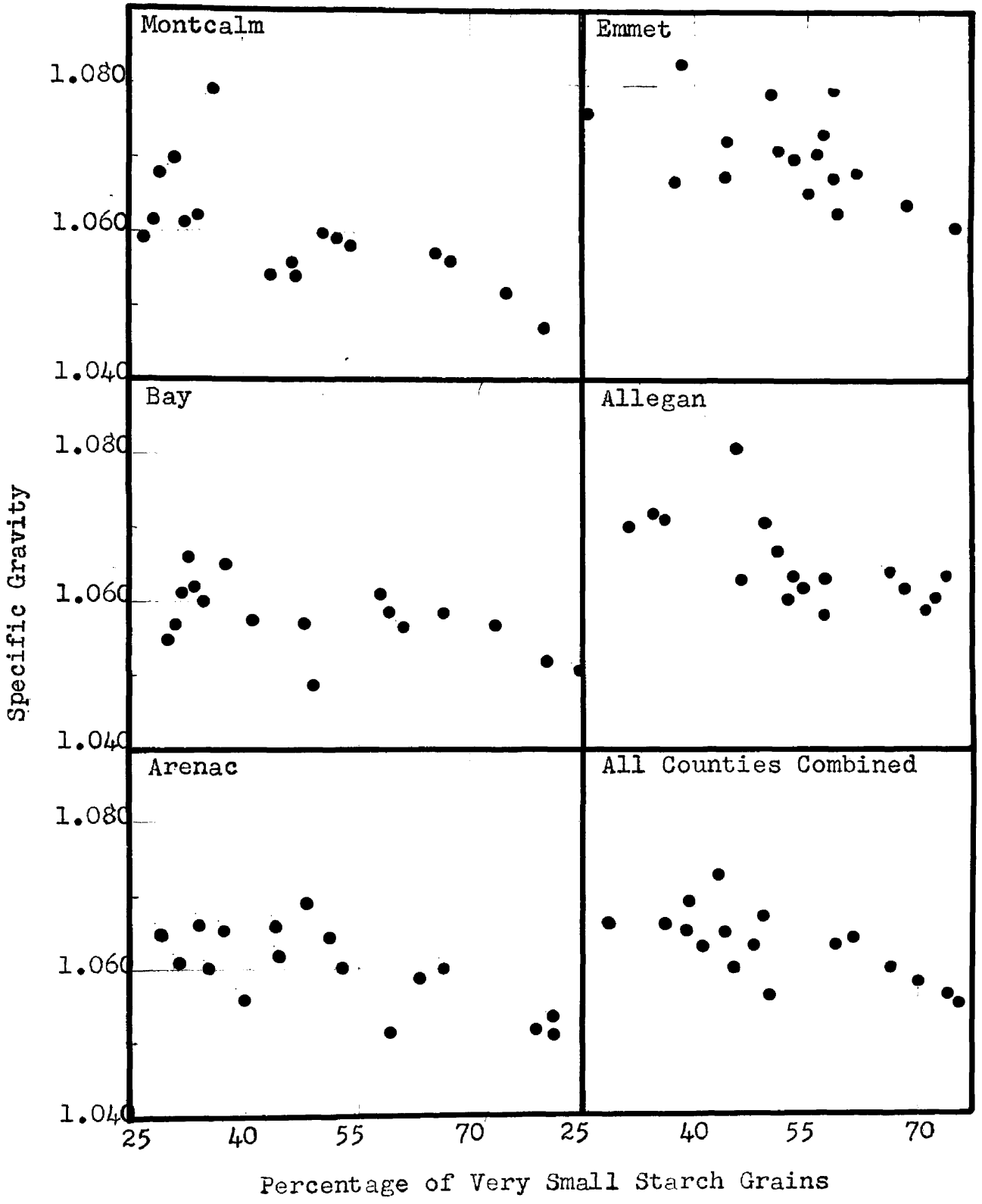


Figure 12: Scatter diagrams of variety means between percentage of very small starch grains, less than 25 microns size, and specific gravity obtained from potato tubers grown at five counties in Michigan, 1955 crop.

The within varieties correlations between percentage of very small starch grains and specific gravity at all counties were negative, strong (all greater than -0.810) and highly significant. The correlation within varieties from the two-way table of variety x location was also highly negatively correlated, r = -0.569 (Table XVII).

Relationship of Percentage of Sizes of Starch Grains to Chip Color Rating

Group 1 - large - above 75 microns. The between variety correlations between the percentage of large starch grains and chip rating were negative at all counties, individually and combined and were statistically significant at all but Emmet County (Table XVI and Figure 13). Thus varieties with a large percentage of large starch grains tended to produce light colored chips. When considering the within variety correlation the coefficient was also negative but was significant at only three counties, Montcalm, Bay and Allegan. The correlation within varieties from the two-way table of variety x location was significant and negative between the two factors. (Table XVII).

Group 2 - medium - between 75 to 50 microns. All individual counties, except Emmet, showed negative and highly significant variety correlations between percentage of medium starch grains and chip rating (Table XVI, Figure 14). The correlations within varieties were negative and significant only at Montcalm and Bay County, r = -0.647 and -0.531, respectively.

TABLE XVI

COEFFICIENTS OF CORRELATION FOR VARIETIES BETWEEN SPECIFIC GRAVITY (x) AND PERCENTAGE OF STARCH GRAINS (y), BETWEEN PERCENTAGE OF STARCH GRAINS (y) AND CHIP RATING (z) AND BETWEEN SPECIFIC GRAVITY (x) AND CHIP RATING (z) BY LOCATIONS AND ALL LOCATIONS COMBINED

Starch Grain Size	r	Montcalm Table 7	Emmet Table 8	Bay Table 9	Arenac Table 10	Allegan Table 11	All 1 Locations Table 12
Group 1 - Large	xy	+0.525*	+0.443	+0.435	+0.576*	+0.558*	+0.566*
Above 75 microns	yz	-0.702**	-0.296	-0.776**	-0.589*	-0.725**	-0.756**
Group 2-Medium-	xy	+0.623**	+0.505*	-0.437	+0.768**	+0.599*	+0.719**
75 to 50 microns	yz	-0.656**	-0.199	-0.794**	-0.723**	-0.828**	-0.802**
Group 3- Small	xy	+0.551*	-0.030	+0.548*	+0.672**	+0.046	+0.679**
50 to 25 microns	yz	-0.259	-0.159	-0.666**	-0.716**	-0.045	-0.502*
Group 4-V.Small	xy	-0.678**	-0.532*	-0.479*	-0.723**	-0.635**	-0.692**
Below 25 microns	yz	+0.732**	+0.261	+0.815**	+0.704**	+0.845**	+0.799**
Entire tuber	xz	-0.571*	-0.514*	-0.639**	-0.789**	-0.626**	-0.744**

* Exceeds 5% level of significance

** Exceeds 1% level of significance

1 The coefficients were obtained from the two-way tables of variety x location rather than from averages of the individual location correlations.

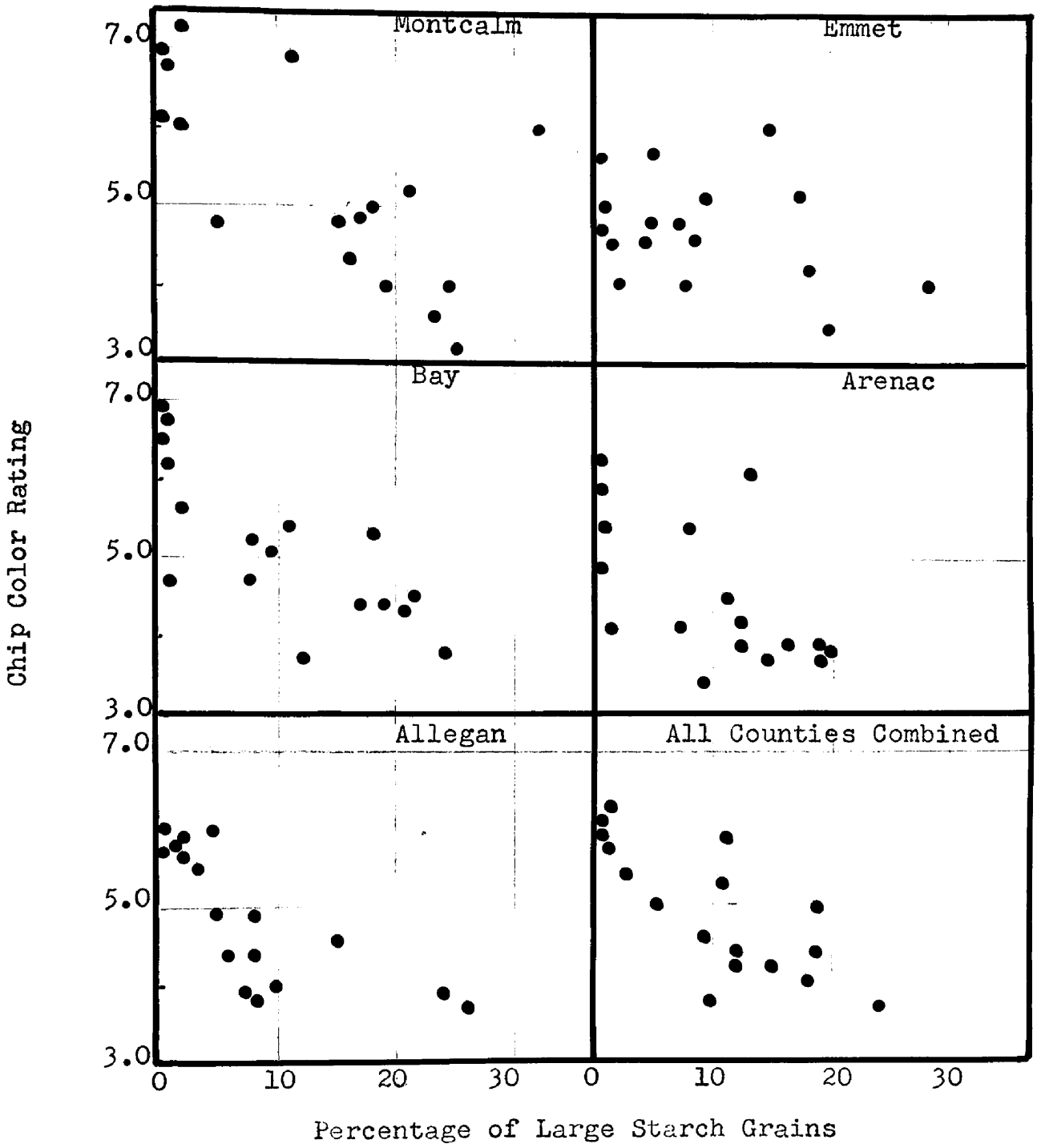


Figure 13: Scatter diagrams of variety means between percentage of large starch grains and chip color rating obtained from potato tubers grown at five counties in Michigan, 1955 crop.

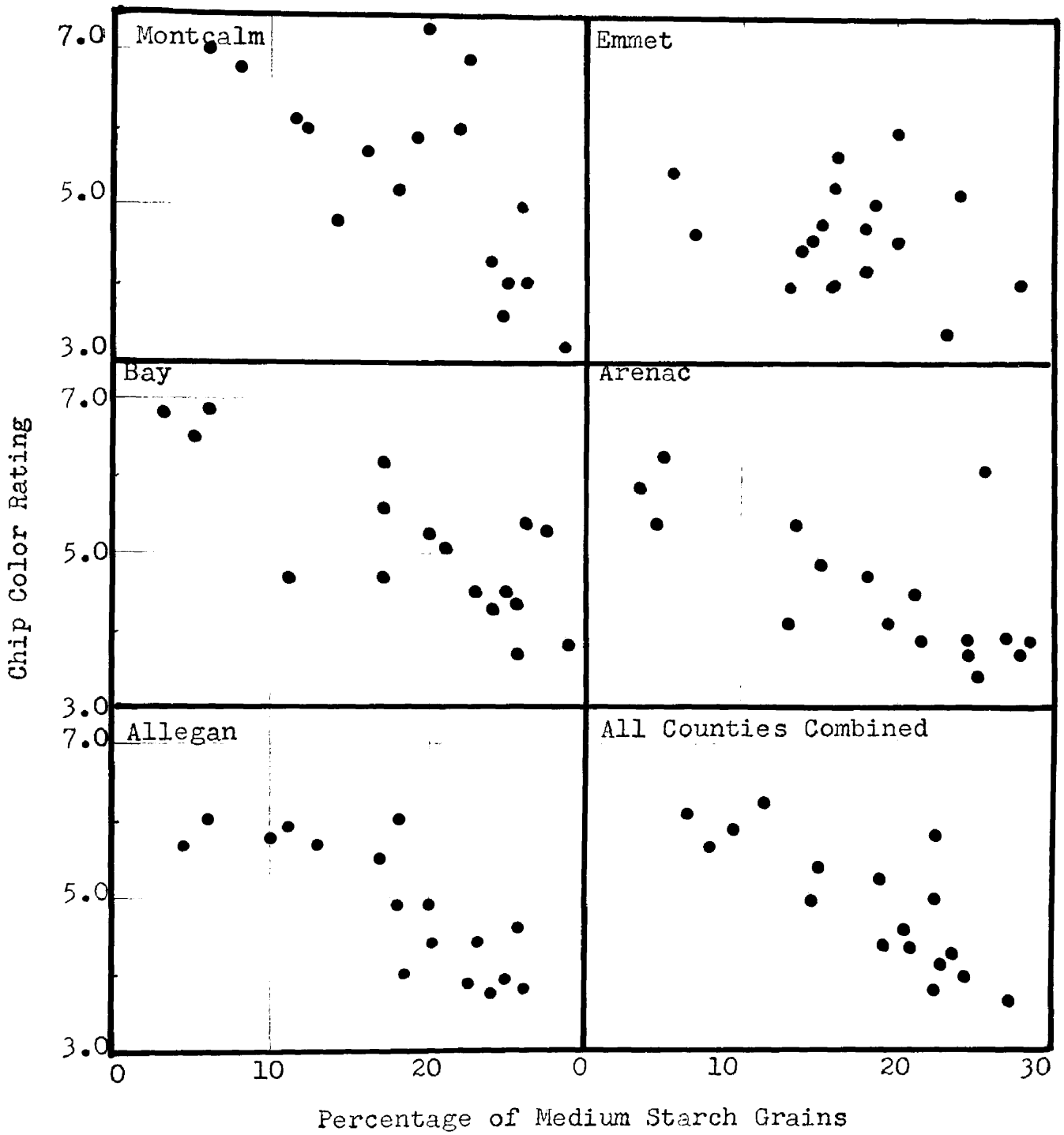


Figure 14: Scatter diagrams of variety means between percentage of medium starch grains and chip color rating obtained from potato tubers grown at five counties in Michigan, 1955 crop.

The correlation within varieties from the two-way table of variety x location between percent medium starch size and chip rating was negative and significant (Table XII).

Group 3 - small - between 50 to 25 microns. The between variety correlation for percentage of small starch grains versus chip color was negative and highly significant at Bay and Arenac Counties (Table XVI). The combined averages of all the counties also gave a negative significant correlation coefficient, -0.502 (Table XVI). There was no significant correlation within varieties. (Table XVII)

As the percentages of large (above 75 microns), medium (between 75 to 50 microns) and small (between 50 to 25 microns), sizes of starch grains increased in the potato tuber, the lighter were the chips as seen from chip color ratings (Figure 13 to 15).

Group 4 - very small - less than 25 microns. The between variety and within variety correlations between percentage of very small starch grains and chip rating showed positive highly significant correlation at all locations except Emmet County, where it was positive but not significant. (Tables XVI - XVII, Figure 16).

Those varieties which had higher sums of percentages of starch grains above 25 microns, naturally had the lower percentage of very small starch grains - below 25 microns -

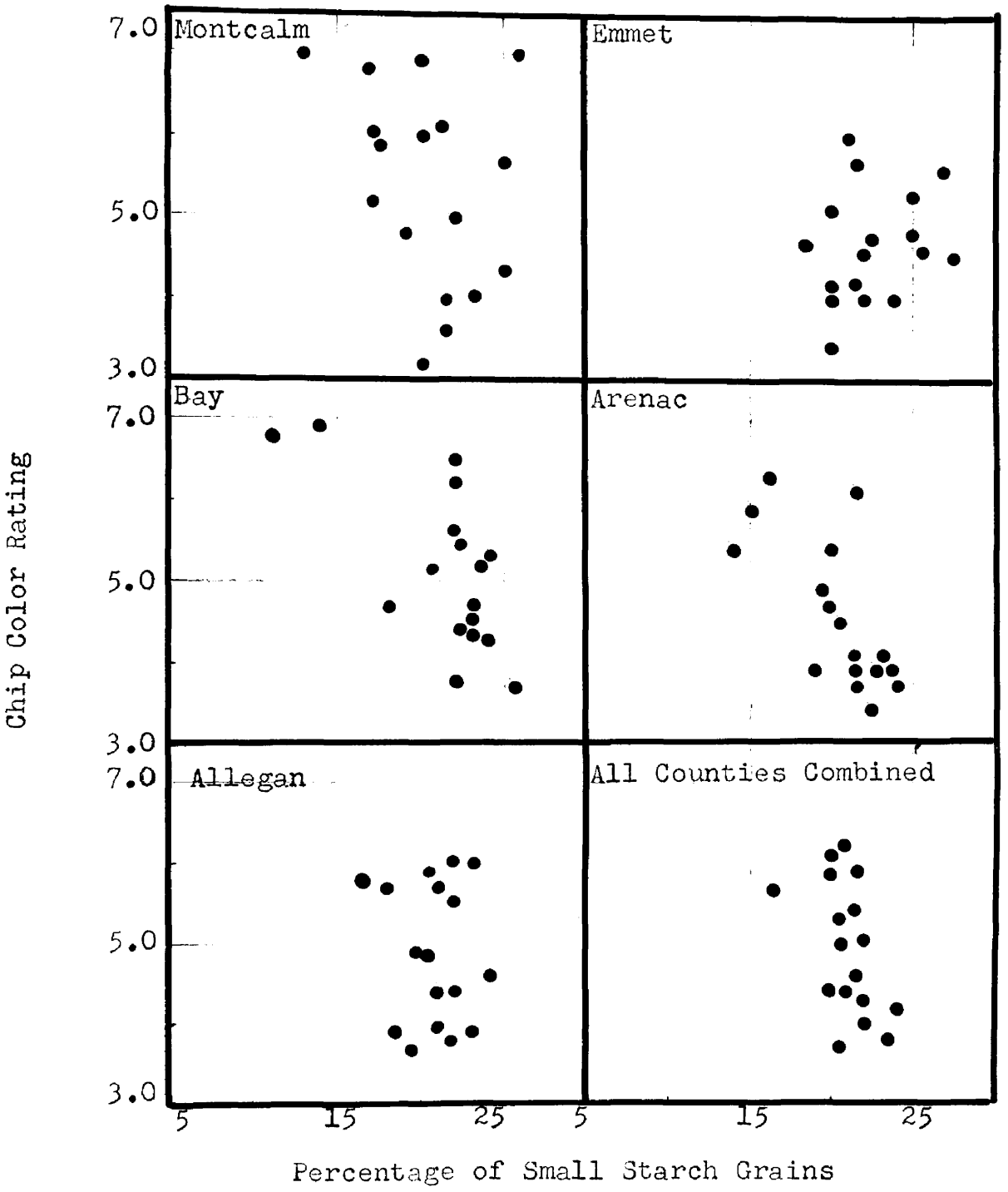


Figure 15: Scatter diagrams of variety means between percentage of small starch grains and chip color rating obtained from potato tubers grown at five counties in Michigan, 1955 crop.

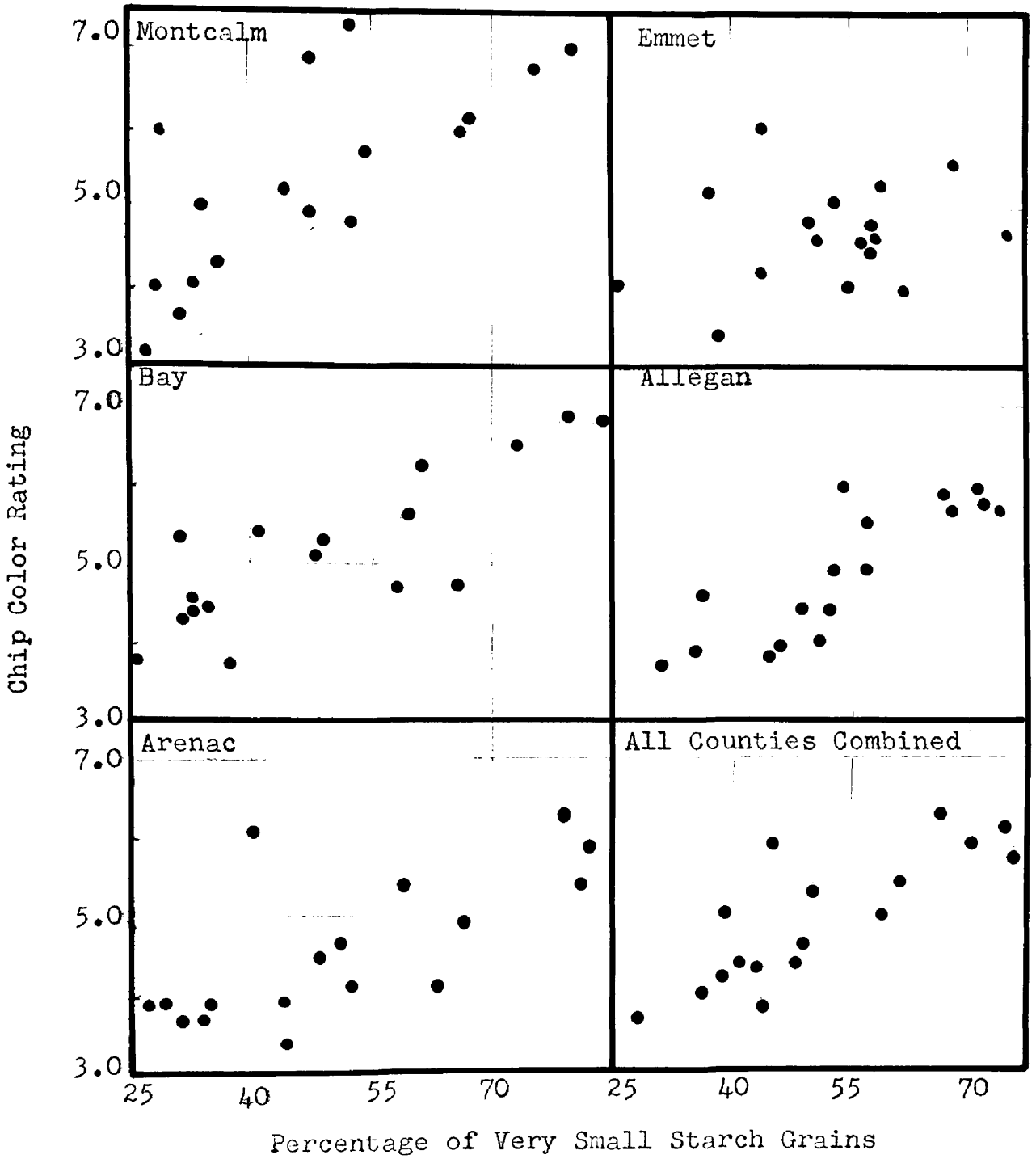


Figure 16: Scatter diagrams of variety means between percentage of very small starch grains and chip color rating obtained from potato tubers grown at five counties in Michigan, 1955 crop.

and were lighter in chip color (Table VII to XII). These varieties, which were lower in percentages of the three large sizes of starch grains had higher percentages of very small starch grains and were darker in chip color (Figures 13 to 16).

Relationship Of Specific Gravity To Chip Rating

The between variety correlations for specific gravity versus chip color rating were negative and statistically significant at each of five counties or when all were combined (Table XVI). From examination of Figure 17 it may be seen that as the specific gravity of a tuber increased, the chips became lighter in color, irrespective of location.

The correlations within varieties at all counties were negative and significant. The correlation within varieties from the two-way table of variety x location between specific gravity and chip rating was -0.475 and highly significant (Table XVII).

Relationship Of Percentage Of Volume Of Starch Grain Sizes To Specific Gravity And Chip Rating

From the variety correlation between volume of different starch grain sizes and specific gravity, it was determined that the percentages of volume of large and medium starch grains have positive and significant correlations (Table XIII). The other two sizes - small and very small - had negative correlations and only that for very small starch grains was

TABLE XVII

COEFFICIENTS OF CORRELATION WITHIN VARIETIES BETWEEN SPECIFIC GRAVITY (x) AND PERCENTAGE OF STARCH GRAINS (y), BETWEEN PERCENTAGE OF STARCH GRAINS (y) AND CHIP RATING (z) AND BETWEEN SPECIFIC GRAVITY (x) AND CHIP RATING (z) BY LOCATIONS AND ALL LOCATIONS COMBINED

Starch Grain Size	r	Montcalm	Emmet	Bay	Arenac	Allegan	All Locations[1]
Group 1-Large Above 75 microns	xy	+0.683**	+0.949**	+0.754**	+0.658**	+0.671**	+0.523**
	yz	-0.563**	-0.257	-0.312*	-0.174	-0.313*	-0.282*
Group 2-Medium 75 to 50 microns	xy	+0.822**	+0.548**	+0.573**	+0.632**	+0.725**	+0.766**
	yz	-0.647**	-0.258	-0.531**	-0.058	-0.079	-0.260*
Group 3-Small 50 to 25 microns	xy	+0.273	+0.243	+0.443**	+0.302*	+0.388**	+0.233
	yz	-0.213	-0.053	+0.109	-0.134	-0.051	-0.311*
Group 4-V.Small Below 25 microns	xy	-0.810**	-0.812**	-0.852**	-0.878**	-0.872**	-0.569**
	yz	+0.911**	+0.266	+0.625**	+0.298*	+0.508**	+0.391**
Entire tuber	xz	-0.720**	-0.332*	-0.455**	-0.392**	-0.403**	-0.475**

* Exceeds 5% level of significance

** Exceeds 1% level of significance

1 The coefficients were obtained from the two-way tables of variety x location rather than from averages of the individual location correlations.

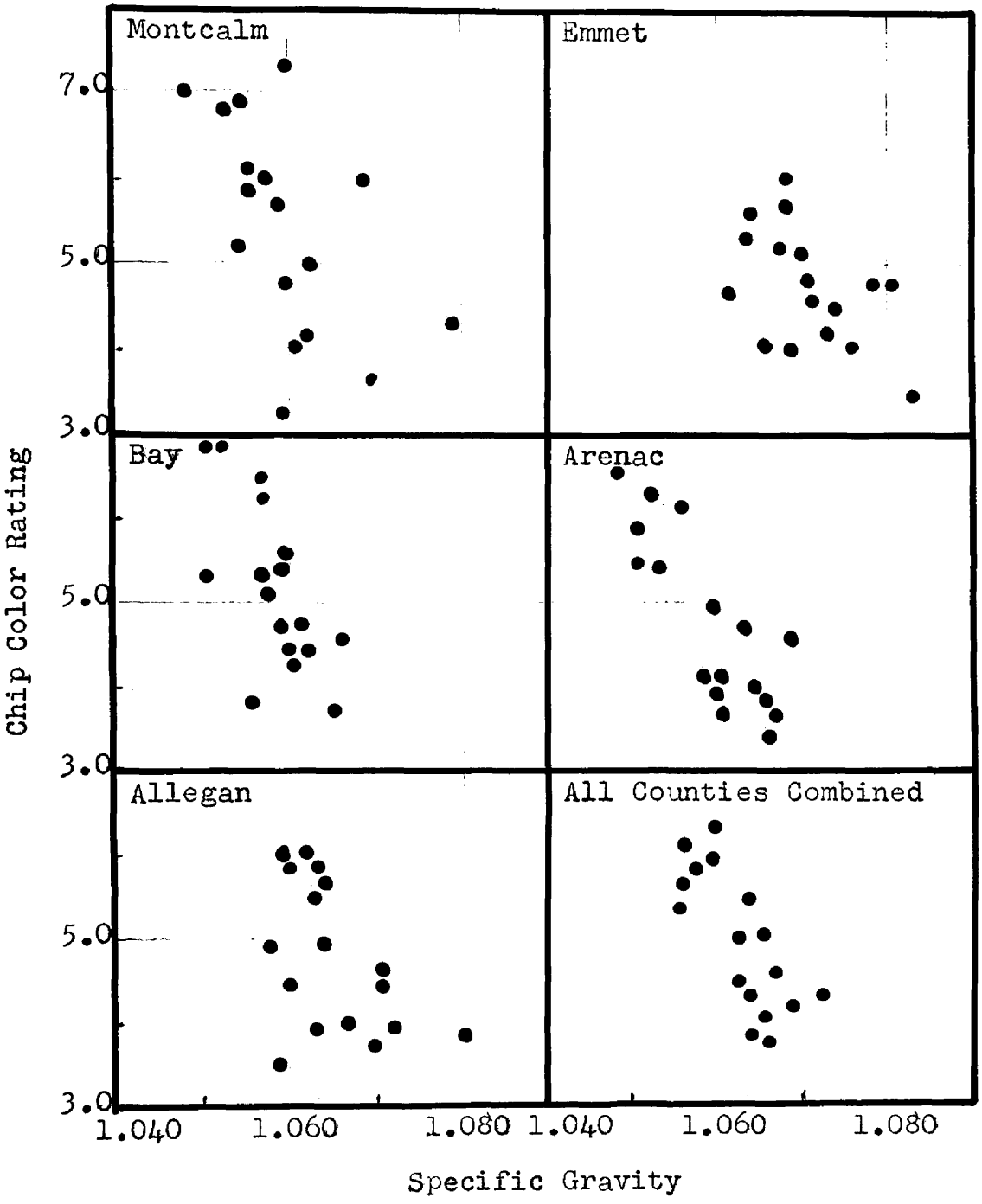


Figure 17: Scatter diagrams of variety means between chip color rating and specific gravity obtained from potato tubers grown at five counties in Michigan, 1955 crop.

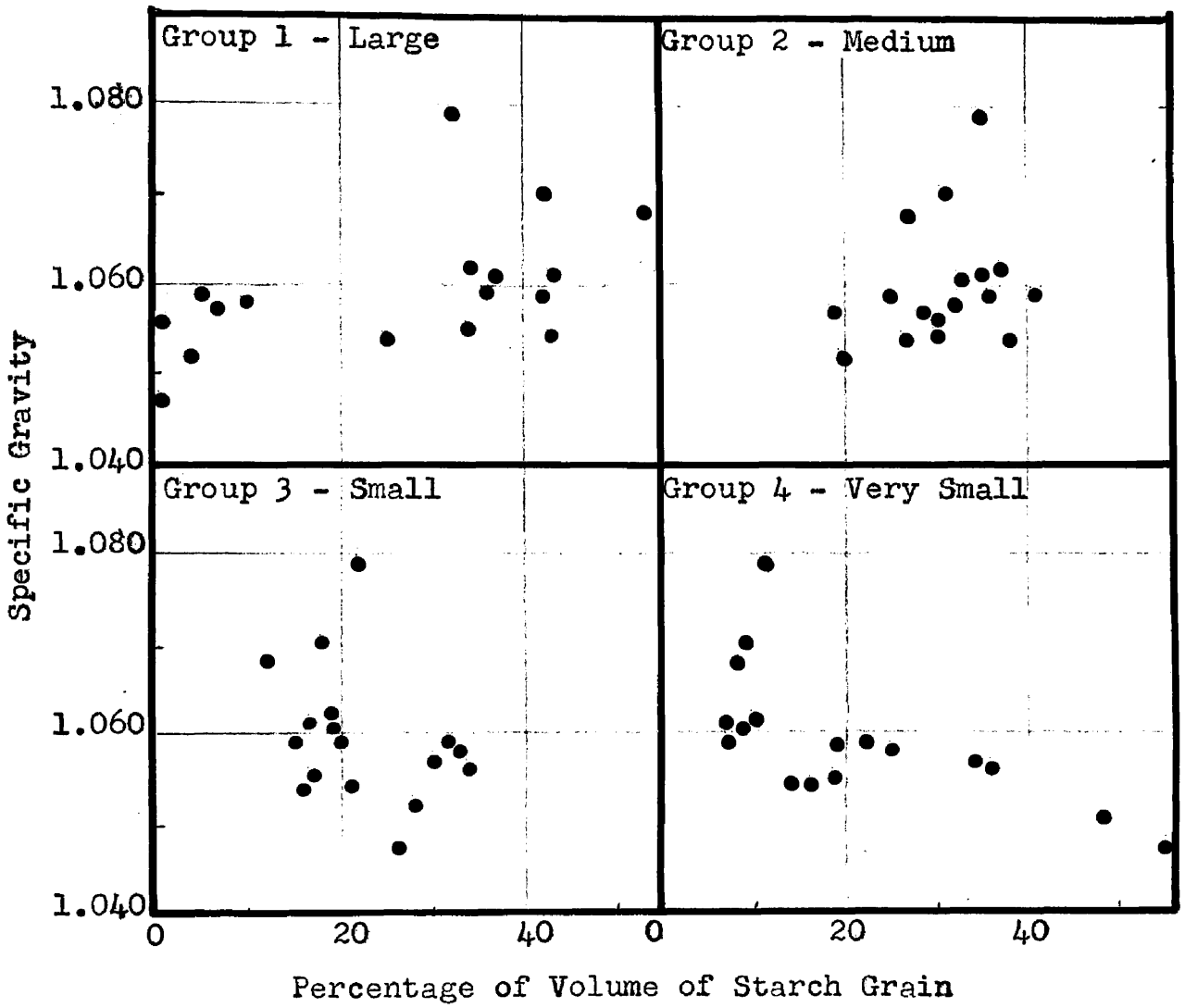


Figure 18: Scatter diagrams of variety means between percentage of volume of starch grains and specific gravity obtained from potato tubers grown at Montcalm County in Michigan, 1955, crop.

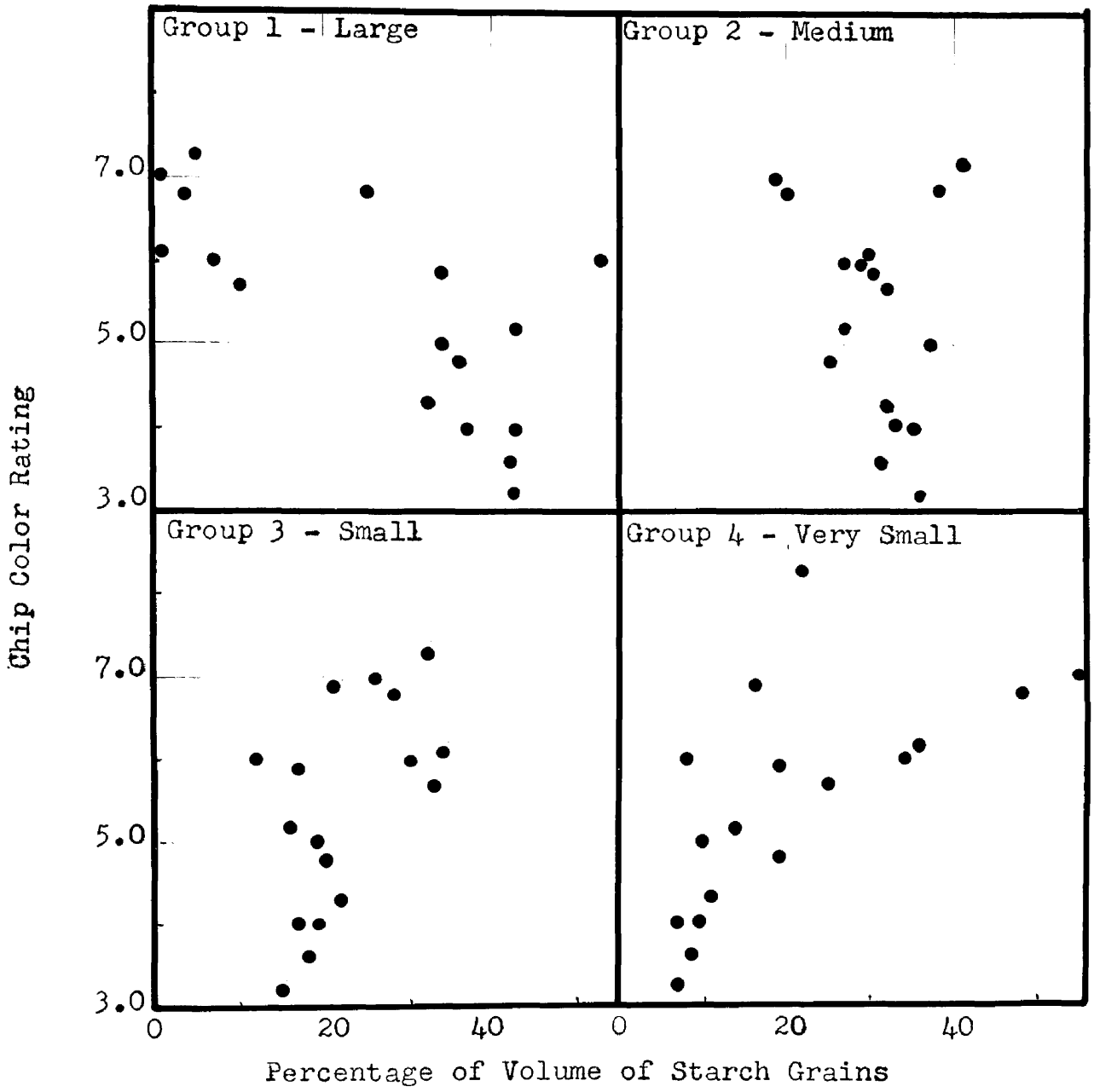


Figure 19: Scatter diagrams of variety means between percentage of volume of starch grains and chip color rating obtained from potato tubers grown at Montcalm County in Michigan, 1955 crop.

significant. On volume basis, as the percentages of large and medium starch grains increased in the tubers of different varieties, the specific gravity also increased and as the percentages of small and very small starch grains increased, the specific gravity decreased.

The same type of trend was noticed in the relationship with chip color rating (Figure 19). The variety correlation between percentage of volume of large starch grain and chip color was negative and highly significant, r -0.689. The correlation between percentage of volume of medium size grains and chip rating was negative but not significant. The correlation between percentage of volume of small and very small starch grains and chip ratings were positive and significant. The higher the percentage of volume of starch grain of the two groups above 50 microns in potato, the lighter the chips, while the percentage of volume of less than 50 microns size, starch grains increased, the darker will be the chips (Figure 19).

Variety Partial Correlation Between Specific Gravity, Percentages Of Starch Grains and Chip Rating

The variety partial correlation, between specific gravity (x) and percentage of starch grain (y) and eliminating chip rating (z), $r_{xy.z}$, was significant only in one case (Table XVIII). The higher the percentage of large, medium and small starch grain, the higher the specific gravity as

TABLE XVIII

COEFFICIENTS OF PARTIAL CORRELATION FOR VARIETIES BETWEEN SPECIFIC GRAVITY (x), PERCENTAGE OF STARCH GRAINS (y) AND CHIP RATINGS (z) BY LOCATIONS AND ALL LOCATIONS COMBINED

Starch Grain Size	r	Montcalm	Emmet	Bay	Arenac	Allegan	All Locations[1]
Group 1-Large	xy.z	+0.202	+0.356	-0.138	+0.224	+0.194	+0.001
Above 75 microns	xz.y	-0.334	-0.468	-0.530*	-0.682**	-0.387	-0.710**
	yz.x	-0.575	-0.088	-0.787**	-0.269	-0.581*	-0.607**
Group 2-Medium	xy.z	+0.406	+0.480	-0.164	+0.467	+0.185	+0.306
75 to 50 microns	xz.y	-0.258	-0.480	-0.534*	-0.529*	-0.290	-0.402
	yz.x	-0.467	+0.083	-0.816**	-0.298	-0.725**	-0.574*
Group 3-Small	xy.z	+0.508*	-0.132	+0.285	+0.249	+0.022	+0.528
50 to 25 microns	xz.y	-0.531*	-0.526*	-0.537*	-0.596*	-0.627**	-0.635**
	yz.x	-0.080	-0.203	-0.537*	-0.410	-0.021	+0.001
Group 4-V.Small	xy.z	-0.465	-0.481	+0.103	-0.385	-0.254	-0.243
Below 25 microns	xz.y	-0.150	-0.859**	-0.489*	-0.570*	-0.020	-0.439
	yz.x	+0.572*	-0.017	+0.826**	+0.316	+0.741**	+0.588*

* Exceeds 5% level of significance
** Exceeds 1% level of significance

1 The coefficients were obtained from the two-way tables of variety x location rather than from averages of the individual location correlations.

seen by the simple (r_{xy}) and partial ($r_{xy.z}$) correlations, whereas the higher the percentage of very small starch grain, the lower the specific gravity (Table XIX).

In partial correlation of $r_{xz.y}$, fourteen values were significant. In general the small size starch grain gave stronger partial correlation values than the other sizes (Table XVIII). From Table XIX, it is clear that the higher the percentage of large, medium and small starch grains the lower the chip rating from both simple (r_{yz}) and partial ($r_{yz.x}$) correlations, whereas the higher the percentage of very small grains, the higher the chip rating.

Out of twenty-four partial correlation values for $r_{yz.x}$, eleven values were significant, three in large size group, three in medium size group, one in small size and four in very small size group (Table XVIII). In general the higher the specific gravity, the lower the chip rating in both simple (r_{xz}) and partial ($r_{xz.y}$) correlations.

TABLE XIX

AVERAGE COEFFICIENTS OF SIMPLE AND PARTIAL CORRELATIONS FOR VARIETIES BETWEEN SPECIFIC GRAVITY (x), PERCENTAGE OF STARCH GRAINS (y), AND CHIP RATINGS (z) REGARDLESS OF SIGN

Correlation	Group 1 Large	Group 2 Medium	Group 3 Small	Group 4 V.Small	Average
Simple - xy	0.517	0.608	0.421	0.623	0.542
Partial - xy.z	0.186	0.335	0.287	0.332	0.285
Difference	0.331	0.273	0.134	0.291	0.257
Simple - yz	0.639	0.667	0.391	0.693	0.598
Partial - yz.x	0.484	0.494	0.209	0.510	0.424
Difference	0.155	0.173	0.182	0.183	0.174
Simple - xz	0.652	0.652	0.652	0.652	0.652
Partial - xz.y	0.518	0.416	0.575	0.421	0.482
Difference	0.134	0.236	0.077	0.231	0.170

DISSCUSSION

Specific Gravity

From the data obtained in the study of the seventeen varieties at the five locations individually or combined, it is evident that there is a varietal difference in the specific gravity of the potato tubers. Early Gem, Redburt, Redkote and Waseca had lower specific gravity than the average at all locations whereas Irish Cobbler, Cherokee and Merrimack had higher specific gravity. It can be concluded that specific gravity is a varietal character. This is in accordance with the findings of Akeley and Stevenson (1,2).

Highly significant differences in specific gravity were found between tubers from the various locations. There was no difference in specific gravity averages of tubers grown on mineral and muck soils. The potatoes from the Emmet County (mineral soil) plots were highest in specific gravity, followed in order by Arenac (muck), Allegan (muck), Montcalm (mineral) and Bay (mineral).

There was also sizeable difference in the specific gravity within a variety which shows that the specific gravity of a potato tuber is influenced not only by the varietal characteristic but also the environmental conditions.

Percentage Of Sizes Of Starch Grain

The starch content of a tuber is in granule form and these granules are in various proportions of different sizes. In this experiment, these sizes were classified into four groups - large - above 75 microns, medium - between 75 to 50 microns, small - between 50 to 25 microns and very small - less than 25 microns. It was found comparatively easy to obtain consistent readings of percentage of large and of very small starch grains whereas with the both intermediate sizes estimate were less reliable. The proportions of the above four sizes vary among the different varieties as shown by the data, (Tables VII to XII). Other workers, Johnson and Boyle (28), Fitch and Barnet (21) and Barham et al (5) reached the same conclusion that starch grain size varied in potato varieties.

Varieties could be classified into two groups. The first group had a large percentage of large and medium starch grains and a low percentage of very small grains. The other group had a large percentage of very small starch grains. Osage, Pungo, Ia 803-3, Ia 961-1, Cherokee, Rushmore and Merrimack can be classified in the first group while Early Gem, Dazoc, Redburt, Waseca, Red LaSoda and Sheridan were in the group with a high percentage of very small starch grains. Thus the findings show that the proportions of these different starch grain sizes could be considered a varietal characteristic, which is in agreement with the findings of Veselovsky (44).

There were differences in the percentages of large, medium and very small starch grains due to the effects of location but only the variation in large starch grains was significant. There were also noticeable differences in the percentages of large, medium and very small starch grain sizes in tubers within a variety. It may be concluded that the percentages of different starch grain sizes are influenced not only by the varietal characteristics but also by the environmental conditions.

Chip Color Rating

From the observations of seventeen potato varieties from five locations it is evident that the color of potato chips was a varietal characteristic (Tables VII to XII). This result is in accordance with those of Wright and Whiteman (50), Wright, et al (51) and Denny and Thornton (15). Osage produced the lightest color potato chips. Chips from Irish Cobbler, Osage, Ia 803-3, Ia 961-1, Cherokee, Rushmore, Sebago and Merrimack potato tubers were desirable where as Early Gem, Redburt, M.S. 1363, Redkote, Waseca, Red LaSoda and Sheridan made undesirable chips from color point of view. Smith (37) is of the opinion that the color of potato chips is a large factor in the quality of chips. Hence, the above potato varieties could be classified as satisfactory or unsatisfactory for potato chip manufacture.

Highly significant differences in chip color ratings were found between locations. The average chip color produced from potato tubers of varieties on muck soil was lighter than that from tubers produced on mineral soil. There were sizeable differences in the color of chips from tubers of any one variety taken from one location. Hence, it could be inferred that the chipping quality of a potato tuber depends upon the variety of the potato and the environmental condition where it is grown.

Relationship Of Percentage Of Sizes Of Starch Grains To Specific Gravity

The percentages of the three larger - size groups, (those above 25 microns) showed positive correlations between the percentage of starch grains and the specific gravity of the tuber. As the percentage of starch grains above 25 microns in size increased in the tuber, the specific gravity increased, irrespective of location. There was a negative correlation between percentage of very small starch grains, less than 25 microns in size, and specific gravity of the tuber. This shows that as the percentage of very small starch grains increases in the tuber, the specific gravity decreases in the potato varieties. It is evident from this that the specific gravity of the tubers was related to the proportions of sizes of starch grains in the tuber, and that both are varietal characteristics as discussed previously.

The three different sizes of starch extracted from Cherokee potato tubers, showed different starch densities. It is evident from the data (Table XIV) that as the starch grains increase in size, their density also increases.

Previous investigations by Burton (10) have shown high correlation (+0.947) between specific gravity and starch content. Since the starch content is in the form of discrete starch grains. The present results indicate that the proportions of different sizes of starch grains could be one of the factors influencing specific gravity.

Comparatively speaking, tubers from Emmet County plots had a high specific gravity but not a high percentage of large starch grains. (Figure 9).

From Figure 20, it may be seen that Emmet County experienced a dry summer. When compared to other counties it had the lowest precipitation (8.45 inches) during the growing season (Appendix 1). It had half normal the rainfall coupled with a higher average temperature than normal years.

The correlation within varieties showed highly significant coefficients as was true in the case of variety means. This indicates that even after the effects of varieties were taken out, the within variety residuals of both factors were positively associated. This relationship indicates that within a variety, apart from varietal influence, the higher the percentage of large starch grains in the tuber the higher the specific gravity of the tuber.

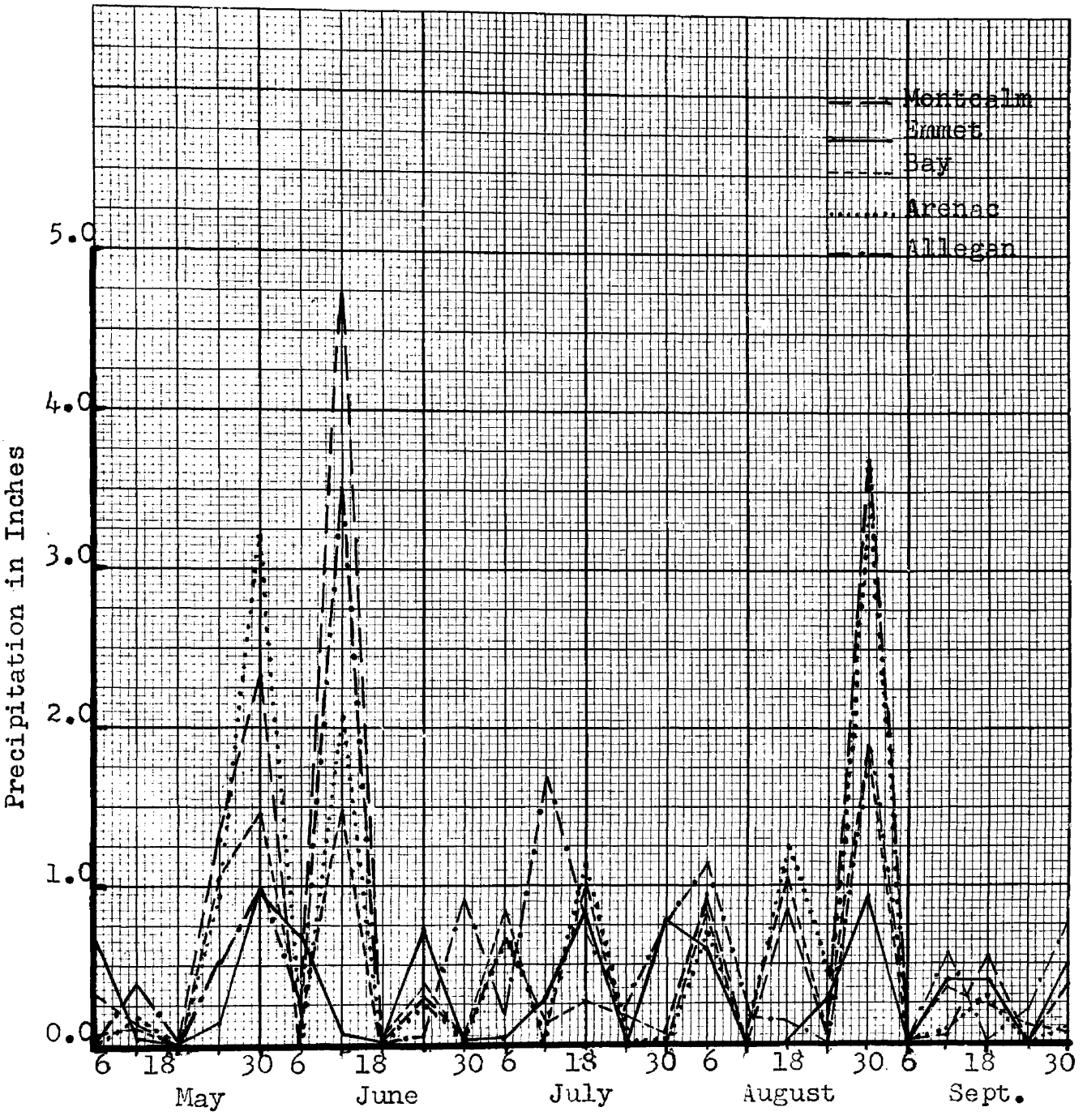


Figure 20: Weekly precipitation during five months in 1955 at five locations in Michigan.

For purposes of observation it was convenient to estimate the proportion of the area occupied by starch grains of various sizes. If one will assume that the layer of starch grains was one grain deep in each case, the proportionate volume in any grain size could be obtained by multiplying the area by the average thickness of the grains of that particular size. In general the correlations between a proportionate volume of starch grain and specific gravity and chip quality were virtually the same as when the area of starch grains was used rather than the calculated volume.

The correlations of amounts of large and medium starch grains with specific gravity were positive whereas negative correlations were found with chip color rating. The correlations were opposite in the case of two smaller grain sizes with these quality factors. This could be a more understandable relationship than a positive correlation between large, medium and small starch grains with specific gravity, as was found when area was used as the measure of quantity of any starch grain size.

Relationship Of Percentage Of Size Of Starch Grain To Chip Color Rating

The potato tubers having a large percentage of starch grains from the three larger-size groups, produced lighter chips, whereas tubers having large percentages of very small starch grains produced undesirably dark colored chips. This

is logical as chip color also depends on specific gravity (46, 51, 29) and in turn specific gravity is related to the percentage of larger starch grains.

In general, the relationship between starch grain sizes and chip color within a variety was similar to the relationship between varieties.

Relationship Of Specific Gravity And Chip Color Rating

In all locations, the generalization may be made that the higher the specific gravity of the tuber, the lighter the chip color. This is in accordance with the findings of Wheeler and Salunkhe (46), Wright and Whiteman (50), and Kunkel, et al (29).

Simple And Partial Correlations

From the data it may be seen that out of seventy-two variety partial correlations, in sixty-five cases values of partial correlations were less than simple correlations and only three changed signs. This shows that when the effect of the third factor was eliminated, the correlation of the other two factors became weaker as compared to that when the effect was not taken out.

In the partial correlation of $r_{xy.z}$, in percentages of large, medium and very small starch grains, the effect of

chip color is considerable but less in small starch grain size; the greater the difference between simple and partial correlation, the greater the effect on chip color (Table XIX).

In partial correlation of $r_{yz.x}$, the effect of specific gravity is about the same in percentages of medium, small and very small starch grains but slightly less in large size starch grains. In general the signs of yz are opposite to those of xy.

When the correlations of r_{xz} and $r_{xz.y}$ were compared, no explanation could be found for high drop in percentages of medium and very small starch grains as compared to large size and specially to small size grains. However, there was very little effect of percentage of small starch grains on xz and on x as seen in xy. All signs were negative.

On the average, regardless of sign, specific gravity of the potato tuber and color of the potato chip are more closely related than either percentage of starch grain sizes with chip color or specific gravity with percentage of starch grains, whether, comparing simple or partial correlations. The weakest partial correlation is $r_{xy.z}$ of the large size group.

Regarding sign, large, medium and small size groups tend to react alike but opposite to very small size group in relationships of specific gravity with percentage of starch grains with chip color rating. This shows that the

percentages of starch grains a bove and below 25 microns have a great effect on specific gravity and chip rating.

This agrees with the findings of size and density (Specific gravity) of starch grains.

SUMMARY AND CONCLUSIONS

In 1955 seventeen varieties of potatoes were grown in four replicated plots at five locations in Michigan. Five tubers of about the same size (U.S. Grade No. 1) were taken from each plot at harvest. These constituted the samples used for the studies on specific gravity, percentage of four sizes of starch grains and chip color rating.

Approximately 1,700 tubers were analyzed in these investigations.

1. At the five locations, each variety, in general, assumed a characteristic rank, high, medium or low, in specific gravity. There was, however, great variability in the specific gravity of individual tubers of a variety at any location, and considerable variation in the average specific gravity between locations.

2. Starch grains in potato tubers were classified into four size groups, large - above 75 microns, medium - between 75 to 50 microns, small - between 50 to 25 microns, and very small - less than 25 microns.

At the five locations, each variety, in most cases, had a specific pattern of starch grain sizes. Some varieties throughout ranked high in large and medium sized grains and low in very small. Other varieties had precisely the opposite proportions. Still others were intermediate in rank in all sizes.

However, there was a wide variability in the proportions of the four sizes in individual tubers from any given plot and considerable difference between location averages.

3. At the five locations, each variety had, in general, a characteristic rank among the seventeen varieties, in potato chip color, some ranking consistently light, others consistently dark.

There was considerable variability in the color of chips from tubers of any one variety taken from any location, and a moderate to small (although highly significant) variation between location averages.

4. The proportions of the four sizes of starch grains in a potato tuber were related to specific gravity.

The higher the proportion of large, medium and small starch grains, the higher the specific gravity. The higher the percentage of very small starch grains (less than 25 microns) the lower the specific gravity of potato tuber.

5. Starch grains extracted from potato tubers and separated into three sizes (above 60 microns, between 60 to 30 microns, less than 30 microns) differed in densities, the larger sizes being denser than the smaller.

6. The potato tubers, having a large percentage of large - medium - small - starch grains, produced light colored potato chips. The tubers which had a large percentage of very small starch grains - less than 25 microns - produced dark colored potato chips.

7. At all the five locations, varieties having tubers with a high average specific gravity produced potato chips lighter in color than those with a low average specific gravity.

8. The percentages of large, medium and small starch grains tend to react alike but opposite to percentage of very small starch grains in relationship with specific gravity and with chip color rating. This means that the percentages of starch grains above and below 25 microns in size have a great effect on specific gravity and chip quality.

LITERATURE CITED

1. Akeley, R. V. and F. J. Stevenson. Yield, Specific Gravity and Starch Content of Tubers In a Potato Breeding Program. Amer. Potato Jour. 20:203-217, 1943.

2. Akeley, R. V. and F. J. Stevenson. The Inheritance of Dry Matter Content in Potatoes. Amer. Potato Jour. 21:83-89, 1944.

3. Alsberg, C. L. Studies Upon Starch. Ind. Eng. Chem. 18:190-, 1926.

4. Ashby, S. F. A Contribution To The Study of Factors Affecting The Quality and Composition of Potatoes. Jour. Agr. Sci. 1:347-357, 1905.

5. Barham, H. N., J. A. Wagoner, B. M. Williams, and G. N. Reed. A Comparison of the Viscosity and Certain Microscopic Properties of Some Kansas Starches. Jour. Agr. Res. 68:331-345, 1944.

6. Barmore, M. A. Potato Mealiness and Changes in Softness In Cooking. Food Res. 2:377-383, 1937.

7. Brautlecht, C. A. Starch - Its Sources, Production and Uses. Reinhold Pub. Corp. New York, p 39, 1953.

8. Briant, A. M., J. P. Catherine, and E. G. Cassel. Physical Properties of Starch From Potatoes of Different Culinary Quality. Food Res. 10:437-444, 1945.

9. Burton, W. G. The Characteristics of Certain Varieties of Potato With Special Reference to Their Suitability For Drying. Ann. Appl. Biol. 31:89-96, 1944.

10. Burton, W. G. The Potato. Chapman and Hall Ltd. Publication London, p 284-287, 1948.

11. Clark, C. F., P. M. Lombard, and E. F. Whiteman. Cooking Quality Of The Potato As Measured By Specific Gravity. Amer. Potato Jour. 17:38-45, 1940.

12. Cochram, F. D., C. L. McCombs, and J. C. Taylor. Study of Specific Gravity and Storage Temperature As Related to Chip Manufacture in Early Summer White Potatoes. Potato Assoc. Amer. Meet. Abs., p 2, 1952.

13. Coughlin, F. J. Quality Control in Potato Chip Manufacturing. Proc. of Prod. & Tech. Div. Meet., National Potato Chip Inst., 1954.

14. Denny, F. E., and N. C. Thornton. Factors For Color In The Production of Potato Chips. Contr. Boyce Thompson Inst. 11:291-303, 1940.

15. Denny, F. E., and N. C. Thornton. Potato Varieties: Sugar Forming Characteristics of Tubers in Cold Storage and Suitability for Production of Chips. Contr. Boyce Thompson Inst. 12:217-252, 1941.

16. Dexter, S. T., and D. K. Salunkhe. Chemical Treatment of Potato Slices in Relation to The Extraction of Sugars and Other Dry Matter and Quality of Potato Chips. Mich. Agr. Exp. Quart. Bull. 35: 102-109, 1952.

17. Dunn, L. E., and R. E. Nylund. The Influence of Fertilizer on The Specific Gravity of Potatoes Grown in Minnesota. Amer. Potato Jour. 22:275-288, 1945.

18. East, E. M. A Study of The Factors Influencing The Improvement of The Potato. Ill. Agr. Exp. Sta. Bull. 127:375-456, 1908.

19. Ezekiel, M. Methods of Correlation Analysis. John Wiley and Sons Publ. p 378, 1930.

20. Freeman, M. E. Measurement of Texture in Baked Potato Tissue. Food Res. 7:451-458, 1942.

21. Fitch, C. L., and E. R. Bennett. The Potato Industry of Colorado. Agr. Exp. Sta. Col. Agr. Coll. Bull. 175, p 14, 1910.

22. Garner, W. Industrial Microscopy - 389 Illus. London, 1932.

23. Gilmore, J. A Study of Quality In Potatoes. Present Estimates Of Quality. Com. Univ. Agr. Exp. Sta. Bull. 230, 1905.

24. Glynne, M. D., and V. G. Jackson. The Distribution of Dry Matter and N in The Potato Tuber. Jour. Agr. Sci. 9:237, 1920.

25. Goldthwaite, N. E. Variations In The Composition of Colorado Potatoes. Colo. Agr. Exp. Sta. Bull. 296, 1925.

26. Janicke, J. Abstract From Jour. Agr. Res. 68:331 (Recz. Chem. 12:381-402), 1932.

27. Johnson, T., and C. Boyle. The Industrial and Nutritive Value of The Potato in Ireland. Jour. Dept. Agr. Ire. 18:443-471, 1918.

28. Johnson, T., and C. Boyle, Observations On The Industrial and Nutritive Value of Potato in Ireland. Dept. Agr. and Tech. Instr. Ire. Jour. 19:416-429, 1919.

29. Kunkel, R., J. Gregory, and A. M. Burkley. Mechanical Separation of Potatoes into Specific Gravity Shows Promise for Potato Chip Industry. Amer. Potato Jour. 28:690-696, 1951.

30. Meiss, P. E., R. H. Treadway, and F. A. Krantz. White Potato Starches. Ind. Eng. Chem. 36:159-163, 1944.

31. Metzer, C. H., J. W. Tobiska, E. Douglas, and C. E. Vail. Some Factors Influencing the Composition of Colorado Potatoes. Amer. Soc. Hort. Sci. Proc. 35:635-643, 1937.

32. Mikuljskil, A. A. Field Crops. Abs. Vol. 6, No. 1, 40, 1953.

33. Nash, L. B. Potato Quality IV - Relation of Variety and Environment Condition to Partial Composition and Cooking Quality. Amer. Potato Jour. 19:91-99, 1941.

34. Radley, J. A. Starch and Its Derivatives. 2nd Ed. Chapman and Hall, London p 346, 558, 1943.

35. Shutt, F. T. Influences of Early and Late Planting and Sprouting on Yield and Dry Matter Content of Potatoes. Dept. Agr. Canada Dept. p 42, 1925.

36. Sjostrom, O. A. Microscopy of Starches and Their Modifications. Ind. Eng. Chem. 28:63-64, 1936.

37. Smith, O. Research Needs of the Potato Chip Industry. Amer. Potato Jour. 27:118-122, 1950.

38. Stevenson, F. J. Starch Content of Potatoes: Amer. Potato Jour. 15:356-357, 1938.

39. Stevenson, F. J., and E. F. Whiteman. Cooking Quality of Certain Potato Varieties as Influenced by Environment. Amer. Potato Jour. 12:41-47, 1935.

40. Stuart, Wm. The Potato: Its Culture, Uses, History and Classification. p 518 - Lippincott Co. Philadelphia, 1923.

41. Sweetman, M. D. Factors Affecting the Cooking Quality of Potatoes. Maine Agr. Exp. Sta. Bul. 383, 1936.

42. Szego, E. Abstract - Jour. Agr. Res. 68:331. (Assoc. des chim de Suer et Distill. Bul. 48:268-274, 1931).

43. Vanasse, N. A., I. D. Jones, and H. L. Lucas. Specific Gravity - Dry Matter Relationship in Potatoes. Amer. Potato Jour. 28:781-791, 1951.

44. Veselovsky, I. A. Biochemical and Anatomical Properties of Starch of Different Varieties of Potatoes and Their Importance for Industrial Purposes. Amer. Potato Jour. 17:330-339, 1940.

45. Vilikovski, Quoted from Starch and Its Derivatives by Radley, p 558, 1943.

46. Wheeler, E. J. and D. K. Salunkhe. Specific Gravity and Date of Planting As It Influences the Color of Potato Chips. Potato Assoc. Amer. Meet. Abs. Papers p 3, 1952.

47. Whitehead, T., T. P. McIntosh, and W. M. Findlay. The Potato in Health and Disease. Oliver & Boyd. Edinburgh, p 400, 1945.

48. Willaman, J J. and R. M. West. Composition of Potato Tubers. Rep. Minn. Agr. Exp. Sta. p 44, 1922.

49. Whittenberger, R. T. and G. C. Nutting. Effect of Phytohormones on Potato Growth and the Size of the Starch Granules. Plant Phys. 24:278-284, 1949.

50. Wright, R. C. and T. M. Whiteman. Varieties and Handling of Potatoes for Chip Manufacture. Potato Chipper 10:50, 1951.

51. Wright, R. C., M. E. Davis, and C. Hendel. Making of Potato Chips. U.S. Agr. Yearbook, 188-189, 1951.

52. Zika, M. Reported from Plant Phys. 24:278-279, 1945.

(Plants 30:151-159, 1939)

APPENDIX 1

WEEKLY PRECIPITATION IN INCHES AT FIVE COUNTIES IN MICHIGAN DURING MAY TO SEPTEMBER

Month		Montcalm Edmore	Emmet Pellston	Bay Bay City	Arenac Standish	Allegan Gull Lake
May	6	0.31	0.69	0.06	0.0	0.03
	12	0.13	0.06	0.10	0.15	0.38
	18	0.0	0.01	0.0	0.0	0.0
	24	1.30	0.14	1.06	0.92	0.51
	31	2.34	0.98	1.48	3.19	0.99
Total		4.08	1.88	2.70	4.26	1.91
June	6	0.0	0.71	0.10	0.03	0.25
	12	4.75	0.08	1.50	2.08	3.51
	18	0.02	0.0	0.0	0.0	0.0
	24	0.30	0.74	0.38	0.26	0.07
	30	0.06	0.0	0.0	0.0	0.92
Total		5.13	1.53	1.98	2.37	4.75
July	6	0.68	0.01	0.85	0.65	0.20
	12	0.14	0.30	0.0	0.0	1.72
	18	0.26	0.82	1.0	1.13	0.69
	24	0.16	0.0	0.0	0.0	0.20
	31	0.13	0.77	0.0	0.01	0.67
Total		1.37	1.90	1.85	1.79	3.48
August	6	0.94	0.59	0.92	0.70	1.13
	12	0.0	0.0	0.0	0.0	0.13
	18	0.85	0.0	1.04	1.26	0.12
	24	0.08	0.29	1.12	0.44	0.01
	31	3.73	0.94	1.85	3.65	1.89
Total		5.60	1.82	3.93	6.05	3.28
September	6	0.0	0.0	0.0	0.0	0.0
	12	0.03	0.40	0.36	0.08	0.58
	18	0.56	0.40	0.26	0.29	0.0
	24	0.0	0.0	0.12	0.0	0.20
	30	0.37	0.52	0.08	0.09	0.75
Total		0.96	1.32	0.82	0.46	1.53
Grand Total		17.14	8.45	11.28	14.93	14.95

APPENDIX 2

SPECIFIC GRAVITY, PERCENTAGE OF FOUR STARCH GRAINS AND AND CHIP COLOR RATINGS OF INDIVIDUAL TUBER FROM FOUR POTATO VARIETIES GROWN AT MONTCALM COUNTY IN 1955

(Varieties were selected in which the data shows the degree of regularity or divergence that may be expected in five tuber samples of four replications)

Variety	Plot No.	Potato No.	Specific Gravity	Percentage of Starch Grains				Chip Color Rating
				Gr. 1	Gr. 2	Gr. 3	Gr. 4	
Irish Cobbler	115	1	1.060	20	30	20	30	5
		2	1.066	20	20	25	35	5
		3	1.073	30	25	25	20	4
		4	1.072	30	20	20	30	6
		5	1.063	25	30	20	25	5
	210	6	1.053	10	25	25	40	5
		7	1.082	45	25	15	15	4
		8	1.056	10	25	25	40	5
		9	1.053	0	25	20	55	7
		10	1.056	5	35	20	40	6
	303	11	1.053	0	20	25	55	7
		12	1.060	20	30	20	30	6
		13	1.064	10	30	25	35	6
		14	1.053	0	20	25	55	7
		15	1.053	0	30	20	50	6
	418	16	1.064	25	30	20	25	4
		17	1.067	30	25	20	25	3
		18	1.060	20	30	20	30	3
		19	1.066	30	20	25	25	3
		20	1.067	30	25	20	25	4
Early Gem	114	1	1.059	0	20	15	65	6
		2	1.054	0	20	10	70	6
		3	1.061	0	20	20	60	7
		4	1.060	0	15	20	65	6
		5	1.061	0	15	20	65	5
	216	6	1.056	0	15	25	60	7
		7	1.061	0	10	25	65	7
		8	1.056	0	10	20	70	7
		9	1.051	0	5	20	75	8
		10	1.060	0	10	20	70	7
	305	11	1.058	0	15	25	60	5
		12	1.056	0	10	25	65	5
		13	1.063	0	20	20	60	4
		14	1.050	0	0	25	75	5
		15	1.056	0	10	25	65	4

APPENDIX 2 (continued)

Variety	Plot No.	Potato No.	Specific Gravity	Percentages of Starch Grains Gr. 1	Gr. 2	Gr. 3	Gr. 4	Chip Color Rating
Early Gem	413	16	1.054	0	5	30	65	6
		17	1.048	0	0	15	85	7
		18	1.054	0	10	25	65	7
		19	1.052	0	5	20	75	7
		20	1.057	0	15	20	65	6
Osage	112	1	1.062	25	30	20	25	3
		2	1.060	30	30	20	20	3
		3	1.064	40	30	15	15	3
		4	1.058	30	30	20	20	3
		5	1.059	30	25	25	20	3
	208	6	1.071	50	30	10	10	2
		7	1.061	30	20	25	25	3
		8	1.066	25	30	20	25	3
		9	1.063	50	30	10	10	3
		10	1.049	0	30	20	50	4
	304	11	1.051	0	30	20	50	4
		12	1.054	20	30	20	30	4
		13	1.066	30	30	20	20	3
		14	1.078	45	30	15	10	2
		15	1.055	5	35	25	35	3
	410	16	1.065	30	30	20	20	4
		17	1.052	0	35	25	40	3
		18	1.049	0	20	25	55	5
		19	1.050	25	20	20	35	3
		20	1.066	30	25	20	25	3
Redkote	110	1	1.076	35	25	20	20	6
		2	1.062	25	20	20	35	4
		3	1.059	20	20	20	40	5
		4	1.052	15	20	20	45	6
		5	1.057	15	30	20	35	4
	212	6	1.061	20	30	20	30	5
		7	1.059	15	25	20	40	4
		8	1.070	35	25	20	20	4
		9	1.067	20	25	25	30	3
		10	1.059	10	25	20	45	7
	307	11	1.045	0	10	20	70	9
		12	1.030	0	0	0	100	9
		13	1.030	0	0	0	100	8
		14	1.048	0	15	20	65	7
		15	1.051	15	20	20	45	7
	411	16	1.032	0	0	0	100	9
		17	1.068	30	25	25	20	4
		18	1.071	35	25	20	20	5
		19	1.062	30	25	20	25	4
		20	1.051	15	20	20	45	7