DENSITY SORTING OF GREEN STOCK PICKLING CUCUMBERS FOR BRINE STOCK QUALITY AND RELATED STUDIES

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ABSTRACT

DENSITY SORTING OF GREEN STOCK PICKLING CUCUMBERS
FOR BRINE STOCK QUALITY AND RELATED STUDIES

By

Dale Earnest Marshall

Michigan leads the nation in the production of cucumbers (*Cucumis sativus* L.) grown for processing. An increasing problem in recent years has been losses due to bloater formation in brined cucumbers, estimated to be over $5 million annually. Balloon bloater formation has been correlated with green stock carpel separation but never with green stock density.

Preliminary findings in 1971 that balloon bloater formation was inversely related to green stock density were verified in 1972 and 1973. A static flotation mechanical separator was used to sort the cucumbers to a ratio of about 20% sinkers (more dense) and 80% floaters (less dense). Density-sorting significantly reduced (.05 level) balloon bloater formation in the sinkers compared to the floaters. In general, lens bloater formation was slightly greater in the sinkers. Total bloater formation was less in sinkers compared the the floaters. Balloon bloater formation in 1-7/16 to 1-9/16 in. diameter fruit was significantly less than in 1-9/16 to 1-7/8 in.

diameter fruit.

During ~~1973~~ 1974 experiments, the specific gravity of 65 experimental and named varieties were measured. Variety averages varied from .9822 to .9582 (a range of .0240). Any variety whose specific gravity was .0087 different from another variety was significantly different (.01 level).

Average specific gravity of the carpel region was .030 to .040 higher than in the wall region. Reducing sugar content was not related to cucumber specific gravity but was significantly different for three harvests from the same plots.

The density-sorting method used had a low capacity. The specific gravity of ethanol-water sorting solutions was affected by evaporation and dilution and required alteration with different size grades, truck loads or varieties. Cucumbers have to be size graded prior to density-sorting. Investigations have shown that sorting pickling cucumbers into more dense sinkers and less dense floaters is effective in reducing balloon and total bloater formation in the sinkers. However, at present several actual or potential limitations with the ethanol-water flotation separation method have been experienced or are discussed.

APPROVED:

______________________ Major Professor

B A Stout Department Chairman

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LIST OF SYMBOLS, ABBREVIATIONS, AND NOMENCLATURE

Brine = Solution of water and 5 to 15% sodium chloride

Brine stock = Cucumbers fermented and stored in brine

bu = Bushel(s)

C = Temperature, degrees Centigrade

cm = Centimeter(s)

cm^3 = Cubic centimeter(s)

F = Temperature, degrees Fahrenheit

ft^3 = Cubic feet

gal = gallon(s)

gm = gram(s)

Green stock = Newly harvested cucumbers as received at the processing plant

ID = Inside diameter

in. = Inch(es)

lb = Pound(s)

L/D = Length-to-diameter ratio

ml = Milliliter(s)

MSU = Michigan State University

OD = Outside diameter

r = Coefficient of linear correlation (+1.0 or -1.0 = perfect correlation)

SD = σ = Standard deviation(s)

SE = Standard error (of coefficients)

SEE = Standard error of estimate

SG = specific gravity

$\bar{x}$ = Sample mean = mean of independent variable values in sample

$\bar{X}$ = Grand mean = mean of all values in test

$\hat{Y}$ = Estimated value of Y for a given value of X (by least-squares method)

Field department size grades:

1A = 1/2 in. to 3/4 in. diameter
1B = 3/4 in. to 1-1/16 in. diameter
2A = 1-1/16 in. to 1-5/16 in. diameter
2B = 1-5/16 in. to 1-1/2 in. diameter
3A = 1-1/2 in. to 1-3/4 in. diameter
3B = 1-3/4 in. to 2 in. diameter

Processing plant size grades:

8/10 = approximately 800 to 1000 cucumbers per 45-gal cask = approximately 1-9/16 to 1-7/8 in. diameter

10/12 = approximately 1000 to 1200 cucumbers per 45-gal cask = approximately 1-7/16 to 1-9/16 in. diameter

CHAPTER I

INTRODUCTION

Michigan and United States Cucumber Production Statistics

Cucumbers (*Cucumis sativus* L.) grown for pickles are a very important crop in Michigan and the United States. Pickling cucumbers make up 54% and 11% of the value of nine principal processing vegetable crops in Michigan and the United States (U.S.), respectively. In Michigan, for the 5-year period 1970-1974, average acreage exceeded 25,000 acres and average production exceeded 100,000 tons, valued at over $10 million annually (USDA 1974) (Appendix A1). During this period, production in the U.S. averaged nearly 600,000 tons valued at nearly $60 million (USDA 1974) (Appendix A2). For the past 57 years (1918-1974), Michigan has produced more pickling cucumbers than any other state with the exception of two years. Yet, for the 1970-1974 period, Michigan has only produced an average of 17.4% of the nation's production. Michigan led the nation in the adoption of once-over mechanical harvesting. During 1973 and 1974 over 90% ov Michigan's acreage was harvested mechanically (Appendix A1). Michigan's mechanized acreage accounted for over 70% of the nation's mechanization. Many Michigan pickle processing plants also receive cucumbers from the South and Southeast. Therefore, the volume of cucumbers brined and processed in Michigan is much greater than just Michigan's production.

Fermenting cucumbers form,at times, internal cavities or hollows of varying size. Such cucumbers, known in the trade as bloaters, appreciably decrease the market value of the finished product.

United States Losses due to Bloater Formation

For the period 1970-1972, the annual loss to the U.S. pickling industry due to bloater formation is estimated to be $5 million (Appendix A3). Approximately 55% of the 1972 U.S. crop was brined (placed in salt solution for storage) until processed (Moore 1973). The remaining 45% was processed as received into fresh-pack products.

Evaluation for Internal Voids

'Pioneer' variety cucumbers examined for internal voids during 1970 and 1971 indicated that over 40% of the 1-1/2 to 2 in. diameter fruits had a carpel separation (or void) of 1/32 in. inside diameter (ID) or larger (Marshall *et al.* 1971, 1972). This observation raised a question as to whether there would be a difference in density between the cucumbers with voids and those without voids. Sneed and Bowers (1970) reported a highly significant correlation (r = .804) between carpel separation and balloon bloating in brined cucumbers. The question of the relationship between cucumber density (specific gravity) and bloater formation appeared worthy of detailed investigation.

Preliminary Experiment -- 1971

In 1971, a trial experiment was conducted to determine green stock density distribution and the relationship between green stock density and brine stock bloating (Marshall *et al.* 1973). Cucumbers were density-sorted into groups with aqueous solutions containing ethanol with specific gravities (SG) of .975 to .955, at .005 increments. Each of the fluid specific gravity groups was placed in a separate cloth bag and brined in the same commercial brine tank along with the original load of cucumbers.

The results indicated that balloon bloater formation was inversely related to green stock SG. Lens bloater formation seemed independent of green stock SG. If the total sample had been density-sorted to obtain a sinker/floater ratio of 20/80, a 75% reduction in balloon bloater formation in the high SG fraction would have been predicted. These favorable results justified detailed investigation which the is the subject of this thesis.

Objectives

1. To determine that bloater formation in brine stock is related to specific gravity of green stock pickling cucumbers.

2. To measure individual cucumber specific gravity as related to: a) fruit diameter, b) variety and c) date of harvest for a given planting.

3. To measure physical and quality factors such as: a) reducing sugar content, b) carpel strength, and c) brine stock firmness as related to specific gravity.

4. To test the density-sorting principle utilizing commercial prototype density-sorting equipment.

CHAPTER II

REVIEW OF LITERATURE

Published literature reveals extensive and long-time use of specific gravity (SG) as an aid to determining quality of many agricultural products.

Specific Gravity Separation

Vegetables. It was recognized as early as 1847 that the amount of dry matter in potatoes influenced quality, and that the dry matter content was related to SG. Heinze *et al.* (1955) cited Smee's 1847 treatise, The Potato Plant, where Smee listed 160 kinds of potatoes ". . . with the weight of each tuber and the SG, which will roughly indicate the quantity of solid material, and consequently the value of each kind." Among the first to use brine solutions to determine the SG of potatoes were the German investigators Schultze (1871) and Fresenius (1881), as cited by Blood and Prince (1940). Specific gravity has also been correlated with culinary and processing qualities of potatoes (Blood and Prince 1940, Kelly and Smith 1944, and Kunkel *et al.* 1952).

Specific gravity separation for quality based upon various attributes of maturity have been correlated in peas, sweet corn, lima beans, snap beans, tomatoes, and carrots (Crawford and Gould 1957, Gould 1957, Kattan *et al.* 1968, 1969, 1970, Kelly and Smith 1944, and Strietelmeier 1959).

Strietelmeier (1959) found that total soluble solids, average grade, average color (a/b ratio), and average firmness in non-puffy 'Rutgers' tomatoes all showed a correlation with SG (r = .90, .92, .84, and .92, respectively). Average size did not correlate with SG. An SG of .9750 was the most efficient point for separating less dense culls. Strietelmeier also found that mature cull watermelons (which generally had "hollowhearts") could be sorted from acceptable melons at an SG of .8700 to .8900 (depending on variety) with an efficiency of 90%.

The only references discussing cucumber or pickle density have been Leonard (1958), Mulvaney (1958), and Samish *et al.* (1957). Leonard reported an average SG of 0.96 (range of .89 to 1.00) for one pickling variety tested, 'Wisconsin SMR-12.' Mulvaney reported the mean SG of two lots of unidentified slicing cucumbers was .940 ± .006 and .936 ± .010. Samish *et al.* reported that the SG of green stock cucumbers increased from .965 SG to 1.000 within 9 days after immersion in fermentation brine where no internal cavities developed. However, where cavities did develop, the SG decreased in proportion to cavity development and to a low of .802 for very large cavities. None of these researchers reported on any results or effects related to green stock density.

Fruits. Wolfe *et al.* (1974) found positive correlations (r > .98) between blueberry density and maturity. Density-sorting is being considered as an alternative to aerodynamic separation to remove green fruit from mature fruit.

DeBaerdemaeker and Segerlind (1974) presented data for 'Midway' strawberries where mean berry weight and berry color correlated with SG. Small (green) berries had the lowest mean SG and mean weight (.886 and 3.96 gm, respectively). Large (red) berries had the highest mean SG and mean weight (.921 and 7.83 gm, respectively). Their data suggest that pink and pink-white berries could effectively be separated with an SG of .911.

Vis *et al.* (1969) successfully separated low-density unpollinated dates from pollinated fruit with water-separation methods. Nichols and Reed (1932) reported a relationship between SG and texture, color, and sugar content of dried prunes.

Grierson and Hayward (1959) described how oranges damaged by low temperatures commonly tend to hang on the tree, showing little or no external evidence of freeze damage. In any but the most severe of freezes, injury is limited to certain areas in the grove or to certain fruit on individual trees, and thus the harvested crop generally includes a mixture of sound and damaged fruit. Because of the drying of the frozen tissues, the SG of the injured fruit tends to decrease in the weeks following a freeze, so that after a month or more the SG of the damaged oranges is lowered enough to afford a means of separating them from sound unfrozen fruit.

Separation of less dense frost-damaged oranges from the more dense unfrozen fruit can be achieved by using a solution whose SG is between that of the sound and the frozen fruit and hence the sound oranges sink and the damaged fruit float. Stout (1964) reported orange juice yield to be correlated (positive) with fruit SG.

Oil crops. Cottonseed density was found to have a highly significant correlation (positive) with germination and growth (Tupper *et al.* 1970). Pawlowski (1963) found a highly significant correlation (negative) between SG of safflower, flax, rape and dehulled sunflower seeds and oil content.

Equipment. Pflug *et al.* (1955) described the use of a potato separator using brine for continuous operation sinker/floater separation. In the potato chipping industry, it is possible to produce more uniform chips by first separating according to SG (Kunkel *et al.* 1952).

Another method of SG separation is to drop the fruit into a flowing stream of liquid in which an adjustable vane separates the damaged oranges which rise more rapidly than the sound ones which rise slowly or even sink (Perry and Perkins 1968). Equipment utilizing this method is manufactured by American Machinery Corporation[1] and Brogdex Company[2]. A modification of this method is obtained by lowering the fruit below the liquid surface and releasing it into the liquid flow rather than dropping the fruit into the sorting solution. Kattan (1968, 1969) used this technique with salt brine to successfully sort tomatoes for color and maturity. Equipment utilizing this method is manufactured by Food Technology Corporation[3] and FMC Corporation[4]. This latter method uses horizontal dividers or skimming conveyors to remove the various grades of fruit. None of these separation methods are new, all having been used in California after the bad freeze of 1913 and subsequently (Sunkist Growers 1957).

In 1917, Chace (1919) found that separation of frost-damaged oranges from sound oranges was not

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[1]American Machinery Corporation, Division of Aeroglide Corporation, Box 3228, Orlando, Florida 32802.

[2]Brogdex Company, 315 W. Grant St., Box 8551, Orlando, Florida 32806.

[3]Food Technology Corporation, Division of General Kinetics, Inc., 12300 Parklawn Dr., Rockville, Maryland 20852.

[4]FMC Corporation, Riverside Division, Box 219, Lindsay, California 93247.

entirely reliable, for some low-density fruits were accepted by the machines tested while some fairly high-density fruits were rejected. The results showed that the correlation of frost damage with SG was far from perfect. Grierson and Hayward (1959) confirmed Chace's results.

Porritt *et al.* (1963) described and illustrated flotation separation equipment for sorting apples with water core (a physiological disorder) from those without water core. The sorting method was similar to that described above for citrus. The fruit were dumped into an alcohol solution at the deep end of the tank where the more dense fruit sank and the less dense fruit floated. Tests showed that satisfactory separation in 'Delicious' apples could be obtained with a solution SG adjusted to about .877.

Methods of Measuring Density and Specific Gravity

The density of a body in the number of units of mass divided by a unite of volume. The specific gravity (SG) of a body is the ratio of its density to the density of water.

Archimedes' principle. The mass of a solid body may always be obtained by weighing, but the volume of an irregular solid cannot be obtained from a measurement of its dimensions. The principle of Archimedes provides a simple method of finding the volume of a solid heavier than water. The approach can be used for irregular bodies; for the volume of an immersed solid is numerically equal to its reduction in mass in water. Hence

$$\text{density} = \text{specific gravity} = \frac{\text{mass of body}}{\text{loss of mass in water}}$$

If the body floats, its volume may still be obtained by attaching a mass heavy enough to force it beneath the water surface. If we let B_a denote the weight in grams of a body in air, M_w denote the weight of the attached mass alone in water, and BM_w denote the weight of the body and attached mass both submerged in water, then:

$$\text{body specific gravity} = \frac{B_a}{B_a + M_w - BM_w}$$

Example:

$$SG = \frac{125.0}{125.0 + 26.1 - 23.6} = .980$$

An application of Archimedes' principle was described by Hulsey *et al.* (1971) as a rapid and precise technique which measured the buoyancy force exerted by a fluid on a submerged body which is directly related to the volume of the body. The technique used an Instron Universal Testing Machine with a submersion device made with metal prongs which diverged downwards and trapped or held the buoyant body below the liquid level. High-density liquids, such as saturated salt brines (SG = 1.204) or organic fluids such as carbon tetrachloride (SG = 1.594), gave the best results.

Pycnometer method. The pycnometer is often used to determine the SG of liquids. It is also useful for determining the SG of bodies less dense than water, such as cucumbers. The pycnometer consists of a glass bottle larger than the object being tested with a ground stopper which has a capillary tube which serves as an overflow for the excess water to be exhausted (Casimir *et al.* 1967).

If we let B_a denote the weight in grams of the body in air, PW denote the weight of the pycnometer full of water, and PBW denote the weight of the pycnometer, the body within it and the remaining volume filled with water, then:

$$\text{body specific gravity} = \frac{B_a}{B_a + PW - PBW}$$

Example:

$$SG = \frac{125.0}{125.0 + 1048.3 - 1045.8} = .980$$

Hydrometer method. This method is based on the principle that objects will float or sink in a given solution depending on the density of the solution. A series of solutions are made up to known densities using a standard SG hydrometer. Commonly, brine solutions are used for objects that sink in water and alcohol or other low-density fluids mixed with water for objects that float in water.

In actual practice, an object is placed in the highest SG solution and then in progressively lower SG solutions until the object just barely sinks or freely sinks. With this technique, the SG of the object will be equal to or higher than the SG of the particular solution in use. The above criteria is used as a practical separation method. However, the actual SG of an object would more accurately be determined if the solution SG was adjusted until the object neither sank nor floated but was suspended at mid-depth in the solution.

The density distribution of a sample of a number of objects would be established by determining the specific gravity group designation for each individual object. Specific gravity, determined by this method, would be relative (to the nearest .005) rather than a precise SG value for each object as compared to either of the two methods discussed above. Therefore, any discussion of cucumber SG categorized by this technique must be in terms of specific gravity group rather than of actual SG.

Another application of the technique which has been used extensively in the potato chipping industry since 1950 was developed by Smith (1950). The potato hydrometer consists of a special basket and calibrated float-scale as also described by Murphy and Goven (1959). Exactly 8 lb of potatoes are put into the basket and into a container of water. The average SG of the potatoes is read directly at the water level on the scale within the instrument. This is a very convenient method for determining average SG for a given lot of objects that sink in water. It does not permit measuring the SG of individual objects, however, nor of objects that float in water.

CHAPTER III

PROCEDURES

Size Grading

Cucumber diameter was measured, in certain tests, to the nearest 0.1 in. Diameter was defined as the distance between two rectangular blocks touching each side of a fruit resting on a horizontal surface (Fig. 1). In other tests, cucumbers were size graded according to one of the size grade designations discussed below before being density-sorted. The pickle industry commonly designates field department size grades for pickling cucumbers as follows:

1A = 1/2 in. to 3/4 in. diameter
1B = 3/4 in. to 1-1/16 in. diameter
2A = 1-1/16 in. to 1-5/16 in. diameter
2B = 1-5/16 in. to 1-1/2 in. diameter
3A = 1-1/2 in. to 1-3/4 in. diameter
3B = 1-3/4 in. to 2 in. diameter

Processing plants generally require narrower diameter ranges, especially in the 3A and 3B sizes which are mainly used for slices and/or spears. Therefore, plant grading equipment have a narrower range and do not coincide with the field grade sizes. Diameter ranges will be specified for each test in the results sections.

Processing plant size designations refer to the average number of cucumbers contained in a 45-gallon cask (PPI). Some of the designations are 8, 10, and 12.

Designation	Number per 45-gal. cask[1]	Approx. diameter
8/10	800/1000	1-9/16 to 1-7/8 in.
10/12	1000/1200	1-7/16 to 1-9/16 in.

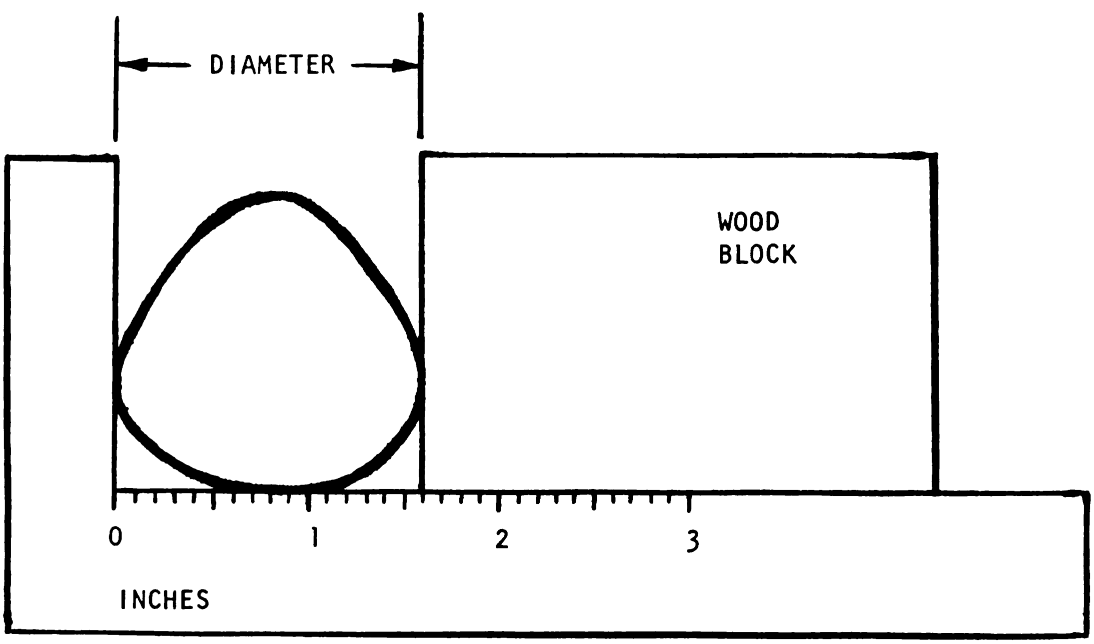

Fig. 1. Method used to measure cucumber diameter.

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[1]These are general figures since the L/D ratio (length to diameter) may vary from lot to lot and from variety to variety, and hence will affect the volume of cucumbers of a given diameter.

Generally, 2.0 in. diameter cucumbers are the largest size grade commercially utilized. Depending upon variety and seed development, slightly larger sizes may be utilized. Bloater formation generally increases as diameter increases because of maturation. Bloater formation therefore is monitored in the largest commercial field department size grade (No. 3 - 1.5 to 2.0 in. diameter). Therefore, much of the data presented (such as the laboratory scale studies) is on size grade No. 3. The data on the commercial prototype density-sorting, however, is presented on the slightly smaller processing plant size grades 10/12 and 8/10 (1-7/16 to 1-7/8 in. diameter).

Density Determination Methods Used

Pycnometer. The pycnometer used was specially constructed and followed the typical design described by Casimir *et al.* (1967). It was constructed with an extra-wide mouth (from a standard Pyrex 71/60 ground-glass tapered joint). Its internal volume was approximately 500 ml and accepted cucumbers up to 5.5 in. in length. Flowing tap water was used which maintained a relatively constant temperature for each run and ranged from an estimated 60 to 65°F. Each individual cucumber was weighed dry, then put into the pycnometer which in turn was overfilled with water. The stopper was gently but firmly inserted into the tapered pycnometer mouth. The surplus water overflowed out the joint with the last few drops being exhausted through the capillary tube located in the stopper. Care was exercised to avoid retention of any air bubbles within the pycnometer. The pycnometer was carefully wiped dry before weighing on a 0-2000 gm capacity single-pan direct reading electric balance.

Hydrometer. All SG determinations with the hydrometer method were made using a series of 190-proof (95%) U.S.P. (United States Pharmacopoeia) ethanol solutions prepared at intervals of .005 SG ranging from .990 to .940. Standard glass SG hydrometers are calibrated at 60°F and require a correction at other temperatures. Prior to the 1973 season, test calibration solutions of ethanol and water were prepared at 60°F. The temperature of the solutions was elevated to over 80°F, reduced to 45°F and then raised back to the initial 60°F, taking hydrometer readings throughout the calibration test. A chart was prepared incorporating the correction factors obtained. A complete description of the density-sorting techniques including the temperature correction chart was prepared (Appendix A4). The SG hydrometer used was calibrated at .0005 SG scale increments.

Cucumbers were density-sorted by putting each cucumber into successively lower .005 SG interval solutions until it sank. The highest SG solution in which a cucumber would sink was defined as its fluid specific gravity group. After the cucumbers were sorted into specific gravity groups, each group was placed in a separate cloth bag and brined in the same commercial brine tank along with the original load of cucumbers.

Laboratory Scale Experiments

Relationship of specific gravity to diameter (1972). Cucumbers for this experiment were obtained from various locations in Michigan. The SG determinations were made by the pycnometer method. Measurements were taken on .4 to 2.6 in. diameter cucumbers. The data points for small-diameter fruit are an average of all those of a given size, or all that would fit into the pycnometer, rather than of a single cucumber's. For example, all 0.5 in. diameter fruit were measured as a composite -- as many as 10 or 20 fruit at a time. Only two or three 1.0 in. diameter fruit would fit in the pycnometer at one time. All cucumbers 1.4 in. diameter and larger were measured one-at-a-time.

Relationship of sample location within a fruit to specific gravity (1972). The pycnometer method was used to determine the SG of the various parts or sample locations of individual cucumbers obtained from various locations in Michigan. The seven sample classifications were as follows:

1 = whole cucumber
2 = stem end half
3 = stem end carpel
4 = stem end wall
5 = blossom end half
6 = blossom end carpel
7 = blossom end wall

The seven parts were evaluated in the order of their classification number. Fruit diameter ranged from 1.5 to 2.4 in. For classifications 3, 4, 6 and 7, approximately 1 in. of the stem end or blossom end was cut off of the respective halves to expose the developed carpel. A narrow knife was used to carefully core and separate the carpel sample from the wall sample.

Relationship of multi-pick harvest dates and variety to specific gravity (1972). Harvest date is defined as the date of multi-pick harvest for successive hand pickings from the same plots. Cucumber SG measurements were taken on 15 varieties from the MSU Department of Horticulture plots in the vicinity of East Lansing, Michigan. The plots were planted in a randomized block design with three replicates. Cucumbers 1.5 to 2.0 in. diameter were harvested by hand on three successive harvest dates from the same plots. This, therefore, did not simulate once-over harvesting but rather multiple harvesting. Specific gravity was determined by the pycnometer method, generally on 12 fruit per replicate per variety. Sometimes no fruit were available, or fewer than 12 were available. A mean SG was calculated for each variety lot and was used in an analysis of variance (Cress 1973). One missing value was calculated for each block when required (Cochran and Cox 1957, p. 302). Seven of the 15 variety plots produced sufficient fruit that could be used in the test.

Relationship of variety to specific gravity (1973, 1974). Cucumber SG measurements were recorded on 1.5 to 2.0 in. diameter fruit of many varieties from the MSU Horticulture plots. Generally, the samples evaluated were mechanically harvested and contained 80 or more fruit in 1973 and 25 or more in 1974.

The SG determinations were made by the hydrometer method obtaining a specific gravity group distribution. The mean SG and standard deviation were calculated from the recorded specific gravity group data.

Relationship of carpel strength and harvest date to specific gravity (1972, 1973). Cucumber SG and carpel strength measurements were recorded on many varieties from the MSU Horticulture plots. Generally, 25 fruit were evaluated per variety for three different harvest dates from the same plots. Cucumbers were 1.5 to 2.0 in. diameter.

The carpel strength measurements were performed with a 6 mm slice thickness, 3/16 in. diameter probe and a 1-3/8 in. inside diameter (ID) annular support (Hooper *et al.* 1972a). The carpel strength was measured with the load cell and chart recorder of the Instron Universal Testing Machine located in the MSU Department of Food Science and Human Nutrition.

Relationship of specific gravity, diameter and harvest number to sugar content (1972). The cucumbers used in this experiment were the same as those described above under "Relationship of harvest number and variety to specific gravity (1972)." Twelve lots (11 varieties) were analyzed for sugar content. Reducing sugar determinations were made with the Lane-Eynon method (AOAC 1970). The tests were conducted by the MSU Department of Food Science and Human Nutrition.

After necessary measurements were recorded on each individual fruit to determine its SG by the pycnometer method, the fruit was prepared for a subsequent sugar determination. Each fruit (1.5 to 2.0 in. diameter) was cut cross-sectionally, retaining the center 2 in. section. The center section was numbered with a black felt pen. The sections were placed in a plastic zip-lock bag numbered with the variety code number. The sections were frozen and analyzed 5 to 6 months later.

The SG of each fruit was calculated and the values for each variety lot arranged in numerical order. Generally, the three sections with the highest and the three lowest SG values per variety lot of 12 were analyzed.

Relationship of brine stock firmness to specific gravity (1973). Up to now, all discussions about quality have been with regard to measurements on green stock cucumbers. Firmness in brined cucumbers or salt-stock is another measure of quality, indicating how much undesirable softening may have occurred while in the fermentation brine. Firmness is measured as the force (lb) required to puncture the wall of a brined cucumber with a 5/16 in. diameter tip of the USDA Fruit Pressure Tester[1] (Magness and Taylor 1925, Bell *et al.* 1955).

The PPI-USDA "Firmness ratings" for size grade No. 3 cured salt-stock are as follows (Etchells and Hontz 1973):

PRESSURE TEST	FIRMNESS RATING
19.5 lb and above	Very firm
15.5 through 19.5 lb	Firm
10.5 through 15.5 lb	Inferior
4.5 through 10.5 lb	Soft
4.5 lb and below	Mushy

The green stock cucumbers used in this experiment were a portion of those described above under "Relationship of variety to specific gravity (1973, 1974)."

[1]Available from: D. Ballauf Mfg. Co., 619 H St. N.W., Washington, D. C.

After the size No. 3 cucumbers were sorted into specific gravity groups by the hydrometer method, each cucumber was marked with its respective specific gravity group number with a black felt pen. Immediately prior to brine stock evaluation a firmness reading was recorded for each fruit.

Brining of samples. After density-sorting into .005 specific gravity groups, each group was placed in a separate cloth bag and brined in the same commercial brine tank with the original load of cucumbers.

Brine stock evaluation. About 100 days later, the brine stock cucumbers were evaluated for internal defects by members of the National Pickle Growers Association's (NPGA)[1] Industry Advisory Committee. Each brine stock cucumber was cut longitudinally. Defects were classified as balloon bloaters (a single large longitudinal cavity) and lens bloaters (many small lens-shaped gas pockets) as illustrated and specified by Etchells *et al.* (1968) and Monroe *et al.* (1969). If a bloater contained both balloon and lens defects, it was classified as a balloon bloater. Honeycomb bloaters (small cavities that form extensively around individual immature seeds) were not

[1]The NPGA has since been dissolved and has been replaced with the Ad Hoc Committee for Pickling Cucumber Research at Michigan State University.

prevalent and have been included with the lens bloater category.

Commercial Prototype Density Sorting

Detailed investigations (1972). The density-sorting principle was tested on a commercial scale with two varieties: 'Heinz 19' at H. J. Heinz, USA, Zeeland, Michigan (one 300-bu tank), and 'Earli Pik' at Aunt Jane's Foods Division, Comstock Foods, Croswell, Michigan (one 300-bu tank). One of two criteria were used to density-sort the two size grades of a given variety: 1) constant SG solution for different sinker/floater ratios for the 'Heinz 19' variety and 2) constant sinker/floater ratio (20/80) using different SG solutions for each size grade for the 'Earli Pik' variety. Floaters were classified as those cucumbers that floated in a sorting solution with a given SG and sinkers were classified as those that sank in the same solution. The 'Heinz 19' cucumbers were brined August 15, 1972, about 35 hours after being mechanically harvested. The 'Earli Pik' cucumbers were brined August 21, 1972, about 40 hours after being mechanically harvested.

Detailed investigation (1973). The density-sorting principle was tested commercially for the second year with two 300-bu tanks (replicates) of 'Premier' variety cucumbers at Aunt Jane's Foods Division, Comstock Foods, Croswell, Michigan. The sorting criterion was: constant sinker/floater ratio (20/80) using different SG solutions for each size grade. The cucumbers were brined August 30, 1973, about 30 hours after being mechanically harvested. The rest of the procedures were the same as in 1972.

Determination of sorting solution specific gravity. Following is the procedure used to determine the SG of the sorting solution necessary to cause the desired percentage of cucumbers to sink. For each test, 225 cucumbers were randomly selected and sorted by the hydrometer method into specific gravity groups at .005 SG increments. Each cucumber was put into successively lower SG solutions until it sank. The highest SG solution in which a cucumber would sink was defined as its specific gravity group. The data were then plotted as percentage-of-sample-that-sinks (PTS) curves.

After the PTS curve had been plotted for a lot, a decision had to be made as to the desired percentage of sinkers. A small percentage of sinkers (i.e., 5 or 10%) would reduce bloater frequency, but would result in an excessive amount of product to produce any appreciable amount of stock to brine and therefore would be rather inefficient. On the other hand, with a large percentage of sinkers (i.e., 30 or 40%), less total product would have to be handled but the bloater reduction benefit would be greatly reduced. Therefore, there exists a trade-off or a break-even point. In all but one case, a 20/80 sinker/floater ratio was arbitrarily selected as discussed below.

To actually determine the required solution SG, the desired sinker percentage, such as 20%, point (A) in Fig. 2 was selected. The 20% PTS was projected to the right until it intersected the desired PTS curve. Next a line was projected straight down from the intersection until it hit the fluid SG border, either point (B) or (C). The tank of sorting solution would then be adjusted to the appropriate SG (B) or (C) for the size grade being sorted.

To show how critical the selection of the solution SG is, assume a single SG (.973) had been chosen (point (D) Fig. 2), such as with criterion 1) above to density-sort both size grades in the same SG solution. The sinker/floater ratio for size grade 8/10 would have been 9% (point (E)) and 43% (point (F)) for the 10/12s. Therefore, it is very important that accurate size grading be done before density-sorting and that care is taken when plotting and reading the PTS curve.

The 20/80 sinker/floater ratio used in the discussion above could be used commercially whereby 100% of already graded, size grade No. 3 cucumbers could be density-sorted. The floaters (80%) would be processed immediately into fresh-pack products. The sinkers (20%)

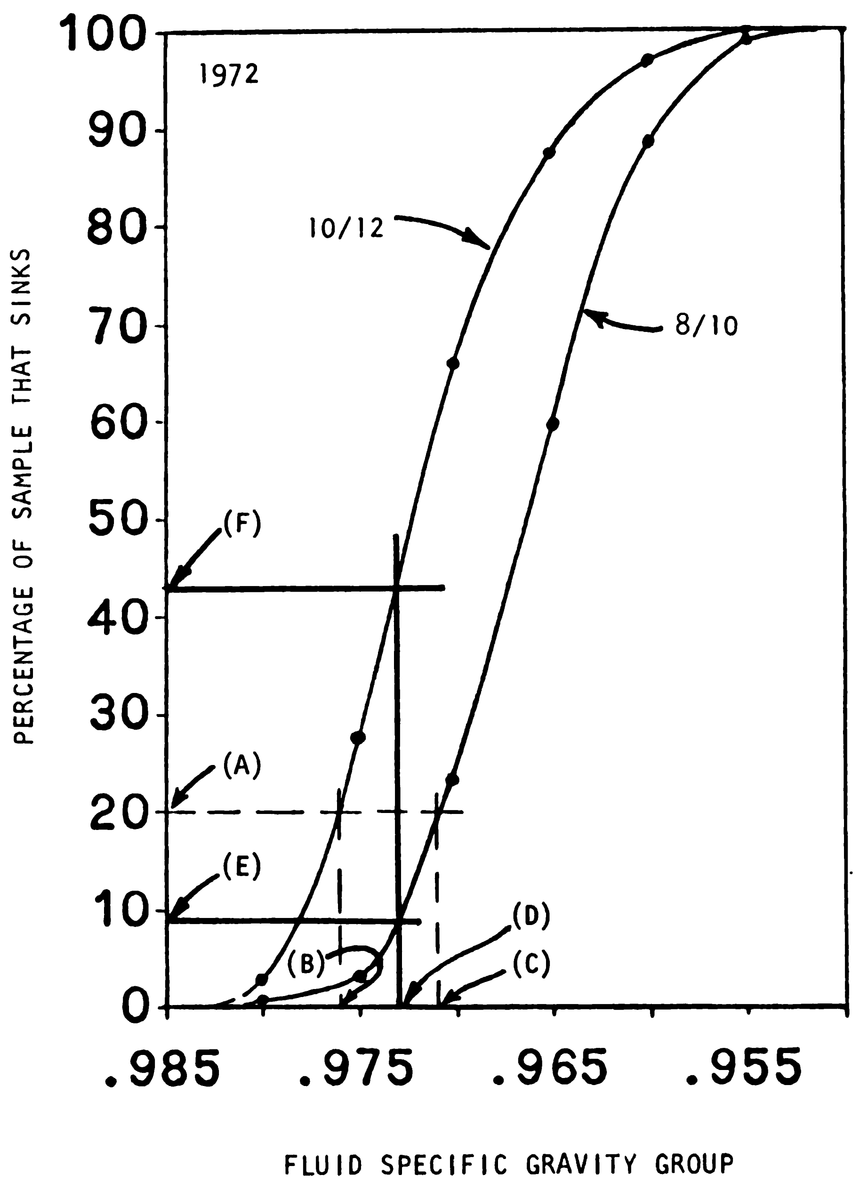


Fig. 2. Percentage of green stock cucumbers that sink in a solution of a given specific gravity. Size grade 10/12 = 1-7/16 to 1-9/16 in. diameter; 8/10 = 1-9/16 to 1-7/8 in. diameter.

would be brined. Early or late in the season, when green stock receipts are lower, generally all cucumbers are fresh-packed and none would be density-sorted. However, at the peak of the season, some must be brined because of the inadequate capacity of the processing plant for fresh packing. Density-sorting could provide a means of separation so that only the least likely to bloat cucumbers would be brined.

Density-sorting equipment. The experimental density-sorting tank used had approximately 1000-gal capacity (3 ft wide and 4 ft deep) and was equipped with a conveyor at each end (Fig. 3). The conveyor that removed the sinkers extended to the bottom of the tank. The floater conveyor extended about 1 ft below the solution level. Sorting was a batch-type process with about 8 or 9 bu being dumped into the density-sorting solution at a time. The floating layer of cucumbers was gently probed with a broom to permit any sinkers held within the floating layer to sink to the conveyor below. The sinker conveyor was then operated and most of the sinkers removed. The next step was to remove the floaters. The two conveyors were not operated simultaneously in order to minimize subsurface solution agitation. During the density-sorting operation, the tank contained 850 to 900 gal of sorting solution.

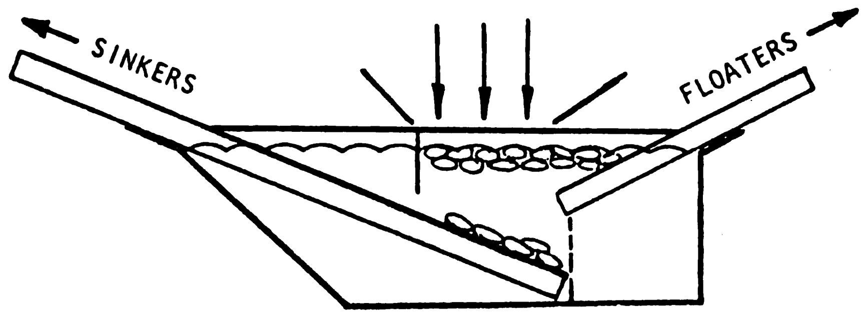


Fig. 3. Side view of experimental tank used to sort green stock pickling cucumbers according to density into floaters and sinkers.

Brining. Density-sorted 10/12 floaters, 8/10 floaters, mixed 10/12 and 8/10 sinkers, and non-density-sorted mixed 10/12s and 8/10s as control were placed in each quadrant (individual compartment) of a 300-bu commercial brine tank. Included also were the bags of sorted .005 specific gravity groups.

Brine stock evaluation. After approximately 100 days the brine stock pickles were evaluated at the same time and in the same manner as described earlier for the laboratory scale experiments.

CHAPTER IV

RESULTS AND DISCUSSION

Laboratory Scale Experiments

Relationship of specific gravity to diameter (1972). Figure 4 presents the relationship between green stock specific gravity (SG) and diameter for a sample of 'Pioneer' variety cucumbers. It clearly indicates a highly significant negative correlation; as cucumber diameter increased, SG decreased. Linear regression coefficients and other related information for three varieties are shown in Table 1.

One explanation for the decrease in specific gravity as diameter increased is the effect of maturity on gaseous volume in cucumber tissues. Fellers (1964) estimated a 17 to 27% increase (depending on sample location) in gaseous volume in size grade No. 3 'SMR-18' variety cucumbers compared to No. 2 size fruit.

"The coefficient of linear correlation (r) is a measure of the degree to which variables vary together or a measure of the intensity of association" (Steel and Torrie 1960, p. 183). Therefore, the coefficient is the extent of correlation between two variables or a measure of how dependent the Y variable is on the

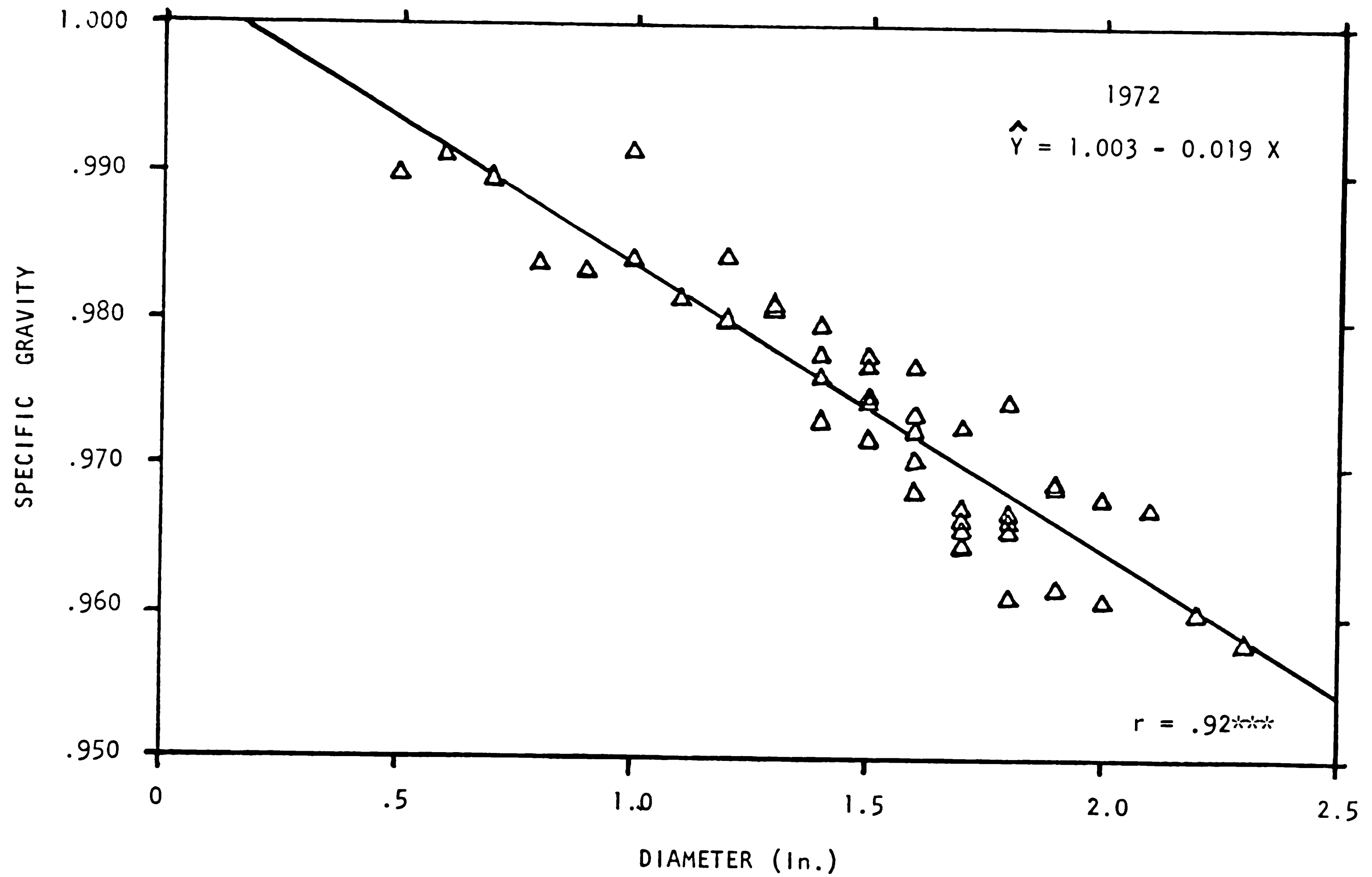


Fig. 4. Relationship of specific gravity to outside diameter of 'Pioneer' variety cucumbers.

Table 1. Regression line coefficients of the relationship of specific gravity to outside diameter for three varieties (1972).

Variety	Linear Regression Coefficients[1]						n	Diameter range (in.)
	A_o	SE	A_1	SE	r	SEE		
Pioneer	1.003	.0019	-.019	.0012	-.92***	.0034	44	.50 to 2.3
Premier	1.003	.0020	-.023	.0012	-.93***	.0044	61	.45 to 2.6
Spartan Jack	1.002	.0033	-.024	.0022	-.86***	.0058	41	.40 to 2.0

[1] $\hat{Y} = A_o + A_1X$; $\hat{Y}$ = Estimated value of Y (specific gravity) for a given value of X (outside diameter), by least-squares method.

A_o = Y intercept; A_1 = Slope of line; SEE = Standard error of estimate.

r = Correlation coefficient; SE = Standard error of coefficient.

Significance: *** = .001 level; n = No. of data points.

independent X variable. A value of the coefficient (r) will always be between +1 and -1. Plus or minus 1 represents perfect correlation, while zero indicates no correlation at all. Thus, in the three varieties discussed above, a high degree of negative correlation existed between SG and diameter. The standard error of estimate (SEE) is a measure of the variation from the least-squares regression line.

Relationship of sample location within a fruit to specific gravity (1972). The mean SG for whole cucumbers and their various parts are shown in Fig. 5. Each data point is the mean SG of the number of cucumbers shown within the parentheses following the variety name. The data points are not continuous in nature, but for clarity of presentation and for ease in following the trend of a given variety, the data points have been connected. One standard deviation is shown for two varieties. There is a marked increase (.030 to .040 SG) for the two carpel or core samples as compared to the wall samples.

Since the stem-end half and the blossom-end half in Fig. 5 are parts of the same whole fruit, one would expect the SG of the whole fruit to be the average of the two respective half-fruit data points. Inspection of the figure indicates this is not the case. One possible explanation of this is sampling error. Another

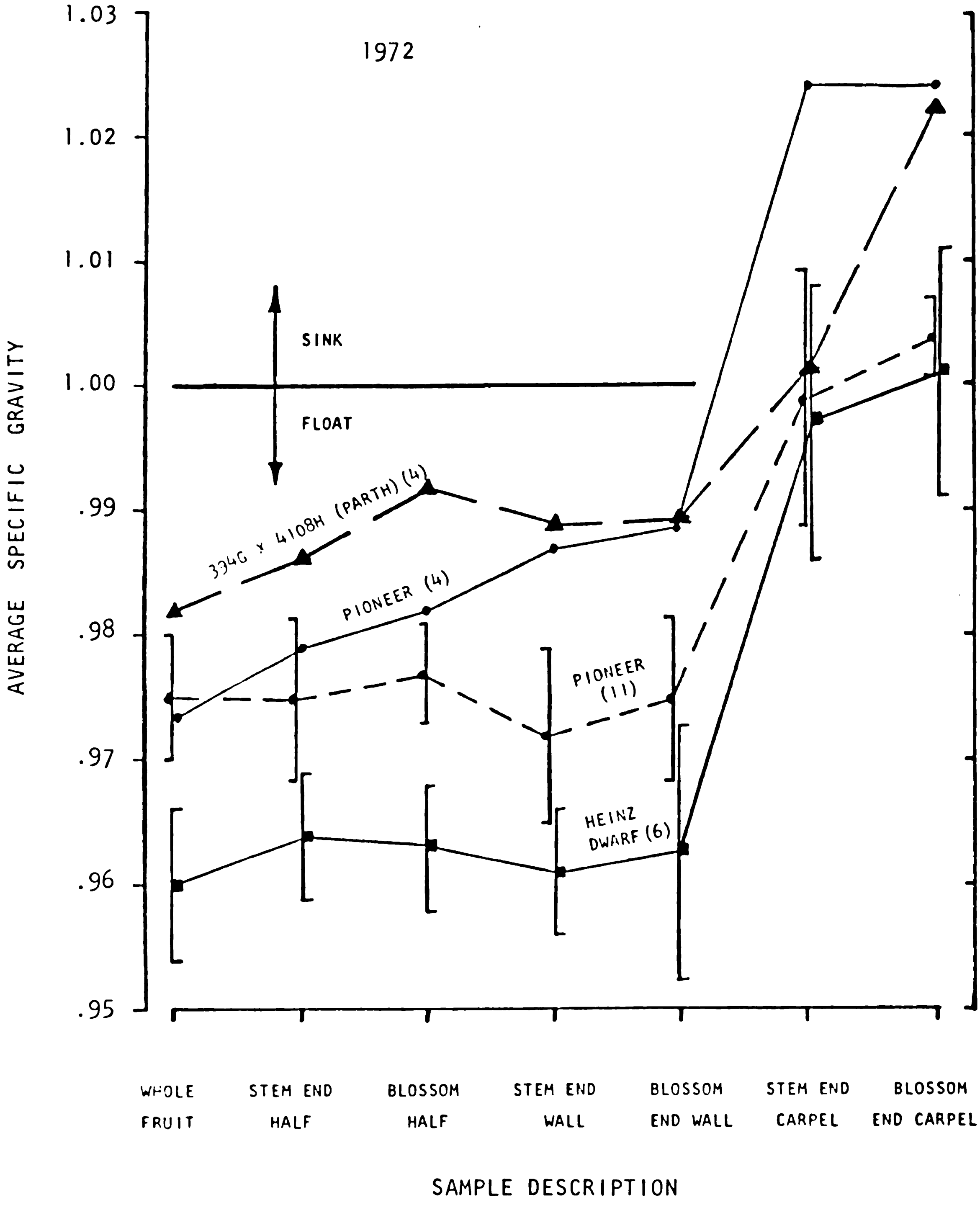


Fig. 5. Average specific gravity of whole and various portions of pickling cucumbers. Numbers within parentheses indicate number of cucumbers in sample. One standard deviation is shown for two varieties (1.5 to 2.0 in. diameter).

explanation is the possible presence of internal voids in the fruit. During SG measurements of the whole fruit, the voids could have been filled with gas which gave a low SG reading. During SG measurements of the fruit halves, any voids would be filled with water resulting in higher SG readings. During the tests no voids were observed. However, there may have been small or undetected voids.

Using a similar analogy to the above discussion, the SG of the wall halves should be lower than the SG of the intact halves. This was exactly the case for the Heinz dwarf (6) variety and the 'Pioneer' (11) variety. In addition, there were similar observations for the blossom end of the 394G x 4108H (Parth) (4) sample.

Since the carpel region is consistently more dense than the wall region it would be of interest to know what percentage the carpel area is of the total cross-sectional area to see what effect the carpel volume may have on the decrease of SG as OD increases. In addition, the influence of SG on diameter should be evaluated. In 1973, 23 slices of 'Mariner' variety and 20 slices of 'Premier' variety ranging from 1.0 to 2.2 in. diameter were photographed. Carpel area and total area were measured from enlargements with a planimeter. Carpel area as a percentage of the total area was plotted against OD. The least-squares regression line for the 'Premier' variety showed a positive relationship indicating carpel percentage increased as OD increased (35.9% for 1.0 in. OD to 38.5% for 2.0 in. OD, a 2.6% increase). On the other hand, the 'Mariner' variety had a definite negative trend with carpel percentage decreasing as OD increased (34.3% for 1.0 in. OD to 29.1% for 2.0 in. OD, a 5.2% decrease).

First of all, this means that the carpel is less than one-third of the total volume when you consider that the percentages above are from center cross-sections and that there is no carpel at the ends of the cucumber. Secondly, the 2.6% increase in area for the 'Premier' variety would increase the SG as diameter increases assuming no change in the SG of either the carpel or wall regions but merely a change in areas. Instead SG decreased with diameter. The 5.2% decrease in area for the 'Mariner' variety is not sufficient to account for approximately a .020 SG drop from 1.0 to 2.0 in. diameter, especially since the seeds are increasing in density and dry matter as they mature. Water is used by cucumber breeders to separate sound developed seeds which sink from light undeveloped seeds which float.

The density of a given cucumber is really a composite of densities for many different sections within the fruit. Primarily, the cucumber is made up of two distinct volumes; the carpel and the wall. As described above, the carpel is more dense than the wall. Therefore, the SG of a given cucumber, or more accurately, the average specific gravity (SG_{avg}), is equal to the product of the wall percentage (P_w) and the wall SG (SG_w) plus the product of the carpel percentage (P_c) and the carpel SG (SG_c). In equation form:

$$SG_{avg} = (P_w \times SG_w) + (P_c \times SG_c)$$

The carpel could even be divided further into components such as seed embryos, gelatinous material, immature and mature seeds, voids, etc. The point is that there are a number of factors contributing to cucumber density.

The thickness or volume of cucumber walls is much larger in some varieties than in those described above (Scott 1975). Where wall thickness is greater, the effect of a dense carpel would be minimized and the average density would be lower. Fellers (1964) estimated the gaseous volume of size grade No. 3 cucumber carpel tissue to be 7.0% and the wall tissue to be 13.7%. The nearly double gaseous volume in the wall tissue as compared to carpel tissue is another explanation for the difference between the specific gravity of the two types of tissue.

Relationship of multi-pick harvest dates and variety to specific gravity (1972). The relationship of harvest dates and variety to SG is shown in Table 2.

(Harvest dates). Based on an analysis of variance, a highly significant SG difference at the .001 level existed between the first, second and third harvest dates. The SG decreased by .010 with each successive harvest. This trend may be caused by changes in soil moisture and/or environmental conditions which influence growth of the plants and fruit. Shaw (1974) found SG of apples decreased with three successive harvests (approx. 2-week intervals). It was shown earlier in this investigation that SG decreased as cucumbers matured (increased in diameter) for a single harvest. The above data indicate that mean SG (of a given diameter) decreased as the vine matured (successive harvests).

(Variety). Based on the analysis of variance, sample means of SG for different varieties did not differ significantly. The highest mean SG ('Pioneer' variety) and the lowest mean SG ('Bounty' variety) had an SG difference of .0052 for the first harvest (which would simulate once-over harvesting). For the second and third harvests, neither variety above remained the highest or lowest SG but their SG

Table 2. Relationship of multi-pick harvest dates and variety to specific gravity. Second and third harvest samples are from same plots as for first harvest (1.5 to 2.0 in. diameter) (1972).

Variety	Harvest Date***			Harvest range SG	Variety mean SG
	1st	2nd	3rd		
Pioneer	.9845 Hi	.9730	.9667	.0178	.9747 Hi
Ranger	.9832	.9675 Lo	.9635	.0197	.9714
Frontier	.9818	.9758 Hi	.9651	.0167	.9742
Spartan Jack	.9801	.9730	.9529 Lo	.0272	.9687 Lo
Premier	.9799	.9743	.9688 Hi	.0111	.9743
Mariner	.9799	.9716	.9632	.0167	.9716
Bounty	.9793 Lo	.9679	.9619	.0174	.9697
Harvest mean SG	.9813	.9719	.9632		
Variety range SG	.0052	.0083	.0159		.0060

*** All significantly different at .001 level.

difference remained nearly constant, .0051 and .0048, respectively. Meanwhile, there was an unexplained increase in the differential between the highest and lowest SG means for all varieties (.0052, .0083 and .0159) for the first, second and third harvests, respectively.

Relationship of variety to specific gravity (1973, 1974). The results of experiments involving the measurement of SG on 10 variety lots (nine different varieties) during 1973 are shown in Table 3. The sample SG means and standard deviations are listed. Tukey's w-procedure was used to evaluate the difference between SG means (Sokal and Rohlf 1969, p. 238). The maximum difference between mean SG values was .0246; however, if the lowest mean SG for the 'Mariner 2' variety is disregarded, the difference is reduced to less than half (.0102). In spite of this small difference, the mean SG values for different varieties were significantly different. Tukey's $LSR_{.05}$ value was .0034 and $LSR_{.01}$ was .0040.

The results for 65 variety lots (55 different varieties) in 1974 are presented in Table 4. The varieties are ranked in descending order according to their mean SG. The difference between the maximum and minimum mean SG (.0240) was virtually identical to the 1973 difference (.0246). Tukey's w-procedure was used

Table 3. Relationship of cucumber variety to sample mean specific gravity (1.5 to 2.0 in. diameter) (1973).

Variety		Standard deviation	Sample mean SG [1]
Rank	Name		
1	Carolina	.0063	.9841 a
2	Pickmore	.0066	.9813 ab
3	Premier	.0070	.9793 bc
4	Perfecto Verde	.0074	.9786 bcd
5	Pioneer	.0082	.9783 bcd
6	Spartan Jack	.0059	.9757 cde
7	Bounty	.0063	.9755 cde
8	Earli Pik	.0052	.9748 de
9	Mariner (1)	.0048	.9739 e
10	Mariner (2)	.0084	.9595 f
Grand Mean			.9761 ± .0066

[1]Sample means followed by the same letter are not significantly different at the 1% level (Tukey $LSR_{.01}$ = .0040).

Table 4. Relationship of cucumber variety to sample mean specific gravity (1.5 to 2.0 in. diameter) (1974).

Variety Rank	Name	Date harvested	Sample standard deviation	Sample mean SG 1/	
1	Perfecto Verde	8-12	.0046	.9822	a
2	Carolina	9-11	.0049	.9796	ab
3	Sumter	8-17	.0037	.9795	ab
4	FX 3904	8-17	.0064	.9787	abc
5	38ND	8-11	.0047	.9784	abc
6	4585	9-11	.0045	.9780	abc
7	(92G X 4108H)X MSU 9429	8-17	.0058	.9779	abc
8	Premier	9-11	.0056	.9772	abcd
9	MSU 319H	8-27	.0073	.9770	abcd
10	(921G X 4108H)X MSU 9429	8-17	.0058	.9764	abcde
11	XP 1040	8-17	.0050	.9756	abcdef
12	38ND	8-17	.0081	.9755	abcdef
13	Unknown-Wm C.	8-13	.0052	.9753	abcdef
14	C5ND	8-17	.0065	.9753	abcdef
15	Bounty	8- 6	.0056	.9753	abcdef
16	Premier	8-12	.0063	.9748	abcdefg
17	38C2	8-17	.0072	.9741	abcdefgh
18	1159	9-11	.0052	.9740	abcdefgh
19	Pickmore, Scab-Res.	8-12	.0079	.9740	abcdefgh
20	Premier	8-12	.0062	.9736	abcdefghi
21	3488 X 8519	8-17	.0055	.9735	abcdefghij
22	Score	9-11	.0071	.9734	bcdefghij
23	Premier	8-12	.0047	.9734	bcdefghij
24	Mariner	8-17	.0060	.9728	bcdefghijk
25	F1HYBR. 130	8-17	.0057	.9724	bcdefghijk
26	(92G X 4108H)X 5802 A	8-17	.0091	.9723	bcdefghijkl
27	Pickmore, Scab-Res.	8-12	.0066	.9722	bcdefghijkl
28	SMR 18	8-17	.0058	.9719	bcdefghijklm
29	Goddess Hyb.	8-17	.0063	.9714	bcdefghijklm
30	Spartan Salad	8-27	.0058	.9714	bcdefghijklm
31	Imp. Pioneer	8-17	.0065	.9706	cdefghijklmn
32	3885	9-11	.0064	.9704	cdefghijklmno
33	MSU 3249U	8-27	.0057	.9702	cdefghijklmno
34	MSU 224G	8-27	.0044	.9702	cdefghijklmno
35	3859	8-17	.0051	.9690	defghijklmnop
36	3534 D	8-17	.0059	.9688	defghijklmnop
37	Perfecto Verde	8-20	.0075	.9685	defghijklmnop
38	Spartan Advance	8-17	.0060	.9677	efghijklmnopq
39	Spartan Jack	8-27	.0052	.9674	fghijklmnopq
40	MSU 183G	8-27	.0104	.9674	fghijklmnopq
41	Spartan Advance	8-21	.0069	.9673	fghijklmnopq
42	MSU 9402	8-27	.0079	.9672	fghijklmnopq
43	National Pickling	8-27	.0064	.9672	fghijklmnopq
44	Spartan Advance	8-27	.0073	.9664	ghijklmnopqr
45	921 X 319 + 20 %	9-10	.0055	.9662	ghijklmnopqr
46	Spartan Progress	8-27	.0066	.9660	hijklmnopqr
47	MSU 8821	8-27	.0067	.9657	hijklmnopqr
48	SC 25	8-21	.0077	.9650	ijklmnopqr
49	Pioneer	8-27	.0073	.9648	jklmnopqr
50	GY14 X 319H	8-17	.0063	.9648	jklmnopqr
51	SR-551F	8-27	.0060	.9644	klmnopqr
52	(394G X 4108)X 5802A	8-17	.0081	.9643	klmnopqr
53	MSU 3393G X SC601H	8-27	.0076	.9642	klmnopqr
54	MSU 35G	8-27	.0086	.9636	lmnopqr
55	Pixie	8-27	.0053	.9636	lmnopqr
56	WS SMR 18	8-27	.0075	.9636	lmnopqr
57	Score	8-27	.0085	.9634	mnopqr
58	MSU 394G	8-27	.0073	.9632	mnopqr
59	Green Spear	8-27	.0078	.9626	nopqr
60	921 X 319 + 10%	9-10	.0063	.9626	nopqr
61	SC 23	8-27	.0061	.9620	nopqr
62	394 X 319 + 20%	9-10	.0063	.9618	opqr
63	SC 601H	8-27	.0075	.9614	pqr
64	GY 14	8-27	.0085	.9594	qr
65	MSU 394G	8-27	.0073	.9582	r
Grand mean				.9699 ± .0057	

1/ Sample means followed by the same letter are not significantly different at the .01 level (Tukey $LSR_{.01}$ = .0087) to evaluate the difference between SG means. Tukey's $LSR_{.05}$ value was .0075 and $LSR_{.01}$ was .0087.

In spite of the fact that the 1972 analysis of variance indicated that variety was not significant, the 1973 and 1974 data show variety differences to be highly signficant (.01 level). As indicated in Fig. 2, a small change in SG, whether between varieties or between size grades of a given variety, will result in a substantial and undesirable change in the sinker/floater ratio. These SG differences may occur due to differences in soil, variety, fertilization, cultural practices, and environmental conditions during the growing season.

Many of the variety lots were brined. They were brined in 5-gal tanks as described by Baker *et al.* (1973). When the brine stock was evaluated in late 1974, very limited bloating had occurred. As a result correlation between bloater formation and SG has not been established for a wide selection of varieties.

It should be noted that in general, though not documented here, a trend exists. Varieties such as 'Carolina' which are considered most resistant to bloating are generally the most dense and varieties which are least resistant to bloating such as 'Pixie' are the least dense. The 'SC 601H' variety generally has a thick wall (Scott 1975), a low bloating frequency (see Table 5), and is at least one exception to the above trend.

Table 5. Varietal differences for green stock carpel separation and subsequent balloon bloating of brine stock; based on two replicates, 30-gal tanks, yeast inoculated (1.5 to 2.0 in. diameter) Baker *et al.* (1973).

Variety	Carpel Phenotype	1971				1972			
		Carpel Strength (gm)	Balloon Bloat (%)	Lens Bloat (%)	Honeycomb Bloat (%)	Carpel Strength (gm)	Balloon Bloat (%)	Lens Bloat (%)	Honeycomb Bloat (%)
MSU 381M	Weak	223	53	3	1	277	28	8	3
Pioneer	Intermediate	317	3	14	8.5	382	4	3	0
SC 601H	Strong	319	3	6	6	427	1	3	0

Relationship of carpel strength and harvest dates to specific gravity (1972, 1973). Research discussed by Hooper *et al.* (1972a and 1972b) and presented by Baker *et al.* (1973) indicates that cucumber carpel strength and balloon bloater formation are inversely proportional (Table 5). The results of the present investigation indicate that green stock SG and balloon bloater formation are inversely proportional. These results would suggest a direct relationship between carpel strength and green stock SG. Thus, when the cucumber carpel strength is high, green stock SG is also high and lens bloaters result instead of balloon bloaters; the carpel is strong enough to resist balloon bloater formation.

(Carpel strength - 1972). Two varieties ('SC 601H' and 'MSU 381M') have been shown to exhibit a widely separated resistance to carpel separation or weakness (Baker *et al.* 1973, Wilson 1974). It seemed logical that there might be some relationship where the known weak carpel strength phenotype ('MSU 381M' variety) might have a low SG, the intermediate carpel strength phenotype ('Pioneer' variety) would have an intermediate SG and the strong carpel strength phenotype ('SC 601H' variety) would have a high SG. Table 6 presents the mean SG for the same three varieties as Table 5. The mean SG for the weak and intermediate phenotypes followed

Table 6. Relationship of harvest dates and carpel phenotype to sample mean specific gravity (1.5 to 2.0 in. diameter) (1972).

Harvest No.	Harvest Date	Variety: MSU 381M / Carpel Phenotype: Weak	Variety: Pioneer / Carpel Phenotype: Intermediate	Variety: SC 601H / Carpel Phenotype: Strong	Harvest mean SG
1st	8-22	-	.972	.966	.9690
2nd	8-25	.959	.967	.961	.9623
3rd	8-30	.968	.971	.969	.9693
4th	9-7	.972	.972	.971	.9716
Variety mean SG		.9663	.9705	.9668	

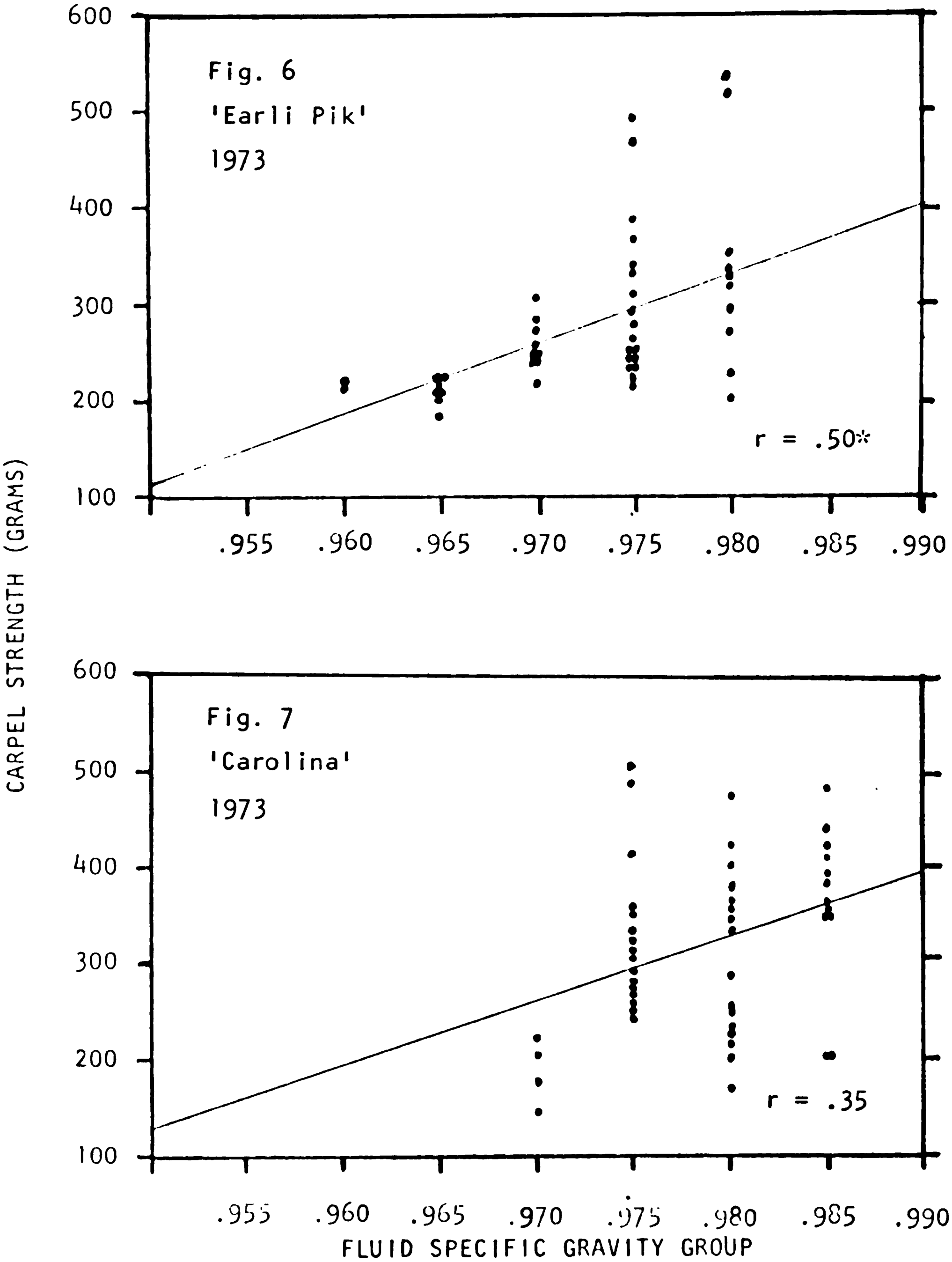
the presumed relationship, but the strong phenotype's SG was almost as low as the SG for the weak variety. A possible reason for the strong phenotype's low SG is that it has a wall thickness which is more than average (Scott 1975).

(Harvest dates - 1972). Specific gravity means are presented in Table 6 for each harvest date and carpel phenotype. The SG for the first harvest was mid-range in magnitude for the intermediate and strong phenotype. The SG was lowest for all three varieties on harvest date 2. For all three varieties the SG increased for the third and fourth harvest dates. The inconsistency in SG for a given variety may have been related to changes in soil moisture and/or other environmental conditions.

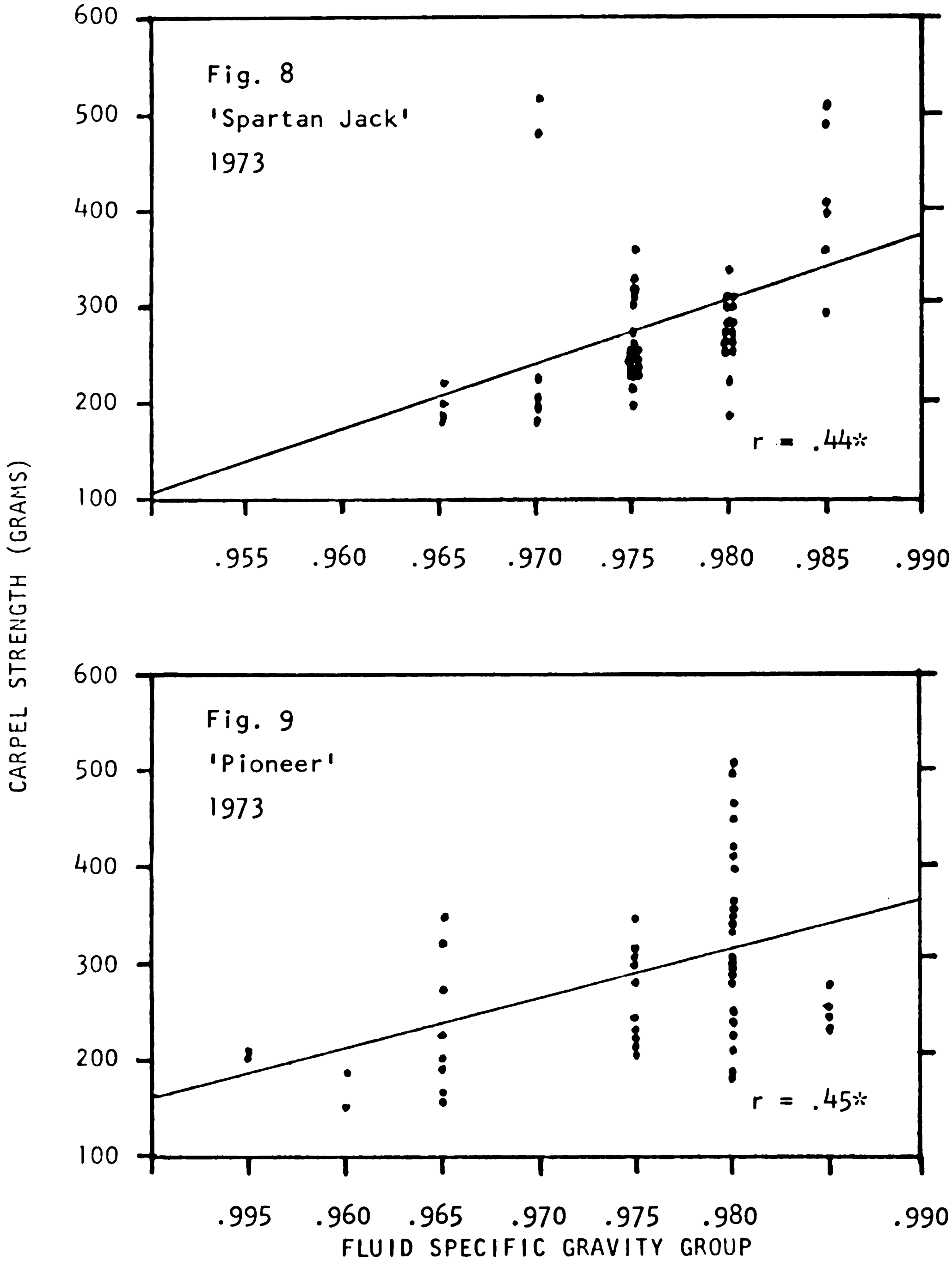
(Carpel strength - 1973). The results of this investigation (eight varieties) are shown in Figs. 6-13 and summarized in Table 7. The individual varieties are listed in descending order based on the slope of the best-fit least-squares regression line. The dependence of carpel strength on SG ranged from a positive correlation for the 'Earli Pik' variety (r = .50*) to virtually no correlation for the 'Perfecto Verde' variety (r = .02 NS). The SEE indicates that the variance from the regression line or scatter of the data generally decreased as the dependence of carpel strength on SG decreased with variety. The causes for these diverse relationships between carpel strength and SG are not clear at this time.

Specific gravity means (from Table 3) and total bloater formation in 5-gal tanks are also shown in Table 7. Bloater formation was small and was generally independent of mean carpel strength and mean SG for different varieties.

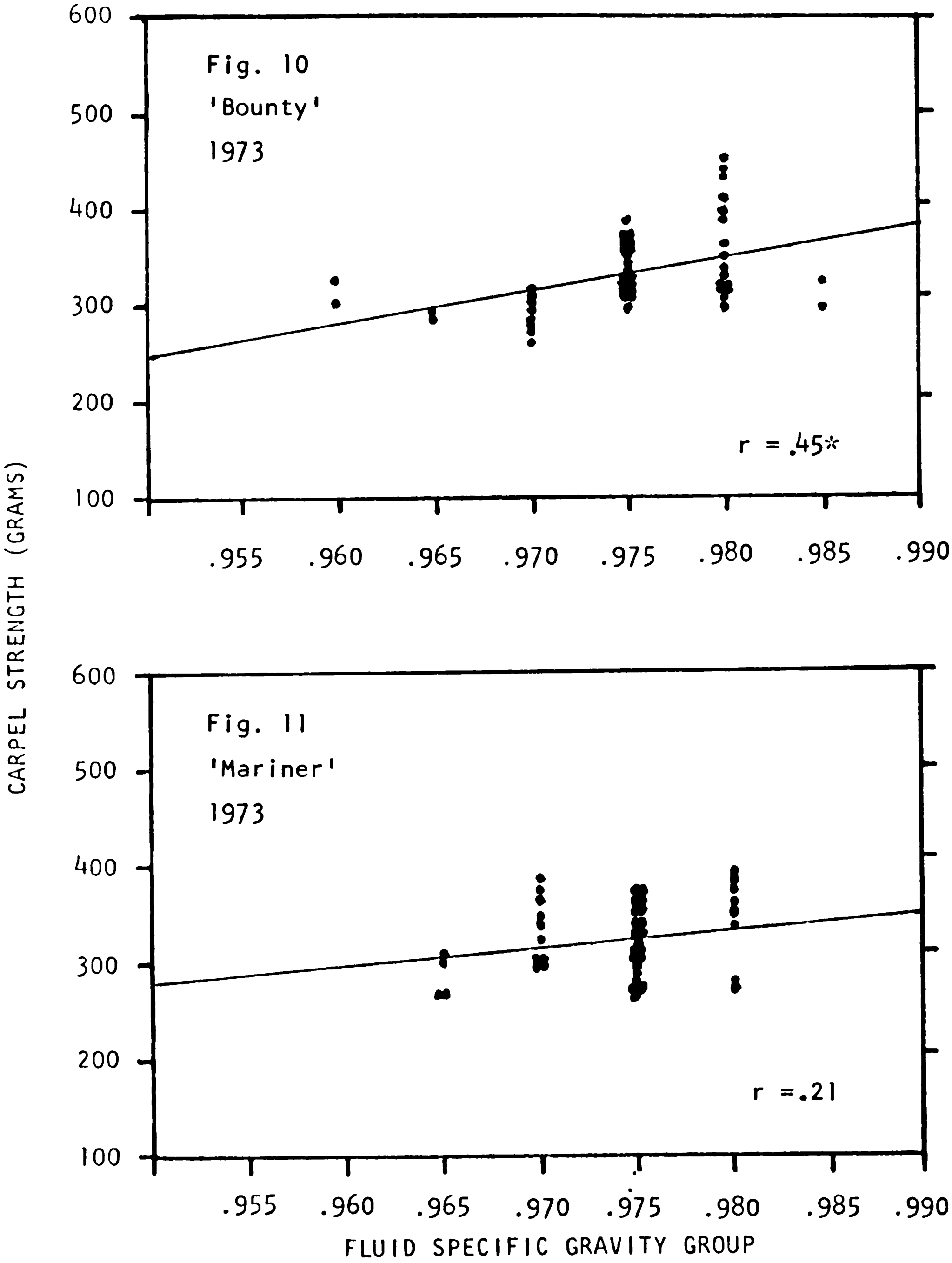
Relationship of specific gravity, harvest date, and diameter to sugar content (1972). Reducing sugar contents were measured on 12 variety lots (11 varieties) with



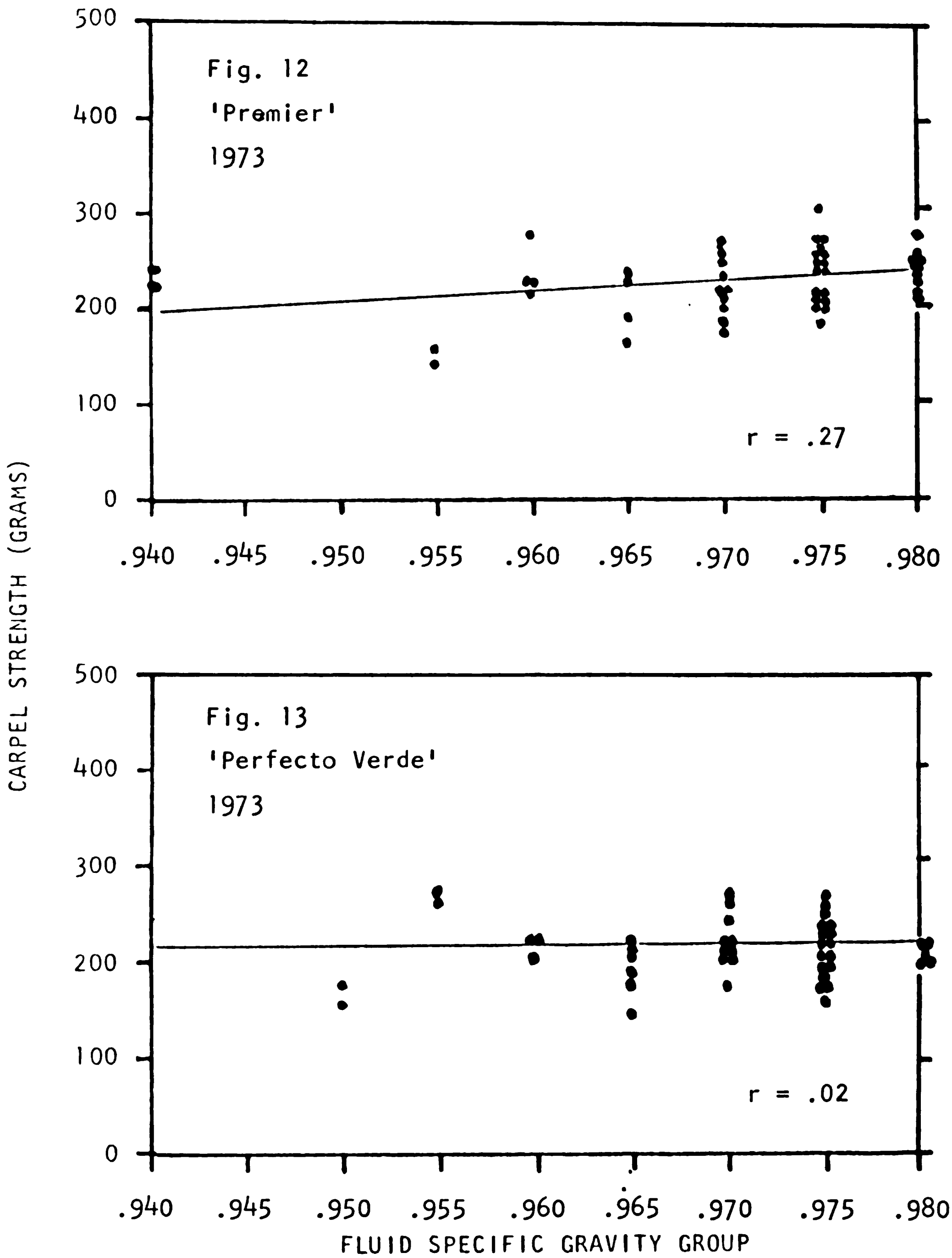
Figs. 6 and 7. Carpel strength measurements of green stock cucumbers sorted into fluid specific gravity groups.



Figs. 8 and 9. Carpel strength measurements of green stock cucumbers sorted into fluid specific gravity groups.



Figs. 10 and 11. Carpel strength measurements of green stock cucumbers sorted into fluid specific gravity groups.



Figs. 12 and 13. Carpel strength measurements of green stock cucumbers sorted into fluid specific gravity groups.

Table 7. Mean carpel strength, bloater formation, mean specific gravity, and linear regression coefficients of best-fit lines of carpel strength versus fluid specific gravity group in Figs. 6 through 13 (1.5 in. to 2.0 in. diameter) (1973).

Variety	Carpel Strength	Bloater Formation	Linear regression coefficients [3]				Sample mean specific gravity
	Sample mean [1] (gm)	Total [2] (%)	A_o	A_1	r	SEE	
Earli Pik	281.9	1.25	-6938	7422	.50*	71.5	.9748
Carolina	319.4 Hi	1.3	-6340	6806	.35 NS	84.9	.9841 Hi
Spartan Jack	285.1	0	-6322	6767	.44*	76.7	.9757
Pioneer	290.1	4.0	-4683	5099	.45*	81.1	.9783
Bounty	233.7	1.2	-3183	3503	.45*	38.6	.9755
Mariner	223.6	3.1	-1623	1896	.21 NS	36.6	.9739 Lo
Premier	229.2	17.0	- 760	1014	.27 NS	32.5	.9793
Perfecto Verde	217.1 Lo	8.7	+ 142	77	.02 NS	29.5	.9786

[1]Mean is average of 50 values (25 cucumbers, 2 slices per fruit).

[2]Balloon + lens type bloaters.

[3]$\hat{Y} = A_o + A_1X$; A_o = Y intercept; A_1 = Slope of line; SEE = Standard error of estimate.
$\hat{Y}$ = Estimated value of Y (carpel strength-grams) for a given X value (specific gravity group)
Significance: * = .05; NS = not significant; r = Correlation coefficient.

three replications for each. Each increase of 1% in sugar solids results in an increase of SG by .004 (Handbook of Chemistry and Physics 1956, p. 1925). The range in reducing sugar content for individual fruit sections was 1.90% (3.10% high, 1.20% low). The correlation between reducing sugar content and cucumber SG was not significant. Differences in SG within a given variety was not due to sugar content.

(Harvest date). Table 8 presents the relationship of harvest date to reducing sugar content. The harvest dates were about 5 days apart. The sugar content was found to be highest for harvest No. 2, and lowest for No. 3. All harvest dates were significantly different at the .01 level. This inconsistency may be related to soil moisture or other environmental factors and/or sampling techniques.

(Diameter). The relationship of reducing sugar content to diameter for all varieties is presented in Table 9. There was a slight tendency for the sugar contents to decrease as diameter increased. Lower (1975) found both positive and negative relationships between sugar content and diameter. No definite conclusions can be drawn based on these limited scale experiments.

Relationship of brine stock firmness to specific gravity (1973). The relationship of brine stock firmness

Table 8. Mean reducing sugar content (percentage) of 11 cucumber variety lots (10 different varieties) for three harvest dates from the same vines (1.5 to 2.0 in. diameter cucumbers) (1972).

Variety	Harvest date **						Variety mean
	1st		2nd		3rd		
	Mean	SD	Mean	SD	Mean	SD	
Spartan Jack (2)	2.21 Hi	.15	-	-	1.88	.27	2.05
Crusader	2.20	.21	2.35 Lo	.31	1.55 Lo	.25	2.03
Bounty	2.16	.10	2.88	.23	1.91	.23	2.32 Hi
SMR 58	2.16	.29	2.69	.10	1.92	.46	2.26
Premier	2.16	.26	2.69	.13	1.62	.17	2.16
Spartan Jack (1)	2.11	.24	2.51	.28	1.76	.21	2.13
Pioneer	2.06	.14	3.10 Hi	.31	1.76	.29	2.31
Mariner	1.99	.17	2.56	.18	1.91	.45	2.15
Pixie	-	-	2.50	.23	1.79	.25	2.15
Frontier	1.97	.23	2.87	.19	1.57	.20	2.14
Pickmore	1.94	.17	2.35	.24	1.66	.13	1.98
Ranger	1.79 Lo	.11	-	-	1.96 Hi	.51	1.88 Lo
Harvest mean	2.07	.21	2.65	.31	1.77	.31	

** All significantly different at .01 level.

SD = Standard deviation

Table 9. Mean reducing sugar content (percentage) of 11 variety lots (10 varieties) presented in Table 8 as related to diameter for three harvest dates (1972).

		Diameter (in.)									
		1.50		1.55		1.60		1.65		1.70	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Harvest date	1	2.01	.25	2.12	.07	2.05	.27	1.84	.30	1.94	.36
	2	2.78	.32	-	-	2.43	.57	2.72	.37	2.21	.37
	3	1.74	.17	1.94	.37	2.18	.41	1.75	.25	1.78	.22
Diameter mean		2.18		2.03		2.22		2.10		1.98	

		1.75		1.80		1.85		1.90		1.95		2.00	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Harvest date	1	1.72	.37	1.89	.27	1.93	.25	1.78	.25	2.00	.20	1.78	.33
	2	2.21	.37	2.37	.43	-	-	2.21	.62	-	-	1.79	.44
	3	1.67	.31	1.57	.24	1.83	.28	1.76	.24	-	-	1.66	.28
Diameter mean		1.87		1.94		1.88		1.92		2.00		1.74	

SD = Standard deviation

to SG for six varieties is presented in Fig. 14. The 'Mariner' and 'Bounty' varieties generally exhibited a negative correlation with firmness increasing as SG decreased. The 'Carolina' variety exhibited a less consistent trend with a generally negative correlation. 'Earli Pik' and 'Perfecto Verde' varieties had the lowest firmness of the six varieties. The 'Earli Pik' variety had no consistent trend. The 'Perfecto Verde' variety had a generally positive correlation.

It should be noted that those varieties with moderate to strong negative correlation had "Firm" or "Very Firm" ratings. The 'Earli Pik' and 'Perfecto Verde' varieties had an "Inferior" firmness rating.

One would expect that as density decreased, firmness would decrease. One explanation would be the decrease in density due to internal voids. This would result in brined cucumbers which are softer and have a lower firmness reading. This trend is generally illustrated by the 'Perfecto Verde' variety. An examination of the 'Mariner' variety curve, which is in the desirable firmness range ("Firm" and "Very Firm"), shows a complete reversal of the above trend. For some reason, when the samples are removed from the brine, and the average firmness is above the "threshold" of about 16 lb, the firmness decreases as density increases.

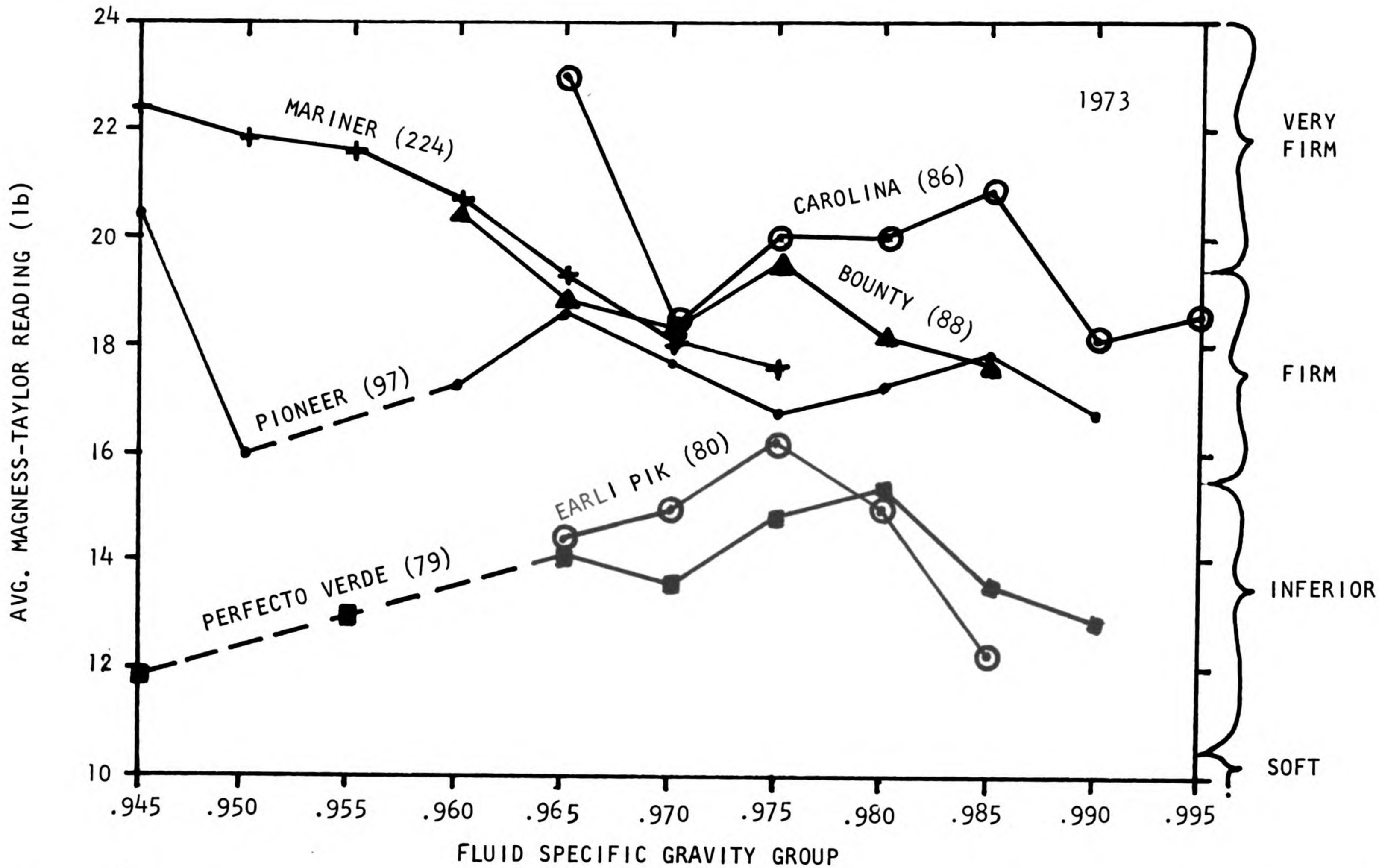


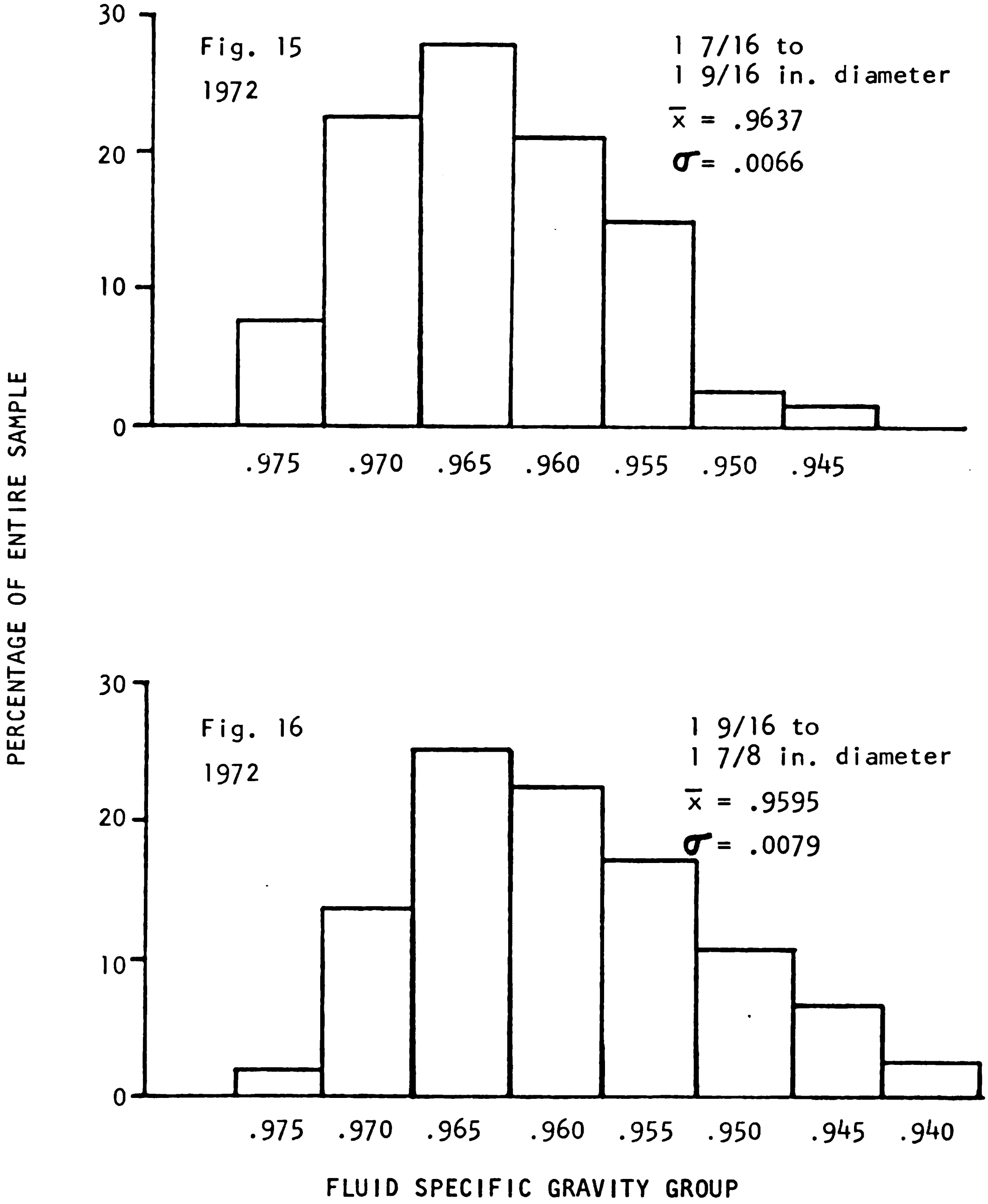
Fig. 14. Firmness of brined cucumbers that were density-sorted as green stock into fluid specific gravity groups. Numbers within parentheses indicate number of cucumbers in sample (1.5 to 2.0 in. diameter).

Frequency distribution (1972, 1973). The distribution of cucumber densities in the .005 specific gravity groups are shown in Figs. 15 through 20. The effect of size grade can be illustrated by the shift of mean SG within each of the three varieties. This shift is most evident in the 'Earli Pik' variety in Figs. 17 and 18 and in the PTS curves shown in Fig. 2 (p. 28).

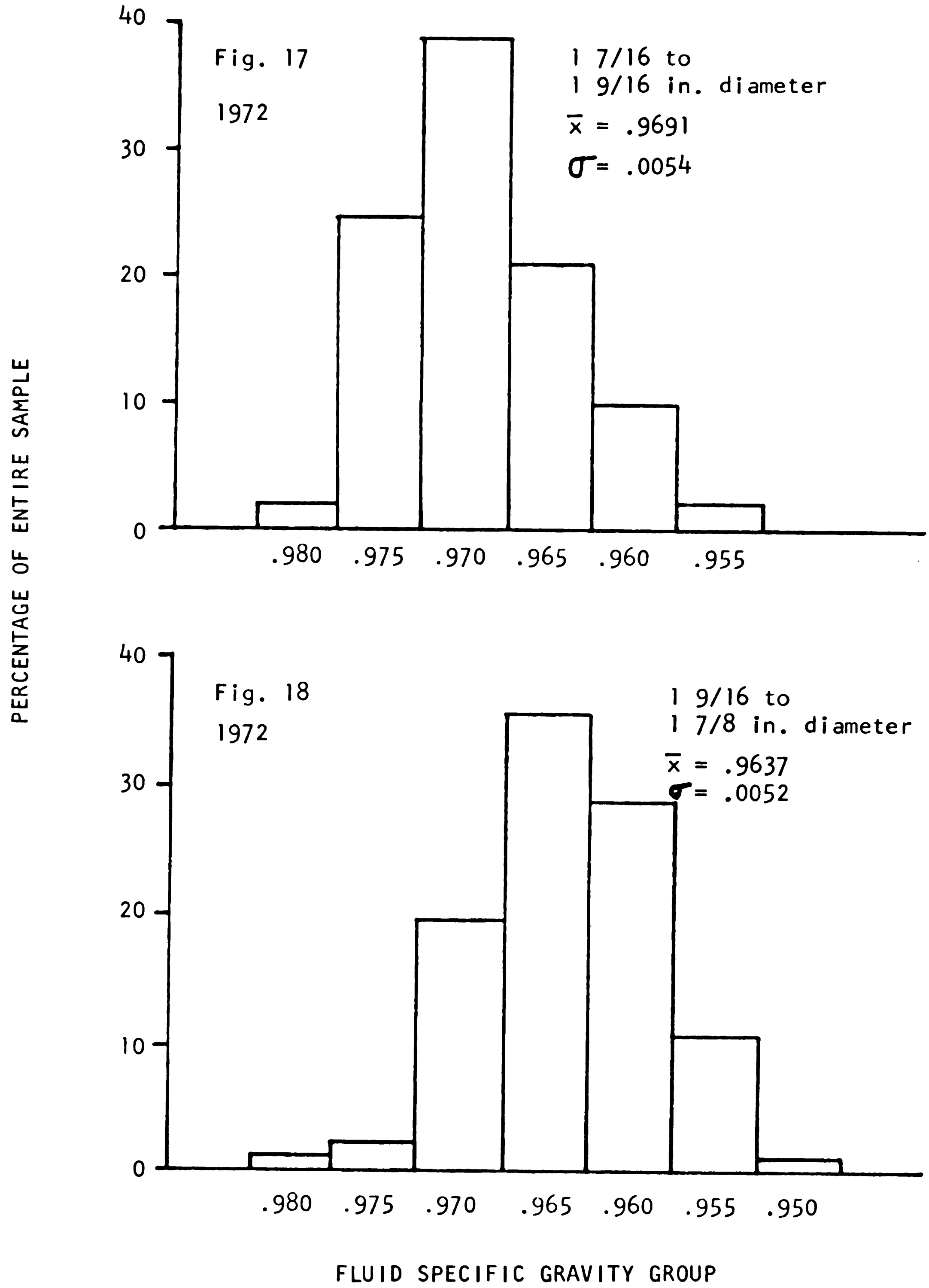
Relationship of bloater formation to specific gravity (1972). The bloater formation of density-sorted 'Heinz 19' and 'Earli Pik' variety cucumbers is presented in Figs. 21 through 24. The correlation coefficients are presented in Table 10. The results indicated that balloon bloater formation in brine stock was consistently inversely related to green stock SG confirming the 1971 preliminary findings.

('Heinz 19'). In general, balloon bloater formation of size grade 10/12 'Heinz 19' cucumbers was inversely related to green stock SG (r = -.72). Balloon bloater formation in size grade 8/10 cucumbers had a highly significant (.001 level) inverse relationship to green stock SG (r = -.96).

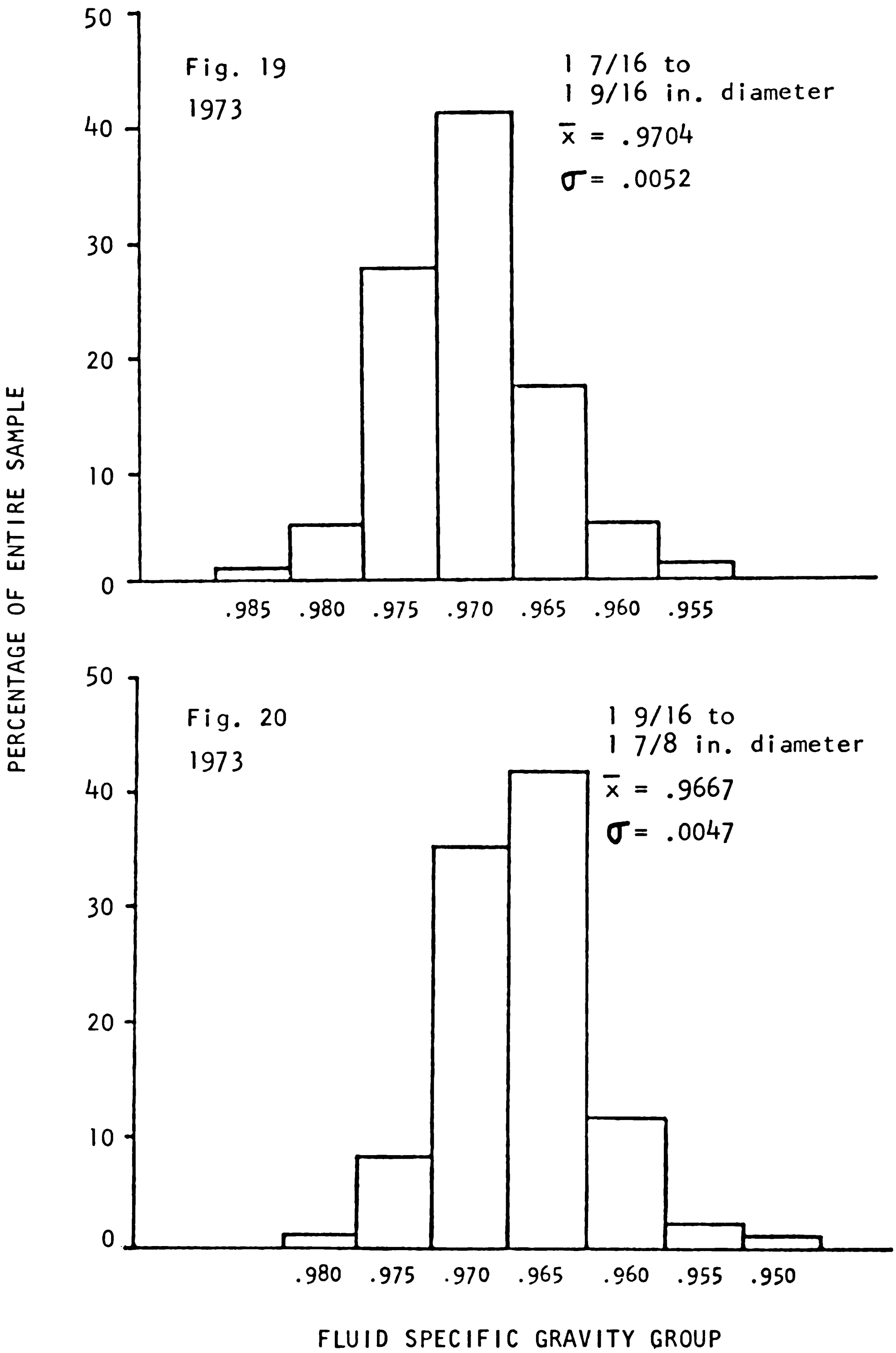
In general, total bloater formation was inversely related to SG for size grade 10/12. Total bloater formation in size grade 8/10 had a significant (.05 level) inverse relationship with SG (r = -.74).



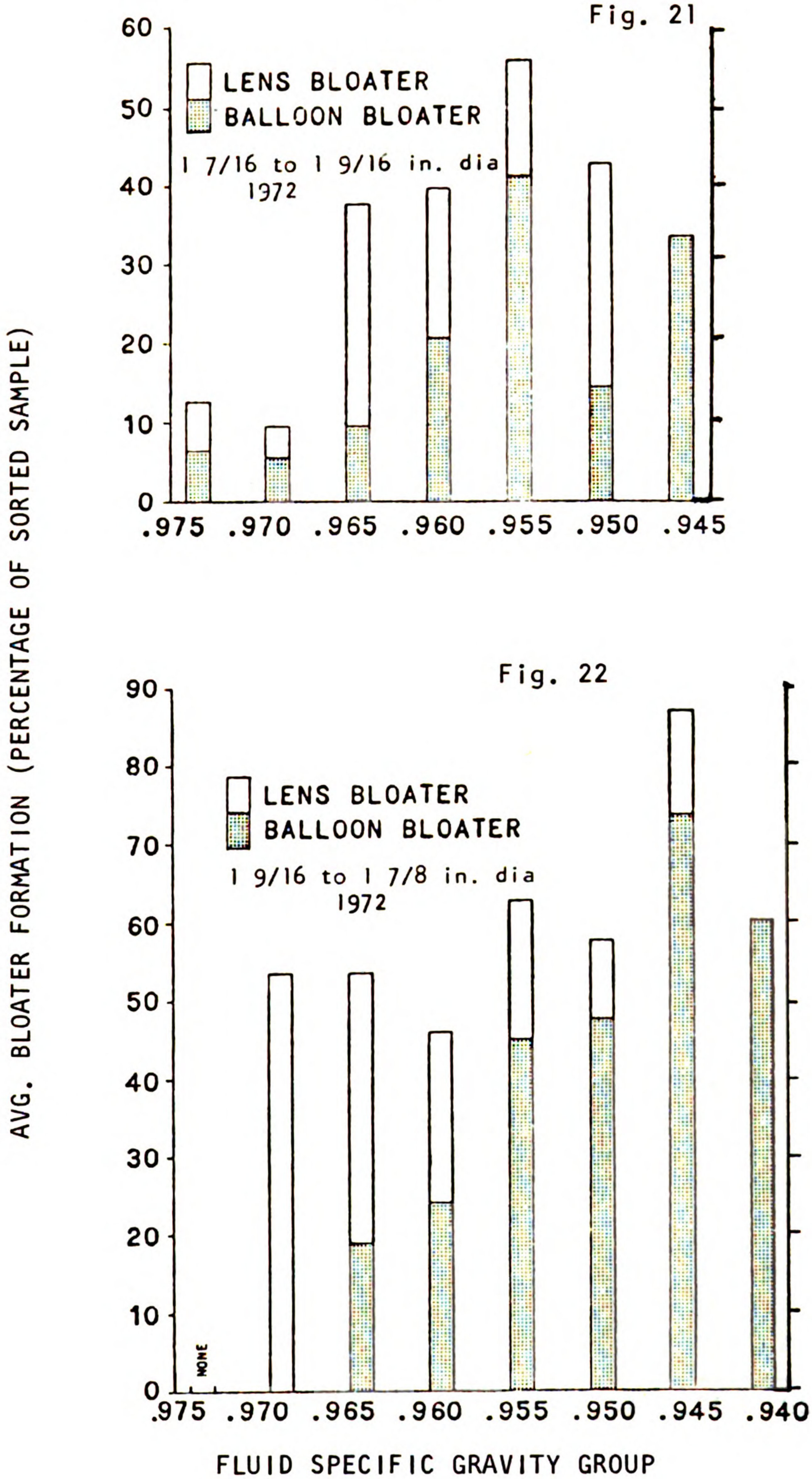
Figs. 15 and 16. Frequency distribution of specific gravity in 'Heinz 19' variety cucumbers.



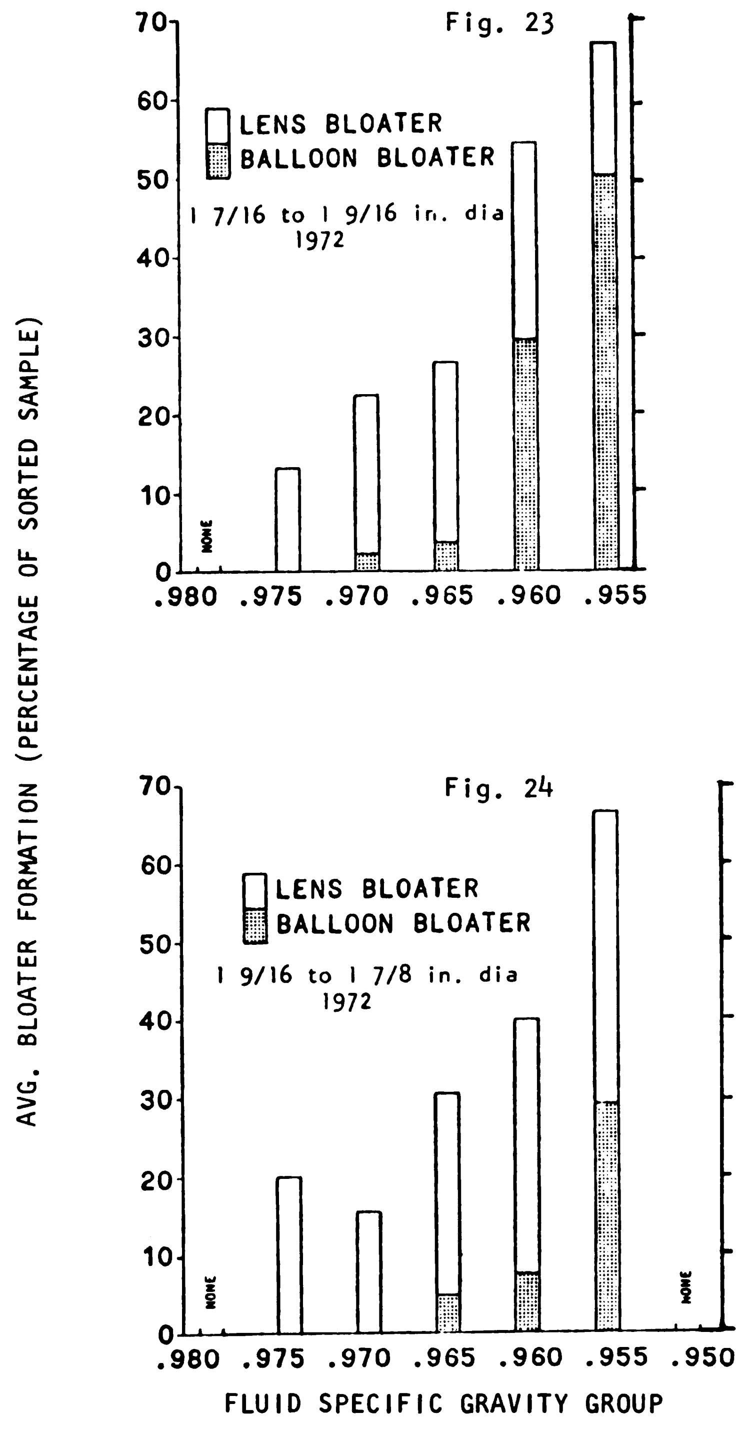
Figs. 17 and 18. Frequency distribution of specific gravity of 'Earli Pik' variety cucumbers.



Figs. 19 and 20. Frequency distribution of specific gravity of 'Premier' variety cucumbers.



Figs. 21 and 22. Bloater formation in mechanically harvested 'Heinz 19' variety cucumbers sorted into fluid specific gravity groups.



Figs. 23 and 24. Bloater formation in mechanically harvested 'Earli Pik' variety cucumbers sorted into fluid specific gravity groups.

Table 10. Correlation coefficients of the relationship between bloater formation and specific gravity of pickling cucumbers (1972, 1973).

Variety (year)	Bloater type					
	Balloon		Lens		Total[1]	
	Size grade					
	10/12	8/10	10/12	8/10	10/12	8/10
Heinz 19 (1972)	-.72	-.96***	.28	.45	-.52	-.74*
Earli Pik (1972)	-.87*	-.31	-.72	-.29	-.98***	-.34
Premier (1973)	-.75*	-.70	.09	.48	-.71	-.55

[1]Total bloater formation = Balloon + lens bloater formations.

Significance: * = .05; ** = .01; *** = .001.

('Earli Pik'). Balloon bloater formation in size grade 10/12 'Earli Pik' cucumbers had a significant (.05 level) inverse relationship to green stock (r = -.87). Balloon bloater formation in size grade 8/10 was inversely related to SG but was not significantly different at the .05 level.

Lens bloater formation had a moderate inverse relationship with green stock SG (r = -.72, -.29) for size grades 10/12 and 8/10, respectively.

Total bloater formation for size grade 10/12 cucumbers had a highly significant (.001 level) inverse

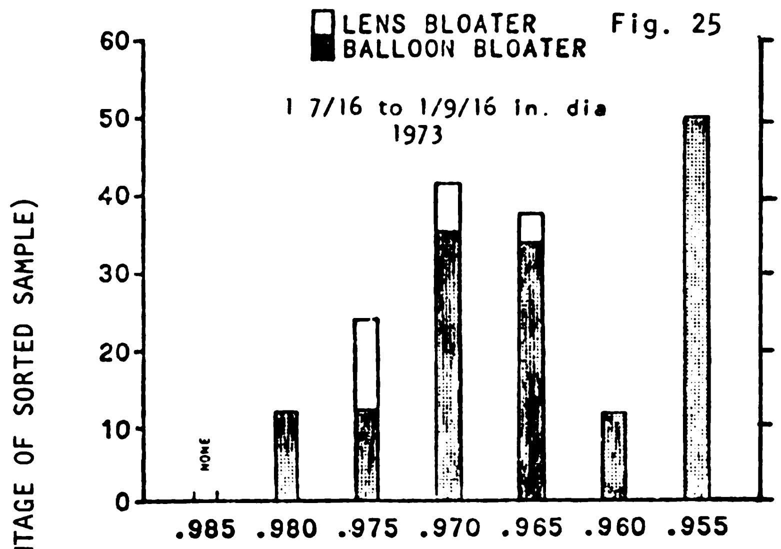
relationship to green stock SG (r = -.98). Total bloater formation was inversely related to SG but was not significantly different at the .05 level.

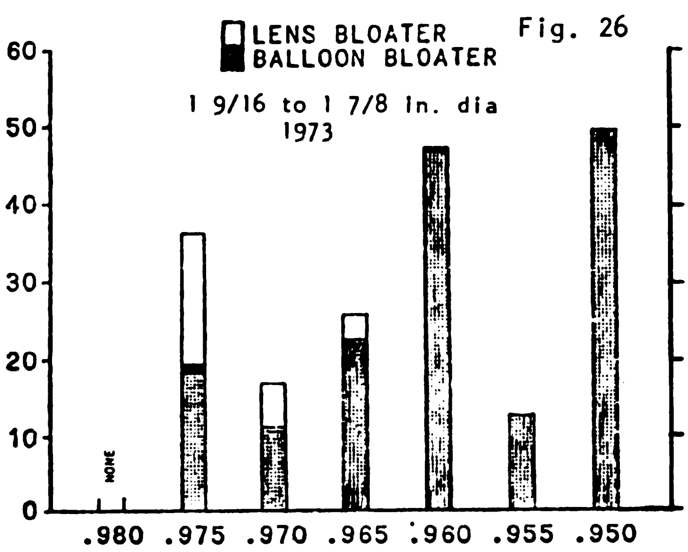
Relationship of bloater formation to specific gravity (1973). The bloater formation of density-sorted 'Premier' variety cucumbers is presented in Figs. 25 and 26. The results reconfirm the findings of 1971 and 1972 that an inverse relationship exists between balloon bloater formation and green stock SG.

Balloon bloater formation in size grade 10/12 cucumbers had a significant (.05 level) inverse relationship to green stock SG (r = -.75). Balloon bloater formation in size grade 8/10 was also inversely related to SG (r = -.70) but was not significantly different at the .05 level.

No definite relationship between lens bloater formation and SG appeared because only limited lens bloating occurred but seemed to decrease as balloon bloating increased. In general, total bloater formation was inversely related with green stock SG (r = -.71 and -.55) for size grades 10/12 and 8/10, respectively.

Percentage-of-sample-that-sink curve and bloater formation curves (1972, 1973). The percentage-of-sample-that-sink (PTS) curves for the 'Heinz 19,' 'Earli Pik' and 'Premier' varieties are shown in Figs. 27



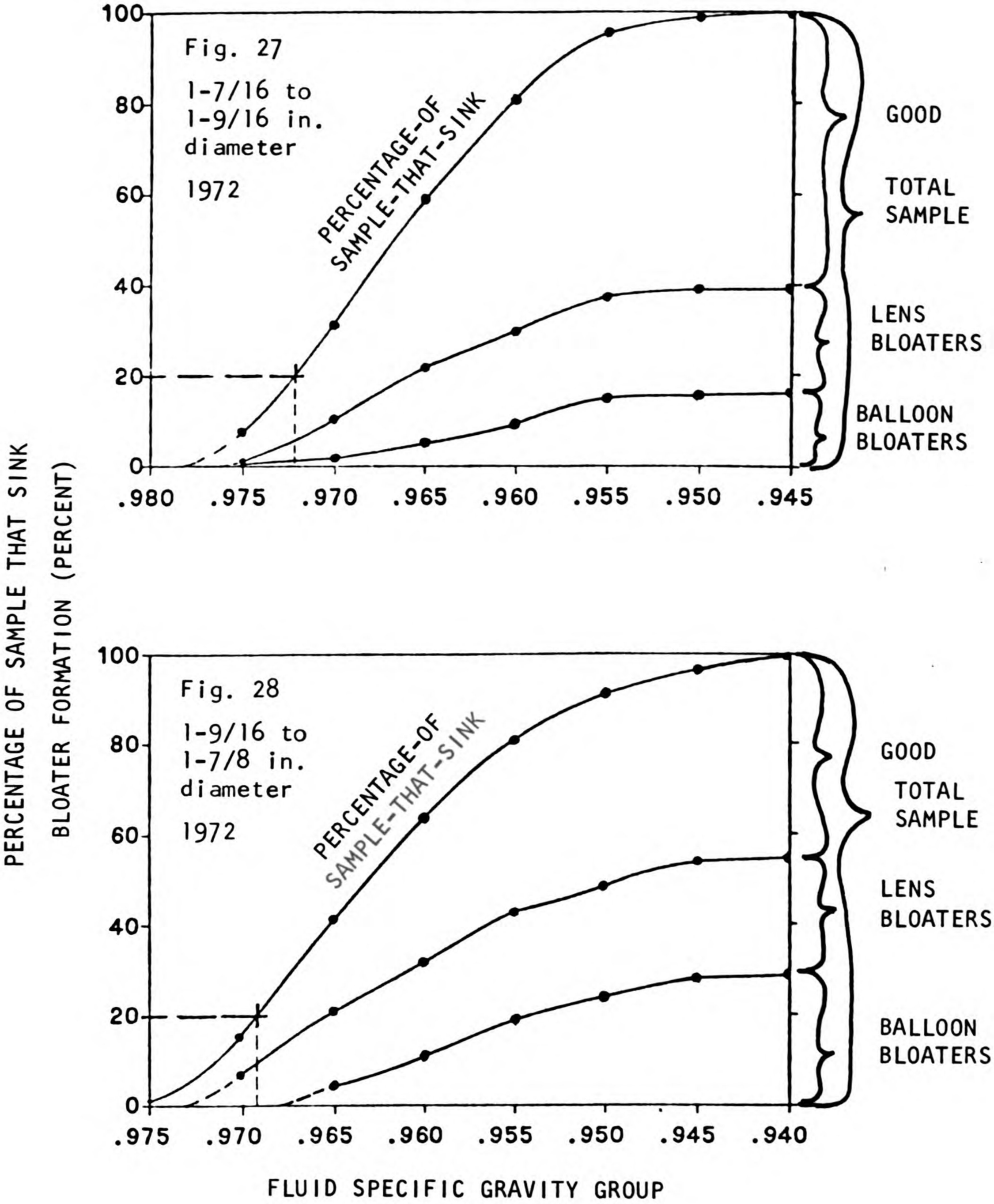


Figs. 25 and 26. Bloater formation in mechanically harvested 'Premier' variety cucumbers sorted into fluid specific gravity groups.

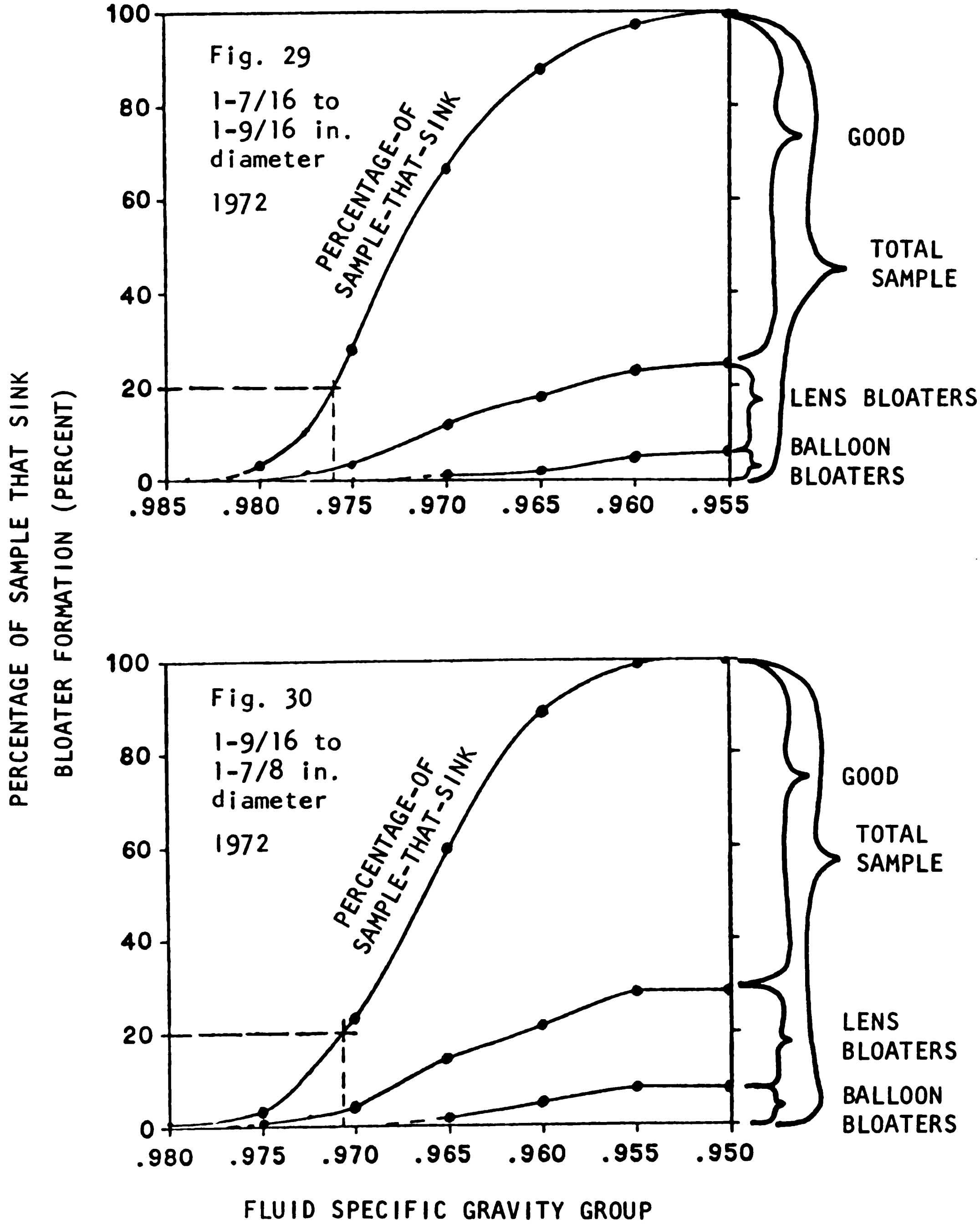
through 30. The curves illustrate the use of the PTS curve in determining the solution SG necessary to obtain a given sinker/floater ratio. When the 'Heinz 19' variety (Figs. 27 and 28) was density-sorted with a constant SG solution for both size grades (.971 SG) 25% of the 10/12s and 11% of the 8/10s sank. The 'Earli Pik' variety (Figs. 29 and 30) was density-sorted with a constant sinker/floater ratio (20/80) using solutions at .976 SG and .971 SG for 10/12s and 8/10s, respectively.

Based on previous discussions, it is clear that in order to maintain a constant sinker/floater ratio that solutions of different SG are necessary for density-sorting different size grades and varieties.

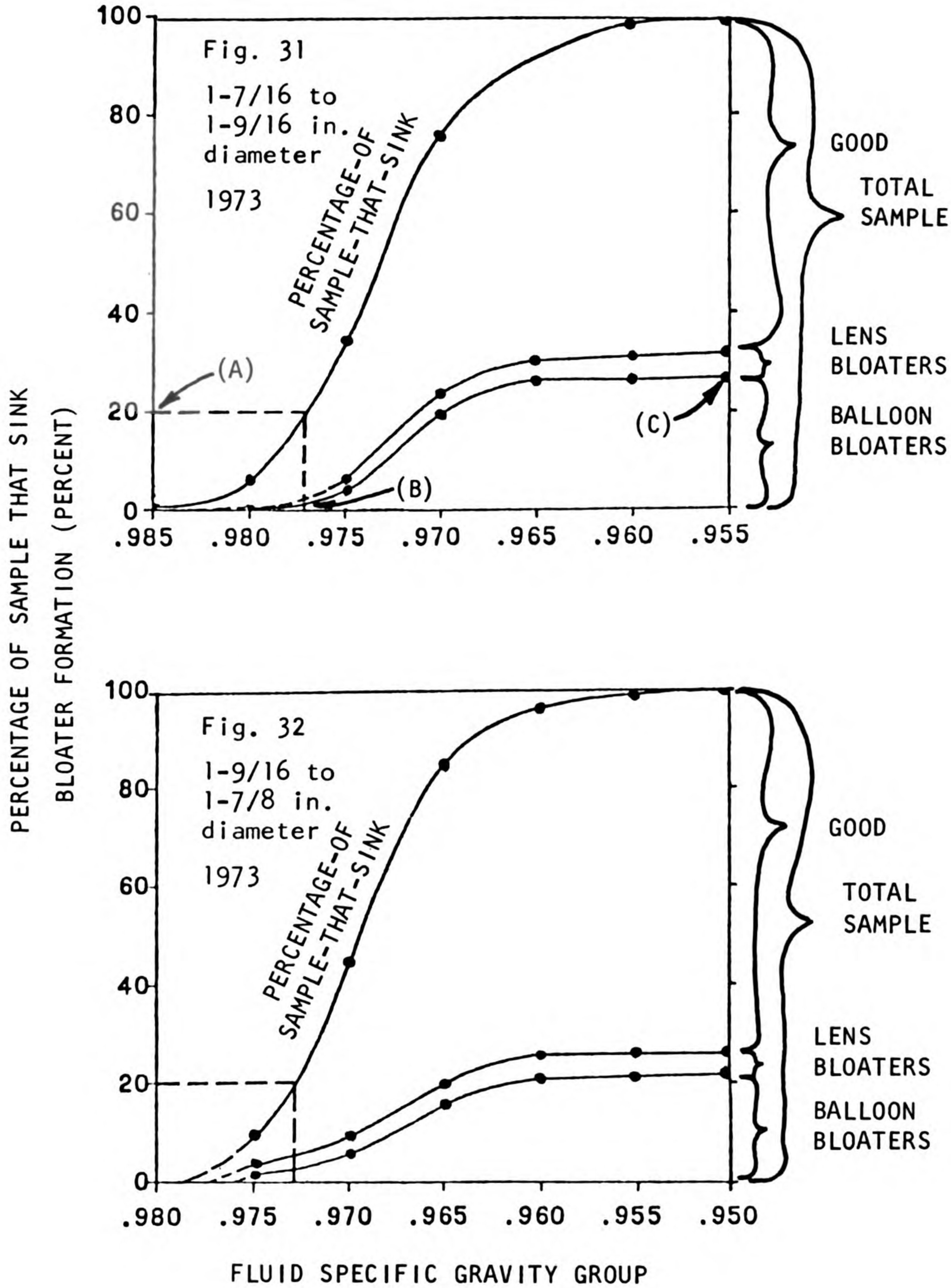
The bloater formation curves are useful in predicting the extent of bloating that would have occurred if the sample had been density-sorted in a particular sinker/floater ratio. For example, in Fig. 31, a 20/80 sinker/floater ratio (point A) would have resulted in a predicted balloon bloater formation of 1.6% (point B). The actual percentage of balloon bloating in the 20% sample would have been 8% (1.6%/20%). If none of the sample had been density-sorted, the balloon bloater formation would have been 26.6% (point C). Therefore, a 70% reduction [(26.6% - 8%)/26.6%] would have been accomplished in the entire sample by density-sorting at a 20/80 ratio.



Figs. 27 and 28. Percentage-of-sample-that-sink curve and bloater formation curves from density-sorted 'Heinz 19' pickling cucumbers.



Figs. 29 and 30. Percentage-of-sample-that-sink curve and bloater formation curves from density-sorted 'Earli Pik' pickling cucumbers.



Figs. 31 and 32. Percentage-of-sample-that-sink curve and bloater formation curves from density-sorted 'Premier' pickling cucumbers.

Commercial Prototype Density-Sorting

Bloater formation (1972). The results of density-sorting for 'Heinz 19' and 'Earli Pik' varieties are presented in Fig. 33. The graphs illustrate that balloon bloater formation was less in sinkers than in floaters. Total bloater formation was least in the sinkers in both varieties.

('Heinz 19'). For the 'Heinz 19' variety, balloon bloater formation in the sinkers was significantly lower (.05 level) than for the floaters. Balloon bloater formation in the smaller size grade was significantly lower (.05 level) than in the larger size. Balloon bloater formation in the smaller size grade was significantly reduced (.05 level) from 36.3% in the floaters to 2.0% in the sinkers (a 94% reduction). This reduction was the largest for all tests conducted. In the larger size grade, balloon bloater formation was significantly reduced (.05 level) from 70.0% in the floaters to 38.8% in the sinkers (a 45% reduction).

Lens bloater formation occurred to a larger extent in the sinkers for both size grades but was not significantly different at the .05 level.

The extent of total bloater formation (balloon + lens) in the sinkers was less than in the floaters for both size grades but was not significantly different at

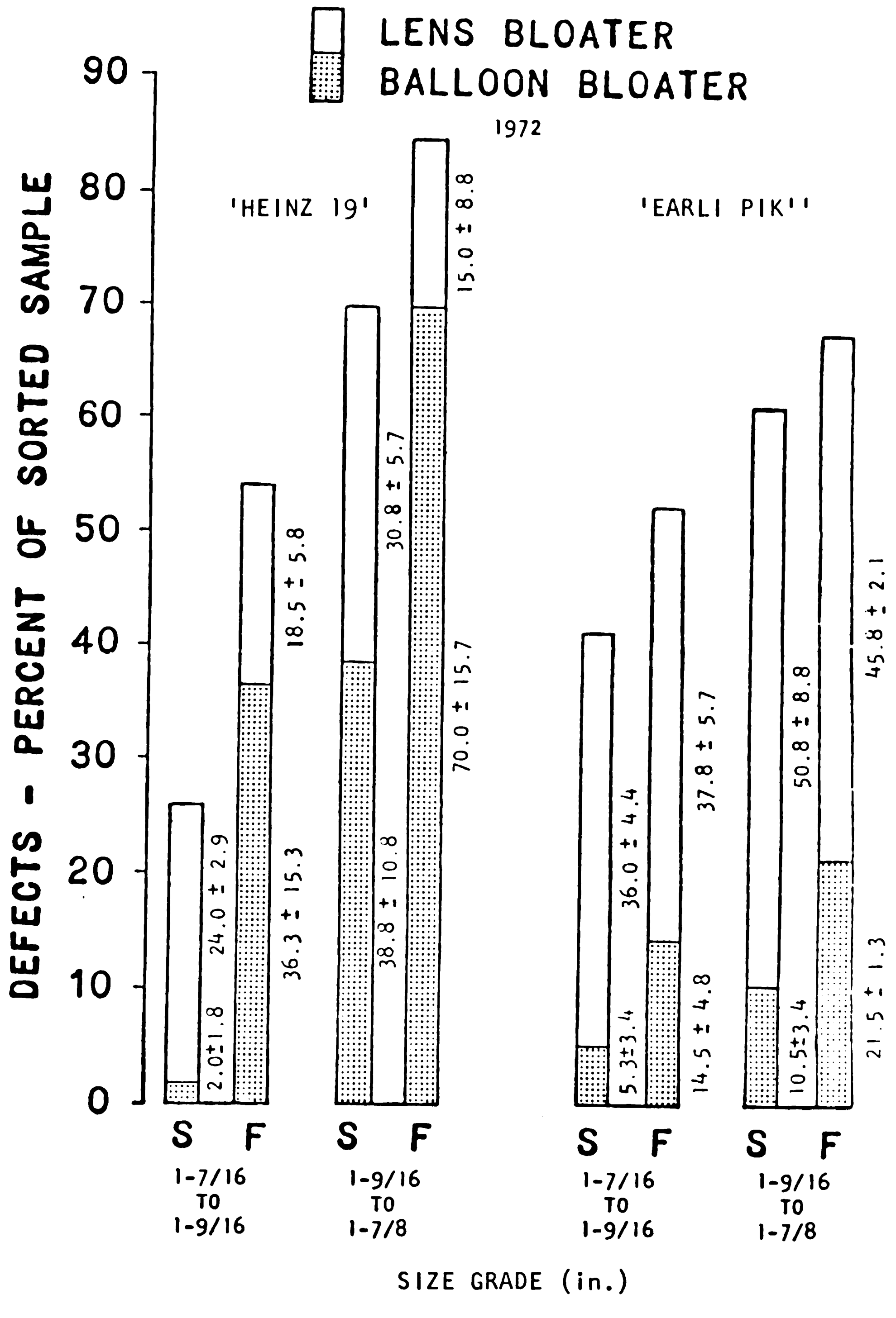


Fig. 33. Bloater formation in two sizes of mechanically harvested cucumbers density-sorted into more dense sinkers (S) and less dense floaters (F). Each variety brined in separate quartered 300-bu tank. Four replications per treatment.

the .05 level. Total bloater formation in the smaller size grade was reduced from 54.8% in the floaters to 26.0% in the sinkers (a 53% reduction). In the larger size grade, total bloater formation was reduced from 85.0% in the floaters to 69.9% in the sinkers (an 18% reduction).

('Earli Pik'). Balloon bloater formation in the 'Earli Pik' variety was significantly lower (.05 level in sinkers than in floaters but not significantly different between size grades. Balloon bloater formation in the smaller size grade was reduced from 14.5% in the floaters to 5.3% in the sinkers (a 63% reduction). In the larger size grade, balloon bloater formation was reduced from 21.5% in the floaters to 10.5% in the sinkers (a 51% reduction).

Lens bloater formation was slightly less in the sinkers for the smaller size grade but was slightly larger in the sinkers for the larger size grade.

Total bloater formation in the sinkers was less than in the floaters for both size grades but was not significantly different at the .05 level. The total bloater formation in the smaller size grade was reduced from 52.3% in the floaters to 41.3% in the sinkers (a 21% reduction). In the larger size grade, the total bloater formation was reduced from 67.3% in the floaters to 61.3% in the sinkers (a 9% reduction).

Bloater formation (1973). The results of density-sorting 'Premier' variety cucumbers are shown in Fig. 34. In contrast to the generally sizable reduction in bloater formation in the sinkers for the 1972 tests, the 1973 tests were not nearly as dramatic.

Balloon bloater formation was less in the sinkers than in the floaters for both size grades, but was not significantly different at the .05 level. Balloon bloater formation in the smaller size grade was significantly less than in the larger size grade at the .05 level. Balloon bloater formation in the smaller size grade was reduced from 52.1% in the floaters to 39.8% in the sinkers (a 24% reduction). In the larger size grade the balloon bloater formation was reduced from 68.4% in the floaters to 58.4% in the sinkers (a 15% reduction).

It should be noted that the 70% reduction in balloon bloater formation predicted from Fig. 31, and the discussion on page 68, for 'Premier' size grade 10/12 cucumbers did not occur; instead, a 24% reduction occurred.

The extent of lens bloater formation was higher in the sinkers for both size grades but was not significantly different at the .05 level.

Total bloater formation in the smaller size grade was less in the sinkers but was significantly greater in the floaters.

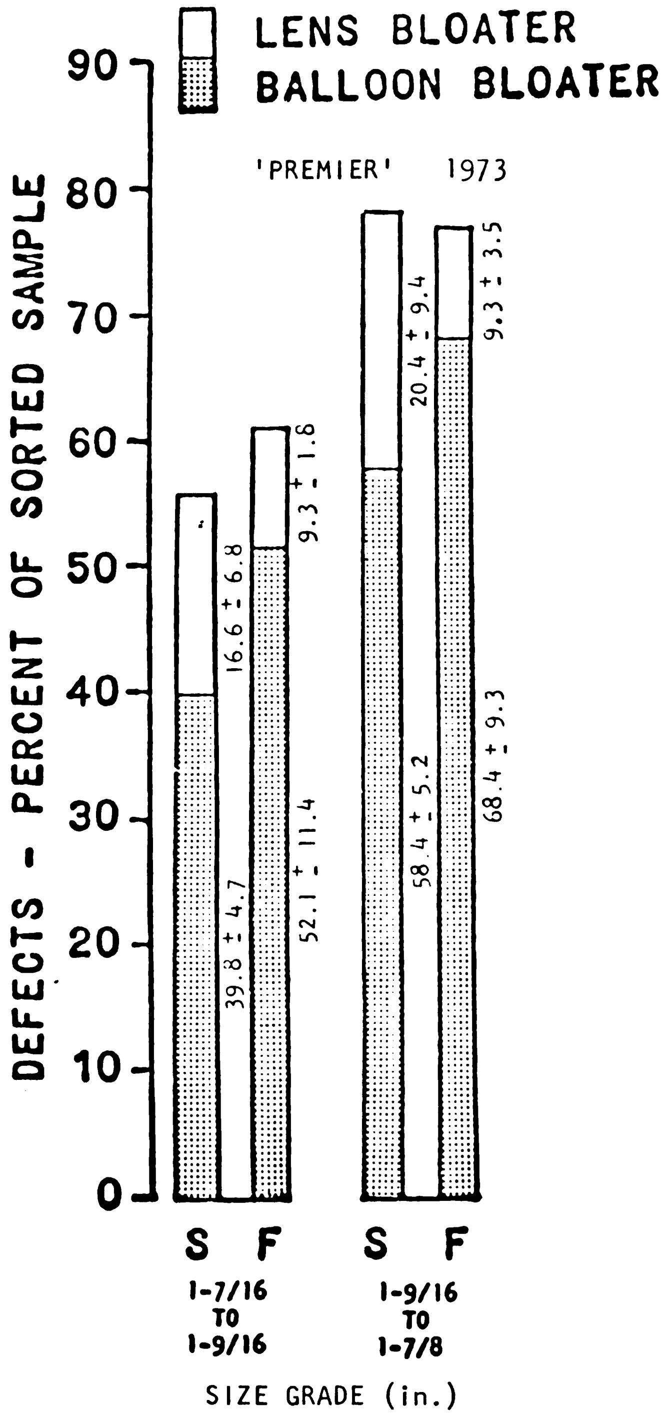


Fig. 34. Bloater formation in two sizes of mechanically harvested cucumbers density-sorted into more dense sinkers (S) and less dense floaters (F) and brined in quartered 300-bu tank. Eight replications per treatment.

General discussion. In three density-sorting tests (three varieties, two size grades per variety) balloon bloater formation was significantly less (.05 level) in the sinkers than in the floaters when sorted into sinker/ floater ratios of approximately 20/80. Balloon bloater formation was found to vary considerably (from 2 to 70%). Balloon bloater formation was less in size grade 10/12 compared to the larger size grade (8/10) in each test.

When the data are pooled for the three density-sorting tests, balloon bloater formation in size grade 10/12 was reduced from 34.3% in the floaters to 15.7% in the sinkers (a 54% reduction). In the larger size grade (8/10) balloon bloater formation was reduced from 53.3% in the floaters to 35.9% in the sinkers (a 33% reduction). When the data from both size grades are pooled, balloon bloater formation was reduced from 43.8% in the floaters to 25.8% in the sinkers (a 41% reduction).

Lens bloater formation was greater in the sinkers than in the floaters in each of the tests except one but was not significantly different in any at the .05 level. The best explanation of this observation is that the brined cucumbers which would have been lens bloaters were weak enough internally to permit balloon bloaters to form. Lens bloater formation was not significantly different between size grades in any of the tests (.05 level).

When the data are pooled for the three density-sorting tests, lens bloater formation in size grade 10/12 increased from 21.9% in the floaters to 25.5% in the sinkers (a 14% increase). In the larger size grade (8/10) lens bloater formation increased from 23.4% in the floaters to 34% in the sinkers (a 31% increase). When the data from both size grades are pooled, lens bloater formation increased from 22.7% in the floaters to 29.8% (a 24% increase).

Total bloater formation was less in the sinkers than in the floaters in each of the tests except one but was not significantly different in any at the .05 level. Total bloater formation was less in size grade 10/12 compared to the larger size grade (8/10) in each test.

When the data are pooled for the three density-sorting tests, total bloater formation in size grade 10/12 was reduced from 56.2% in the floaters to 41.2% in the sinkers (a 27% reduction). In the larger size grade (8/10) total bloater formation was reduced from 76.7% in the floaters to 69.9% in the sinkers (a 9% reduction). When the data from both size grades are pooled, total bloater formation was reduced from 66.4% in the floaters to 55.6% in the sinkers (a 16% reduction).

The mean SG for the three density-sorting tests varied from a minimum of .9637 to a maximum of .9704 (a range of .0067) for size grade 10/12. For size grade 8/10, the mean SG varied from a minimum of .9595 to a maximum of .9667 (a range of .0072). Differences were almost as large between the size grades within a given variety, ranging from .0037 to .0054. Ranges of this magnitude confirm that the solution SG would have to be altered between size grades and varieties with a static flotation separation technique.

Density-sorting selectively separates cucumbers according to a physical characteristic (SG_{avg}) that is related to an internal characteristic that may vary between and within varieties such as carpel or suture strength, carpel SG, wall SG, wall thickness, gaseous volume of the various tissues, internal voids, diameter and maturity. This characteristic (SG_{avg}) has been shown to be related to a fruit's resistance to bloat in the fermentation brine. That is, a dense cucumber separated from less dense cucumbers by density-sorting does not prevent bloating per se, by preventing the cause of bloating; but it merely selectively sorts out those fruits more able to resist the cause(s) that result in bloater formation.

During one of the commercial density-sorting tests, a container of the sorting solution (SG = .971) was set aside in order to monitor the solution's increase in SG due to evaporation. The SG of the solution increased .0020 per hour during sunny daylight hours and .0003 per hour during the night due to evaporation alone.

Dilution of the sorting solution was another problem encountered. Dilution can occur in at least two ways. Most cucumbers are either unloaded into water, handled in water, flumed by water and/or spray-cleaned with water during size grading. Any water or fluids retained on the cucumbers will cause sorting solution dilution. Since cucumbers are about 95% water, any cut, broken, or smashed fruit may exude internal fluids and dilute the sorting solution.

A static flotation mechanical separator is a low-capacity system but by the nature of its principle it is very accurate. The accuracy is due to the fact that the cucumbers have sufficient time in the sorting solution to sink or float according to their SG before they are removed from the sorting tank. Other types of mechanical sorters such as those utilizing the rate-of-rise principle (Kattan *et al.* 1968, 1969) may not sort cucumbers according to their SG nearly as accurately as the static flotation separator. One major problem anticipated in sorting with the rate-or-rise principle is the effect the shape factor, or length-to-diameter ratio (L/D) of the object being sorted may have on sorting accuracy. This shape factor might be referred to as a hydro-dynamic property which would be analogous to the aerodynamic property of an object moving through air. Whereas the use of the rate-of-rise principle has been used successfully by Kattan *et al.* on tomatoes ($L/D \cong 1.0$) in a moving stream of water, it is doubtful that the sorting accuracy in cucumbers ($L/D = 2.6$ to 3.0) would be as high as with the static flotation principle.

An adequate random sampling system would have to be developed and routinely followed for each load of cucumbers in order to establish a PTS curve to determine the correct SG for the sorting solution. To maintain a given sorting ratio, each processing plant pallet box of graded cucumbers from a given truck load would have to be kept separate or marked with its proper sorting SG.

Density-sorting can be used as a valuable tool in brining research. Depending on the test, it can eliminate another variable and improve the accuracy of the treatment results. It has already been used in cucumber handling research (Heldman *et al.* 1974). It can also assist plant breeders in evaluating new varieties when there may only be a small quantity of fruit available to evaluate. Specific gravity can be measured and still have the fruit brined.

Feasibility of density-sorting cucumbers with an ethanol-water solution. The static flotation mechanical separator provided a very convenient approach to density-sorting the cucumbers used in this research. However, before this method is seriously considered for use in a commercial processing plant, a number of observations and/or anticipated problems discussed below should be considered.

Cucumbers would have to be accurately size graded before being density-sorted. The SG of the density-sorting solution would have to be altered for different size grades within a given truck load and probably for different truck loads and different varieties. This is because of the inverse relationship between cucumber SG and diameter and because cucumber SG varies with different varieties.

The SG of ethanol-water density-sorting solutions will be adversely affected by evaporation of the ethanol. Dilution may occur from internal fluids released by cut or broken cucumbers or from water retained on cucumber surfaces from handling or grading systems.

Residue and/or other studies may have to be conducted to satisfy regulatory agencies that ethanol does not have to be included as an ingredient on the product label. Imbibing of U.S.P. ethanol would be possible and therefore appropriate security precautions would be required.

Disposal of old or contaminated ethanol-water solutions may adversely affect the operation of lagoon-type disposal systems and/or may not conform to present or future effluent regulations.

The principle of sorting pickling cucumbers into two density groups has been shown to be an advantage in reducing balloon bloater formation. Average balloon bloater formation in three varieties tested was 41% to 54% less (depending on size grade) in the sinkers compared to the floaters. Average total bloater formation was 9 to 16% less in the sinkers compared to the floaters. Average lens bloater formation was adversely affected with a 24 to 31% increase in the sinkers compared to the floaters.

The density-sorting principle is worthy. However, at present several actual and potential limitations with the ethanol-water flotation separation method have been experienced or discussed. Other sorting solutions and/or sorting methods may permit the density-sorting technique to be a useful and practical method of bloater reduction.

CHAPTER V

CONCLUSIONS

1. The specific gravity of 'Pioneer' variety green stock pickling cucumbers was found to have a highly significant negative correlation ($r = -.92$) with outside diameter. Cucumber specific gravity decreased about .019 for each 1.0 in. increase in diameter.

2. Average specific gravity of the carpel region was found to be consistently higher (.030 to .040) than in the wall region.

3. The average specific gravity of seven varieties evaluated decreased about .010 for each of three successive hand harvests from the same plots.

4. The specific gravity averages of 65 variety lots (55 different varieties) varied from .9822 to .9582 (a range of .0240). Any two varieties whose average specific gravities differed by .0087 or more were significantly different at the .01 level.

5. Some varieties such as 'Carolina,' 'Earli Pik,' 'Spartan Jack,' 'Pioneer' and 'Bounty' had a positive correlation between carpel strength and green stock specific gravity. Other varieties such as 'Premier' and 'Perfecto Verde' had no correlation. No relationship was found between carpel strength and bloater formation or specific gravity in limited tests.

6. Reducing sugar content was not related to cucumber specific gravity. Reducing sugar content was significantly different (.01 level) for three harvest dates from the same plots. The second harvest date was the highest (2.65%), the third harvest date was the lowest (1.77%), and the first was 2.07%.

7. Firmness of brined cucumbers was generally negatively correlated with green stock specific gravity for varieties with "Firm" or "Very Firm" firmness ratings. In varieties with "Inferior" or "Soft" firmness ratings, firmness was generally positively correlated with green stock specific gravity.

8. Balloon bloater formation was inversely related to the specific gravity of the green stock cucumbers. There was no consistent trend

between lens bloater formation and green stock specific gravity. In general, total bloater formation was inversely related to specific gravity.

9. A flotation-type mechanical separator was successfully used for two year's tests to density-sort pickling cucumbers. Ethanol-water solutions (with specific gravity of .969 to .977) were used as a sorting medium to cause a selected proportion of a sample of cucumbers to sink (about 20%) and the balance to float (about 80%).

10. Cucumbers have to be size-graded according to diameter before density-sorting.

11. In general, the specific gravity of the density-sorting solution would have to be altered for different size grades, truck loads, or varieties, to maintain a constant sinker/floater ratio.

12. Use of ethanol-water solutions for density-sorting may pose the following problems: a) evaporation of the ethanol, b) dilution of the sorting solution by water retained from cucumber unloading, handling and/or grading systems, c) residue or other studies to satisfy regulatory

agencies that ethanol is not an ingredient and d) disposal of used sorting solutions.

13. Green stock cucumbers were density-sorted into two groups -- more dense sinkers and less dense floaters. The results of density-sorting cucumbers (to approximately a 20/80 sinker/floater ratio) revealed the following for three different varieties, two size grades per variety:

    a) Balloon bloater formation was less in the sinkers than in the floaters in all tests and significantly less (.05 level) in two of the three tests conducted.

    b) Balloon bloater formation was less in the smaller size grade cucumbers (1-7/16 to 1-9/16 in. diameter) compared to the larger size (1-9/16 to 1-7/8 in. diameter) and significantly less (.05 level) in two of the three tests conducted.

    c) Lens bloater formation was generally greater in the sinkers than in the floaters but was not significantly different at the .05 level.

    d) Total bloater formation was less in the sinkers than in the floaters in five of the six tests but was not significantly different in any at the .05 level.

14. Density-sorting techniques can be used as a valuable tool in brining research. Depending on the test, it can eliminate another variable and improve the accuracy of the response of the treatment results.

15. Investigations have shown that sorting pickling cucumbers into more dense sinkers and less dense floaters is effective in reducing balloon and total bloater formation in the sinkers. However, at present several actual or potential limitations with the ethanol-water flotation separation method have been experienced or are discussed.

CHAPTER VI

SUGGESTIONS FOR FUTURE WORK

1. Examine the complex interrelationships in a single experiment of variables such as: cucumber specific gravity (intact and portions), carpel strength, carpel separation, placental hollow brine stock firmness, bloater formation with variety, harvest date, different growing locations and various soil and environmental conditions.

2. Evaluate ultra-sonics for non-destructive internal cucumber quality measurement.

3. Evaluate cucumber wall and carpel cell structures to determine cause(s) for wide differences in specific gravity.

4. Evaluate commercial specific gravity sorting equipment used in citrus, tomatoes, etc. for cucumbers.

5. Evaluate other liquid materials for use in sorting solutions.

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APPENDICES

Appendix A1

Acreage, yield, production, value and mechanical harvest percentage for cucumbers for pickles in Michigan, 1918-1974.

YEAR	ACREAGE		YIELD		PRODUCTION		VALUE	
	PLANTED	HARV'D	TONS/AC	BU/AC	000 TONS	% OF U.S.	000 $	$/BU
1918		31,670	1.22	51	38.76	45	1,227	.76
1919		25,180	1.37	57	34.44	49	1,134	.79
1920	No Record of Acres Planted 1918 - 1929	26,000	.82	34	21.21	46	822	.93
1921		29,470	1.68	70	49.51	46	2,146	1.04
1922		25,050	.96	40	24.05	38	872	.87
1923		26,840	1.03	43	27.70	35	1,280	1.11
1924		35,440	.58	24	20.41	34	962	1.13
1925		36,810	1.32	55	48.59	29	2,248	1.11
1926		25,030	1.01	42	25.23	28	1,030	.98
1927		17,350	.72	30	12.49	20	468	.90
1928		22,840	1.32	55	30.15	28	1,105	.88
1929		21,000	.70	29	14.61	16	548	.90
1930	33,000	30,000	1.22	51	36.72	21	1,377	.90
1931	23,600	22,000	1.20	50	26.40	20	737	.67
1932	11,000	9,300	.96	40	8.93	22	153	.41
1933	22,000	20,000	1.34	56	26.80	32	482	.43
1934	25,500	22,500	1.10	46	24.84	25	497	.48
1935	31,000	26,000	.96	40	24.96	22	520	.50
1936	29,100	24,440	1.61	67	39.30	27	982	.60
1937	32,700	29,000	1.68	70	48.72	26	1,279	.63
1938	25,200	22,700	1.78	74	40.31	28	1,025	.61
1939	15,800	13,700	1.49	62	20.38	23	467	.55
1940	32,300	26,500	1.13	47	29.89	20	897	.72
1941	35,500	31,500	1.73	72	54.43	28	1,860	.82
1942	37,400	33,000	1.80	75	59.40	30	2,030	.82
1943	28,100	23,200	1.25	52	28.95	19	1,158	.96
1944	29,300	25,100	1.58	66	39.76	22	1,823	1.10
1945	34,100	27,400	1.30	54	35.51	19	1,791	1.21
1946	47,800	42,900	1.37	57	58.68	23	4,034	1.65
1947	40,700	35,600	1.46	61	52.11	21	3,041	1.40
1948	45,000	40,000	1.44	60	57.60	24	3,960	1.65
1949	49,100	46,300	1.66	69	76.67	27	3,834	1.20

Appendix A1 (Continued)

YEAR	ACREAGE		YIELD		PRODUCTION		VALUE		MECH'L, HARV'G % OF ACREAGE***
	PLANTED	HARV'D	TONS/AC	Bu/AC	000 TONS	% OF US	000 $	$/Bu	
1950	39,600	33,600	.72	30	24.19	14	2,218	2.20	
1951	47,600	44,800	1.54	64	68.81	25	4,730	1.65	
1952	48,800	45,800	1.85	77	84.65	26	5,290	1.50	
1953	41,700	39,700	2.04	85	80.98	25	5,230	1.55	
1954	38,000	36,200	2.06	86	74.71	25	4,203	1.35	
1955	37,500	35,500	2.45	102	86.90	28	4,345	1.20	
1956	38,000	35,800	2.54	106	91.03	28	4,744	1.25	
1957	40,000	38,000	3.05	127	115.82	31	5,791	1.20	
1958	31,000	28,200	3.53	147	99.48	28	4,974	1.20	
1959	25,000	22,700	4.61	184	104.65	32	5,013	1.20	
1960	23,500	20,600	4.82	193	99.29	30	5,173	1.30	
1961	26,500	24,400	5.23	209	127.61	31	6,916	1.36	
1962	23,800	22,100	5.30	212	117.13	29	5,997	1.28	
1963	26,000	24,900	5.60	224	139.44	30	7,335	1.32	
1964	25,500	23,700	5.05	202	119.68	28	7,971	1.67	0
1965	17,800	16,500	5.75*	230*	94.83*	22*	7,584	2.33	2.5
1966	20,900	19,600	6.23	249	122.11	23	11,161	2.29	13
1967	29,600	26,600	4.45	178	118.37	20	13,139	2.77	20
1968	22,900	21,200	4.37	175	92.64	16	9,208	2.48	20
1969	23,100	22,200	4.08	163	90.60	18	9,332	2.58	35
1970	24,700	23,200	4.48	179	103.95	18	10,353	2.49	65
1971	25,000	24,500	3.38	135	82.80	15	7,618	2.30	85
1972	28,700	26,000	3.76	150	97.80	17	8,391	2.14	90
1973	27,200	26,400	4.07	163	107.45	18	9,477	2.20	>90
***1974	29,400	27,400	4.23	169	115.90	19	14,488	3.13	>90
1975									
1976									
1977									
1978									
1979									

SOURCE: USDA Statistical Reporting Service

1/ Prior to 1959 the production reporting unit was bushels (48 Lb.). From 1959 on, the production reporting unit has been tons (50 Lb./Bu. used for calculations).

* Includes 13,630 Tons harvested but not marketed.

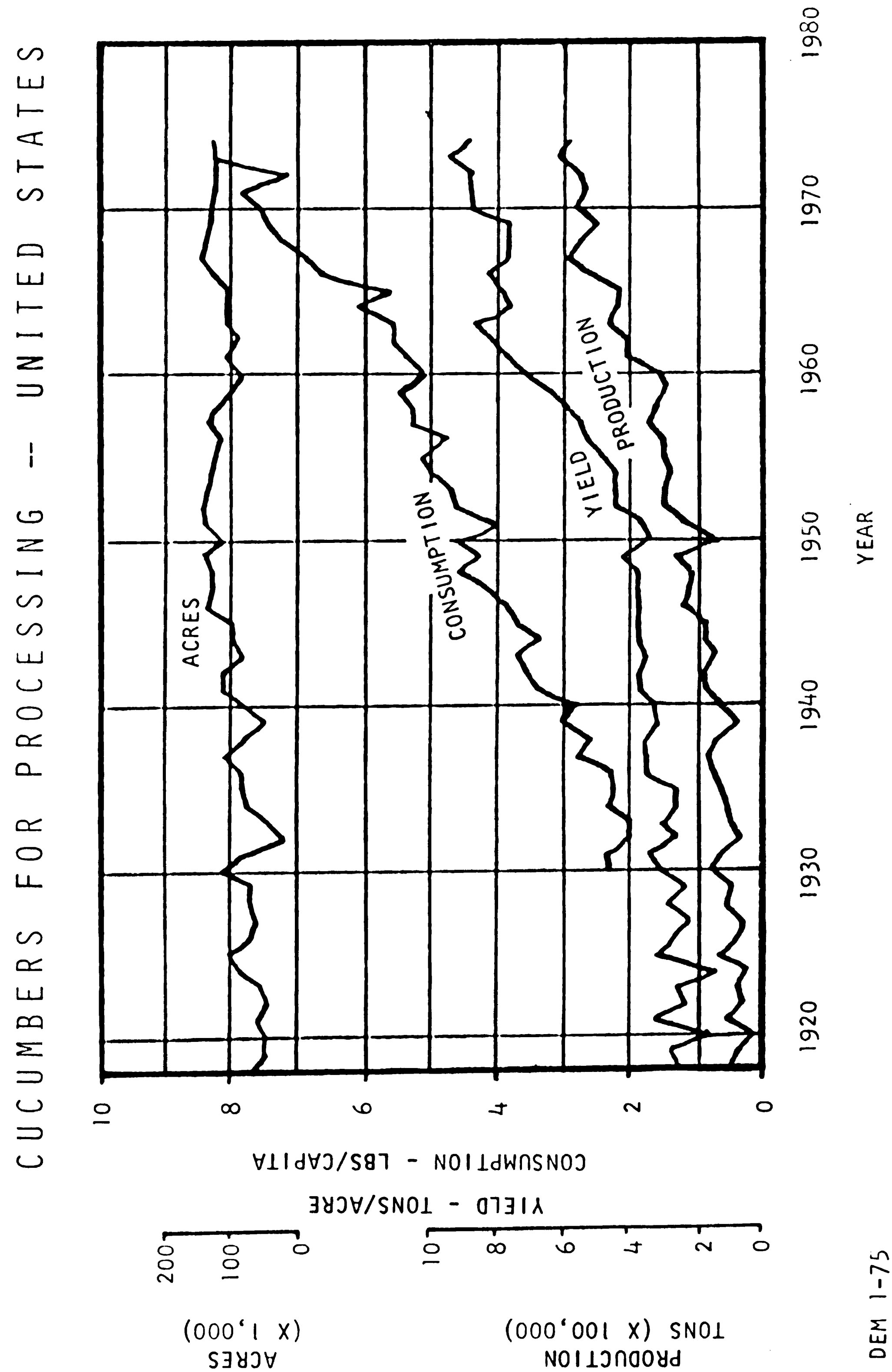
** Industry Advisory Committee Estimate

*** Preliminary

DEM 1-75

Appendix A2

Acreage, consumption, yield and production of cucumbers for pickles for the United States, 1918-1974.



Appendix A3

Calculations of annual loss due to bloater formation in the United States.

ASSUMPTIONS:

1. \$1,000,000 annual loss because of bloater formation (Etchells and Jones 1951). Since the article reports on a June 1950 talk, the data would have been for the 1949 season or earlier.

2. Average U.S. production of cucumbers for processing:

   1947-49 = 264,000,000 tons
   1970-72 = 574,300,000 tons

3. Average U.S. value of cucumbers:

   1947-49 = \$1.45/bu
   1970-72 = \$2.34/bu

4. Percentage of U.S. production brined:

   1947-49 = 90%
   1970-72 = 55% (Moore 1973)

5. Increase in bloater formation from 1947-49 to 1970-72 = 235% (Moore 1975)

CALCULATIONS:

1970-72: $547.3 \text{ million tons} \times 40 \frac{\text{bu}}{\text{ton}} \times 2.34 \frac{\$}{\text{bu}} \times .55$

= \$29,565,000 value of crop brined

1947-49: 264 X 40 X 1.45 X .90 = \$13,781,000 value of crop brined

$\frac{29,565,000}{13,781,000}$ = 2.15 increased value of crop brined in 1970-72 compared to 1947-49

1970-72 Bloater formation loss:

\$1,000,000 X 2.15 increase in value X 2.35 increase in bloater percentage = \$5,000,000 annual loss in 1970-72

Appendix A4

Cucumber density-sorting information sheet describing technique, equipment, sorting procedure, data sheet and hydrometer reading chart.

CUCUMBER DENSITY SORTING INFORMATION

A. OBJECTIVE:

1) Determine average green stock density or specific gravity (S.G.) of different varieties.
2) Determine distribution of density within a given sample.
3) Determine effect of geographic location (soil, moisture, temperature, etc.) on density of a given variety.
4) Determine relationship of green stock density to bloater formation.

B. SORTING PRINCIPLE USED:

Solutions of water and ethanol in 0.005 S.G. decreasing steps.

C. SORTING TECHNIQUE USED:

1) Put a few cucumbers at a time in the highest S.G. pail. If they don't sink, keep transferring each to the next lowest S.G. solution until each finally sinks. The highest S.G. solution a cucumber sinks in is its S.G. category.

D. EQUIPMENT AND SUPPLIES:

Hydrometer (.940 - 1.010), thermometer, 8 to 10 plastic sorting pails (2 to 5 Gal. -- like used in institutional packs -- with lids -- to prevent evaporation when not in use), 1 Qt. plastic graduated measuring cup, water, ethanol, Instruction Data sheets.

E. INSTRUCTIONS FOR PREPARING SORTING SOLUTIONS:

1) Mark pails in .005 S.G. increments from .990 to .945
2) Fill the pails with water to about 65% full for the .990 S.G., decreasing to about 40% full for .940 S.G. (after addition of ethanol pails will be about 70% full). Do not mix the .955, .950, and .945 solutions until positive they'll be needed.
3) Addition of ethanol to water raises the resulting solution temperature. Therefore, mix approximate solutions ahead of first actual use to permit temperature to equalize.
4) The approximate percentage by volume of ethanol required to achieve a given S.G. initially are shown on the bottom of the data sheet.

F. ACTUAL SORTING PROCEDURE:

1) Since the hydrometer is calibrated for a solution temperature of 60°F, corrections must be made to obtain the "true" S.G. category. The corrected hydrometer reading required is shown on the lower half of the data sheet.
2) Examples: Solution Temperature is 70°F:
   a) For the .985 S.G. category the corrected hydrometer reading is .9839 to obtain a "true" S.G. of .985.
   b) Similarly, to obtain a "true" S.G. of .940 the hydrometer must read .9362.
3) After solution S.G. has been adjusted to required hydrometer reading, as outlined above, select sample of 100 or 200 cukes that have been graded to size 3 A (1-1/2 to 1-3/4 in.) or 3 B (1-3/4 to 2 in. dia.). They must be free of any mud or dirt for accurate density sorting. Record sample information on top of data sheet.
4) Put about 1/2 dozen cukes into the highest S.G. solution. Take all that float and shake solution from cucumbers and hands and transfer to next lower S.G. solution until each cuke sinks. If the cuke sinks in the highest S.G. solution mixed, make up a new solution .005 S.G. higher. The correct S.G. category is the highest S.G. solution in which each cuke sinks
5) Put sorted cukes into correct S.G. category trays, buckets or bags until entire sample is density sorted. When done with an entire sample, count cukes in each S.G. category and record on data sheet.
6) Check solution S.G. every 15 minutes. Make appropriate corrections as required by carry-over, evaporation, dilution, etc.
7) If sorted samples are to be brined, identify bags for brine stock evaluation and indicate on data sheet.
8) Please send copy of data sheet to address shown below.

For more Information or Information/Data sheets contact:

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USDA-ARS-NCR
207 Agricultural Engineering Dept.
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Appendix A4 (Continued)

DENSITY SORTING DATA SHEET

SAMPLE A

COMPANY ____________ GROWER AND FIELD ADDRESS ________________________ SAMPLE NO. ______

DATE HARVESTED ______ TIME HARVESTED __________ SAMPLE WAS HAND HARVESTED___

DATE EVALUATED ______ TIME EVALUATED __________ SAMPLE WAS MCHE HARVESTED___

SOLUTION TEMP ______°F SAMPLE IS: 3A's _____ 3B's _____ MIXED ________

DENSITY SORTED BY ____________________________ WERE SAMPLES BRINED? ______

COMMENTS ____________________________________ VARIETY______________

SAMPLE B

COMPANY ____________ GROWER AND FIELD ADDRESS ________________________ SAMPLE NO. ______

DATE HARVESTED ______ TIME HARVESTED __________ SAMPLE WAS HAND HARVESTED___

DATE EVALUATED ______ TIME EVALUATED __________ SAMPLE WAS MCHE HARVESTED___

SOLUTION TEMP ______°F SAMPLE IS: 3A's _____ 3B's _____ MIXED ________

DENSITY SORTED BY ____________________________ WERE SAMPLES BRINED? ______

COMMENTS ____________________________________ VARIETY______________

	NUMBER OF CUCUMBERS IN EACH SG CATEGORY GROUP										
	.990	.985	.980	.975	.970	.965	.960	.955	.950	.945	.940
SAMPLE A											
SAMPLE B											

TEMP °F	TRUE SPECIFIC GRAVITY CATEGORY GROUPS										
	.990	.985	.980	.975	.970	.965	.960	.955	.950	.945	.940
	Hydrometer Reading Required to Obtain Corrected S.G. Category										
48	.9909	.9863	.9817	.9770	.9724	.9678	.9631	.9585	.9539	.9492	.9446
50	.9908	.9861	.9814	.9767	.9720	.9673	.9626	.9579	.9532	.9485	.9438
52	.9906	.9859	.9811	.9763	.9716	.9668	.9621	.9573	.9526	.9478	.9431
54	.9905	.9856	.9808	.9760	.9712	.9664	.9616	.9567	.9519	.9471	.9423
56	.9903	.9854	.9806	.9757	.9708	.9659	.9610	.9562	.9513	.9464	.9415
58	.9902	.9852	.9803	.9753	.9704	.9655	.9605	.9556	.9506	.9457	.9408
60	.9900	.9850	.9800	.9750	.9700	.9650	.9600	.9550	.9500	.9450	.9400
62	.9899	.9848	.9797	.9747	.9696	.9645	.9595	.9544	.9494	.9443	.9392
64	.9897	.9846	.9794	.9743	.9692	.9641	.9590	.9538	.9487	.9436	.9385
66	.9895	.9844	.9792	.9740	.9688	.9636	.9584	.9533	.9481	.9429	.9377
68	.9894	.9841	.9789	.9737	.9684	.9632	.9579	.9527	.9474	.9422	.9369
70	.9892	.9839	.9786	.9733	.9680	.9627	.9574	.9521	.9468	.9415	.9362
72	.9891	.9837	.9783	.9730	.9676	.9622	.9569	.9515	.9461	.9408	.9354
74	.9889	.9835	.9781	.9726	.9672	.9618	.9563	.9509	.9455	.9401	.9346
76	.9888	.9833	.9778	.9723	.9668	.9613	.9558	.9503	.9448	.9394	.9339
78	.9886	.9831	.9775	.9720	.9664	.9609	.9553	.9498	.9442	.9387	.9331
80	.9885	.9829	.9772	.9716	.9660	.9604	.9548	.9492	.9436	.9379	.9323
82	.9883	.9826	.9770	.9713	.9656	.9599	.9543	.9486	.9429	.9372	.9316
84	.9882	.9824	.9767	.9710	.9652	.9595	.9537	.9480	.9423	.9365	.9308
	Approximate percent of ethanol required (by volume)										
	6	11	16	21	26	30	34	38	41	44	47

BIOGRAPHY

The author was born in Pinckney, Michigan, August 13, 1934. He was raised on his father's farm at Gregory, Michigan, and learned about agriculture at an early age. His father was an "early adopter" of new farm equipment and practices. As an example, he purchased the first live power-take-off tractor, power hay rake, and roll hay baler in the area. The same local equipment dealer sold us a silo unloader which was the first of that brand to be installed in the state of Michigan. This type of early machinery experience brought about the author's ultimate desire for future training as an Agricultural Engineer.

The author graduated from Stockbridge High School in June, 1952, and farmed with his father on the family 420-acre livestock and grain farm. He attended an 8-week Agricultural Engineering Short Course at Michigan State College during winter term 1953. He returned to the farm and stayed until September 1956, when he entered Michigan State University. Upon graduation in December 1960 with a B.S. degree in Agricultural Engineering, he moved to the Minneapolis, Minnesota, area to work for Farmhand, Inc. at Hopkins. During his 2-1/2 years with Farmhand he worked on the design of forage boxes, manure spreaders and portable grinder-mixers.

In July 1963 he moved to Milford, Indiana, to work for Chore-time Equipment, Inc., manufacturers of automatic poultry feeding equipment. He designed an automatic controlled hog feeder system utilizing the company's centerless auger. He was granted a U.S., British, German and French patent on the design.

In August, 1966, the author joined his present employer, the Fruit and Vegetable harvesting group of the Agricultural Research Service, United States Department of Agriculture at Lake Alfred, Florida. During his 3 years' work in Florida, he designed a citrus pick-up machine to pick up fruit removed with a tree shaker.

In July, 1969, he was transferred to his present research location at the Agricultural Engineering Department, Michigan State University, East Lansing, Michigan. His responsibilities have been the mechanization of the harvesting and handling of cucumbers and grapes.

He is married to the former Patricia Jean Cochran, and they have two children: Brenda Joy and Todd Edson.