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Abstract approved: Andrea C. Mackey

The purpose of the present study was to investigate the effect of a number of physical and chemical attributes upon muskmelon texture as described by sensory evaluation. Measurements of turgor pressure, percent moisture, total sugars, alcohol-insoluble-solids, three pectic fractions, total pectic materials, starch and cellulose were performed on 50 melons. The melons were purchased at random from a retail market in Corvallis, Oregon, over a five-week period during July and August, 1966. Subjective evaluation of textural quality was provided by a five-membered panel employing a pre-tested ballot. On five-point scales, judges rated resistance to cutting, resistance to biting, resistance to crushing, crispness, fibrousness and sweetness. Simple and multiple correlation analyses were performed to elucidate relationships between the objective and subjective observations.

Considerable variation was found among melons for most of the attributes. Variation was largest in the case of water-soluble pectic substances and cellulose and least for alcohol-insoluble-solids.

According to the results of this study, melon texture is determined to a great extent by the type and amount of cell wall constituents. Significant multiple correlations were found between cell wall constituents, cellulose and protopectin, and sensory panel scores for resistance to cutting, resistance to biting, resistance to crushing and crispness. Fruit maturity, as inferred from starch and protopectin content, also exerted an effect upon texture. Significant multiple correlations were found between starch and protopectin and panel scores for resistance to cutting, resistance to crushing and crispness.

Although not specifically related to texture, a significant and positive simple correlation was found between total sugars and sweetness. Similarly, significant negative correlations were found between starch and total sugars and starch and sweetness.

Turgor pressure, percent moisture, alcohol-insoluble-solids, total sugar, water-soluble pectic substances, pectates-pectinates and total pectic materials were found not to be reliable indicators of muskmelon texture. Although turgor pressure did not exhibit a significant relationship to any textural aspects, a trend was observed

in the data. As a result of this observation and difficulty encountered in measuring turgor pressure, further work with this variable is recommended.

Proximate composition of the melons analyzed compared favorably with published data. This observation lends confidence to the methods and analyses employed. Large standard deviations calculated for some of the attributes measured emphasize the extent of variation among melons, the difficulty in assessing texture in an objective manner and the problem encountered in marketing and purchasing the fresh fruit.

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CHEMICAL ATTRIBUTES OF MUSKMELON RELATED TO TEXTURE

INTRODUCTION

Various factors influence the kinds and forms of produce purchased and consumed in the Western States. Among these are season, wife's education, family income and the quality of the fruits and vegetables (Hard, et al., 1963). Consumers tend to prefer fresh fruits and vegetables to processed products (Dunsing and Bowles, 1961a). Hard, et al. (1963) reported that the quality of produce available in the Western states varied noticeably. In their study 19 percent of the buyers were dissatisfied with the overall quality of fresh produce.

Quality of fresh fruit and vegetables is evaluated by the homemaker on the basis of a number of characteristics such as color, flavor, shape, lack of wilting, softness and firmness. Several of these factors are related solely to textural quality of the food.

Textural characteristics of foods vary and the meaning of the word itself is ambiguous. Since the Webster dictionary definition of texture is difficult to apply to foods, the food field needs its own definition of texture (Kramer, 1964). The definition of texture used in this study was related primarily to mouthfeel, i.e., texture is the evaluation of a food by perception with the skin or muscle senses of

the mouth of its physical characteristics excluding sensations of temperature or pain. The chemical sensation of taste is not included in this definition and texture is not regarded as having visual or finger-touch components. However, since initial judgments of texture are often based on the resistance to cutting, this factor was included in the definition used.

Muskmelon is a popular fruit which varies in its textural aspects. Coles, et al. (1961) reported that muskmelons were available to Western consumers in 51 to 85 percent of stores surveyed from May through September in the Western region. Muskmelon is usually consumed fresh although some work has been initiated on processing methods (Harris and Kaffezakis, 1966).

Although muskmelon enjoys popularity and is widely available, variation in the fruits makes it difficult for consumers to select fruit with acceptable texture. These several considerations led to the initiation of this study. The purposes were:

1. To determine some chemical and physical factors that may contribute to the texture of muskmelon as they are purchased from retail markets.
2. To find reproducible methods of assessing muskmelon texture.
3. To utilize sensory panel evaluation of muskmelon to ascertain correlations between chemical and physical tests

and sensory scores.

4. To determine whether objective tests may serve as reliable measures of muskmelon texture.

REVIEW OF LITERATURE

Consumer acceptance of foods is affected by many factors including personal preferences, availability of the food, money available, age and experience of the homemaker, family composition and numerous others. The initial purchase of a commodity, such as fruits and vegetables, and the decisions for repeated purchase are related to the factors enumerated. In addition, assessments of produce quality influence the homemaker's choice. Some products may be judged primarily by flavor characteristics. It has been reported that consumer preferences for canned pears are affected predominantly by flavor intensity and sweetness of the juice (Pangborn and Leonard, 1958; Sather and Calvin, 1963). Other reports indicate that texture greatly affects the quality of a product. Postlmayer, Luh and Leonard (1956) state that acceptance of canned peaches is influenced by the texture of the fruit. Fox and Kramer (1966) found that the separation of flavor and texture was difficult. In their study the evaluation of flavor of green beans was influenced by the texture of the beans, tender beans being rated better in flavor.

Texture itself can be one of the most important factors contributing to consumer acceptance of a food (Weier and Stocking, 1949; Whittenberger, 1951). It is probably more difficult to achieve acceptable texture in many foods than to obtain desirable flavors.

Matz (1962) notes that many modifications of bread flavor are accepted by consumers, but a relatively small change in texture can cause rejection.

Using a word association test, Szczesniak and Kleyn (1963) found that laboratory "consumers" were highly aware of texture as an important characteristic of food. Most responses were related to degree of hardness, i.e., soft, hard; cohesiveness, i.e., crisp, crunchy, chewy, tender; and moisture content, i.e., dry, juicy, moist, wet.

Importance of Texture

Hard, et al. (1963) reported that Western consumers regarded various textural characteristics of importance when purchasing fresh produce. They looked for firmness in fresh green beans and peaches and ripeness in peaches and strawberries. Lack of wilting was important in selection of green beans and broccoli. Dunsing and Bowles (1961b) reported that certain California meal planners looked for textural characteristics of freshness, ripeness and firmness among other quality factors when buying fresh fruits and vegetables. Gould, et al. (1957) found texture was considered by a consumer panel as an important characteristic in good quality potato chips and whole kernel and cream-style canned corn.

Defining Texture

Several attempts have been made to find an encompassing definition of texture for the food industry, but as yet no one definition is used universally (Kramer, 1959; Matz, 1962; Szczesniak, 1963a). Most assessments of texture are probably based on the manner in which a food feels in the mouth, or its mouthfeel. The Taste Testing and Consumer Preference Committee of the Institute of Food Technologists defines mouthfeel as "the mingled experience derived from the sensations of the skin in the mouth after ingestion of a food or beverage. It relates to density, viscosity, surface tension, and other physical properties of the material being sampled." (Kramer, 1959). A qualitative definition similar to this which was set forth in the introduction was used in this study.

Objective tests have been attempted in order to provide a quantitative definition of texture. As yet, no single objective measurement has been reported that can be used to measure texture in its entirety. Although sensory tests must ultimately be relied upon to determine what texture is and whether the texture of a food is acceptable or unacceptable (Matz, 1962; Szczesniak, 1963b), objective measurements have the advantage of eliminating numerous uncontrollable factors which affect human judgments, such as personality, weather, etc. However, objective measurements are valuable

only to the extent that they can indicate total subjective quality (Amerine, Pangborn and Roessler, 1965). It has been of great interest to develop objective methods for evaluating texture to eliminate inherent human errors, costs of human evaluations and variability in human judgments. A rapid objective method of assessing textural quality would be advantageous for economic procurement of fresh produce by various institutions such as the military (Fox and Kramer, 1966). And reproducible objective methods could provide results which would be comparable between analysis times and between various workers.

Before objective tests can be used to assess texture in lieu of sensory judgments, measurements must be found or developed which will meaningfully correlate with sensory evaluations.

Several approaches utilizing different methods have been taken in attempts to relate sensory and objective measurements. Szczesniak, Brandt and Friedman (1963) developed a rating scale for the quantitative evaluation of food texture with several common foods representing points on the scale of hardness, brittleness, chewiness, gumminess, viscosity and adhesiveness. Using a pressure tester, Wiley and Worthington (1955) found a highly significant correlation (0.91) between pressure tester readings of fresh Italian prunes and flavor panel evaluations of the canned fruit. Blanchard and Maxwell (1941) found that the sugar content of two groups of peas

gave correlations of 0.73 and 0.74 with average scores of quality, including flavor, texture, appearance and color, as measured by a taste panel. Makower, et al. (1953), also studying peas, found that the alcohol-insoluble-solids (AIS) content gave the most significant correlation with sensory evaluation of texture. More mature peas with tougher skins were found to have the highest AIS content. Total solids, density, tenderometer values and two flotation techniques gave less reliable correlations. Using flavor panel evaluations of mealiness on mild mashing of cooked potatoes LeTourneau and Zaehringer (1965) found significant positive correlations with several measured quantities including alcohol-insoluble-solids, specific gravity and starch content. Kirkpatrick, et al. (1959) reported that acceptable flesh texture of apples, judged by a pressure tester, was dependent upon storage temperature. Postlmayer, et al. (1956) reported that shear press values and taste panel evaluations of canned peaches correlated so well that, in their estimation, the shear press can be used to objectively measure canned peach texture. In this study, high shear press values were positively correlated with panel judgments of firmness.

Currence and Larson (1941) compared flavor panel evaluations of muskmelon quality with refractive indices of the juice in an attempt to show a mathematical relationship between these two. Previous work (Chase, Church and Denny, 1924; Porter, Besson

and Allenger, 1940) had indicated that the higher refractive index measurements were correlated with desirable edible quality.

Currence and Larson (1941) reported that variation existed between melons and within melons. A flavor panel rated the blossom end significantly higher in quality than the stem end (as was also shown by Davis, Whitaker and Bohn, 1953) and the bottom significantly higher than the top. Analysis of refractometer readings did not show significant differences between the various parts of the fruit, and the differences that did occur were not consistent with the sensory measurements. The authors concluded that the quality differences between and within melons were caused by factors not measured by the refractometer.

Chemical Factors Contributing to Texture in Fruits

Texture of a fruit is closely related to its structural make-up (Isherwood, 1960; Reeve, 1953). Contributing to the structure are cell wall constituents lending rigidity and mechanical strength, intercellular binding forces and cell turgor (Matz, 1962). Each of these categories embraces a number of distinct factors affecting texture. It might be said that these categories are regulated by the maturity of the fruit since changes in the cell wall, middle lamella and sometimes turgidity are observed. Since no one factor causes or may account for texture, and all are related (Isherwood, 1960),

to obtain a real picture of fruit texture it is necessary to consider a number of constituents.

Cell Wall Materials

A great number of investigations on the texture of plant material have been concerned with the measurement of cell wall constituents which include cellulose, pectic substances, hemicelluloses and lignin (Frey-Wyssling, 1950; Siegel, 1962). Sterling (1963) notes that the cell wall is responsible for the unique texture of many foods. Nightingale, Addoms and Blake (1930) and Blake, et al. (1931) reported that as peaches ripen, a decrease in protopectin and cellulose is accompanied by a gradual thinning of the cell walls and a decrease in resistance to a pressure tester. Simpson and Halliday (1941) attributed the changes from fresh vegetable texture of carrots and parsnips to cooked texture to disintegration of the cell wall which was accompanied by a decrease in protopectin and concomitant increase in pectates. Some kind of histological change was also noted involving the cellulose.

Cellulose is a polymer of 1,4-linked, β-D-glucopyranose units which is found in the primary, but probably concentrated in the secondary walls of plants in a dense interwoven structure. It is the most abundant of the structural components (Frey-Wyssling, 1952; Robinson, 1963). Materials found associated with cellulose in the

cell walls were named hemicelluloses. These are polysaccharide polymers of varying structures which have been thought to bind cellulose in aggregates (Aspinall, 1963; Siegel, 1962). Lignin adds structure to woody plant tissues and may be found at levels up to 30 percent (Robinson, 1963). It is present at low percentage levels in herbaceous plants (Robinson, 1963) and for this reason is probably not of great importance in non-woody fruit tissues. In some vegetables such as green beans, woodiness may accompany maturation. Several authors urge that further attention be given to the investigation of lignin which due to its reactive nature may combine with cell wall materials (Isherwood, 1960).

In the absence of lignin, the pectic substances become more important to structure. These are found in the primary cell walls and middle lamella (Doesburg, 1965; Robinson, 1963; Siegel, 1963). The terminology of the pectic substances was clarified in 1943 (Kertesz, et al.). They were formerly considered to be solely α-D-(1,4)-linked galacturonic acid residues (Kertesz, 1951). However it has been determined that other sugars including rhamnose, galactose, arabinose, and small amounts of 2-0-methyl-D-xylose and 2-0-methyl-D-fucose, L-fucose and D-xylose may be a part of the pectin in some plants, covalently linked to the polygalacturonic acid backbone or even forming an integral part of the main chain (Albersheim in Bonner and Varner, 1965; Doesburg, 1965). Usually

80 percent of the carboxyl groups of the pectic substances are esterified with methyl alcohol and 20 percent are free acids or salts. Some secondary alcohol groups may be esterified as acetyl esters (Doesburg, 1965). The pectins also vary in molecular size. Pectins may affect texture due to their molecular variation according to McCready and McComb (1954). The pectic substances found in the cell wall are probably the water-soluble pectins and alkali-soluble pectins (protopectins). The alkali-soluble pectin may be associated (bonded) with the cell wall materials especially cellulose and possibly protein (Joslyn, 1962). The calcium pectates and pectinates are located in the middle lamella (Kertesz, 1951; Personius and Sharp, 1939).

Cellulose Effects. In certain fruits it has been found that cellulose may be of main importance to the textural characteristic. Kertesz, Eucare and Fox (1959) reported that the firmness of raw apples is due to its cellulose content. Changes observed on ripening however were not due to changes in the amount or quality of the cellulose. Other studies by these workers (Glegg and Kertesz, 1957; Kertesz, et al., 1964) attributed textural losses in apples and carrots, subsequent to ionizing radiation treatment, to degradation of cellulose.

Pectin Effects. Some investigators have credited the pectic substances of the cell wall as having the greatest effect on texture.

Addoms, Nightingale and Blake (1930) and Postlmayer, et al. (1956) stated that differences between clingstone and freestone varieties of peaches were not due to differences in the percentage of cellulose but rather to the greater retention of a higher content of protopectin in the cell walls of the clingstone variety.

Cellulose and Pectin Effects. Other workers have attributed textural characteristics to a combined effect of the pectic substances and cellulose (Isherwood, 1960; Kanujoso and Luh, 1967). Deshpande and Salunke (1964) stated that softening in peaches and apricots was a result of protopectin degradation and solubilization of cell and cell wall components. Sistrunk and Moore (1967) reported that cellulose and water-soluble pectin were important in the character of thawed frozen strawberries. They stated that berries harvested late, i.e., which were more mature, contained more cellulose. There was also less water-soluble pectin found probably due to its demethylation and reaction with other constituents. The more mature berries also gave lower shear press values. Luh, et al. (1960) felt that consistency of tomato juice may be affected by cellulose as it is combined with pectin or other high molecular weight polymers. In a varietal study of fresh strawberries, Wade (1964) noted that textural differences may be due to the nature of the association between the insoluble pectins of the cell wall with other cell wall polysaccharides.

Cellular Adhesion

Although the cell walls contain pectins, these substances are also credited with being the materials with adhesive forces which tend to prevent cell wall separation. This cementing function may be due to the calcium content and the molecular size of the pectic substances in the middle lamella and cell wall (Sterling and Bettelheim, 1955). The prevention of cell separation by the pectic substances is counteracted by starch content of the cells. Starch tends to cause rounding of the cells and hence their separation (Sterling and Bettelheim, 1955). Therefore, although starch is not a polysaccharide of the cell walls, it exerts an effect on texture. Sterling and Bettelheim (1955) believe starch to be the principal determining factor of potato texture. According to Wiley and Stembridge (1961), starch content is closely correlated with apple firmness, with the firm apples having a higher proportion of starch than cellulose. As starch decreased in proportion, cellulose increased indicating a link between these two components.

Since the predominant form of pectin in the middle lamella is thought to be the slightly methylated pectic substances, these molecules can bind calcium ions quite firmly and probably cement by bonding the calcium with pectic substances associated with two different cells (Hamson, 1952; Hsu, Deshpande and Desrosier, 1965).

Treatment of tomatoes with calcium chloride solution increased firmness of the fruit (Laconti and Kertesz, 1941). The investigators believed that the firming was caused by the formation of some insoluble compound or compounds, and that the formation of a gel-like substance, such as calcium pectate, could provide support to cellular structure. They did find higher concentrations of calcium pectate in treated tomatoes vs. untreated controls which supported their hypothesis.

Cell Turgor

The force with which the sap of living cells, tending to escape, pushes outward against their confines is called turgor pressure (Meyer and Anderson, 1952). Cell turgor is probably important in the crispness of succulent vegetables such as celery, lettuce, and cucumbers (Crafts, Currier and Stocking, 1949; Matz, 1965). Those foods without an abundant supply of structural elements to maintain cell form depend upon the turgidity of the cells for their characteristic form (Crafts, et al., 1949; Sterling, 1963). Matz (1965) states that melons which have lost their turgor have a complete loss of texture due to collapse of the tissue, whereas celery may lose crispness, but retain a tough texture and much of its original volume because it contains more structural material.

Kertesz, et al. (1964) have stated that losses in the texture of

beet flesh upon irradiation may be due in part to loss of cell turgidity of which they made no measurements. Strohmaier (1953) attributed toughness of frozen apricot skins to their tendency to separate from the flesh which had lost its turgor on freezing. He did not make measurements of turgor.

Turgor pressure (TP) has been measured directly by few workers (Crafts, et al., 1949). Usually it is measured indirectly using methods which will reliably measure osmotic pressure (OP) and diffusion pressure deficit (DPD) values. Calculation of TP is then based upon the following relationship (Crafts, et al., 1949; Meyer and Anderson, 1952):

Diffusion Pressure Deficit (DPD) = Osmotic Pressure (OP) - Turgor Pressure (TP)

Although intercellular pressure is sometimes considered as an osmotic quantity, (OP = DPD + TP + A), Crafts, et al. (1949) suggest that it is best to consider this as part of the TP when the cells are associated in a tissue.

The uptake, distribution and eventual loss of water from a plant requires that it travel through a selectively permeable membrane from a region of higher solvent concentration to a region of lower solvent concentration (or higher solute concentration) until equilibrium is reached (Crockford and Knight, 1964). The force with which pure water will tend to cross in to the solution contained

within a semi-permeable membrane is called the osmotic pressure (OP). It may also be defined as the pressure on the solution side of a membrane that is sufficient to just prevent osmosis when pure solvent exists on the opposite side. The OP of a solution is a measureable colligative property.

A cell in which TP equals OP, when immersed in pure water, will show no net gain or loss of water. However, if TP is less than OP, pure water will tend to enter the cell with a force equal to the difference between the two pressures. Water will move until TP = 0, then net passage of water will cease. The entrance of pure water into a cell depends upon the difference between the maximum possible TP (which is equal to OP) and the actual TP. This difference is called diffusion pressure deficit (DPD). It is a significant measurement in plant water relations for it represents the tendency with which pure water tends to enter a cell (Crafts, et al., 1949). Water moves between cells when there is a concentration gradient. If a solution outside of a cell, enclosed by a selectively permeable membrane, is hypertonic to the cell, the cell will lose water to the outside solution, becoming plasmolyzed. It will lose both an amount of water and cell volume. Conversely, a solution that is hypotonic to the cell will osmose into the cell until equilibrium is reached causing increased water content and cell volume.

Measurement of OP can be based on plasmolysis, but is most

accurately determined cryscopically (Crafts, et al., 1949) provided a representative sample of juice is used (Kramer and Currier, 1950). Several methods of obtaining sap samples have been tried. Killing plant tissue by heating, with subsequent expression of the sap was shown by Mallery (1934) to give somewhat high values for OP. He however felt that for an extensive series of determinations, it gave results which were just as reliable as those from samples released from tissues by freezing. Daneen (1934) used sap expressed under 7000 lb/in^2 from autoclaved wheat plants with seemingly satisfactory results. Freezing of the plant tissue with subsequent juice extraction using a press or centrifugation gave ready expression of representative juice samples according to Gortner and Harris (1914) and Meyer (1929).

The diffusion pressure deficit has been measured in a number of ways including gravimetric or volumetric measurements, vapor equilibration, hygrometer and refractometer measurements (Kramer, and Brix, 1961). According to Huber (cited by Carr and Goff, 1961), the lack of data on DPD is due to the great labor involved and difficulty encountered in methodology compared to the relative ease of cryoscopic determination of OP.

Total moisture content can be indicative of certain textural qualities. Matz (1965) notes that moisture has been a valuable indicator of texture in corn and beans since dry matter increases in

proportion as the product becomes more mature and tough.

Effect of Maturity on Fruit Texture

The maturity of fruits has been reported to influence texture indicating that changes occurring during ripening are important. Some of the most dramatic changes during this time occur in the fruit cell wall, reflected by softening of the fruit (Spencer in Bonner and Varner, 1965). In apples and pears, there is a rapid decrease in net protopectin directly after picking with a concomitant proportional increase in pectic acid; both fractions remain constant for a time, then development of a mealy texture accompanies the final decrease in pectin (Spencer in Bonner and Varner, 1965).

The actual mechanisms of cell wall softening during ripening of fruit are still not fully understood. The pectic substances undergo shortening of chain length, demethylation and deacetylation (Doesburg, 1965). These changes can affect bonding with other polygalacturonide chains or with associated cell wall constituents such as cellulose and hemicelluloses thus affecting cell wall consistency. Acidity and calcium concentration may also have an effect (Spencer in Bonner and Varner, 1965).

Reeve (1947) reported that pectic substances of the middle lamella of peas not only varied between varieties, but differed within one variety depending upon the degree of maturation. Luh and

Dastur (1966) reported that the texture of canned apricots varied with the ripeness level of the fresh fruit which they attributed to differences in the pectic substances.

The pectins are not the only components of importance during ripening. In apples, Wiley and Stembridge (1961) attribute softening due to maturity and ripening to a decrease in total AIS and to changes in components of AIS. Decreased starch concentration and decreased proportion of starch to cellulose seemed to be the most important factors related to softening. Sistrunk and Moore (1967) report an increased cellulose content in strawberries with increased maturity.

Previous Analyses of Muskmelons

Some measurements of melon quality have been done. Davis, Baker and Kasmire (1964) used a number of visual characteristics to determine muskmelon quality such as net tightness, net height, background color, firmness and ratio of melon length to cross diameter, i.e., shape. They used soluble solids as the measure of good melon quality and found meaningful multiple correlations between net tightness, background color, shape and firmness with soluble solids. They also reported large variations among melons. Other workers have used refractive indices as a measure of good eating quality of muskmelons (Brantley and Warren, 1961; Chace, et al., 1924; Porter, et al., 1940). Hartman and Gaylord (1941) believed that

refractive indices of juice were useful, but needed better correlation with taste for the refractive index to be a reliable measure of edible quality. They found variation in soluble solids content among melons, as had been previously reported by Chace, et al. (1924). These latter workers also reported that soluble solids, refractive indices and sucrose content of the juice increased as melons ripened and that melons gain in flavor, not sweetness, during storage. Davis, et al. (1953) also stated that sugar content does not increase after this fruit is picked.

Several workers have combined measurements of soluble solids with pressure test measurements (Gilbart and Dedolph, 1964; Ogle and Christopher, 1957). The pressure test reveals the force required for a plunger to penetrate into a fruit. According to Haller (cited in Doesburg, 1965) some cells are squeezed by the plunger, others are pushed aside. Several factors then influence pressure test readings such as cell size, intercellular spaces, cell cementing substances and cell wall thickness. Alrich (cited in Doesburg, 1965) has stressed the positive influence of cellular turgidity on pressure test readings. Studies relating pressure test measurements with certain chemical factors in fruits have not always shown a correlation with differences in pectic substances (Doesburg, 1965). This may be due to the fact that such a device measures a number of variables.

The muskmelon fruit is not homogeneous (Scott and MacGillvray, 1940). Variability within fruits has been the subject of several investigations. Currence and Larson (1941) and Scott and MacGillvray (1940) showed that least variable measurements of soluble solids were obtained from a juice sample expressed from the entire fruit, but that sampling a longitudinal section gave satisfactorily comparable results for their work. It has already been noted that the ends and top and bottom of melons were found to vary (Currence and Larson, 1941).

Some of the most extensive tests on melon fruits were conducted by Rosa (1928). He found that in vine-ripened fruit there was a progressive increase in total sugars, dry matter, soluble solids and specific gravity of the juice during ripening. Levels of dextrose and levulose decreased as sucrose formed and sucrose formed more rapidly than reducing sugars. The total amount of pectin was constant but the high proportion of protopectin in unripe fruit decreased rapidly as the fruit ripened with a corresponding increase in soluble pectic substances. Fruits picked immature showed little increase in sugars during storage, and a small decrease with time as respiration occurred; there was no appreciable gain in sweetness; and protopectin was converted to soluble pectin.

In summary, the most common methods for evaluation of quality of muskmelons have been analysis for soluble solids and

pressure test measurements. No studies attempting to establish relationships of chemical and physical attributes of muskmelons with texture of the fruit have been made.

METHODS AND MATERIALS

Sampling Procedure

Ripe melons were purchased at random from a local market in Corvallis, Oregon. The fruit was refrigerated at 40-42°F from the time of purchase until used. This period did not exceed two days. Fifty melons were analyzed during a five week period in July and August, 1966. Sampling was performed in as representative and consistent a manner as possible. The technique is illustrated in Figure 1.

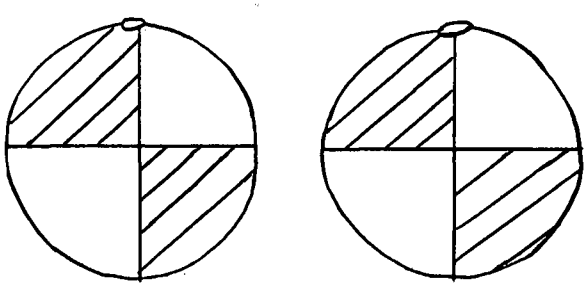


Figure 1. Diagram of Method of Sampling Muskmelons.

After each melon was cut in half from the stem to the blossom end, the respective halves were cut into quarters. The portions which are shaded in Figure 1, consisting of eighths of a melon, were used for the sensory evaluation. The unshaded portions were used for the objective analyses. It can be seen that each group (shaded and unshaded) of eighths collects a sample from the top, bottom, and both ends of the melon. By this means, an attempt was made to reduce variation within melons.

Sampling for the chemical determinations was done in the following manner. Ten four cm cores with a diameter of one cm were taken with a cork borer for determinations of the diffusion pressure deficit (DPD). The remaining tissue was removed from the rind leaving approximately one cm depth of flesh attached to the rind which was discarded. The freed tissue was diced and randomly mixed. Thirty g were removed for the various chemical tests. The remaining portion of the dice was blended in a Waring Blendor at high speed for 15 to 30 seconds. Forty g were reserved for moisture determinations and the remainder of the blendate was immediately frozen in a pre-cooled glass petri plate over dry ice and stored in a freezer at $0^{\circ}C$. This sample was used for determination of osmotic pressure (OP). The several steps are outlined in Figure 2.

Subjective Evaluation

Material for the sensory tests was cut from the rind with approximately one cm depth of combined flesh and rind discarded. The flesh to be tasted was diced, randomly mixed, and served to a trained panel. Five panel members were selected from persons employed in the Home Economics Foods Research Laboratory. Two training sessions, which met the requirements suggested by Matz (1962), were held to familiarize the judges with goals of the

study, criteria for judgment, and terminology of the ballot. In addition, samples for comparison were presented. The judges were in agreement with each other on their ratings of the trial samples. Subsequent to the training sessions, sensory evaluations were done on an individual basis.

A standard ballot was employed. After preliminary evaluation of several melons, a tentative ballot was constructed. This ballot was used in the training sessions, discussed by the panel, and subsequently modified to express clearly what they believed were the qualities being evaluated. A copy of the final ballot is shown in the Appendix (p. 75). The following characteristics were judged on five-point scales: resistance to bite, resistance to cut, crispness as opposed to leatheriness, resistance to crushing (firmness), degree of fibrousness and sweetness.

The panel was served under standard conditions. Two melons were judged at each session with no more than four melons being evaluated per day. Data are presented in the Appendix (p. 78).

Objective Analyses

The flow diagram shown in Figure 2 illustrates the steps followed in the physical and chemical analyses.

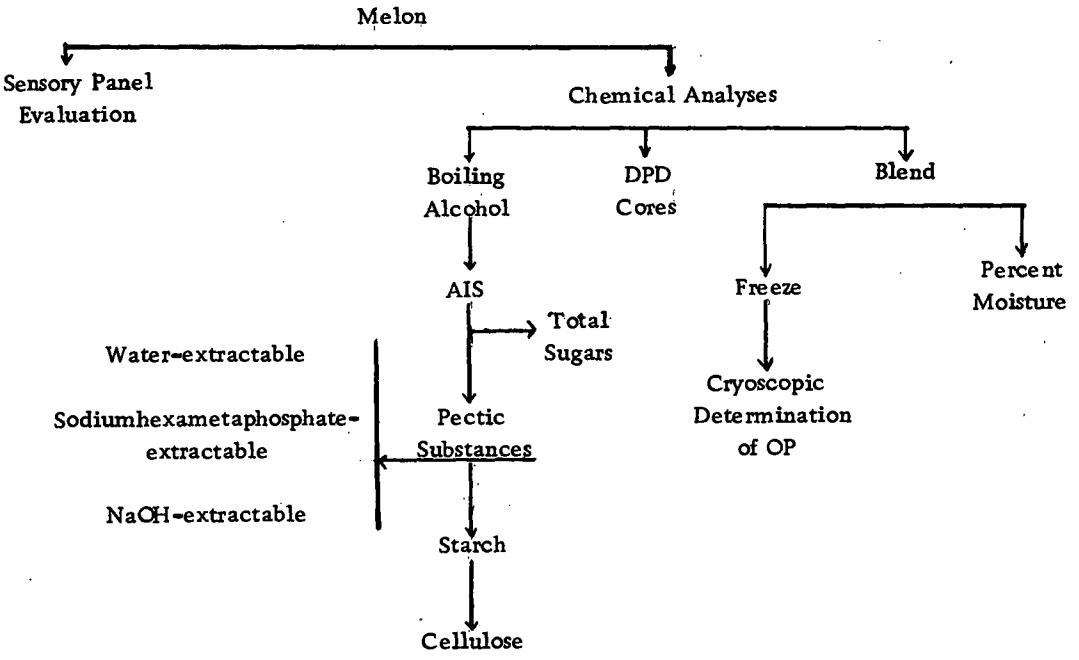


Figure 2. Flow Diagram of Analyses Performed

Turgor Pressure

Since no reliable method for directly determining turgor pressure (TP) is known, it was calculated from the following relationship (Crafts, et al., 1949).

$$DPD = OP - TP$$

DPD was measured using a modification of a gravimetric procedure outlined by Machlis and Torrey (1956). All surfaces of the ten cores from each melon were blotted carefully on absorbent paper to insure consistent surface moisture. After blotting, the initial weight of each core was noted, and the cores then placed in one of several jars containing sucrose solution varying from 0.2 to 0.7M. The systems were closed and equilibrated for 75 minutes. Sucrose concentrations necessary for DPD determinations and length of the equilibration period were predetermined from trial samples. The room temperature was noted half-way through the equilibration time.

After 75 minutes, the cores were removed from the solutions one at a time, blotted and their final weights recorded. The weight change was calculated and plotted against sucrose concentration to determine the DPD (Ashby and Wolfe, 1947). A representative graph illustrating the calculation is included in the Appendix (p. 74). That concentration of sucrose which would result in a zero weight change and would be equivalent to DPD was noted from the graph for

each sample. After conversion to atmospheres at 0°C, the values were used to calculate TP. Conversion was accomplished according to the following equation (Crockford and Knight, 1964).

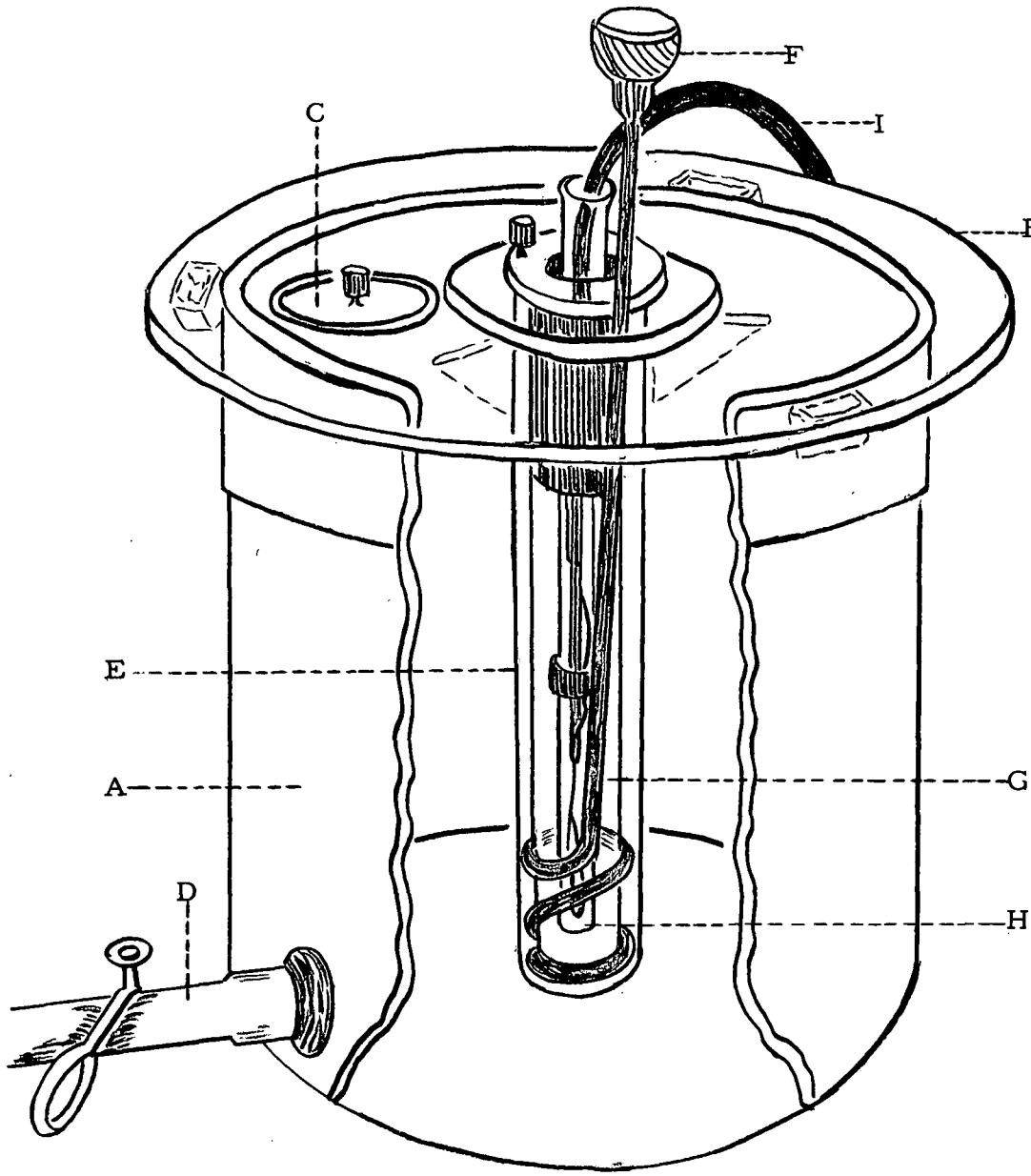
$$DPD = \frac{(22.4)(M)(273)}{T}$$

where M = Molar concentration (from graph)

T = laboratory temperature (°K)

Osmotic pressure (OP) was determined cryoscopically. Frozen samples, each tested within eight hours of freezing, were thawed for ten minutes at room temperature, centrifuged in a clinical centrifuge at high speed, and filtered through Whatman #4 filter paper. Ten ml of filtrate were used to determine the freezing point.

The apparatus used for the freezing point determination, shown in Figure 3, was a modification of that described by Skovolt and Bailey (1935). An earthenware vessel fitted with a plastic lid was packed with layers of chipped ice and sodium chloride. A large tube (3.5 x 20.5 cm) containing a 60 percent glycerol: water (w:w) solution (freezing point = -37.7°C) was inserted through the lid into the brine and equilibrated for 30 minutes. A smaller tube (1.5 x 19.5 cm), containing the sample and a thermistor (Model 14B, Western Electric Co.) was immersed in the large tube to a constant depth (Zeffert and Hormats, 1949). Constant manipulation of a



A	Earthenware vessel	F	Glycerol stirring rod
B	Plexiglass lid	G	Sample tube
C	Ice port	H	Tube enclosing thermistor
D	Drainage port and clamp	I	Thermistor connection to ohmmeter
E	Tube containing 60% glycerol		

Figure 3. Diagram of Apparatus Used for Cryoscopic Determination of Osmotic Pressure.

stirrer facilitated temperature equalization. The thermistor was protected by a glass tube filled with the 60 percent glycerol solution. The temperature changes occurring in the sample were followed by measuring the changes in electrical resistance of the thermistor with a Beckman Soil Ohmmeter, Model 300. Microampere readings were taken at zero time and subsequently at 15 second intervals until a constant reading, equal to the freezing point, was obtained.

To convert microamperes to the corresponding temperatures, a calibration curve was constructed. Preliminary investigations revealed that readings for freezing of muskmelon juice ranged between 90 and 54 microamperes. Glycerol solutions were maintained at specific temperatures in ice, salt and water baths. By inserting the thermistor and a thermometer into the glycerol, microampere and temperature readings could be obtained simultaneously. Thermistor and thermometer readings were taken over a range of 94.5 to 41.5 microamperes corresponding to +13.7 to -15.0°C for the standard curve. Microamperes were plotted on semilogarithmic paper against temperature as shown in Figure 4 (Valassi, 1956). The curve from -15°C to +5°C was magnified, Figure 5, for precise temperature readings since the freezing point of all juice samples fell between these temperatures. Conversion of the extent of freezing point depression to OP values at 0°C was accomplished using the following equation (Crafts, et al., 1949; Crockford and Knight, 1964).

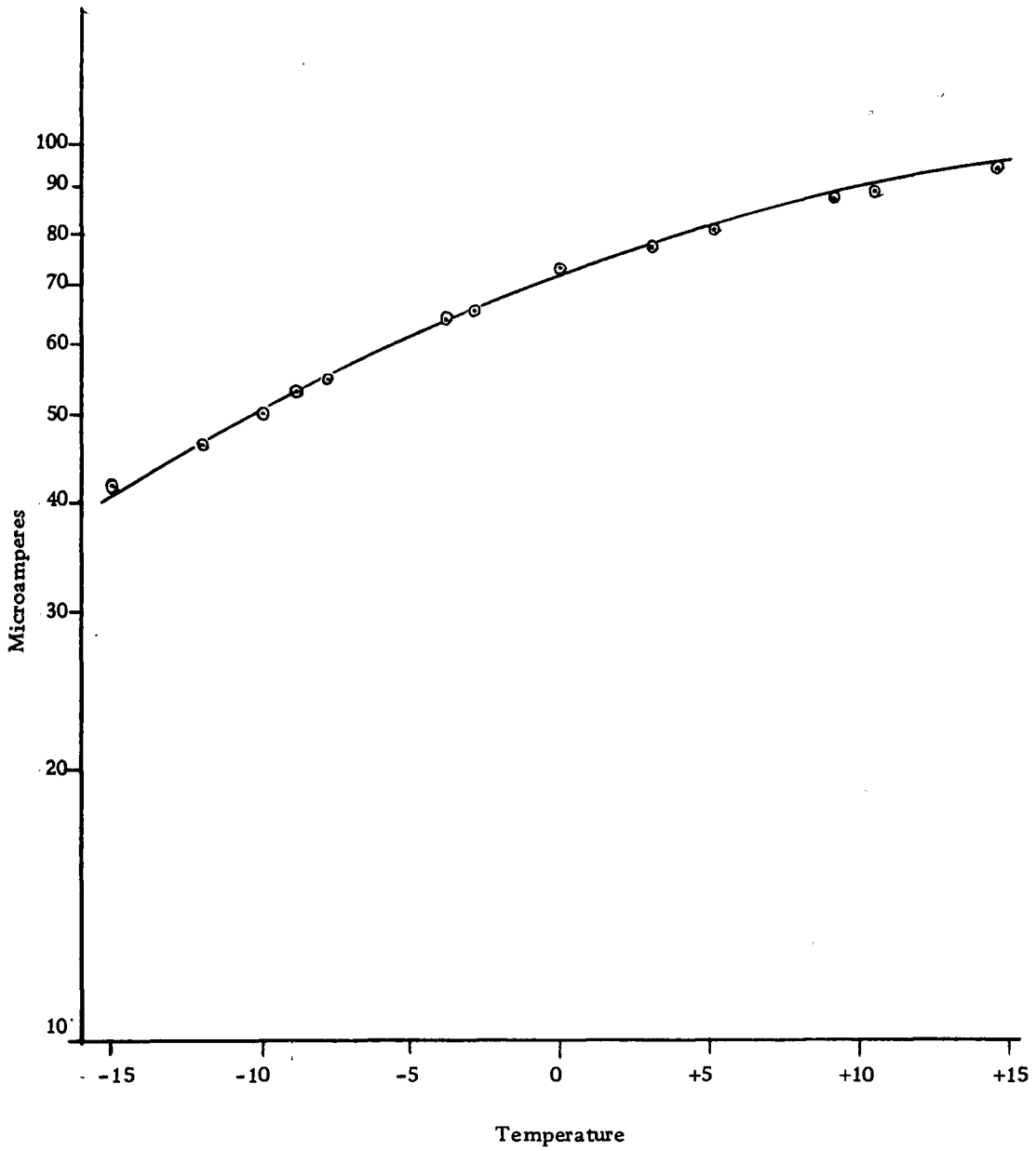


Figure 4. Relationship between Temperature, ^{o}C, and Microampere Readings Made by Means of a Thermistor, Type 14-B, Western Electric Company, with a Beckman Ohmmeter, Model 300.

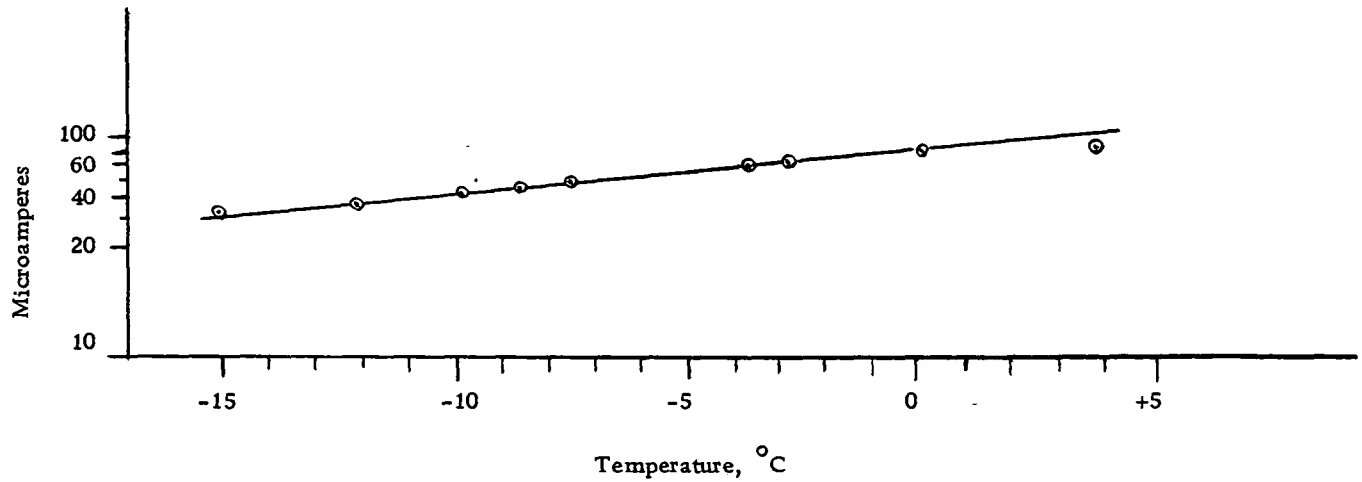


Figure 5. Magnified Section of Temperature Curve in the Range of -15 to +5°C Corresponding to Microampere Readings Taken From Curve Illustrated in Figure 4.

$$OP = \frac{\Delta}{1.86} (22.4)$$

where Δ = freezing point depression in ^{o}C.

The values obtained for OP compare favorably with tabulated values reported by Harris and Gortner (1914) who used freezing point depression to determine OP of plant tissues.

Turgor pressure was then calculated using the values obtained for DPD and OP determinations. Numerical values for the water quantities for each melon are tabulated in the Appendix (p. 76).

Percent Moisture

The percent moisture of the fresh melon tissue was determined in duplicate. Two 20 g portions of the blendate (the other portion of which was used for determination of OP) were weighed into previously tared aluminum pans and dried in an oven at 50^{o}C for 24 hours under 28 inches of vacuum (Gizis, 1963). The samples were removed from the oven to a desiccator for equilibration to room temperature and reweighed. Percent moisture was calculated using the following equation:

$$\text{Percent Moisture} = \frac{I - F}{I} \times 100$$

where I = initial weight

F = final weight

Values for each melon are listed in the Appendix (p. 76).

Alcohol-Insoluble-Solids (AIS)

A modification of a method described by Sistrunk (1959) was used for the determination of alcohol-insoluble-solids (AIS). Each diced 30 g sample reserved for chemical analyses, was blended with 60 ml of boiling 95 percent ethanol for 30 seconds. The slurry was transferred to centrifuge tubes and held in a water bath at 80°C for 15 minutes. Centrifugation in a clinical centrifuge at high speed for 10 minutes was followed by decantation of the sugar-containing supernatant into a beaker. The residue was resuspended in 60 ml of 60 percent, room temperature ethanol. Resuspension, 10 minutes centrifugation and decantation into the same beaker was done twice to insure thorough extraction. The alcoholic supernatant was then concentrated to 100 ml on a hot plate.

The residue was removed from the centrifuge tubes to a previously tared watch glass and dried in an oven at 50° C under 28 inches of vacuum for 16 hours. After equilibration in a desiccator, it was reweighed. Data are reported in the Appendix (p. 76) as g AIS per 100 g edible portion (EP) of muskmelon.

The dried material was stored for approximately four weeks in capped vials for later analysis.

Total Sugars

Three ml of the yellow, concentrated alcoholic extract were decolorized with 0.1 g of Norit decolorizing charcoal. A 0.5 ml aliquot of the decolorized solution was diluted to 100 ml with distilled water. Duplicate samples were then analyzed for total sugars using a colorimetric method (Dubois, 1956). To a one ml aliquot of the diluted sample, one ml water, one ml of 5 percent phenol solution and five ml concentrated sulfuric acid were added. After standing for 10 minutes, the solution was stirred and held in a water bath at 30°C for 15 minutes. The absorbance was read on a Klett-Summerson Photoelectric Colorimeter using a blue filter, #42, and standardized tubes. The instrument was set against a reagent blank.

A standard curve, Figure 6, was prepared using glucose, vacuum dried for three hours at 50°C. The data are reported in the Appendix (p. 76) as g total sugars (expressed as glucose) per 100 g EP of muskmelon.

Pectic Substances

For the determination of the component parts of the AIS, the dried material was finely ground with clean sand using a mortar and pestle. Pectic substances were extracted according to the method of Dietz and Rouse (1953). Forty ml of distilled water were added

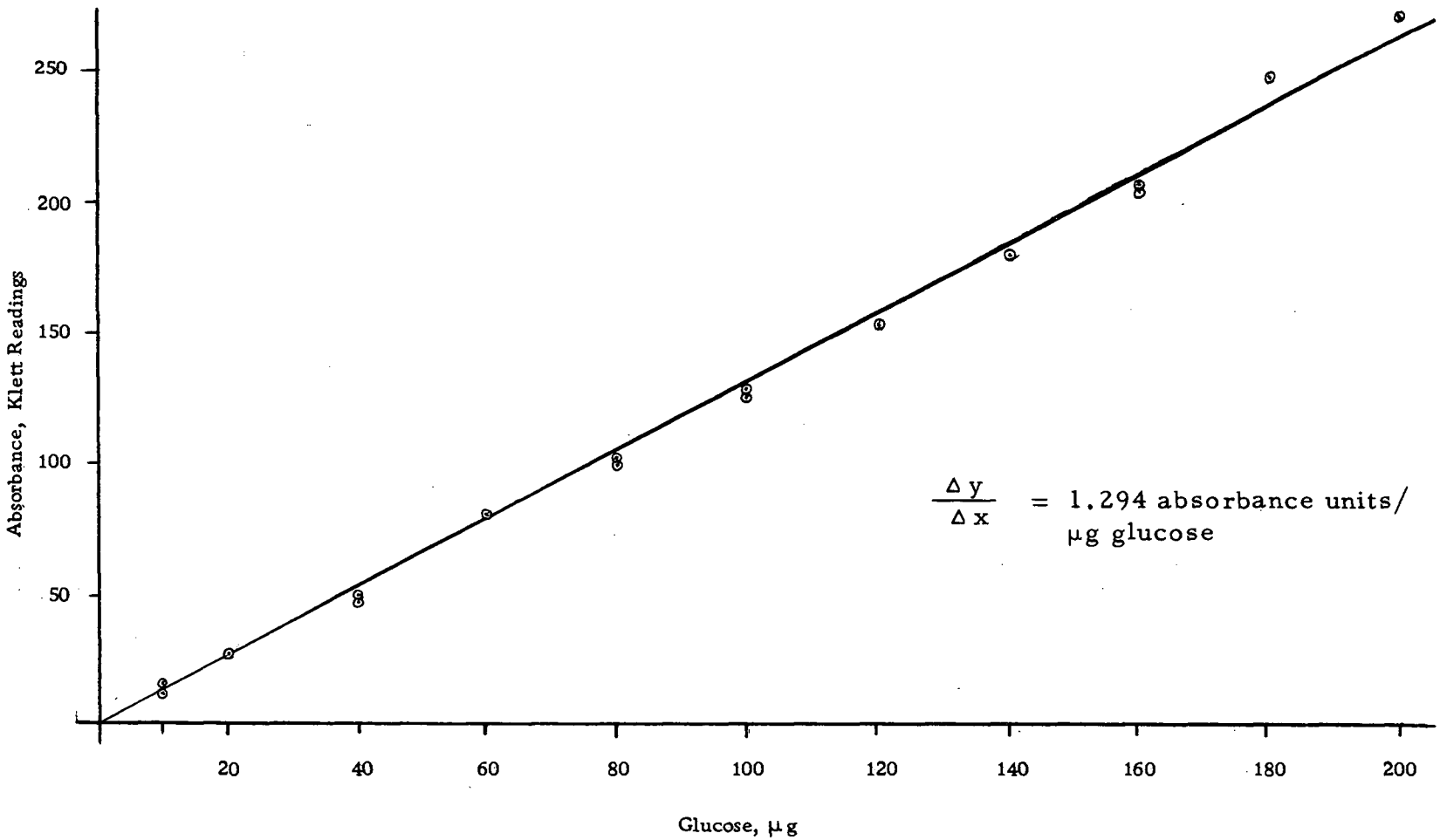


Figure 6. Standard Curve for Glucose.

to the ground material in a test tube with ca 1/8 tsp Hyflosupercel, a diatomaceous earth, added to aid precipitation (Sistrunk, 1959). After the material had settled for 10 minutes, the suspension was centrifuged for 10 minutes and the supernatant decanted into a 100 ml volumetric flask. The steps involved in the extraction of the water-soluble pectins were repeated with decantation into the same volumetric flask. Five ml of 1N sodium hydroxide (NaOH) were added to the flask and the solution diluted to volume. After mixing it was allowed to stand at least 15 minutes before beginning the colorimetric procedure.

To the residue in the centrifuge tubes, 40 ml of 40 percent sodium hexametaphosphate were added to extract the second fraction of pectic substances. The mixture was allowed to settle for 10 minutes, centrifuged and decanted into a second 100 ml volumetric flask. The procedure was repeated for thorough extraction. Five ml of 1 N NaOH were added to the contents of the volumetric flask which were then diluted to volume. After at least 15 minutes had elapsed to insure complete saponification, the colorimetric procedure was begun.

To obtain the high-methoxy pectic substances, the remaining residue was extracted with 40 ml of 0.05 N NaOH for 15 minutes at room temperature with occasional stirring. After a 10 minute centrifugation the supernatant was decanted into a 100 ml volumetric

flask and diluted to volume. After allowing at least 15 minutes for saponification, colorimetric procedures were begun.

The colorimetric analyses were done in duplicate. To one ml aliquots of the three pectin fractions were added 0.5 ml of 0.1 percent alcoholic carbazole. Six ml of concentrated sulfuric acid were then added from a buret with constant agitation. The solutions were stoppered, color development proceded and exactly 15 minutes after the addition of acid, the absorbance was read on a Klett-Summerson Photoelectric Colorimeter using a green filter, #54, and standard tubes. The instrument was set against a reagent blank.

Concentration of the pectin fractions is reported in the Appendix (p. 76) as mg of galacturonic acid per 100 g EP of muskmelon taken from a standard curve, Figure 7, which was prepared according to methods of Dietz and Rouse (1953).

Starch and Cellulose

The extraction of starch and cellulose was done according to the method of Viles and Silverman (1949) and measured colorimetrically using the method of Dubois (1956). After the extraction of the pectic substances from the AIS, 20 ml of distilled water were added to the remaining residue. The suspension was brought to a boil on a hot plate and filtered through Whatman #4 filter paper. The residue was washed with hot water until the filtrate was adjusted to 20 ml.

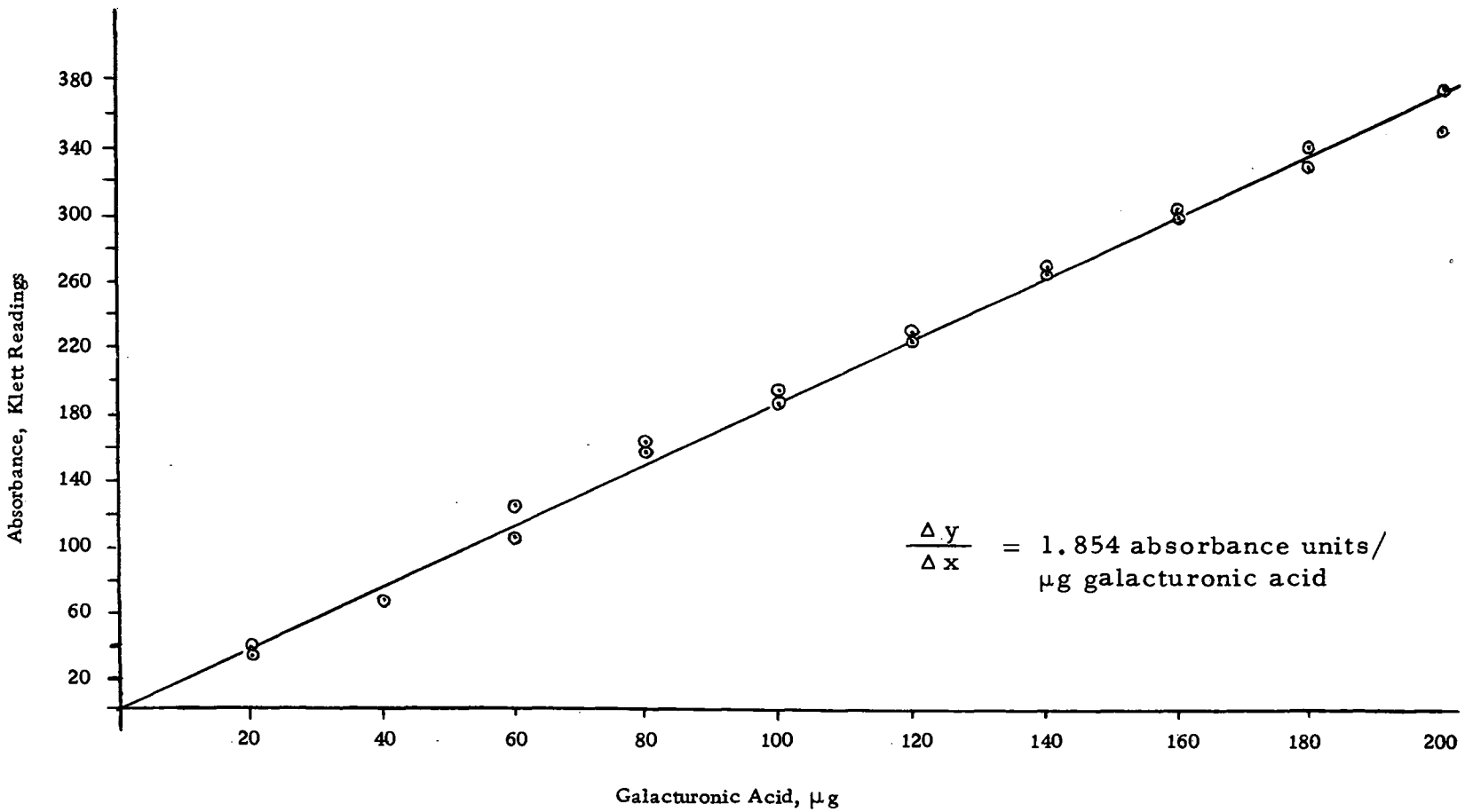


Figure 7. Standard Curve for Galacturonic Acid.

Material left on the filter paper was removed and suspended in 10 ml of water. The cellulose was digested for 30 minutes in a solution to which was added sufficient concentrated sulfuric acid, 9.75 ml, to yield a final concentration of ca 60 percent. Data from the subsequent colorimetric analysis of the digested material were reported as cellulose, but probably included hemicellulosic components.

To a 0.5 ml aliquot from the starch solution and a one ml aliquot of a 1:50 ml dilution of the digested cellulose, one ml water, one ml of 5 percent phenol and five ml concentrated sulfuric acid were added. Duplicate samples were analyzed. After 10 minutes, the solutions were stirred, held in a water bath at 30°C for 15 minutes and read colorimetrically as for total sugars (Dubois, 1956). The concentrations of starch and cellulose were expressed as concentration of the hydrolytic products. Data were taken from the glucose standard curve, Figure 6, and are reported in the Appendix (p. 76) as mg of glucose per 100 g EP of muskmelon.

Statistical Analysis

Certain of the chemical data were thought to be of more importance than others as having possible correlations with the judges' scores for the several textural characteristics, e.g., possible correlations of TP with crispness; cellulose content related to

fibrousness. Correlation coefficients and multiple correlations were determined for those data for which meaningful relationships might be expected.

Considerable variation in the data was noted. It will be recalled that no duplicate measurements were made from one melon, so all variations were among melons. To assist in studying and interpreting the data, the standard deviation for each chemical attribute was calculated (Steel and Torrie, 1960).

EXPERIMENTAL RESULTS

Preliminary Investigation

Food composition tables (Watt and Merrill, 1963) reveal that muskmelons contain 7.5 percent carbohydrate and 91.2 percent moisture. In planning the investigation, it was anticipated that the protein and fat content (totaling 0.8 percent) would not be as significant in affecting muskmelon texture as the water and carbohydrate components.

Qualitative tests for several carbohydrates were done using various histochemical techniques somewhat specific for different components. A thin section of melon tissue was stained with ruthenium red prepared by dissolving a few crystals of the dye in water (Johansen, 1940). After 15 minutes, red staining of some materials was observed under a microscope, indicating the presence of pectic substances.

According to Johansen (1940), methylene blue will stain the pectins violet, but is not as specific as ruthenium red. Cellulose stained with methylene blue will appear bluish in color. A methylene blue:water (1;10,000, v:v) solution was prepared and applied to a thin section of muskmelon. When examined microscopically, violet colored pectic substances were noted. In addition, certain fiber-like strands appeared as a blue color. Hemicellulose and lignin should

appear green with this dye, but no green color appeared.

Another test was carried out to detect the presence of cellulose. Following Johansen (1940), the tissue to be analyzed was mounted on a microscope slide and treated with an iodine solution (0.3 g idodine, 1.5 g potassium iodide and 100 ml water). A 75 percent sulfuric acid solution was allowed to diffuse under the cover glass. The development of a blue color indicated the presence of hydrolyzed cellulose. The above information and reports in the literature would indicate the advisability of studying a number of cell wall constituents in an initial investigation of the texture of a fruit.

Staining with a weak iodine solution and microscopic observation by means of polarized light suggested the presence of starch (Johansen, 1940).

Since the sample size would limit the DPD determination to one analysis per melon, preliminary trials were carried out to ascertain the reliability of but one determination. As many DPD determinations as possible from one melon were carried out. The test was performed as outlined previously taking as many cores from each melon as possible. Two melons were used and were analyzed one week apart. From melon one it was possible to sample sufficient cores for two DPD determinations and from melon two, three determinations were done.

Comparison of the plotted data yielded sucrose concentration

values of 0.455 and 0.457M for melon one and 0.487, 0.488 and 0.492 for melon two, at which the melon cores showed zero weight change. The differences observed among the values within a melon could be real, i.e., due to within melon variation, or could be due to error in several steps of the technique; blotting, weighing or making the original sucrose solutions. Because of the large difference between melons and the small differences within melons, it was concluded that one DPD determination per melon would provide a reasonably precise measure of the actual DPD. For the final analyses, one DPD determination was run for each melon.

Relation Between Chemical and Sensory Evaluations

Percent Moisture

Values of percent moisture for the melons studied ranged from 81.17 to 91.90 percent with a mean of 89.4 percent. These figures compare favorably with published values (Watt and Merrill, 1963) that canteloupe fruits are 91.2 percent moisture. Data for all melons are tabulated in the Appendix (p. 76).

None of the textural characteristics evaluated by the sensory panel were found to be significantly correlated with the percent of moisture. On several ballots, i.e., for melons numbered 1, 2, 3, 4, 7, 31, 36, and 42 comments pertaining to juiciness were noted.

These comments did not follow any trend with regard to the measured amount of moisture present.

Total Sugars

Measurements of total sugars produced values of 4.17 to 11.33 g per 100 gm EP with a mean of 7.42 gm per 100 gm EP. Values for each melon are given in the Appendix (p. 76).

Numerous workers have related refractive indices and soluble solids measurements to quality of melons, as previously discussed. The values for total sugars determined in this study were found to be correlated with the assessment of sweetness by the sensory panel, Table I. Sweetness is an important quality characteristic, but it does not reflect a judgment of texture except perhaps indirectly. The values for total sugars were not correlated with scores for any of the attributes of texture that were judged.

Alcohol-Insoluble-Solids

The AIS consists of polysaccharide materials of several types, proteins and possibly other substances. The values obtained ranged from 0.75 to 1.66 g per 100 g of fruit (EP) with a mean of 1.10 g per 100 g EP. Data for each melon are presented in the Appendix (p. 76).

Significant correlations of the AIS with sensory evaluation of

Table I. Simple Correlation Coefficients between Chemical Analyses and Judges Scores for Texture of Muskmelons (50 Observations).

Chemical Attributes	Textural Indices					
	Resistance to Cutting	Resistance to Biting	Crispness	Resistance to Crushing	Fibrousness	Sweetness
Percent Moisture	.025		.163	-.138		
Turgor Pressure	.056	.035	.028	.080		
Alcohol-Insoluble-Solids	-.254	-.249	-.096	-.273	-.277	
Total Sugars	.048	.071	-.024	.021		.562**
Water-soluble Pectic Substances	-.048	.001	.054	-.034	.092	
Pectates-Pectinates	-.117	.073	-.186	-.073	-.164	
Protopectin	-.547**	-.395**	-.300*	-.237	-.244	
Total Pectic Substances	-.255	-.110	-.111	-.152	-.055	
Starch	-.576**	-.353*	-.406**	-.400**	.254	-.378**
Cellulose	-.302*	-.152	-.278	-.202	-.243	

Starch vs. Total Sugars = -.660**

Osmotic Pressure vs. Total Sugars = .374**

** = Indicates significance at 1% level

* = Indicates significance at 5% level

Table II. Multiple Correlations between Some Chemical and Sensory Data for Muskmelons (50 Observations).

Chemical Attributes	Textural Indices				
	Resistance to Cutting	Resistance to Biting	Crispness	Resistance to Crushing	Fibrousness
Starch and Protopectin	.654**	.438**	.422*	.422*	.289
Starch and Cellulose	.585**	.355	.430**	.405*	.302
Cellulose and Protopectin	.548**	.400*	.336	.313	.281
Alcohol-Insoluble-Solids and Percent Moisture				.287	
Starch and Percent Moisture			.409*	.480**	

** = Indicates significance at 1% level
* = Indicates significance at 5% level

texture were obtained by Makower (1953) when studying peas. No similar significance was obtained in this study, as may be seen in Tables I and II. The component parts of the AIS, which are discussed later, were more important in their contribution to muskmelon texture than total AIS. This finding is comparable to results found for apples by Wiley and Stembridge (1961).

Pectic Substances

The pectic substances were measured as three individual fractions and then mathematically combined to obtain a total value. The fruits varied in their pectin concentrations, but most fruits contained a greater amount of the water-soluble pectins than of the other two fractions. The quantitative amount of water-soluble pectins ranged from 25.80 to 147.72 mg with a mean of 57.57 mg per 100 g EP, for the pectates-pectinates 18.96 to 61.74 mg with a mean of 32.51 mg per 100 g EP and a range of 15.10 to 54.02 with a mean of 32.33 mg per 100 g EP was obtained for the alkali-soluble pectins. Total pectins ranged from 82.33 to 238.77 mg with a mean of 122.10 mg per 100 g EP. Complete data are tabulated in the Appendix (p. 76).

When correlation coefficients were calculated between total pectin and the pectin fractions with sensory panel scores, it was found that only the protopectin fraction gave a statistically

significant result, Table I. The higher the protopectin content, the lower the judges' scores for resistance to cutting and resistance to biting, i.e., the tougher the fruit flesh was judged to be. The assessment of leatheriness was also significantly correlated with protopectin content. The more protopectin, the less crisp or more leathery the fruit was judged to be.

Multiple correlations of protopectin and starch with sensory panel judgments were significant at the 5% level or above for resistance to biting, resistance to cutting, leatheriness and resistance to crushing, Table II. Also as seen in Table II, multiple correlations of protopectin and cellulose with sensory panel measurements were significant at the 5% level or above for resistance to cutting and resistance to biting.

Starch

The starch content of muskmelons ranged from 10.46 to 30.91 mg per 100 g EP. The mean was 17.24 mg per 100 g EP. Data for each melon are listed in the Appendix (p. 76).

Correlations between starch content and resistance to biting were significant at the 5% level and between starch and resistance to cutting, at the 1% level, indicating that the tougher the melon was to cut and to bite, the more starch it contained. Similarly, leatheriness and resistance to crushing were significantly correlated with

the amount of starch. The more starch contained in a melon, the less crisp it was judged to be and the more firm or difficult to crush.

An expected negative correlation was obtained between starch and sweetness. Those melons low in starch were rated more sweet, Table I.

The multiple correlations of starch and the protopectin fraction has already been discussed. Multiple correlation of starch and cellulose with judges scores for resistance to cutting, crushing and leatheriness were significant at the 5% level or above, Table I. However the effects of starch plus cellulose did not seem to differ from those indicated by starch alone as shown by the multiple correlation coefficient. Multiple correlations of starch and percent moisture with leatheriness and resistance to crushing also did not seem to show much difference in effect from simple correlations between starch and these textural attributes.

Cellulose

The range of cellulose concentrations was from 24.14 to 269.47 mg per 100 g EP, with a mean of 172.41 mg. Data for each melon are presented in the Appendix (p. 76).

The correlation coefficient for cellulose content with resistance to cutting was significant at the 5% level. The degree of significance

increased to 1% when cellulose content and protopectin were used in multiple correlation with resistance to cutting, and a significant multiple correlation was found for resistance to bite.

Turgor Pressure

Turgor pressure values ranged from 2.82 to 18.87 atmospheres with a mean of 12.11 atmospheres. Complete data are tabulated in the Appendix (p. 76). The measurements of turgor pressure showed no significant correlations with any of the variables scored by the sensory panel. However, the regression of TP with some of these variables did have a positive slope, indicating trends toward possible interrelationships, i.e., as the TP increases, the easier a melon is to cut, to bite and the more crisp rather than leathery it seems.

Variation Between Melons

A summary of the data obtained, Table III, shows the range of values, means and standard deviations for each chemical attribute measured. A large variation was found among melons in the content of water-soluble pectin ($s = 21.12$), which affects the total pectins ($s = 26.42$), and cellulose ($s = 19.11$). Least variation was found between melons in total AIS content ($s = 0.168$).

Table III. Ranges, Means and Standard Deviations of Chemical Attributes of 50 Muskmelons.

Chemical Attribute	Range	Mean	Standard Deviation
Moisture (g/100 g EP*)	81.17 - 91.90	89.40	± 1.53
Total sugars (g glucose/100 g EP)	4.17 - 11.33	7.42	± 1.60
Alcohol-Insoluble-Solids (g/100 g EP)	0.75 - 1.66	1.10	± 0.17
Pectic Substances (g galacturonic acid/100 g EP)			
Water-soluble	25.80 - 147.72	57.57	± 21.12
Pectates-Pectinates	18.96 - 61.74	32.51	± 8.74
Protopectin	15.10 - 54.02	32.33	± 8.68
Total	82.33 - 238.77	122.20	± 26.42
Starch (mg glucose /100 g EP)	10.46 - 30.91	17.24	± 4.41
Cellulose (mg glucose/100 g EP)	24.14 - 269.47	172.41	± 19.11
Osmotic Pressure (Atm - $0^{\circ}C$)	12.04 - 27.69	21.38	± 3.34
Diffusion Pressure Deficit (Atm - $0^{\circ}C$)	6.72 - 12.13	9.17	± 1.22
Turgor Pressure (Atm - $0^{\circ}C$)	2.82 - 18.87	12.11	± 3.03

*EP = edible portion of muskmelon

Proximate Composition

A comparison of values obtained in this study with values for the proximate composition of melons given in the U.S.D.A. Handbook #8 (Watt and Merrill, 1963) shows favorable agreement. Using mean data found in this study, the mean percent moisture was 89.40 percent; 91.2 percent is given in the handbook. Carbohydrate is given in the handbook as 7.5 g per 100 g EP, while in this study a summation of mean values of total sugars, total pectins and starch yields a mean value for carbohydrate of 7.55 g per 100 g EP. In this study, the mean value for AIS was 1.10 g per 100 g EP and when the component parts of the AIS, i.e., starch, cellulose and pectins, are subtracted, 0.79 g remains unaccounted for. This is probably protein, nucleic acids and other minor components. This amount is comparable to a protein content of 0.70 g per 100 g EP given in the handbook.

The amount of each chemical constituent for each melon was totaled. On the average, 97.75 g of the 100 g EP of muskmelon could be accounted for by those analyses performed.

DISCUSSION AND CONCLUSIONS

This discussion will concern itself with those findings of greatest importance, i.e., those which showed statistical significance or which need further study for clarification.

Since no significant correlations were obtained between percent moisture and textural characteristics judged by the sensory panel, it appears that this measurement is not a reliable indicator of texture of muskmelons. The comments pertaining to juiciness which were noted on the ballots did not follow any trend with respect to total moisture content, but may indicate ease of release of sap from the cells by a weakened cell wall structure. Addoms, et al. (1930) associated increased juiciness of peaches with a decrease in thickness of cell walls and actual breaking of cell walls. Siegel (1962, p. 50) presents data on peaches in which cell wall thickness and degree of esterification of pectins are related to juiciness. As ripening progressed, juiciness increased while a possible weakening of cell wall structure took place.

Stage	Cell diameter (μ)	Wall thickness (μ)	Ester (%)
Immature	91	1.1	81
Green	130	1.3	89
Ripening	123-146	2.1-1.7	93-100
Hard ripe	142	1.8	96
Firm ripe	141	1.3	84
Soft ripe	148	1.1	58

It would seem from these data that the lesser thickness of the cell wall accompanies a decreased proportion of high-methoxy pectin and could therefore account for weakened cell structure allowing easier release of the sap.

In this study, protopectin concentration of those melons noted to be "juicy" had a mean value of 25.2 mg per 100 g. The over-all mean for alkali-soluble pectins was 32.3 mg per 100 gm indicating that the "juicy" melons were more ripe. Being more ripe, they may have had thinner walls, which might release juice more easily, thus accounting for the comments of "juicy" on the ballots.

It would appear that the characteristic of juiciness might be an important one to assess in future muskmelon studies in relation to pectin content and histological study of the cell walls.

As seen in Tables I and II, the AIS was more important in its constituent parts than as an entity itself. This kind of finding was also reported to be the case for apples, by Wiley and Stembridge (1961). The component parts of the AIS that were measured are discussed as they affect texture.

High proportions of starch and protopectins tend to indicate immaturity in fruits. Softening usually accompanies ripening during which protopectin and starch concentrations decrease. It follows then that if the content of starch and protopectin is low, the fruit is ripe. Since the content of starch and protopectin found in this study

showed significant multiple correlations with panel evaluations of cutting, biting and resistance to crushing, it may be said that these textural characteristics are related to the maturity of the fruit. A clear understanding of the dynamics of the physiology of fruit ripening will probably facilitate an understanding of fruit texture.

The ease of biting and cutting depends in part upon the ease of breaking across the cell walls. The stronger the cell wall, the more resistant it will be to cutting and biting. The high-methoxy pectins in peaches are seen to be highest in proportion at the time the wall is thickest (Siegel, 1962). The degree of thickness may make the cell wall stronger due to the association of the various polymers through covalent linkages, hydrogen bonds or strong attractions. The strength of the cell wall would have an effect on the amount of force required to cut or bite through the fruit. Multiple correlation of cellulose and protopectin of muskmelons with resistance to cutting and biting has already been noted. This may be accounted for by wall thickness which is related to maturity. No measurements of wall thickness were made in this study. Further investigations on muskmelon texture would be aided by histological observations.

The importance of cellulose and protopectin to texture was reported by Blake, et al. (1931) who stated that decreasing firmness of

peaches directly correlated with decrease in protopectin, cellulose and thickness of cell walls. Luh, et al. (1960) reported that cellulose and protopectin content of the fruit affect the consistency of tomato juice which may be due to the nature of binding forces between the two polymers.

Expected significant correlations were obtained between sweetness scores and total sugars. The significance might be higher if the exact proportions of each component sugar were known since sugars vary in sweetening power per molecule (Amerine, et al., 1965). Also, a negative correlation between starch and sugars was found indicating that differences in maturity were actually measured since starch is converted to sugars upon ripening.

Osmotic pressure was found to have a significant positive correlation with total sugars. This was expected since OP is a colligative property dependent upon the concentration of solutes. The significance might have been higher had other solute molecules been considered, since sugars are only a part of the dissolved materials in cells.

Since many investigators have alluded to the importance of TP to texture and since muskmelon has such a high percentage of moisture, TP measurements might be expected to account for some part of muskmelon texture. However, no significant correlations were found for TP values and any of the sensory panel judgments of

texture. The positive slope of the plotted data indicates that a trend is possible, i.e., the higher the TP the more crisp, less leathery and the less resistant to cutting and biting. It would seem logical that cells with a high TP, i.e., the more distended the cells were, the more crisp the tissue would be. Also, distended cells would tend to split across the cell membrane easily, making them less resistant to cutting and biting.

The reasons that the TP was not found to be significant may be: 1) the more predominant effect of the cell wall constituents and starch on the texture, or 2) lack of accuracy of the methods used in measuring OP and DPD. The author had confidence in the several steps involved in the determination of OP, but the method for DPD probably needs to be reevaluated and another tried. Refractometer readings to ascertain changes in sucrose solutions in which the tissue has been equilibrated seems a likely next step. Ashby and Wolfe (1947) found comparable values of DPD for potatoes using the gravimetric and refractometer methods; however, there was a difference of 0.2 M for carrots and 0.4 M for iris leaves, with the gravimetric method yielding the higher result. They favored the refractometer method. Vapor equilibration techniques may also provide greater precision in the measurement of the DPD and should be tried.

It was hoped that the chemical data would provide correlation

with the sensory evaluation of fibrousness of the melons thus assisting in a tentative identification of the composition of the fibrous materials. However, no significant correlations were found and no meaningful trends. It would appear that histological examination of the tissue would be helpful.

The variation in water-soluble pectin may be explained by a possible variation in the degree of ripeness. The water-soluble pectins are hydrolysis products of protopectin which appear upon ripening. This conversion continues after the fruit is picked. Since melons are picked at differing stages of ripeness for distribution to retail markets, variation in ripeness is to be expected.

The differences in cellulose content were large and are probably due to actual differences among the 50 melons sampled. It is possible that melons obtained from a local store over a period of five weeks were not of the same variety. It seems likely that different varieties of melons, or melons produced in different areas would have varying chemical compositions. Kertesz, et al. (1964) attributed firmness of raw apples to cellulose content. They did not believe, however, that changes in amount or quality of this constituent were related to changes in texture of apples upon ripening. For these reasons, variation noted in cellulose of muskmelons is not attributed to differences in maturity of the melons sampled.

Although less variation was found in total sugars, percent

moisture and starch, it is possible that this variation could be accounted for by differences among melons. The differences were probably not due to within melon variation since care was taken to randomize the samples served to the panel. Also the panel was instructed to give over-all judgments, not judgments based on sampling one piece of the dice. In addition, muskmelons do not appreciably increase in sugar content after picking (Davis, et al., 1953). However, variation in sugars certainly occurs if melons are picked at different stages of ripeness. The percent moisture of a fruit such as muskmelons would not be expected to vary excessively unless shriveling was apparent or the inner flesh had been exposed to the atmosphere. Melons purchased for this study were not wilted and care was taken to serve the panel fruit that was freshly cut.

AIS content showed the least variation. The component parts of the AIS varied somewhat more. This might indicate a dynamic interrelationship between the constituent fractions contained within the AIS of muskmelons as has been suggested to exist between starch and cellulose in apples (Wiley and Stembridge, 1961).

The conclusion that variation encountered was due to real differences between melons and not due to sources of error in the analytical methods employed, is also supported by the fact that 97.75 percent of the 100 g EP was accounted for by the analyses. Furthermore, the favorable comparison of the proximate composition to

published data demonstrates that analysis was complete and precise. The 2.25 percent not accounted for may include ash, pigment, acids and other minor constituents which were not measured in this study.

SUMMARY

A number of chemical and physical attributes of muskmelons were investigated in order to ascertain their contribution to textural quality. Objective measurements of turgor pressure, percent moisture, alcohol-insoluble-solids, total sugars, three pectic fractions, total pectic materials, starch and cellulose were performed. Subjective assessments of texture were provided by the use of a sensory panel. Simple and multiple correlation coefficients were calculated to elucidate relationships between the objective and subjective observations.

Turgor pressure, percent moisture, alcohol-insoluble-solids, total sugars, water-soluble pectic substances, pectates-pectinates and total pectic materials were found not to be reliable indicators of muskmelon texture. Although turgor pressure did not exhibit a significant relationship to any textural aspects, a trend was observed in the data. As a result of this observation and because of difficulty encountered in measuring turgor pressure, further work with this variable is recommended.

A positive correlation between total sugars and scores for sweetness and a negative correlation between starch content and scores for sweetness was found. Starch and total sugars were negatively correlated.

Several of the chemical attributes were related to one or more textural aspects. The cell wall constituents, cellulose and protopectin, were significantly correlated with sensory panel scores for resistance to cutting, resistance to biting, resistance to crushing and crispness, i.e., the higher the cellulose and protopectin content, the more resistant to cutting, biting and crushing and less crisp or more leathery the fruit was judged to be. Fruit maturity, as inferred from starch and protopectin content, also exerted an effect upon texture. Significant multiple correlations were found between starch and protopectin with panel scores for resistance to cutting, resistance to crushing and crispness. The higher the starch and protopectin content, the more resistant to cutting and crushing and less crisp or more leathery the fruit was judged to be.

Large variations were found among melons for most of the attributes measured. Proximate composition of the melons analyzed compare favorably to published data.

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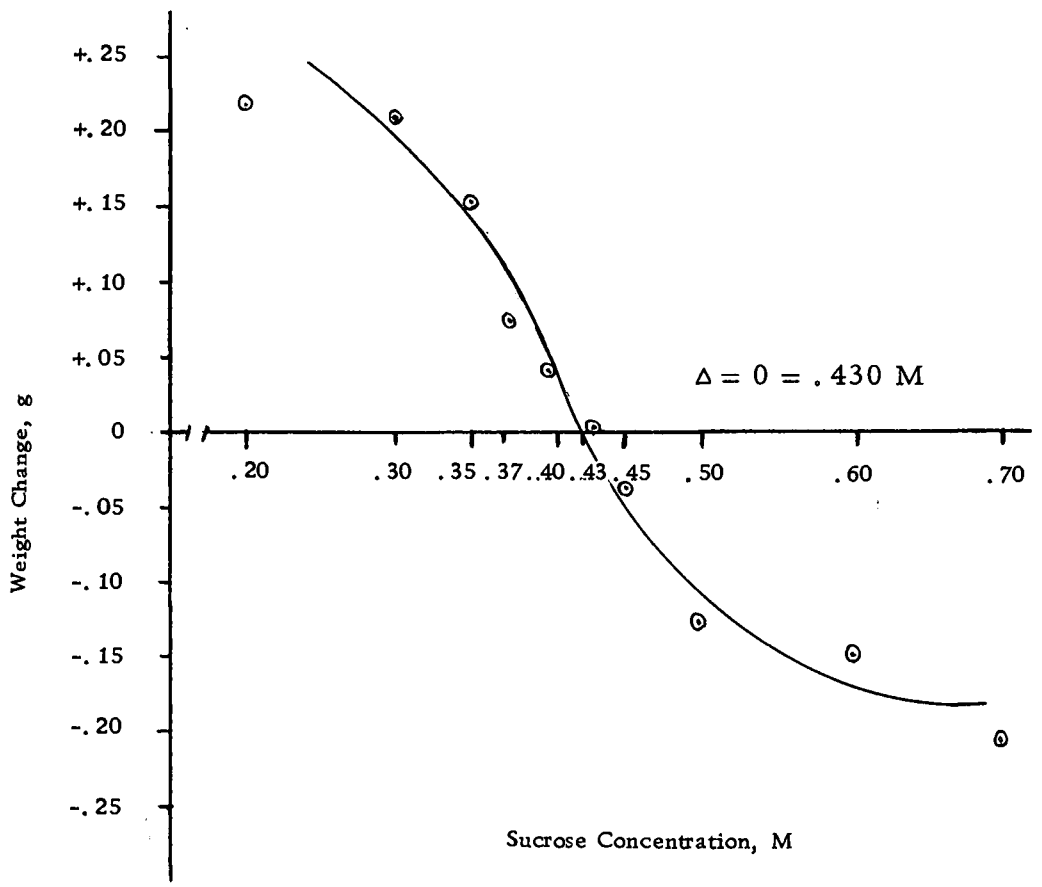
APPENDICES



Appendix Figure 1. Representative Graph Illustrating Determination of DPD from Relationship between Weight Change of Melon Core and Molar Concentration of Bathing Solution.

SCORE CARD FOR CANTELOUPE TEXTURE

JUDGE _____

DATE _____ CANTELOUPE NUMBER _____

Score	Tenderness (resistance to cutting and biting through)		
	bite		cut
(5)	___	very tender	___
(4)	___	quite tender	___
(3)	___	fairly tender	___
(2)	___	somewhat tough	___
(1)	___	very tough	___

Crispness (yield to first entrance of spoon and teeth)

(5)	___	very crisp
(4)	___	quite crisp
(3)	___	fairly crisp
(2)	___	somewhat leathery
(1)	___	leathery

Firmness (press chunk with tongue against roof of mouth)

(5)	___	very easy to crush
(4)	___	quite easy to crush
(3)	___	fairly easy to crush
(2)	___	somewhat resistant to crushing
(1)	___	resistant to crushing

Score	Fibrousness (after chewing)
(5)	___ quite "melty"
(4)	___ fairly "melty"
(3)	___ slightly fibrous
(2)	___ somewhat more fibrous
(1)	___ fibrous residue

Sweetness

(5)	___ pleasingly sweet
(4)	___ slightly under sweet
(3)	___ moderately undersweet
(2)	___ undersweet
(1)	___ very undersweet

Comments:

APPENDIX TABLE I. CHEMICAL DATA FOR 50 MUSKMELONS

Melon Number	Moisture %	Total Sugars (g glucose/ 100 g EP)	AIS (g/100 g EP)*	Pectic Substances (mg galacturonic acid/100 g EP)				Starch (mg glucose/ 100 g EP)	Cellulose (mg glucose/ 100 g EP)	Total Weight of Measured Constituents (g/100 g EP)	Osmotic Pressure (Atm)	Diffusion Pressure Deficit (Atm)	Turgor Pressure (Atm)
				Water-soluble	Pectates-Pectinates	Protopectin	Total						
1	89.15	6.23	1.27	29.66	30.29	24.18	84.13	12.06	43.65	96.65	12.04	9.22	2.82
2	89.22	7.32	1.10	25.80	21.12	38.47	85.39	17.31	40.66	97.64	19.26	8.30	10.96
3	85.56	5.98	1.50	52.13	20.67	26.78	99.58	14.01	38.12	93.04	21.67	8.52	13.15
4	90.51	5.67	1.11	38.83	28.40	15.10	82.33	11.08	24.14	97.29	19.26	8.73	10.53
5	86.41	10.87	1.66	122.24	33.26	18.16	173.66	10.46	109.31	98.94	22.88	10.38	12.50
6	88.60	7.16	1.43	66.06	28.94	28.31	123.31	15.20	130.92	97.19	21.67	9.42	12.25
7	85.80	8.91	0.86	56.18	25.98	24.90	107.06	16.85	110.59	95.57	21.67	9.50	12.17
8	91.74	5.59	0.81	79.51	30.02	26.78	136.31	22.46	133.45	98.14	13.24	8.46	4.78
9	89.72	7.57	0.84	61.57	25.71	43.23	130.51	11.44	188.12	98.13	21.67	8.96	12.71
10	88.84	8.96	0.75	51.05	20.67	24.27	95.99	21.53	59.74	98.55	21.67	8.64	13.03
11	91.79	6.10	1.05	49.61	27.50	40.99	107.67	21.33	166.38	98.94	21.67	9.06	12.61
12	88.84	7.78	1.17	59.77	34.51	23.55	117.83	14.84	170.20	97.79	25.28	11.36	13.92
13	88.37	7.29	1.00	42.78	24.00	22.65	89.43	13.39	216.08	96.66	25.28	8.68	16.60
14	89.28	6.31	1.12	62.47	26.69	27.23	116.39	14.12	150.00	96.71	22.28	9.95	12.33
15	88.45	7.73	1.07	60.22	18.96	25.26	104.44	17.52	142.37	97.25	22.28	10.40	11.88
16	87.93	8.45	1.21	60.22	25.98	32.90	119.10	21.33	134.74	97.59	22.28	11.39	10.89
17	90.50	7.78	1.00	56.18	25.26	22.88	104.32	11.44	127.10	99.28	21.67	9.10	12.57
18	90.64	4.69	1.15	49.43	32.28	30.83	112.54	15.46	222.43	96.48	21.67	6.72	14.95
19	88.75	8.17	1.12	54.83	26.51	31.46	112.80	20.50	222.43	98.04	25.28	10.93	14.35
20	87.48	9.27	1.17	58.42	24.63	25.17	108.22	16.38	152.53	97.92	22.28	10.36	11.92
21	90.60	6.10	0.95	53.75	25.26	28.22	107.23	15.15	146.18	97.65	21.67	8.58	13.09
22	90.93	6.21	1.21	89.88	33.71	30.38	153.97	10.72	162.56	98.35	19.26	8.10	11.16
23	89.06	7.83	1.07	56.63	27.14	25.53	109.30	16.90	115.66	97.96	21.67	9.47	12.20
24	86.05	10.23	1.14	62.47	25.62	22.56	110.65	16.79	113.12	97.42	25.28	11.37	13.91
25	88.80	7.62	1.10	47.64	32.09	42.42	122.15	25.04	264.38	97.52	22.28	10.16	12.12
26	89.11	8.42	1.00	44.58	18.96	42.06	105.60	14.73	219.90	98.53	22.28	8.97	13.31
27	90.22	6.39	1.19	72.80	37.39	28.31	138.50	13.38	241.51	97.80	22.28	8.78	13.50
28	88.43	8.81	1.23	47.10	34.49	32.90	114.49	13.44	190.66	98.47	21.67	10.19	11.48

Appendix Table I (continued)

Melon No.	Moisture %	Total Sugars (g glucose/ 100 g EP)	AIS (g/100 g EP)*	Pectic Substances (mg galacturonic acid/100 g EP) Water-soluble	Pectates-Pectinates	Protopectin	Total	Starch (mg glucose/ 100 g EP)	Cellulose (mg glucose/ 100 g EP)	Total Weight of Measured Constituents (g/100 g EP)	Osmotic Pressure (Atm)	Diffusion Pressure Deficit (Atm)	Turgor Pressure (Atm)
29	88.57	9.02	1.10	54.83	37.75	30.20	122.78	14.94	236.41	98.69	25.28	10.64	14.64
30	89.56	8.35	1.12	52.85	54.11	30.65	137.61	17.41	226.25	99.03	22.28	9.62	12.66
31	87.49	7.98	0.96	70.11	26.51	27.23	123.85	14.73	193.19	96.43	13.24	8.65	4.59
32	89.62	6.16	1.17	60.22	29.48	37.93	127.63	19.27	213.52	96.95	16.86	8.89	7.97
33	88.89	7.16	1.16	91.23	40.81	37.39	169.43	17.82	188.12	97.21	21.67	8.64	13.03
34	91.64	6.34	1.03	61.12	42.42	40.81	144.35	13.91	165.23	99.01	21.67	8.54	13.13
35	90.87	6.75	1.41	147.72	37.03	54.02	238.77	18.24	188.12	99.03	16.86	9.12	7.74
36	90.50	8.37	0.77	76.85	40.09	25.53	142.47	13.29	188.12	99.64	25.28	9.84	15.44
37	88.58	8.73	1.05	61.12	33.71	48.18	143.01	14.73	246.58	98.36	25.28	9.44	15.84
38	89.40	11.33	1.00	54.38	61.74	31.55	147.67	14.22	198.29	101.73	21.67	6.25	15.42
39	89.94	7.93	1.11	61.12	30.74	47.10	138.96	17.21	198.29	98.98	22.88	10.10	12.78
40	89.08	8.22	1.08	53.57	35.77	44.22	133.56	21.12	160.16	98.38	22.88	9.59	13.29
41	89.70	7.21	1.00	54.83	42.78	31.01	128.62	16.28	188.12	97.91	27.69	8.82	18.87
42	89.63	8.09	0.92	33.79	33.08	26.33	93.20	22.93	209.74	98.64	22.88	6.92	15.96
43	90.56	7.68	1.10	37.21	47.82	38.29	123.32	22.26	269.47	99.34	21.67	8.79	12.88
44	89.78	8.76	1.07	35.95	35.95	38.29	110.19	22.81	231.32	99.61	21.67	8.22	13.45
45	90.71	7.98	1.20	46.20	36.31	43.86	126.37	26.38	221.15	99.89	22.88	12.13	10.75
46	89.82	8.35	1.00	36.22	34.51	23.55	94.28	16.59	175.39	99.17	13.24	7.40	5.84
47	90.95	4.17	1.15	53.21	32.09	47.46	132.76	30.91	218.62	96.27	19.26	8.61	10.65
48	91.17	4.43	1.04	34.69	37.57	29.57	101.83	17.21	191.94	96.64	16.86	7.04	9.82
49	90.64	4.25	0.96	42.60	42.96	37.03	122.59	24.11	254.21	95.85	21.67	8.24	13.43
50	91.90	4.48	1.07	47.10	46.20	40.63	133.93	20.61	221.15	97.45	19.26	9.42	9.84

* EP = edible portion of muskmelon

APPENDIX TABLE II. SENSORY PANEL MEAN* SCORES FOR 50 MUSKMELONS

Melon Number	Resistance to Cutting	Resistance to Biting	Crispness	Resistance to Crushing	Fibrousness	Sweetness
1	3.40	2.20	2.80	2.00	1.80	3.20
2	4.00	2.40	3.00	3.00	2.60	4.60
3	3.40	2.60	2.40	3.00	1.80	4.20
4	4.40	3.20	3.00	3.40	2.60	3.00
5	4.00	2.60	3.20	2.80	2.80	4.60
6	2.80	2.20	2.60	2.00	1.40	2.40
7	3.20	2.00	2.40	2.20	1.40	2.60
8	4.40	3.60	2.75**	4.00	3.60	1.60
9	4.00	3.00	3.20	3.80	3.00	3.00
10	3.20	2.40	3.00	3.40	2.60	2.00
11	2.80	1.60	3.00	2.00	2.40	1.20
12	3.00	2.20	2.40	2.20	1.80	2.20
13	3.80	2.60	2.80	2.40	2.20	2.80
14	3.60	2.60	3.40	2.60	2.20	2.40
15	3.40	2.80	3.00	2.20	2.20	3.60
16	2.40	1.60	1.80	1.20	1.20	2.20
17	4.00	3.20	3.00	2.40	2.80	2.60
18	3.40	2.60	2.80	2.60	2.00	1.40
19	3.00	2.00	3.00	2.00	1.20	3.80
20	3.20	1.80	2.60	2.40	2.00	3.60
21	3.80	2.20	2.60	3.40	2.20	2.40
22	4.40	3.20	2.60	4.60	2.60	2.20
23	4.40	3.20	2.80	3.80	2.60	3.40
24	3.00	2.20	3.00	2.00	2.40	4.00
25	1.80	1.00	2.20	1.40	1.40	2.20
26	4.40	2.75**	2.40	3.80	2.00	3.20
27	4.20	3.40	2.80	4.00	2.80	1.80
28	3.20	2.00	2.80	2.40	1.60	3.20
29	3.20	1.80	2.80	1.60	2.00	3.20
30	3.20	2.60	2.40	2.00	1.20	3.20
31	3.60	2.60	2.40	2.00	2.00	3.00
32	2.20	1.40	2.60	1.60	2.00	1.60
33	3.60	2.80	2.80	2.80	2.40	3.60
34	4.00	3.40	2.80	4.00	2.20	1.60
35	2.00	1.80	2.60	1.20	1.80	1.40
36	4.40	3.00	2.60	3.20	1.60	3.40
37	3.20	2.60	3.00	2.60	2.60	2.80
38	3.80	3.20	2.80	3.80	2.20	4.40
39	2.00	1.20	2.00	1.00	1.60	1.60
40	3.00	2.20	2.60	2.20	1.80	2.20
41	4.20	3.20	3.00	3.20	3.00	2.80
42	4.00	3.40	2.40	2.80	2.20	3.20
43	3.00	2.60	1.60	3.00	1.20	2.60
44	2.60	1.80	2.80	2.40	2.00	1.80
45	2.40	2.20	2.20	2.20	1.80	2.40
46	4.80	3.80	3.20	4.20	3.40	2.60
47	2.40	2.40	2.40	1.60	2.00	1.80
48	3.80	3.20	3.20	3.00	2.80	2.60
49	2.80	2.20	2.60	1.80	2.00	1.80
50	2.60	1.80	2.80	1.60	1.80	1.40

* = Mean of five judgments

** = Mean of four judgments