## Abstract

CRIPPEN, KAREN L. The Effect of Grind, Salt Concentration and Sucrose Concentration on the Flavor and Texture of Peanut Butter. (Under the direction of Donald D. Hamann and Clyde T. Young).

A 3x3x3 factorial design was used to study the effect of grind size (0.003-, 0.011- or 0.018-in. gap between stones in the peanut butter mill), salt concentration (0, 0.6 or 1.2%) and sucrose concentration (0, 3 or 6%) on the flavor and texture of peanut butter. Sensory methods included descriptive flavor and texture analysis, and consumer preference evaluation of flavor and texture. Instrumental extrusion viscometry parameters, as well as instrumental evaluation of hardness and adhesiveness, were determined for comparison with sensory texture descriptors.

Sour aroma increased with decreasing grind size. As grind size increased, instrumental adhesiveness and hardness increased while sensory mastication adhesiveness, spreadability and consumer preference of texture decreased. Briny aroma, roasted peanut flavor, salty flavor, nutty aftertaste and salty aftertaste increased when salt was added at either 0.6 or 1.2%. The 0.6% salt concentration gave highest values for

overall impression of aroma and flavor, briny aroma, salty flavor and aftertaste, and consumer preference of flavor. Added salt improved the ease of swallowing and consumer acceptance of texture over no salt. Sweet aroma, flavor and aftertaste were increased by added sucrose while sour flavor, bitter flavor and aftertaste were decreased. The 3% sucrose resulted in the highest value for consumer preference of flavor. Added sucrose caused decreases in instrumental adhesiveness, the descriptive characteristics of adhesiveness, and consumer acceptance of texture, but it increased ease of swallowing.

# The Effect of Grind, Salt Concentration and Sucrose Concentration on the Flavor and Texture of Peanut Butter

by

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# BIOGRAPHY

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After graduation from high school in Olathe, Kansas in May, 1973 she married Airman First Class Devany Crippen of the U. S. Air Force. After being stationed at Forbes Air Force Base, Kansas; Osan Air Force Base, Korea and Eglin Air Force Base, Florida the author and her husband remained in Florida and attended Okaloosa-Walton Junior College. After moving back to Kansas she attended Mid-America Nazarene College for one year then transferred to Kansas State University. There she received her Bachelor of Science Degree in Food Science in May, 1981 and Master of Science in Food Science in May 1983. In July, 1983 the author started work on her Doctor of Philosophy Degree in Food Science at North Carolina State University.

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# REVIEW OF LITERATURE

# INTRODUCTION

Peanut butter is popular in the United States. It is a $0.8 billion industry (Southwest Georgia Planning Commission, 1982). The dominant flavor characteristics in peanut butter are roasted peanut, under or over roasted peanut, salty, oxidized (painty), chemical/sour and bitter (Syarief et al., 1985a). The dominant texture characteristics are adhesiveness, smoothness, perception of particles and initial oiliness (Syarief et al., 1985b). More people like their peanut butter sweet than unsweetened. The number of people that like salty peanut butter is about the same as the number that do not like it salty (How and Young, 1985). People select commercial peanut butters based on particle size and most people prefer crunchy texture (How and Young, 1985). Particle size, salt concentration and sugar concentration of peanut butter are important in consumer acceptance, but their actual effects on peanut butter flavor and texture remain undocumented. The literature is sketchy on the effect of these three factors on any food product. Industrial efforts focus on marketing strategy; studies on the effects of process variables on sensory perception are limited.

The object of this study was to observe the effects of particle size, salt concentration and sucrose concentration on the flavor and texture of peanut butter. Sensory aspects, including descriptive flavor and texture analysis and consumer acceptability, were studied. Gas chromatographic headspace analysis and instrumental rheological tests were conducted.

# LITERATURE REVIEW

## Peanut Butter

Peanut butter is a comminuted spread prepared by grinding good quality, shelled, roasted peanuts, from which the skins have been removed, and to which salt is added as a seasoning (U.S.D.A., 1962). It must contain at least 90% peanuts and have no artificial flavors or colors, nonnutritive sweeteners, or preservatives. Peanut spreads and imitation peanut butters have different standards (U.S.D.A., 1978). Traditionally, peanut butter was made of a blend of virginia and spanish market types. The Florunner cultivar is widely used now because of its oil content (45-56%), its ability to give good quality peanut butter and its slightly lower cost (Southwest Georgia Planning Commission, 1982).

Peanut butter comes in three texture types. Smooth has an even texture with no perceptible grainy peanut particles. Regular or creamy has a definitely grainy texture with perceptible peanut particles not more than 1/16-in. in diameter. Chunky or crunchy has partially fine and partially grainy particles with substantial amounts larger than 1/16 in. in diameter (How and Young, 1985; Woodroof, 1973; 1983).

**Peanut Butter Processing**

Shelled peanuts are roasted to a medium roast in large quantities in continuous roasters. Color is an indicator of degree of the roast and can be measured instrumentally by colorimetry. The roasted peanuts are cooled by forced air to prevent over roasting. Blanching removes the skins from the peanut kernels, and can be accomplished with break rollers and forced air. Break rollers also aid in removing the hearts which cause bitterness and a grayish tint to peanut butter. Next the peanuts are inspected and screened. Scorched or rotten nuts, rocks and other foreign or undesirable matter are removed. This can be done with blowers, magnets and electric eyes (color sorters), as well as, by human inspectors. Grinding is done by comminuters, attrition mills, homogenizers, disintegrators, hammer mills or colloidal mills. Generally two grinding operations are used. The first grind reduces nuts to a medium grind. The second makes a fine or smooth texture. Additives, such as salt, sugar and stabilizer are added between grinds to aid mixing and dissolving. To prevent overheating of nuts during grinding, the mill may be cooled by a water jacket. Peanut butter is deaerated and cooled to less than 120°F before it is packaged. After packaging it is allowed to remain undisturbed for 48 hrs. to allow complete crystallization of the fat to occur (Woodroof, 1973; 1983).

**Peanut Butter Flavor**

Maillard-type browning reactions are responsible for formation of compounds associated with the typical roasted-peanut flavor in peanut butter. Newell et al. (1967) postulated that aspartic acid, glutamic acid, glutamine, asparagine, histidine and phenylalanine are the precursor amino acids for good roast peanut flavor, while threonine, tyrosine, lysine and an unidentified nitrogen-containing compound are thought to be precursors of atypical or off flavors in roast peanuts. When the off-flavor precursors are predominant, off flavors will be evident, but if concentrations are low the typical roasted peanut flavor will be more dominant. Glucose and fructose are the principal sugars present in peanuts that enter the sugar-amine reaction (Mason et al., 1969). Newell et al. (1967) postulated a mechanism for the formation of volatile flavor compounds from sugars and amino acids that results in the formation of 2,5-dimethylpyrazine, which is one of the major flavor compounds associated with roasted peanut flavor (Mason and Hamming, 1966; Koehler et al., 1971). Several volatile compounds that are considered contributors to the 'nutty' flavor have been isolated from roasted peanuts. The alkylpyrazines are considered to be the backbone of the 'nutty' roast peanut aroma (Johnson et al., 1971).

Syarief et al. (1985a) found that the important flavor characteristics in peanut butter are roast peanut, under or over roast, salty, oxidized (painty), chemical/sour, sweet and bitter. How and Young (1985) found that 56% of the 320 participants in their survey liked sweet peanut butter, 36% did not like sweet and 8% had no preference. They also noted that 47% liked salty peanut butter, 46% did not and 7% had no preference.

**Peanut Butter Texture**

Peanut butter has plastic viscosity characteristics that are governed by the interaction of the oil phase and solid phase. Plastic materials do not flow immediately with the application of a small force. Peanut butter is thixotropic, meaning the viscosity will decrease as the peanut butter is worked or stirred. It regains its higher viscosity after it has had time to rest (Tiemstra, 1973). The apparent viscosities of peanut butter at a moderate shear rate of 100 $sec^{-1}$ range from about 23 to 7 pa-s (pascal-second) at 25°C and 9 to 3 pa-s at 40°C (Ahmed and Young, 1982).

Texture profile notes found to be significant to peanut butter texture included adhesiveness, smoothness, perception of particles and initial oiliness (Syarief et al., 1985a). How and Young (1985) found that of the 320 subjects surveyed 47% preferred crunchy peanut butter, 27% preferred smooth, 14% preferred creamy and 13% had no preference. Particle size seemed to be more important than flavor in one's selection of a favorite brand of peanut butter. Sticky peanut butter was disliked by 71% of the subjects, 24% liked sticky peanut butter and 5% had no preference.

**Effect of Particle Size on Texture**

Crippen et al. (1987) found that particle size significantly affected firmness, smoothness, gumminess, adhesiveness during mastication, ease of swallowing, mouth coating and spreadibility. They also found that lack of uniformity, associated with fewer passes through the grinder, caused peanut butters to be less adhesive. Particle size influenced the extrusion viscosity of peanut butter at 40°C. Woodroof et al. (1945) stated that coarse grinding reduced stickiness. Kondakova et al. (1981) found that, when cocoa particles less than 10μm were present, the intermediate fat layer would be sufficient to permit satisfactory processing and would reduce the amount of fat required for processing. Seiler and Weipert (1981) studied particle size of rye extrudates and found viscosity increased with decreasing particle size of the milled products. Ground peanuts with particles of 2.8μ were more viscous than those with larger particle sizes ranging from 4 to 7μ (Crippen, unpublished data).

**Effect of Texture on Flavor**

Syarief et al. (1985a) found that, for most foods evaluated in their study, flavor characteristics that had similar definitions, but were evaluated at different stages, tended to have high positive loadings on the same factor (explain the same characteristic). An exception to this occurred when whole peanuts were evaluated for aroma, flavor-by-mouth and aftertaste. The profile for aroma was different than those for flavor-by-mouth and aftertaste. Reduction in particle size during mastication seemed to account for the difference (Syarief et al., 1985a). Kleinert (1979) reported that flavor variations can result from differences in particle or crystal sizes, such as is true in sugar; reducing the size of crystals with a mortar and pestle changes perceived flavor of sugars. This is partly due to increased total surface area when particles are affecting flavor and increased release of volatiles affecting aroma and flavor. Kleinert (1979) also stated that liquid fat and smaller fat crystals aid in the release of larger quantities of volatiles, producing increased interaction between the tongue surface and taste compounds. Pickett and Holly (1952) found a larger quantity of total volatiles when raw peanuts were ground so as to pass through a 20-mesh sieve. Ito et al. (1983) showed that ground coffee that would pass through a 20- to 28-mesh sieve had the maximum amount of aroma compounds.

Wells et al. (1980) compared ground beef patties against desinewed beef patties. The grinding plate had openings of 0.32 cm. The desinewing apertures were 0.19 to 0.25 cm or 0.25 to 0.32 cm. The panel rated beef flavor intensity on an 8-point scale where 8=extremely intense to 1=extremely bland scale. Panelist's scores for flavor intensity were higher for desinewed than for ground product, indicating removal of connective tissue intensified flavor components. Particle size data were not given, but this research indicates that interference of connective tissue reduces flavor release in a fashion similar to larger particle sizes. Any changes in the physical shape or form of a food particle could alter the behavior of its volatile components by changing vapor pressure or rate of release of constituents (ASTM, 1968).

## The Effect of Viscosity on Flavor and Taste

In a study done by Marshall and Vaisey (1972) on the effect of viscosity of hydrocolloid gels on sweetness of sodium sucaryl, it was found by multiple regression analysis that measured mechanical texture factors accounted for 52.3% of the variability in sweetness, although no single texture characteristic had a dominant role in sweetness. It is evident, however, that texture characteristics play a role in sweetness variability. Moskowitz and Arabie (1970) determined that viscosity differences imparted by sodium carboxymethylcellulose affected the flavor intensities of concentrations of glucose, citric acid, sodium chloride and quinine sulfate. Generally all concentrations of carboxymethylcellulose with the four substances showed that an increase in solution viscosity decreased taste intensities. Pangborn et al. (1973) studied the effects of low concentrations of five food hydrocolloids on the taste intensities of aqueous solutions of sucrose, citric acid, sodium chloride, saccharin and caffeine. In general, sourness of citric acid and bitterness of caffeine were suppressed, while sweetness of saccharin was enhanced. Sourness was affected the most and saltiness the least.

They concluded that, except for sweetness, these effects were independent of viscosity and appeared to be related to the physicochemical properties of the hydrocolloids and taste compounds. Viscosities of 16 cps (centipoise) were required to significantly reduce the sweetness of sucrose. Also, the addition of sucrose increased the viscosities of all gum solutions. Pangborn and Szczesniak (1974) studied the flavor- and odor-modifying effects of low concentrations of hydroxypropylcellulose and sodium carboxymethylcellulose on acetaldehyde, acetophenone, butyric acid and dimethly sulfide. In general, addition of the hydrocolloids decreased both the odor and flavor intensities. Overall, the effects were independent of viscosity. Skramlik (1926) stated that intensity of taste is greater in aqueous media than in paraffin oil. This condition may be related to the combined effects of viscosity, solubility of the compounds in oil and of the oil in saliva (Skramlik, 1926).

## Taste Interrelationships

There has been little agreement as to the effect that salt, sugar, acids or bitter compounds have on each other's taste intensities. One reason for the conflict is that the experiments were not thorough

(Pangborn, 1960). Using trained judges Pangborn (1961) found that increasing citric acid generally decreased apparent sweetness intensities at sucrose concentrations ranging from 0.5 to 20%. This disagrees with Kamen et al. (1961) who used untrained judges. Pangborn (1962) found that sucrose decreased apparent saltiness of 3.24, 1.08 and 0.36% sodium chloride in aqueous solution. A salt concentration of 0.12% was unaffected by the addition of sucrose. The apparent sweetness of 2.25 and 0.75% sucrose was enhanced significantly by 0.12, 0.36 and 1.08% sodium chloride. The sweetness of 6.75% sucrose was depressed slightly by sodium chloride and that of 20.25% sucrose was reduced greatly. Beebe-Center et al. (1959) and Kamen et al. (1961) reported that sucrose has no enhancing or masking effect on saltiness. Kamen et al. (1961) found that salt had no effect on bitterness, salt tends to mask sweetness, high concentrations of salt (1.5%) tend to enhance sourness of low concentrations of citric acid (0.009%), sucrose reduced the intensity of bitterness, and also sucrose reduced the intensity of sourness. Kamen et al. (1961) agreed with Fabian and Blum (1943) and Pangborn (1960) that sucrose reduced the intensity of sourness. Kamen et al. (1961) agreed with Pangborn (1960) that sucrose decreased saltiness of sodium chloride and the sourness of acid. Pangborn (1960) also found that the sourness of citric acid, at all concentrations tested was depressed upon the addition of threshold or sub-threshold amounts of sodium chloride and caffeine, as well as sucrose. Sucrose seemed to have the greatest reducing effect and sodium chloride had the least. She also noted that citric acid and caffeine, as well as, sucrose reduced the saltiness of sodium chloride with approximately equal effect. Bitterness of caffeine was reduced by sucrose, sodium chloride and citric acid. Pangborn (1960) reported that sucrose depressed the sourness of citric acid in an apricot nectar medium. In lima bean puree, added sucrose masked acid taste, citric acid masked sweetness, sodium chloride depressed sourness, sucrose masked saltiness and sodium chloride masked sweetness except at low concentrations of both, where salt slightly enhanced sweetness (Pangborn and Trabue, 1964). In a similar study with canned tomato juice (Pangborn and Chrisp, 1964), basic taste interactions agreed with aqueous solution studies (Pangborn, 1961; 1962) and with the lima bean puree studies (Pangborn and Trabue, 1964). Due to large variabilities among panelists, it is thought that the effect of one compound on the apparent intensity of another is not significant (Pangborn and Chrisp, 1964).

Salt and sucrose have been found to affect aroma compounds. Chappell (1953) reported that sodium chloride enhanced the intensity of lemon oil flavor. Studying the effect of sucrose in apricot, peach and pear nectars showed that sucrose enhanced the fruit flavor up to a point, beyond which it masked fruit flavor (Valdes et al., 1956). Sub-threshold levels of sucrose enhanced the spicing flavors in processed and genuine dill pickles (Pangborn et al., 1958; 1959).

Poll and Flink (1984) studied the effect of salt on headspace analysis and sensory response of apple juice. They found that esters, aldehydes and alcohols are affected differently by the addition of salt. Alcohols, such as hexanol and off aromas, increased while esters, such as hexyl acetate and the fruit aromas did not change much with the addition of salt. Aldehydes, such as trans-2-hexenal increased with the addition of salt but not as much as the alcohols. The ratios of peak areas (with salt/without salt) of acetates and ethyl esters were dependent on total chain length. When Poll and Flink (1984) transformed Kieckbusch and King's (1979) data into a ratio of peak areas (headspace with sucrose/ headspace without sucrose), these values decreased with increasing chain length in the presence of sugar, showing that sucrose has the same effect as salt. The results were similar for model systems. The values in model systems were about 44% higher than in apple juice. The sugar innately present in apple juice is most likely responsible for this difference (Poll and Flink, 1984).

**Summary**

The addition of salt and sugar has an effect on human perception of basic tastes and natural flavors in foods, as well as the release of volatile compounds as determined by gas chromatographic headspace analysis. The particle size of ground foods can affect the release of volatiles and textural properties, such as smoothness.

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# MANUSCRIPT I

## EFFECT OF SUCROSE CONCENTRATION, SALT CONCENTRATION AND GRIND SIZE OF THE FLAVOR OF PEANUT BUTTER

## MANUSCRIPT I

# EFFECT OF SUCROSE CONCENTRATION, SALT CONCENTRATION AND GRIND SIZE ON PEANUT BUTTER FLAVOR

## ABSTRACT

A 3 x 3 x 3 factorial design was used to study the effect of sucrose concentration, salt concentration and grind size on the flavor of peanut butter. A descriptive sensory flavor analysis with 26 characteristics was used to describe flavor. Degree of liking or disliking was rated by a consumer preference panel using a hedonic scale. Sucrose concentration had little effect on descriptive flavor characteristics, except for the basic tastes of sweet, bitter and sour. Three percent sucrose concentration received the highest hedonic score for flavor. Increases in salt concentration caused increases in roasted peanut and nutty characteristics and decreases in under-roasted characteristics. Peanut butters with 0.6% added salt received the highest hedonic preference score. Grind size had little effect on the descriptive sensory flavor characteristics and no effect on the consumer preference.

# INTRODUCTION

Peanut butter is a popular snack food item in the United States. It is eaten on bread and crackers, and used in formulations of cookies and candies. A survey by How and Young (1985) showed that 56% of those surveyed liked a sweet peanut butter and 36% did not. Forty-seven percent liked salty peanut butter and 46% did not. The effects that sugar and salt have on peanut butter flavor are not known. Poll and Flink (1984) studied the effect of salt on head space analysis and sensory aroma of apple juice. Off aromas increased, and fruit aromas remained about the same when salt was added. Several studies have been done on the effect of salt on sweetness, sourness and bitterness and of sugar on saltiness, sourness and bitterness (Beebe-Center et al., 1959; Gregson and McCowen, 1963; Pangborn, 1960; Pangborn and Chrisp, 1964), but the results varied.

The size of peanut particles or grind has an effect on consumer acceptance of peanut butter texture (How and Young, 1985), but its effect on flavor is only alluded to in the literature. Ito et al. (1983) and Pickett and Holly (1952) indicated that the total amount of aroma components from head space analysis of coffee and peanuts, respectively, were highest when particle size would pass through a 20-mesh sieve. Syarief et al. (1985) found that a descriptive flavor panel described roughly the same character notes for aroma as they did for flavor-by-mouth and aftertaste for most foods, including peanut butter. Whole peanuts were found to be an exception, having a different profile for aroma than for flavor-by-mouth and aftertaste.

The objective of this study was to determine how sucrose concentration, salt concentration and peanut butter grind affected the flavor of peanut butter. Descriptive flavor analysis and consumer sensory preference evaluation, based on degree of liking or disliking, were methods of choice.

## MATERIALS AND METHODS

### Peanut Butter Preparation

A 3 x 3 x 3 factorial design was used for this study producing 27 different peanut butter combinations. The factors were sucrose concentration, salt concentration and grind size (gap between grinding stones). Each factor had three levels which were:

1. Sucrose concentration
   a. 0%
   b. 3%
   c. 6%

2. Salt concentration
   a. 0%
   b. 0.6%
   c. 1.2%
3. Grind size
   a. 0.003 in. (fine grind)
   b. 0.011 in. (medium grind)
   c. 0.018 in. (coarse grind)

A second replication using a second shipment of peanuts gave a total of 54 peanut butter samples prepared.

Medium runner peanuts, purchased from Seabrook Blanching Corporation, Edenton, NC, were roasted to a medium roast, blanched, hearts removed and vacuum packaged in 50-lb. bags in boxes prior to shipping. The peanuts were placed in freezer storage (-18°C) upon arrival at North Carolina State University. Peanuts were removed from freezer storage three days prior to peanut butter milling to allow them to equilibrate to room temperature.

For particle size uniformity peanuts were ground three times in a Morehouse peanut butter mill, model no. 504X. On the first pass the grinding stone gap was set at 0.018 in. For the coarse grind peanut butters the gap between stones remained at this setting. For the fine and medium grinds the grinding stone gap was readjusted to the proper gap after the first pass. All ingredients were added to the peanut butter between the second and third pass.

Sugar used was Baker's special-Fruit Granulated pure cane sugar (Borden Incorporated, Columbus, OH). The salt was Culinar 999 Fine salt, food grade (Morton Salt Company, Chicago, IL). Stabilizer (CPC International, Union City, NJ) was added to all peanut butters at 1.5% concentration. It consists of mono and diglycerides derived from palm oil.

After grinding peanut butters were deaerated in a customized vacuum mixer equipped with a water jacket (Green Manufacturing Co., Elk Grove Village, IL). Tap water was circulated through the jacket to cool the peanut butter to an average fill temperature of 35.6°C (96°F). The pressure was lowered to 10 psi (0.680 Atm.) during cooling. The peanut butters were filled into 18-oz. jars with metal screw caps, allowed to set for four days at room temperature to allow full crystallization of lipids, and then stored at -18°C until testing.

**Descriptive Sensory Flavor Analysis**

The panel consisted of nine panel members who were chosen on the basis of interest, availability and normal ability to taste and smell (Caul, 1957). The panel members were all women over the age of 25 who were trained specifically to do descriptive flavor and texture analysis on a wide variety of food products.

One jar from each treatment combination of each replication was used for the descriptive flavor analysis. The peanut butters were removed from freezer storage 24 hr. prior to the panel session. Eight hours later samples were placed in 1-oz. plastic Dixie cups with lids. They remained at room temperature until panel time. Each peanut butter was assigned an unique random three digit code and presented to the panel in random order. Panelists were presented two peanut butters per session to evaluate flavor and texture. Skippy peanut butter (CPC, International, Union City, NJ) was used as the reference standard. Definitions of the flavor characteristics are presented in Table 1. The scale used was a 14-point descriptive scale converted to a 14-point numeric scale for statistical analysis (Table 2).

**Sensory Preference Evaluation of Flavor**

Each peanut butter combination from each replication was subjected to consumer evaluation. A nine-point hedonic scale, ranging from like extremely (9) to dislike extremely (1) was used (Table 3). There were 42 panelists, all of whom were employees or students in the Department of

Table 1. Descriptive sensory flavor analysis definitions.

Aroma-sensations perceived by the nose when the sample is sniffed.

- Overall impression-measure of the degree of blending of the character notes, intensities and order of appearance together with the manner in which they affect the overall aroma of the product.
- Painty-degree to which sample has an aroma associated with old oil or paint.
- Sweet- sweet aroma.
- Roasted peanut-aroma of a cooked (roasted) peanut-a nutty aroma.
- Under-roasted-the aroma of raw peanuts.
- Over-roasted-aroma of over-roasted peanuts, from barely over roasted to charred.
- Sour- aroma associated with acids.
- Stale-degree to which fresh aromas have been lost and replaced with 'old' or strawlike note.
- Briny-aroma of salt.

Flavor-sensations perceived by the tongue, mouth surfaces, throat and nose when the sample is eaten. Flavor includes the basic tastes, olfactory and mouth feel sensations.

- Overall impression-measure of the degree of blending of the character notes, intensities and order of appearance together with the manner in which they affect the overall flavor of the product.
- Painty-degree to which sample has a flavor associated with old oil or paint.
- Roasted peanut-flavor of cooked (roasted) peanut- a nutty flavor.
- Under-roasted-the flavor of raw peanuts.
- Over-roasted-flavor of over-roasted peanuts, from barely over roasted to charred.
- Sweet-basic sweet taste.
- Sour-basic sour taste.
- Stale-degree to which fresh flavors have been lost and replaced with 'old' or strawlike note.
- Salt-basic salt taste.
- Bitter-basic bitter taste.

Table 1. (Continued).

<u>Aftertaste</u>-the presence of a taste, odor or mouthfeeling after the sample has been swallowed. Evaluations should be made during the first minute after swallowing.

<u>Nutty</u>-the nut-like flavor that remains after swallowing the sample

<u>Painty</u>-degree to which sample has an aftertaste associated with old oil or paint.

<u>Sweet</u>-basic sweet taste remaining after swallowing.

<u>Salt</u>-basic salt taste remaining after swallowing.

<u>Bitter</u>-basic bitter taste remaining after swallowing.

<u>Under-roasted</u>-flavor of raw peanut remaining after swallowing.

<u>Over-roasted</u>-flavor of over-roasted peanut remaining after swallowing.

Table 2. Descriptive sensory analysis rating scale.

| Descriptive scale | | Numeric scale |
|---|---|---|
| 0 | not detectable | 1 |
| )( | threshold | 2 |
| <u>)(</u>-1 | | 3 |
| )(-1 | | 4 |
| )(-<u>1</u> | | 5 |
| 1 | slight | 6 |
| <u>1</u>-2 | | 7 |
| 1-2 | | 8 |
| 1-<u>2</u> | | 9 |
| 2 | moderate | 10 |
| <u>2</u>-3 | | 11 |
| 2-3 | | 12 |
| 2-<u>3</u> | | 13 |
| 3 | strong | 14 |
| Overall impression scale | | |
| VL | very low | 1 |
| L | low | 2 |
| <u>L</u>-M | | 3 |
| L-M | | 4 |
| L-<u>M</u> | | 5 |
| M | medium | 6 |
| <u>M</u>-H | | 7 |
| M-H | | 8 |
| M-<u>H</u> | | 9 |
| H | high | 10 |

Table 3. Consumer preference evaluation scale.

| | |
|---|---|
| 9 | like extremely |
| 8 | like very much |
| 7 | like moderately |
| 6 | like slightly |
| 5 | neither like nor dislike |
| 4 | dislike slightly |
| 3 | dislike moderately |
| 2 | dislike very much |
| 1 | dislike extremely |

Food Science at North Carolina State University. All panelists tasted all peanut butters. Flavor and texture were evaluated. Each peanut butter was randomly assigned a three digit number and was randomly assigned a date for presentation to the panel. Three peanut butters were presented at each panel session. The order of sample presentation was varied so that each peanut butter had an equal chance of being first, second or last and an equal chance of being preceded or followed by the other two peanut butters being presented on a particular day. To prevent fatigue the panels were conducted twice a week with one or two days between panels. Peanut butters were served in 1 oz. plastic Dixie cups with plastic caps. Spoons were supplied for sampling.

## Statistical Analysis

The significance of the factors (main effects) and interactions were determined by analysis of variance using the General Linear Models Procedure (SAS, 1982). The Waller-Duncan k-ratio t test was used to determine where significant differences occurred.

# RESULTS AND DISCUSSION

## Effect of Sucrose Concentration

Sucrose concentration had a significant ($p<0.05$) effect on sweet aroma, sweet flavor, sour flavor, bitter flavor, sweet aftertaste and bitter aftertaste (Table 4). As was expected, sweet aroma, sweet flavor and sweet aftertaste increased when the sucrose concentration was increased. Sour flavor, bitter flavor and bitter aftertaste decreased when sucrose was added. These results agree with studies in which sucrose reduced the bitterness of caffeine (Pangborn, 1960), and depressed apparent sourness of citric acid in a tomato juice medium (Pangborn and Chrisp, 1964). More work is needed to determine the extent bitter peanuts can be improved by added sugar.

Sucrose concentration had a significant ($p<0.05$) effect on the preference evaluation of flavor (Table 5). Sucrose concentration of 3% resulted in the highest flavor score, and it was significantly ($p<0.05$) higher than the 0 and 6% scores. The flavor score with 6% added sucrose was second highest. Peanut butter with no sugar added received a significantly ($p<0.05$) lower score.

The overall impression of flavor and consumer preference of flavor

Table 4. Mean squares and coefficients of variability from the analysis of variance for descriptive flavor characteristics.

| Source of variation | df | AOI[+] | APT | ASW | ARP | AUR | AOR | ASO | AST | ABR | FOI | FPT | FRP | FUR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sucrose Conc. (Su) | 2 | 0.380 | 0.076 | 35.400** | 1.688 | 0.040 | 2.949 | 0.053 | 2.910 | 0.051 | 10.648 | 0.221 | 0.614 | 0.068 |
| Salt Conc. (Sa) | 2 | 8.871* | 0.084 | 0.338 | 0.377 | 0.164 | 6.143 | 0.136 | 0.231 | 3.256** | 14.529* | 0.069 | 5.138* | 0.667* |
| Grind size (G) | 2 | 5.631 | 0.122 | 1.860 | 0.494 | 0.168 | 1.659 | 1.117* | 2.397 | 0.245 | 3.992 | 0.147 | 0.402 | 0.256 |
| G x Sa | 4 | 0.436 | 0.078 | 1.148 | 1.173 | 0.084 | 6.801 | 0.217 | 1.123 | 0.753 | 2.358 | 0.148 | 0.886 | 0.128 |
| G x Su | 4 | 0.397 | 0.049 | 0.834 | 1.358 | 0.010 | 2.367 | 0.407 | 2.362 | 0.793 | 0.759 | 0.134 | 1.003 | 0.078 |
| Sa x Su | 4 | 3.802 | 0.084 | 1.553 | 1.766 | 0.111 | 5.468 | 0.239 | 0.928 | 0.299 | 7.855 | 0.120 | 2.432 | 0.082 |
| G x Sa x Su | 8 | 0.506 | 0.050 | 0.253 | 1.193 | 0.063 | 4.494 | 0.560 | 0.591 | 0.623 | 1.071 | 0.094 | 0.689 | 0.043 |
| Replication (R) | 1 | 2.229 | 0.262 | 3.404* | 4.324 | 0.021 | 2.728 | 3.483** | 4.573 | 4.532** | 3.850 | 0.532 | 1.584 | 0.100 |
| Error (RxGxSaxSu)[•] | 26 | 2.212 | 0.083 | 0.583 | 1.172 | 0.069 | 2.773 | 0.281 | 1.538 | 0.345 | 3.434 | 0.156 | 1.142 | 0.109 |
| C.V. (%) (RxGrxSaxSu) | | 9.552 | 9.485 | 9.178 | 6.509 | 9.003 | 21.641 | 10.005 | 19.960 | 11.499 | 13.048 | 13.090 | 5.913 | 11.051 |
| Panel | 7 | 3.207* | 4.818** | 3.772* | 0.785 | 0.150* | 17.929* | 4.134 | 9.770* | 1.102 | 7.564 | 0.612 | 8.261 | 0.399 |
| Error (R x Panel) | 7 | 0.662 | 0.054 | 0.967 | 0.703 | 0.029 | 3.471 | 0.527 | 1.693 | 0.749 | 3.008 | 0.242 | 1.855 | 0.114 |
| C.V. (%) (R x Panel) | | 5.225 | 7.650 | 11.821 | 5.041 | 5.851 | 24.208 | 13.689 | 20.939 | 16.942 | 12.212 | 16.316 | 7.535 | 11.304 |
| Grand Mean | | 5.505 | 1.074 | 2.941 | 5.880 | 1.029 | 2.721 | 1.875 | 2.197 | 1.806 | 5.021 | 1.066 | 6.391 | 1.056 |

*,**ANOV component was significantly ($p<0.05$) and highly significantly ($p<0.01$) different, respectively

[•]Analysized as a split-plot design with panelists as plots

[+]AOI-overall impression (aroma), APT-painty (aroma), ASW-sweet (aroma), ARP-roasted peanut (aroma), AUR-under-roasted (aroma), AOR-over-roasted (aroma), ASO-sour (aroma), AST-stale (aroma), ABR-briny (aroma), FOI-overall impression (flavor), FPT-painty (flavor), FRP-roasted peanut (flavor), FUR-under-roasted (flavor), FOR-over-roasted (flavor), FSW-sweet (flavor), FSO-sour (flavor), FST-stale (flavor), FSA-salt (flavor), FBI-bitter (flavor), TNU-nutty (aftertaste), TPT-painty (aftertaste), TSW-sweet (aftertaste), TSA-salt (aftertaste), TBI-bitter (aftertaste), TUR-under-roasted (aftertaste) and TOR-over-roasted (aftertaste)

Table 4 Continued

| Source of variation | df | FOR[+] | FSW | FSO | FST | FSA | FBI | TNU | TPT | TSW | TSA | TBI | TUR | TOR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sucrose Conc. (Su) | 2 | 10.378 | 268.013** | 5.835** | 2.501 | 3.134 | 22.515** | 1.032 | 0.170 | 172.895** | 4.149 | 14.549** | 0.070 | 4.684 |
| Salt Conc. (Sa) | 2 | 6.939 | 7.125 | 0.062 | 3.274 | 232.309** | 0.276 | 6.812* | 0.168 | 9.568** | 167.557** | 0.412 | 0.241* | 5.108 |
| Grind size (G) | 2 | 1.185 | 2.572 | 0.175 | 0.839 | 3.713 | 0.233 | 0.047 | 0.120 | 0.570 | 0.554 | 0.036 | 0.162 | 0.967 |
| G x Sa | 4 | 2.657 | 0.733 | 0.288 | 2.597 | 1.749 | 0.442 | 1.313 | 0.127 | 0.968 | 2.553 | 2.858 | 0.053 | 8.749* |
| G x Su | 4 | 5.834 | 1.994 | 0.197 | 2.592 | 0.768 | 1.003 | 0.190 | 0.066 | 1.143 | 0.747 | 0.269 | 0.028 | 3.156 |
| Sa x Su | 4 | 8.471 | 8.609* | 0.593 | 3.000 | 8.053** | 3.220 | 2.732 | 0.073 | 5.237* | 5.062* | 1.444 | 0.072 | 6.353 |
| G x Sa x Su | 8 | 2.705 | 0.563 | 0.354 | 1.086 | 0.842 | 1.542 | 0.968 | 0.088 | 0.677 | 0.478 | 1.917 | 0.014 | 4.466 |
| Replication (R) | 1 | 6.393 | 19.945** | 10.834** | 24.141** | 2.937 | 7.531* | 5.974 | 0.112 | 11.884** | 5.619 | 0.849 | 0.156 | 1.846 |
| Error (RxGxSaxSu)[●] | 26 | 3.717 | 2.261 | 0.298 | 1.976 | 1.780 | 1.709 | 1.936 | 0.135 | 1.486 | 1.567 | 1.284 | 0.062 | 3.187 |
| C.V. (%) (RxGrxSaxSu) | | 19.083 | 12.315 | 9.171 | 21.332 | 12.256 | 12.797 | 9.015 | 12.280 | 12.802 | 14.079 | 12.411 | 8.541 | 21.398 |
| Panel | 7 | 19.745** | 6.868** | 2.524 | 5.677 | 6.342 | 12.408 | 7.967* | 0.687** | 6.982** | 3.288 | 21.592** | 0.228 | 18.643** |
| Error (R x Panel) | 7 | 2.139 | 0.615 | 0.908 | 2.996 | 1.859 | 3.396 | 1.307 | 0.079 | 0.804 | 1.299 | 2.229 | 0.108 | 2.496 |
| C.V. (%) (R x Panel) | | 14.476 | 6.424 | 16.012 | 26.264 | 12.527 | 18.038 | 7.407 | 9.392 | 9.415 | 12.817 | 16.347 | 11.237 | 18.941 |
| Grand Mean | | 3.572 | 4.316 | 2.104 | 2.330 | 3.848 | 3.612 | 5.457 | 1.058 | 3.367 | 3.144 | 3.229 | 1.034 | 2.949 |

*,**ANOV component was significantly ($p<0.05$) and highly significantly ($p<0.01$) different, respectively

[●]Analysized as a split-plot design with panelists as plots

[+]AOI-overall impression (aroma), APT-painty (aroma), ASW-sweet (aroma), ARP-roasted peanut (aroma), AUR-under-roasted (aroma), AOR-over-roasted (aroma), ASO-sour (aroma), AST-stale (aroma), ABR-briny (aroma), FOI-overall impression (flavor), FPT-painty (flavor), FRP-roasted peanut (flavor), FUR-under-roasted (flavor), FOR-over-roasted (flavor), FSW-sweet (flavor), FSO-sour (flavor), FST-stale (flavor), FSA-salt (flavor), FBI-bitter (flavor), TNU-nutty (aftertaste), TPT-painty (aftertaste), TSW-sweet (aftertaste), TSA-salt (aftertaste), TBI-bitter (aftertaste), TUR-under-roasted (aftertaste) and TOR-over-roasted (aftertaste)

Table 5. Mean squares and coefficients of variability from the analysis of variance, and means for consumer preference of flavor.

| Source of Variation | df | Flavor |
|---|---|---|
| Sucrose concentration(Suc) | 2 | 104.950** |
| Salt concentration(Salt) | 2 | 102.523** |
| Grind size(Gr) | 2 | 6.654 |
| Gr x Salt | 4 | 9.536** |
| Gr x Suc | 4 | 2.376 |
| Salt x Suc | 4 | 11.299** |
| Gr x Salt x Suc | 8 | 3.699 |
| Replication (Rep) | 1 | 3.562 |
| Error(RepxGrxSaltxSuc)[#] | 26 | 2.155 |
| C.V. (%) | | 3.756 |
| Mean | | 6.030 |

| Level[+] | 0 | 1 | 2 |
|---|---|---|---|
| Grind size | 6.13[a] | 5.94[c] | 6.01[b] |
| Salt concentration | 5.67[b] | 6.41[a] | 6.01[a] |
| Sucrose concentration | 5.62[c] | 6.35[a] | 6.13[b] |

*,**ANOV component is significantly ($p<0.05$) and highly significantly ($p<0.01$) different, respectively

[#]Analysized as a split-plot design with panelists as plots (panelist were not included in this table)

[+]Levels of each factor are grind size: 0=0.003in., 1=0.001in. and 2=0.018in.; salt concentration: 0=0%, 1=0.6% and 2=1.2%; and sucrose concentration: 0=0%, 1=3% and 2=6%

[a,b,c] Means with the same letter were not significantly ($p<0.05$) different

resulted in highest scores for 3% sucrose. Even though these were different types of sensory tests, there was some relationship between the two. The characteristics that are important in determining overall impression were some of the same characteristics the preference panel used to evaluate degree of liking.

### Effects of Salt Concentration

Overall impression of aroma and flavor (Table 4) were significantly ($p<0.05$) affected by salt concentration with the highest scores for 0.6% salt, and the lowest scores for 0% salt. Added salt increased briny aroma, roasted peanut flavor, salty flavor, nutty aftertaste and salty aftertaste. The briny aroma, salty flavor and salty aftertaste (Table 4) would obviously increase with increased salt concentration. Observing that roasted peanut flavor and nutty aftertaste were both increased significantly ($p<0.05$) by added salt showed that salt enhances the peanut flavor of peanut butter. Salt has been shown to enhance some flavors such as lemon oil (Chappell, 1953) and fruit flavors of apricot, peach and pear nectars (Valdes et al., 1956). The under-roasted flavor and aftertaste decreased significantly ($p<0.05$) by adding salt, showing that under-roasted flavor is masked by added salt. Sweet aftertaste decreased significantly when salt was added at both concentrations showing that the lingering sweet aftertaste is masked by salt. This agreed with the study done by Pangborn (1960) and Pangborn and Chrisp (1964) that salt depressed sweetness in 6.75% sucrose solution and tomato juice medium.

Salt concentration had a significant ($p<0.05$) effect on the preference evaluation of flavor (Table 5). The highest flavor score for salt concentration was at 0.6% salt; 1.2% was significantly ($p<0.05$) lower and 0% was even lower ($p<0.05$).

Overall impression of aroma and flavor, and consumer preference score for flavor received the highest scores for the peanut butters with 0.6% salt. This indicates the two tests were measuring the same qualities.

### Effect of Grind Size

Grind size had a significant ($p<0.05$) effect on sour aroma (Table 4). This was the only flavor characteristic affected by particle size. As the grind size increased so did the score for sour aroma with a significant ($p<0.05$) increase between medium and coarse grinds. Grind size had no significant effect on the consumer preference evaluation of flavor (Table

5). Even though grind has been shown to be an important factor in consumer purchasing of peanut butter (How and Young, 1985), this study shows that it had little effect on flavor.

The fine grind peanut butters received highest scores for overall impression of aroma and flavor in the descriptive sensory test and in the consumer preference test.

**Results That Were Not Affected by the Three Factors**

Painty aroma, roasted peanut aroma, under-roasted aroma, over-roasted aroma, stale aroma, painty flavor, over-roasted flavor, stale flavor, painty aftertaste and over-roasted aftertaste were not affected by the factors studied in this experiment (Table 4). Off-flavors, such as stale and painty, were minimal thus differences due to grind size, salt concentration and sucrose concentration were not detectable. It was interesting that roasted peanut aroma and under-roasted aroma were not affected by the factors in this study while their flavors were. This shows a perception difference in aroma and flavor.

**Interactions Between Factors**

There was a significant ($p<0.05$) grind size by salt concentration interaction on consumer preference of flavor. The 0% salt concentrations for all grinds resulted in low flavor scores (Figure 1). The 0.6% salt concentration resulted in the highest flavor scores of all grinds, except the coarse grind where it was the same as 1.2% salt, showing that, in a coarsely ground peanut butter, changing salt concentration from 0.6 to 1.2% does not affect flavor preference.

Sweet flavor, salty flavor, sweet aftertaste and salty aftertaste had significant ($p<0.05$) salt concentration by sucrose concentration interactions along with significant main effects on salt concentration and/or sucrose concentration. The sweet flavor and sweet aftertaste had generally the same pattern which is shown for sweet flavor in Figure 2. Both amounts of added salt (0.6 and 1.2%) slightly decreased sweetness at the 3 and 6% sucrose concentration, but slightly increased sweetness at 0% sucrose. Salt slightly masked sweetness, except at naturally occurring concentrations in peanuts, where salt slightly increased sweetness. At 0% sucrose, increased salt concentration increased salty flavor more than at 3 and 6% sucrose (Figure 3). This showed that sucrose masked saltiness to some extent, especially at 1.2% salt concentration. Sucrose and salt had an effect on the perception of each other's taste and the effect was based on concentration. This supports

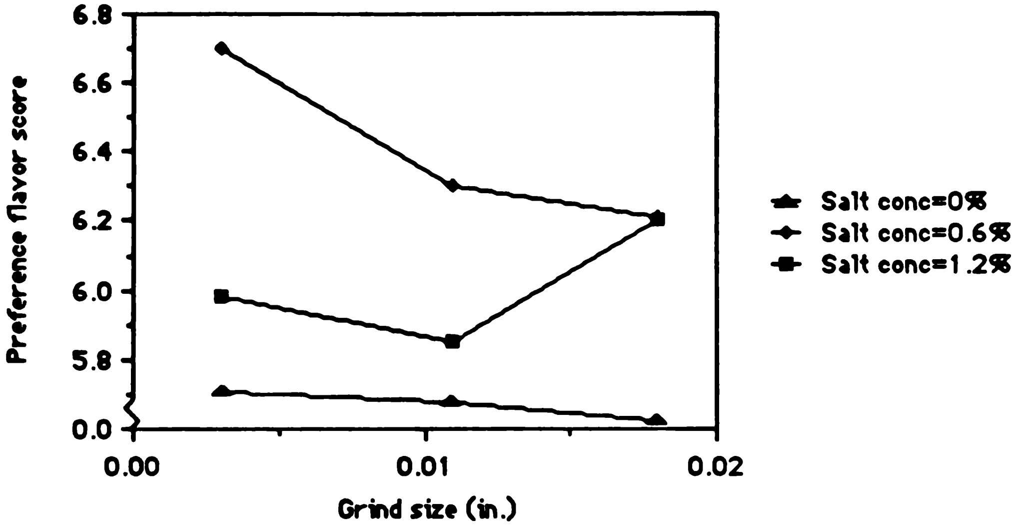


Figure 1. Grind size by salt concentration interaction for consumer preference of flavor.

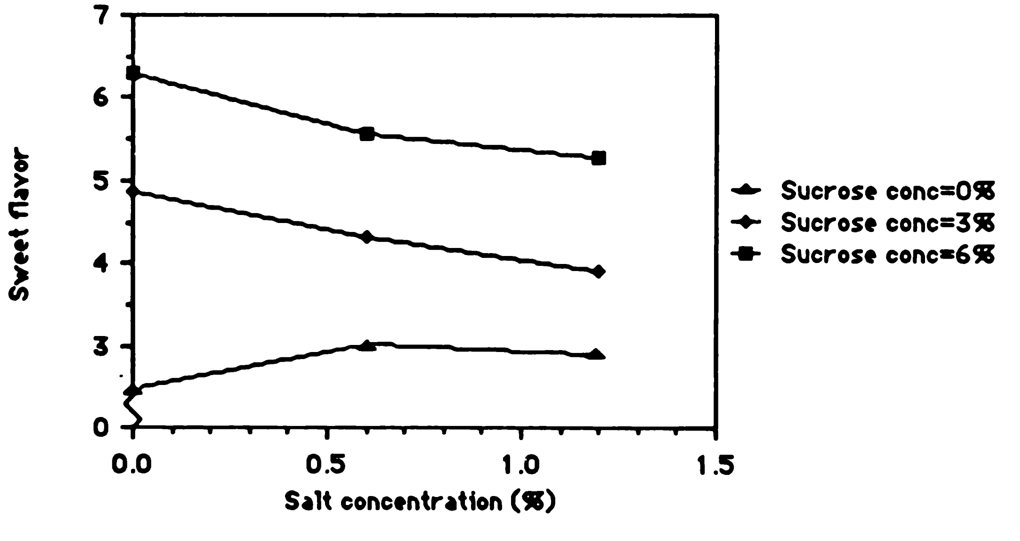


Figure 2. Salt concentration by sucrose concentration interaction for sweet flavor.

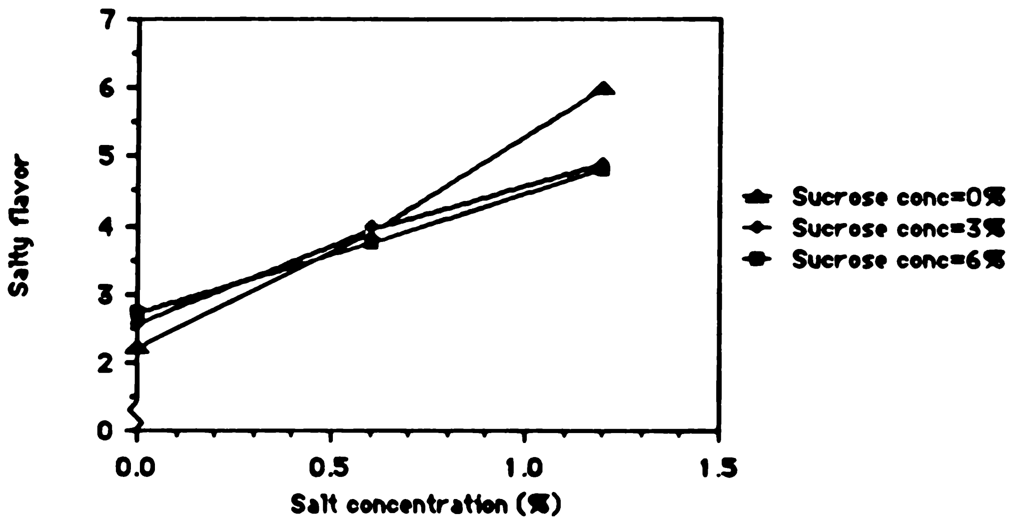


Figure 3. Salt concentration by sucrose concentration interaction for salty flavor.

previous work (Pangborn, 1960; Pangborn and Chrisp, 1964) that showed that salt affected sweetness, sucrose affected saltiness and concentration was a factor in the magnitude of the effect.

There was a significant ($p<0.05$) sucrose concentration by salt concentration interaction effect on consumer preference of flavor (Figure 4). The 3% sucrose was prefered for all concentrations of salt, except at 1.2% salt where 3 and 6% sucrose scored the same. Sucrose at the highest concentration had the second highest scores for 0 and 0.6% salt concentrations. The 0% sucrose concentration received lowest scores at all salt concentrations. No sucrose and 1.2% salt scored the lowest of all. With no added salt 0 and 6% sucrose received much lower scores than 3% sucrose. At 1.2% salt, added sucrose improved preference scores the most.

**Effects of Replication**

Sweet aroma, sour aroma, briny aroma, sweet flavor, sour flavor, stale flavor, bitter flavor and sweet aftertaste were significantly ($p<0.05$) different between replications (Table 4). This was due to the fact that each replication was processed from a different lot of peanuts. There were no significant differences between replications based on the

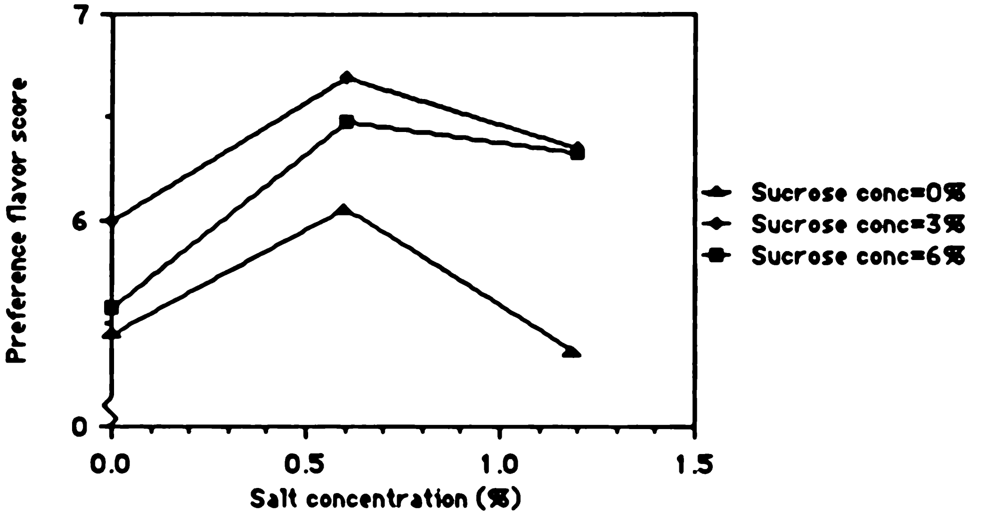


Figure 4. Salt concentration by sucrose concentration interaction for consumer preference of flavor.

flavor preference data indicating that consumers are less discerning than the trained panel or that flavor characteristic differences cancel each other.

### Differences Between Panelists

A split-plot design was used for the analysis of variance because all panelist's samples came from the same jar. Using the split-plot design, panelists had significant ($p<0.05$) differences among means for overall impression (aroma) painty aroma, sweet aroma, under-roasted aroma, over-roasted aroma, stale aroma, over-roasted flavor, sweet flavor, nutty aftertaste, painty aftertaste, sweet aftertaste, bitter aftertaste and over-roasted aftertaste. This indicates differences between panelists perception of these flavor characteristics. The split-plot analysis allowed for the removal of this source of variation when analyzing the factors, sucrose concentration, salt concentration and grind size.

## CONCLUSIONS

Increased sucrose concentration increased the intensity level of sweet aroma, sweet flavor and sweet aftertaste, and decreased sour flavor, bitter flavor and aftertaste. Three percent added sucrose gave highest consumer preference scores.

Added salt (0.6 and 1.2%) increased briny aroma, salty flavor, salty aftertaste, roasted peanut flavor and nutty aftertaste. The 0.6% concentration gave highest values for overall impression (aroma and flavor), as well as for consumer preference of flavor.

Fine grinding of the peanut butters decreased the sour aroma characteristic. In this study, this was the only characteristic significantly affected by grind.

The salt concentration and sucrose concentration effect on salty flavor and sweet flavor were not independent as evidenced by significant interactions. With no sucrose, salty and sweet flavors were affected differently by salt than at 3 and 6% sucrose. The effect of salt concentration on consumer preference was not independent of either grind size or sucrose concentration as evidenced by significant interactions.

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# MANUSCRIPT II

## EFFECT OF GRIND SIZE, SUCROSE CONCENTRATION AND SALT CONCENTRATION ON THE TEXTURE OF PEANUT BUTTER

# MANUSCRIPT II

## EFFECT OF GRIND SIZE, SUCROSE CONCENTRATION AND SALT CONCENTRATION ON PEANUT BUTTER TEXTURE

## ABSTRACT

The effect of particle size, salt concentration and sucrose concentration on peanut butter texture was studied. A 3 x 3 x 3 factorial with three grinds (fine, medium and coarse), three salt concentrations (0, 0.6 and 1.2%) and three sucrose concentrations (0, 3 and 6%) was used in formulating the peanut butters. Eleven sensory descriptive characteristics were examined, along with instrumental hardness, adhesiveness and power law flow model constants. A consumer panel rated the peanut butter texture using a 9-point hedonic scale. Increased grind size decreased sensory smoothness, spreadability, adhesiveness and consumer panel preference ratings, but increased instrumental adhesiveness and hardness. Increased sucrose caused decreases in instrumental adhesiveness, sensory adhesiveness and consumer texture ratings. Added salt (0.6 and 1.2%) increased the ease of swallowing, as well as consumer preference of texture.

# INTRODUCTION

Texture plays an important role in people's acceptance of foods. In some foods it may be more important than flavor. People are generally unaware of texture of foods because they take it for granted. Much of the time it is noticed only when human expectations are violated. Many people equate texture of foods with quality and deviations from expected texture indicate something is wrong with the food (Szczesniak and Kahn, 1971). Szczesniak and Kahn (1971) also found that people tend to be conscious of foods which they lack control during mastication. The food may be perceived as dangerous when the texture is not easily managed. For example, sticky foods refuse to go down when swallowed and adhere to the teeth, tongue, gums and palate causing discomfort and anxiety (Szczesniak and Kahn, 1971). A study by How and Young (1985) found that 71% of the people surveyed disliked sticky peanut butter. They also found that selection of favorite brands of peanut butter is based on particle size, producing smooth, creamy or crunchy peanut butter. Texture of peanut butter is important to consumers.

Processing parameters can affect peanut butter texture. The objectives of this study were to determine how grind size, salt concentration and sucrose concentration affect peanut butter texture using sensory and instrumental tests.

## MATERIAL AND METHODS

### Peanut Butter Preparation

The peanut butters used in this study were treatment combinations of three factors at three levels each, from two replications (Crippen, 1987). The three factors were grind size, salt concentration and sucrose concentration. The gap between the mill stones that determined grind was set at 0.003, 0.011 or 0.018 in. resulting in fine, medium and coarse grinds, respectively. The salt concentrations were 0, 0.6 and 1.2% and the sucrose concentrations were 0, 3 and 6%. A 1.5% concentration of stabilizer was used in all peanut butters.

### Descriptive Texture Analysis Methods

The texture profile panel consisted of nine members selected on the basis of interest, availability, personality and lack of artificial dentures. They were all women over the age of twenty-five trained according to guidelines described by Civille and Szczesniak (1973). The definitions of the texture characteristics are listed in Table 1. A 14-point descriptive

Table. 1. Descriptive sensory texture analysis definitions.

First compression-place full tip of spoon (approx. 1/4 teaspoon) in mouth, press between tongue and palate.

- Overall impression-degree of blending of the character notes, intensities and order of appearance together with the manner in which they affect the overall texture of the product.
- Firmness-amount of force required to compress fully.
- Adhesiveness-amount of force required to remove sample from palate with tongue.
- Smoothness-absence of any particles in the product including crystals.
- Oiliness-degree to which sample is oily.

Mastication-place full tip of spoonful on tongue and manipulate with tongue and teeth.

- Gumminess-amount of energy required to disintegrate sample to a state ready for swallowing (count number of chews).
- Adhesiveness-degree to which sample sticks to mouth surfaces and teeth during mastication.
- Smoothness-degree to which sample is free of particles other than crystals during mastication.
- Crystallinity-degree to which hard crystals are perceived.

Swallowing

- Ease of swallowing-degree to which prepare sample is ready to swallow.
- Mouthcoating-degree to which mouth surfaces have oily or peanut butter coating.

Spreadability-ease with which the sample spreads over a cracker with a wooden spatula or a knife requiring very little effort.

scale was used by the panelists (Crippen, 1987). This was converted to a 14-point numeric scale for statistical analysis. The scale encompasses the entire range of intensity of textural characteristics of all foods and not just in peanut butter (Szczesniak et al., 1963).

**Instrumental Methods**

**Extrusion viscometry**: The consistency index (k), flow behavior index (n) and their product (kn) were determined from extrusion viscosity data obtained at 25°C. The peanut butter was extruded through a tube using an Instron Universal Testing Machine, model 1122, as described by Kawanari et al. (1981). Two sets of tubes were used. Each set was comprised of a long and short tube. One set was 4.46 mm in diameter and 100.8 and 16.0 mm long, respectively, while the other set was 3.18 mm in diameter and 106.4 and 15.75 mm long, respectively. The difference in extrusion force was determined and used along with viscometer dimensions to calculate the shear stress. The shear strain rate was calculated from the crosshead velocity and instrument dimensions. For each peanut butter the power law model, $\tau=k\dot{\gamma}^n$, was determined where $\tau$ is the shear stress and $\dot{\gamma}$ the shear strain rate. This model was considered suitable because preliminary testing showed that the peanut butters did not exhibit a yield stress at the test temperature. The slope of the shear stress-shear strain rate curve is $d\tau/d\dot{\gamma}$, and

$$\frac{d\tau}{d\dot{\gamma}} = \frac{d}{d\dot{\gamma}} k\dot{\gamma}^{n}$$

$$= kn\dot{\gamma}^{n-1}$$

if $\dot{\gamma}=1$ then $kn\dot{\gamma}^{n-1}=kn$, therefore kn represents the slope of the shear stress-shear strain rate curve where the shear rate is equal to unity. This value is approximately the apparent Newtonian viscosity at low shear rates.

**Imitative tests**: Imitative tests attempt to imitate actual chewing conditions and may correlate well with sensory tests. The imitative test used in the present study was a form of the instrumental texture profile analysis described by Bourne (1978). An Instron Universal Testing Machine, model 1130, was used to measure the force required to compress a specified mass of peanut butter (10g) at room temperature (approx. 22°C) between two parallel plates and then pull the plates apart. The peanut butter was applied to the upper plate which had an area of 2551.8 $mm^2$. The minimum distance (maximum compression) between the upper and lower plates was 1.65 mm. The speed at which the upper and base plates were brought together was 50 mm/min. Maximum force required to compress the peanut butter was recorded as hardness, and the maximum force required to pull the upper and the lower plates apart was recorded as adhesiveness.

**Sensory Preference Evaluation of Texture**

A nine-point hedonic scale was used to determine the degree of liking or disliking of peanut butter texture. Panelists consisted of 42 employees and students of the Department of Food Science, North Carolina State University. The details of the method are found in Crippen (1987).

**Statistical Analysis**

Analysis of variance and Waller-Duncan k-ratio t tests were performed on main effects or factors using general linear models (SAS,1982). Significant interactions, replication differences and panelist variation (when applied) were determined using the same method.

## RESULTS AND DISCUSSION

**Effect of Grind Size**

Grind size had a significant ($p<0.05$) effect on sensory smoothness on first compression, adhesiveness and smoothness during mastication, crystallinity and spreadibility (grand means, coefficients of variation, and mean squares are shown in Table 2). As grind size increased, smoothness on first compression decreased. This was due to perceived particles in the coarser ground peanut butters that were not as evident in the medium and less so in fine ground peanut butters. Coarse grinding decreased ($p<0.05$) adhesiveness during mastication over medium and fine grinds. This supported a statement made by Woodroof et al. (1945) that stickiness of peanut butter can be reduced by coarse grinding. The magnitude of crystallinity significantly ($p<0.05$) increased between fine and medium grinds. A slight decrease in crystallinity between medium and coarse grinds was perceived by some panelists, but it was not significant overall. Spreadability was decreased ($p<0.05$) by increased grind size with the major difference being between the coarse grind and the other two. Texture preference scores decreased as grind size increased ($p<0.01$) (Table 3). Evidently consumers are willing to accept some increase in adhesiveness so long as the peanut butter is smooth and low in crystals.

A coarse grind was significantly ($p<0.05$) higher in instrumental hardness than the medium and fine grinds (Table 4). It also made instrumental adhesiveness significantly ($p<0.05$) higher than medium and

Table 2. Mean squares and coefficients of variability from the analysis of variance for descriptive texture characteristics.

| Source of variation | df | XOI[+] | XFR | XAD | XSM | XOL | XGU | XAV | XSN | XCY | XES | XMC | XSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grind size(Gr) | 2 | 0.497 | 5.232 | 5.634 | 198.231** | 2.302 | 21.016 | 6.163* | 358.655** | 26.194* | 0.068 | 9.679 | 11.666** |
| Sucrose conc.(Su) | 2 | 0.685 | 2.782 | 6.645* | 33.337** | 0.933 | 16.479 | 10.346** | 9.433 | 573.412** | 14.498* | 7.757 | 0.911 |
| Salt conc.(Sa) | 2 | 7.031* | 2.932 | 2.050 | 2.247 | 1.805 | 5.909 | 3.466 | 5.166 | 58.432** | 9.510* | 2.728 | 1.197 |
| Gr x Sa | 4 | 1.485 | 1.189 | 1.369 | 5.119 | 0.906 | 6.076 | 1.458 | 2.900 | 5.741 | 1.838 | 1.815 | 1.200 |
| Gr x Su | 4 | 0.703 | 2.170 | 3.912 | 10.603* | 0.883 | 8.763 | 0.916 | 6.502 | 6.558 | 1.190 | 0.632 | 1.278 |
| Sa x Su | 4 | 1.287 | 1.019 | 3.881 | 3.394 | 0.214 | 5.069 | 0.489 | 4.875 | 46.088** | 4.842 | 1.385 | 0.576 |
| Gr x Salt x Su | 8 | 0.690 | 1.563 | 2.610 | 2.913 | 2.009 | 1.564 | 2.055 | 2.072 | 2.004 | 3.461 | 2.341 | 0.992 |
| Replication(R) | 1 | 0.316 | 9.346 | 2.265 | 15.339* | 2.561 | 55.969** | 3.950 | 2.338 | 2.829 | 1.121 | 7.164 | 6.346* |
| Error(RxGrxSaxSu) | 26 | 1.417 | 2.729 | 1.901 | 2.603 | 1.235 | 7.058 | 1.359 | 3.315 | 5.872 | 2.647 | 2.941 | 1.263 |
| C.V. (%)(RxGrxSaxSu) | | 9.414 | 7.071 | 4.720 | 7.009 | 11.913 | 3.811 | 3.666 | 6.929 | 11.675 | 7.584 | 5.934 | 3.395 |
| Panelist(P) | 7 | 3.335 | 2.149 | 41.430** | 3.447 | 5.772** | 107.977** | 35.925** | 14.106** | 4.819 | 37.088** | 39.111** | 1.794 |
| Rep x P | 7 | 3.444 | 0.861 | 6.616** | 2.629 | 0.798 | 18.809 | 1.257 | 0.856 | 2.075 | 5.136 | 4.011 | 1.421 |
| C.V (%) (PxR) | | 14.675 | 3.971 | 8.800 | 7.044 | 9.576 | 6.221 | 3.525 | 3.512 | 6.940 | 10.564 | 6.930 | 3.602 |
| Grand Mean | | 4.471 | 8.261 | 10.335 | 8.138 | 3.298 | 24.649 | 11.245 | 9.314 | 7.338 | 7.585 | 10.218 | 11.702 |

*,**ANOV component is significantly ($p<0.05$) and highly significantly ($p<0.01$) different, respectively

[+]XOI=overall impression, XFR=firmness, XAD=adhesiveness, XSM=smoothness, XOL=oiliness, XGU=gumminess, XAV=adhesiveness (mastication), XSN=smoothness (mastication), XCY=crystallinity, XES=ease of swallowing, XMC=mouth coating and XSP=spreadibility.

Table 3. Mean squares and coefficients of variability from the analysis of variance, and means for consumer preference of texture.

| Source of Variation | df | Texture |
|---|---|---|
| Grind size(Gr) | 2 | 107.540** |
| Sucrose concentration(Suc) | 2 | 33.978** |
| Salt concentration(Salt) | 2 | 29.350** |
| Gr x Salt | 4 | 11.125* |
| Gr x Suc | 4 | 4.246 |
| Salt x Suc | 4 | 2.610 |
| Gr x Salt x Suc | 8 | 3.407 |
| Replication(R) | 1 | 5.499 |
| Error (RxGrxSaltxSuc) | 26 | 2.991 |
| C.V. (%)(RxGrxSaltxSuc) | | 4.502 |
| Grand Mean | | 5.928 |

| Level+ | 0 | 1 | 2 |
|---|---|---|---|
| Grind size | 6.33[a] | 5.87[b] | 5.58[c] |
| Salt concentration | 5.72[a] | 5.96[b] | 6.11[b] |
| Sucrose concentration | 6.01[a] | 6.09[a] | 5.69[b] |

*,**ANOV component is significantly ($p<0.05$) and highly significantly ($p<0.01$) different, respectively

+ Levels of each factor are grind size: 0=0.003 in., 1=0.011 in. and 2=0.018 in.; salt concentration: 0=0%, 1=0.6% and 2=1.2%; and sucrose concentration: 0=0%, 1=3% and 2=6%

Means with the same letter are not significantly different ($p<0.05$)

Table 4. Mean squares and coefficients of variability from the analysis of variance for instrumental texture analysis parameters.

| Source of variation | df | k+ | n | nk | Adhesive | Hard. |
|---|---|---|---|---|---|---|
| Grind size(Gr) | 2 | 6361.24 | 0.008 | 1115.98 | 0.438* | 0.404* |
| Sucrose Conc.(Suc) | 2 | 2332.96 | 0.001 | 371.46 | 0.527* | 0.511* |
| Salt Conc.(Salt) | 2 | 3935.34 | 0.004 | 460.77 | 0.086 | 0.100 |
| Gr x Salt | 4 | 3604.19 | 0.006 | 546.95 | 0.114 | 0.101 |
| Gr x Suc | 4 | 10703.97 | 0.012 | 1725.14 | 0.243 | 0.197 |
| Salt x Suc | 4 | 10050.29 | 0.019 | 1480.03 | 0.093 | 0.081 |
| Gr x Salt x Suc | 8 | 2334.12 | 0.004 | 345.52 | 0.094 | 0.118 |
| Replication(Rep) | 1 | 3249.61 | 0.002 | 684.07 | 0.773* | 0.616* |
| Error | 26 | 6291.39 | 0.009 | 887.44 | 0.116 | 0.211 |
| C.V. (%) | | 63.06 | 16.592 | 44.24 | 20.589 | 22.180 |
| Grand Mean | | 125.77 | 0.582 | 67.34 | 1.654 | 1.540 |

*ANOV component was signigicantly ($p<0.05$) differently
+k = consistency index, n = flow behavior index, nk = approximate apparent Newtonian viscosity at low shear rates, Adhesive = adhesiveness and Hard = hardness

fine grinds. This differed from sensory adhesiveness which decreased with increased grind size. Thus, the instrumental test used here did not imitate adhesiveness in the mouth. The inverse relationship may be attributed to differences in mouth and room temperature and to interaction between peanut particle surface and the instrument surface material. The metal of the plates on the instrument differs from mouth surfaces in adhesive properties (Baier, 1975).

**Effects of Sucrose Concentration**

Sucrose concentration had a significant ($p<0.05$) effect on adhesiveness and smoothness during first compression, adhesiveness during mastication, crystallinity and ease of swallowing (Table 2). Added sucrose decreased the adhesiveness of peanut butter during both first compression and mastication. Specifically, the 6% concentration decreased adhesiveness during mastication ($p<0.05$) over the 3 or 0% concentrations. For adhesiveness during first compression 6% sucrose did not produce a significantly different result from 3%, but adhesiveness was lower ($p<0.05$) than for the 0% level. How and Young (1985) reported that many consumers dislike sticky or adhesive peanut butters. Added sugar acts as a nucleus in fat crystallization making a peanut butter less adhesive (Howe,1928; Woodroof et al., 1945).

Smoothness on first compression was significantly ($p<0.05$) decreased by sucrose concentration because added sucrose caused perceived crystals. The definition of "smoothness during mastication" did not include crystallinity in the definition, therefore it was not affected by sucrose concentration. Sucrose concentration caused a highly significant ($p<0.01$) increase in its perception of crystallinity. Ease of swallowing was significantly ($p<0.05$) improved by sucrose concentration. The effect of 3% sucrose was not different ($p<0.05$) from 0%, but 6% significantly ($p<0.05$) increased the ease of swallowing. According to Syarief et al. (1985) ease of swallowing is inversely related to adhesiveness. Our results agree with this. A less adhesive peanut butter is easier to swallow and added sugar improves both of these characteristics.

Texture preference scores decreased as sucrose concentration increased ($p<0.01$). Sugar granules did not completely dissolve during processing and were perceived as gritty during evaluation, thus having a negative effect on the ratings.

The mean values of instrumental hardness and adhesiveness were both significantly ($p<0.05$) affected by sucrose concentration. Sucrose at 3% slightly decreased adhesiveness, but 6% sucrose made the peanut butter significantly ($p<0.05$) less adhesive. Sucrose at 3% decreased the hardness as well, but 6% decreased it significantly ($p<0.05$).

**Effects of Salt Concentration**

Salt concentration had a significant ($p<0.05$) effect on overall impression, crystallinity and ease of swallowing. As salt concentration increased so did the crystallinity characteristic. Salt, at both 0.6 and 1.2%, increased ($p<0.05$) the ease of swallowing.

The consumer panel preferred peanut butter texture associated with higher concentrations of salt ($p<0.01$). A significant ($p<0.05$) increase occurred between no salt and both concentrations of added salt demonstrating that salt not only enhances flavor (Crippen, 1987) but improves texture.

**Results Not Affected by the Variables of this Study**

The sensory descriptive notes of firmness, oiliness and mouth coating were not significantly ($p<0.05$) affected by grind size, salt concentration or sucrose concentration.

The flow behavior index (n), consistency index (k) and their product (nk) were also not affected ($p<0.05$) by any of the three variables (Table 4). This supports the findings of Crippen et al. (1987) that grind size and formulation (no salt and no sugar, salt and no sugar, and salt and sugar) had no significant ($p<0.05$) effect on the flow behavior index, consistency index or the product of the two in peanut butter at 25°C. These values, as in the present work, were from extrusion viscometry analysis which yields fundamental flow properties. In this other study coefficients of variability for predicting firmness and smoothness from n and k were as high as 0.5 and 0.6, but prediction equations for all other sensory texture characteristics performed less well. Overall, extrusion viscometry parameters correlated poorly with most sensory texture characteristics.

**Interactions Between Factors**

A significant ($p<0.05$) interaction between grind size and sucrose concentration for sensory smoothness during first compression is shown in Figure 1. Smoothness decreased as particle size increased for all sucrose concentrations. As the sucrose concentration increased from 3 to 6% the magnitude of smoothness during first compression for each particle size decreased. The 0% sucrose concentration, however, was affected differently by particle size than the other two concentrations.

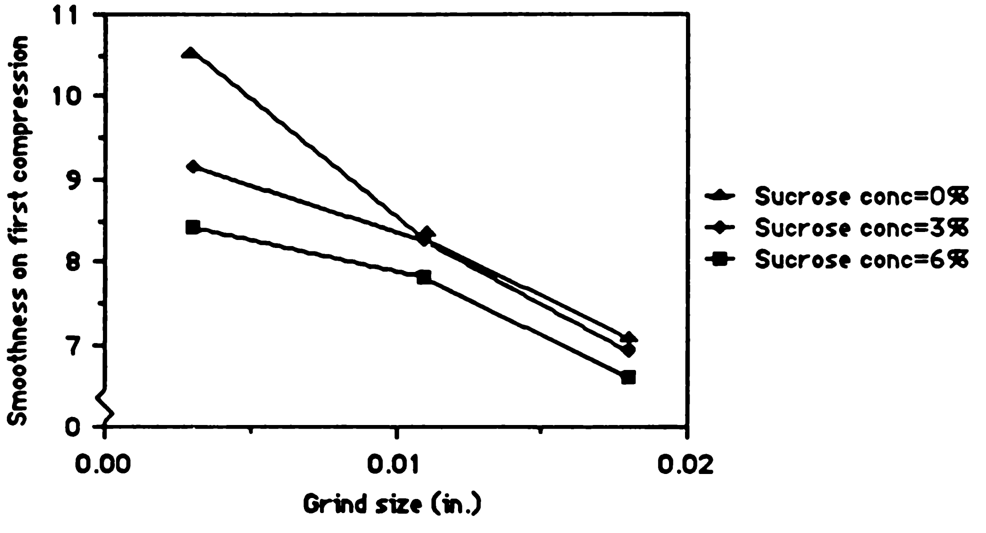


Figure 1. Grind size by sucrose concentration interaction for smoothness during first compression.

The fine grind at 0% sucrose resulted in the highest score and added sucrose caused a larger decrease in smoothness than was true for the coarser grinds.

There was a significant ($p<0.05$) interaction between salt concentration and sucrose concentration for the sensory crystallinity note (Figure 2). This means that differences in crystallinity between salt concentrations are not independent of sucrose concentration. Added sugar resulted in a higher magnitude of crystallinity with 6% being higher than 3%. Only at 0% sucrose did added salt increase crystallinity values. If sucrose was added, the effect of salt on crystallinity disappeared. Due to the low water content of peanut butter salt and sugar are not easily dissolved. The concentration of salt and sugar in this study were greater than the saturation point and perceived crystals resulted.

**Effect of Replications and Panelists**

The two peanut sources (replications) showed significant ($p<0.05$) differences for smoothness during first compression, gumminess and spreadability for the descriptive sensory analysis (Table2). The hardness and adhesiveness of the instrumental tests showed significant ($p<0.05$) differences between replications as well (Table 4). This means that the

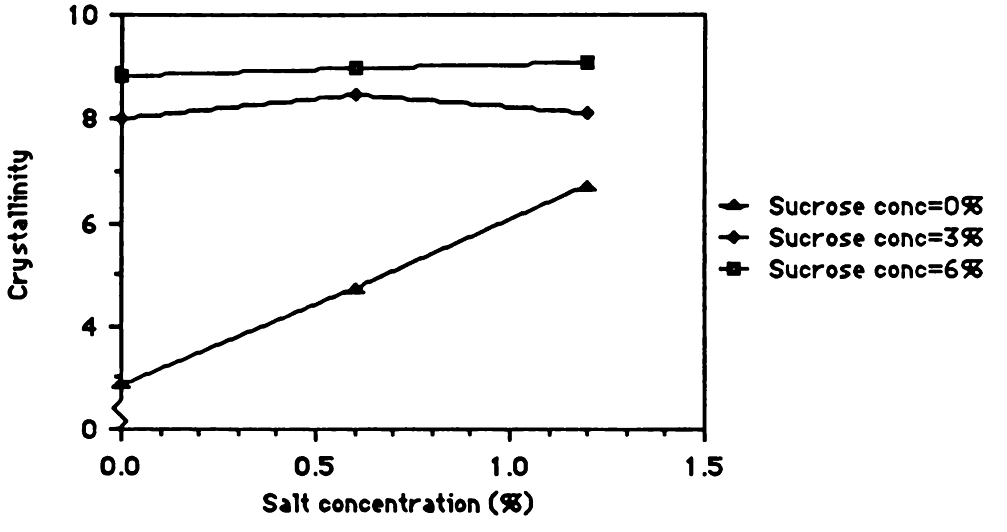


Figure 2. Salt concentration by sucrose concentration interaction for crystallinity.

two peanut replicates had textural differences.

The descriptive panelists differed significantly ($p<0.05$) on their responses for adhesiveness on first compression, oiliness, gumminess, adhesiveness during mastication, smoothness during mastication, ease of swallowing and mouthcoating. This indicates that individual panelists perceived the characteristics differently.

## CONCLUSIONS

As grind size increased, the consumer preference rating of texture decreased. The sensory descriptive characteristics adhesiveness during mastication and spreadability on a cracker decreased as grind size increased, while adhesiveness on first compression (bite) seemed to decrease slightly but not significantly. This confirms the work of Crippen et al. (1987) who found that adhesiveness during mastication decreased as particle size increased. Instrumental adhesiveness increased with increased grind size indicating a lack of true imitation by the instrumental method. However, added sucrose caused both sensory adhesiveness and instrumental adhesiveness to decrease. According to comments on ballots the consumer texture ratings decreased as sucrose concentration increased due to perceived crystals. Added sucrose increased the ease of swallowing which was inversely related to adhesiveness. Added salt increased the ease of swallowing and consumer panel texture ratings.

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# APPENDIX

Appendix A. Gas chromatographic headspace analysis.

Headspace analysis was performed to support the sensory work in this study. However, there is still considerable uncertainty as to how gas chromatographic headspace analysis relates to actual sensory characteristics. So far most of the peaks known to be associated with flavor characteristics have been associated with off-flavors. Off-flavors were very low in these peanut butters, so headspace analysis did not relate clearly to the sensory work.

## MATERIALS AND METHODS

One jar of peanut butter from each treatment combination was allowed to warm to room temperature. Peanut butter (1.5 g) were weighed into a 5-ml reacti-vial (Pierce Chemical Co., Rockford, IL). Two teflon-lined silicon septa were held on the vial with a screw cap. The vials were heated in a block heater (Pierce Chemical Co., Rockford, IL) at 150°C for 30 min. A Hamilton gas-tight syringe (Hamilton Co., Reno, NV) was used to remove 1ml of the headspace gas from the heated vial. The syringe was kept in a 50°C vacuum oven (Precision Co., Chicago, IL) at 25 psi. between injections.

Headspace gas was injected into the injection port (200°C) of a

Shimadzu GC-9A gas chromatographic system equipped with a Shimadzu flame ionization detector Model 9A and a Shimadzu C-R3A integrator. Nitrogen (40 ml/min) was used as the carrier gas. The glass column, 1 m long with an inside diameter of 0.003175 m and was packed with 80 to 100 mesh Porapack-PS (Supelco Inc., Bellefonte, PA). Program conditions were 2.5 min at 75°C, followed by a 15°C per min increase to 173°C and 30°C per min to 215°C. The temperature was held at 215°C for 2.5 min before the cooling cycle began. Twenty-eight peaks were monitored and the percent of total area under the curve was calculated by the integrator for each peak.

## RESULTS AND DISCUSSION

Poll and Flink (1984) found that salt added to apple juice had an effect on headspace analysis. Esters, aldehydes and alcohols were affected differently. Concentrations of alcohols increased, esters remained the same and aldehydes increased, but less than alcohols. In this work salt concentration affected some peak's percent of total area but not others (Table 1). The total peak area was decreased by the addition of salt. Sucrose concentration affected several peaks and the total peak area. The total peak area was decreased by the addition of

Table A 1 Mean squares and coefficients of variability from the analysis of variance for gas chromatographic headspace peaks and total peak area

| Source of variation | df | P1 | P2 | P3 | P4[+] | P5 | P6[+] | P7 | P8 | P9 | P10 | P11 | P12 | P13 | P14 | P15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grind Size (G) | 2 | 0 0941** | 0.0150** | 0.0002 | 0.0007 | 0 0624** | - | 7.2955 | 9.9573** | 0.0826 | 0.0877 | 0 0877* | 0.0196 | 80.4958** | 0.0383** | 0.3351 |
| Salt Conc. (Sa) | 2 | 0.0200 | 0.0105** | - | 0.0001 | 0 0197* | 0.0006** | 47.3283** | 4 7471** | 0.0829 | 0.0197 | 0.0058 | 0.0075 | 123.9372** | 0.0017 | 1 0030* |
| Sucrose Conc. (Su) | 2 | 0 0009 | 0 0007 | 0.0002 | 0.0001 | 0 0009 | 0 0005* | 8.5035 | 2.5472* | 0.0260 | 0.2810** | 0.0284 | 0.0028 | 34.8426 | 0.0139 | 2.6359** |
| G x Sa | 4 | 0.0170 | 0.0049* | 0.0006 | 0.0009 | 0 0137 | 0.0004* | 18.4869* | 2 6962** | 0 1731* | 0.0768 | 0.0581 | 0.0104 | 63.0573** | 0.0056 | 0.9033* |
| G x Su | 4 | 0 0124 | 0.0024 | 0.0003 | 0 0004 | 0.0109 | 0.0003 | 22.4855** | 0 7821 | 0.0600 | 0.1560** | 0.0891* | 0.0012 | 34.5614* | 0.0366** | 1.0838** |
| Sa x Su | 4 | 0 0131 | 0.0016 | 0.0001 | 0.0003 | 0 0097 | 0.0001 | 23.7914** | 0.9147 | 0.0339 | 0.0279 | 0.0438 | 0.0082 | 47.4138** | 0.0092 | 0 2270 |
| G x Sa x Su | 8 | 0.0143 | 0.0033 | 0.0003 | 0.0009 | 0 0119* | 0 0002 | 24.6297** | 4.0066** | 0.0544 | 0.0982** | 0.1688** | 0.0135 | 97.2368** | 0.0179** | 1.2285** |
| Replication (R) | 1 | 0 0119 | 0 0347** | 0.0008 | 0.0100** | 0 0510** | 0.0070** | 488.3908** | 34.0682** | 3.4675** | 0.0637 | 0.3795** | 0.0034 | 1083.8914** | 0.0405* | 3 9045** |
| Error | 90 | 0.0077 | 0.0016 | 0.0003 | 0.0005 | 0.0055 | 0.0001 | 6.0886 | 0.6295 | 0.0501 | 0.0317 | 0.0279 | 0.0067 | 13.2696 | 0.0064 | 0.2925 |
| C V (%) | | 12.8006 | 12.1487 | 95.0718 | 162.5702 | 13.2228 | 33.1230 | 9.4126 | 7.6578 | 68.3625 | 8.3720 | 37.1972 | 36.5710 | 15.5667 | 8.6525 | 7.5748 |
| Grand Mean | | 0.6838 | 0.3313 | 0.1881 | 0.0013 | 0.5632 | 0.0034 | 26.2148 | 10.3604 | 0.3275 | 2.1277 | 0.4495 | 0.2241 | 23.4009 | 0.9236 | 7.1397 |

| Source of variation | df | P16 | P17 | P18 | P19 | P20 | P21 | P22 | P23 | P24 | P25 | P26 | P27 | P28 | TOPA• |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grind Size (G) | 2 | 0.0622** | 0 0083** | 0.8764** | 0.1125 | 2.5254 | 0.0187 | 0 0154 | 0.0087 | 0.0269 | 0.0770 | 0.8263** | 0.0421 | 0.1044 | 2 6779 |
| Salt Conc. (Sa) | 2 | 0.0042 | 0.0007 | 0.8956** | 0.3471* | 0.7597 | 0.0020 | 0 0865* | 0.0105 | 0.3439* | 0.0018 | 0.4488 | 0.0050 | 0.4573** | 28 3239** |
| Sucrose Conc. (Su) | 2 | 0.0005 | 0.0001 | 2.6089** | 0.1720 | 1.2654 | 1.7269** | 0.0396 | 0.0201* | 0.0193 | 0.0273 | 0.2479 | 0.1733 | 0.1592 | 4 9011 |
| G x Sa | 4 | 0.0064 | 0.0005 | 0.7687** | 0.1416 | 0.3771 | 0.1110 | 0.0816** | 0.0241** | 0.1564 | 0.0918 | 0.3917 | 0.0909 | 0.2389* | 8 9147** |
| G x Su | 4 | 0.0056 | 0.0006 | 0.6232** | 0.3311** | 0.7310 | 0.8034* | 0.0239 | 0.0222** | 0.0677 | 0.1841** | 0.4631* | 0.0143 | 0.0442 | 2.4201 |
| Sa x Su | 4 | 0.0007 | 0.0005 | 0.0609 | 0.1050 | 0.9914 | 0.4093 | 0.0069 | 0.0062 | 0.0047 | 0.0502 | 0.5840* | 0.2127* | 0.0314 | 1.2707 |
| G x Sa x Su | 8 | 0.0100* | 0.0009 | 0.7495** | 0.0723 | 1.9972 | 0.9318** | 0.0798** | 0.0101 | 0.1540 | 0.1523** | 0.3941* | 0.0654 | 0.1987* | 4 0620* |
| Replication (R) | 1 | 0.0180 | 0.0189** | 5.3027** | 2.1479** | 1.1552 | 1.2510* | 1.6634** | 0.2344** | 2.8543** | 1 1094** | 5.2382** | 0.3522* | 2.6438** | 108 9666** |
| Error | 90 | 0.0046 | 0.0009 | 0.1703 | 0.0797 | 1.0337 | 0.2883 | 0.0228 | 0.0061 | 0.0830 | 0.0476 | 0.1691 | 0.0794 | 0.0752 | 1.7576 |
| C.V. (%) | | 5.6761 | 114.6543 | 7.0782 | 9.0864 | 13.1806 | 15.2888 | 13.6828 | 49.0457 | 19.0868 | 50.6924 | 34.9701 | 103.2728 | 25.2783 | 21 0790 |
| Grand Mean | | 1.1962 | 0.0258 | 5.8304 | 3.1069 | 7.7136 | 3.5122 | 1.1047 | 0.1588 | 1.5099 | 0.4305 | 1.1758 | 0.2728 | 1.0849 | $6.2894 \times 10^6$ |

*,**ANOV component was significantly ($p<0.05$) and highly significantly ($p<0.01$) different, respectively

[+] Mean squares are $\times 10^{-2}$

• Mean squares are $\times 10^{12}$

sucrose. Some peaks increased, some decreased, and some were unaffected by the addition of salt and sucrose. A typical chromatogram of headspace volatile peaks is shown in Figure 1.

Ito et al. (1983) and Pickett and Holly (1952) indicated that total amounts of aroma components from headspace analysis of coffee and peanuts, respectively, were highest when particle size would pass through a 20 mesh sieve. Grind sizes studied in this work affected several peaks, but caused no significant change in total peak area.

There were two-way interactions between factors for several of the peaks and the total peak area. There were three-way interactions on some peaks. This indicated that the factors studied were not independent of each other, and that one factor acted differently in the presence of another. The two-way interactions are illustrated in the following Figures 2 through 28.

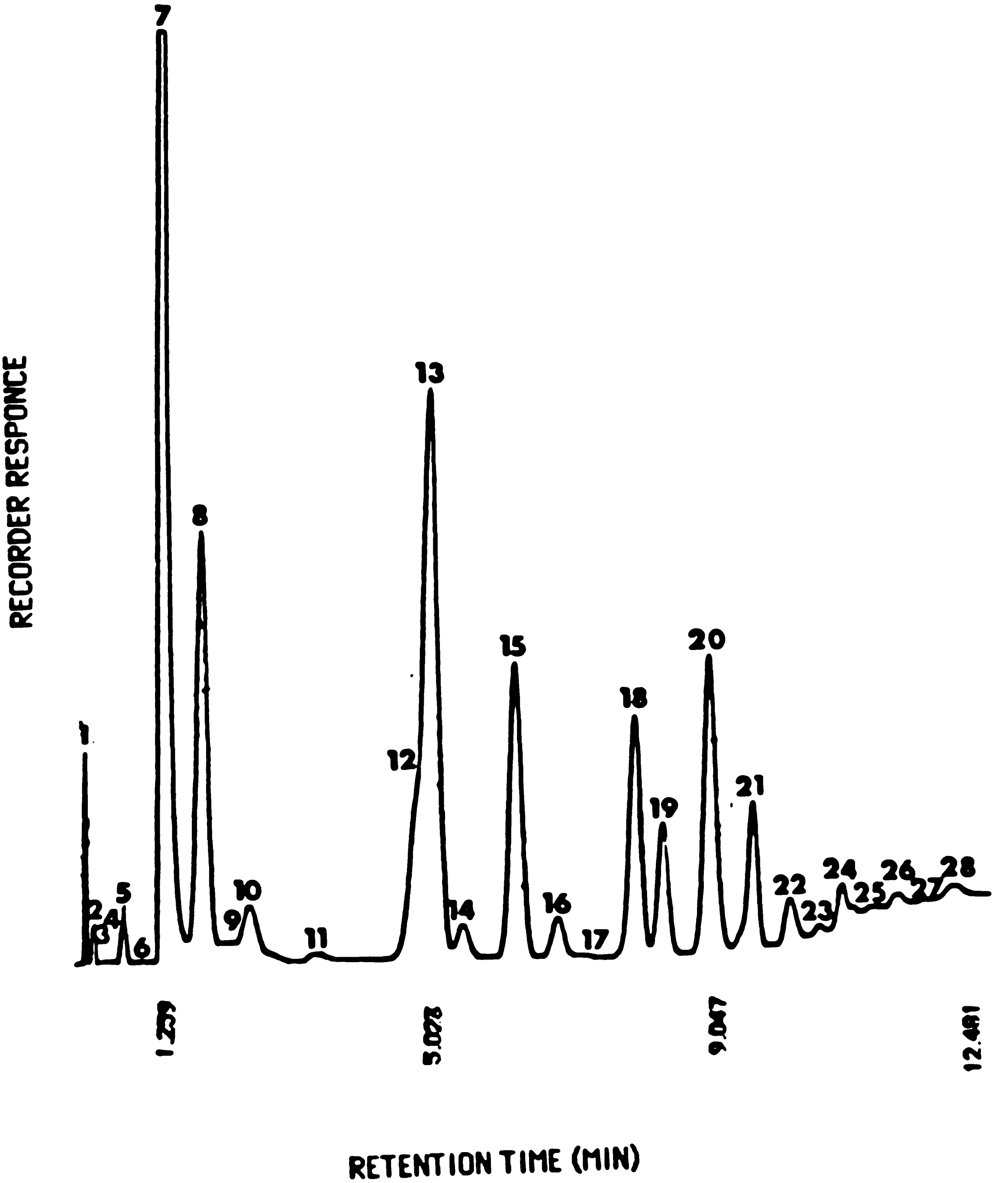


Figure 1. Typical chromatogram of headspace volatile profile of peanut butter.

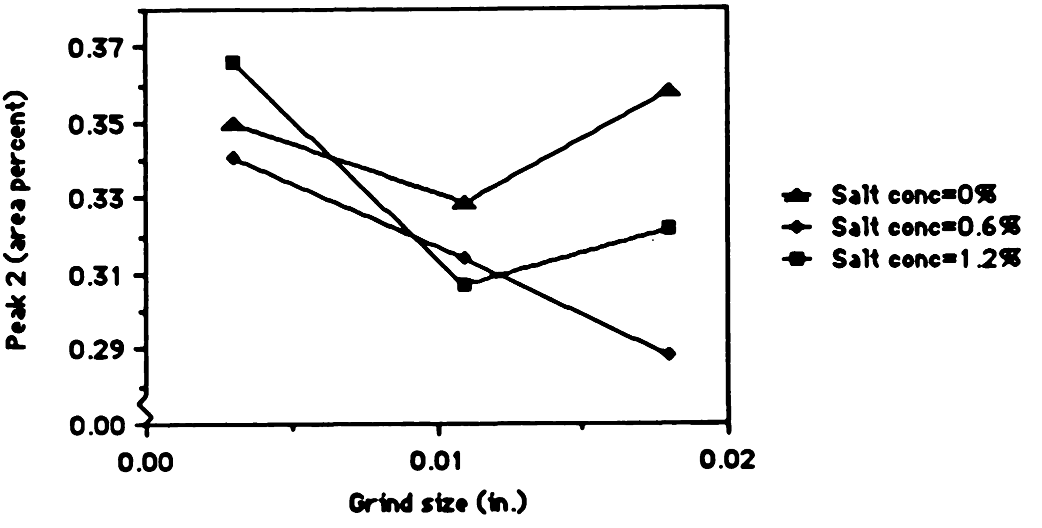


Figure 2. Grind size by salt concentration interaction for peak 2.

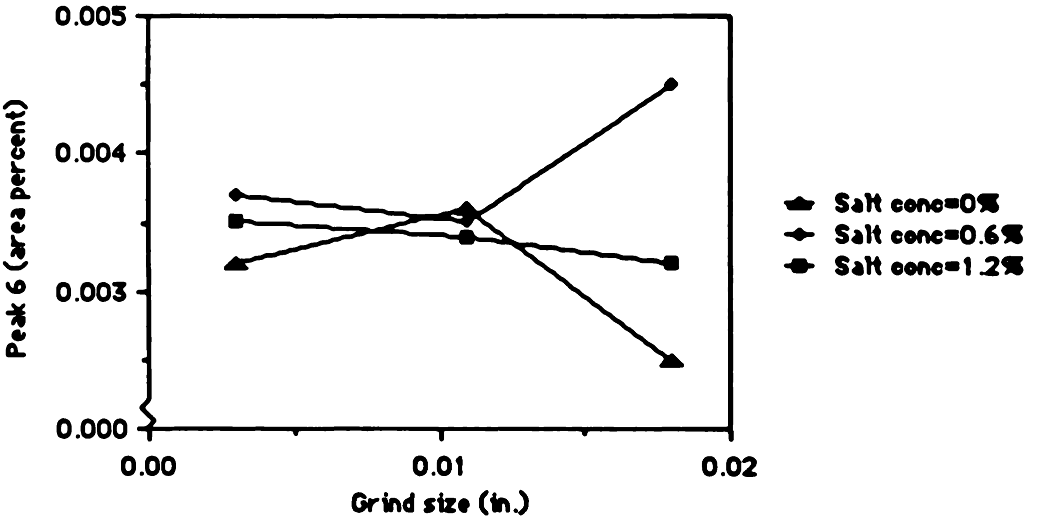


Figure 3. Grind size by salt concentration interaction for peak 6.

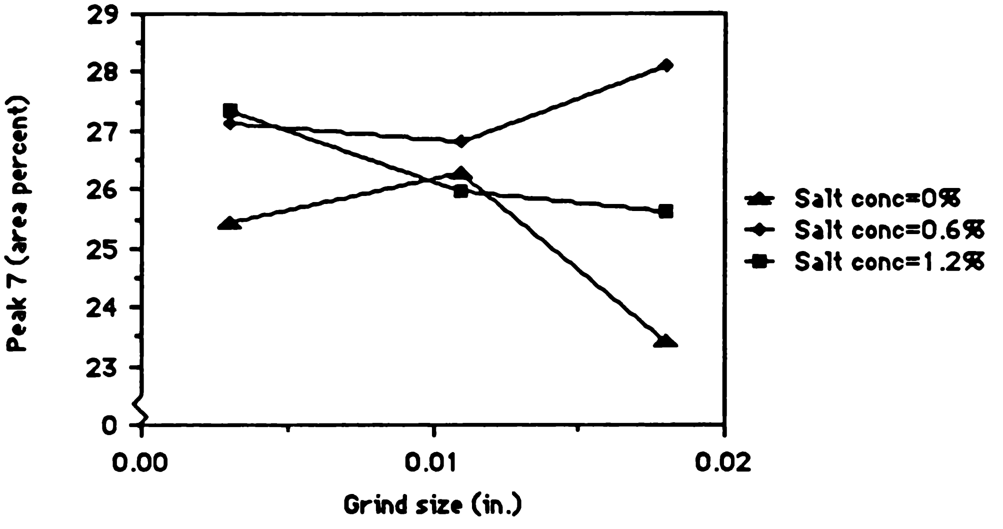


Figure 4. Grind size by salt concentration interaction for peak 7.

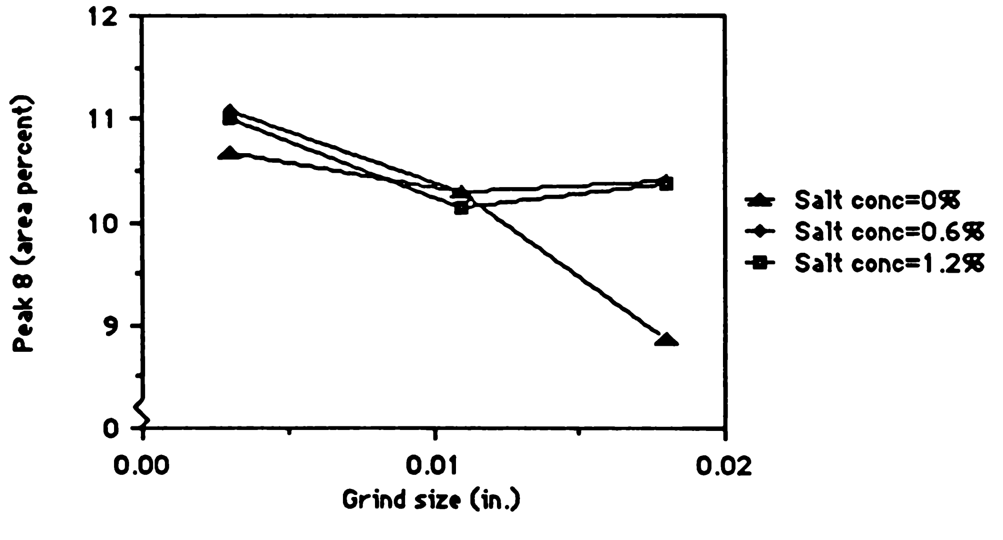


Figure 5. Grind size by salt concentration interaction for peak 8.

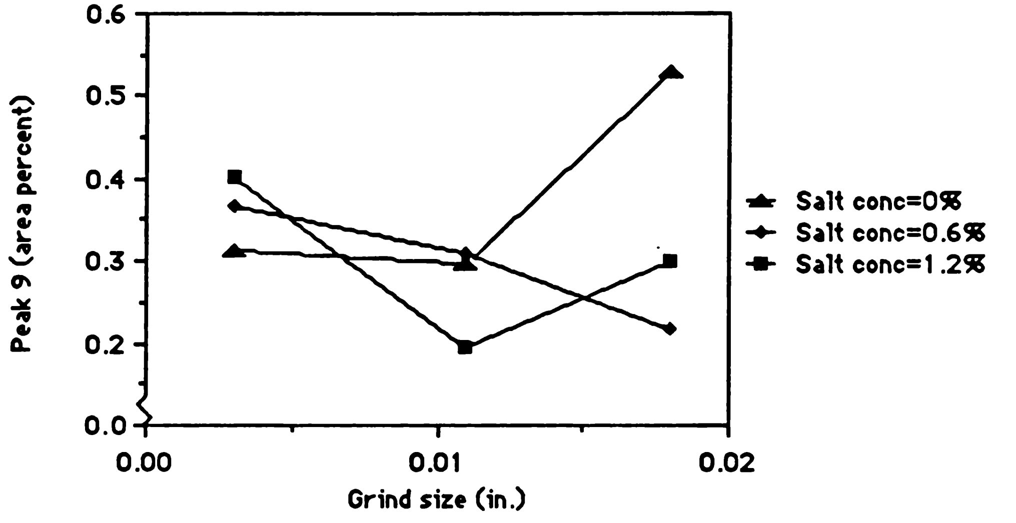


Figure 6. Grind size by salt concentration interaction for peak 9.

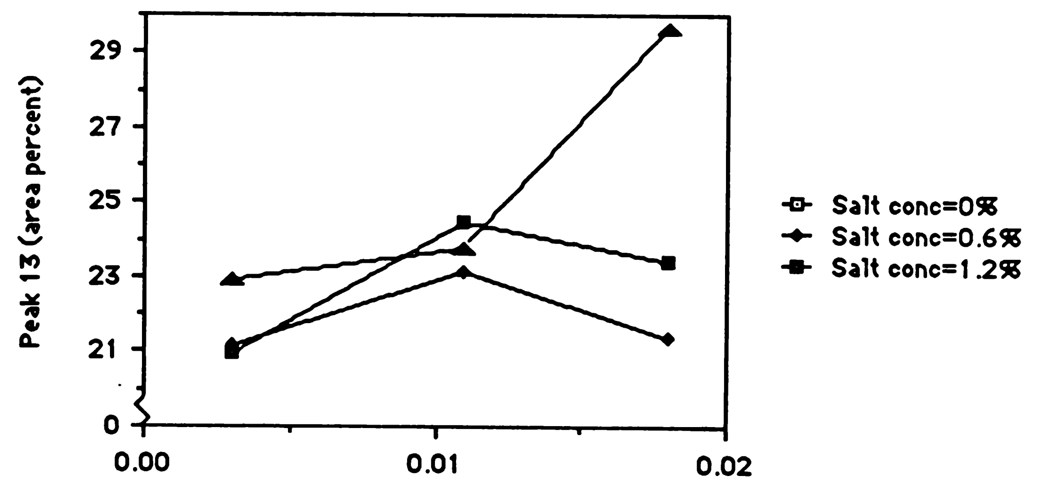


Figure 7. Grind size by salt concentration interaction for peak 13.

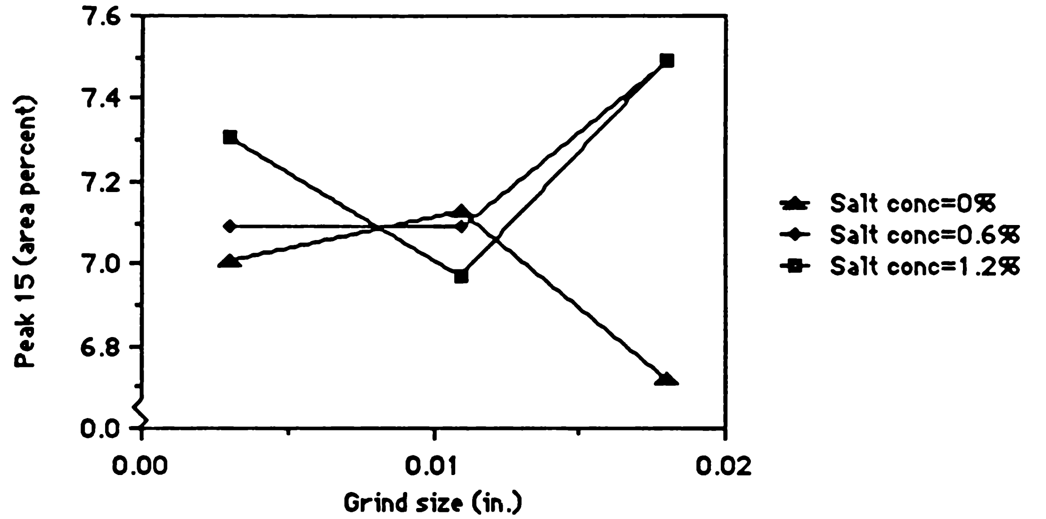


Figure 8. Grind size by salt concentration interaction for peak 15.

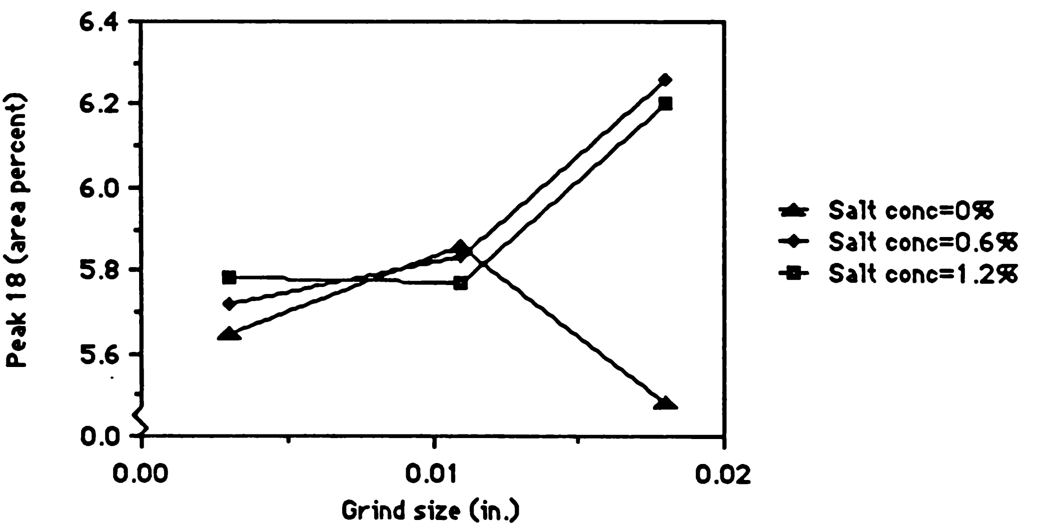


Figure 9. Grind size by salt concentration interaction for peak 18.

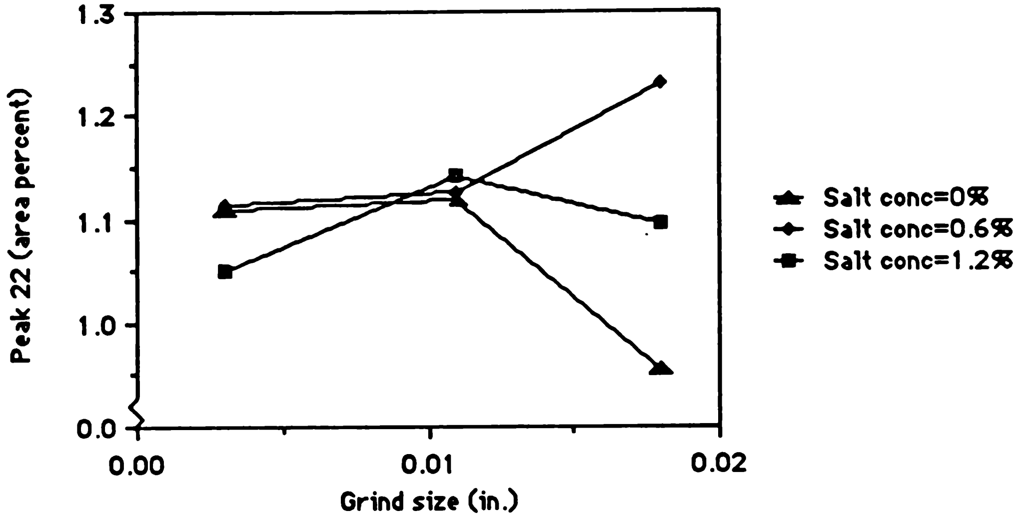


Figure 10. Grind size by salt concentration interaction for peak 22.

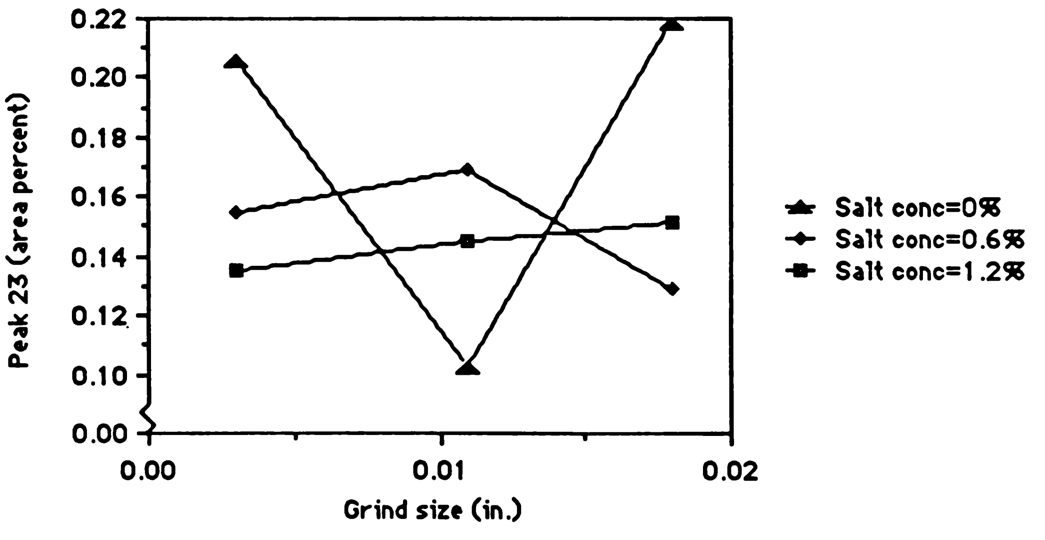


Figure 11. Grind size by salt concentration interaction for peak 23.

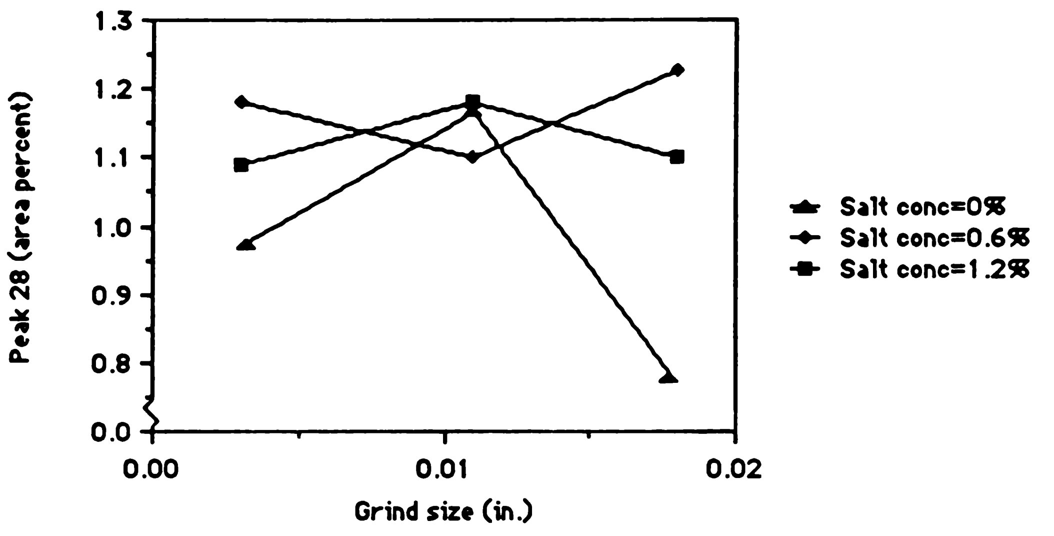


Figure 12. Grind size by salt concentration interaction for peak 28.

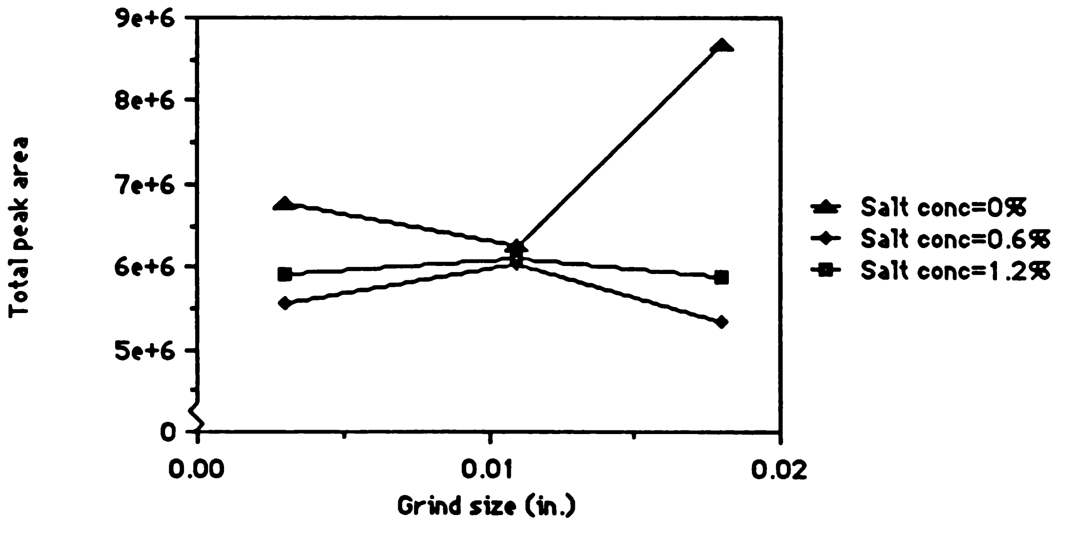


Figure 13. Grind size by salt concentration interaction for total peak area.

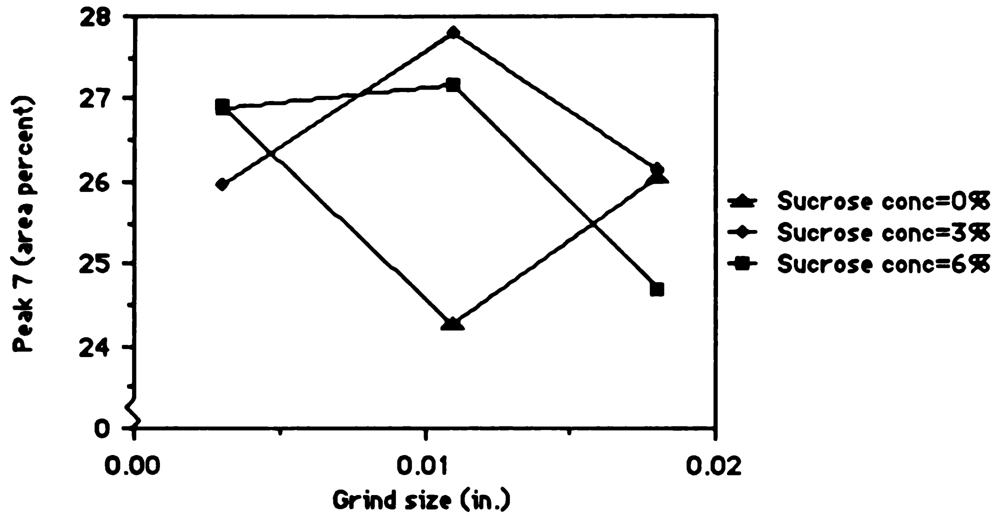


Figure 14. Grind size by sucrose concentration interaction for peak 7.

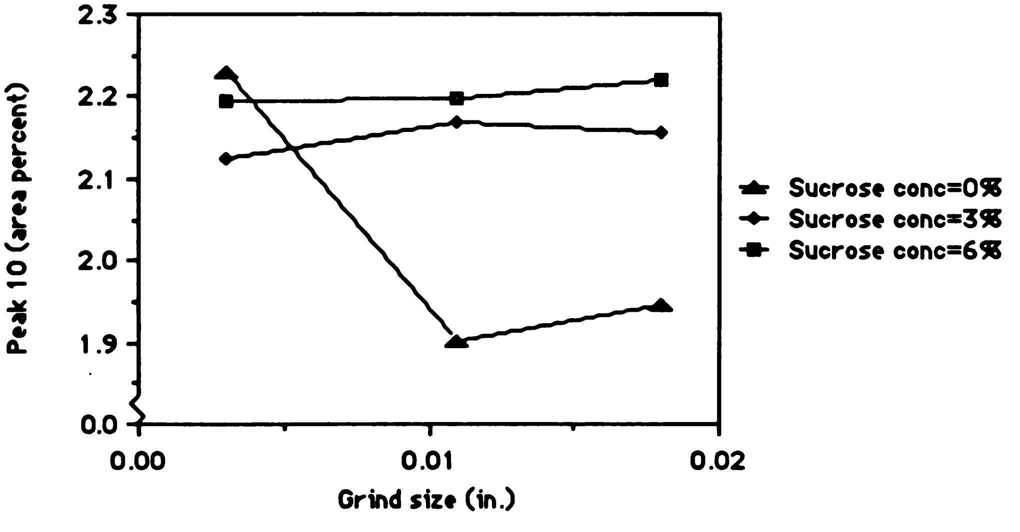


Figure 15. Grind size by sucrose concentration interaction for peak 10.

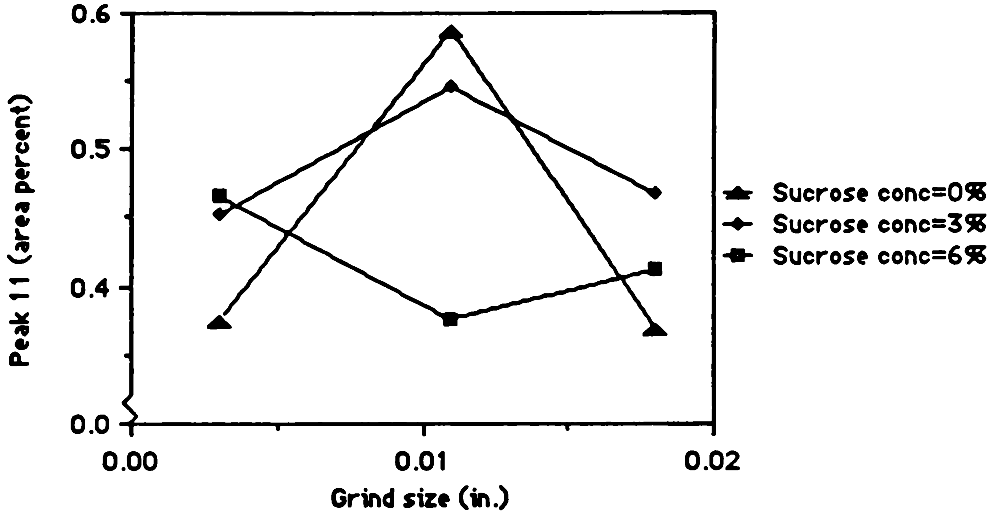


Figure 16. Grind size by sucrose concentration interaction for peak 11.

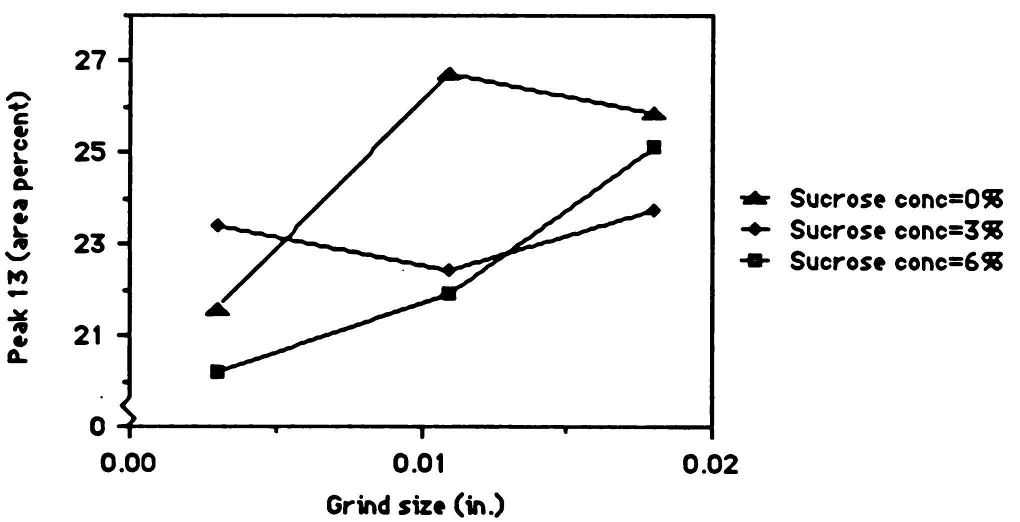


Figure 17. Grind size by sucrose concentration interaction for peak 13.

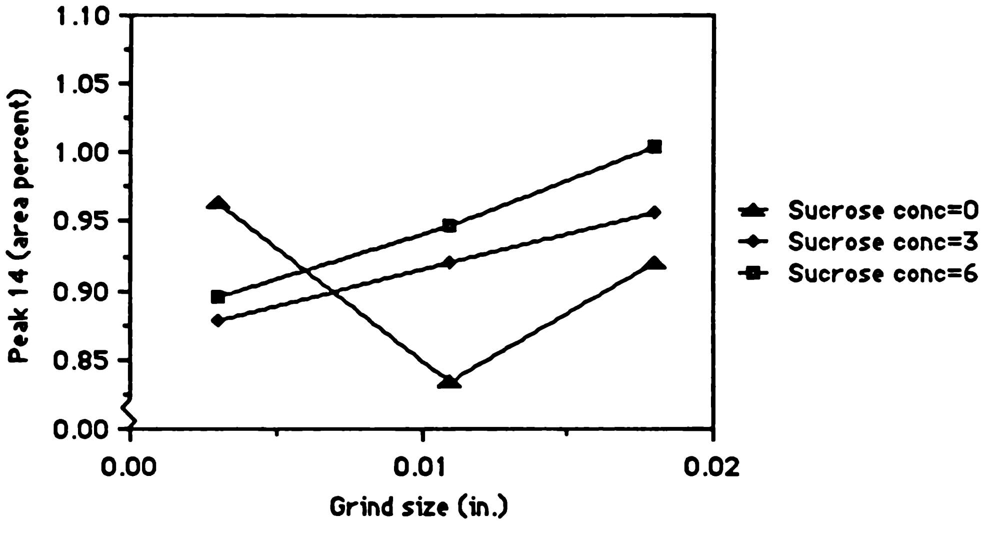


Figure 18. Grind size by sucrose concentration interaction for peak 14.

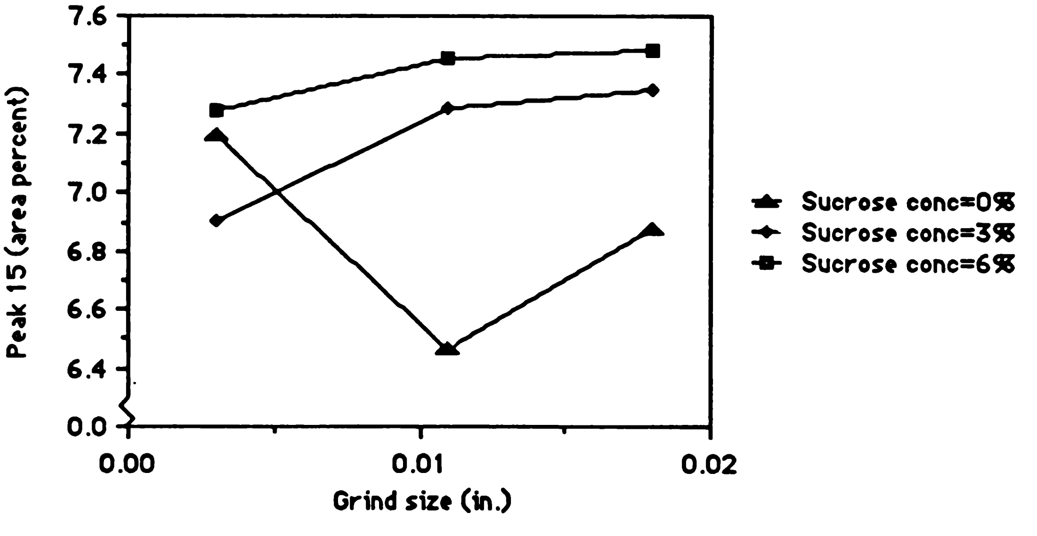


Figure 19. Grind size by sucrose concentration interaction for peak 15.

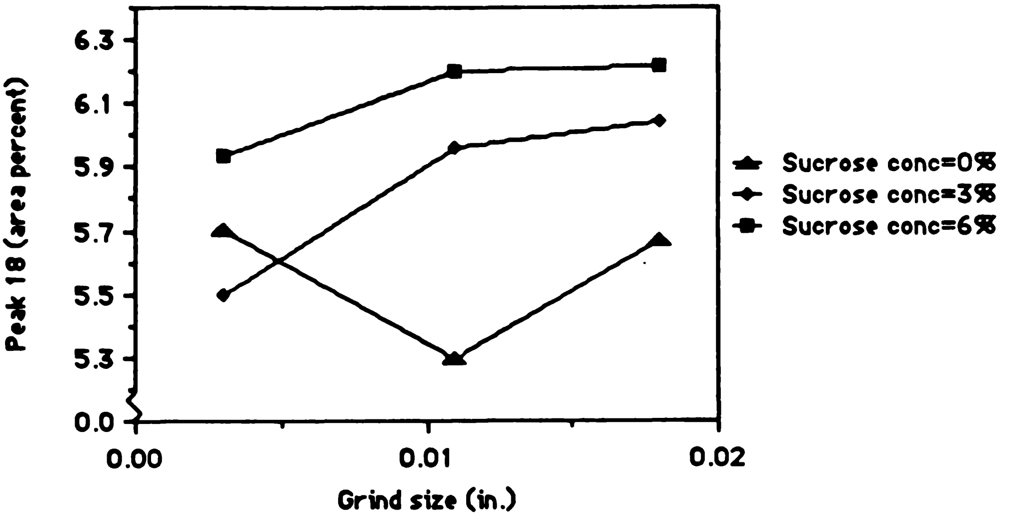


Figure 20. Grind size by sucrose concentration interaction for peak 18.

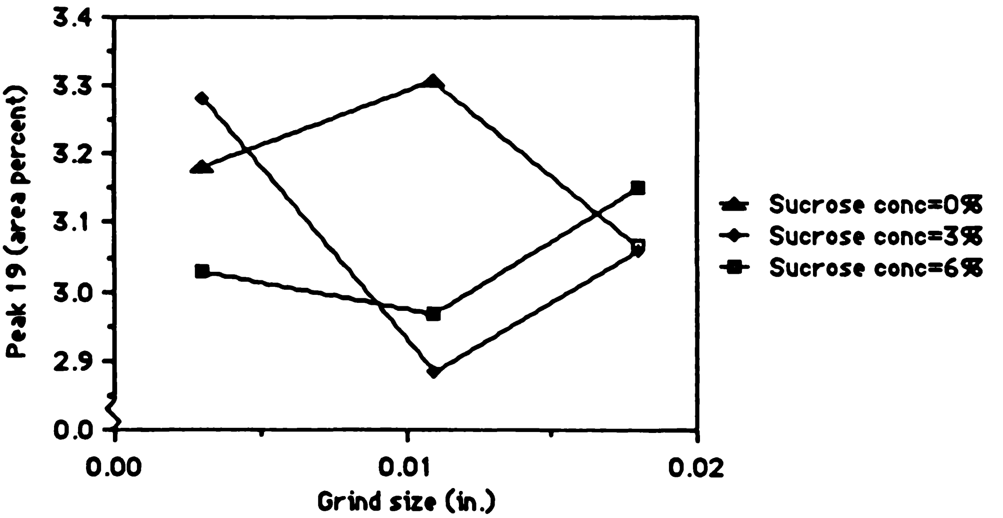


Figure 21. Grind size by sucrose concentration interaction for peak 19.

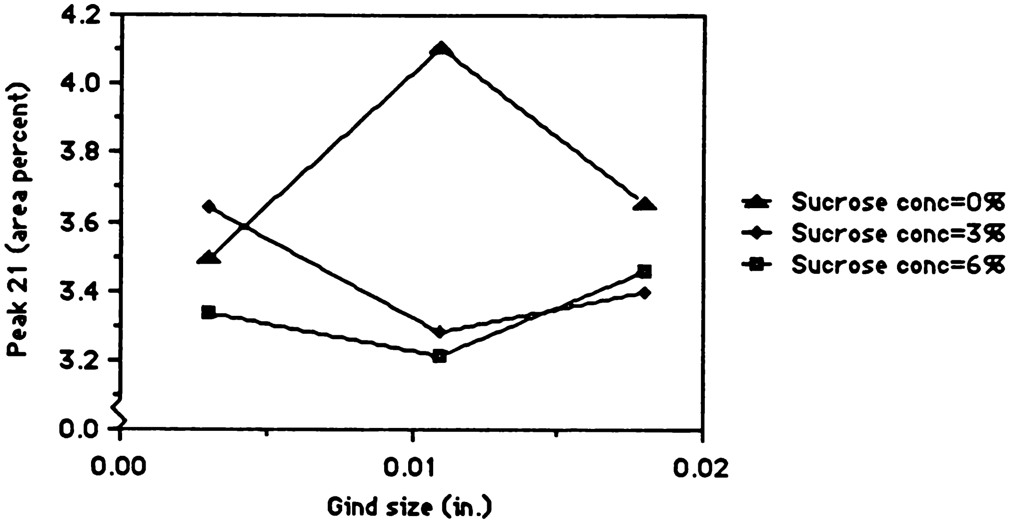


Figure 22. Grind size by sucrose concentration interaction for peak 21.

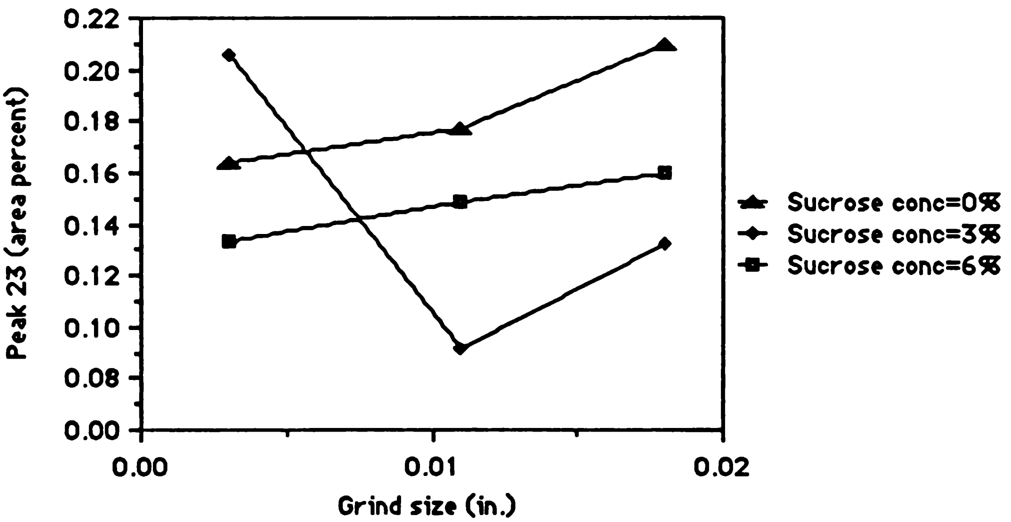


Figure 23. Grind size by sucrose concentration interaction for peak 23.

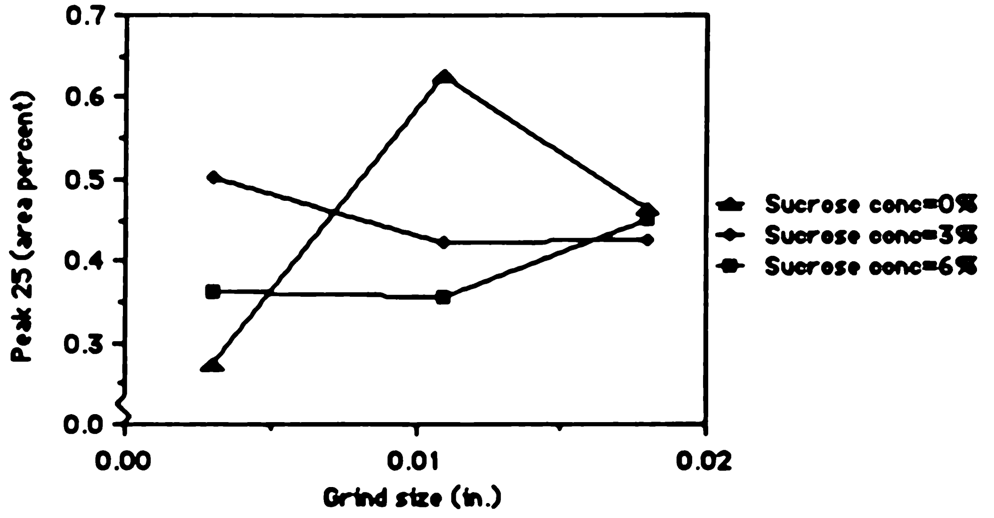


Figure 24. Grind size by sucrose concentration interaction for peak 25.

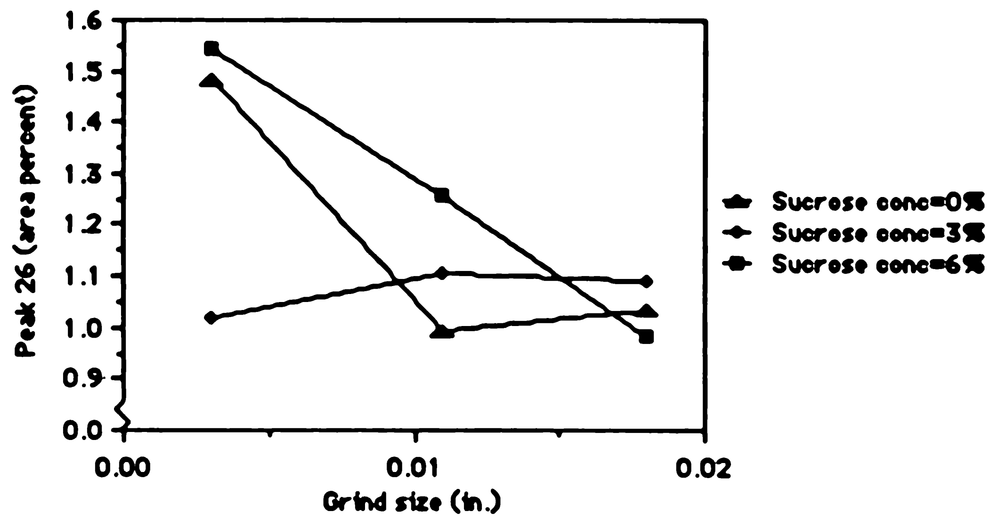


Figure 25. Grind size by sucrose concentration interaction for peak 26.

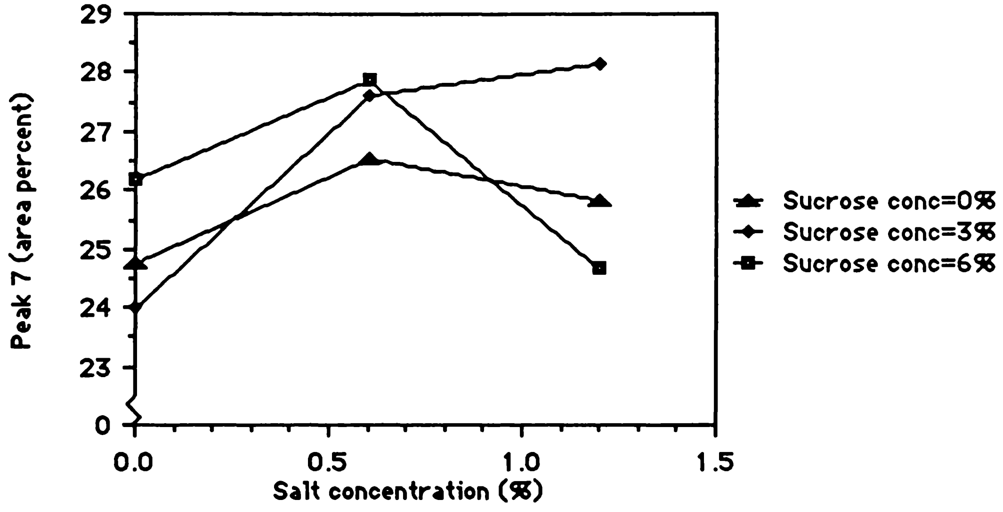


Figure 26. Salt concentration by sucrose concentration interaction for peak 7.

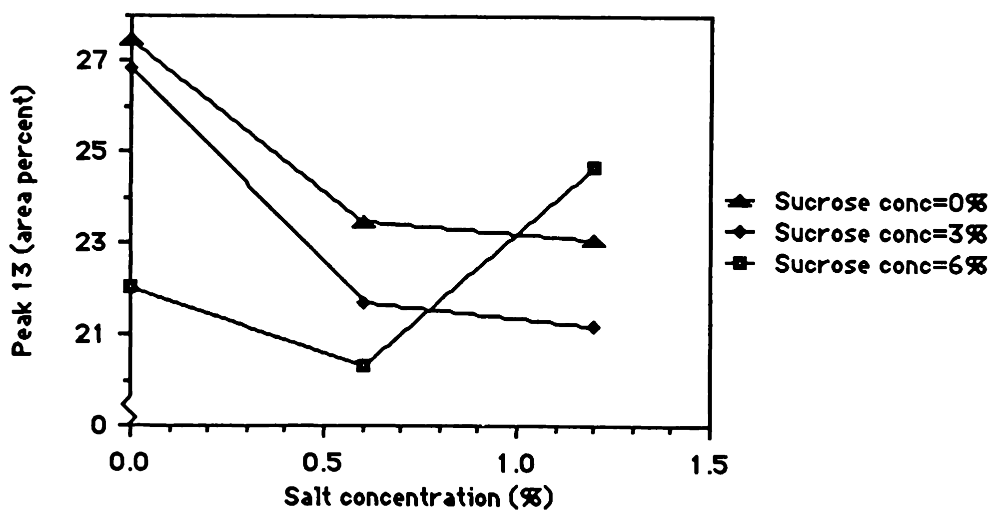


Figure 27. Salt concentration by sucrose concentration interaction for peak 13.

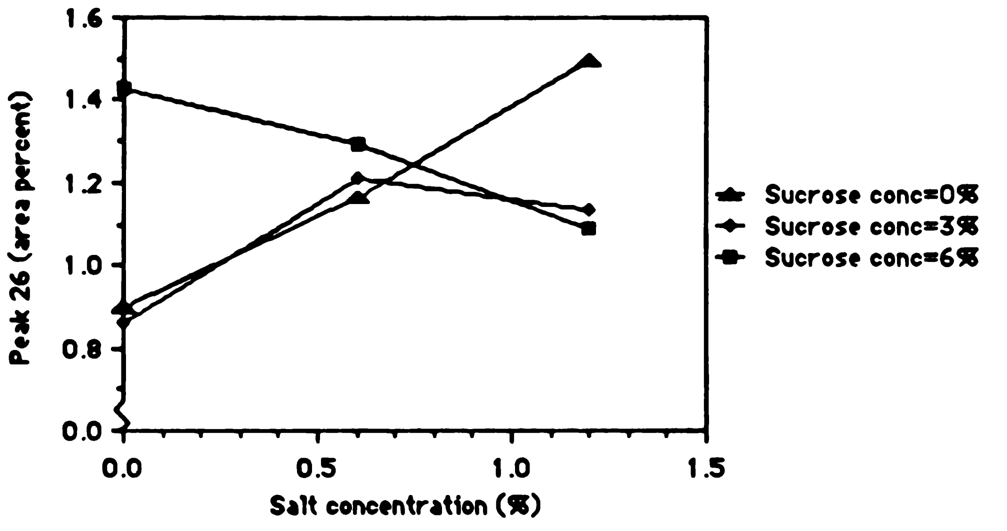


Figure 28. Salt concentration by sucrose concentration interaction for peak 26.

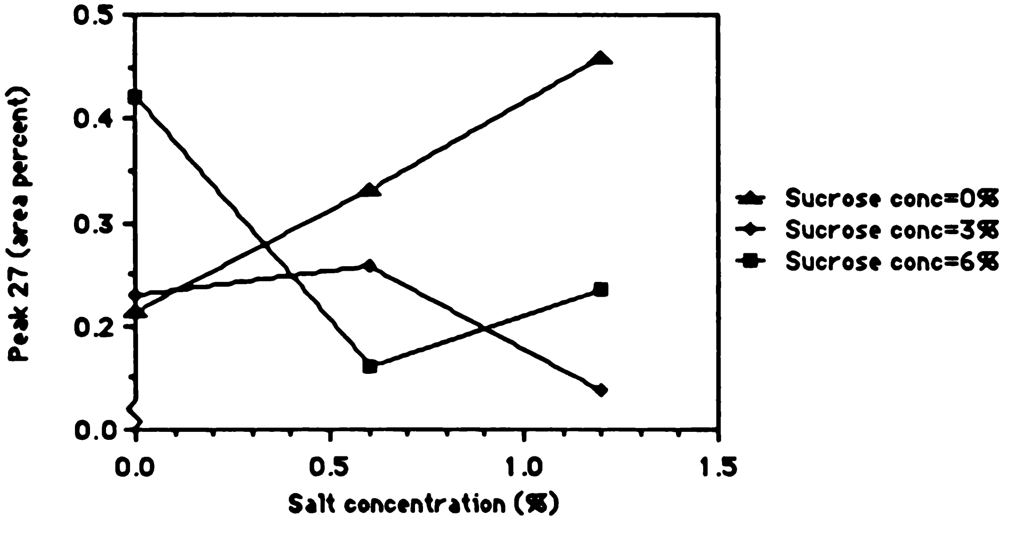


Figure 29. Salt concentration by sucrose concentration interaction for peak 27.

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Pickett, T.A. and Holly, K.T. 1952. Peanut roasting studies. Ga. Agr. Exp. Sta. Tech. Bull. No. 1. pp 5-36.

Poll, L. and Flink, J.M. 1984. Aroma analysis of apple juice: Influence of salt addition on headspace volatile compostion as measured by gas chromatography and corresponding sensory evaluations. Food Chem. 13:193-207.

Appendix B. Tables of means of descriptive flavor analysis.

| Grind Size | 0.003in. | 0.011in. | 0.018in. |
|---|---|---|---|
| **Aroma** | | | |
| Overall Impression | $5.674^{a}$ | $5.553^{a}$ | $5.282^{a}$ |
| Painty | $1.085^{a}$ | $1.041^{a}$ | $1.097^{a}$ |
| Sweet | $3.062^{a}$ | $2.854^{a}$ | $2.903^{a}$ |
| Roasted Peanut | $5.946^{a}$ | $5.862^{a}$ | $5.831^{a}$ |
| Under-roast | $1.000^{a}$ | $1.016^{a}$ | $1.073^{a}$ |
| Over-roast | $2.837^{a}$ | $2.634^{a}$ | $2.685^{a}$ |
| Sour | $1.806^{b}$ | $1.821^{b}$ | $2.000^{a}$ |
| Stale | $2.039^{a}$ | $2.293^{a}$ | $2.266^{a}$ |
| Briny | $1.853^{a}$ | $1.772^{a}$ | $1.790^{a}$ |
| **Flavor** | | | |
| Overall Impression | $5.201^{a}$ | $4.951^{a}$ | $4.903^{a}$ |
| Painty | $1.070^{a}$ | $1.032^{a}$ | $1.097^{a}$ |
| Roasted Peanut | $6.442^{a}$ | $6.382^{a}$ | $6.347^{a}$ |
| Under-roast | $1.023^{a}$ | $1.041^{a}$ | $1.105^{a}$ |
| Over-roast | $3.535^{a}$ | $3.691^{a}$ | $3.492^{a}$ |
| Sweet | $4.426^{a}$ | $4.301^{a}$ | $4.218^{a}$ |
| Sour | $2.085^{a}$ | $2.130^{a}$ | $2.097^{a}$ |
| Stale | $2.326^{a}$ | $2.260^{a}$ | $2.403^{a}$ |
| Salty | $3.628^{a}$ | $3.992^{a}$ | $3.935^{a}$ |
| Bitter | $3.667^{a}$ | $3.593^{a}$ | $3.573^{a}$ |
| **Aftertaste** | | | |
| Nutty | $5.426^{a}$ | $5.488^{a}$ | $5.460^{a}$ |
| Painty | $1.070^{a}$ | $1.024^{a}$ | $1.081^{a}$ |
| Sweet | $3.395^{a}$ | $3.325^{a}$ | $3.379^{a}$ |
| Salty | $3.085^{a}$ | $3.236^{a}$ | $3.113^{a}$ |
| Bitter | $3.248^{a}$ | $3.195^{a}$ | $3.242^{a}$ |
| Under-roast | $1.023^{a}$ | $1.008^{a}$ | $1.073^{a}$ |
| Over-roast | $3.023^{a}$ | $2.959^{a}$ | $2.863^{a}$ |

$^{a,b,c}$ Means with the same superscript are not significantly ($p<0.05$) different

Appendix B. Continued.

| Salt Concentration | 0% | 0.6% | 1.2% |
|---|---|---|---|
| **Aroma** | | | |
| Overall Impression | 5.220$^{b}$ | 5.754$^{a}$ | 5.545$^{ab}$ |
| Painty | 1.071$^{a}$ | 1.048$^{a}$ | 1.107$^{a}$ |
| Sweet | 2.992$^{a}$ | 2.944$^{a}$ | 2.886$^{a}$ |
| Roasted Peanut | 5.835$^{a}$ | 5.944$^{a}$ | 5.862$^{a}$ |
| Under-roast | 1.071$^{a}$ | 1.016$^{a}$ | 1.000$^{a}$ |
| Over-roast | 2.480$^{a}$ | 2.802$^{a}$ | 2.886$^{a}$ |
| Sour | 1.850$^{a}$ | 1.921$^{a}$ | 1.854$^{a}$ |
| Stale | 2.165$^{a}$ | 2.246$^{a}$ | 2.179$^{a}$ |
| Briny | 1.653$^{c}$ | 1.802$^{b}$ | 1.967$^{a}$ |
| **Flavor** | | | |
| Overall Impression | 4.653$^{b}$ | 5.357$^{a}$ | 5.057$^{ab}$ |
| Painty | 1.071$^{a}$ | 1.040$^{a}$ | 1.089$^{a}$ |
| Roasted Peanut | 6.142$^{b}$ | 6.587$^{a}$ | 6.447$^{a}$ |
| Under-roast | 1.142$^{a}$ | 1.016$^{b}$ | 1.008$^{b}$ |
| Over-roast | 3.370$^{a}$ | 3.841$^{a}$ | 3.504$^{a}$ |
| Sweet | 4.583$^{a}$ | 4.309$^{ab}$ | 4.049$^{b}$ |
| Sour | 2.071$^{a}$ | 2.127$^{a}$ | 2.224$^{a}$ |
| Stale | 2.142$^{a}$ | 2.484$^{a}$ | 2.366$^{a}$ |
| Salty | 2.504$^{c}$ | 3.857$^{b}$ | 5.228$^{a}$ |
| Bitter | 3.543$^{a}$ | 3.635$^{a}$ | 3.658$^{a}$ |
| **Aftertaste** | | | |
| Nutty | 5.173$^{b}$ | 5.619$^{a}$ | 5.585$^{a}$ |
| Painty | 1.055$^{a}$ | 1.024$^{a}$ | 1.098$^{a}$ |
| Sweet | 3.701$^{a}$ | 3.278$^{b}$ | 3.114$^{b}$ |
| Salty | 2.055$^{c}$ | 3.055$^{b}$ | 4.358$^{a}$ |
| Bitter | 3.126$^{a}$ | 3.302$^{a}$ | 3.260$^{a}$ |
| Under-roast | 1.087$^{a}$ | 1.016$^{b}$ | 1.000$^{b}$ |
| Over-roast | 2.890$^{a}$ | 3.159$^{a}$ | 2.797$^{a}$ |

$^{a,b,c}$ Means with the same superscript are not significantly ($p<0.05$) different

Appendix B. Continued.

| Sucrose Concentration | 0% | 3% | 6% |
|---|---|---|---|
| **Aroma** | | | |
| Overall Impression | $5.549^{a}$ | $5.444^{a}$ | $5.523^{a}$ |
| Painty | $1.082^{a}$ | $1.095^{a}$ | $1.047^{a}$ |
| Sweet | $2.418^{c}$ | $2.913^{b}$ | $3.469^{a}$ |
| Roasted Peanut | $5.992^{a}$ | $5.754^{a}$ | $5.898^{a}$ |
| Under-roast | $1.016^{a}$ | $1.048^{a}$ | $1.023^{a}$ |
| Over-roast | $2.713^{a}$ | $2.579^{a}$ | $2.867^{a}$ |
| Sour | $1.869^{a}$ | $1.889^{a}$ | $1.867^{a}$ |
| Stale | $2.205^{a}$ | $2.333^{a}$ | $2.055^{a}$ |
| Briny | $1.844^{a}$ | $1.778^{a}$ | $1.797^{a}$ |
| **Flavor** | | | |
| Overall Impression | $4.836^{a}$ | $5.341^{a}$ | $4.883^{a}$ |
| Painty | $1.090^{a}$ | $1.087^{a}$ | $1.023^{a}$ |
| Roasted Peanut | $6.311^{a}$ | $6.452^{a}$ | $6.406^{a}$ |
| Under-roast | $1.041^{a}$ | $1.079^{a}$ | $1.047^{a}$ |
| Over-roast | $3.902^{a}$ | $3.540^{ab}$ | $3.289^{b}$ |
| Sweet | $2.795^{c}$ | $4.357^{b}$ | $5.727^{a}$ |
| Sour | $2.311^{a}$ | $2.119^{b}$ | $1.891^{c}$ |
| Stale | $2.311^{a}$ | $2.444^{a}$ | $2.234^{a}$ |
| Salty | $4.008^{a}$ | $3.802^{a}$ | $3.742^{a}$ |
| Bitter | $4.098^{a}$ | $3.508^{b}$ | $3.250^{b}$ |
| **Aftertaste** | | | |
| Nutty | $5.361^{a}$ | $5.500^{a}$ | $5.508^{a}$ |
| Painty | $1.066^{a}$ | $1.087^{a}$ | $1.023^{a}$ |
| Sweet | $2.172^{c}$ | $3.365^{b}$ | $4.508^{a}$ |
| Salty | $3.320^{a}$ | $3.143^{a}$ | $2.977^{a}$ |
| Bitter | $3.631^{a}$ | $3.159^{b}$ | $2.914^{b}$ |
| Under-roast | $1.033^{a}$ | $1.055^{a}$ | $1.056^{a}$ |
| Over-roast | $3.188^{a}$ | $2.913^{a}$ | $2.758^{a}$ |

$^{a,b,c}$ Means with the same superscript are not significantly ($p<0.05$) different

Appendix C. Tables of means of gas chromatographic headspace analysis.

| Grind Size | 0.003in. | 0.011in. | 0.018in. |
|---|---|---|---|
| Peak 1 | 0.735$^{a}$ | 0.657$^{b}$ | 0.653$^{b}$ |
| Peak 2 | 0.351$^{a}$ | 0.317$^{b}$ | 0.324$^{b}$ |
| Peak 3 | 0.021$^{a}$ | 0.020$^{a}$ | 0.015$^{a}$ |
| Peak 4 | 0.001$^{a}$ | 0.002$^{a}$ | 0.001$^{a}$ |
| Peak 5 | 0.606$^{a}$ | 0.538$^{b}$ | 0.542$^{b}$ |
| Peak 6 | 0.003$^{a}$ | 0.003$^{a}$ | 0.003$^{a}$ |
| Peak 7 | 26.580$^{a}$ | 26.372$^{a}$ | 25.654$^{a}$ |
| Peak 8 | 10.919$^{a}$ | 10.243$^{b}$ | 9.860$^{c}$ |
| Peak 9 | 0.357$^{a}$ | 0.269$^{a}$ | 0.353$^{a}$ |
| Peak 10 | 2.184$^{a}$ | 2.088$^{b}$ | 2.105$^{ab}$ |
| Peak 11 | 0.431$^{ab}$ | 0.505$^{a}$ | 0.417$^{b}$ |
| Peak 12 | 0.251$^{a}$ | 0.216$^{ab}$ | 0.202$^{b}$ |
| Peak 13 | 21.739$^{b}$ | 23.739$^{a}$ | 24.900$^{a}$ |
| Peak 14 | 0.913$^{a}$ | 0.900$^{a}$ | 0.959$^{b}$ |
| Peak 15 | 7.127$^{a}$ | 7.065$^{a}$ | 7.228$^{a}$ |
| Peak 16 | 1.239$^{a}$ | 1.188$^{b}$ | 1.158$^{c}$ |
| Peak 17 | 0.013$^{b}$ | 0.025$^{b}$ | 0.041$^{a}$ |
| Peak 18 | 5.712$^{b}$ | 5.819$^{ab}$ | 5.972$^{a}$ |
| Peak 19 | 3.164$^{a}$ | 3.058$^{a}$ | 3.092$^{a}$ |
| Peak 20 | 7.984$^{a}$ | 7.653$^{ab}$ | 7.476$^{b}$ |
| Peak 21 | 3.491$^{a}$ | 3.542$^{a}$ | 3.505$^{a}$ |
| Peak 22 | 1.094$^{a}$ | 1.130$^{a}$ | 1.091$^{a}$ |
| Peak 23 | 0.168$^{a}$ | 0.141$^{a}$ | 0.167$^{a}$ |
| Peak 24 | 1.516$^{a}$ | 1.540$^{a}$ | 1.472$^{a}$ |
| Peak 25 | 0.380$^{a}$ | 0.470$^{a}$ | 0.447$^{a}$ |
| Peak 26 | 1.349$^{a}$ | 1.122$^{b}$ | 1.038$^{b}$ |
| Peak 27 | 0.309$^{a}$ | 0.231$^{a}$ | 0.274$^{a}$ |
| Peak 28 | 1.080$^{a}$ | 1.147$^{a}$ | 1.028$^{a}$ |
| Total peak area$^{+}$ | 60.990$^{a}$ | 61.328$^{a}$ | 66.179$^{a}$ |

$^{a,b,c}$ Means with the same superscript are not significantly ($p<0.05$) different

$^{+}$ Actual number is $\times 10^5$

Appendix C. Continued.

| Salt Concentration | 0% | 0.6% | 1.2% |
|---|---|---|---|
| Peak 1 | 0.696ᵃ | 0.663ᵃ | 0.694ᵃ |
| Peak 2 | 0.346ᵃ | 0.316ᵇ | 0.331ᵃᵇ |
| Peak 3 | 0.019ᵃ | 0.019ᵃ | 0.017ᵃ |
| Peak 4 | 0.001ᵃ | 0.001ᵃ | 0.001ᵃ |
| Peak 5 | 0.581ᵃ | 0.542ᵃ | 0.567ᵃ |
| Peak 6 | 0.003ᵇ | 0.004ᵃ | 0.003ᵃᵇ |
| Peak 7 | 25.026ᵃ | 27.307ᵇ | 26.289ᵇ |
| Peak 8 | 9.971ᵇ | 10.609ᵃ | 10.506ᵃ |
| Peak 9 | 0.379ᵃ | 0.303ᵃ | 0.299ᵃ |
| Peak 10 | 2.101ᵃ | 2.144ᵃ | 2.139ᵃ |
| Peak 11 | 0.452ᵃ | 0.452ᵃ | 0.444ᵃ |
| Peak 12 | 0.217ᵃ | 0.241ᵃ | 0.214ᵃ |
| Peak 13 | 25.366ᵃ | 21.901ᵇ | 22.938ᵇ |
| Peak 14 | 0.921ᵃ | 0.919ᵃ | 0.932ᵃ |
| Peak 15 | 6.955ᵇ | 7.208ᵃᵇ | 7.263ᵃ |
| Peak 16 | 1.186ᵃ | 1.198ᵃ | 1.205ᵃ |
| Peak 17 | 0.025ᵃ | 0.030ᵃ | 0.022ᵃ |
| Peak 18 | 5.656ᵇ | 5.915ᵃ | 5.924ᵃ |
| Peak 19 | 3.201ᵃ | 3.026ᵇ | 3.095ᵃᵇ |
| Peak 20 | 7.839ᵃ | 7.548ᵃ | 7.762ᵃ |
| Peak 21 | 3.523ᵃ | 3.504ᵃ | 3.509ᵃ |
| Peak 22 | 1.062ᵃ | 1.153ᵃ | 1.097ᵃ |
| Peak 23 | 0.179ᵃ | 0.152ᵃ | 0.144ᵃ |
| Peak 24 | 1.413ᵇ | 1.586ᵃ | 1.530ᵃᵇ |
| Peak 25 | 0.426ᵃ | 0.430ᵃ | 0.435ᵃ |
| Peak 26 | 1.071ᵃ | 1.221ᵃ | 1.239ᵃ |
| Peak 27 | 0.291ᵃ | 0.254ᵃ | 0.274ᵃ |
| Peak 28 | 0.963ᵇ | 1.168ᵃ | 1.124ᵃ |
| Total Peak Area⁺ | 72.421ᵃ | 56.594ᵇ | 59.576ᵇ |

a b c Means with the same superscript are not significantly ($p<0.05$) different

⁺ Actual number is $\times 10^5$

Appendix C. Continued.

| Sucrose Concentration | 0% | 3% | 6% |
|---|---|---|---|
| Peak 1 | 0.690$^{a}$ | 0.681$^{a}$ | 0.681$^{a}$ |
| Peak 2 | 0.337$^{a}$ | 0.331$^{a}$ | 0.326$^{a}$ |
| Peak 3 | 0.016$^{a}$ | 0.021$^{a}$ | 0.019$^{a}$ |
| Peak 4 | 0.001$^{a}$ | 0.001$^{a}$ | 0.002$^{a}$ |
| Peak 5 | 0.569$^{a}$ | 0.560$^{a}$ | 0.560$^{a}$ |
| Peak 6 | 0.003$^{b}$ | 0.004$^{a}$ | 0.003$^{ab}$ |
| Peak 7 | 25.771$^{a}$ | 26.592$^{a}$ | 26.293$^{a}$ |
| Peak 8 | 10.035$^{b}$ | 10.415$^{a}$ | 10.639$^{a}$ |
| Peak 9 | 0.342$^{a}$ | 0.350$^{a}$ | 0.290$^{a}$ |
| Peak 10 | 2.032$^{b}$ | 2.150$^{a}$ | 2.204$^{a}$ |
| Peak 11 | 0.442$^{a}$ | 0.487$^{a}$ | 0.420$^{a}$ |
| Peak 12 | 0.221$^{a}$ | 0.230$^{a}$ | 0.221$^{a}$ |
| Peak 13 | 24.653$^{a}$ | 23.239$^{ab}$ | 22.279$^{b}$ |
| Peak 14 | 0.907$^{a}$ | 0.917$^{a}$ | 0.946$^{a}$ |
| Peak 15 | 6.856$^{c}$ | 7.170$^{b}$ | 7.401$^{a}$ |
| Peak 16 | 1.196$^{a}$ | 1.191$^{a}$ | 1.201$^{a}$ |
| Peak 17 | 0.023$^{a}$ | 0.026$^{a}$ | 0.028$^{a}$ |
| Peak 18 | 5.563$^{c}$ | 5.823$^{b}$ | 6.112$^{a}$ |
| Peak 19 | 3.187$^{a}$ | 3.085$^{a}$ | 3.047$^{a}$ |
| Peak 20 | 7.486$^{a}$ | 7.683$^{a}$ | 7.978$^{a}$ |
| Peak 21 | 3.747$^{a}$ | 3.450$^{b}$ | 3.333$^{b}$ |
| Peak 22 | 1.064$^{a}$ | 1.103$^{a}$ | 1.148$^{a}$ |
| Peak 23 | 0.183$^{a}$ | 0.146$^{a}$ | 0.146$^{a}$ |
| Peak 24 | 1.499$^{a}$ | 1.484$^{a}$ | 1.548$^{a}$ |
| Peak 25 | 0.451$^{a}$ | 0.452$^{a}$ | 0.388$^{a}$ |
| Peak 26 | 1.179$^{a}$ | 1.070$^{a}$ | 1.278$^{a}$ |
| Peak 27 | 0.332$^{a}$ | 0.209$^{a}$ | 0.276$^{a}$ |
| Peak 28 | 1.007$^{a}$ | 1.132$^{a}$ | 1.117$^{a}$ |
| Total Peak Area$^{+}$ | 67.312$^{a}$ | 61.052$^{ab}$ | 60.205$^{b}$ |

$^{a,b,c}$ Means with same superscript are not significantly ($p<0.05$) differently

$^{+}$ Actual number is $\times 10^{5}$

Appendix D. Tables of means of descriptive texture analysis characteristics.

| Grind Size | 0.003in. | 0.011in. | 0.018in. |
|---|---|---|---|
| First Compression | | | |
| Overall Impression | 4.535[a] | 4.406[a] | 4.468[a] |
| Firmness | 8.209[a] | 8.089[a] | 8.484[a] |
| Adhesiveness | 10.465[a] | 10.415[a] | 10.121[a] |
| Smoothness | 9.380[a] | 8.122[b] | 6.863[c] |
| Mastication | | | |
| Oiliness | 3.256[a] | 3.455[a] | 3.185[a] |
| Gumminess | 24.240[b] | 24.683[ab] | 25.040[a] |
| Adhesiveness | 11.357[a] | 11.366[a] | 11.008[b] |
| Smoothness | 10.969[a] | 9.325[b] | 7.581[c] |
| Crystallinity | 6.822[b] | 7.780[a] | 7.435[ab] |
| Other | | | |
| Ease of Swallowing | 7.628[a] | 7.545[a] | 7.581[a] |
| Mouth Coating | 10.411[a] | 10.309[ab] | 9.927[b] |
| Spreadibility | 11.876[a] | 11.878[a] | 11.347[b] |

[a,b,c] Means with the same superscript are not significantly ($p<0.05$) different

Appendix D. Continued.

| Salt Concentration | 0% | 0.6% | 1.2% |
|---|---|---|---|
| First Compression | | | |
| Overall Impression | 4.181$^{b}$ | 4.659$^{a}$ | 4.577$^{a}$ |
| Firmness | 8.181$^{a}$ | 8.444$^{a}$ | 8.154$^{a}$ |
| Adhesiveness | 10.323$^{a}$ | 10.214$^{a}$ | 10.471$^{a}$ |
| Smoothness | 8.079$^{a}$ | 8.071$^{a}$ | 8.268$^{a}$ |
| Mastication | | | |
| Oiliness | 3.220$^{a}$ | 3.246$^{a}$ | 3.431$^{a}$ |
| Gumminess | 24.583$^{a}$ | 24.849$^{a}$ | 24.512$^{a}$ |
| Adhesiveness | 11.449$^{a}$ | 11.119$^{a}$ | 11.163$^{a}$ |
| Smoothness | 9.213$^{a}$ | 9.238$^{a}$ | 9.496$^{a}$ |
| Crystallinity | 6.638$^{c}$ | 7.397$^{b}$ | 8.000$^{a}$ |
| Other | | | |
| Ease of Swallowing | 7.268$^{b}$ | 7.667$^{ab}$ | 7.829$^{a}$ |
| Mouth Coating | 10.409$^{a}$ | 10.103$^{a}$ | 10.138$^{a}$ |
| Spreadibility | 11.685$^{a}$ | 11.627$^{a}$ | 11.797$^{a}$ |

$^{a,b,c}$ Means with the same superscript are not significantly ($p<0.05$) different

Appendix D. Continued.

| Sucrose Concentration | 0% | 3% | 6% |
|---|---|---|---|
| **First Compression** | | | |
| Overall Impression | 4.500[a] | 4.532[a] | 4.383[a] |
| Firmness | 8.139[a] | 8.444[a] | 8.195[a] |
| Adhesiveness | 10.590[a] | 10.349[ab] | 10.078[b] |
| Smoothness | 8.697[a] | 8.135[b] | 7.609[c] |
| **Mastication** | | | |
| Oiliness | 3.418[a] | 3.198[a] | 3.281[a] |
| Gumminess | 24.836[a] | 24.841[a] | 24.281[a] |
| Adhesiveness | 11.541[a] | 11.294[a] | 10.914[b] |
| Smoothness | 9.525[a] | 9.436[ab] | 8.992[b] |
| Crystallinity | 4.746[c] | 8.198[b] | 8.961[a] |
| **Other** | | | |
| Ease of Swallowing | 7.385[b] | 7.381[b] | 7.977[a] |
| Mouth Coating | 10.369[a] | 10.349[a] | 9.945[a] |
| Spreadibility | 11.787[a] | 11.698[a] | 11.625[a] |

[a,b,c] Means with the same superscript are not significantly($p<0.05$) different

Appendix E. Table of means of instrumental characteristics.

| Grind Size | 0.003in. | 0.011in. | 0.018in. |
|---|---|---|---|
| Extrusion Viscometry | | | |
| Consistency Index | 121.102[a] | 109.752[a] | 146.469[a] |
| Flow Behavior Index | 0.566[a] | 0.606[a] | 0.573[a] |
| Apparent Viscosity | 66.313[a] | 60.030[a] | 75.677[a] |
| Imitative Tests | | | |
| Adhesiveness | 1.544[b] | 1.585[b] | 1.832[a] |
| Hardness | 2.197[b] | 2.252[b] | 2.607[a] |

| Salt Concentration | 0% | 0.6% | 1.2% |
|---|---|---|---|
| Extrusion Viscometry | | | |
| Consistency Index | 109.763[a] | 128.646[a] | 138.914[a] |
| Flow Behavior Index | 0.600[a] | 0.574[a] | 0.572[a] |
| Apparent Viscosity | 61.886[a] | 68.255[a] | 71.880[a] |
| Imitative Tests | | | |
| Adhesiveness | 1.733[a] | 1.612[a] | 1.616[a] |
| Hardness | 2.466[a] | 2.287[a] | 2.302[a] |

[a,b,c] Means with the same superscript are not significantly ($p<0.05$) different

Appendix E. Continued.

| Sucrose Concentration | 0% | 3% | 6% |
|---|---|---|---|
| Extrusion Viscometry | | | |
| Consistency Index | 112.635[a] | 131.972[a] | 132.715[a] |
| Flow Behavior Index | 0.590[a] | 0.578[a] | 0.577[a] |
| Apparent Viscosity | 62.297[a] | 68.613[a] | 71.111[a] |
| Imitative Tests | | | |
| Adhesiveness | 1.774[a] | 1.729[a] | 1.458[b] |
| Hardness | 2.518[a] | 2.458[a] | 2.080[b] |

[a,b,c] Means with the same superscript are not significantly ($p<0.05$) different

Appendix F. Means and coefficients of variation of gas chromatographic headspace peaks.

| Peak No. | Mean Peak Time (min) | Coefficient of Variation (%) |
|---|---|---|
| 1 | 0.150 | 4.567 |
| 2 | 0.255 | 5.866 |
| 3 | 0.357 | 3.327 |
| 4 | 0.519 | 4.731 |
| 5 | 0.686 | 1.749 |
| 6 | 0.929 | 1.552 |
| 7 | 1.259 | 1.487 |
| 8 | 1.807 | 1.345 |
| 9 | 2.135 | 1.410 |
| 10 | 2.474 | 1.171 |
| 11 | 3.400 | 1.536 |
| 12 | 4.227 | 0.963 |
| 13 | 5.023 | 0.457 |
| 14 | 5.531 | 0.378 |
| 15 | 6.281 | 0.302 |
| 16 | 6.863 | 0.276 |
| 17 | 7.244 | 0.142 |
| 18 | 7.968 | 0.200 |
| 19 | 8.370 | 0.187 |
| 20 | 9.047 | 0.174 |
| 21 | 9.661 | 0.138 |
| 22 | 10.185 | 0.132 |
| 23 | 10.603 | 0.113 |
| 24 | 10.929 | 0.193 |
| 25 | 11.310 | 0.135 |
| 26 | 11.701 | 0.188 |
| 27 | 12.059 | 0.161 |
| 28 | 12.481 | 0.246 |