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Title: THE USE OF L-ASPARTYL-L-PHENYLALANINE METHYL ESTER (ASPARTAME) AS A SWEETENING AGENT IN ORANGE SHERBET

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The objective of this investigation was to develop an acceptable aspartame sweetened orange sherbet which might offer significant caloric reduction and cost advantages, and hence be applicable to commercial production.

A control sherbet, with a preference level equal to a commercially available orange sherbet was used as the reference. An orange sherbet, which incorporated aspartame as a partial sweetener was formulated. Due to a significant reduction of the solids content, the following stabilizers and bulking agents were studied individually and in combination to determine their effectiveness in improving the sherbet quality: arabinogalactan, carrageenan, guar gum, gum arabic, gum tragacanth, locust bean gum, a proprietary ice cream stabilizer, a proprietary sherbet stabilizer, purified wood cellulose, microcrystalline cellulose, and xanthan gum. Magnitude

estimations of sweetness, modified texture profiles, and preference tests were utilized to determine the desirability of the different sherbet formulations. The data were statistically analyzed.

Following one month of -25.5°C storage, the experimental formulations utilizing 37.5% of the sweetness as aspartame with xanthan gum or the combination of carrageenan and locust bean gum were equal in preference to the control sherbet.

The Use of L-Aspartyl-L-phenylalanine Methyl Ester (Aspartame) as a Sweetening Agent in Orange Sherbet

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INTRODUCTION

The past two decades have seen a significant increase in the use of non-nutritive sweeteners. Their use by diabetic and diet conscious persons has triggered a chain reaction of research on new sweeteners, their applications, and safety. One new sweetener, aspartame, is of interest because it is a protein, and may be less harmful to humans than totally foreign organic chemicals.

Aspartame is the generic name of the dipeptide sweetener, 1-methyl-N-L-aspartyl-L-phenylalanine. It is reported (Cloninger and Baldwin 1974) as being approximately 180 times sweeter than sucrose. Aspartame possesses a clean, full sweetness, with no bitter or metallic aftertaste, unlike many other low calorie sweeteners. The applications of aspartame could include: 1. calorie reduction, 2. prevention of nutrient dilution, 3. bulk reduction, 4. super sweetening, 5. reduction of negative sucrose-association properties, 6. flavor enhancement, 7. reduction of the cost of sweetening, and 8. expansion of the world sugar sweetening capacity.

The objective of this study was to formulate an orange sherbet utilizing aspartame and still maintain the acceptable sweetness and desirable characteristics of the original product.

LITERATURE REVIEW

Brief History of Sugar Substitutes

The search for sweet tasting substances has occupied man since prehistoric times. The first interest in noncaloric sweeteners emerged with the accidental discovery of saccharin in 1879. Cyclamates were first used as a sweetener in the 1940's and were an important sugar substitute until banned by the Food and Drug Administration in 1969. The past two decades have seen an increase in the use of non-nutritive sweeteners, with a concomitant increase in research efforts to find a safe, non-nutritive sweetener for diabetics and diet conscious persons.

There are a number of chemical compounds that resemble sucrose-type sweeteners. These include intensively sweet compounds such as aspartame, stevioside and glycyrrhizin, and taste modifiers like the miracle fruit (Synsepalem dulcificum). Only a few of the sweet tasting materials can be considered suitable for human consumption. Those sweeteners derived from the constituents of food may be less hazardous than totally foreign organic materials.

Chemistry of Aspartame

Aspartame's chemistry is summarized by Searle (1975). Aspartame is N-L-aspartyl-L-phenylalanine 1-methyl ester. It is a

white crystalline powder, with a molecular weight of 294.3 and a very slight acetic odor. The specific rotation in 15N formic acid is 15.91. Dissociation constants and pK determined at 250°F (121.1°C) are $pK_1 = 3.1$ and $pK_2 = 7.9$, the isoelectric point is 5.2.

On prolonged heating aspartame converts to its diketopiperazine before melting, therefore no melting point can be observed.

Certain moisture, temperature and pH conditions can hydrolyze aspartame to the dipeptide, aspartylphenylalanine. The dipeptide can then cyclize to the diketopiperazine (DKP) as shown in Figure 1. The decomposition is accompanied by a proportional loss in sweetness.

Searle (1975) reports studies at elevated temperatures showing only 5% decomposition to DKP after 70 hours at 105°C, and 20% after 50 hours at 120°C.

Decomposition under dry conditions of storage occurs principally by loss of methanol to the dipeptide and by the simultaneous loss of methanol and water to form DKP. Only aspartylphenylalanine and DKP were detected in the chromatograms of samples stored in a closed container at 40°C for up to one year. After six months storage at 40°C, increases of as much as 1% of DKP and 0.5% aspartylphenylalanine were found. The constituent amino acids were not seen in these chromatograms.

Aspartame contains 3-5% incidental water due to its method of preparation. Moisture equilibrium levels of aspartame at 88% RH

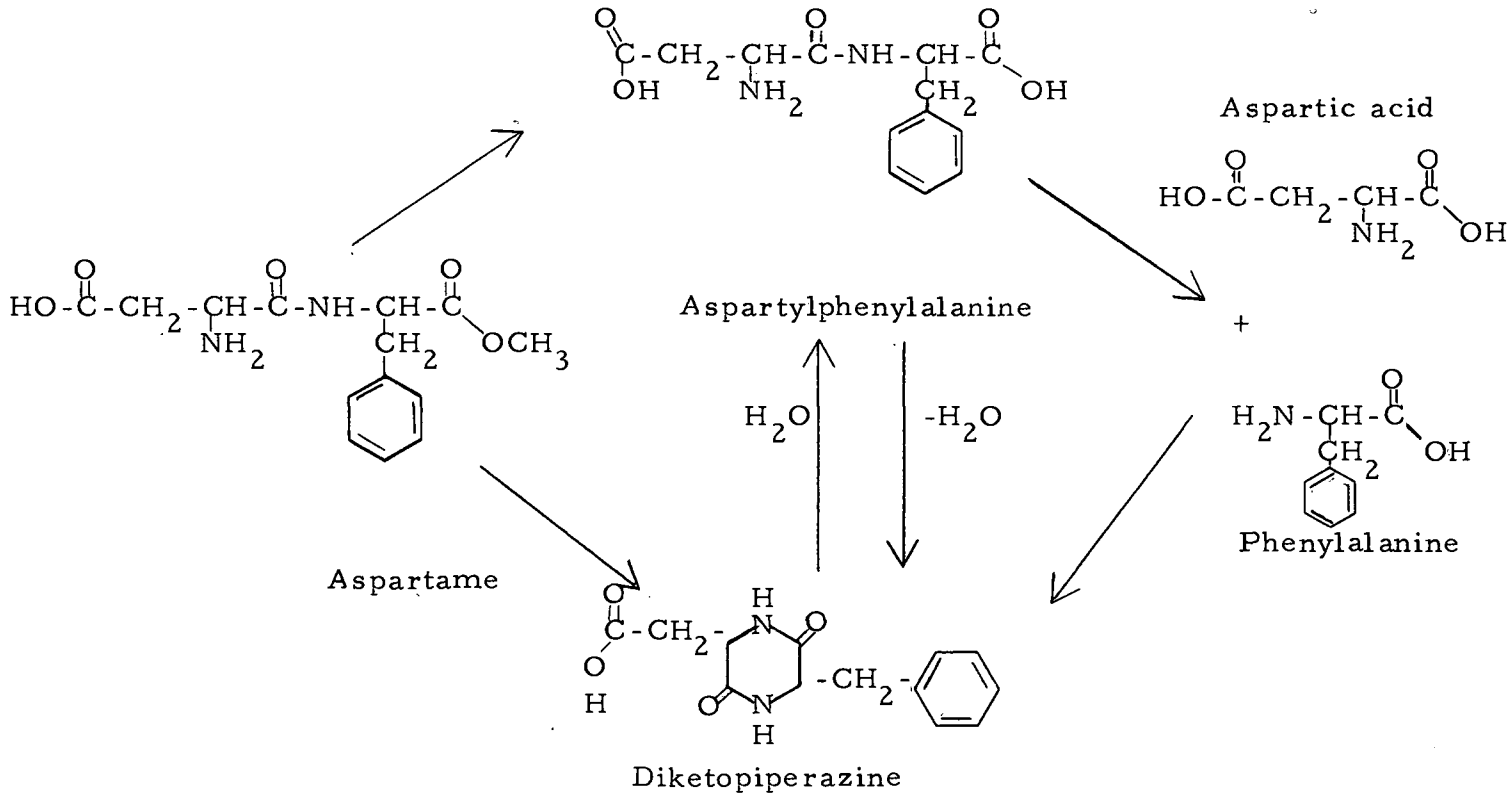

Figure 1. Aspartame hydrolysis.

and 40°C is 8.3%, and 7.5% at 49°C and 56% RH. The effect of moisture content on the stability was determined at 8% moisture. From an initial level of 0.54% DKP, after 2 weeks at 70°C there was 2.19% DKP, and after 12 weeks at 55°C the DKP concentration was 2.75%.

In solution aspartame decomposition follows a first order reaction dependent on time, temperature, pH, and water activity. The half-life for aspartame at pH 4 and 10°C is 3.3 years.

Aspartame

Aspartame is the methyl ester of a dipeptide of the two amino acids, aspartic acid and L-phenylalanine. Aspartame was discovered during routine research for aids to ulcer patients. An American patent (Bachman 1973) was applied for in which aspartame was synthesized by methylation of Asp-Phe with MeOH containing HCl. Asp-Phe was prepared by coupling N-formyl-L-aspartic acid anhydride with L-phenylalnine and deblocking at 60° in 37% aqueous HCl for 4-5 hours.

Mazur et al. (1973) found that the L-aspartic acid molecule was the essential component for sweetness and that considerable latitude was possible in the other molecule. They also found the methyl ester to be the most potent ester and that the sweet taste resided in the LL isomer for both the dipeptide and amide.

Separately the two molecules of aspartame do not exhibit a sweet taste. Deutsch (1975) reports aspartic acid to taste flat and phenylalanine to manifest a bitter note.

Sweetness and Flavor

The reported sweetness of aspartame varies from 160 to 200 times as sweet as sucrose. Searle (1975) and Deutsch (1975) claim aspartame to be 200 times as sweet as sugar. McCormick (1975) reported aspartame to be 180 times as sweet as aqueous sucrose. Aspartame was found by Cloninger and Baldwin (1970, 1974) to be 160 times sweeter than sucrose in aqueous solution. Cloninger and Baldwin (1974) further illustrate that the magnitude of the sucrose equivalent of aspartame decreased as the level of sweetness increased. At the 2% sucrose level aspartame was 182 times sweeter than sucrose, but only 43 times sweeter than 30% sucrose.

McCormick (1975) and Searle (1975) report that aspartame has a clean, full sweetness taste impression, without any bitter or metallic aftertaste. Flavor profiles conducted by Searle (1975) have shown aspartame to have essentially the same balance of flavor notes as sucrose when compared at isosweet concentrations. McCormick (1975) using trained tasters found the initial sweetness of aspartame to occur slightly later and remain slightly longer than sucrose. It is

believed this is due to aspartame being perceived further back in the mouth than sucrose.

Synergy

Wolfe (1975) has shown in lemonade systems that aspartame has a synergistic effect with other sweeteners such as sucrose, dextrose, cyclamate, and saccharin. At a level of 0.25% aspartame (99.75% dextrose weight/weight) there should be approximately 23% sweetness synergism.

Synergism with solutions of aspartame with sucrose, Na saccharin, and Ca cyclamate was reported by Cloninger and Baldwin (1970). When 0.09% aspartame was compared with 10% sucrose as a sweetener for a non-carbonated orange-flavored beverage, the beverage with aspartame was significantly ($p < 0.01$) sweeter and less sour than the beverage with sucrose (Cloninger and Baldwin 1974).

When working with 1.5% gelatin, in pH 4.6 buffered solutions, Cloninger and Baldwin (1974) found 0.025% aspartame sweeter than 4% sucrose, and 0.12% aspartame sweeter than 12% sucrose. However they found no significant effect on sweetness of sucrose or aspartame due to combination with gum arabic or carboxymethyl cellulose at either the high or low sweetness levels. Vaisey et al. (1969) and Arabie and Moskowitz (1971) found a decrease in sweetness of sucrose and saccharin with an increase in viscosity.

Besides synergy with sweetness, Searle (1975) claims that aspartame can function as a flavor potentiator, especially with fruit flavors in drinks and gelatin desserts.

Solubility

Aspartame's minimum solubility in water is at its isoelectric point (pH 5.2) and maximum solubility is at pH 2.2. Solubility improves with temperature increase. Isoelectric aspartame has limited solubility in organic solvents and aspartame is essentially insoluble in oil according to Searle (1975).

Diabetes and Phenylketonuria

Aspartame is metabolized as a protein and therefore is not a factor in the diabetic diet (McCormick 1974).

Deutsch (1975) reports that if aspartame replaced all other sweeteners in the average American diet, the individual average daily consumption would be 0.8 g or about 3 calories. That 0.8 g of aspartame would provide 80 mg of methyl ester, 328 mg aspartic acid, and 450 mg phenylalanine. This would suggest, that for "poverty level" Americans, who consume approximately 100 g of amino acids per day from food, aspartame would add less than one percent additional amino acids.

Aspartic acid, which is not an essential amino acid, is one of the most abundant amino acids, and is present in all dietary proteins. The 328 mg aspartic acid from 0.8 g aspartame is about one-half the quantity supplied by 8 oz of milk (Bogert et al. 1966).

Phenylalanine is an essential amino acid. Bogert et al. (1966) list the minimum daily requirement of phenylalanine at 1.12 g for men and women. The average daily intake is four to five grams; the excess is converted to tyrosine. Humans that suffer from the condition known as phenylketonuria, lack the enzyme phenylalanine hydroxylase, and therefore must restrict their dietary intake of phenylalanine. Phenylketonurics would not be able to tolerate aspartame.

Products containing aspartame would need to be labeled with the warning statement, "PHENYLKETONURICS: CONTAINS PHENYLALANINE," as required by the FDA (Federal Register 1974).

Food Additive Petition

A food additive petition was filed March 5, 1973 by G.D. Searle Co., Chicago, Illinois, to provide for the safe use of aspartame in foods as a nutritive substance with intense sweetness and flavor-enhancing properties (Federal Register 1973, 1974).

The petition sought the allowance of aspartame as a sweetening agent in: 1. dry free flowing sugar substitutes for table use in

package units not to exceed the sweetening equivalent of 2 tsp of sugar, 2. sugar substitute tablets, 3. cold breakfast cereal, 4. chewing gum, 5. dry bases for beverages, coffee and tea, gelatins, puddings and fillings, and dairy product analog toppings.

Aspartame Safety

McCormick (1974) summarized the findings on aspartame safety presented at the 1974 American College of Nutrition meetings. Results of the animal tests with aspartic acid were discussed by Stegink (1974). Stegink refuted the question of aspartate and glutamate safety raised by John Olney, Assoc. Prof. of Psychiatry, Wash. Univ. School of Med., St. Louis, Mo. Olney's (1974) research showed that brain damage results in newborn mice when high doses of monosodium glutamate are administered. L-aspartic acid and aspartame reportedly act in a similar manner.

Stegink (1974) also reported placental transfer studies that show neither glutamate nor aspartate cross the placenta, even when there are markedly elevated maternal levels of these amino acids. Other feeding studies were summarized by Nutting (1974). They included administration of the dipeptide via the diet and included rat, mouse, hampster, monkey, and dog feedings. Feeding levels ranged from single dose to continuous feeding throughout the animal's life span. A no-effect level of 2 g/kg/day in all studies was found.

Oppermann (1973) studied aspartame to see if it would be digested as naturally occurring dipeptides. The metabolism of ^{14}C aspartame, labeled separately in the methyl, aspartyl, and phenylalanine moieties, was compared with ^{14}C labeled methanol, aspartic acid and phenylalanine. The metabolism of each moiety was reported to be the same as its free counterpart. Oppermann concluded that aspartame was digested to its three constituents that were then absorbed as natural components in the diet.

Both L-aspartic acid and L-phenylalanine, to which aspartame is hydrolyzed in the digestive tract, are approved as safe food additives to improve the biological quality of protein under 21CFR121.101 and 121.1002..

The decomposition products of aspartame in aqueous solutions stored at elevated temperatures for a prolonged period were identified by Furda et al. (1975). They found L-aspartyl-L-phenylalanine, L-aspartic acid, L-phenylalanine methyl ester, and 3-carboxymethyl-6-benzyl-2,5-diketopiperazine (DKP) (see Figure 1). L-aspartic acid and L-phenylalanine methyl ester are decomposition products from the splitting of the peptide linkage of aspartame. L-phenylalanine is the end product of the demethoxylation of L-phenylalanine methyl ester.

L-aspartic-L-phenylalanine is formed by the demethoxylation of aspartame and 3-carboxymethyl-6-benzyl-2,5-diketopiperazine is a product of cyclization of aspartame with the release of methanol.

The safety of L-aspartic acid and L-phenylalanine is discussed under Diabetes and Phenylketonuria.

The methyl ester of aspartame is the same as that found in fresh fruits and vegetables. It is metabolized primarily to CO_2 with some being excreted unchanged in the breath (Oppermann 1973).

Oppermann conducted a study to determine the effect of continued ingestion of aspartame on phenylalanine metabolism in monkeys. It was found that after aspartame had been administered at doses of 15 or 60 mg/kg for 10 days these treatments had essentially no effect on the disappearance of intravenously administered ^{14}C-phenylalanine from the plasma. The conversion of labeled phenylalanine to tyrosine was not affected, nor was the rate of incorporation of labeled protein changed.

Bost (1974), concluded from mutagenic examination that aspartame and DKP do not represent a genetic hazard to man. Fertility, reproduction, and teratology studies on aspartame and DKP were reported by McConnell (1974) to have no adverse affect on mating behavior, fertility, or conception, at any dose level to 4 g/kg/day for aspartame or 2/g/kg/day for DKP in rats or rabbits.

DKP (3-carboxymethyl-6-benzyl-2, 5diketopiperazine) has been suspected of causing uterine polyps in aged female rats (Anon 1975a, b, c). An FDA collation of three independent pathology reviews concluded:

> If one considers the level of DKP used in the study, the percent of DKP contained in aspartame, the low incidence of uterine polyps in the study and even assuming that women will react in a manner similar to the rat, the possibility that uterine polyps will occur as the result of aspartame ingestion appears to be very remote (Anon 1975b).

Friday, December 5, 1975 the FDA published a stay of effectiveness of the regulation permitting certain uses in food of the sweetening substance aspartame (Federal Register 1975).

Sherbet

An annual survey of frozen dessert trends, by Dairy and Ice Cream Field (Anon 1974, 1975d) reported that sherbet accounted for 4.2% of total frozen dessert production in 1974, up 1% from 1973. In 1974, 38.7% of sherbet production was orange flavored, down from 39.6% in 1973.

Arbuckle (1966) defines sherbet as a frozen product made from sugar, water, fruit acid, color, fruit or fruit flavoring, stabilizer and a small amount of milk solids added in the form of skim milk, whole milk, condensed milk, or ice cream mix. Sherbet differs from ice in that an ice contains no milk solids.

According to Arbuckle (1966) sherbet is differentiated from ice cream by the following: 1. a higher fruit acid content, minimum of 0.35%, 2. lower overrun, usually 25-45%, 3. a coarser texture, 4. greater cooling characteristic due to coarser texture and lower

melting point and, 5. an apparent lack of richness due to lower milk solids.

Legal standards (21CFR20.4) require a titratable acidity of the finished fruit sherbet, calculated as lactic acid of not less than 0.35%. The weight of milk fat must be not less than 1% and not more than 2%. Weight of total milk solids not less than 2% and not more than 5% of the weight of the finished fruit sherbet. The finished fruit sherbet weighs not less than 6 lbs to the gallon, except when microcrystalline cellulose is used and then the finished fruit sherbet weighs not less than 6 lbs to the gallon, exclusive of the weight of the microcrystalline cellulose.

Production

The general procedure for the production of sherbet is the same throughout the literature, i.e., Frandsen (1950), Arbuckle (1966), and Sommer (1951). A base is first prepared by addition of the dry ingredients to a portion of the water. Care must be taken to avoid lumps, and heating may be necessary to facilitate solution. The base is cooled before addition of the other ingredients. Aging of the base for 12-24 hours is necessary only when gelatin or agar-agar are used. Flavor, color, fruit acid, additional water as needed, and pasteurized milk, cream, or ice cream mix are added just prior to freezing. Prevention of curdling is attained by careful addition of the

acidifying agent to the cold mix (Arbuckle 1966).

The freezing process is similar to ice cream. Product freezing is two distinct operations: 1. freezing a portion of the water out of the mix and 2. whipping in a desired amount of air.

Ice cream and sherbet are generally frozen in continuous freezers. The mix usually enters the back of the freezer and, is forced forward, the water partially frozen and, air incorporated. In batch freezers the mix is frozen to a certain point, the refrigerant shut off, and the mix whipped to the desired overrun.

Sherbet Defects

Sommer (1951) discussed problems unique to sherbet due in part to the lower fat and milk solids content: i.e., "settling out" of sugar syrup (bleeding), a crusty-crystallization of the sugar at the top surface, and the difficulty of obtaining smooth texture and desired overrun. The "bleeding" syrup defect can be controlled by proper stabilization and maintenance of low overrun. Arbuckle (1966) attributed the above mentioned defects to too high sugar content (in excess of 32%), and too high storage temperatures.

Surface crust is due to surface evaporation of moisture. Sommer (1951), Arbuckle (1966), and Frandsen (1950) suggested the incorporation of corn syrup in sherbet formulations to reduce the freezing point of the mix. The lower the freezing point of the sherbet

base, the less likely the surface will partially melt, which serves to release moisture. When the released water refreezes, it is unable to retain the sugar in solution, and hence sugar crystals are formed. Surface crust formation was shown by Sommer (1951) to also be due to sucrose crystallization and the refreezing of liberated water.

Arbuckle (1966) described coarseness defects in sherbet as a result of: 1. an insufficient amount of solids, sugar or stabilizer, 2. drawing from the freezer at too high a temperature, and 3. improper storage and handling of the sherbet.

The freezing point of the sherbet base, and the refrigerant temperature determine how rapidly the sherbet is frozen. Rapid freezing serves to promote the desired formation of small ice crystals. Fast frozen sherbet is drawn from the freezer at a lower temperature, which leaves less ice to be formed in the hardening room.

To effect improved body and texture in ice milk products, Bodyfelt (1975) suggested the reduction of the freezing point with use of additional monosaccharides in order to freeze more of the water in the freezer.

Body and texture of the sherbet is also affected by the balance of ingredients. Bodyfelt, Youtz, and Schmidt (1975) stated that milk solids not fat and milk fat should be in a 1:1 ratio for best results. The lower DE corn syrups have a greater percentage of higher

saccharides, and therefore contribute more to the body and texture of the product per unit weight than do higher DE corn syrups.

Roberts and Dahle (1954), Beck (1954, 1957), and others presented formulations of low carbohydrate ice creams which used sorbitol and other polyhydric compounds to lower the freezing point.

Stein (1966) noted that when using non-nutritive sweeteners in dietary products a perceived increase in body or mouthfeel occurred when the product pH was lowered.

Gums and Stabilizers

The substantial reduction of sugar content in low calorie sherbets establishes the need for substances to replace sucrose properties other than sweetness, such as imparting bodying and textural characteristics, freezing point depression, bulk, ability to blend and enhance flavors, and the preservative effect of high sugar concentrations.

Gums and other stabilizers have been used most effectively to counteract the reduction in sugar solids.

Potter and Williams (1950) discussed the importance of stabilizers and emulsifiers in controlling the texture of frozen desserts. The main function of stabilizers and emulsifiers is to reduce the amount of free water in the mix. They may take up water as water of hydration, cause a gel structure to form throughout the

mix, and/or react with certain milk constituents to form substances that take up water of hydration.

Gums and stabilizers are hydrocolloids which Dahlberg (1926) classified into five categories:

1. exudates--gum arabic, gum tragacanth
2. extracts--agar-agar, alginates, carrageenan and arabinogalactan
3. flour--locust bean gum, guar gum
4. fermentation gums--xanthan
5. synthetic--CMC, microcrystalline cellulose

They are all polysaccharides, none known to contain more than six types of sugar units in its structure. Their properties of water solubility and high viscosity are related to the presence of hydroxyl groups which form hydrogen bonds with water molecules. Each has its own advantages and disadvantages in sherbet and will be discussed below.

Gelatin

Arbuckle (1966) stated that gelatin is unsuitable for sherbet stabilization because it tends to cause high overrun.

Agar-Agar

The limitation of agar-agar (Glicksman 1962) is its insolubility in cold water. Once solubilized it does swell and absorb large quantities of water and thus helps prevent a coarse product. Arbuckle (1962) believed it creates a crumbly body and if used alone gives low overrun. Glicksman (1969) believed it can be replaced in sherbets and ices with locust bean gum and/or guar gum and be more economical.

Karaya

A partially acetylated polysaccharide of high molecular weight, Glicksman (1969) reported karaya unacceptable because it is not water soluble, forms viscous colloidal sols and the viscosity is lowered by heating, acids and electrolytes. Its maximum viscosity is at pH 8.5.

Gum Tragacanth

Gum tragacanth is rarely used as a sherbet stabilizer in the U.S., partially due to the high price of the ingredient. Glicksman (1962) suggested its use in sherbet at a level of 0.5%, but believed it is better when used with other stabilizers. Andres (1975) noted that it is a particularly effective suspending agent because of its long shelf-life and acid resistance.

Propylene Glycol Alginate

Propylene glycol alginate has found wide acceptance in low pH foods (Glicksman 1962). It is water dispersible, helps to maintain smooth texture during storage, provides a smooth meltdown without serum drainage and increases whippability. The propylene glycol ester produces a thin mix that will not clump or gel and is more resistant to acids and various salts such as Ca than the alginic salts. It is suggested for sherbets at a level of 0.15-0.25%.

Pectin

Pectin is not used as much as in previous years because of its sensitivity to acids and ions such as Ca. Its method and time of addition must also be controlled to prevent clumping and precipitation of particles (Glicksman 1969).

Gum Arabic

Glicksman (1963) reported gum arabic (acacia) to be the most soluble gum with solutions up to 50% concentration possible, most gums only 5%. It is capable of holding great quantities of water as water of hydration. Glicksman (1969) reported it incompatible with Na alginate and gelatin, however it is quite compatible with methyl cellulose, CMC, and larch gum. It has food emulsifying properties

especially with the addition of electrolytes.

In ice cream it is used at a level of 6-9 oz per 100 gal of mix. Ice cream with gum arabic has been found not to melt readily.

Locust Bean Gum

Glicksman (1962) described locust bean gum as the "ideal stabilizer." Locust bean gum is readily dispersible in cold water, inert to calcium salts and acidity, produces a uniform viscosity which is not destroyed by agitation, cools uniformly, allows incorporation of air, provides heat-shock resistance, and does not provide any taste of its own or flavor masking.

Locust bean gum has been reported as being only slightly soluble in cold water (General Mills 1973). If the water temperature is raised to 85° C or above, the gum will disperse and hydrate readily. It is compatible with food ingredients and the synergism with carrageenan or agar produces significant reduction in syneresis. Locust bean gums are manufactured in different granulations, varying in rate of hydration, viscosity potential, and dispersibility.

Carrageenan

Carrageenan is only partially soluble in cold water, heat and agitation are necessary for complete solubility. Solutions are stable in the pH range 7 to 10.5. Exposure to high temperatures must be

minimized to maintain stability at low pH ranges. Carrageenan (Moirano 1966) has the ability to react with milk and other proteins to produce lasting gels and suspensions, functions to prevent wheying off. Its size and strongly anionic polyelectrolytic character allow it to form complexes and act synergistically with for example guar and locust bean gum. Moirano (1966) and Glicksman (1962) found carrageenan to be beneficial in diet foods because it acts as a bulking agent and imparts a feeling of fullness. He also used it effectively in ice pops flavored and colored with artificial aniline dyes. The negatively charged carrageenan reacts with the positive aniline to form a chemical bond and prevent migration of color. One manufacturer has suggested the use of carrageenan at 0.015-0.020% in ice cream and 0.25-0.5% in dietectic foods (Stauffer Chemical Company 1973).

Guar Gum

Guar gum is characterized by its low flavor content, very fast initial hydration and high terminal velocity, which makes it suitable for HTST processes where full hydration is needed rapidly. It is stable within a pH range of 1-10.5 and is not affected by salts. Glicksman (1962, 1969) recommends its usage in ice cream at 0.3% of mix. Guar gums are produced in different grades varying in granulation, viscosity, rate of hydration, and dispersibility.

Xanthan

Xanthan gum is soluble in hot or cold water, but agitation is necessary to prevent clumping. At gum concentrations above 0.15% a peak viscosity is reached with 0.08% monovalent salts and most salts of divalent metals, after which the further addition of salt has no effect on viscosity. Temperatures up to 93.33°C do not effect viscosity. Combination with galactomannans such as guar and locust bean gum show a synergistic viscosity increase. Xanthan/locust bean gum combinations form a thermally reversible gel when solutions are heated above 54.44°C and cooled. A preblended xanthan gum/galactomannan combination is commercially available.

Arabinogalactan

Arabinogalactan, used only as a bulking agent, is a non-digestible gum from the Western Larch tree. It can be used on an equal weight basis to the sucrose it replaces. Daniels (1973) discussed its use in low calorie products including sherbet. A patent by Stanko (1969) utilized arabinogalactan containing artificial sweeteners which they claim to have the appearance, flavor, and physical properties of sugar. Stanko recommended using 10 to 25% of the sweetened product as the arabinogalactan-sweetener substitute.

Arabinogalactan is soluble in either hot or cold water, and solutions are fluid to 60% concentration. Arabinogalactan solutions in pH ranges of 1.2 to 11.4 do not change viscosity at 25°C.

Microcrystalline Cellulose

The properties of microcrystalline cellulose depend on its dispersion as small particles, many of which measure less than 0.15 micron, Kenney and Josephson (1972) have reported. They found, with the use of photomicrographs (300x magnification), that in ice milk without microcrystalline cellulose the solids flocculated, leaving wide dendritic liquid channels in which relatively large ice crystals might form during freeze-thaw cycles. In the ice milk containing microcrystalline cellulose a more homogeneous, nonflocculated pattern with smaller and fewer liquid channels was observed. The latter favored maintenance of small ice crystals and smooth texture during heat shocking.

Levels of microcrystalline cellulose of 0.4% or higher were needed in ice cream and ice milk to produce maximum benefits. Keeney and Josephson (1972) found that filling quart cartons without voids became more difficult as microcrystalline cellulose concentration increased. Microcrystalline cellulose tended to make the ice cream and ice milk less coarse and/or icy. It also lessened the

serum separation or wheying. Legal standards (21CFR20.4) allow microcrystalline cellulose in fruit sherbets to a level not to exceed 0.5% by weight of the finished product.

MATERIALS AND METHODS

Basic Procedure for Sherbet

The preparation and freezing methods were the same for all formulations of orange sherbet. The Emery Thompson Model 20 batch freezer and all equipment were sanitized prior to use with a 25 ppm iodine sanitizer. The procedure involved pasteurization of sherbet base, cooling to 1.1°C, addition of the remaining ingredients, freezing of the sherbet, and hardening for a minimum of 24 hours prior to sensory evaluation.

The sherbet base consisted of water, sweetening agent(s) (except aspartame), and the stabilizer(s). The sweetening agent(s) and stabilizer(s) were weighed to the nearest 0.5 g, then mixed thoroughly to facilitate solubilization. The water (25°C) was added to these dry ingredients and the mixture thoroughly agitated. The formula base was then pasteurized by heating for 30 minutes at 71°C (160°F). The base was agitated throughout pasteurization.

After pasteurization, the containers of base were covered and placed in a 1.1°C room to cool for approximately 24 hours.

Because aspartame has been reported to hydrolyze at high temperature with a consequent loss in sweetness (Searle 1975), aspartame was not incorporated prior to pasteurization. Though aspartame is more soluble at lower pH it is less stable in acid

solutions, hence it was dissolved in the citric acid just prior to freezing. A 10 minute agitation period was required for solubilization of the aspartame.

The citric acid solution was a 50% concentration (by weight) prepared by autoclaving for 15 minutes at 15 lbs psi, then covered and kept refrigerated until needed.

The coloring agent and orange flavor were measured and added to the base and blended.

The sherbet base and ice cream mix in sequence were added to the freezer. The dasher was engaged and the refrigerant introduced to the freezer barrell. The aspartame/citric acid solution was then slowly added to the contents of the freezer.

The overrun was checked with the use of a standard ice cream scale, until an overrun of approximately 35% was obtained. The refrigerant and dasher were shut off and the sherbet drawn into 1/2 or one gallon cartons. Each batch produced approximately 2 1/2 gallons of finished product. The cartons were immediately placed into a -25.5° C hardening room.

Control Sherbet

To secure a commercial standard which could be used as a typical or high quality reference for selecting an acceptable base formulation, six commercial brands of orange sherbet were evaluated

by laboratory preference panels. Four tests were conducted scoring two to four samples per test.

After a commercial standard was selected, orange sherbets were produced utilizing three different base formulas. Preference ratings of the three different base formula sherbets with the commercial standard were used to select the control formula for all the experimental samples. The composition for the three different sherbet base formulas are given in Table 3.

Methods of Evaluation

Sensory evaluation panels were conducted in the six individual testing booths in the flavorium of Wiegand Hall. Each booth contained a sink with running water for rinsing and for expectoration, if desired. White incandescent lights were used to allow maximum observation of the samples.

All sherbet samples were served in 3 1/4 oz paper portion cups coded with three digit random numbers. The placement of samples on the serving trays was randomized. Sample size for preference and magnitude estimation tests was 3/4 oz, and for descriptive texture profiling 1 1/2 oz. When more than one sample was served at a time, size and shape were kept as uniform as possible. Samples were served from the -25.5°C freezer into the portion cups, then held in the freezer compartment of a refrigerator (-10.0 to -20.1°C) until

judged. Panels were conducted between 10:00-11:00 am and 2:30-3:30 pm. Rinsing and expectoration were left to the discretion of the judge. Judges were staff members and graduate students of the Department of Food Science and Technology, and were chosen only on the basis of availability.

Products being judged were discussed only with those who sought information, and then only after judging was completed.

Preference Panels

Preference panels of 25-30 judges evaluated both the commercial and the experimental sherbets. The experimental sherbets were evaluated 1-3 days after hardening and again after one month's storage at -25.5°C. The color, texture, flavor, and overall desirability were scored on nine point scales from 9, very desirable to 1, very undesirable as shown in Figure 2. The data were analyzed by analysis of variance.

Magnitude Estimation

Magnitude estimations or ratio scaling of the sherbet's level of sweetness was conducted using 25-35 judges to determine if sweetness level changed over time, or if there was a synergistic sweetness effect with dextrose and aspartame. APM 3 served as the reference. Samples, including a blind reference, were coded with three digit

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Oregon State University

Product: Name _____

Date: _____

Please write the sample number in the space following the statement which best describes your opinion of the sample.

	Color	Texture	Flavor	Over-all Desirability
9 - extremely desirable				
8 - very desirable				
7 - moderately desirable				
6 - slightly desirable				
5 - neither				
4 - slightly undesirable				
3 - moderately undesirable				
2 - very undesirable				
1 - extremely undesirable				

Which sample did you prefer? _____

Why?

Figure 2. Preference panel ballot.

random numbers. The ballot used is shown in Figure 3.

The F statistic was calculated to determine if there were significant differences in sweetness levels.

Texture Profile Technique

The texture profile technique as adapted to consumer panels by Szczesniak et al. (1975) was used. The ballot (Figure 4) contained 22 words characterizing orange sherbet. The 25 judges were asked to rate the texture characteristic on a six point scale. The end boxes were labelled 'not at all' and 'very much so', with the center four boxes unlabelled. The boxes were numbered one to six for quantitation, with one being 'not at all' and six, 'very much so'.

Near the beginning and at the end of the testing period, the judges were asked to rate (without a sample) what they thought the 'ideal' sherbet should be. This 'ideal' served as a reference for comparison with the descriptive texture profiles of the experimental formulations.

Judges scoring became more consistent with experience, therefore only those judges experienced with the technique were used throughout the experiment.

Department of Food Science & Technology
Oregon State University
BALLOT
Magnitude Estimations

In front of you is a reference and series of coded cups filled with stimulus solutions. Your task is to tell how sweet the coded samples seem by assigning numbers proportional to sweetness of the "ref" sample. If the second stimulus is nineteen times as sweet as the "ref", assign it a number 19 times as large. If it seems 1/11 as sweet, assign it a number 1/11 as large, and so forth. Use numbers, fractions, and/or decimals, but make each assignment proportional to the sweetness of the "ref" sample as you perceive it.

Assign the reference a value of 20.

Ignore all side tastes, and judge only sweetness. If you rinse between tastes use the water provided in the flasks.

Solution #	Magnitude Estimation
"ref"	20

Thank you for your cooperation !

Figure 3. Magnitude estimation ballot.

Department of Food Science & Technology
Oregon State University

NAME:

Date:

Orange Sherbet

Below is a list of terms commonly used to describe sherbet. Using these terms, we would like you to describe the sample. To do this, please check one of the six boxes along the side of each term to indicate the degree to which you feel this sample has the characteristics described by that term. It is very important for our test that you make a choice for each term.

	Not at all					Very much so
Gummy						
Mouth Coating						
Watery						
Cold						
Chalky						
Light						
Airy						
Thin						
Soft						
Thick						
Icy						
Orangy						
Crumbly						
Firm						
Disappears						
Slippery						
Bad						
Grainy						
Creamy						
Smooth						
Brittle						
Good						

Figure 4. Descriptive texture profile ballot.

Meltdown

Sherbet samples were subjected to meltdown examination before undergoing any heat shock, and after ten fluctuations of temperature, -2 to -15°C over a 24 hour period.

Stabilizers

Twenty aspartame sweetened sherbets were prepared with varying levels of aspartame and/or the stabilizer. The formulas were labelled APM 1-20.

Ten stabilizers were used alone or in combination. Sources of stabilizers are shown in Appendix A.

'Stabilizer A' was a commercial brand of sherbet stabilizer containing a blend of locust bean gum, guar gum, glyceryl monodistearate, cellulose gum, Polysorbate 80, carrageenan, and standardized with dextrose.

The proprietary stabilizer, stabilizer B, primarily consisted of microcrystalline cellulose.

Federal standards of identity allow microcrystalline cellulose in sherbet at a level not to exceed 0.5% by weight. A second proprietary source of microcrystalline cellulose, which contained carboxymethylcellulose was used. It was a fine white powder, free of odor and flavor.

A highly purified wood cellulose was added as a bulking agent. The cellulose was a white powder, fine, but not superfine like arabinogalactan. The cellulose had a chalky flavor and odor.

Arabinogalactan, a bulking agent from the Western Larch tree, was a very fine white powder. Arabinogalactan had a sweet acidic odor, a very bitter flavor and a strong aftertaste.

Powdered gum tragacanth, USP grade, was utilized. It was a cream colored power with no odor or flavor.

The locust bean gum used was 150 mesh granulation. It was a cream white powder of 12.0% moisture. It was cold water soluble and had a bland flavor and odor.

Guar gum, with a balance of granular and finely ground edible guar gum, was used. It was a cream white color, cold water dispersible, with a medium fast hydration rate. The guar gum had a bland taste and odor, and contained a maximum of 13.0% moisture.

The carrageenan used was the sulfated polysaccharide carrageenan in the form of its calcium salt, standardized with dextrose. It was a free flowing powder due to roll drying with the aid of small amounts of mono and diglycerides. The carrageenan was tan colored, approximately 30 mesh, with a moisture content of 10-12%. It had a slight odor and no flavor.

Xanthan gum was a fermented, highly purified, high molecular weight polysaccharide. It was a fine, cream white powder with 14.0%

maximum moisture content. The xanthan gum exhibited a pseudoplastic nature in solution.

A spray dried gum arabic was utilized. It was a cream colored, very fine powder, with a bland taste and odor.

The sources of ingredients are given in Table 10.

RESULTS AND DISCUSSION

The preference panel scores did not show any of the six commercial samples of orange sherbet to be the most desirable on all four of the quality parameters, color, texture, flavor, and overall desirability. Thus commercial sample B, which on the last test, scored either equal to or higher than the other samples on all four quality parameters was selected as the commercial standard (Table 1).

The preference tests which included the three different base formulations for orange sherbet and the selected commercial standard, indicated that formula Base 3, was equal in preference (Table 2) to the commercial standard in color, texture, flavor, and overall desirability. Base 3 was chosen as the control sherbet.

The composition of the base and aspartame formulations is given in Table 3, freezing points and overruns in Table 6, meltdown characteristics in Table 7, mean flavor preference scores in Table 8, and mean descriptive texture profile scores in Table 9.

Removal of Sugar

The removal of sucrose from sherbet results in the loss of other functional properties of sucrose besides sweetness. Sucrose and corn syrup solids contributed 26.35% solids of the sherbet. These solids give the sherbet smooth body and texture, increase the heat shock

resistance, prevent shrinkage, surface crustation and bleeding, lower the freezing point of the mix, and give the sherbet its characteristic meltdown and mouthfeel.

Only part of the sugar was replaced with aspartame. Dextrose was incorporated in the formula to provide the remaining sweetness and to help lower the freezing point. Dextrose has the lowest sweetness level of the monosaccharides and therefore could provide more solids than other monosaccharides when used at an equal sweetness level.

The sherbet (APM 1) (Table 3) with 50% of the sweetness derived from aspartame contained only 21.98% total solids. APM 2 (Table 3) with 25% of the sweetness contributed by aspartame had a total solids content of 29.08%. The higher solids level of APM 2 were sufficient to lower the freezing point from -1.1°C (APM 1) to -1.33°C (APM 2), which was the freezing point of the control sherbet (Base 3).

The sherbet with 50% sweetness from aspartame (APM 1) was scored significantly lower ($p < 0.05$) than the control sherbet in texture, and overall desirability. A decrease in aspartame to 37.5% with an accompanying increase in dextrose to 62.5%, (% total sweetness) was sufficient to increase the preference of the sherbet (APM 3) to a level not significantly different from the control. Two intermediate formulas APM 4 and APM 5 (42% and 46% aspartame sweetness, respectively) were produced to try to find a more definite delineation

of preference between aspartame sweetened sherbets. There were no significant differences in overall desirability between either of these and the control formulation. Thus APM 1 (50% aspartame sweetness) was the only less preferred product.

Allowing APM 1, 2, and 3 to undergo heat shock caused all three to shrink between 1/2 and 3/4 inch per 1/2 gallon carton. Heat shock also caused surface crustation in the form of white beads of crystallized sugar.

Because the dextrose did not provide enough solids to maintain the body and texture of the original aspartame product (APM 1, 2 and 3) during storage, it was decided to try and increase the solids without significantly increasing the caloric content.

When first produced, APM 3 appeared to have the best balance of caloric content and acceptable preference ratings. Therefore, it was used as the reference formulation for the variations of stabilizers and bulking agents to be added. The different stabilizers and levels used are given in Table 5.

Stabilizers and/or Bulking Agents

A proprietary ice cream stabilizer, (Stabilizer B) was added to APM 3 and APM 4 at a level of 1.25% with a decrease in the original stabilizer, (Stabilizer A) to 0.1%, forming APM 6 and APM 7, respectively. When first frozen, APM 6 and 7 were both significantly

($p < 0.1$) higher than APM 3 and 4 in overall desirability. After six weeks of storage neither APM 6 nor 7 were significantly different in desirability from one week old APM 3.

APM 7 was remade near the end of the experiment and when tested immediately after hardening, the texture but not the overall desirability was rated significantly ($p < 0.01$) lower than the control sherbet. However, after four weeks of storage, the texture and overall desirability of APM 7 were both rated significantly lower ($p < 0.01$) than the control.

Although the addition of stabilizer B increased the total solids of each formulation by 1%, it caused an increase in the freezing point. At 37.5% aspartame sweetness the freezing point increased from -3.30- -2.78 to -2.78- -2.20°C, and at 42% aspartame it increased from -2.20 to -1.10°C. The freezing time and overrun were not affected.

The descriptive texture profile of APM 7 after one month of storage showed the sherbet to have greatly decreased in quality. The profile included increases in icy, brittle, grainy, and watery responses, and decreases in creamy and smooth.

APM 7 had a characteristic meltdown after one month storage and 24 hours heat shock.

Gum Arabic

Gum arabic was added at 0.4% and 0.57% levels to APM 3 (APM 8 and 9). The stabilizer in APM 8 was reduced to 0.2% for a total of 0.6% stabilizer. In APM 9 the stabilizer remained the same with a total of 0.71% stabilizer.

The gum arabic dispersed readily with the water and dextrose. There was no off odor, although in APM 8 with the higher level of gum arabic there was a slight yellow color in the base. When pasteurized and cooled there was no increase in viscosity or settling out of solution.

The overrun and freezing temperatures of APM 8 were lower than APM 9. When tested directly after hardening, the texture of APM 9 was significantly ($p < 0.05$) preferred over that of APM 8. There were no significant differences in preference ratings between APM 9 and the control sherbet. After one month of storage, the texture scores for both APM 8 and 9 were significantly ($p < 0.01$) lower than the control sherbet.

Directly after hardening there were no differences in overall desirability between APM 8, 9 and the control sherbet. However, after one month of storage, the overall desirability of APM 9 was significantly ($p < 0.05$) lower than the control.

No descriptive texture profiles or meltdown tests were conducted on either APM 8 or 9.

Gum Tragacanth

Gum tragacanth was added to the basic APM 3 formulation at a level of 0.5% with a decrease in commercial stabilizer to 0.3% (APM 10). After pasteurization and cooling the base was a translucent liquid. The tragacanth did not affect the freezing time, temperature or overrun of the sherbet.

Directly after hardening, the texture was significantly ($p < 0.05$) lower than the control sherbet. After one month of storage, both texture and overall desirability were significantly ($p < 0.01$) lower than the control.

The descriptive texture profile of APM 10 showed it to be quite different from the ideal sherbet. It was significantly ($p < 0.01$) more icy, brittle, crumbly, grainy, and watery, and less creamy and smooth than the ideal.

The meltdown of the tragacanth sherbet was wheyed off and moderately curdy before and after heat shocking.

Arabinogalactan

Arabinogalactan was added to APM 1 at a level of 10% solids (APM 11). This increased the total solids from 21.98% to 31.87%,

and lowered the freezing temperature to -3.33°C.

The arabinogalactan was added to the base prior to pasteurization. It was fairly easy to solubilize, however, some turned into a sticky mass that required approximately 20 minutes, and a temperature of 60°C to solubilize. Time appeared to be more important than temperature in the solubilization.

When wetted the arabinogalactan turned yellow. The base of the formulation was brownish-yellow in color with quite a pungent woody and caramel odor. The odor was not as prevalent after cooling at 4.4°C. The sherbet did not appear nearly as stiff as the previously frozen formulations at equal time and temperatures, therefore with a normal freezing time the overrun was 50%.

The arabinogalactan sherbet (APM 11) had an acidic-woody type off flavor with a strong aftertaste. The texture was not sticky but may have lacked body due to the high overrun. It was easy to dip at -25.56°C whereas the usual APM formulations were brittle and could not be dipped.

The brown color of the base did not appear to affect the color of the final product. The off odor was not great but probably would have been significant in a flavor panel. No sensory evaluation tests were conducted on APM 11.

Locust Bean Gum

Locust bean gum was added to the basic formula at a level of 0.25% with 0.55% stabilizer A (APM 12). After pasteurization and cooling the base was slightly more viscous than without the locust bean gum.

When first frozen there were no significant differences in color, texture, flavor, or overall desirability between APM 12 and the control. After one month of storage, flavor and overall desirability of APM 12 were significantly ($p < 0.05$) lower than the control. Due to the lower preference for the flavor, of APM 12, it was remade with an increase in fruit flavor. This resulted in no significant differences in flavor or overall desirability between APM 12 and the control when tested after one month of storage. The descriptive texture profile showed the second APM 12 to be fairly close to the ideal, although significantly more thick and gummy, less light and airy, and less icy, brittle and crumbly.

Locust bean gum caused the sherbet not to melt, and to have slight wheying during meltdown. There was no difference before and after heat shock.

Carrageenan and Locust Bean Gum

Carrageenan and locust bean gum were added to APM 3 at two levels both with carrageenan and locust bean gum in a 1:5.5 ratio (APM 13 and 14). Both stabilizers readily dissolved. When initially pasteurized both APM 13 and 14 were slightly creamy or muddy colored but after cooling for 24 hours, they became more translucent.

APM 13 was the firmest of the bases after cooling. It was hard to stir, and when added to the hopper of the freezer, the freezer dasher had to be turned on to pull the base into the freezer. APM 14 was a slightly less firm gel than APM 13, but still had to be broken before adding to the freezer.

The carrageenan gum increased whippability of the sherbet resulting in higher overruns and freezing temperatures and shorter freezing times.

Clear clumps of base, 1/4" x 1/2", were found in the sherbet.

APM 13 was rated significantly ($p < 0.05$) lower than the control sherbet in texture, flavor, and overall desirability. APM 13 was also significantly ($p < 0.05$) lower than APM 14 in texture and overall desirability. APM 14 was the only formulation which was significantly ($p < 0.05$) better than the control sherbet both before and after storage.

The descriptive texture profile of APM 14 showed it to be less icy and brittle than the 'ideal', and more gummy. After storage, only the characteristics smooth, creamy, soft, and watery were significantly lower than the 'ideal'.

The initial meltdown showed APM 14 not to melt and to have slight wheying off. After storage and heat shock it was slightly curdy rather than wheyed off.

Carrageenan and Guar Gum

Carrageenan and guar gums were added to APM 3 (APM 15 and 16) in the same proportion as carrageenan and locust bean gum were added in APM 13 and 14. APM 15 and 16 base solutions were opaque cream or wheat colored. However, no extra color was added and there was no significant difference in color preference in the finished product.

After cooling, both bases were solid gels. APM 15 was more firm with APM 16 like a pectin gel. Unlike either APM 13 or 14, APM 16 would flow when stirred.

The carrageenan increased the whippability of the mixes causing shorter times to obtain the desired overruns, and thus higher freezing temperatures due to the shorter time in the freezer.

APM 15 scored significantly ($p < 0.05$) lower in texture than either APM 16 or the control and lower than APM 16 in overall

desirability. There were no significant differences between the preference ratings of APM 16 and the control.

The descriptive texture profile of APM 16 showed it to be significantly ($p < 0.05$) less creamy and smooth, and more thick and gummy than the 'ideal'.

After heat shock, the meltdown of APM 16 was slightly curdy.

Microcrystalline Cellulose

Microcrystalline cellulose was added to the basic formula at a level of 0.5% by weight, with a corresponding decrease in stabilizer to 0.3% (APM 17).

The base was slightly white colored with the microcrystalline cellulose (MC) appearing to be in suspension rather than true solution. After cooling 24 hours the MC had settled slightly but was still in suspension. There was no increase in viscosity of the base after pasteurization or cooling.

Directly after hardening, the descriptive texture profile revealed the MC sherbet (APM 17) to be more icy, watery, brittle, and grainy, and less smooth and creamy than the ideal. After one month of storage, the profile showed significant ($p < 0.01$) increases in these defects. The preference tests showed the texture of APM 17 to be significantly ($p < 0.01$) lower than the control after one month of storage. However, there was no difference in overall desirability.

Heat shock exposure did not affect the meltdown of APM 17. The sherbet did not melt, was slightly curdy, and moderately wheyed off.

Xanthan Gum

Xanthan gum was added to APM 3 at a level of 0.25% and the stabilizer decreased to 0.55% (APM 18). When water was added, the xanthan gum formed soft lumps, which disappeared with heat and agitation. After pasteurization and cooling the base was a solid gel. The color and flavor were added to the freezer instead of the base. Several small lumps of base were found in the sherbet, some clear and others highly colored.

The overrun of APM 18 was reached more rapidly than normal causing the final freezing temperature to be higher (-2.2°C).

The xanthan sherbet was more gummy and less icy than the 'ideal', however, it was closer to the 'ideal' than any of the other experimental formulations.

After hardening and after one month of storage, the preference panel scores showed no significant difference between APM 18 and the control sherbet in color, texture, flavor, or overall desirability.

After heat shock APM 18 did not melt, had slight wheying and was curdy.

Purified Wood Cellulose

A highly purified wood cellulose was added to the APM 1 formula at a level of 10.00% total solids (APM 20). Stabilizer A was reduced from 0.6% to 0.43%. The wood cellulose increased the total solids of the sherbet to 31.8%. The wood cellulose went easily into a very smooth dispersion, similar to a thin white sauce. The base was white with no off odor. After cooling 24 hours the cellulose had settled leaving approximately a one inch layer of syrup at the top. The cellulose went easily back into dispersion with agitation.

When drawn from the freezer the sherbet that was last removed appeared to have already formed large ice crystals. This may have been partially due to the refrigerant being left on during the drawing process and as the sherbet slowly came in contact with and fell away from the sides of the freezer it underwent heat shock. The refrigerant was also left on during the drawing of the second batch of APM 1, but there was no evidence of large ice crystal formation. The additional 0.2% stabilizer in APM 1 may have been sufficient to bind more water and thus prevent large ice crystal formation.

Two-and-a-half times as much coloring (32.5 ml vs 12.5 ml for the original product) was needed to color the sherbet with cellulose. The color was still opaque, not the typical bright orange. The sherbet (APM 20) was much harder than any of the other products

immediately after removal from the hardening room (-25.5°C). It could not be dipped but rather had to be pried with a knife.

The sherbet had a very chalky flavor and cardboardy texture. No flavor panels were carried out on the product.

Flavor Synergism

With the orange flavor used in these formulations there was no evidence of flavor synergism. The orange flavoring was increased from 18 to 26 ml, and the citric acid increased from 22 to 27.5 ml between formulas APM 1 and APM 20. At the higher levels, the flavor of the sherbets were equal in preference to the control sherbet. However, descriptive texture profiles scored all sherbets, including the control as significantly ($p < 0.01$) less "orangy" than the 'ideal'.

Sweetness Synergism

Aspartame was not found to have a synergistic sweetness effect with dextrose.

Two magnitude estimation flavor panels were conducted. The results are shown in Table 4. On the first panel no significant differences in sweetness were indicated between the 5 samples, APM 1, 3, 6 and, APM 1 and 3 stored one month. The second panel (Base 3, APM 3, 10, 16 and 18) did show significant ($p < 0.05$) differences, however, the control sherbet scored higher than the reference (APM

3), and the other APM sherbets scored lower (including the blind reference). Since the sweetness of the APM sherbets was calculated to be equivalent to the control sherbet, the lower ratings would indicate there was no evident sweetness synergism.

The first magnitude estimation panel also showed no decrease in sweetness of the sherbet stored for 2 1/2 months.

Cost Reduction

At the present time the cost of aspartame and dextrose results in the cost of the aspartame sherbet to be greater than the control sherbet. In the future with increased production of aspartame, the product may be less expensive to produce compared with the control sherbet.

Caloric Reduction

Those formulations utilizing APM 3 basic formula would accomplish approximately a 25% decrease in calories.

Base 3	143 cal/100 g
APM 3	110
APM 1	97

SUMMARY AND CONCLUSIONS

Preference panels were conducted on six proprietary orange sherbets to secure a commercial standard. A control sherbet formulation with a preference level equal to the commercial standard was then produced. Utilizing aspartame as a partial sweetener, orange sherbet formulations were produced using 11 different stabilizers, alone and in combinations. Preference panels and descriptive texture profiles were used to evaluate the sherbets. The data were analyzed by analysis of variance.

The following conclusions were drawn from the results of this investigation:

1. No proprietary orange sherbet was significantly preferred in color, texture, flavor, and overall desirability.
2. Without the addition of extra solids and/or stabilizers, commercial production of sherbet utilizing aspartame is not viable. Sherbet using aspartame as a partial sweetener had an equal preference level directly after hardening, however after one month of -25.5°C storage, preference levels were significantly lower than the control.
3. The experimental formulations utilizing xanthan gum and a combination of locust bean gum and carrageenan had the most acceptable preference tests and descriptive texture profiles.

4. Arabinogalactan could not be used in orange sherbet due to its significant off flavor and aftertaste.
5. Microcrystalline cellulose tended to cause the product to be more brittle, crumbly, and icy than the control.
6. Cellulose gave the product a chalky flavor and texture.
7. Gum arabic caused a significant decrease in texture preference after one month of storage.
8. Gum tragacanth, locust bean gum, and the combination of carrageenan and locust bean gum significantly increased the gumminess of the product.
9. All experimental formulations had acceptable meltdowns, however only APM 7 was considered 'good' or satisfactory both before and after undergoing heat shock.
10. APM 3 (37.5% sweetness from aspartame) provided approximately a 25% reduction in calories.
11. Aspartame was not found to have a synergistic sweetness effect with dextrose nor a synergistic flavor effect with the orange flavoring used.
12. At the present time the aspartame sherbets are significantly more expensive to produce than commercial sherbet.

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APPENDICES

Table 1. Mean preference scores[1,2]--commercial orange sherbet.

Brand	Overall Desirability	Color	Texture	Flavor
A	5.86	6.94	6.71	5.74
B	6.09	6.49	6.74	6.20
C	5.94	6.91	5.74	6.03
D	6.03	5.41	7.06	6.20
LSD .05	0.67	0.65	0.69	0.74

[1]Score range 9, "extremely desirable" to 1, "extremely undesirable.

[2]35 judgements per sample.

Table 2. Mean preference scores[1,2]--control vs commercial standard.

	Overall Desirability	Color	Texture	Flavor
Control	7.72	8.10	7.76	7.62
Commercial standard	7.27	7.89	7.24	7.34

[1]Score range 9, "extremely desirable" to 1, "extremely undesirable.

[2]29 judgements per sample.

Table 3. Base and experimental formulations.

	Base 1		Base 2		Base 3	
	Grams	% TS	Grams	% TS	Grams	% TS
Cane sugar	1002	22.38	750	16.57	750	16.57
Corn syrup solids	542.4	11.50	406.8	8.66	458.7	9.77
Stabilizer A	19.5	0.4	20.5	0.44	19.5	0.4
Water	2142		2522.7		2449	
Ice cream mix	795.5	6.65	795.5	6.65	795.5	6.65
Fruit flavor	18.0		18.0		18.0	
Citric acid	1.7	0.5	7.0	0.5	22.6	0.5
Orange color	5.0		5.0		13.0	
Total solids	4526.1	41.43	4526.30	32.82	4525.6	33.89
	APM 1		APM 2		APM 3	
	Grams	% TS	Grams	% TS	Grams	% TS
Dextrose	642	14.23	963.8	21.3	803.14	17.75
Aspartame	2.64	0.06	1.32	0.03	2.04	0.045
Stabilizer A	29.25	0.6	29.25	0.6	29.25	0.6
Water	3032		2682		2839	
Ice cream mix	795.5	6.65	795.5	6.65	795.5	6.65
Fruit flavor	18.0		18.0		19.5	
Citric acid	22.5	0.5	22.5	0.5	22.5	0.5
Orange color	12.5		12.5		12.5	
	4554	21.98	4526.37	29.08	4523.43	25.545

Table 3. Continued.

	APM 4		APM 5	
	Grams	% TS	Grams	% TS
Dextrose	744.79	16.46	693.43	15.32
Aspartame	2.22	0.05	2.44	0.054
Stabilizer A	29.25	0.6	29.25	0.65
Water	2895		2946	
Ice cream mix	795.5	6.65	795.5	6.65
Fruit flavor	21.0		21.0	
Citric acid	24.0	0.5	25.0	0.5
Orange color	12.5		12.5	
	4524.26	24.26	4525.12	23.17

	APM 6		APM 7	
	Grams	% TS	Grams	% TS
Dextrose	749.79	16.5	803.17	17.75
Aspartame	2.22	0.05	2.04	0.045
Stabilizer A	4.53	0.1	4.53	0.1
Stabilizer B	56.57	1.25	56.57	1.25
Water	2863		2805	
Ice cream mix	795.5	6.65	795.5	6.65
Fruit flavor	21.0		21.0	
Citric acid	25.0	0.5	25.0	0.5
Orange color	12.5		12.5	
	4530.11	25.05	4525.31	26.295

Table 3. Continued.

	APM 8		APM 9	
	Grams	% TS	Grams	% TS
Dextrose	803.17	17.75	803.17	17.75
Aspartame	2.04	0.045	2.04	0.045
Stabilizer A	9.74	0.2	29.25	0.6
Gum arabic	19.48	0.4	2.56	0.057
Water	2839		2833	
Ice cream mix	795.5	6.65	795.5	6.65
Fruit flavor	21.0		21.0	
Citric acid	25.0	0.5	25.0	0.5
Orange color	12.5		12.5	
	4527.43	25.545	4524.02	25.592

	APM 12		APM 19	
	Grams	% TS	Grams	% TS
Dextrose	803.17	17.75	803.17	17.75
Aspartame	2.04	0.045	2.04	0.045
Stabilizer A	25.0	0.545	25.0	0.545
Locust bean gum	11.3	0.25	11.3	0.25
Water	2830		2830	
Ice cream mix	795.5	6.65	795.5	6.65
Fruit flavor	21.0		26.0	
Citric acid	25.0	0.5	27.5	0.5
Orange color	12.5		12.5	
	4525.51	25.74	4533.01	25.740

Table 3. Continued.

	APM 10			APM 11	
	Grams	% TS		Grams	% TS
Dextrose	803.17	17.75	Dextrose	642.0	14.19
Aspartame	2.04	0.045	Aspartame	2.64	0.06
Stabilizer A	13.6	0.3	Stabilizer A	19.5	0.4
Gum tragacanth	22.6	0.5	Arabinogalactan	454.0	10.07
Water	2833		Water	2500	
Ice cream mix	795.5	6.65	Ice cream mix	795.5	6.65
Fruit flavor	21.0		Fruit flavor	26.0	
Citric acid	25.0	0.5	Citric acid	27.5	0.5
Orange color	12.5		Orange color	12.5	
	4528.41	25.745		4479.44	31.87

	APM 13		APM 14	
	Grams	% TS	Grams	% TS
Dextrose	803	17.75	803	17.75
Aspartame	2.0	0.045	2.0	0.045
Stabilizer A	12.67	0.28	22.85	0.505
Locust bean gum	20.0	0.44	11.3	0.25
Carrageenan	3.6	0.08	2.05	0.045
Water	2830		2830	
Ice cream mix	795.5	6.65	795.5	6.65
Fruit flavor	26.0		26.0	
Citric acid	27.5	0.5	27.5	0.5
Orange color	12.5		12.5	
	4532.77	25.745	4532.7	25.745

Table 3. Continued.

	APM 15		APM 16			APM 17	
	Grams	% TS	Grams	% TS		Grams	% TS
Dextrose	803.0	17.75	803	17.75	Dextrose	803	17.75
Aspartame	2.0	0.045	2.0	0.045	Aspartame	2.0	0.045
Stabilizer A	12.67	0.28	22.85	0.505	Stabilizer A	13.6	0.3
Guar gum	20.0	0.44	11.3	0.25	Microcrystalline cellulose	22.6	0.5
Carrageenan	3.6	0.08	2.05	0.045	Water	2830	
Water	2830		2830		Ice cream mix	795.5	6.65
Ice cream mix	795.5	6.65	795.5	6.65	Fruit flavor	26.0	
Fruit flavor	26.0		26.0		Citric acid	27.5	0.5
Citric acid	27.5	0.5	27.5	0.5	Orange color	12.5	
Orange color	12.5		12.5				
	4532.77	25.745	4532.70	25.745		4532.7	25.745

	APM 18			APM 20	
	Grams	% TS		Grams	% TS
Dextrose	803	17.75	Dextrose	642	14.19
Aspartame	2.0	0.045	Aspartame	2.64	0.06
Stabilizer A	24.9	0.55	Stabilizer A	19.5	0.4
Xanthan gum	11.3	0.25	Cellulose	450.0	10.03
Water	2830		Water	2556	
Ice cream mix	795.5	6.65	Ice cream mix	795.5	6.65
Fruit flavor	26.0		Fruit flavor	21.0	
Citric acid	27.5	0.5	Citric acid	25.0	0.5
Orange color	12.5		Orange color	32.5	
	4532.7	25.745		4544.14	31.83

Table 4. Magnitude estimation of sweetness--orange sherbet.

	Degrees of Freedom	Mean Square	F
First magnitude estimation:			
Total	172		
Sweetness	4	614.75	1.41
Error	168	437.01	
Second magnitude estimation:			
Total	124		
Sweetness	4	378.5	2.715*
Error	120	139.4	

*Significant at 5%.

Table 5. Stabilizers.

	% Aspartame Sweetness	% Orange Sherbet Stabilizer	% Total Solids	% Additional Stabilizer(s)
APM 1	50.0	0.6	21.98	
APM 2	25.0	0.6	29.08	
APM 3	37.5	0.6	25.545	
APM 4	42.0	0.6	24.25	
APM 5	46.0	0.6	23.10	
APM 6	42.0	0.1	25.05	Ice cream 1.25
APM 7	37.5	0.1	26.055	Ice cream 1.25
APM 8	37.5	0.2	25.545	Gum arabic 0.4
APM 9	37.5	0.65	25.6	Gum arabic 0.057
APM 10	37.5	0.3	25.745	Gum tragacanth 0.5
APM 11	50.0	0.4	31.87	Arabinogalactan 10.07
APM 12	37.5	0.545	25.74	Locust bean gum 0.25
APM 13	37.5	0.28	25.745	Locust bean gum 0.44 Carrageenan gum 0.08
APM 14	37.5	0.505	25.745	Locust bean gum 0.25 Carrageenan gum 0.045
APM 15	37.5	0.28	25.745	Guar gum 0.44 Carrageenan gum 0.08
APM 16	37.5	0.505	25.745	Guar gum 0.25 Carrageenan gum 0.045
APM 17	37.5	0.3	25.745	Microcrystalline cellulose 0.50
APM 18	37.5	0.55	25.745	Xanthan 0.25
APM 19	37.5	0.545	25.745	Locust bean gum 0.25
APM 20	50.0	0.4	31.8	Wood cellulose 10.07

Table 6. Freezing points and overrun--orange sherbet.

	Freezing Point	% Overrun
APM 1	-1.1°C	40
APM 2	-3.3	45
APM 3	-3.3 (-4.4)	45 (35)
APM 4	-2.22	35
APM 5	-1.44	35
APM 6	-1.1	35
APM 7	-2.22 (-2.77)	40 (40)
APM 8	-3.88	35
APM 9	-4.72	30
APM 10	-2.78 (-3.89)	48 (35)
APM 11	-3.33	50
APM 12	-3.88	30
APM 13	-2.22	40
APM 14	-2.22 (-3.88)	42 (40)
APM 15	-2.22	35
APM 16	-2.22 (-3.88)	45 (35)
APM 17	-2.77 (-3.88)	37 (35)
APM 18	-2.22 (-3.89)	40 (35)
APM 19	-2.22 (-3.89)	35 (35)
APM 20	-4.44	35

Numbers in parentheses are from the second freezing.

Table 7. Meltdown characteristics--orange sherbet.

	Prior to Heat Shock	After Heat Shock*
Base 3	slight wheying slightly curdy	wheying slightly curdy
APM 3	doesn't melt wheying curdy	wheying curdy
APM 7	good	good
APM 14	doesn't melt slight wheying	doesn't melt slight curdy
APM 16	good	slight curdy
APM 17	doesn't melt slightly curdy moderate wheying	doesn't melt slight curdy wheying
APM 12	doesn't melt slight wheying	doesn't melt slight wheying
APM 10	wheying moderate curdy	wheying curdy
APM 18	doesn't melt slight wheying	doesn't melt very slight wheying curdy
Commercial	slight curdy	

*Sherbet placed in home 'no frost' freezer for 24 hours. Temperature fluctuated between -2.0°C and -15.0C at least ten times.

Table 8. Mean flavor panel scores--orange sherbet.[1, 2] 68

	Overall Desirability	Color	Texture	Flavor
Control-range	5.20-7.30	7.21-8.10	6.03-7.80	4.94-7.60
Control	6.67[a]	7.64[a]	6.98[a]	6.57[a]
Differences from the mean flavor scores of the control				
APM 1	-1.05[d]	-0.30	-2.10[d]	-0.50[d]
APM 1(b)	-1.75[d]	-0.33	-2.67[d]	-0.80[d]
APM 2	0.25	0.15	0.10	0.55
APM 2(b)	0.04	0.20	0.30	-0.07
APM 3	-0.45	0.30	-0.45	-0.20
APM 3(b)	-0.18	-0.03	-0.73	0.20
APM 4	-0.11	0.03	-0.76	-0.24
APM 5	0.43	-0.17	-0.91	-0.52
APM 6	0.47	-0.24	0.05	0.46
APM 6(c)	0.24	0.00	0.02	0.54
APM 7	0.27	-0.18	0.14[d]	0.34
APM 7(c)	0.08	-0.33	-0.49[d]	0.13
APM 8	-0.17[d]	-0.03	-0.29[d]	0.11
APM 8(b)	-0.68[d]	0.10	-2.24[d]	0.60
APM 9	0.40	0.23	0.80[d]	0.37
APM 9(b)	-0.58	0.06	-1.60[d]	0.26
APM 10	-0.76[d]	0.20	-1.04[d]	-0.44
APM 10(b)	-1.68[d]	0.14	-1.92[d]	-0.60
APM 12	0.43[d]	0.15	-0.32	0.24[d]
APM 12(b)	-0.64[d]	0.07	-0.26	-0.83[d]
APM 13	-0.62[d]	0.03	0.00	-0.70[d]
APM 14	0.07[d]	0.13	0.70	-0.14[d]
APM 14(b)	1.40[d]	-0.40	0.16[d]	-1.70[d]
APM 15	-0.50	0.03	-1.00[d]	0.03
APM 16	0.16	0.23	0.03	0.23
APM 16(b)	0.36	0.04	0.08[d]	0.70
APM 17	-0.29	-0.29	-1.04[d]	0.38
APM 17(b)	0.08	0.42	-1.96[d]	0.51
APM 18	0.44	0.04	0.28	0.72
APM 18(b)	0.50	0.34	-0.42	0.92

[1] Score range: 9, extremely desirable to 1, extremely undesirable.

[2] 25 to 30 judgements per sample.

a = mean of 19 tests.

(b) = 4 weeks storage--25.5° C.

(c) = 6 weeks storage--25.5° C.

d = significantly different from control ($p < 0.05$).

Table 9. Descriptive texture profile--orange sherbet.

	Gummy	Mtn. Coating	Slippery	Light	Airy	Thick	Thin	Creamy	Smooth	Icy	Brittle
Ideal 1	1.24	2.04	2.48	3.80	2.92	3.72	2.08	5.00	5.24	2.36	1.48
Ideal 2	1.32	2.24	2.36	3.76	3.12	3.52	2.20	4.32	4.72	3.32	1.68
Base 3	2.16	2.88^{b}	2.64	3.0 ^{d}	2.44^{d}	4.32^{b}	1.68^{d}	4.60	4.64	1.52^{d}	1.28
APM 3	1.32	2.12	2.08^{c}	3.8	3.64^{b}	2.60^{d}	3.24^{b}	2.24	2.84^{d}	4.92^{b}	3.92^{b}
APM 7	1.84^{b}	2.84^{b}	2.24^{a}	4.24^{b}	3.60^{b}	3.04^{d}	2.64^{b}	3.84	4.12^{d}	3.20	2.04^{a}
APM 7(2)	1.80^{b}	2.84^{b}	2.36	4.21^{b}	3.40^{b}	2.06^{d}	3.28^{b}	2.68	2.88^{d}	4.80^{b}	3.72^{b}
APM 14	2.52^{b}	2.96^{b}	2.76^{a}	3.28^{d}	2.56^{d}	4.56^{b}	1.84^{c}	4.96	5.32^{a}	2.16^{d}	1.08^{c}
APM 14(2)	2.48^{b}	3.20^{b}	2.56	2.80^{d}	2.40^{d}	4.44^{b}	1.68^{d}	4.40	4.80	2.28^{d}	1.04^{d}
APM 16	3.48^{b}	2.96^{b}	2.84^{b}	3.16^{d}	2.76	4.24^{b}	2.60^{b}	4.68	4.80	2.64	1.36
APM 16(2)	3.20^{b}	2.88^{b}	2.48	3.16^{d}	2.40	4.56^{b}	1.84	4.00	4.36^{d}	2.72	1.28
APM 12	3.28^{b}	2.96^{b}	3.16^{b}	3.24^{d}	2.56^{d}	4.32^{b}	2.12	5.16	5.08	1.28^{d}	1.04^{d}
APM 19(2)	2.52^{b}	3.16^{b}	3.44^{b}	2.60^{d}	2.04^{d}	4.88^{b}	1.80^{c}	4.80	4.92	2.16^{d}	1.12^{c}
APM 18	2.76^{b}	3.00^{b}	2.52	3.36^{d}	2.68^{d}	4.68^{b}	2.00	4.72	5.00	2.16^{d}	1.12^{c}
APM 18(2)	2.76^{b}	2.68^{b}	2.88	3.00^{d}	2.56^{d}	4.08^{b}	2.12	4.56	4.88	2.04^{d}	1.08^{c}
APM 17	1.40	2.48^{b}	2.40	4.36^{b}	3.96^{b}	2.40^{d}	3.60^{b}	2.88	3.76^{d}	3.92^{b}	2.20^{b}
APM 17(2)	1.52	2.04	2.24	3.84	3.24	2.60^{d}	3.48^{b}	2.24	2.84^{d}	4.72^{b}	3.96^{b}
APM 10	1.64	2.72^{b}	2.24	3.92	3.28^{b}	2.96^{d}	3.52^{b}	2.84	3.48^{d}	4.24^{b}	3.04^{b}
APM 10(2)	1.60	2.76^{b}	2.12	3.92	3.60	2.56^{d}	3.36^{b}	2.04	2.32^{d}	4.88^{b}	4.60^{b}
LSD (.05) =	0.35	0.24	0.32	0.28	0.29	0.29	0.33	0.28	0.26	0.40	0.38
LSD (.01) =	0.45	0.32	0.42	0.37	0.38	0.39	0.43	0.37	0.35	0.52	0.51

Table 9. Continued.

	Grainy	Crumbly	Firm	Soft	Cold	Orangy	Chalky	Watery	Disappears	Bad	Good
Ideal 1	1.4	1.4	4.32	3.68	5.28	5.24[d]	1.04	1.76	2.84	1.04	5.96
Ideal 2	1.68	1.88	4.32	3.80	5.12	5.28	1.04	1.96	2.92	1.00	5.92
Base 3	1.44	1.20[c]	4.76[b]	3.60	4.80[d]	4.60[d]	1.64[b]	1.48[d]	2.92	1.72[b]	4.64[d]
APM 3	3.72[b]	4.00[b]	4.04[c]	2.32[d]	5.32	4.44[d]	1.56[b]	3.32[b]	3.56	2.76[b]	3.80[d]
APM 7	2.56[b]	2.08[a]	3.84[d]	3.44	5.04	4.64[d]	1.88[b]	2.28[b]	3.08	2.12[b]	4.44[d]
APM 7(2)	3.44[b]	4.00[b]	3.52[d]	2.56[d]	5.20	4.80[d]	1.80[b]	3.28[b]	3.28	2.40[b]	4.40[d]
APM 14	1.20	1.20[c]	4.92[b]	3.72	5.28	4.68[d]	1.68[b]	1.92	2.64	1.72[b]	5.00[d]
APM 14(2)	1.48	1.08[d]	4.88[b]	3.04[d]	5.44	4.64[d]	1.56[b]	1.64	2.72	1.88[b]	4.56[d]
APM 16	1.68	1.28	4.64[a]	3.36	5.00	4.24[d]	1.64[b]	1.96	3.12	2.36[b]	4.60[d]
APM 16(2)	2.12[b]	1.28	4.68[b]	3.16[d]	5.04	4.40[d]	1.80[b]	1.80	3.04	1.80[b]	4.40[d]
APM 12	1.16	1.08[d]	3.56[d]	4.24[b]	4.84[d]	4.24[d]	1.60[b]	1.68	3.08	1.72[b]	4.88[d]
APM 19(2)	1.20	1.12[d]	4.44[c]	3.64	5.12	4.00[d]	1.44[b]	1.68	2.52	2.32[b]	4.28[d]
APM 18	1.24	1.12[d]	4.16	4.16[a]	5.00	4.72[d]	1.52[b]	1.88	2.80	2.08[b]	4.80[d]
APM 18(2)	1.28	1.08[d]	4.16	4.20[a]	5.32	4.56[d]	1.68[b]	2.04	3.04	2.12[b]	4.76[d]
APM 17	2.76[b]	2.80[b]	3.88[d]	3.08[d]	5.12	4.72[d]	1.48[b]	3.40[b]	3.76[a]	2.24[b]	4.56[d]
APM 17(2)	3.48[b]	4.28[b]	3.80[d]	2.04[d]	5.64[b]	4.56[d]	1.72[b]	3.24[b]	3.32	2.28[b]	3.88[d]
APM 10	3.48[b]	2.88[b]	4.28	2.64[d]	5.40	4.60[d]	2.00[b]	3.12[b]	4.20[b]	2.20[b]	4.16[d]
APM 10(2)	3.92[b]	4.28[b]	3.88[d]	2.15[d]	5.40	4.64[d]	2.16[b]	3.48[b]	3.76[a]	2.92[b]	3.44[d]
LSD (.05) =	0.43	0.39	0.28	0.31	0.24	0.25	0.32	0.28	0.70	0.38	0.29
LSD (.01) =	0.56	0.51	0.36	0.41	0.32	0.33	0.41	0.37	0.92	0.50	0.38

1 = Score range 1, 'not at all' to 6, 'very much so'. 2 = 25 judgments per sample. (a) = Significant (.05) more than 'ideal'. (b) = Significant (.01) more than 'ideal'. (c) = Significant (.05) less than 'ideal'. (d) = Significant (.01) less than 'ideal'.

Table 10. Ingredient sources.

Aspartame:	G.D. Searle Co., Chicago, Illinois.
Arabinogalactan:	St. Regis Paper Co., Tacoma, Wn.
Carrageenan:	Stauffer Chemical Co., Food Ing. Division Carastay ACN 28852
Color:	R&H Brand, Richardson and Holland Inc., Seattle, Wn. Orange Sherbet Emulsion Liquid Bright Orange Shade
Corn syrup solids:	A.E. Staley Manufacturing Co., Decatur, Illinois Staley Star-Dri 35R
Flavor:	R&H Brand Orange Sherbet Emulsion, Richardson and Holland Co., Seattle, Wn.
Guar gum:	General Mills; Chemicals Inc.; Food Ingredients. Supercol GF Lot No. A4316D
Gum arabic:	Tragacanth Importing Co., New York Gum Arabic Spray Dry Lot, Nov 7, 1975
Gum tragacanth:	Blumauer-Frank Drug Co., Portland, Oregon USP Grade-Powder
Ice cream mix:	Sunnybrook Dairy, Corvallis, Oregon 12% fat, 11% MSNF, 17.5% sugar
Locust bean gum:	General Mills; Chemicals, Inc.; Food Ingredients. Supercol 903 P.O. 1473
Microcrystalline cellulose:	FMC Corp.; Avicel Dept.; Marcus Hook, Penn. Avicel RC-591 Lot No. D3331
Purified wood cellulose:	Brown Co., Berlin New Hampshire BW-300 Food Grade - Wood Cellulose
Stabilizer A:	"Gemco" Sherbet Stabilizer Germantown, Products. Broomal, Pa.
Stabilizer B:	"Summit" Ice Cream Stabilizer Germantown Products. Broomal, Pa.
Xanthan gum:	General Mills; Chemicals Inc., Food Ingredients. Supercol Xanthan Gum Type 700 Lot No. A4263D