THE RHEOLOGICAL EFFECT OF HYDROCOLLOIDS ON SELECTED ATTRIBUTES OF A LEMON FLAVORED BEVERAGE CONTAINING ARTIFICIAL SWEETENERS

BY

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(ABSTRACT)

Because of the increased demand for low calorie products, more products are being sweetened with artificial sweeteners. Perceived sweetness may be affected by other food ingredients, such as hydrocolloids. The purpose of this study was to examine the effects of xanthan gum, carboxymethylcellulose-low, and carboxymethylcellulose-medium on the attributes of a lemon flavored beverage sweetened with an artificial sweetener. Each hydrocolloid was added to the beverages to attain the following viscosities - 10 cps, 15 cps, and 20 cps. The table top formulations of artificial sweeteners used to sweeten the beverage samples were Sweet One® (contains acesulfame-K) and Equal® (contains aspartame). A modified Quantitative Descriptive Analysis method was used as the sensory evaluation technique to determine the intensity of sourness, sweetness, lemon flavor, bitterness, and aftertaste in the beverages of varying viscosities.

In the samples containing Sweet One®, CMC-L increased sweetness whereas in the samples containing Equal®, sweetness first decreased significantly before increasing with increasing viscosity. CMC-M did not

significantly affect the sweetness of either sweetener although it tended to decrease the sweetness of Equal®. CMC-L and CMC-M decreased lemon flavor and sourness in the samples with both sweeteners; CMC-L decreased the intensity of these attributes more than CMC-M. The only significant change caused by the addition of xanthan gum to the beverages was a decrease in the sweetness of the samples sweetened with Equal®. Xanthan gum affected the attributes of the lemon flavored beverages the least whereas CMC-L had the greatest effect on the attributes.

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CHAPTER 1
INTRODUCTION

The perception of sweet taste is a quality of foods and beverages that people have always found to be enjoyable and desirable. Before the period in which sugar refining was possible, sweetness could only be provided by sweet tasting fruits and vegetables. Once the technology was developed to refine sugar from sugar cane and beet at reasonable prices, consumers were able to fulfill their desire for sweetness by adding sugar to other foods and beverages (Sardesai and Waldshan, 1991).

In Western Society, obesity and other health related problems have been associated with people becoming more sedentary and not compensating by decreasing their caloric intake. Sugar, which provides four calories per gram, may not only lead to obesity and related diseases if eaten often, but also may cause dental carries (Giese, 1993). Since the most desired basic taste is sweetness, it may be difficult to convince consumers to lower sugar consumption as a way to decrease caloric intake and avoid other associated problems caused by sugar.

Alternative sweeteners offer the consumer the opportunity to enjoy sweet tasting foods without concern about the negative effects of sugar intake. Currently, there are three alternative sweeteners which are approved for use in the United States - aspartame, acesulfame-potassium (acesulfame-K), and saccharine (Giese, 1993). Since the sweetening power of each of these artificial sweeteners is greater than the sweetening power of sucrose, all three are considered high intensity sweeteners. Therefore, in food products, they are used in much smaller quantities than sucrose for the same intensity of sweetness.

Besides aiding in reducing caloric intake, two of the alternative sweeteners, acesulfame-K and saccharine, have been shown to reduce the incidence of dental carries (Sardesai and Waldshan, 1991).

In the last decade, as consumers have become more knowledgeable about health-related issues, the demand for a greater variety of reduced calorie foods and beverages has also grown (Stamp, 1990). These trends have caused an increased interest in artificial sweeteners and a desire by consumers for their use in a wider variety of foods and beverages.

As the use of artificial sweeteners increases, it is important to understand how other food ingredients affect their sweetening power in foods and beverages. This is especially important since a certain sweetness quality and intensity is necessary for the acceptability of a product containing an artificial sweetener (Pangborn *et al.*, 1973). Thickening agents are often used concurrently with artificial sweeteners to provide the "body" which sucrose normally provides and artificial sweeteners do not provide to food and beverage products (Glicksman and Farkas, 1966). Thickening agents have been shown to affect taste perception (Malkki *et al.*, 1993). The effect of a thickening agent on taste perception has been shown to be specific to both the type and amount of thickening agent and of the taste compound(s) present in the food system. Therefore, it is critical to understand the relationship between the thickening agent and the sweetness perception of the artificial sweetener. In addition, it is also important to know how other taste attributes in a food or beverage product are affected by the addition of a thickening agent. Adjustments in the formulation may be necessary to compensate for changes in taste perception.

The purpose of this study was to examine the effect of carboxymethylcellulose-low (CMC-L), carboxymethylcellulose-medium (CMC-M), and xanthan gum on the attributes of lemon flavored beverages sweetened with either Equal® or Sweet One®. The objectives were: 1) to determine how the addition of the hydrocolloids affected certain selected attributes (sweetness, sourness, lemon flavor, bitterness, aftertaste) of the lemon flavored beverages, 2) to determine if increased levels of each hydrocolloid, and therefore increased viscosity, contributed to further modification of taste perception, and 3) to determine if the different hydrocolloids added to create the same viscosities affected the attributes in similar or different ways.

CHAPTER 2
REVIEW OF LITERATURE

ARTIFICIAL SWEETENERS

Use of Equal® Sweetener (Aspartame) as a Sweetening Agent

Equal® is a sweetening agent consisting of a mixture of dextrose with maltodextrin and the sweetener aspartame (Nutrasweet® brand). Aspartame is composed of two amino acids, aspartic acid and the methyl ester of phenylalanine, and therefore it is considered to be a nutritive sweetener (Stamp, 1990). The sweetener was accidentally discovered by a researcher at the Searle research laboratories in 1965. It was approved for use in certain dry foods in 1981 and for use in carbonated beverages in 1983 by the Food and Drug Administration. Currently, aspartame is used in products such as tabletop formulations (Equal®), chewing gum, carbonated beverages, frozen desserts, juice drinks, and powdered mixes for gelatin, puddings, fillings, beverages, and instant coffee (Sardesai and Waldshan, 1991).

Aspartame is approximately 150-200 times sweeter than sucrose depending on its food application (Stamp, 1990). Compared to a 3% sucrose solution, it has 215 times the sweetness intensity of sucrose As the concentration of the sucrose solution to which it is compared increases, though, the potency of aspartame decreases (Inglett, 1984). Aspartame is described as having sucrose like sweetness (Stamp, 1990). Aspartame has been reported as having a bitter-like aftertaste (Redlinger and Setser, 1987).

In its dry form, aspartame is an odorless white crystalline powder that is stable for many years in its dry form (Holmer, 1984). In aqueous solutions, aspartame has limited solubility; at 20° C, up to a 1% solution can be made.

Solubility increases slightly with an increase in temperature or a decrease in pH (Stamp, 1990). In solution, the stability of aspartame is limited and depends upon the temperature, pH, and amount of available water. At 25° C, the sweetener is most stable between the pH range of 3-5. As the temperature increases, the stability of aspartame decreases (Holmer, 1984). At low temperatures, the stability is increased-most likely as a result of decreased free moisture (Holmer, 1984). Short time heat treatment of products containing aspartame such as ultra high temperature (UHT) and high temperature short time (HTST) pasteurization treatments result in very little aspartame loss (Stamp, 1990). Due to its decreased stability with high temperatures, aspartame can not be used in products which are heated or baked (Giese, 1993).

There has been extensive testing of the safety of aspartame and its breakdown products. Although there have been reports of adverse side reactions, FDA has stated that aspartame is safe when used for its approved purposes (Stamp, 1990). Since aspartame is susceptible to hydrolysis, microbial degradation, and other breakdown reactions, originally there was concern that the breakdown products of aspartame might be unsafe (Lindsay, 1985b). Studies have shown that, although the breakdown products of aspartame are not sweet, they are not harmful at the levels which might be ingested (Sardesai and Waldshan, 1991). Breakdown products of aspartame include diketopiperazine, methanol, aspartic acid, and phenylalanine (Sardesai and Waldshan, 1991). Aspartame may be harmful for people with phenylketonurea (PKU), though, and products containing aspartame must therefore carry a warning label. Aspartame has been given an acceptable daily intake of 50 mg/kg body weight (Stamp, 1990).

Use of Sweet One® Sweetener (Acesulfame-K) as a Sweetening Agent

Sweet One® is a sweetening agent consisting of a mixture of dextrose, the sweetener acesulfame-K (Sunette® brand), cream of tartar, calcium silicate, and natural flavors. Acesulfame-K is the potassium salt of 6-methyl-1,2,3-oxathiazine-4(3H)-one-2,2-dioxide (Lipinski, 1991b). It was discovered by a researcher at Hoechst Corporation in 1967 and in 1988 was approved in the United States for limited use in foods (Giese, 1993). The products in which acesulfame-K can be used include tabletop formulations (Sweet One), chewing gum, chocolate confections, cakes, cookies, hard and soft candies, and dry mixes for powdered drinks, desserts, and puddings (Hood and Schoor, 1990; Lipinski, 1991a).

Acesulfame-K has 200 times the sweetness intensity of sucrose when compared to a 3% sucrose solution. As the concentration of the sucrose reference solution increases, though, the potency of acesulfame-K decreases (Giese, 1993). The sweetness of acesulfame-K has a rapid onset and some researchers have found it to have a bitter or metallic aftertaste when used at high concentrations (Stamp, 1990). The sweetness profile of acesulfame-K is affected by the medium in which it is used (Hood and Schoor, 1990). A synergistic effect occurs when acesulfame-K is mixed with either aspartame or sodium cyclamate-the sweetness of the mixture is perceived stronger than the sum of the sweetness of the two sweeteners alone (Giese, 1993).

In its dry form, acesulfame-K is made up of odorless, clear to white colored, monoclinic crystals (Volz *et al.*, 1991). Although the sweetener does not have a clear melting point, it begins to decompose at temperatures higher than

200° C. When acesulfame-K is subjected to temperatures and exposure periods common for food storage and manufacturing, no substantial decomposition is found (Lipinski, 1991b).

Acesulfame-K rapidly solubilizes in water, with up to 270 g/liter dissolving at 20° C. Greater amounts of the sweetener can be dissolved as the temperature of aqueous solutions increase (Stamp, 1990). Acesulfame-K is generally stable when found in aqueous systems having a pH within the range normally associated with foods and beverages. Ninety-nine percent of the acesulfame-K can be recovered from a solution with a pH of 7.5 stored for 10 years at room temperature. As temperatures increase or pH levels decrease, stability will also decrease (Lipinski, 1991b).

Unlike other artificial sweeteners, such as aspartame, acesulfame-K can be used for baking. Within normal temperatures used for baking, there is no deterioration of the sweetener. Even when cookies are baked at temperatures much higher than normal, no loss of sweetness is found (Lipinski, 1990).

Over 50 international studies have examined the safety of acesulfame-K (Giese, 1993). It has been recognized as safe by both the Food and Drug Administration and the World Health Organization. FDA has given the sweetener an acceptable daily intake value of 15 mg/kg body weight (Stamp, 1990). When ingested, acesulfame-K is completely absorbed, and within 24 hours most of the sweetener is eliminated through the kidneys. The sweetener is not metabolized and leaves the body unchanged (Volz *et al.*, 1991).

VISCOSITY IMPARTING AGENTS

Hydrocolloids, or gums, can be used in food products for thickening. An important property of liquids thickened with hydrocolloids is rheology, or flow behavior. Solutions containing hydrocolloids differ in their rheological behavior. Since rheological behavior affects the sensory properties of a solution, hydrocolloids with differing flow behaviors may have differing effects on the acceptability of a product (Glicksman, 1982). In a Newtonian system, shear stress is directly related to the shear rate, and viscosity remains constant with changes in shear. In a pseudoplastic system, increases in shear rate causes a decrease in shear stress and viscosity. In a bingham system, a minimum shearing rate or force is needed to get a solution flowing (yield point), after which the solution acts in a pseudopolastic manner (Glicksman, 1982).

Use of Carboxymethylcellulose (CMC) as a Thickening Agent

Carboxymethylcellulose is a chemically modified derivative of cellulose. It consists of carboxymethyl groups ether linked to the hydroxyl sites of the beta-anhydroglucose units of cellulose. Unlike cellulose, CMC is water soluble as a result of the anionic carboxymethyl groups (Keller, 1986).

The cellulose used for the production of CMC is derived from cotton linters and wood pulp (Keller, 1984). Although the specific procedures for producing CMC differ depending on the type of CMC desired, two basic steps are used to bring about the carboxymethylation of cellulose. The first step involves solubilizing the cellulose with alkali. During the second step, the cellulose is reacted with sodium monochloroacetate (Anderson and Andon, 1988). Depending on its use, CMC is made to different levels of purity. Food grade CMC is 99.5% pure (Keller, 1984).

Many types of CMC exist as a result of variations in certain physical characteristics such as degree of polymerization, degree of substitution, and uniformity of substitution. Degree of polymerization (DP) denotes the average number of anhydroglucose units per CMC molecule. As the chain length increases, the molecular weight and ability to impart viscosity increases (Keller, 1984). Carboxymethylcellulose is divided into three groups based on degree of polymerization-CMC-Low (CMC-L), CMC-Medium (CMC-M), and CMC-High (CMC-H). The approximate DP of CMC-L is 400, of CMC-M is 1100, and of CMC-H is 3200 (Elliot and Ganz, 1974). Each group is able to impart a specific range of viscosities to a solution when used at certain concentrations. Another characteristic, the degree of substitution (DS), represents the number of hydroxyl groups on each anhydroglucose unit which are substituted with carboxymethyl groups (Keller, 1984). In total, there are three hydroxyl groups on each unit which can be substituted. As the DS increases, the solubility of the polymer in water also increases. A DS of at least 0.4 is needed to keep CMC in solution while the highest possible DS for food grade CMC is 0.95. The most common DS for food grade CMC is 0.7 (Keller, 1984).

The uniformity of the substitution also affects the properties of CMC. When the carboxymethyl substitutions are more uniformly dispersed on the cellulose chain, the polymer is more uniformly solubilized, the solutions produced are more smooth flowing, and the cellulose gum is more compatible with other ingredients in solution (Keller, 1984). Another advantage to an increased DS and/or a more uniformly substituted CMC polymer is an increased acid stability. Acid attacks the ether linkage between two anhydroglucose units which are unsubstituted. The carboxymethyl groups stearically hinder acid attack. Possible areas of attack are decreased when there is an increase in the number of substitutions and when the substitutions are more evenly distributed (Keller, 1984).

The rheological behavior imparted by CMC depends on its degree of polymerization and substitution as well as the shear stress applied. At very low stress levels, all types of CMC in solution act in a Newtonian manner. As both the molecular weight of the polymer and the stress level increase, CMC acts in an increasingly pseudoplatic manner. This occurs because longer polymers tend to align with the direction of flow; therefore, there is a decreased resistance to flow (Keller, 1984). CMC in solution might also behave in a thixotrophic manner. Carboxymethylcellulose polymers with a low DS, a high DP, and/or randomly substituted carboxymethyl groups tend to impart thixotrophic behavior. Thixotrophic behavior can be defined as "a type of pseudoplastic flow with time dependence" (Keller, 1984). While a solution with pseudoplastic behavior reverts directly back to its standing viscosity when shear stress is discontinued, a solution with thixotrophic behavior needs a certain amount of time to revert back to its standing viscosity when shear stress is discontinued. In addition, a solution with thixotrophic behavior increases in viscosity over time when untouched. These responses occur as a result of unsubstituted areas on the CMC chains. Unsubstituted areas are generally insoluble and over time reassociate to form a three dimensional network. This network will increase the viscosity of the solution. While a nonthixotrophic solution has a smooth consistency, a thixotrophic solution has more of an "applesauce-like" consistency. Thixotrophy increases as the concentration of CMC in a solution increases (Keller, 1984).

The viscosity of a solution containing CMC is affected by factors that include concentration, temperature and pH. As expected, the viscosity of a solution will increase as the amount of CMC added increases. Instead of increasing proportionally, though, viscosity increases exponentially as CMC is added (Keller, 1986). Although CMC is soluble in both cold and hot water, a decrease in viscosity occurs when solutions containing CMC are heated. The decrease in viscosity is normally reversible when the solutions are cooled. If the solution is heated at a high temperature for a extended period of time, though, a permanent decrease in viscosity may occur. Although CMC solutions are generally stable in a pH range of 4-10, lower pH's will cause CMC to precipitate while higher pH's will cause a decrease in solution viscosity (Keller, 1986).

The effects of salts on solutions containing CMC depend on the type and amount of salt used. Carboxymethylcellulose is more tolerant of salts than other hydrocolloids because of its very hydrophilic nature. Carboxymethylcellulose will react with most monovalent ions to form soluble salts. Depending on the concentration of salt present, divalent and trivalent ions can either prevent CMC from reaching its full viscosity or can precipitate CMC. Under specific conditions, trivalent cations can also cause a solution containing CMC to gel (Keller, 1986).

Carboxymethylcellulose is susceptible to both microbiological degradation and cellulases, which can lead to a reduction of the viscosity of a CMC solution. Exposure of CMC solutions to sunlight and entrained air also contribute to the degradation of CMC. Molecular oxygen causes oxidative degradation which is increased in the presence of heavy metals. Due to these problems, care must be taken when CMC is stored (Keller, 1986).

Use of Xanthan Gum as a Thickening Agent

Xanthan gum is an exopolysaccharide produced from the fermentation of the microorganism *Xanthomomnas campestris,* which can be naturally isolated from the rutabaga plant (IFT, 1991). Beside being used as a thickener in a food product, it can also be used as a stabilizer, to offer body, and to suspend particulates.

The structure of xanthan gum can be described as "an anionic polyelectrolyte derivative of cellulose" (Bewersdorff and Singh, 1988). The backbone of xanthan gum consists of beta-1,4 linked D-glucose units, which is the structure of cellulose (Pettitt, 1982). A trisaccharide side chain which consists of a glucuronic acid between two mannose units is linked to every other glucose unit. A pyruvic acid is ketally linked to approximately half of the terminal mannose units while the mannose unit attached directly to the backbone has an acetyl group (Pettitt, 1982). Over a wide temperature range in solution, the backbone conforms to a rigid rod-like helical structure while the side chains fold back around the backbone. This structure is stabilized by non-covalent bonding between the backbone and sidechains (Sanderson *et al.*, 1982).

Rheologically, xanthan gum in solution is considered to have pseudoplastic behavior after a high yield value. This behavior can be related to the gums structure in solution. In solution, the polymer chains become entangled and form a complex network. A certain amount of applied shear is needed to disrupt this network, which is the cause for the high yield value. At higher levels of applied stress, the chains become progressively less entangled and therefore pseudoplastic behavior is seen (Sanderson *et al.*, 1982).

The effect of salts on the viscosity of xanthan gum depends both on the concentration of the gum and the salt. At xanthan gum concentrations lower than 0.15% and low salt concentrations (less than 0.02 M sodium chloride), there is a slight decrease in viscosity. At higher salt concentrations, the viscosity is increased. The increase in viscosity is a result of the neutralization of the intramolecular repulsion normally caused by the charged side chains. With the charges of the side chains neutralized, the xanthan gum chains "self-associate", or contract somewhat and form "worm-like coil structures" (Bewersdorff and Singh, 1988). Peak viscosity will be reached at monovalent salt concentrations higher than 0.08%. At xanthan gum concentrations higher than 0.15%, salts such as sodium chloride have an viscosity-increasing effect. The self-association of the xanthan chains at gum concentrations higher than 0.15% causes a gel-like structure to form. When the salt concentration is higher than 0.02 to 0.07%, no further effect on viscosity is seen (Glicksman, 1982). Many divalent salts, such as those of calcium and magnesium, affect viscosity in the same manner as monovalent salts (Cottrell *et al.*, 1980).

In addition to characteristics already mentioned, xanthan gum has many desirable characteristics which make it a valuable gum for use in the food industry. One important quality is that it is soluble in both cold and hot water. In addition, the viscosity of xanthan gum is generally stable over the pH range of 1-13 and the temperature range of 0-100° C (IFT, 1991). Xanthan gum is not affected by enzymes and has long-term stability in many food systems. In frozen products, xanthan gum offers freeze thaw stability (IFT, 1991).

Taste Perception

Taste is perceived when saporous compounds interact with receptors located on taste buds. Taste buds are located mainly on the tongue but are also found on the mucosa of the palate and areas of the throat (Meilgaard *et al.*, 1991). Taste compounds have specific molecular configurations which are complementary to their receptor sites. When a taste compound comes in contact with a complementary receptor, reactions goverened by chemical factors within the taste buds occur which elicit a particular taste. The intensity of a specific taste is thought to be proportional to the rates of these reactions (Cussler *et al.*, 1979).

There are unique receptors for each basic taste (sweetness, sourness, bitterness, and saltiness). Compounds which interact with these receptors have a specific molecular configuration. For instance, compounds which elicit a sweet taste are theorized to have a covalently bound H-bonding proton site, an electron negative orbital site which is located three angstroms from the former site, and a lipophilic region. Compounds which elicit a bitter taste are though by some to have a polar group and a hydrophobic group while others theorize that bitter compounds have the same sites described above for compounds which elicit sweetness. In the latter case, compounds eliciting a bitter taste would have a different molecular configuration than those compounds eliciting a sweet taste. Saltiness is theorized to be elicited through contact of a hydrated cation-anion complex with its receptor. Presently it is difficult to define compounds which elicit sourness, but compounds such as hydronium ions and dissociated or nondissociated anions are thought to be involved (Lindsay, 1985a).

Effects of Viscosity on Taste Perception

The influence of viscosity on taste perception has proven to be a complex issue. Mackey and Valassi (1956) examined the effects of viscosity on the taste thresholds of sucrose, caffeine, tartaric acid, and sodium chloride. In order to vary viscosity, tomato juice and custard were prepared as liquids, foams, and gels through the use of gelatin. The researchers found that the thresholds were lowest in aqueous solutions and that thresholds increased as the viscosity of the medium increased. Further work by Mackey (1958) examined the intensity of saccharine, caffeine, and quinine in aqueous solutions, mineral oil, and methyl cellulose solutions prepared to the same viscosity level as mineral oil. Mackey found that the intensities of the compounds were greatest in the aqueous solutions, intermediate in the methyl cellulose solutions, and lowest in the mineral oil. Stone and Oliver (1966) also examined the effects of viscosity on taste thresholds and intensities by manipulating the viscosity of 1-10% sucrose solutions with either 3% cornstarch or 1% CMC-H. As found previously, thresholds increased as viscosity increased. The CMC solutions had higher thresholds than the cornstarch solutions. The researchers also found that sweetness ratings were higher, although not significant, in the solutions containing the hydrocolloids.

Both sets of studies found that thresholds of taste compounds increased when the viscosity of the medium which they were in increased. The intensities of the taste compounds did not change in a consistent manner when viscosity was increased. In addition, different viscosity imparting agents did not seem to decrease thresholds or change intensities to the same extent. Stone and Oliver (1966) commented that gums differ in their "sliminess", or tendency to thin with increasing shear rates, and that gums might affect sweetness differently as a result of having different sliminesses. Vaisey *et al.* (1969) used hydrocolloids differing in sliminess in order to evaluate how they differed with respect to affecting the sweetness of 3.5-4.5% sucrose solutions. Three hydrocolloids were used- CMC-H, guar, and cornstarch. They identified CMC-H as being more slimy than cornstarch and slightly more slimy than guar gum. The researchers found that the more slimy gums, CMC and guar, tended to delay sweetness perception more than the less slimy gum cornstarch. It was also found that slimy gums either decreased or had no effect on sweetness. Vaisey *et al.* (1969) concluded that more slimy gums generally tend to mask sweetness more than less slimy gums.

Pangborn *et al.* (1973) investigated how the viscosity imparted by different hydrocolloids at levels common to beverages affected the intensity of different taste compounds in aqueous solutions. Instead of categorizing hydrocolloids by sliminess, these researchers categorized hydrocollids by their rheological behavior. The hydrocolloids utilized in this study were xanthan gum (bingham), CMC-L (Newtonian), CMC-M (pseudoplastic), sodium alginate (pseudoplastic), and hydroxypropylcellulose (HPC) (Newtonian). The taste compounds examined were sucrose, saccharine, citric acid, sodium chloride, and caffeine. Overall, the researchers found that the effect on taste intensity depended on both the type of hydrocolloid and the type of taste compound. When the taste intensity of a compound was modified, though, it was modified in the same direction (increased or decreased) by all of the hydrocolloids affecting the compounds intensity. Specifically examining the sweet compounds, the intensity of sucrose was decreased by the presence of HPC, CMC-M, and xanthan gum and not affected by CMC-L or sodium alginate, and the intensity of saccharine was increased by CMC-L, CMC-M, and sodium alginate and not affected by xanthan gum or HPC. Sucrose was the only compound which appeared to be affected by viscosity per se. The researchers noted that the hydrocolloids that increased the taste intensity of saccharine contained sodium, and that perhaps sodium has something to do with the sweet taste of saccharine. The intensity of the sour compound, citric acid, was significantly reduced by the presence of all of the hydrocolloids. Bitterness, which was represented by caffeine, was decreased by the presence of CMC-L, sodium alginate, and xanthan gum and was not affected by HPC and CMC-M.

Christensen (1980) investigated how CMC influenced the sweetness intensity of sucrose. The researcher found that CMC-H at a viscosity level of 2,025 csk significantly reduced the sweetness intensity of aqueous solutions containing up to .12M sucrose. Solutions with higher levels of sucrose were not affected by the CMC-H. Christensen (1980) also investigated how CMC-L, CMC-M, and CMC-H at viscosity levels of 1 csk to 1,296 csk affected the sweetness intensity of .06M - 1M sucrose solutions. The results indicated that the higher viscosity levels produced by CMC-M and CMC-H decreased the sweetness intensity of the sucrose solutions while CMC-L did not decrease sweetness intensity at any level of viscosity. Since the different forms of CMC did not affect the solutions in the same manner, and since about three times more CMC-L was needed to bring about the same viscosity levels as CMC-H, the researcher concluded that neither viscosity nor concentration related effects were responsible for decreasing the sweetness of the solutions. The researcher noted that, since CMC contains sodium, the larger amount of sodium present in the solutions thickened with CMC-L may have reversed the depressing effect of the hydrocolloid-if sodium does actually have the taste-enhancing property which it has been postulated to have.

Food systems and beverages have been examined to determine how viscosity effects sweetness. Pangborn *et al.* (1978) investigated how the addition of certain hydrocolloids, including xanthan, CMC-L, and CMC-M, influenced the taste intensities of tomato juice, coffee, and an orange drink. They found that, in all cases, the taste intensities of the drinks were decreased by the addition of one of the hydrocolloids. Pangborn and Koyasako (1981) examined the sweetness of two products, a chocolate creme and a chocolate pudding, which had the same ingredients except for the addition of more starch and agar to the pudding. The researchers found that the sweetness intensity was decreased in the more viscous pudding when compared to the creme. Burns and Noble (1985) examined how the addition of the viscosity imparting agent Polycose, which has Newtonian rheology, influences the sweetness of vermouth. They found that the sweetness of vermouth is increased by the addition of small amounts of Polycose.

Limited work has been done on investigating the influence of viscosity on the artificial sweeteners aspartame and acesulfame-K. Redlinger and Setser (1987) investigated how the sweetness intensity of sucrose, aspartame, acesulfame-K, and other sweetening agents differed between an aqueous solution and a viscous cream. The researchers found that sweetness intensity was higher for all of the sweeteners in the aqueous solution. Fernandez *et al.* (1990) examined the time-intensity characteristics of a 100 g/L sucrose solution, a 1 g/L aspartame solution, and a 0.38 g/L (60:40 w/w) aspartame:acesulfame-K solution. In order to determine if a viscosity level equal to that of a 10% sucrose solution would affect the intensity profiles of the solutions containing the artificial sweeteners, xanthan gum was added to the aspartame and aspartame:acesulfame-K solutions. The researchers detected no difference in the intensity profiles of the solutions containing artificial sweeteners with and without xanthan gum.

SENSORY EVALUATION -QUANTITATIVE DESCRIPTIVE ANALYSIS

Sensory evaluation is a method of measurement in which people are used as measuring instruments to evaluate the sensory characteristics of a product. Many different kinds of products can be analyzed through sensory evaluation, including foods and beverages, skin care products, fabrics and paper, and tobacco products. Sensory evaluation is mainly used for research, product development, and quality control. (Penfield and Campbell, 1990).

Quantitative descriptive analysis (QDA) is a sensory evaluation technique that can be used to quantitatively define the sensory characteristics of a product (Penfield and Campbell, 1990). When this technique is used, panelists are selected on the basis of their ability to distinguish between different sensory attributes in product samples. Once chosen, panelists work together to develop and define a list of attributes describing the product. Panelists are then trained to evaluate the attributes according to their intensity on a linear scale. The linear scale which panelists use consists of a 15 cm line which is anchored on each end by a descriptor. The word on the left signifies that the attribute is negligible in the sample while the word on the right signifies that there is a high degree of the attribute present in the sample. The line in between represents the different intensities of the attribute between the extremes. During actual testing, panelists work alone in isolated booths to evaluate specific attributes of the test samples. Testing of each sample variation is repeated many times in order to determine if the results are reproducible. Once the results have been collected, the responses marked on the linear scales are converted to numerical scores. These scores are then analyzed through statistical analysis to determine if the attributes of the different variations significantly differ (Stone *et al.*, 1974).

Quantitative descriptive analysis has been used for evaluating many different kinds of food products. As an example of a quantitative descriptive analysis study, Piggott and Mowat (1991) used QDA to evaluate changes which occur in cheese during maturation. As usually found in a QDA study, the researchers carefully selected panel members from a larger group of possible candidates. Once the panel members were chosen, the researchers worked with the panelists to develop a "cheese attribute" list. The panel members were given in depth training on recognizing the attributes and they were also given training on the line scale procedure used to quantitatively measure the attributes. Once the actual testing period began, the panelists evaluated cheese samples in an isolated, quiet, temperature and luminated controlled sensory booth. The data was statistically analyzed to evaluate for quantitative differences in the attributes of cheeses at different maturation levels. Overall, this study clearly showed many of the characteristics of a typical QDA study.

CHAPTER 3
MATERIALS AND METHODS

EXPERIMENTAL DESIGN

The experimental design for evaluating the effect of hydrocolloids on the taste perception of artificially sweetened lemon flavored beverages is shown in Appendix B. The study consisted of two parts which were evaluated independently; in the first half of the study Equal® was used as the sweetening agent and in the second half Sweet One® was used as the sweetening agent. For each sweetening agent, three hydrocolloids, xanthan gum, carboxymethylcellulose-low (CMC-L), and carboxymethylcellulose-medium (CMC-M), were used to thicken the drink samples. Each hydrocolloid was used at three levels to attain the following viscosities - 10 cps, 15 cps, and 20 cps. Therefore, there were nine variations (3 x 3) per sweetener type. In an incomplete block design, each variation was evaluated eight times per panelist.

SCHEDULE OF RESEARCH

The study period lasted for eight weeks. During the first four weeks, samples containing Equal® were evaluated while during the remaining four weeks, samples containing Sweet One® were evaluated. During each week of the study period, three testing sessions were held. Testing was normally done on Tuesdays, Wednesdays, and Thursdays. Makeup testing was done on two Mondays and on a few other instances at other times during the week when it was most convenient for the panelists. At each session, six samples, in addition to the reference, were analyzed for sweetness, lemon flavor, sourness, bitterness, and aftertaste. The sample presentation schedule followed for the study period is shown in Appendix C. Samples were presented to the panelists in a random order.

SAMPLE FORMULATIONS AND PREPARATION

A beverage system was used in this study to determine the effects of hydrocolloids on the taste perception. Lemonade flavored Kool-aid® unsweetened dry mix was used to provide flavor to the samples. Kool-aid® was used as the flavoring agent because it easily provided a consistent amount of flavor to the samples. Among beverage flavors considered for the study (cherry, orange, lemonade, and grape), lemonade flavor was chosen because the panelists were able to rank a series of flavored samples with increasing concentrations of sucrose best when lemonade flavored Kool-aid® was used.

Carboxymethylcellulose-low (CMC-L), carboxymethylcellulose-medium (CMC-M), and xanthan gum were added to the beverages to impart viscosities of 10, 15, and 20 cps. The artificially sweetened beverages without added hydrocolloid had a viscoity of 8 cps.

The formulations and procedures used for the preparation of each of the samples are shown in Appendix D. The amount of lemonade dry mix used to prepare the samples was the same amount which would normally be used to prepare lemonade kool-aid®. The artificial sweeteners were added at levels to produce beverages which had a "medium" sweetness. The amount of each sweetener needed to produce this "medium" sweetness was determined by finding a level of each sweetener in the lemon flavored beverage which was comparible to the sweetness of a lemon flavored 7.5% sucrose solution. A 7.5% sucrose solution was chosen since this amount represents an intensity score of approximately 7.5 out of 15 (0= no sweetness, 15= intense sweetness) according to work done by Hill Top Research, Inc. (Meilgaard et al., 1991), which is a "medium" sweetness level. After preparation, the viscosity of the solutions were measured with the Brookfield viscometer (Stoughton, MA). For this procedure, spindle 2 at 50 rpm was used.

INGREDIENTS

The xanthan gum (Keltrol TF™, lot # 10537K) was donated by Merck & Co., Inc. (Kelco Div., San Diego, CA). The carboxymethylcellulose-Low (7LF, lot # FP1010295) and carboxymethylcellulose-Medium (7MF, lot # FP1010164) were donated by Hercules, Inc. (Aqualon Div., Wilmington, DE). The hydrocolloids were stored at room temperature away from direct light in their original containers.

The sweeteners, Equal® (Stadt Corp., Brooklyn, NY, lot # 3L02M04,3L02M10) and Sweet One® (Nutrasweet Company, Deerfield, IL, Insp. by 1611220283, 1111932223, 1111592752), and the Kool-aid® lemonade drink mix (Kraft General Foods, Inc., White Plains, NY, lot # 3095A114) were purchased from a local grocery store in Blacksburg, Va. These ingredients were stored in closed containers at room temperature away from direct light. Sweet One® was used as the source of acesulfame-K and Equal® was used as the source of aspartame in this study.

SENSORY EVALUATION

Participants for sensory evaluation were recruited from the Department of Human Nutrition and Foods on the basis of interest and availability. Eight participants began the study. All participants were graduate students in the Department of Human Nutrition and Foods and were between the ages of 22-40 years. Seven of the panelists were female and one was male. Two panelists, both female, became ill during the second and third week of the study and therefore were dismissed from the study. Since the sweetener Equal® was used for the first half of the study and the sweetener Sweet One® was used for the second half, only six of the panelists evaluated the samples containing Sweet One®. Training was done during five sessions which each lasted for approximately thirty minutes. Training included familiarizing the panelists with the taste of Equal® and Sweet One®, determining the attributes of the lemon flavored beverages, using the scoresheet, and rating the attributes of the beverages. During the testing, the sensory evaluation sessions were conducted in the Wallace Hall sensory evaluation facilities at Virginia Tech (Blacksburg, Va.). Sensory testing was done in individual booths under fluorescent lighting.

Sensory evaluation was completed using a modification of quantitative descriptive analysis (QDA) (Stone et al., 1974). At the beginning of each session, panelists were given a reference sample which contained the artificial sweetener being evaluated, a pencil, water, and unsalted crackers. The reference sample was prepared with the same amount of sweetener and lemonade dry mix as the test samples but did not contain any of the hydrocolloids. The reference solution was given to the panelists at each session in order to give the panelists a reference point from which to judge how the attributes of the test samples were affected. Panelists received six approximately 35 ml drink samples to evaluate per session. Each sample was identified by a random three-digit code. Each drink sample was given to the panelists one at a time along with a scoresheet for the sample. An example of the scoresheet which was used is shown in Appendix E. When evaluating each sample, panelists were asked to sip the sample, make sure the sample had been in contact with all parts of the mouth, and then swallow the sample. The panelists were then instructed to make a vertical mark on the line for each attribute on the scoresheet to indicate their perception of the intensity of the attributes. Panelists were asked to evaluate the reference sample in addition to the sample in question on each scorecard. Between samples, the panelists were instructed to take a bite of cracker and then rinse their mouths with water.

STATISTICAL ANALYSIS

For statistical purposes, the data from the Equal® sweetened drinks and the Sweet One® sweetened drinks were analyzed separately. Five attributes in each drink sample were analyzed. For each attribute, the two main effects tested were type of hydrocolloid and viscosity. Analysis was done for each attribute to determine if a significant difference in attribute intensity existed :

- -between samples containing one type of hydrocolloid and the reference sample
- -between samples containing the same hydrocolloid but having different viscosities
- -between samples containing different hydrocolloids but having the same viscosity level

In addition, a contrast test was done for each attribute to determine if increased amounts of the different hydrocolloids affected the attribute in the same way. The Statistical Analysis System (Cary, North Carolina) was used for statistical analysis. The statistical procedures which were used included Analysis of Variance and Duncan's Multiple Range test.

CHAPTER 4
RESULTS

The purpose of this study was to determine how viscosity imparted by hydrocolloids affected the flavor attributes of a lemon flavored beverage containing an artificial sweetener. The two artificial sweeteners used to prepare the beverages were Equal® (contains sweetening agent aspartame) and Sweet One® (contains sweetening agent acesulfame-K). Since exact equisweet concentrations for these sweeteners were not determined, the results obtained from the samples containing the different sweeteners were analyzed separately and will therefore be discussed separately. The viscosity of the samples was adjusted to approximately 10, 15, and 20 cps with one of the following hydrocolloids: CMC-L, CMC-M, or xanthan gum. The selected attributes included sweetness, lemon flavor, sourness, bitterness, and aftertaste.

Effect of Hydrocolloids on Selected Attributes of the Samples Containing Equal®

The mean intensity values for the attributes of the lemon flavored beverage variations containing Equal® are shown in Table 1. In the reference sample, sweetness was given the highest intensity score (7.67). Lemon flavor was perceived almost as strong as sweetness (7.32) while sourness was perceived to be less intense (6.51) Bitterness was perceived less intense (4.06) than aftertaste (5.20).

Carboxymethylcellulose-Low (CMC-L)

The changes in the attribute intensities with the addition of CMC-L are shown in Figure 1. At the lowest viscosity, 10 cps, CMC-L significantly depressed

Table 1

Rheological Effect of CMC-L, CMC-M, and Xanthan Gum on Selected Attributes of a Lemonade Beverage Containing Equal®

HYDROCOLLOID	VISCOSITY (cps)	SWEETNESS	LEMON FLAVOR	SOUR	BITTER	AFTERTASTE
reference		7.67[1] ab[2]	7.32 a	6.51 a	4.06 a	5.20 a
CMC-L	10	6.53 cd	5.74 c	5.49 bc	4.17 a	5.20 a
CMC-L	15	7.37 abc	5.32 c	4.87 c	4.40 a	5.38 a
CMC-L	20	7.90 a	4.43 d	4.06 d	4.61 a	5.43 a
CMC-M	10	6.78 cd	6.07 bc	5.75 b	4.00 a	5.07 a
CMC-M	15	6.90 bcd	5.62 c	4.99 c	4.20 a	5.16 a
CMC-M	20	6.81 cd	5.54 c	5.30 bc	4.10 a	5.05 a
Xanthan	10	6.63 cd	6.82 ab	6.90 a	4.36 a	4.99 a
Xanthan	15	6.34 d	6.85 ab	6.50 a	4.20 a	4.92 a
Xanthan	20	6.22 d	6.64 ab	6.56 a	4.69 a	5.59 a

[1] Scores range from 0 to 15. 0 indicates a lack of the attribute whereas 15 indicates a strong intensity of the attribute.

[2] Means followed by different letters in the same column are significantly different at $p<0.05$.

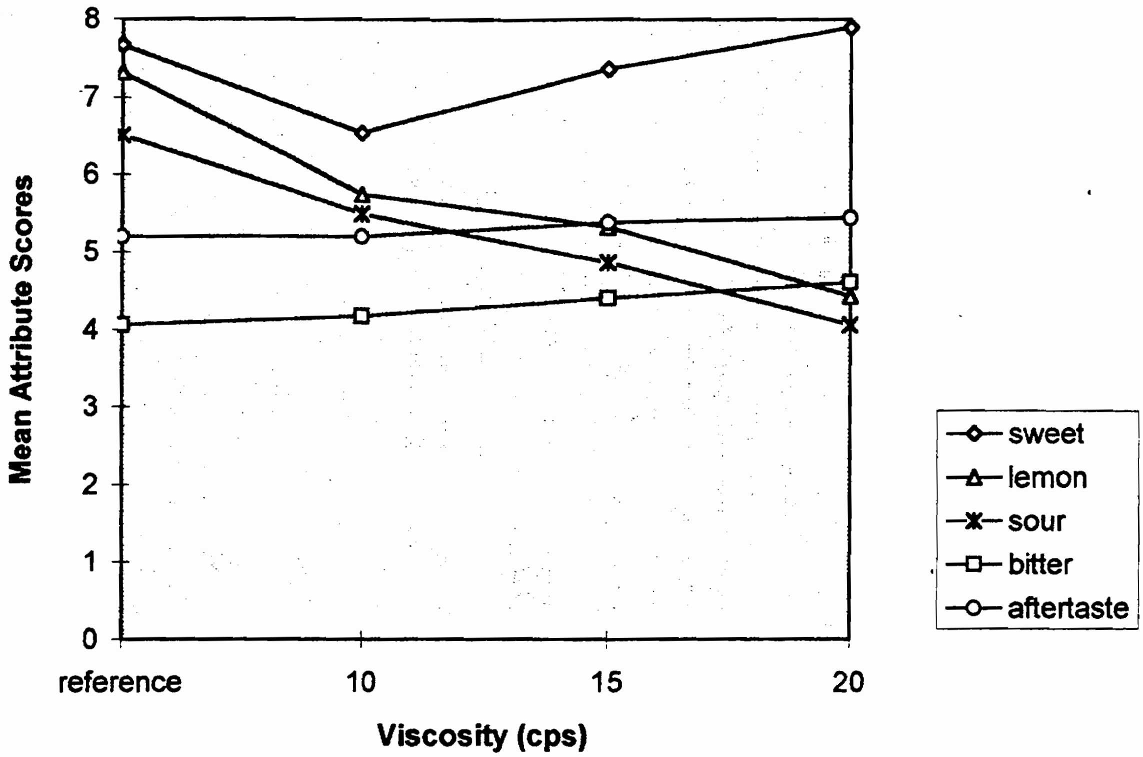

Figure 1: Effect of CMC-L at different usage levels on the attributes of the samples sweetened with Equal®. 0=lack of attribute<8<15=intense attribute.

sweetness compared to the reference. Sweetness intensity was increased as viscosity increased from 10 to 20 cps. Although the sweetness of the samples having viscosities of 10 cps and 15 cps were not significantly different, the sample having a viscosity of 20 cps was significantly sweeter than the sample having a viscosity of 10 cps. Lemon flavor and sourness were significantly depressed in all of the samples containing CMC-L compared to the reference. In the sample having a viscosity of 20 cps, lemon flavor and sourness were significantly decreased compared to the samples having lower viscosities. Bitterness and aftertaste were not significantly affected by addition of CMC-L, although both attributes tended to slightly increase with increasing viscosity.

Throughout the viscosity range tested, sweetness remained the attribute with the highest perceived intensity. As viscosity increased, lemon flavor and sourness decreased in an almost parallel manner.

Carboxymethylcellulose-Medium

The changes in the intensities of the attributes with the addition of CMC-M are shown in Figure 2. Compared to the reference, sweetness was significantly depressed in the samples with viscosities of 10 and 20 cps. Although not significant, the sweetness of the sample having a viscosity of 15 cps was depressed compared to the reference. Lemon flavor and sourness were significantly depressed in all of the samples containing CMC-M compared to the reference. Bitterness and aftertaste were not significantly affected by the addition of CMC-M at any viscosity. Increased levels of CMC-M did not further significantly alter the intensity of the attributes, although lemon flavor tended to decrease.

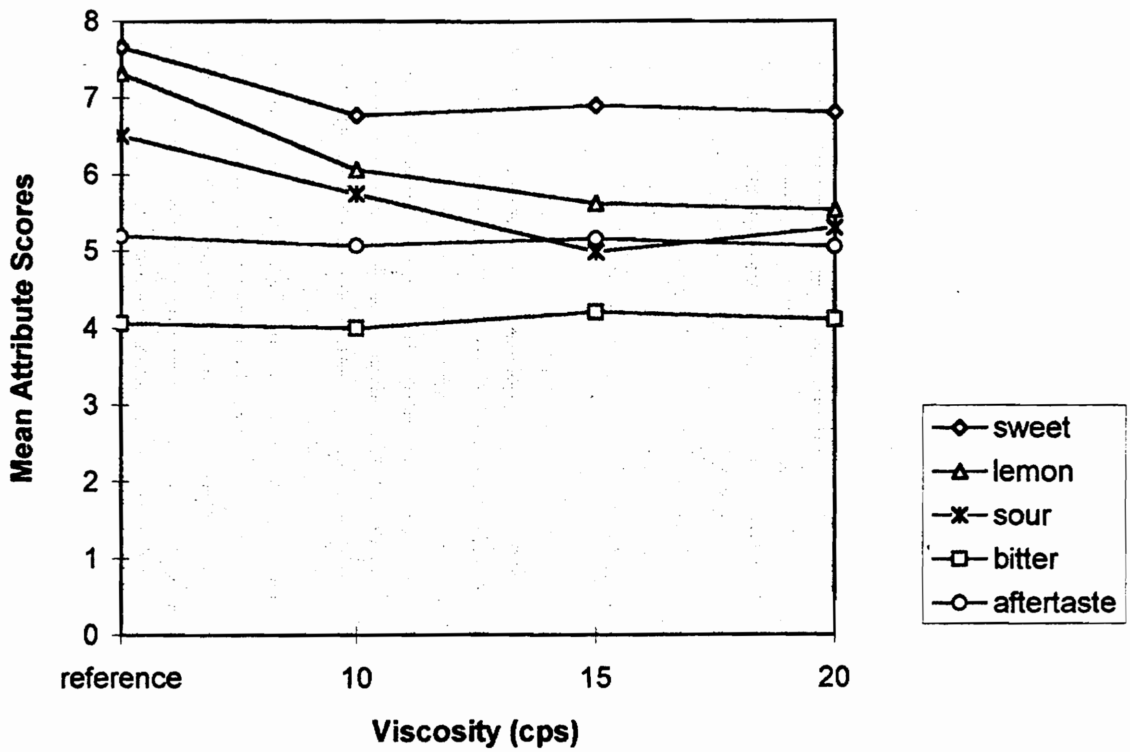

Figure 2: Effect of CMC-M at different usage levels on the attributes of the samples sweetened with Equal®. 0=lack of attribute<8<15=intense attribute.

Although the lemon flavor and sourness of the samples containing CMC-M were significantly depressed compared to the reference, generally the order of the attributes by intensity did not change with increasing viscosity. At the viscosity level of 15 cps, sourness was given a slightly lower score than aftertaste.

Xanthan Gum

The effects of xanthan gum on the attributes of the drink samples are shown in Figure 3. Xanthan gum significantly depressed sweetness at all viscosity levels compared to the reference. Lemon flavor, sourness, bitterness, and aftertaste were not significantly affected by the addition of xanthan gum at any of the viscosity levels, although lemon flavor in the samples containing xanthan gum tended to be depressed compared to the reference. Increased levels of xanthan gum did not significantly affect the intensity of the attributes, although sweetness tended to decrease with increasing viscosity.

The decrease in sweetness may account for the fact that lemon flavor and sourness were more intense than sweetness in all of the samples containing xanthan gum. In the sample with a viscosity level of 10 cps, sourness was slightly more intense than lemon flavor. In the other samples containing xanthan gum, lemon flavor was slightly more intense than sourness.

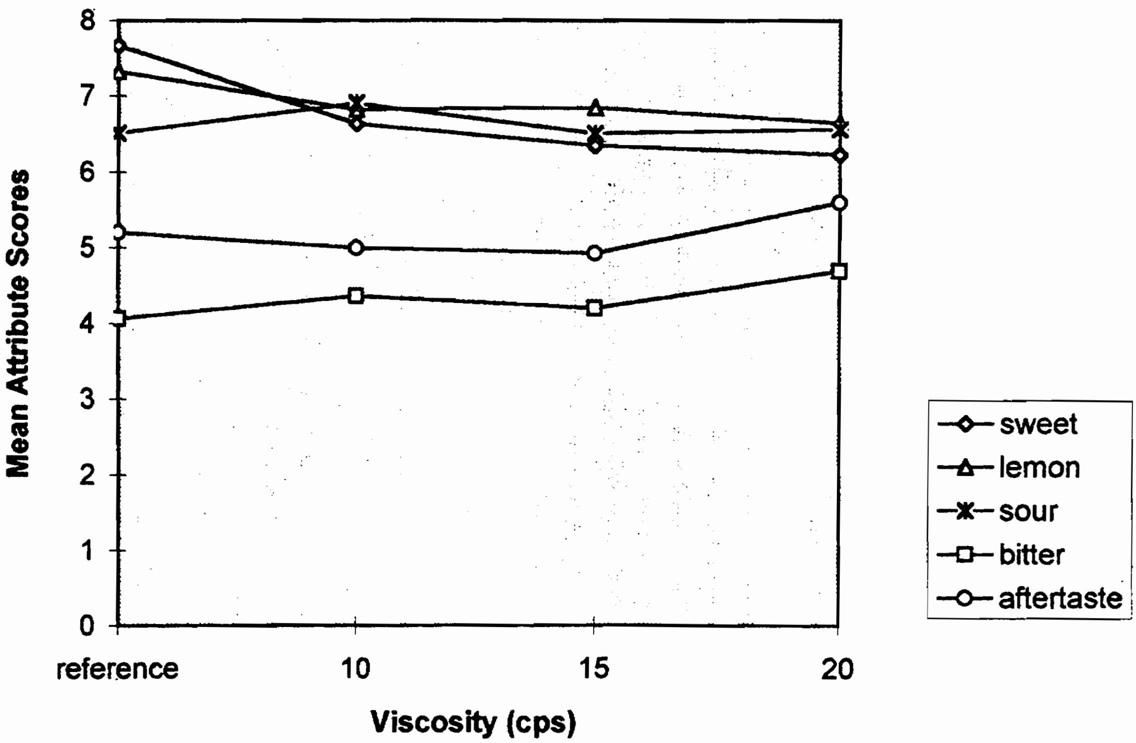

Figure 3: Effect of xanthan gum at different usage levels on the attributes of the samples sweetened with Equal®. 0=lack of attribute<8<15=intense attribute.

A Comparison of Hydrocolloids and the Attributes of Samples Containing Equal®

The mean sweetness scores for the samples are shown in Figure 4. Compared to the reference, the sweetness of the samples containing xanthan gum was significantly depressed at all viscosity levels, while in the samples containing CMC-L, sweetness was only significantly depressed in the sample with a viscosity of 10 cps. Sweetness was depressed in all of the samples containing CMC-M, although only the sweetness of the samples with viscosities of 10 and 20 cps were significantly depressed. Generally, increased amounts of CMC-L tended to increase sweetness, increased amounts of CMC-M maintained one level of depressed sweetness, and increased amounts of xanthan gum tended to decrease sweetness. The CMC-L sample having a viscosity level of 20 cps was significantly more sweet than all CMC-M and xanthan gum samples.

The mean scores for lemon flavor are shown in Figure 5. The lemon flavor of the samples containing CMC-L and CMC-M was significantly depressed compared to the reference, whereas the lemon flavor was not significantly depressed in the samples containing xanthan gum. Increased amounts of CMC-L and CMC-M generally tended to decrease lemon flavor while increased amounts of xanthan gum did not affect lemon flavor. When comparing samples of the same viscosity level, the samples containing CMC-L tended to have less lemon flavor than their counterparts containing CMC-M. The CMC-M sample with a viscosity of 20 cps had significantly more lemon flavor than the CMC-L sample with a viscosity of 20 cps. Samples containing xanthan gum had significantly more lemon flavor than those samples with CMC-L and CMC-M. A

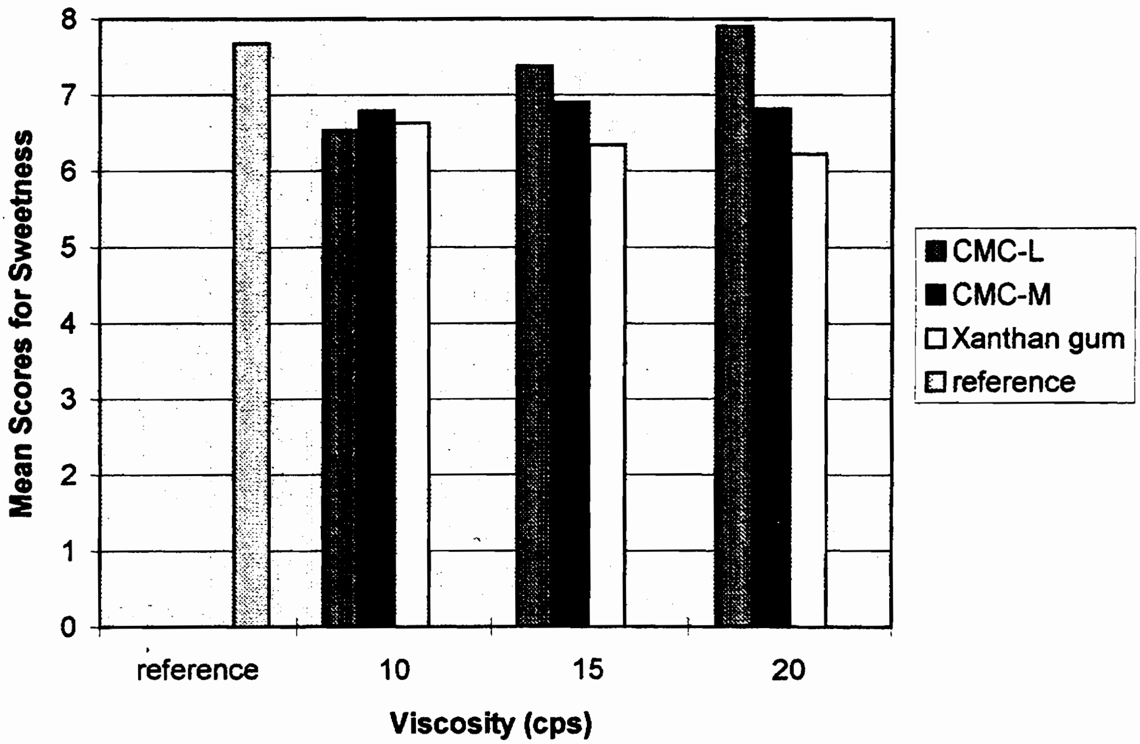

Figure 4: A comparison of the mean sweetness scores for the samples sweetened with Equal®. 0=no sweetness<8<15=intense sweetness.

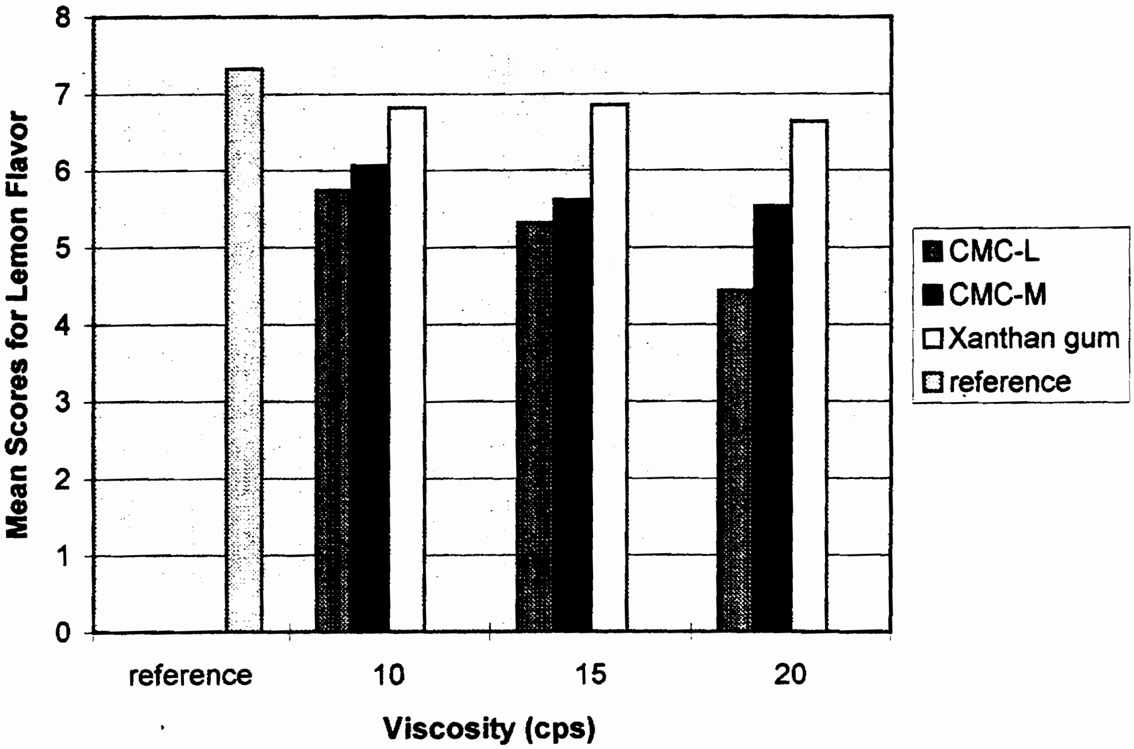

Figure 5: A comparison of the mean lemon flavor scores for the samples sweetened with Equal®. 0=no lemon flavor<8<15=intense lemon flavor.

significant contrast effect was found for lemon flavor indicating that increasing levels of the hydrocolloids affected lemon flavor in different ways.

The mean sourness scores for the samples are shown in Figure 6. Compared to the reference, the sourness of the samples containing CMC-L and CMC-M was significantly depressed, whereas the sourness of the samples containing xanthan gum was not affected. When comparing samples of the same viscosity level, the samples containing CMC-L tended to be less sour than their counterparts containing CMC-M. The CMC-M sample having a viscosity level of 20 cps was significantly more sour than the CMC-L sample having a viscosity level of 20 cps. All of the samples containing xanthan gum were significantly more sour than the CMC-L and CMC-M samples. There was a significant contrast effect for sourness indicating that increasing levels of the three hydrocolloids affected sourness in different ways.

The addition of hydrocolloids did not significantly affect the bitterness or aftertaste of any of the samples.

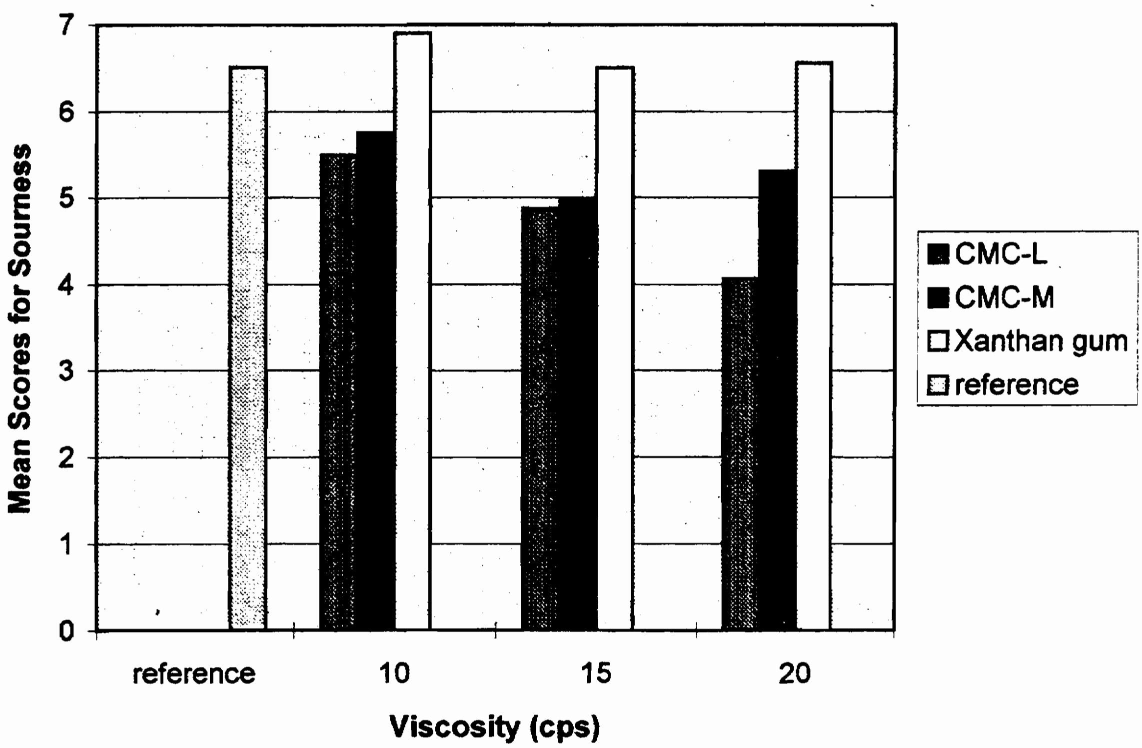

Figure 6: A comparison of the mean sourness scores for the samples sweetened with Equal®. 0=lack of sourness<7<15=intense sourness.

Effect of Hydrocolloids on the Selected Attributes of Samples Containing Sweet One®

The mean intensity values for the attributes of the lemon flavored beverage variations containing Sweet One® are shown in Table 2. In the reference sample, sourness was given the highest intensity score (7.24). Sweetness (6.51) and lemon flavor (6.61) were perceived to have about the same intensity. Aftertaste (5.81) was perceived to have almost the same intensity as bitterness (5.92).

Carboxymethylcellulose-Low (CMC-L)

The changes in the attribute intensities with the addition of CMC-L are shown in Figure 7. At a viscosity of 20 cps, sweetness was significantly increased and lemon flavor was significantly depressed compared to the reference. Although not significant, the samples having viscosities of 10 and 15 cps had increased sweetness intensities and depressed lemon flavor compared to the reference. Increased viscosity significantly increased sweetness intensity and tended to decrease lemon flavor. Sourness was significantly depressed in all of the samples containing CMC-L compared to the reference. Increased viscosity significantly decreased sourness. Bitterness and aftertaste were not significantly affected by the addition of the hydrocolloid.

Although sourness was the attribute with the highest intensity score in the reference, sweetness was the most intense attribute in the samples containing CMC-L. Lemon flavor, as well as sourness, was depressed by increased

Table 2

Rheological effect of CMC-M, CMC-L, and Xanthan Gum on Selected Attributes of a Lemonade Beverage Containing Sweet One®

HYDROCOLLOID	VISCOSITY (cps)	SWEETNESS	LEMON FLAVOR	SOUR	BITTER	AFTERTASTE
reference		6.51[1] bcde[2]	6.61 a	7.24 a	5.92 a	5.81 a
CMC-L	10	6.78 bc	5.75 abc	5.92 bcd	6.55 a	5.58 a
CMC-L	15	7.43 ab	5.72 abc	5.50 de	5.65 a	5.10 a
CMC-L	20	8.10 a	5.12 c	4.87 e	5.75 a	5.71 a
CMC-M	10	5.93 cde	5.92 abc	6.43 abc	6.30 a	5.27 a
CMC-M	15	6.62 bcd	5.91 abc	6.70 ab	6.64 a	5.26 a
CMC-M	20	5.64 de	5.55 bc	5.74 cd	6.11 a	5.49 a
Xanthan	10	6.12 cde	6.16 ab	7.22 a	6.22 a	5.49 a
Xanthan	15	6.48 bcde	6.46 ab	6.68 ab	6.07 a	4.81 a
Xanthan	20	5.49 e	6.09 abc	6.71 ab	6.84 a	5.75 a

[1] Scores range from 0 to 15. 0 indicates a lack of the attribute whereas 15 indicates a strong intensity of the attribute.

[2] Means followed by different letters in the same column are significantly different at $p<0.05$.

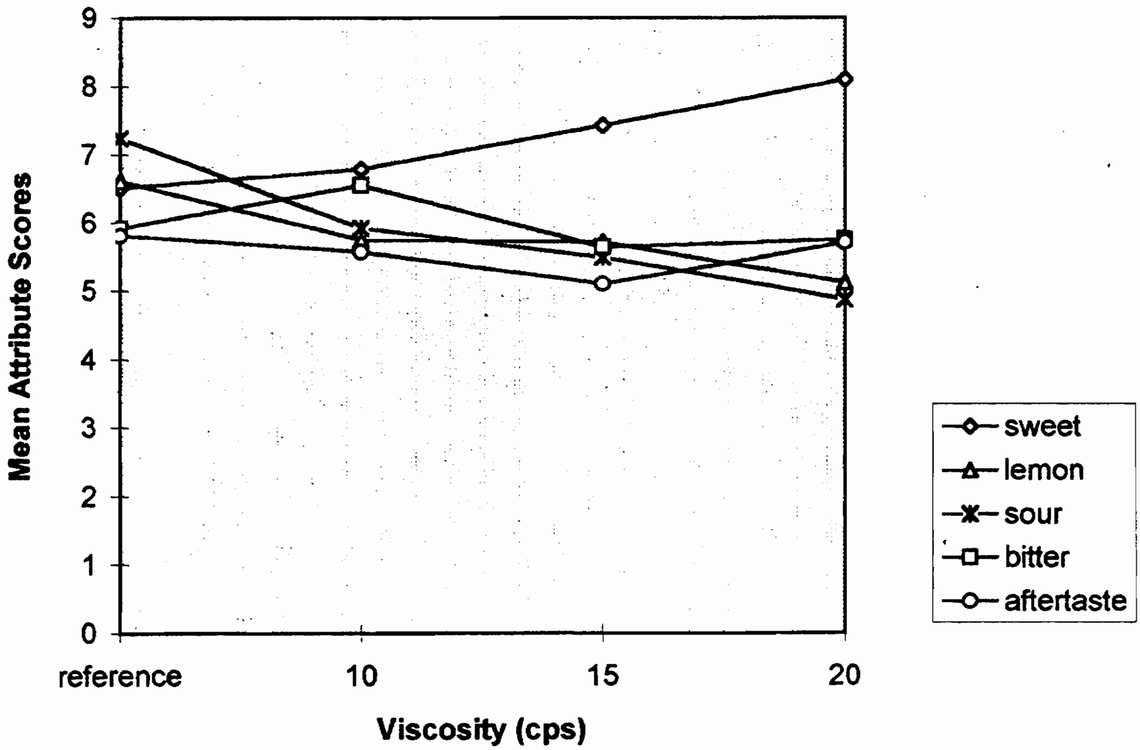

Figure 7: Effects of CMC-L at different usage levels on the attributes of the samples sweetened with Sweet One®. 0=lack of attribute<9<15=intense attribute.

viscosities. Sourness and lemon flavor were the two most intense attributes in the reference but were the least intense attributes in the sample having a viscosity of 20 cps.

Carboxymethylcellulose-Medium (CMC-M)

The changes in the intensities of the attributes with the addition of CMC-M are shown in Figure 8. The addition of CMC-M did not significantly affect the sweetness of the samples compared to the reference. Sweetness intensity followed an irregular pattern of first decreasing, then increasing, and then decreasing again as viscosity increased. Although not significant, lemon flavor tended to be depressed in the samples containing CMC-M compared to the reference. Lemon flavor tended to decrease with increased viscosity. The sourness of the sample having a viscosity of 20 cps was significantly depressed compared to the reference. The sourness of the samples having viscosities of 10 and 15 cps tended to be depressed but were not significantly different than the reference. Although the sample having a viscosity of 20 cps was not significantly less sour than the sample having a viscosity of 10 cps, it was significantly less sour than the sample having a viscosity of 15 cps. Bitterness and aftertaste were not significantly affected by the addition of CMC-M.

With added CMC-M, sourness remained the most intense attribute except in the sample having a viscosity of 20 cps. Although sourness remained relatively more intense than lemon flavor and lemon flavor remained relatively more intense than aftertaste at all viscosities, sweetness and bitterness varied in their relative intensities in relation to the other attributes.

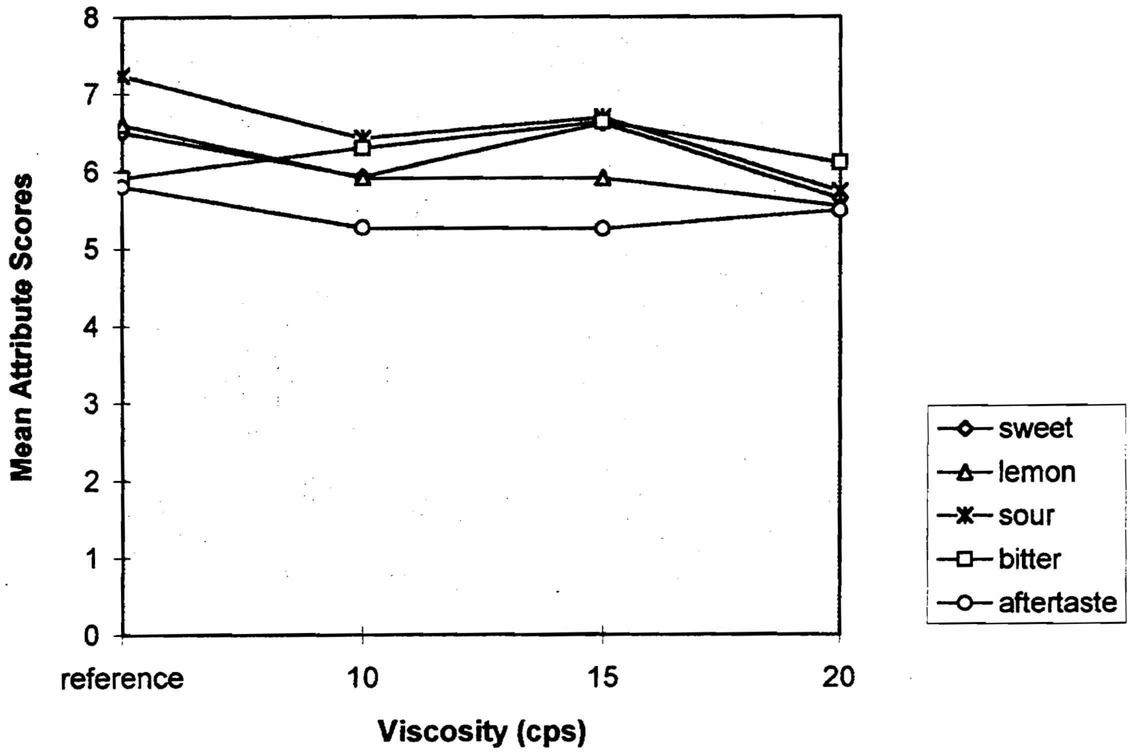

Figure 8: Effects if CMC-M at different usage levels on the attributes of the samples sweetened with Sweet One®. 0=lack of attribute<8<15=intense attribute.

Xanthan Gum

The effects of xanthan gum on the attributes of the drink samples are shown in Figure 9. The addition of xanthan gum at all three levels did not have a significant effect on any of the attributes of the samples.

Although there were no significant changes in the attributes from the reference, the "descriptions" of the samples containing varied amounts of xanthan gum were different. Sourness was the most intense attribute except in the sample having a viscosity of 20 cps. Although sourness remained relatively more intense than lemon flavor and lemon flavor remained relatively more intense than aftertaste in all of the samples, sweetness and bitterness varied in their relative intensities in relation to the other attributes.

A Comparison of Hydrocolloids and the Attributes of Samples Containing Sweet One®

The mean sweetness scores for the samples are shown in Figure 10. The sweetness of the samples containing xanthan gum or CMC-M was not significantly affected by the addition of hydrocolloid, although in both instances sweetness first decreased, then increased, and then decreased again with increasing viscosity. The addition of CMC-L increased the sweetness of the samples although only the sample having a viscosity of 20 cps was significantly sweeter than the reference. The sample containing CMC-L at a viscosity level of 20 cps was significantly more sweet than all of the samples containing CMC-M or xanthan gum. A significant contrast effect was found for sweetness indicating that increasing levels of the hydrocolloids affected sweetness in different ways.

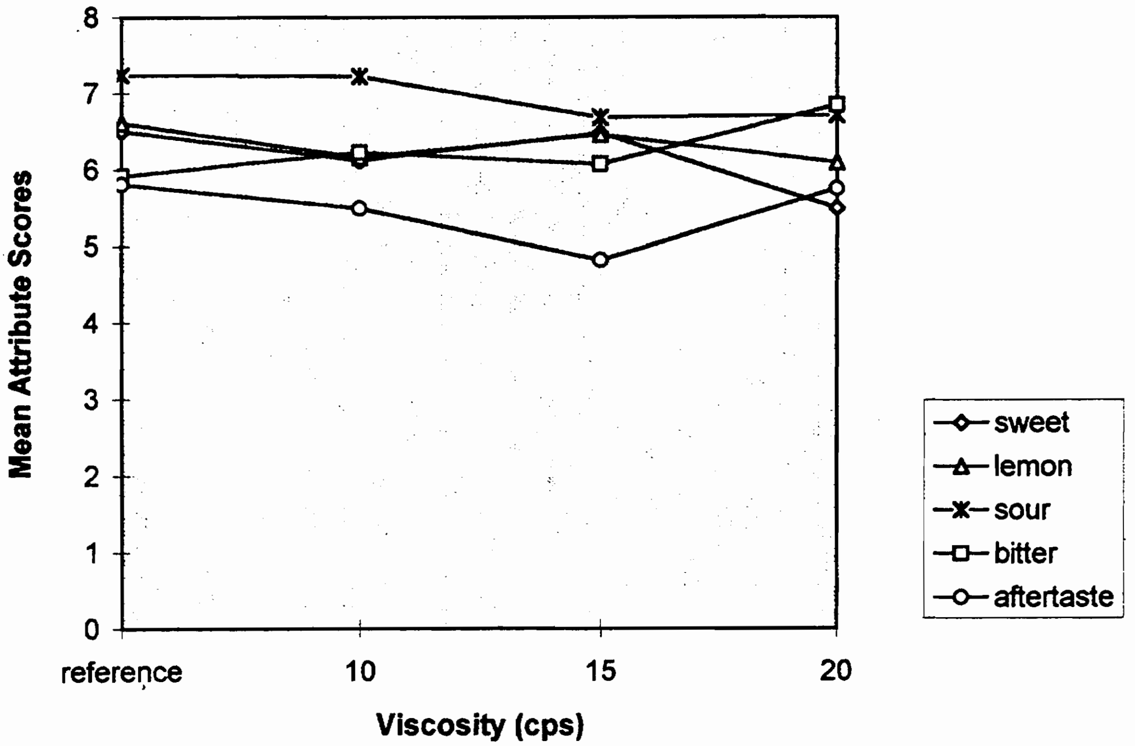

Figure 9: Effects of xanthan gum at different usage levels on the attributes of the samples sweetened with Sweet One®. 0=lack of attribute<8<15=intense attribute.

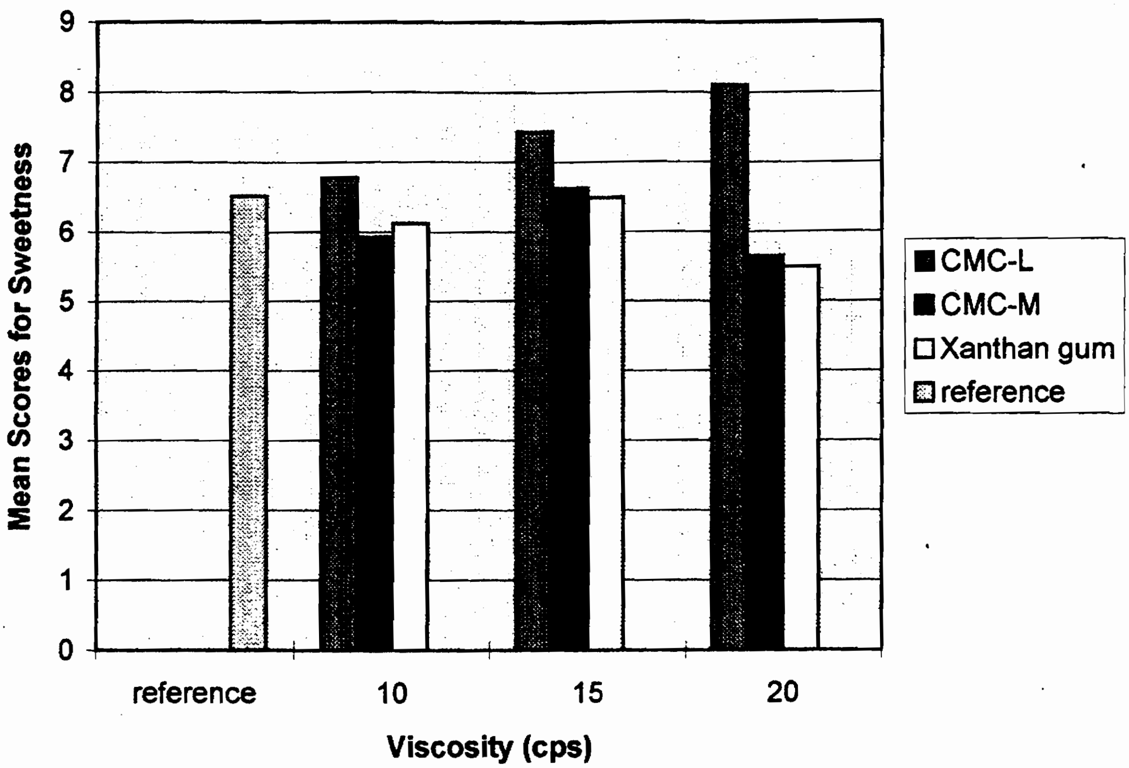

Figure 10: A comparison of the mean sweetness scores for the samples sweetened with Sweet One®. 0=no sweetness<9<15=intense sweetness.

The mean scores for lemon flavor are shown in Figure 11. Lemon flavor tended to be depressed by the addition of CMC-L and CMC-M, although only the lemon flavor of the samples having a viscosity of 20 cps was significantly depressed compared to the reference. When comparing samples of the same viscosity level, the CMC-L samples tended to have less lemon flavor than their counterparts containing CMC-M. Xanthan gum did not have a significant effect on lemon flavor compared to the reference.

The mean sourness scores for the samples are shown in Figure 12. CMC-L significantly depressed sourness, CMC-M tended to depress sourness, and xanthan gum did not affect sourness compared to the reference. When comparing samples of the same viscosity level, the CMC-L samples having viscosities of 15 and 20 cps were significantly less sour than their counterparts containing CMC-M. All of the samples containing xanthan gum were significantly more sour than the CMC-L samples having viscosity levels of 15 and 20 cps and the CMC-M sample with a viscosity level of 20 cps. A significant contrast effect was found for sourness indicating that increasing levels of the hydrocolloids affected sourness in different ways.

The addition of hydrocolloids did not significantly affect the bitterness or aftertaste of the samples.

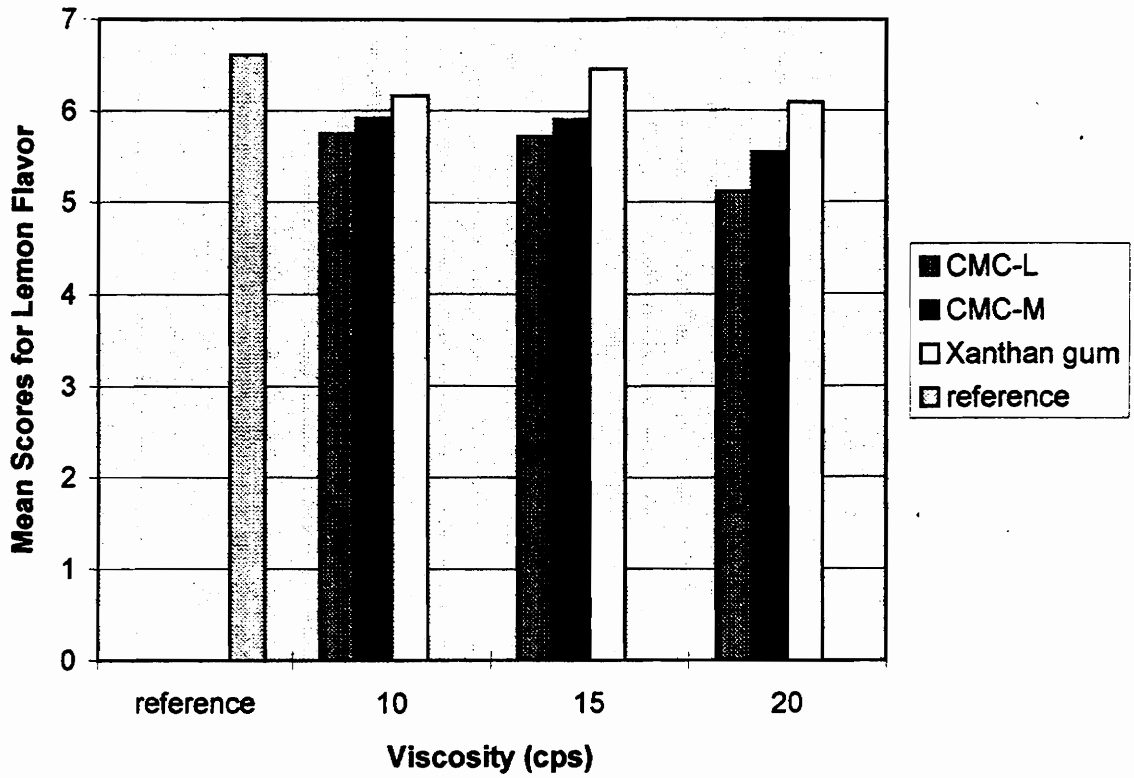

Figure 11: A comparison of the mean lemon flavor scores for the samples sweetened with Sweet One®. 0=no lemon flavor<7<15=intense lemon flavor.

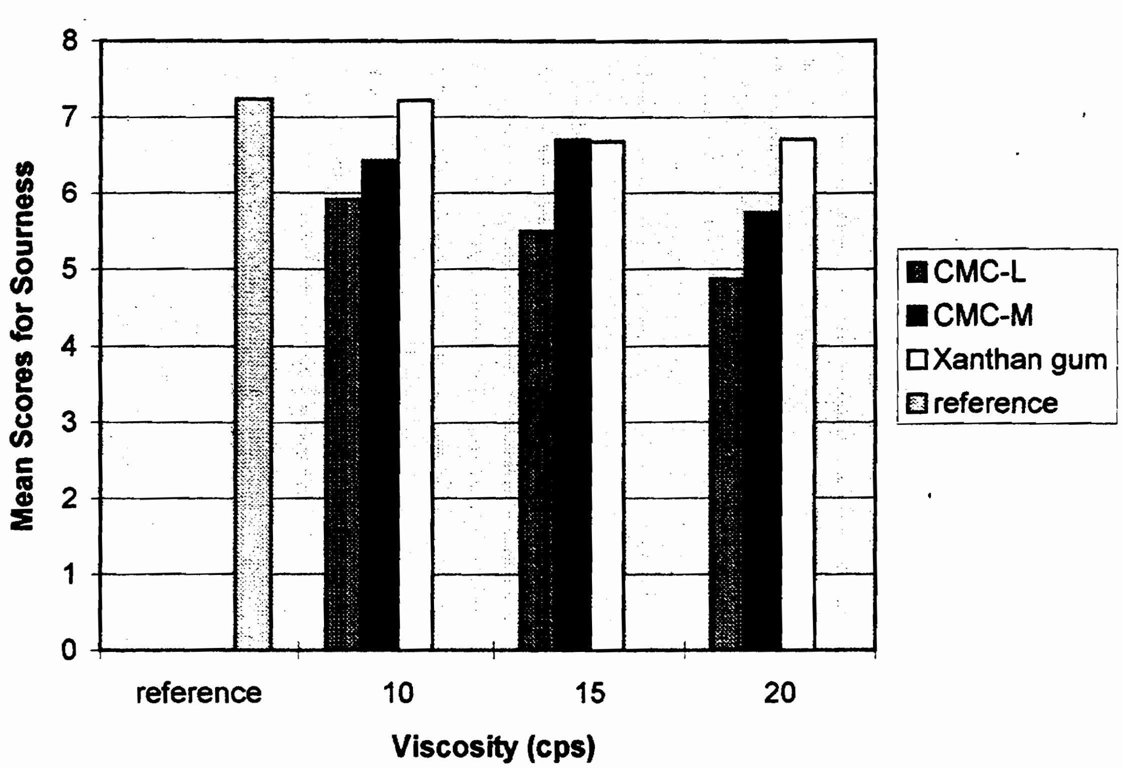

Figure 12: A comparison of the mean sourness scores for the samples sweetened with Sweet One®. 0=no lemon flavor<8<15=intense lemon flavor.

Comparison of the Samples Sweetened with Equal® and Sweet One®

Although equisweet concentrations of the gums were not used, a comparison of how the hydrocolloids affected the attributes of the drink samples with different sweeteners will be briefly discussed.

Sweetness

The addition of carboxymethylcellulose-low added to attain a viscosity level of 10 cps significantly depressed the sweetness of the beverage containing Equal ® but increasing viscosities increased sweetness. When added to the beverage containing Sweet One®, CMC-L increased sweetness with increased viscosity. Carboxymethylcellulose-medium and xanthan gum tended to have the same effect on the sweetness of each sweetener. In the samples containing Equal®, xanthan gum significantly depressed the sweetness of all of the samples whereas CMC-M significantly depressed the sweetness of the samples having viscosities of 10 and 20 cps. Although not significant, the sweetness of the sample containing CMC-M at a viscosity level of 15 cps was depressed. Carboxymethylcellulose-medium and xanthan gum both did not significantly affect the sweetness of Sweet One®; in both cases, increasing viscosity produced by each hydrocolloids first decreased sweetness, then increased sweetness, and then decreased sweetness.

Lemon Flavor

Xanthan gum did not significantly affect the lemon flavor in the samples with either sweetener. Carboxymethylcellulose-medium and CMC-L significantly depressed the lemon flavor of all the samples sweetened with Equal®. In the samples sweetened with Sweet One®, CMC-L and CMC-M tended to depress lemon flavor; at a viscosity level of 20 cps, lemon flavor was significantly depressed by each hydrocolloid. Carboxymethylcellulose-low had a greater depressing effect than CMC-M on the lemon flavor of the samples with both sweeteners.

Sourness

Xanthan gum did not significantly affect the sourness of the samples containing Equal® or Sweet One®. The sourness of the samples sweetened Equal® or Sweet One® were depressed by the addition of CMC-L. Carboxymethylcellulose-medium significantly depressed the sourness in all of the samples sweetened with Equal®, but with Sweet One® only the sample having a viscosity of 20 cps was significantly depressed compared to the standard.

Bitterness

None of the hydrocolloids had a significant effect the on the bitterness of the samples sweetened with Equal® or Sweet One®.

Aftertaste

Aftertaste in the samples containing Equal® and Sweet One® was not significantly affected by the addition of the hydrocolloids.

CHAPTER 5
DISCUSSION

This study investigated the effects of hydrocolloids on the taste perception of a lemon flavored beverage sweetened with an artificial sweetener. Two artificial sweeteners were examined in this study, aspartame in the form of Equal ® and acesulfame-K in the form of Sweet One®.

A reference solution was made with each sweetener. Originally, it was desired that both reference samples would have a "medium" sweetness level and would be perceived to have intensity scores of approximately 7.5. The reference sample containing Equal® (sweetness intensity score = 7.67) was sweeter than the reference sample containing Sweet One® (sweetness intensity score = 6.51). A lower amount of Sweet One® was used since the panelists found it difficult to detect the different attributes with higher amounts of Sweet One®. This was caused by the intense bitterness which was perceived with higher levels of Sweet One®. Although the same amount of unsweetened lemonade dry mix was used to prepare the two reference samples, lemon flavor and sourness were not perceived have the same intensities in the two references. In the reference sample containing Equal®, lemon flavor was perceived to be more intense than the lemon flavor of the reference sample containing Sweet One®. One the other hand, sourness was perceived to be more intense in the reference sample containing Sweet One®. Research has indicated that aspartame increases the intensity of fruit flavors, which may relate to the more intense lemon flavor of the reference sample made with Equal® (Matysiak and Noble, 1991). Sourness may have been more intense in the reference sample made with Sweet One® because of the less intense sweetness and lemon flavor. Bitterness and aftertaste were both perceived to be higher in the reference sample containing Sweet One®. Acesulfame-K has been noted to have a bitter aftertaste (Sardesai and Waldshan, 1991).

Effect of Hydrocolloids on Taste Perception

This study, in addition to past research, found that viscosity itself does not necessarily affect flavor compounds in a specific manner (Christensen, 1980; Pangborn *et al.*, 1978). Instead, the effect of a viscosity producing agent on the intensity of a taste attribute appears to be specific to the taste compound, the viscosity producing agent, and the concentration of the viscosity producing agent.

Two types of CMC were used in this study- CMC-L and CMC-M. The difference between these two forms is their polymer length; with CMC-M longer than CMC-L. As a result of the differences in polymer length, a greater amount of CMC-L is needed compared to CMC-M to bring a solution to particular viscosity (Keller, 1984). CMC-M and CMC-L had differing effects on the attributes of the lemon flavored beverages. Generally, increased amounts of CMC-L tended to increase the sweetening effect of both Sweet One® and Equal® (after the sweetness initially decreased in Equal® sweetened samples), whereas CMC-M tended to depress the sweetness of Equal® and had a nonsignificant but variable effect on the sweetness of Sweet One® with increased concentrations. Christensen (1980) found that the sweetness of a sucrose solution was maintained by the addition of CMC-L whereas when CMC-M was added to bring about the same viscosity level, CMC-M tended to depress the sweetness. The author noted that this may have been caused by the greater amount of CMC-L needed to bring about the same viscosity as compared to CMC-M. CMC contains sodium which has been reported to have a taste-enhancing property; since more sodium would be present with greater amounts of CMC, the taste enhancing property would be stronger. Pangborn *et al.* (1973) found that both types of CMC decreased the sweetness of sucrose whereas CMC increased the sweetness of saccharine in a range of visocities similar to those used in this study. The authors did not report whether CMC-L or CMC-M had a greater effect on the sweetness of these compounds. In a study done with an orange flavored drink, CMC-L depressed the sweetness of the beverage whereas CMC-M did not (Pangborn *et al.*, 1978). These results are opposite to those found in this study, but the orange flavored beverages were most likely sweetened with sucrose, not an artificial sweetener. CMC-L and CMC-M both generally tended to decrease the intensity of lemon flavor and sourness in the samples containing each sweetener. CMC-L had a greater depressing effect on both sourness and lemon flavor than CMC-M. In the study with the orange flavored drink, CMC-M and CMC-L also depressed sourness and (orange) flavor. Both of these attributes in the orange drink were also reduced more by CMC-L than CMC-M (Pangborn, 1978). Bitterness and aftertaste were not significantly affected by the addition of the hydrocolloids in the samples with either sweetener. These attributes did not show a steady pattern of increasing or decreasing with increased viscosity. It might be expected that an attribute would either increase, decrease, or remain unchanged with increasing viscosity. The panelists perception of bitterness and aftertaste may have been influenced by factors which may have not allowed for a clear perception of these attributes. Since a bitter-like aftertaste has been reported for both acesulfame-K and aspartame (Redlinger and Setser, 1987), it may have been difficult for the panelists to differentiate between bitterness and aftertaste. In addition, the panelists may have had different sensitivities to bitterness or the aftertastes produced by the artificial sweeteners.

There are many theories as to why the two forms of CMC differentially affect taste attributes. The different polymer lengths might allow for the formation of matrixes which affect the rate of movement of taste molecules differently. Polymer length might also determine if CMC interacts with the receptor as a surfactant (Christensen, 1980). The different rheological behaviors of the two CMC forms might also be a reason each affects taste perception differently. Rheological behavior will be discussed below.

Xanthan gum was the other hydrocolloid used to impart viscosity. Like CMC, the backbone of xanthan gum consists of beta-glucose units which form cellulose, but differs from CMC in the structure of the side chains. Xanthan gum tended to affect sweetness in the same manner as CMC-M. Xanthan gum significantly depressed the sweetness of Equal®, whereas it had a nonsignificant "depressing, increasing, depressing" effect on the sweetness of Sweet One® with increased concentrations. Xanthan gum did not have a significant effect on the sourness or lemon flavor of the beverages with either sweetener. In the study discussed above with the orange drink (Pangborn *et al.*, 1978), xanthan gum had a greater decreasing effect on (orange) flavor and sweetness than CMC-L and CMC-M and less of a decreasing effect on sourness than CMC-L and CMC-M (Pangborn, 1978). In this study, xanthan gum did have more of a depressing effect on sweetness and less of an effect on sourness than CMC-L and CMC-M. Lemon flavor, though, was affected less by the addition of xanthan gum as compared to CMC-L and CMC-M. Bitterness and aftertaste were not significantly affected by the addition of xanthan gum. As with the CMC solutions, bitterness and aftertaste did not follow a pattern of increasing or decreasing with increased viscosity.

There have been many theories as to why taste is affected by viscosity imparting agents. It is thought that the intensity of a taste compound is proportional to the rates of the reactions which occur when a taste compound comes into contact with the taste buds. As soon as a taste compound reaches the taste buds, it will quickly react. One theory is that viscosity producing agents affect the rate of diffusion of the taste compounds to the tongue (Cussler *et al.*, 1979). Another theory is that there are physical-chemical interactions between a viscosity imparting agent and a taste compound which changes the diffusion rate or the accessibility of the compound to the taste receptors (Christensen, 1980)

Rheology may also be a factor as to why hydrocolloids affect taste compounds differently. As stated previously, a solution containing CMC-L has Newtonian behavior, a solution containing CMC-M has pseudoplastic behavior, and a solution containing xanthan gum has bingham behavior at the viscosity levels tested in this study. Generally, this indicates that a solution thickened with CMC-L will stay at the same viscosity with increasing shear whereas solutions thickened with CMC-M or xanthan gum will decrease in viscosity with increasing shear. Solutions containing hydrocolloids differ in their behaviors with increasing shear because of the matrix the hydrocolloid polymers form in solution and the way the polymers react to increasing shear. The manner in which different hydrocolloid polymers react to shear and therefore influence the movement of other compounds could possibly affect the rate of diffusion of taste compounds to the tongue surface.

In sensory testing, solutions containing hydrocolloids which change viscosity with changes in shear rate might cause variability in responses. In the mouth, shear is caused by the tongue. Research has found that individuals differ in the shear they apply to solutions and that the same individual at different times might apply different amounts of shear to solutions (Christensen, 1984). Also, it is possible that individuals apply different amounts of shear to solutions with different viscosities. Therefore, on a sensory panel, panelists may be applying different shear rates to a solution. For a particular non-Newtonian solution, this means that not all panelists are evaluating the solution at the same viscosity in the mouth. Since viscosity level influences the taste perception of certain compounds, panelists may be perceiving the intensity of compounds differently. Since the amount in which individuals differ in tongue shear rate is unknown, the importance of interpersonal variation is not known. In this study, this may have been a factor in the evaluation of the samples containing CMC-M and xanthan gum.

CHAPTER 6
CONCLUSIONS

The effect of viscosity imparted by xanthan gum, CMC-L, and CMC-M on the taste perception of lemon flavored beverages sweetened with either Equal® or Sweet One® was studied using a modified quantitative descriptive analysis sensory evaluation technique. The results indicated that viscosity itself does not affect taste perception, but that at a certain viscosity level, both the viscosity imparting agent and the taste compound influence the manner in which taste perception is altered.

Sweetness intensity was affected differently by the three hydrocolloids. Xanthan gum significantly decreased sweetness intensity in the samples sweetened with Equal® but did not affect the sweetness intensity of the samples sweetened with Sweet One®. CMC-L increased the sweetness intensity of the samples sweetened with Sweet One®. In the samples sweetened with Equal®, sweetness significantly decreased before increasing with increasing viscosity. CMC-M did not significantly affect the sweetness of either sweetener although it tended to decrease the sweetness of Equal®.

The different hydrocolloids also affected the intensity of the other beverage attributes in different ways. Xanthan gum did not significantly affect lemon flavor, sourness, bitterness, or aftertaste. CMC-L and CMC-M both decreased lemon flavor and sourness in the samples with both sweeteners. CMC-L decreased these attributes more than CMC-M. Bitterness and aftertaste were not significantly affected in any of the samples.

Implications of these results are that, during development of an artificially sweetened beverage containing a hydrocolloid, formulation changes may be needed to adjust the attributes to their desired intensity. Of the three hydrocolloids examined in this study, xanthan gum affected the beverages the least. Therefore, in the development of an artificial sweetened beverage, xanthan gum may be a better choice to impart body rather than CMC-L or CMC-M. Hydrocolloids are also used at times to mask the undesirable qualities of artificial sweeteners, such as bitterness or aftertaste (Glicksman and Farkas, 1966). This study found that none of the hydrocolloids examined masked bitterness or aftertaste in the samples. Therefore, in order to mask these attributes, other hydrocolloids would need to be examined.

Further research is needed to determine the mechanisms by which hydrocolloids affect taste perception, and why different hydrocolloids affect taste perception differently. This might be partially accomplished by examining the behavior of the hydrocolloid polymers in solution: what secondary and tertiary structures do they form in solution, what type of matrix do the polymers form, do the polymers form bonds with other compounds which are present, and how are they disrupted by shear rate. It might also be valuable to examine how hydrocolloids are affected by the presence of ionic compounds, such as some artificial sweeteners, and different pH levels.

In addition, for evaluation of non-Newtonian solutions, further understanding of how individuals manipulate liquids with their tongues might allow for more accurate results in sensory testing. Perhaps with further research a procedure can be developed so that individuals can apply the same shear to solutions during sensory testing.

Additional research is also needed to improve the perception of artificial sweeteners. Both the samples with Equal® and Sweet One® were found to have an aftertaste and bitter components.

Under the conditions of this study, the following recommendations are made:

1. Pseudoplastic or bingham hydrocolloids should be used rather than Newtonian hydrocolloids to preserve the attributes and overall flavor of a beverage.
2. Hydrocolloids should not be used to mask bitterness or aftertaste.
3. Beverages containing different concentrations of a hydrocolloid may have different attribute intensities. Therefore, different levels of a hydrocolloid may need to be examined to determine which contributes to the best flavor profile.

CHAPTER 7
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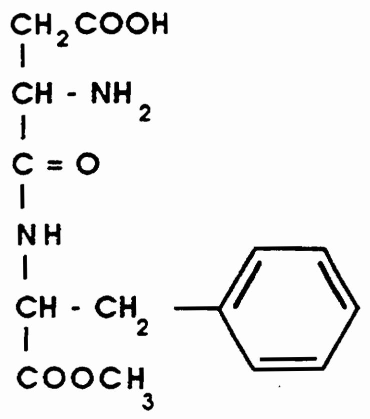
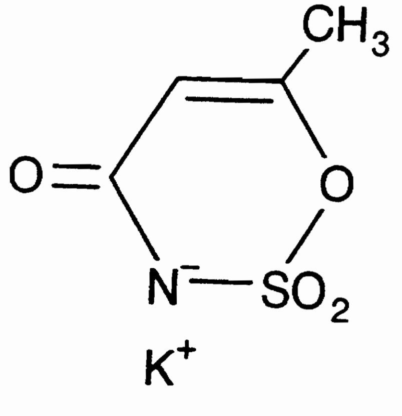
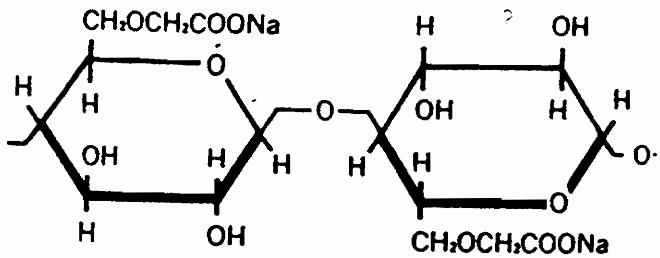
Appendix A
Structures



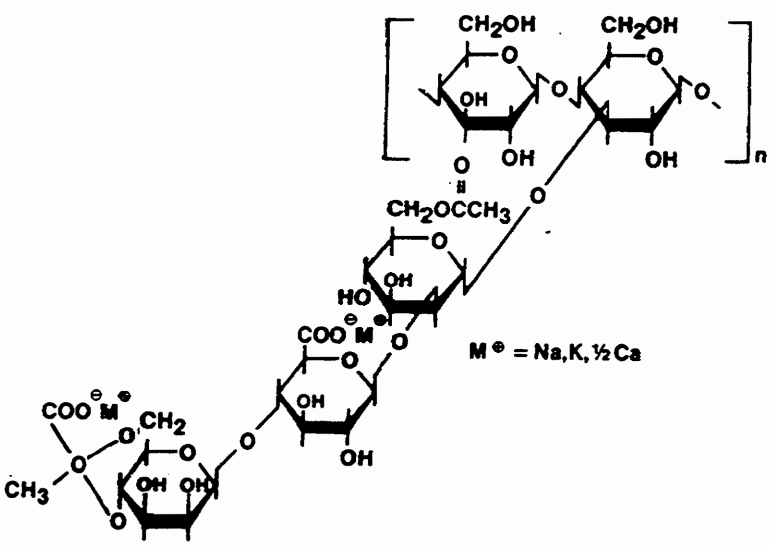
ASPARTAME



ACESULFAME-K



CARBOXYMETHYLCELLULOSE



XANTHAN GUM

Appendix B
Experimental Design

Experimental Design for Evaluating the Effects of Viscosity Imparted by Hydrocolloids on the Sweetness Intensity of Artificial Sweeteners

	Hydrocolloid		
viscosity	CMC-L	CMC-M	Xanthan
10 cps			
15 cps			
20 cps			

Sweetening Agent
Equal® (with aspartame) or Sweet One® (with acesulfame-K)

Appendix C
Schedule of Research

Group A = samples sweetened with Equal®

		SAMPLES					
week 1	Session 1	1	2	4	5	7	8
	Session 2	2	3	5	6	8	9
	Session 3	1	3	4	6	7	9
week 2	Session 1	1	2	5	6	7	9
	Session 2	1	3	4	5	8	9
	Season 3	2	3	4	6	7	8
week 3	Session 1	1	3	5	6	7	8
	Session 2	1	2	4	6	7	9
	Session 3	2	3	4	5	7	9
week 4	Session 1	4	5	6	7	8	9
	Session 2	1	2	3	4	5	6
	Session 3	1	2	3	7	8	9

Group B = samples sweetened with Sweet One®

		SAMPLES					
week 5	Session 1	1	2	4	5	7	8
	Session 2	2	3	5	6	8	9
	Session 3	1	3	4	6	7	9
week 6	Session 1	1	2	5	6	7	9
	Session 2	1	3	4	5	8	9
	Season 3	2	3	4	6	7	8
week 7	Session 1	1	3	5	6	7	8
	Session 2	1	2	4	6	7	9
	Session 3	2	3	4	5	7	9
week 8	Session 1	4	5	6	7	8	9
	Session 2	1	2	3	4	5	6
	Session 3	1	2	3	7	8	9

* Incomplete block design from Cochran, W.G. and Cox, G.M. 1957. Experimental Designs, John Wiley & Sons, New York, p. 474

SAMPLES

Group A=Equal®

	Hydrocolloid	Viscosity (cps)
1	CMC-L	10
2	CMC-L	15
3	CMC-L	20
4	CMC-M	10
5	CMC-M	15
6	CMC-M	20
7	Xanthan	10
8	Xanthan	15
9	Xanthan	20

Group B = Sweet One®

	Hydrocolloid	Viscosity (cps)
1	CMC-L	10
2	CMC-L	15
3	CMC-L	20
4	CMC-M	10
5	CMC-M	15
6	CMC-M	20
7	Xanthan	10
8	Xanthan	15
9	Xanthan	20

Appendix D
Formulation and Preparation of Samples

Samples were prepared with lemonade flavored Kool-aid® unsweetened powder, double distilled water at room temperature (22-24° C), Equal® or Sweet One® sweetener, and either xanthan gum, carboxymethylcellulose-Low, or carboxymethylcellulose-Medium. The formulation and mixing procedures used to prepare the samples were as follows:

Per 400 ml double distilled water:

Ingredient	Grams
Powdered drink mix	.844
Artificial sweetener (one sweetener)	
Equal®	3.6
Sweet One®	3.2
Hydrocolloid (one hydrocolloid)	
CMC-L (10 cps)	.71
CMC-L (15 cps)	1.9
CMC-L (20 cps)	3.2
CMC-M (10 cps)	.403
CMC-M (15 cps)	.8
CMC-M (20 cps)	1.07
Xanthan (10 cps)	.07
Xanthan (15 cps)	.15
Xanthan (20 cps)	.24

Mixing procedures:

1. The powdered drink mix, artificial sweetener, and hydrocolloid were weighed out using a Mettler analytical scale (model AE 166, Princeton, NJ).

2. Approximately 350 ml of double distilled water at room temperature (22-24° C) was added to a beaker. A stir bar was put in the water and the beaker was placed on a stir plate at high speed. The combined drink mix, sweetener, and hydrocolloid was slowly added to the water.

3. After all of the dry mixture is added to the water, the volume was brought up to 400 ml.

3. The viscosity of the solution was measured with the Brookfield viscometer (Stoughton, MA). Spindle 1 at 50 rpm was used. The viscosity was rechecked every hour during testing to ensure that no changes in viscosity occur.

Appendix E
Example of the Scorecard

Panelist Number __________

Sample Number __________

A sample is given as a reference. When tasting the reference, take a sip of the sample, make sure it contacts all parts of your mouth, and then swallow. Please indicate the intensity of the different attributes for the reference by making a vertical line where you feel it is appropriate and label it with "r".

Please take a sip of the sample, make sure it contacts all parts of your mouth, and then swallow. Please indicate the intensity of the different attributes for the sample by making a vertical line where you feel it is appropriate.

Between tasting each sample, take a bite of cracker and rinse with water.

not sweet — very sweet

no lemon flavor — intense lemon flavor

not sour — very sour

not bitter — very bitter

no aftertaste — intense aftertaste

comments:

VITA

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