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THE ROLE OF MOLECULAR SIZES OF CARBOHYDRATES ON MOUTH SENSATIONS.

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THE ROLE OF MOLECULAR SIZES OF CARBOHYDRATES ON MOUTH SENSATIONS

by

Sarah Frances Stallings

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Approved by

Albert C [illegible]

Joan P. Cassilly

Dissertation Co-Advisors

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro.

Dissertation Co-Advisors: Albert E. Purvey

Joan P. Cassilly

Committee Members: Helen C. Magee

William A. Powers

Mildred B. Johnson

December 13, 1977

Date of Acceptance by Committee

ABSTRACT

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The effects of addition to sweet potatoes of varying amounts of dextrin, glucose, maltose, and starch on mouth sensations, apparent viscosity, and static yield were tested. Sensory evaluations were conducted a minimum of four times on each sweet potato-carbohydrate mixture, and mixtures were objectively evaluated by a Brookfield viscosimeter for static yield and a Haake Rotovisco Model RV-1 Viscometer for apparent viscosity. A two-way analysis of variance was used to test for differences between mean sensory panel ranks, static yield values, and apparent viscosity values of different sweet potato mixtures. A regression technique was used to determine whether linear, quadratic, or cubic effects were found with increasing amounts of carbohydrates.

To further test the effects of variations in starch, maltose, and dextrin on apparent viscosity and static yield, a model system approximating the protein, carbohydrate, fat, and water composition of a cured, uncooked sweet potato was prepared. Nine variations of the model system were made in which the dextrin, starch, and maltose content were varied; all other components remained constant. Mean static yield and apparent viscosity values were tested as a function of quantity of starch, maltose, and dextrin.

Increasing quantities of corn starch added to sweet potatoes significantly increased the dry mouthfeel characteristics and decreased apparent viscosity and static yield. No significant differences were found between increasing quantities of maltose and mouthfeel, apparent viscosity, or static yield. No significant differences were found between increasing quantities of dextrin or glucose in baked sweet potatoes and mouthfeel characteristics or apparent viscosity. As dextrin increased, static yield significantly decreased, and as glucose increased, static yield significantly increased at first and then decreased. Increasing quantities of sweet potato starch added to baked sweet potatoes which were subsequently heated significantly affected the mouthfeel characteristics, apparent viscosity, and static yield. Moist mouthfeel characteristics significantly increased at first and then decreased; apparent viscosity and static yield increased and then decreased.

Starch was the primary carbohydrate component which exerted an influence on apparent viscosity and static yield in the model system and variations. As starch decreased, with either increases of maltose or dextrin, the apparent viscosity and static yield decreased.

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CHAPTER I

INTRODUCTION

Factors which determine the acceptance or rejection of foods include color, taste, odor, and texture. Research within the past 15 years has focused on the importance of mouthfeel, a textural property, on the acceptability of certain high carbohydrate foods (Szczesniak & Farkas, 1962; Stone & Oliver, 1966). Mouthfeel, as defined in the Sensory Testing Guide (1964), is the "mingled experience deriving from the sensations of the skin in the mouth during and/or after ingestion of a food or beverage." Total mouthfeel is related to the density, viscosity, surface tension, and other physical properties of the sampled material.

Szczesniak and Farkas (1962) reported a correlation between mouthfeel and the rheological properties of a number of gum solutions. These investigators could predict mouthfeel characteristics from objective measures of viscosity and rate of shear made on solutions. It has also been demonstrated (Mackey & Valassi, 1956) that thresholds for the four basic tastes are affected by different food textures.

Textural characteristics of cooked sweet potatoes have been used as a method of classification. The Food Buyer's Information Book (Todoroff, 1950) denotes two types of sweet potatoes: the dry type which is mealy and pasty when cooked and the moist or "yam" type which becomes soft, watery, and syrupy when cooked. The moist and dry mouthfeel characteristics of sweet potatoes as determined by sensory panels have been studied and correlated with objectively measured rheological properties (Rao, Hamann, & Humphries, 1975; Nelson, 1973). Most of the studies have concluded that the moist mouthfeel becomes apparent as a result of breakdown of starch into smaller molecular units during curing and cooking of the potatoes (Nelson, 1973; Sistrunk, Miller, & Jones, 1954; Jenkins & Geiger, 1957). Starch and its degradation products play a major role in determining the texture of many other foods (Osman, 1967). Methods to control the rate and extent of starch degradation during sweet potato processing to produce the desired textural characteristics have been studied (Scruggs, 1975; Deobald, McLemore, Hasling, & Catalano, 1968; Hoover & Harmon, 1967). Lohmar, Weakley, and Lauterbach (1956) developed a controlled degradation of waxy-corn starch by alpha-amylase in order to obtain dextrins for use in fractionation of human blood. These investigators suggested that, within limits, it is possible to preselect conditions of starch conversion to lead to desired products.

The steps in the degradation of starch are well documented. Dextrins, a class of polysaccharides with widely varying physical properties, maltose, a disaccharide, and the monosaccharide, glucose, result from the hydrolytic breakdown of starch (Lohmar et al., 1956). As starch is progressively broken down in certain foods, the texture becomes softer, the viscosity decreases, and the mouthfeel becomes more moist. The specific components reponsible for these changes have not been well documented.

The exact role of starch and its conversion products on textural features of cooked sweet potatoes and other foods has not been defined. Further research would be important to food processors. If the carbohydrates which influence the moist mouthfeel could be identified, processors could adjust their curing, canning, or freezing procedures to modify mouthfeel characteristics and thus produce a more acceptable product. Research in this area may have implications for those who process other high starch products such as pumpkin, squash, and white potatoes.

Sweet potatoes were selected for use in the present study because carbohydrate changes during curing and conversion are well documented (Jenkins & Geiger, 1957; Sistrunk et al., 1954), because of their economic impact in certain states (Taylor & Hamilton, 1962; Kushman, 1967), and because of the influence of mouthfeel on consumer acceptability (Edmond & Ammerman, 1971).

The objectives of the present study were:

1. To determine if small molecular weight dextrins, as well as maltose and glucose, act as lubricants for starches to give a more moist mouthfeel to high starch foods.
2. To construct a model sweet potato system based on the carbohydrate, fat, protein, and moisture content of a cured, uncooked sweet potato, and to determine the effects of variations in starch, dextrin, and maltose content on apparent viscosity and static yield.

CHAPTER II

REVIEW OF LITERATURE

Carbohydrates include a diverse group of compounds which vary in molecular weight from 90 for triose sugars to over 4,000,000 for certain starches and fibers. The major carbohydrates important to the food industry include starches, dextrins, maltose, glucose, fructose, and sucrose. According to Commerford and Scallet (1965), the inherent properties of man-made or naturally occurring carbohydrate materials containing oligosaccharides or polysaccharides are at least partially dependent upon the properties of the individual sugars composing them.

Chemical, Physical, and Sensory Properties of Starches

Due to structure and molecular size, various starches have been used to perform a variety of functions in foods; these functions include: thickening, colloid stabilization, moisture-retention, gel-formation, coating, and glazing (Schock, 1969). Food technologists are most interested in the colloidal properties of a particular starch in an aqueous dispersion. Of these properties, the following are the most important: sol clarity, organoleptic characteristics, viscosity, color, flow characteristics, gel and adhesive strength, and film properties (Waldt & Kehoe, 1959).

Over a century ago, Nageli (1865) found that potato and wheat starches were affected differently by certain chemicals. Since then, several researchers have compared some of the physical properties of different starches. The importance of these differences in physical properties of starches relative to their practical application is well recognized. Today the variety of natural starches available has been augmented by many chemically modified starches which have diverse characteristics and uses.

Until 1958, recorded data on certain properties of starches of importance in food products, such as gel strength and cold-paste viscosity, were sparse. Prior to that time, the choice of a starch for use in a particular food was based primarily on tradition. In 1911, Harrison found a relation between viscosity and the degree of swelling of starch granules. Woodruff and Nicoli (1931) found that five percent pastes of corn, wheat, rice, potato, arrowroot, and cassava starches failed to form gels unless they were heated above 90^{o}C. Cassava did not gel when heated to 99.5^{o}C. Knowles and Harris (1943) concluded that gel strength and viscosity were two distinct and different properties.

Osman and Mootse (1958) suggested that a more complete characterization of various food starches according to their behavior during food preparation was essential if the behavior of starch-thickened food products was to be understood. These investigators studied how the extent of cooking affected a number of properties of starch pastes and reported that there were great differences in the concentration of various starches and flours required to produce the same maximum hot paste viscosity and also variations in the way in which different starch pastes responded to cooking beyond a point. If waxy rice starch were cooked 20 minutes beyond attainment of maximum viscosity there was little effect; however, if sago starch (and others) were cooked to the same extent there was considerable effect. The degree of "set-back" after three minutes of cooking beyond maximum viscosity varied with the type of starch.

It has now been well established that the inherent physical properties of any native raw starch are principally dependent on its genetic origin which determines the granule size, amylose-amylopectin ratio, and the molecular weight of the amylose and amylopectin polymers (Waldt & Kehoe, 1959). Starch occurs in the form of white granules which are usually made up of an organized structure containing both a linear polymer of glucose (amylose) and a branched chain polymer of glucose (amylopectin). All varieties of starch are composed almost entirely of polysaccharides yielding glucose on acid hydrolysis (Meyer, Bernfeld, Boissonnas, Gurtler & Noelting, 1949). Starches are insoluble in cold water and relatively resistant to naturally occurring hydrolytic agents. The linear polymer and the longer branches of the nonlinear polymer exhibit a tendency to associate with other linear molecules.

Amylose comprises approximately 17-27 percent of common starches such as corn, wheat, potato, and tapioca. There are textural differences between gels formed from longer and shorter chained amylose because orientation and association are more difficult in the longer chains. The degree of polymer association also explains the difference in gelatinization temperatures of different types of starch. Amylose has a strong tendency to form insoluble complexes with fatty acids or monoglycerides; amylopectins, however, have no affinity for lipids (Longley & Miller, 1971). Waxy starches which are entirely amylopectin form pastes that are clear and highly viscous, but they do not gel unless used in very high concentrations (30 percent). They are used when high viscosity without gel formation is needed, for example in pie fillings and salad dressings.

Attempts have been made to relate hot-paste viscosity curves to other starch properties. Campbell and Briant (1957) observed that pastes prepared from smaller granules of starch from a certain botanical species have a higher viscosity than those prepared from larger granules. The interpretation of Katz (1938) of the hot-paste viscosity curve has been widely accepted. The investigator interpreted it as an overlapping of two curves, one caused by the progressive swelling of starch granules and the other by their breaking down. Katz (1938) further suggested that in samples cooked 20 minutes beyond the point at which maximum viscosity was reached, the intermolecular bonding had been destroyed to a considerable degree. Factors such as the ratio of amylose to amylopectin and size of the amylose were suggested as being of minor importance in comparison with bonding within granules in determining the characteristics of many starch pastes. Osman and Mootse (1958) concluded that after prolonged cooking the cold-paste viscosity of the unmodified starches appeared to depend more on concentration than on the botanical source of the starch. With shorter cooking times, no similarities between various starches were observed.

Medcalf and Gilles (1965) studied the properties of starches from 17 varieties of wheat in which the percent of amylose in the starches varied from 23.4 to 27.6. These investigators found that starches from durum wheat had the highest amylose, larger water-binding capacity, greater iodine absorption, and lower temperature of initial pasting. Dahle (1971) studied the starch-binding effects of wheat flour proteins and found that the association of gelatinized wheat starch and wheat protein occurs at acidic and neutral pH but diminishes at alkaline pH. Heat was found to modify the proteins and cause denaturation which resulted in the loss of starch-binding properties and affected viscosity.

Greenwood (1964) stated that the most important characteristic of a starch dispersion was its viscosity; the researcher reported that when starch was cooked to 95°C, held at that temperature for one hour, cooled to 50°C, and then held one hour, each starch exhibited a characteristic curve. Tapioca starch was shown to swell readily and give a high peak viscosity, but the granules were so fragile that an extensively decreased viscosity resulted. Cereal starches produced more restricted swelling and a lower peak viscosity; there was a pronounced increase in viscosity on cooling. The cross-bonded waxy sorghum gave no peak viscosity, and there was little evidence of granular breakdown.

Ott and Hester (1965) studied the amount of soluble amylose needed for gel structure in relation to degree of granule swelling and the size of the hydrated starch granule. These investigators reported that the amount of amylose needed for gels of equal strength was approximately three times greater in the absence of amylopectin granules than in the presence of well hydrated and intact granules. The role of amylose in forming gels was suggested as being the chief material forming the gel network which entraps unabsorbed water and as the binding material linking together the intact starch granules and fragments. Ott and Hester (1965) further stated that, with other factors being equal, the degree of hydration of the starch granules and the size of the swollen particles appeared to determine the amount of amylose needed for a firm gel structure.

In the past, much of the research on starch has focused on the textural features which are imparted to processed and/or fabricated foods. Reeve (1954) stated that more information was needed on the role of starch in determining the texture of certain naturally occurring foods such as potatoes.

Bettelheim and Sterling (1955b) noted that specific gravity and starch content were significantly correlated with organoleptic textural scores of cooked potatoes. These investigators concluded that the swelling of the gelatinized starch granules was a major factor which tended to cause rounding off of cells and cell separation and was, therefore, responsible for potato texture. No relationship was found between the chemical nature (amylose content) of the starch and potato texture.

Walter, Purcell, and Nelson (1975) showed that the amount of starch remaining after baking sweet potatoes was related to mouthfeel characteristics perceived by sensory panels and objective measures of intrinsic viscosity. These investigators suggested that the extent of conversion of starch to dextrins and maltose was related to the increase in the desirable moist mouthfeel characteristic.

Kuhn, Desrosier and Ammerman (1959) noted that the quality of potatoes is judged primarily by the texture of the cooked tuber. White potatoes which have been baked should preferably have a moderately dry to dry, mealy texture. They suggested that more knowledge of the molecular structure and size of starch was needed before the relation of starch and texture could be explained.

Chemical, Physical, and Sensory Properties of Other Carbohydrates

The physical, chemical, and sensory properties of various molecular sizes of carbohydrate have been studied. Johnson and Srisuthep (1975) reported the physical and chemical characteristics of maltooligosaccharides (G_1 to G_{12} polymers) from partially hydrolyzed amylose starch. They found that the specific gravity of solutions of the carbohydrates increased with chain length and concentration. Refractive indices did not increase with chain length but did with increased concentration. Solubility decreased with chain length; the G_9 and G_{10} polymers did not completely dissolve at eight to ten percent concentrations. In addition, relative viscosity and hygroscopicity increased with the molecular weight of the oligosaccharide.

Woodruff and Nicoli (1931), Whittenberger and Nutting (1948), and Hester, Briant, and Personius (1956) reported that the food products thickened with starch were influenced in varying degrees by other ingredients present. Bean and Osman (1959) tested the effects of different sugars at various concentrations on the viscosity and gel strength of starch pastes in systems free of the influence of other ingredients. The sugars and syrups tested were sucrose, dextrose, fructose, maltose, lactose, invert syrup, and corn syrup of three different levels of hydrolytic conversion. They found that lower concentrations (five and ten percent) of sugars tended to increase the maximum hot-paste viscosities. Sugar concentrations greater than 20 percent of the weight of the water present progressively decreased the viscosity. At higher concentrations, there were significant differences in the effects of different sugars. Increased concentrations of sugars and syrups also changed the shape of the gelatinization curves. Generally, viscosity decreased with increased amounts of sugar, and the temperature at which maximum viscosity was reached was raised by the presence of monosaccharides.

The principal effect of sugar on starch pastes apparent from photomicrographs by Whittenberger and Nutting (1948) was suggested as inhibition of the swelling of starch granules. These investigators suggested that sugar molecules compete with starch for the available water. Hester et al. (1956) also concluded that the hydration of starch granules was inhibited by the presence of sucrose. They found that the temperature of initial rise in hot-paste viscosity was raised which indicated delayed swelling of the starch granules; the maximum viscosity of the starch paste was lower or not reached at 95°C, indicating less swelling. They further noted that the disintegration of the granules was less, and the amount of soluble material diffusing from the starch granules was less when sucrose was present. Starch gels decreased in rigidity, and with high sucrose concentration, gels would not form.

Saeed, ElTinay, and Khattab (1975) noted that the viscosity of mango nectar was related to the pectic substances, a type of hetero-polysaccharide, present. These researchers showed that when mango nectar was treated with pectin enzymes at different concentrations, a decreased viscosity resulted. Pectic substances were concluded to be the major constituent responsible for viscosity in mango nectar. Other studies have also shown that texture is closely associated with the amount and nature of pectins in fruit. In peaches, soft-fleshed varieties have a relatively high proportion of pectins in a water soluble form when ripe. Firm-fleshed varieties show a higher proportion of pectic substances in an insoluble form when optimal stage of maturity is reached (Shewfelt, Paynter & Jen, 1971; Postlmayr, Luh & Leonard, 1956). Bettelheim and Sterling (1955a) suggested that the textural qualities of white potatoes were related to the pectic substances. Although no obvious relationship was found between the pectic substances and texture of potatoes, cooking was found to decrease the intrinsic viscosity of potatoes while increasing solubility of the pectic materials. Bettelheim and Sterling (1955a) stated that, although the swelling of gelatinized starch granules which caused cell separation was a major factor responsible for potato texture, the tendency for cell separation is counterposed to a lesser extent by the calcium content and molecular size of pectic materials in the middle lamella and cell wall.

Dahle, Brusco, and Hargus (1973) studied the effects of beta amylolytic degradation of pastes and waxy maize starch. They noted that viscosity decreased as chain length shortening progressed in both neutral and alkaline media. They maintained that viscosity in waxy starches was attributable to a limited association of unbranched chain ends of neighboring molecules. They suggested that a certain minimal chain length was required, and shortening the chain length lessened the contribution to viscosity from this type of association.

The molecular size of carbohydrates affects functional properties and uses in foods (Waldt & Kehoe, 1959; Whistler & BeMiller, 1959). Food applications of dextrins depend on adhesive and binding abilities and to a lesser extent on colloidal properties. These carbohydrates are produced in the United States by dry heating or roasting of unmodified starches, by conversion of starch by certain enzymes, or by acid hydrolysis of wet starch. Depending on method of preparation, dextrins can have moderate to high solubilities in water, and pastes can have low to moderate viscosities. In general, dextrins are more soluble than the parent starch, have lower viscosity in solution, higher reducing power, and altered adhesive characteristics (Whistler & BeMiller, 1959).

Common sugars such as sucrose, glucose, galactose, fructose, maltose, and lactose are hygroscopic and vary in water-binding capacity and solubility. Fructose is the most soluble, followed by sucrose, glucose, maltose, and lactose. Sweetness also varies; fructose is sweetest, followed by sucrose, glucose, galactose, maltose, and lactose.

Fructose-containing substances, such as honey, are used in many food products which are to be stored because fructose is extremely hygroscopic and retains moisture. Solutions of sugars become more viscous on heating (Paul & Palmer, 1972).

Although a great deal of information is available concerning the properties of carbohydrates, the precise relationship between these properties and mouthfeel is only vaguely understood. That physical properties affect texture has been amply demonstrated, but the specific qualities of carbohydrates which account for these physical properties and mouthfeel of carbohydrate-containing foods are debatable.

Food Texture and Taste Perception

The effect of the texture of certain high carbohydrate foods on taste perception has been studied. Mackey and Valassi (1956) demonstrated that thresholds for the four basic tastes are affected by different food textures. These investigators found that sensitivity for taste substances increased in water solutions and decreased in gels and foams. Further research by Mackey (1958) reported that substances such as caffeine, quinine, and saccharin were slightly less discernable in water with methylcellulose than in plain water. It was suggested that, in systems where there is more shear thinning in the mouth, perception of the basic tastes (sweet, sour, bitter, salt) is increased.

Szczesniak and Farkas (1962) reported a correlation between mouthfeel and the rheological properties of a number of gum solutions. These investigators could predict mouthfeel characteristics (nonslimy, somewhat slimy, very slimy) from objective measures of viscosity and rate of shear made on solutions.

Vaisey, Brunon, and Cooper (1969) studied sweetness-texture interactions in cornstarch, guar, and carboxymethylcellulose sols. Viscosity curves over a range of sucrose concentrations from 2.5 to 5.5 percent in the three gums were determined. The relationship between the curves and sweetness perception as determined by rates of sweetness recognition, matching of equisweetness in different gums, and ranking in order of sweetness by a sensory panel was studied. The investigators found that gums which had less viscosity decrease as shear rates increased tended to mask sweetness perception. They stated that information concerning the sensory properties of carbohydrate hydrocolloids is essential because of their increased use in foods for bodying, thickening, bulking, masking of aftertastes, flavor-blending, and controlling of freezing and melting. They suggested that mouthfeel of hydrocolloid sols is complicated by the interrelationships of their molecular structure and bonding, molecular size, and degree of particle dispersion, as well as by inherent chemical characteristics.

Starch Conversion and Textural Change

Extensive research has focused on characterization of carbohydrates, carbohydrate changes, and changes in textural characteristics during curing, cooking, and processing of sweet potatoes (Hasselbring & Hawkins, 1915; Hopkins & Phillips, 1937; Miyake, 1915; Barham & Wagoner, 1946; Culpepper & Magoon, 1926; Sistrunk et al., 1954; Sistrunk, 1971; Deobald, Hasling, & Catalano, 1971; Gore, 1923; Nelson, 1973; Scruggs, 1975). Sweet potatoes contain large amounts of starch and remain low in sugar content during the growing season (Hasselbring & Hawkins, 1915). After harvest and when stored at high temperatures, the conversion of starch to sugar is rapid but slows and reaches an equilibrium state. Hasselbring and Hawkins (1915) demonstrated that curing brings about carbohydrate changes and that sugar increased in sweet potatoes cured at 6^{o} to $7^{o}C$ to a greater extent than in those cured at 12^{o} to $30^{o}C$. They suggested that hydrolysis of starch in sweet potatoes resulted in formation of reducing sugars and that sucrose was synthesized from the reducing sugars.

Hopkins and Phillips (1937) studied storage temperatures and starch-sugar changes in sweet potatoes. Both cured and uncured roots were stored at temperatures which ranged from 50^{o} to $70^{o}F$. Sucrose was found to increase from 2.5 percent in freshly dug roots to 3.3 percent after curing. More sucrose was found to accumulate at the lower temperatures. They proposed that changes in the amount of sucrose could be used as a measure of starch degradation.

Culpepper and Magoon (1926) reported that starch was transformed into dextrin and sucrose during the storage of sweet potatoes and that some of the starch was split to form maltose during cooking. They suggested that the sweetness of cooked sweet potatoes was dependent on the amount of sucrose formed during storage since sucrose content remained stable during cooking. Earlier research by Stone (1890) showed that dextrins were formed when sweet potatoes were baked, and Ali and Jones (1967) later reported that baking converted most of the starch in sweet potatoes into maltose and dextrins. Gore (1920, 1923) found that diastase activity upon slow cooking of roots was responsible for the conversion of starch. Culpepper and Magoon (1926) suggested that the maltose resulting from the degradation of starch during cooking affected texture and resulted in softness of cooked roots.

Considerable research has centered on starch conversion in processing of different varieties of sweet potatoes (Culpepper & Magoon, 1926; Sistrunk et al., 1954; McConnell & Gottschall, 1957). Freshly dug roots have been found to rapidly lose their ability to yield a firm processed product because of carbohydrate changes during storage (Baumgardner & Scott, 1962). Although consumers have indicated a preference for the moist or "yam" type of sweet potato, sweet potato processors tend to sacrifice sweetness and flavor to achieve firmness and wholeness in canned products (Edmond & Ammerman, 1971; Scruggs, 1975).

When roots are freshly dug, moist types of cultivars do not display the moist mouthfeel characteristic; this quality only becomes apparent after curing when the roots are held at 85°F and 80 to 90 percent relative humidity to allow healing of wounds during harvesting. The moist mouthfeel characteristic continues to increase for a time during storage. Even the dry type of sweet potato increases slightly in moistness after curing and storage (Nelson, 1973). Earlier work by Lambou (1958) reported that the enzyme beta-amylase was responsible for most starch breakdown during curing and storage. Ikimiya and Deobold (1966), in later research, isolated a sweet potato alpha-amylase which had an optimum activity temperature of 70° to 75°C at pH 6.0. Dextrins were found to be the major product formed by action of alpha-amylase on starch. Deobold, Hasling, and Catalano (1971) reported that the enzyme alpha-amylase increased during curing and storage of sweet potatoes.

Walter et al. (1975) studied the relationship between alpha- and beta-amylase activity in six sweet potato cultivars on moistness and carbohydrate changes of baked roots. Although they found no direct relationship between beta-amylase activity and the quantity of maltose produced, as the alpha-amylase activity in the raw root increased and dextrin content increased. The molecular size of the total dextrin extract was found to decrease when the roots were baked. Walter et al. (1975) further observed that the intrinsic viscosity (a property of molecular size), dextrin extract, and starch content were correlated with sensory panel scores for moistness.

Methods to control the extent of starch degradation by amylolytic enzyme activity to produce desired textural characteristics of foods and other materials have been studied (Scruggs, 1975; Deobold et al., 1968; Hoover & Harmon, 1967). Hoover (1966) developed an "enzyme activation" technique in which the naturally occurring amylolytic enzyme was activated by preheating ground raw material by steam injection. The procedure was used in production of sweet potato flakes, and the researcher maintained that the hydrolysis of starch could be controlled by use of the technique. Later studies by Hoover and Harmon (1967) reported the carbohydrate changes in sweet potato flakes when the technique was employed. They observed that there was no significant difference in sucrose and hexose sugars as a result of the treatment;

more than 90 percent of the increase in maltose, however, was found to occur within ten minutes after preheating the raw ground material to 177^{o}F. Deobold et al. (1968), using the enzyme activation technique described by Hoover (1966), tried to control the amylolytic activity in order to produce dehydrated sweet potato flakes which were uniform in quality. These investigators noted that when freshly harvested roots, which have limited amylolytic activity, were processed, maltose formation could be correlated with flake characteristics. Experiments using freshly harvested (uncured) roots showed that a maltose content of at least 38 percent was required for acceptable flakes.

Scruggs (1975) attempted to increase moistness of canned sweet potatoes by using a slow heat canning process which would allow additional time for increased alpha-amylase activity. Although sensory panelists were unable to detect an increased moist mouthfeel in the roots, additional starch was converted into smaller molecular size carbohydrates as was evidenced by the reduced viscosity.

Lohmar et al. (1956) devised a procedure to control the degradation of waxy-corn starch by malt alpha-amylase in order to produce dextrins having specific viscosities for human blood fractionation. The enzymatic degradation of the starch was performed at 60^{o}C and was followed viscometrically. The researcher reported that an empirical relationship was found between enzyme concentration, specific viscosity of the conversion liquor, and time of conversion. They emphasized that it was possible to preselect conditions of conversion to obtain desired products which could have a variety of uses.

Starch and its conversion products, as well as other carbohydrates, have an effect on subjectively and objectively evaluated textural characteristics of many high carbohydrate foods. As indicated previously, mouthfeel characteristics of cooked roots have been definitely shown to affect consumer acceptability of both white and sweet potatoes (Edmund & Ammerman, 1971; Kuhn et al., 1959). Because of the importance of mouthfeel, recent research by Rao et al. (1975) has attempted to devise an objective test to measure moist mouthfeel of sweet potatoes. These researchers found that apparent viscosity could be used as a method of classifying sweet potato cultivars on the basis of moist mouthfeel for both uncured and cured roots. Apparent viscosity tended to decrease with increased storage time and moist mouthfeel, as measured by a sensory panel, increased. Rao et al. (1975, p. 99) further stated that it was "possible to define an arbitrary range of numerical values of apparent viscosity to classify dry, medium, and moist mouthfeel characteristics."

Nelson (1973) described mouthfeel characteristics as a property which becomes apparent after baking and is independent of water content of the roots. She was able to correlate shear press readings and sensory panel rankings for moist mouthfeel. According to Walter et al. (1975, p. 795) "the textural property of 'moistness' and 'dryness' in sweet potatoes is a complex organoleptic sensation." At present, no single causative factor has been identified, although the amount of starch remaining after baking has been implicated. Moist mouthfeel characteristics may also be the result of variations in the quantities of maltose, dextrins, glucose, and/or pectins present after baking. Further research on the components present in baked potatoes and the effects of small variations in the various molecular sizes of carbohydrates on mouthfeel is needed. Sweet potato processors are currently manipulating processing in order to control starch conversion by activation of the enzyme, alpha-amylase. In the future, if the carbohydrate(s) responsible for the moist mouthfeel characteristic could be identified, this carbohydrate (or carbohydrates) could be added in processing to achieve the desired product.

CHAPTER III

PROCEDURES

The effects of addition of various carbohydrates (dextrins, glucose, maltose, and starch) on mouth sensations were tested by mixing the carbohydrates into sweet potatoes which were subjectively evaluated by a sensory panel and objectively evaluated by a Brookfield viscosimeter and a Haake Rotovisco Model RV-1 Viscometer. In addition, a model system based on the protein, carbohydrate, fat, and water composition of a standard sweet potato was prepared. Nine different variations of the model system were made in which the dextrin, starch, and maltose content were varied. Apparent viscosity and static yield measurements were made on the model system and the variations.

Preparation of Sweet Potato-Carbohydrate Mixtures

Sweet potatoes of the All Year variety (S.C. 1149-19), obtained from the South Carolina Agricultural Experiment Station/Edisto Branch, were used in the series to which dextrins, uncooked corn starch, glucose, and maltose were added. The Jewel variety, obtained from the same source, was used in the heated starch series. Based on textural characteristics, the All Year potato, an experimental variety, would be classified as a "dry" type, and the Jewel variety would be classified as a "moist" type of sweet potato.

The sweet potato-carbohydrate mixtures were prepared each morning prior to evaluation by the taste panel. Roots were washed, punctured to prevent bursting, and baked in a preheated oven at 375^{o}F for 70 to 90 minutes. After baking and cooling, each root was sliced lengthwise, and the flesh was removed; fibrous flesh next to the skin was not removed. The flesh was placed in a large bowl and mixed with a fork to produce a homogeneous mixture.

One hundred gram portions of well mixed potatoes, the indicated quantities of the carbohydrate (Table 1) under study, and water were placed in a Kitchen Aid Mixer (Model K-45) and mixed for one minute at a speed setting of 4.5. The carbohydrates used in the preparations were dextrins, corn starch, sweet potato starch, maltose, and glucose. Manufacturer or source of the carbohydrates is presented in Appendix A. The procedure for extraction of sweet potato starch used in the heated starch series is presented in Appendix B. Quantities of carbohydrate used in each series are shown in Table 1.

Selection of the quantity of each type of carbohydrate used in each series was based on previous research on the changes in carbohydrates during cooking (Walter, Purcell & Hoover, Unpublished). When adding carbohydrates, the amount of carbohydrate reported by various investigators (Walter et al., Unpublished; Lambou, 1958; Hopkins & Phillips, 1937) was the base value; additions were made on the basis of percent increases over the base value which had been observed during processing. For example, Walter et al. (Unpublished) reported the base value in dehydrated sweet potato flakes for maltose as 12 percent by weight; during starch conversion the maltose content increased to 38 percent, dextrins increased slightly, and starch decreased from 50 to 30 percent.

Table 1

Quantities of Carbohydrates Used in Sweet Potato Mixtures

Types of Carbohydrates	Quantity of Carbohydrates Added gm/100 gm	Percent of Carbohydrates Above Amount in Standard* Potato
Dextrin	0.39	25
Dextrin	0.79	50
Dextrin	1.58	100
Glucose	0.08	10
Glucose	0.16	20
Glucose	0.32	40
Maltose	0.50	20
Maltose	0.75	30
Maltose	1.00	40
Starch, Corn (Unheated)	1.37	10
Starch, Corn (Unheated)	2.74	20
Starch, Corn (Unheated)	4.11	30
Starch, Sweet Potato (Heated)	0.27	2
Starch, Sweet Potato (Heated)	0.69	5
Starch, Sweet Potato (Heated)	1.37	10

*Composition of standard sweet potato based on quantities reported (Watt & Merrill, 1963; Walter, Purcell, & Hoover, Unpublished).

The quantity of water added to each sweet potato-carbohydrate mixture was based on the ratio of carbohydrate to water in a standard sweet potato (i.e. 1:3). Control samples (samples having no carbohydrates added) were mixed by the same procedure used in the sweet potato-carbohydrate mixtures, but no water was added.

The procedure for mixing all sweet potato-carbohydrate mixtures was the same. Preparation of all samples, except the heated starch series, was complete following mixing. In the heated starch series, each sweet potato-carbohydrate mixture and control were heated for approximately five minutes until the mixture reached 80°C. Samples were allowed to cool to room temperature and to stand for two hours prior to taste panel testing. Samples were preserved by freezing at -10°C for a period of two months prior to making static yield and apparent viscosity measurements.

Sensory Panel Evaluations

To ascertain differences in mouthfeel of the sweet potato mixtures, ranking tests were administered to panel members. All sensory evaluations were performed in the Experimental Foods Laboratory in the School of Home Economics at Winthrop College, Rock Hill, South Carolina.

A panel composed of 21 volunteers from faculty and students at Winthrop College evaluated the dextrin, glucose, maltose, and unheated starch series. There were five males and sixteen females who participated in testing. The heated starch series was evaluated by 10 volunteers, two males and eight females, from faculty and students at Winthrop College. Ages of panel members ranged from 20 to 50 years.

Each panel member was asked to complete a questionnaire on food allergies and sign a consent form prior to being accepted (Appendix C). All members were informed of the purpose of the study and were given identical instructions during the training sessions (Appendix C).

Panelists were trained one day prior to evaluating the mixtures. The training session consisted of allowing subjects to taste a series of five different cooked sweet potato cultivars which varied from moist to dry in mouthfeel characteristics. Moist potatoes included the Centennial and Gem varieties. Jewel was used as intermediate in mouth sensations; dry sweet potato varieties included Pelican Processor and All Year. The classification of the potatoes into these groups (except for All Year) had been suggested by Nelson (1973).

The All Year variety was obtained from the South Carolina Agricultural Experiment Station/Edisto Branch. All other varieties were grown at the North Carolina State University Agricultural Experiment Station at Clayton, North Carolina.

The training session was concluded by requiring subjects to complete two triangle tests to determine whether they could detect mouthfeel characteristics which had been previously described. In the trials, two samples of Gem and one of All Year varieties were presented; subjects were asked to determine which sample was different and whether it was more moist or more dry than the two samples which were the same. The form used in the triangle test is presented in Appendix C.

In subsequent sessions, panelists were presented four potato samples at a time, each sample being assigned a randomly selected three digit code which was changed for each test. A total of eight samples was tested each day. Each set of four samples consisted of a control to which no carbohydrate additions had been made and three other samples containing increasing amounts of dextrins, maltose, glucose, heated sweet potato starch, or unheated corn starch. One teaspoon portions of samples were presented on white, non-porous plates in a taste panel booth. The booth was illuminated by a red light during testing to mask color differences which might result from carbohydrate additions. Panelists were provided a napkin, fork, glass of tap water, pencil, score sheet, and samples.

Sensory evaluations took place between 1:00 P. M. and 5:00 P. M. on Tuesday, Wednesday, and Thursday for a period of one month. A ranking procedure was used for scoring; panel members were asked to rank the four coded samples on each plate. A ranking of one denoted "most dry" and a ranking of four represented "most moist." The form used for evaluations is presented in Appendix C. Each series was evaluated by panel members a minimum of four different times.

Objective Evaluations of Sweet Potato-Carbohydrate Mixtures

Viscosity determinations were made with a Haake Rotovisco Model RV-1 Viscometer, using an SVP-II rotor. Readings were taken at a speed factor of 6 representing 97.2 revolutions per minute. Static yield measurements were made with a Brookfield viscosimeter which was set at a speed factor representing 2.5 revolutions per minute. Twenty-four gram portions of sweet potato mixtures used for taste panel evaluations were mixed with 18 grams of water (4:3 dilution) and allowed to stand for three hours prior to testing. All tests were conducted at room temperature (approximately 25^{o}C).

Preparation of Model System

A model system based on starch, dextrin, maltose, sucrose, glucose, pectin, protein, fat, water, and fiber content of a cured, uncooked sweet potato was prepared. Compositional data for preparing the model system were obtained from various sources (Watt & Merrill, 1963; Lambou, 1958; Walter et al., Unpublished; Hopkins & Phillips, 1937).

In subsequent trials, the quantities of dextrin, maltose, and starch were altered from the model system to determine the effect on apparent viscosity as measured by the Haake Rotovisco Viscometer or on static yield as measured by the Brookfield viscosimeter.

Compositional data for the model system and variations are presented in Appendix D. In most variations, maltose and/or dextrin were increased at the expense of starch while content of other components remained constant. Total carbohydrate content was also constant (22.8 $\pm$ .2 percent).

Protein used in the procedure was extracted from sweet potatoes and was obtained from the Food Science Department of North Carolina State University at Raleigh. Fiber used in the model system and its variations was extracted according to the procedure detailed in Appendix E. Mazola brand corn oil and Sure-Jell brand pectin were purchased from a local store and used in all mixtures. Manufacturer or source of the dextrin (Liquid-Dex), glucose, sucrose, and maltose has been presented in Appendix A. Distilled water was used in the model system and variations.

Ingredients were weighed on a Mettler analytical balance. Dry ingredients were mixed together, water was added, and the mixture was heated to 85^{o}C for solution of components and gelation of the starch and dextrin. The model system and variations were prepared in duplicate and stored for five days at -10^{o}C. Samples were then thawed, allowed to reach room temperature, and homogenized. Some particles remained in the mixtures; the mixtures were, therefore, autoclaved at 121^{o}C for 15 minutes at 20 psi. Following cooling a 24-gram sample of the model system and each variation was mixed with 42 grams of distilled water and allowed to stand for three hours prior to measurements of apparent viscosity and static yield. Procedures used for the apparent viscosity and static yield measurements were identical to those previously described for the sweet potato-carbohydrate mixtures.

Statistical Analysis of Data

Mean ranks from sensory panel data were calculated and a two-way analysis of variance was used to determine whether there was a significant difference between sweet potatoes to which increasing quantities of dextrin, glucose, maltose, or starch had been added. Using a regression technique (Hicks, 1964), degress of freedom and sums of squares for treatment (derived from analysis of variance) were partitioned into linear, quadratic, and cubic effects to determine response to increased amounts of carbohydrates. A non-parametric test, the Friedman test, was used to analyze rank sums of each individual day of sensory panel data. Multiple Comparisons test, using an alpha level of .05, was used to determine where differences between treatments could be found.

Mean static yield and apparent viscosity values were calculated and a two-way analysis of variance was employed to determine whether significant differences existed between various controls and sweet potato-carbohydrate mixtures. To determine response of static yield and apparent viscosity to increasing amounts of added carbohydrates, a regression technique (Hicks, 1964) was used to partition degrees of freedom and sums of squares for treatment (derived from the analysis of variance) into linear, quadratic, and cubic effects.

Due to the limited number of samples prepared for the model system and variations, a specific statistical method for differences could not be employed. Mean static yield and apparent viscosity values were calculated for the model system and variations.

CHAPTER IV

DATA AND ANALYSIS

Sweet potatoes were chosen as a system to study the effect of molecular size of carbohydrates on mouth sensations. There has been considerable research on characterization of carbohydrates in the roots (Miyake, 1915; Lambou, 1956; Lambou, 1958; Sistrunk et al., 1954), and objective methods have been developed which correlate with moist mouthfeel described by sensory panels (Rao et al., 1975; Nelson, 1973). Sweet potatoes were, therefore, assumed to be a particularly valuable food in which to test for changes in mouthfeel as additions of various types of carbohydrates were made.

Sweet potatoes of the All Year variety were used in the series to which corn starch, dextrin, glucose, or maltose was added. The All Year variety would be classified as a dry type of sweet potato; additions of small molecular size carbohydrates (glucose, maltose, and dextrin) would be expected to increase moist mouthfeel of the root. Additions of a large molecular size carbohydrate (corn starch) to the sweet potato could potentially increase dry mouthfeel characteristic.

Sweet potatoes of the Jewel variety were used in the mixtures to which sweet potato starch was added; the mixtures were heated following additions. The Jewel potatoes were rated as a moderately moist/ moderately dry variety in previous research (Nelson, 1973); starch additions could increase dry mouthfeel characteristics of the roots.

In the triangle test which was used to train panel members, only two of 21 subjects evaluating the dextrin, corn starch, glucose, and maltose series failed to identify the odd sample presented in one of the tests (Appendix F). Only one of 10 panel members evaluating the heated sweet potato starch series was unable to select the odd sample in one of the triangle tests (Appendix F). Random guessing in the triangle test would provide a 0.33 probability of a correct answer. The number of correct answers necessary to establish significant differences at the .001 probability level would be 25 out of 42 and 14 out of 20 triangle tests (Krum, 1955; Roessler, Warren & Guymon, 1948).

Corn Starch-Sweet Potato Mixtures

Sensory Evaluations

Daily and average sensory panel rankings are presented in Table 2. A significant linear response ($P < .02$) was found when the average ranks were tested using a regression technique (Appendix G). As increasing quantities of corn starch were added to the sweet potatoes, dry mouthfeel sensation increased at 10 percent additions of starch; at 20 percent additions there was a leveling off which was followed by an increased dryness as 30 percent additions of starch were made (Figure 1).

Significant differences ($P < .05$) were found between the mixtures with the Friedman Test for daily sensory ranking data on the first day, and highly significant differences ($P < .01$) were found on the third and fourth days of the sessions (Table 2). Using the Multiple Comparison method (Table 3) with a .05 significance level, differences on the

Table 2

Daily and Average Taste Panel Ranks* for Increasing Quantities of Corn Starch (Unheated)

Subject	First Day				Second Day				Third Day				Fourth Day			
	Percent		Increase		Percent		Increase		Percent		Increase		Percent		Increase	
No.	0	10	20	30	0	10	20	30	0	10	20	30	0	10	20	30
1	3	2	4	1	1	3	4	2	4	3	1	2	2	3	4	1
2	4	2	3	1	1	2	4	3	2	1	3	4	4	1	2	3
3	4	3	2	1	3	2	1	4	4	1	3	2	3	1	2	4
4	1	4	3	2	1	3	2	4	4	2	3	1	4	3	2	1
5	2	1	4	3	4	2	3	1	4	2	1	3	3	1	2	4
6	3	4	2	1	1	3	2	4	4	1	3	2	4	1	3	2
7	3	4	2	1	1	3	4	2	4	3	2	1	4	1	2	3
8	2	4	1	3	1	3	4	2	3	4	2	1	4	1	2	3
9	1	2	4	3	1	3	2	4	1	4	3	2	4	2	1	3
10	1	2	4	3	4	1	3	2	3	4	1	2	3	1	4	2
11	4	3	1	2	3	4	1	2	4	2	1	3	4	2	3	1
12	1	3	4	2	3	4	2	1	4	3	2	1	4	2	3	1
13	4	2	3	1	2	3	4	1	2	4	3	1	4	1	2	3
14	3	2	4	1	4	3	2	1	4	2	1	3	3	2	1	4
15	4	1	2	3	3	2	4	1	4	3	2	1	1	2	4	3
16	3	4	1	2	2	4	3	1	4	3	2	1	4	3	2	1
17	2	4	3	1	2	3	4	1	2	1	3	4	2	1	4	3
18	2	3	4	1	4	1	2	3	3	1	4	2	4	3	1	2
19	2	4	1	3	2	3	1	4	4	3	1	2	4	2	1	3
20	4	2	3	1	2	4	1	3	4	2	3	1	4	2	3	1
21	4	3	2	1	4	3	2	1	4	2	3	1	4	1	3	2
$\overline{X}$ Rank	2.7	2.9	2.6	1.7	2.3	2.8	2.6	2.2	3.4	2.4	2.2	1.9	3.4	1.7	2.4	2.5
N of Subjects	21				21				21				21			
Q Value	9.23 ($P < .05$)				2.60 ($P < .50$)				16.28 ($P < .010$)				20.03 ($P < .010$)			

*Ranking: 1 = Most Dry; 4 = Most Moist

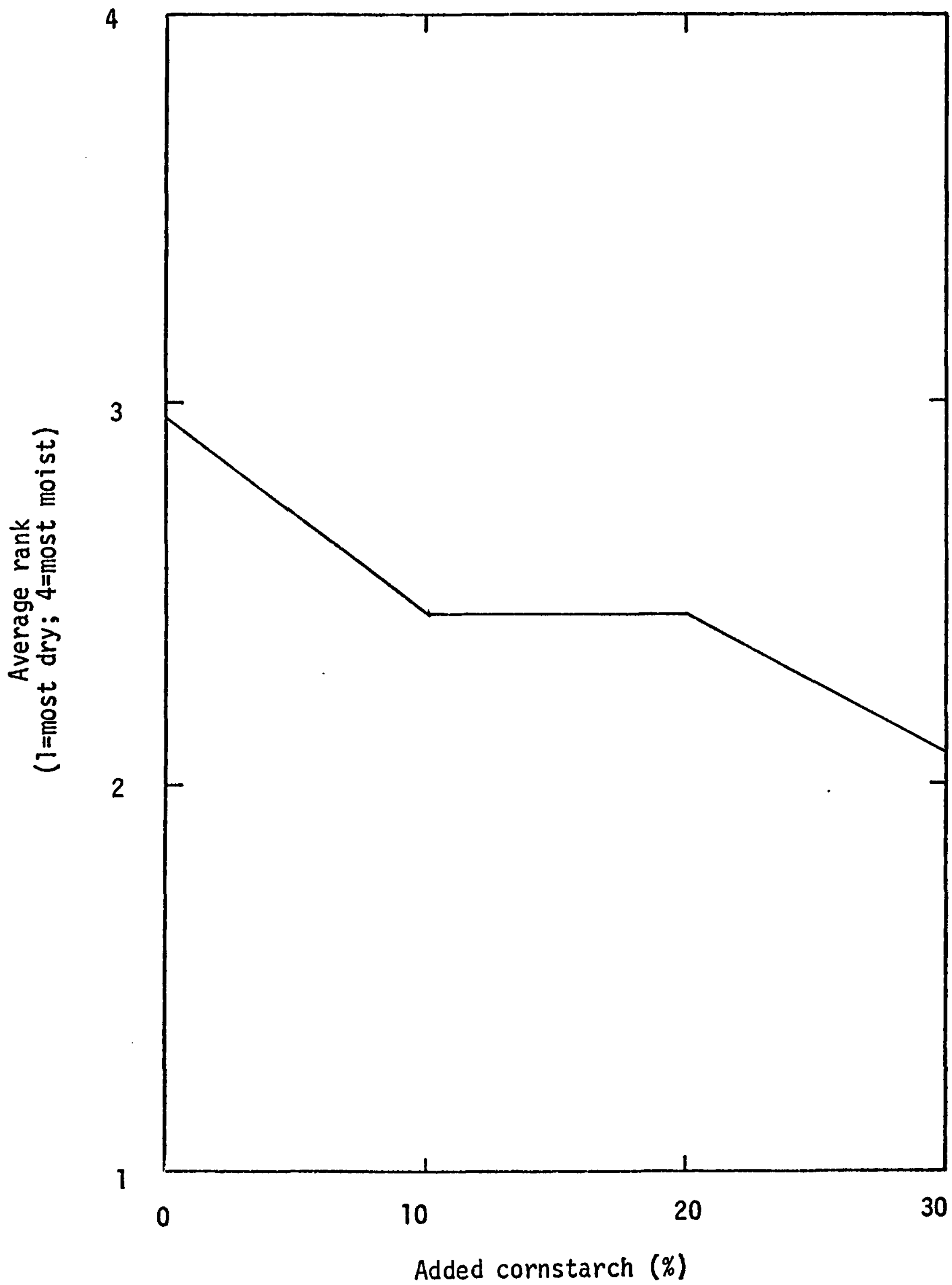

Figure 1. Average rank with increasing quantities of corn starch (unheated)

Table 3

Multiple Comparison of Mouthfeel Characteristics of

Corn Starch-Sweet Potato Series (Unheated)*

Day	Percent Starch Above Amount in Standard Sweet Potato			
	Control	10	20	30
First Day	More moist than 30%	More moist than 30%	More moist than 30%	More dry than Control, 10 or 20%
Second Day	No Significant Differences			
Third Day	More moist than 10, 20, or 30%	More dry than Control	More dry than Control	More dry than Control
Fourth Day	More moist than 10, 20, or 30%	More dry than Control	More dry than Control	More dry than Control

*.05 Significance Level

first day were found between the control and 30 percent addition of starch; the control sample tended to be more moist. Differences were also found between the 10 and 20 percent and 30 percent additions of starch; both 10 and 20 percent additions were more moist than the 30 percent. No significant differences were found on the second day; third and fourth day data, however, were similar. The control sample was found to be significantly more moist than samples to which 10, 20, or 30 percent additions of starch had been made. These data tended to support the assumption that the larger the quantity of starch in sweet potatoes, the more dry the mouthfeel characteristic of the root.

Apparent Viscosity and Static Yield Measurements

Daily and average apparent viscosity and static yield values are presented in Appendix G. When average apparent viscosity values for increasing quantities of corn starch were tested using a regression technique, a highly significant ($P < .01$) linear response was found (Appendix G). A ten percent addition of corn starch to sweet potatoes caused a significant decrease in apparent viscosity of the mixture. Addition of 20 percent corn starch resulted in a slight decrease in apparent viscosity; however, addition of 30 percent corn starch caused a further significant decrease in apparent viscosity (Figure 2).

A highly significant ($P < .01$) linear response was found when average static yield values for increasing quantities of corn starch were tested using a regression technique (Appendix G). With a ten percent addition of corn starch, there was a decrease in static yield of the mixtures which tended to level off at the 20 percent additions. With further

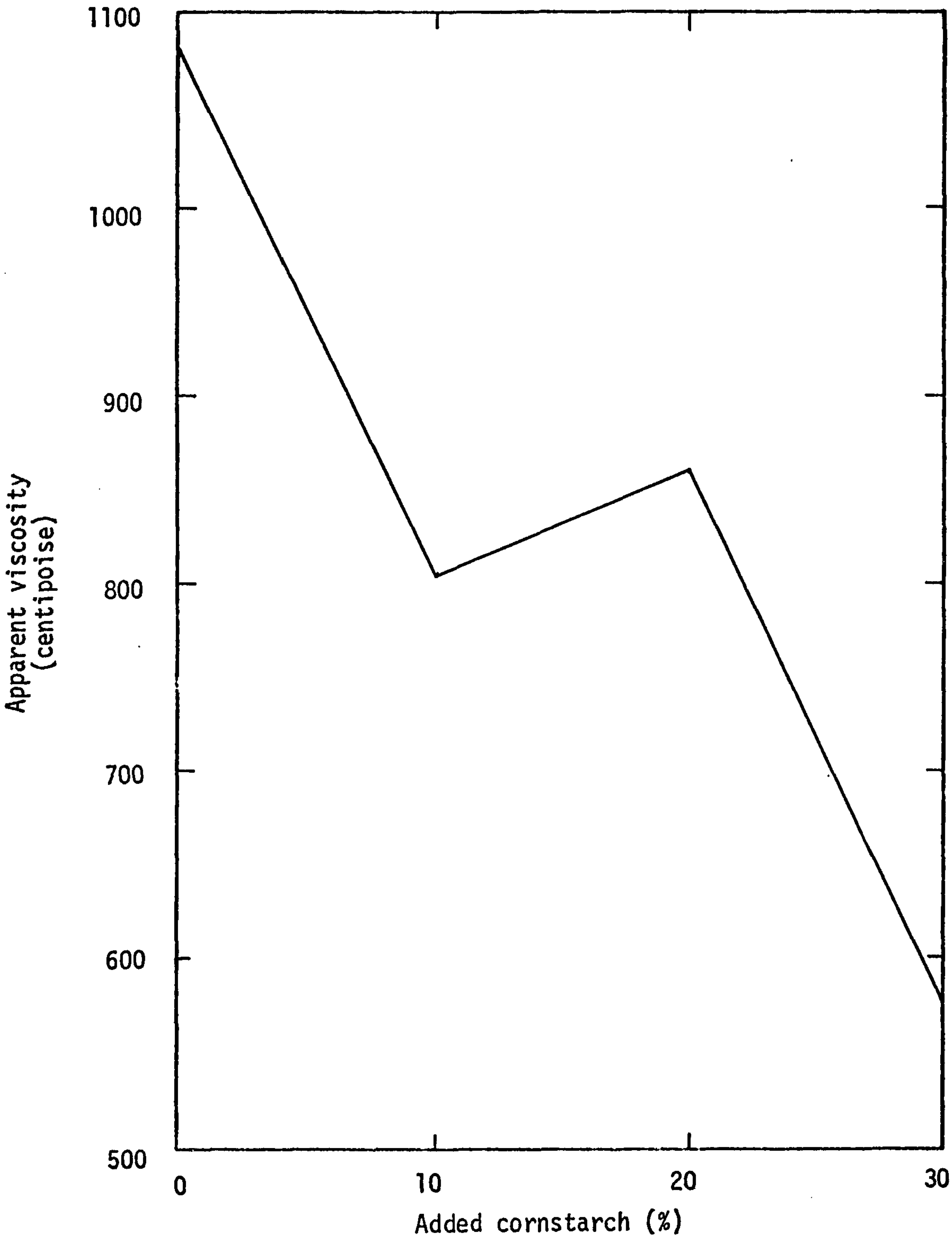

Figure 2. Average apparent viscosity with increasing quantities of corn starch (unheated)

increases in corn starch (30 percent), static yield continued to decrease (Figure 3). It should be noted that changes in static yield (Figure 3) are remarkably similar to average rank of the sensory evaluation panel (Figure 1).

Dextrin-Sweet Potato Mixtures

Sensory Evaluations

Sensory panel rankings, daily and average, for dextrin-sweet potato mixtures are presented in Table 4. No significant differences were found between average ranks of different mixtures with a two-way analysis of variance (Appendix H). When average group ranks were tested using a regression technique, no significant linear, cubic, or quadratic effects were found. As the percentage of dextrin increased in the potato mixtures, average rank decreased slightly at first and then gradually increased (Figure 4). It should be noted, however, that average sensory panel rankings were similar for each of the mixtures.

Using the Friedman Test for daily ranking data, significant differences ($P < .05$) were found between ranks on the second and third days of the panel sessions, and highly significant differences ($P < .01$) were found on sensory panel ranks on the first and fourth days (Table 4).

With the Multiple Comparison method (Table 5), differences on the first day were found between the control sample and samples which had 25, 50, and 100 percent additions of dextrin; dextrin additions were evaluated as more moist than the control. On the second day of the taste panel, there was a significant difference between the control and the 100 percent addition of dextrin; the control sample tended to be ranked

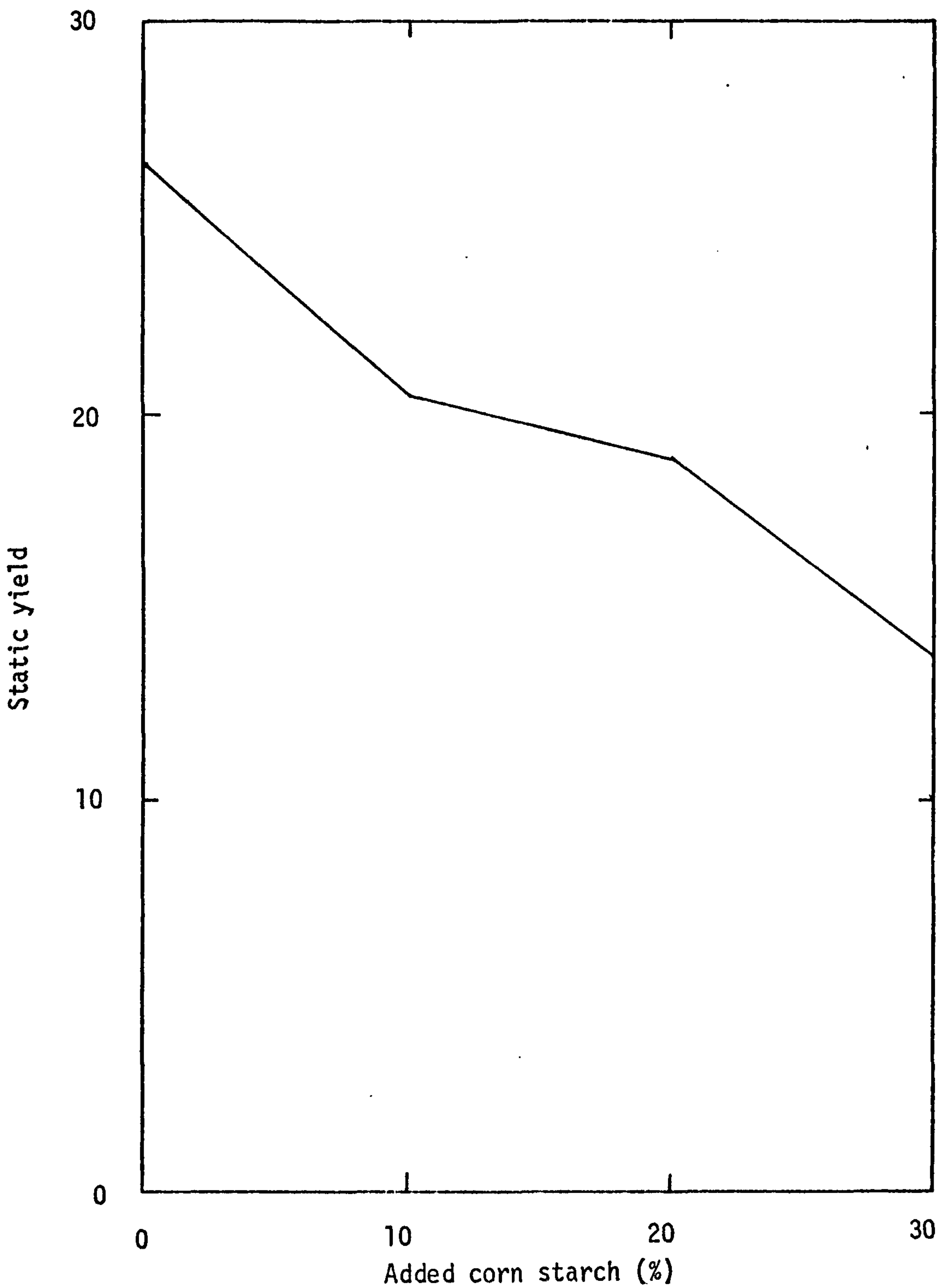

Figure 3. Average static yield values with increasing quantities of corn starch (unheated)

Table 4

Daily and Average Taste Panel Ranks* for Increasing Quantities of Dextrin

Subject	First Day				Second Day				Third Day				Fourth Day				Fifth Day			
	Percent Increase				Percent Increase				Percent Increase				Percent Increase				Percent Increase			
No.	0	25	50	100	0	25	50	100	0	25	50	100	0	25	50	100	0	25	50	100
1	-	-	-	-	3	4	2	1	2	1	4	3	2	3	4	1	4	2	3	1
2	1	4	2	3	4	2	3	1	3	1	2	4	4	3	1	2	4	2	3	1
3	2	1	4	3	-	-	-	-	3	1	2	4	3	2	1	4	1	2	3	4
4	1	4	2	3	1	3	4	2	2	3	4	1	3	1	2	4	2	1	3	4
5	-	-	-	-	4	2	3	1	3	1	4	2	4	3	1	2	3	2	4	1
6	1	2	4	3	4	3	2	1	3	4	2	1	4	3	2	1	3	1	4	2
7	-	-	-	-	1	4	3	2	4	2	1	3	3	4	1	2	3	2	1	4
8	1	3	4	2	4	1	2	3	2	1	3	4	3	4	1	2	1	2	3	4
9	-	-	-	-	2	4	3	1	2	1	3	4	2	3	4	1	3	2	4	1
10	-	-	-	-	1	4	2	3	3	2	1	4	4	3	2	1	1	3	2	4
11	-	-	-	-	1	4	3	2	4	1	2	3	3	4	2	1	2	1	3	4
12	3	4	2	1	4	2	3	1	3	4	1	2	2	3	4	1	3	1	4	2
13	2	4	3	1	4	3	1	2	3	1	2	4	2	4	1	3	2	4	1	3
14	2	4	1	3	-	-	-	-	4	2	1	3	4	3	2	1	2	1	4	3
15	-	-	-	-	4	2	1	3	4	3	2	1	4	3	2	1	1	3	2	4
16	-	-	-	-	4	2	3	1	4	3	1	2	4	3	2	1	1	2	4	3
17	1	4	2	3	-	-	-	-	4	1	2	3	4	1	3	2	4	3	1	2
18	-	-	-	-	2	1	4	3	3	1	2	4	1	4	3	2	3	2	1	4
19	1	2	4	3	-	-	-	-	1	2	4	3	4	3	2	1	1	4	2	3
20	-	-	-	-	4	3	2	1	4	1	3	2	4	2	1	3	4	1	2	3
21	1	3	4	2	-	-	-	-	1	2	3	4	3	2	1	4	2	3	1	4
$\overline{X}$ Rank	1.5	3.2	2.9	2.5	2.9	2.8	2.6	1.8	3.0	1.8	2.3	2.9	3.2	2.9	2.0	1.9	2.4	2.1	2.6	2.9
N of Subjects	11				16				21				21				21			
Q Value	11.40 ($P < .01$)				7.88 ($P < .05$)				11.00 ($P < .025$)				15.69 ($P < .01$)				4.49 ($P < .25$)			

*Ranking: 1 = Most Dry; 4 = Most Moist

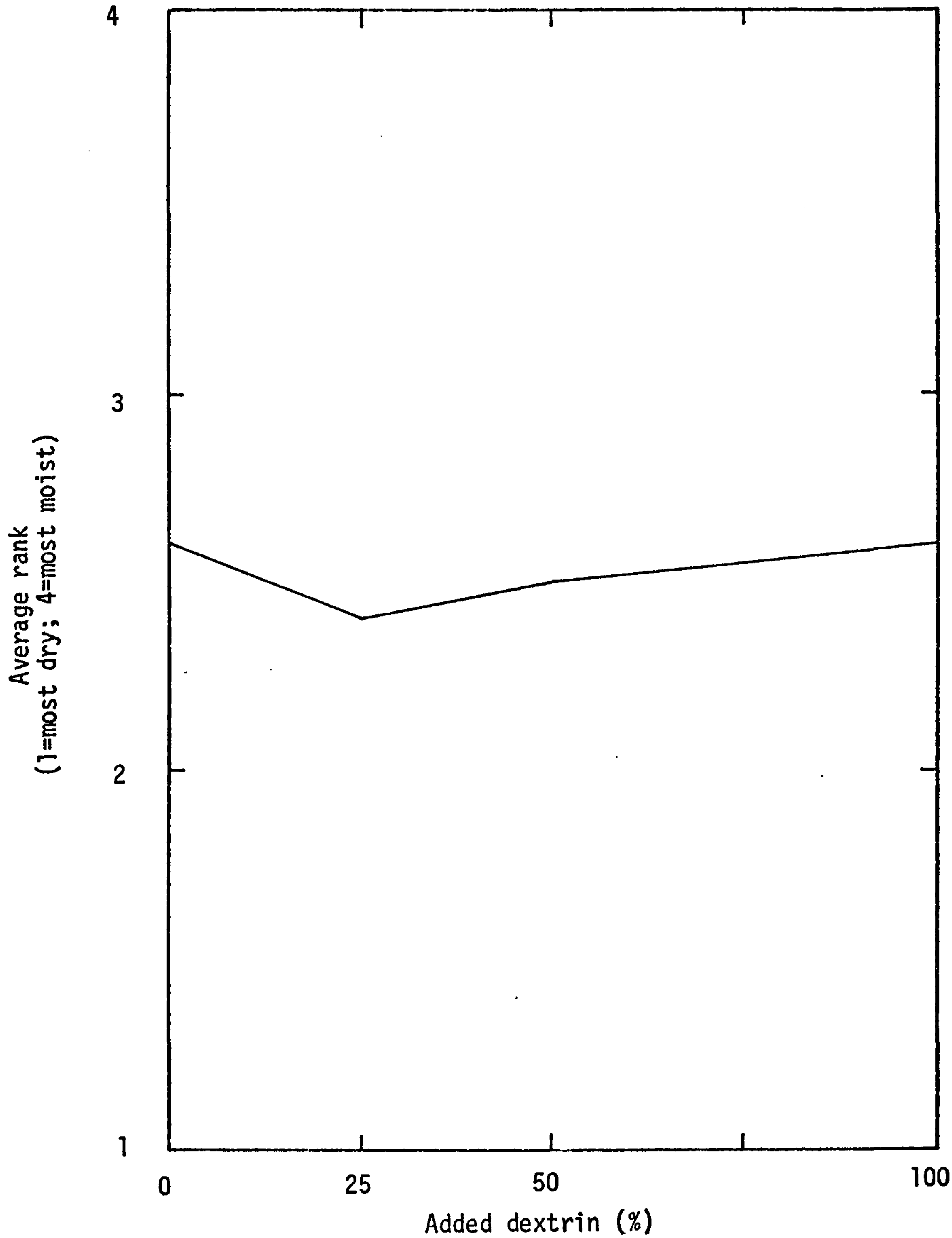

Figure 4. Average rank with increasing quantities of dextrin

Table 5

Multiple Comparison of Mouthfeel Characteristics of

Sweet Potato-Dextrin Series*

	Percent Dextrin Above Amount in Standard Sweet Potato			
	Control	25	50	100
First Day	More dry than 25, 50 or 100%	More Moist than Control	More moist than Control	More moist than Control
Second Day	More moist than 100%	More moist than 100%	More moist than 100%	More dry than Control, 25 or 50%
Third Day	More moist than 25%	More dry than Control and 100%	No significant difference	More moist than 25%
Fourth Day	More moist than 50 or 100%	More moist than 50 or 100%	More dry than Control or 25%	More dry than Control or 25%
Fifth Day	No significant differences			

*.05 Significance level

more moist. There were also significant differences between the 100 percent and 50 and 25 percent additions with 50 and 25 percent increases being ranked more moist than the 100 percent. On the third day, significant differences were found between the control and 25 percent addition of dextrin; the control sample was evaluated as more moist. There was also a significant difference between 100 percent and 25 percent additions; the 100 percent addition was ranked more moist. On the fourth day of sensory panel evaluations, there were significant differences between the control sample and 100 and 50 percent increases in dextrin; the control sample was found to be more moist than other samples. There was also a difference between the 25 percent and the 100 percent and 50 percent increases in dextrin; the 25 percent increase in dextrin was more moist (Table 5). No significant differences were found on the fifth day of sensory evaluations.

Apparent Viscosity and Static Yield Measurements

Daily and average apparent viscosity and static yield values are presented in Appendix H. No significant differences were found between average apparent viscosity values of different mixtures with a two-way analysis of variance (Appendix H). Although no significant linear, quadratic, or cubic effects were found with the regression technique, it should be noted that there was a continued and steady decrease in the apparent viscosity when increasing amounts of dextrin were added (Figure 5).

A highly significant ($P < .01$) linear response was found when average static yield values for increasing quantities of dextrin were tested using a regression technique (Appendix H). With a 25 percent addition of

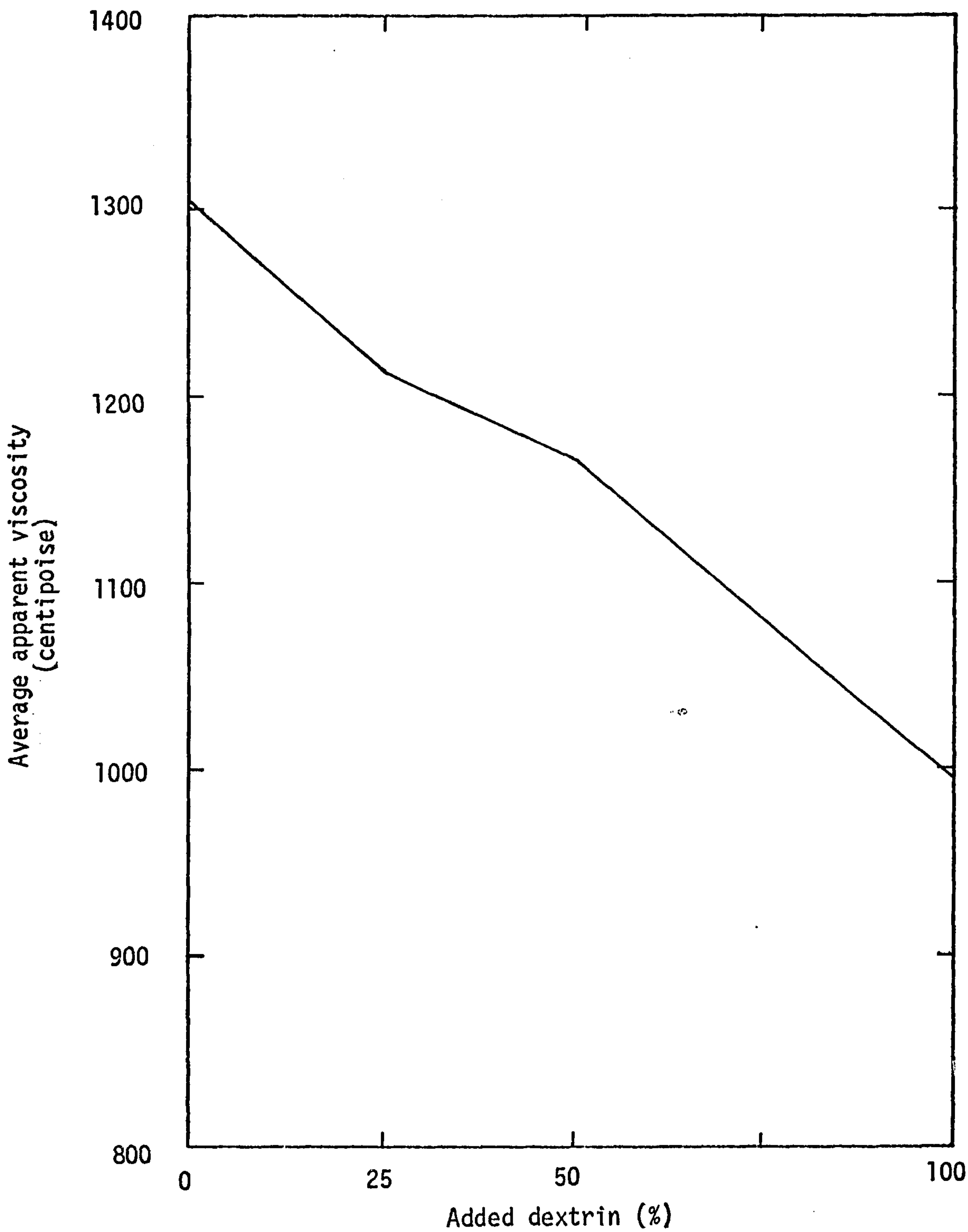

Figure 5. Average apparent viscosity with increasing quantities of dextrin

dextrin, there was a slight increase in static yield of the mixtures. Further increases in the quantity of dextrin caused a decrease in static yield values (Figure 6).

Glucose-Sweet Potato Mixtures

Sensory Evaluations

Daily and average sensory panel rankings are given in Table 6. Group treatment ranks are presented in Appendix I. No significant linear, quadratic, or cubic responses were found between average ranks when increasing amounts of glucose were added to sweet potatoes (Appendix I). There was a sharp decrease in moist mouthfeel at 10 percent additions of glucose, but 20 and 40 percent additions were similar to that of 10 percent (Figure 7).

Highly significant differences ($P < .01$) were found between mixtures with the Friedman Test for daily sensory ranking data on the first and fourth days, and significant differences ($P < .05$) were found on the second day of the panel sessions (Table 6). With the Multiple Comparison method (Table 7) using a .05 significance level, significant differences on the first day were found between the control sample and samples which had 10 and 20 percent additions of glucose; the control sample was more moist than the other two. Significant differences were also found between the 40 percent and 10 and 20 percent increases in glucose; the sample having the 40 percent addition was more moist (Table 7).

Significant differences found between the ranks on the second day were between the control and 40 percent additions and between 20 and 40

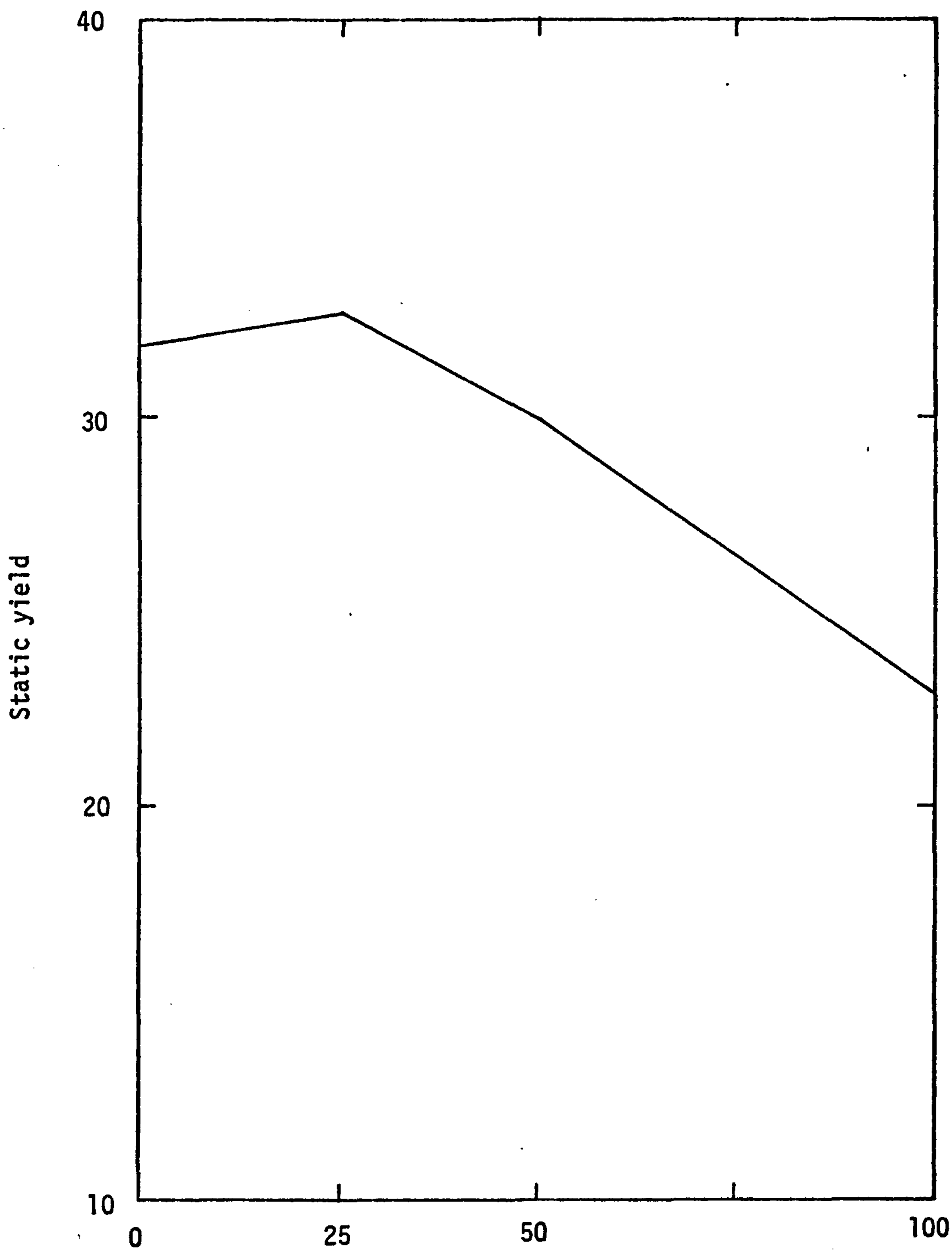

Figure 6. Average static yield with increasing quantities of dextrin

Table 6

Daily and Average Taste Panel Ranks* for Increasing Quantities of Glucose

Subject No.	First Day Percent Increase 0	10	20	40	Second Day Percent Increase 0	10	20	40	Third Day Percent Increase 0	10	20	40	Fourth Day Percent Increase 0	10	20	40
1	4	1	2	3	4	3	2	1	3	4	2	1	4	3	1	2
2	4	1	2	3	3	2	4	1	2	4	3	1	1	4	2	3
3	1	3	2	4	1	2	3	4	1	4	2	3	4	1	3	2
4	4	2	1	3	2	3	1	4	3	4	2	1	4	3	2	1
5	4	2	1	3	1	3	4	2	4	2	3	1	4	3	1	2
6	2	1	4	3	4	1	2	3	3	2	1	4	4	3	1	2
7	3	4	1	2	2	3	4	1	1	4	3	2	3	4	1	2
8	4	2	1	3	4	1	2	3	1	4	3	2	4	2	1	3
9	4	1	2	3	4	2	1	3	2	1	4	3	4	3	2	1
10	3	2	1	4	1	3	4	2	1	3	2	4	4	2	1	3
11	4	1	2	3	4	1	2	3	3	1	4	2	4	2	3	1
12	4	1	2	3	4	1	3	2	4	1	2	3	4	2	1	3
13	1	4	3	2	1	4	2	3	1	4	3	2	4	2	1	3
14	4	2	1	3	2	3	4	1	3	4	2	1	4	1	3	2
15	4	1	2	3	3	1	4	2	1	4	2	3	4	3	1	2
16	3	2	1	4	4	2	3	1	1	4	3	2	4	2	3	1
17	4	1	3	2	2	4	3	1	3	2	4	1	4	2	3	1
18	4	1	2	3	4	2	3	1	3	1	2	4	3	1	2	4
19	4	1	2	3	2	3	4	1	4	1	3	2	1	3	4	2
20	4	1	2	3	4	3	2	1	4	1	3	2	2	1	4	3
21	1	2	3	4	3	1	2	4	3	2	1	4	1	4	3	2
$\overline{X}$ Rank	3.3	1.7	1.9	3.1	2.8	2.3	2.9	2.1	2.5	2.8	2.5	2.3	3.4	2.4	2.1	2.2
N of Subjects	21				21				21				21			
Q Value	29.87 ($P < .01$)				9.86 ($P < .025$)				6.03 ($P < .25$)				18.96 ($P < .01$)			

*Ranking: 1 = Most Dry; 4 = Most Moist

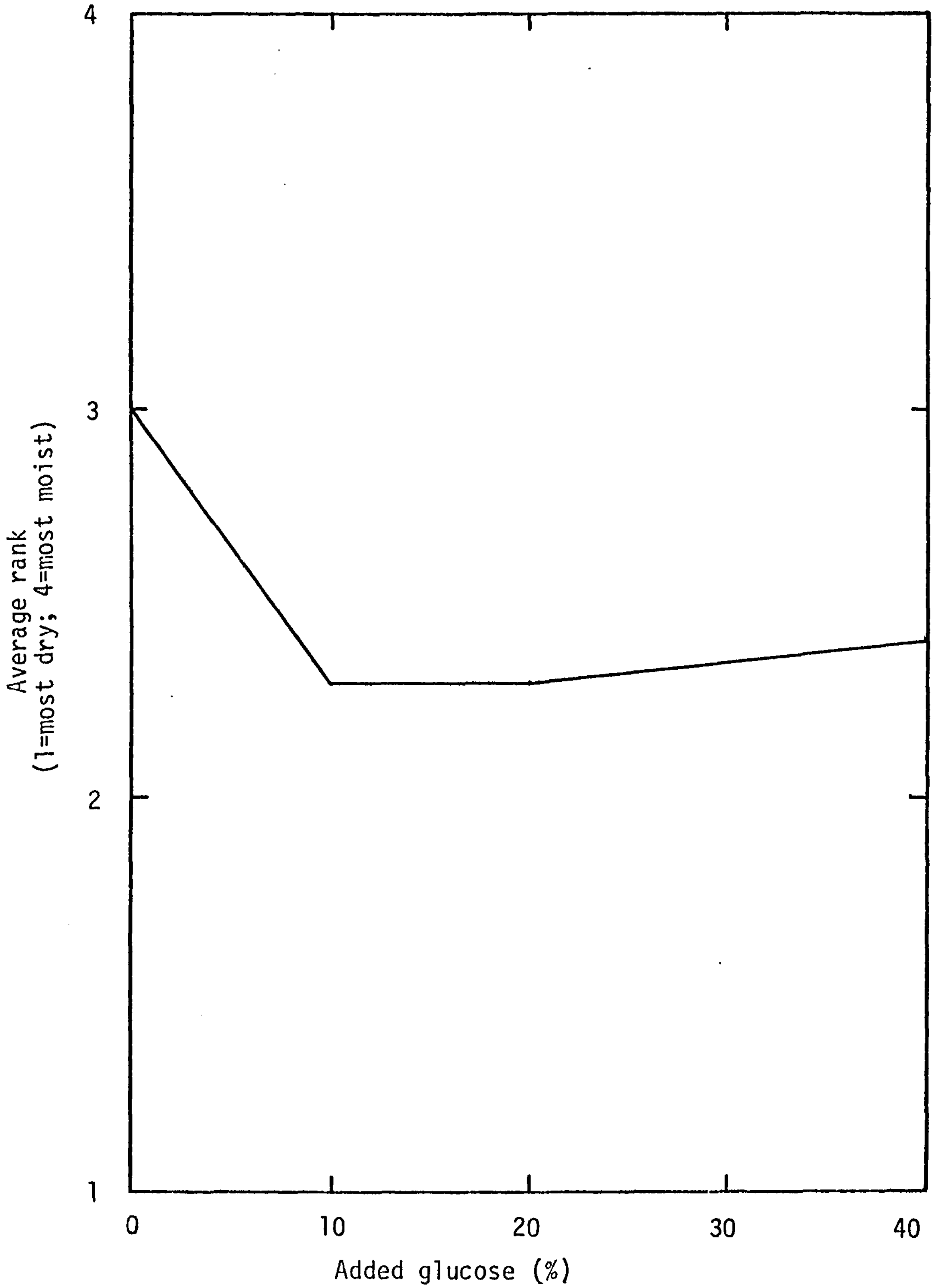

Figure 7. Average rank with increasing quantities of glucose

Table 7

Multiple Comparison of Mouthfeel Characteristics of

Glucose-Sweet Potato Mixtures*

Day	Percent Glucose Above Amount in Standard Sweet Potato			
	Control	10	20	40
First Day	More moist than 10 or 20%	More dry than Control or 40%	More dry than Control or 40%	More moist than 10 or 20%
Second Day	More moist than 40%	No significant difference	More moist than 40%	More dry than Control or 20%
Third Day	No Significant Differences			
Fourth Day	More moist than 10, 20, or 40%	More dry than Control	More dry than Control	More dry than Control

*.05 Significance Level

percent additions of glucose. The control sample was more moist than the 40 percent, and the 20 percent was more moist than the 40 percent additions of glucose. No significant differences were found between ranks on the third day of the sensory panel. On the fourth day of sensory evaluations, significant differences were observed between the control sample and samples which had 10, 20, and 40 percent increases in glucose. The control sample was more moist than other samples (Table 7).

Apparent Viscosity and Static Yield Measurements

Average daily and group mean apparent viscosity and static yield values are presented in Appendix I. No significant differences were found between average apparent viscosity values of different mixtures with a two-way analysis of variance (Appendix I). No significant linear, quadratic, or cubic effects were found with the regression technique. As increasing quantities of glucose were added, apparent viscosity first increased (with 10 and 20 percent additions) and then decreased (Figure 8).

A significant ($P < .05$) linear response was found between average static yield values and increasing quantities of glucose (Appendix I). With 10 percent increases of glucose, static yield remained fairly constant. A dramatic increase in static yield was observed with 20 percent additions and was followed by a decrease with 40 percent additions of glucose (Figure 9).

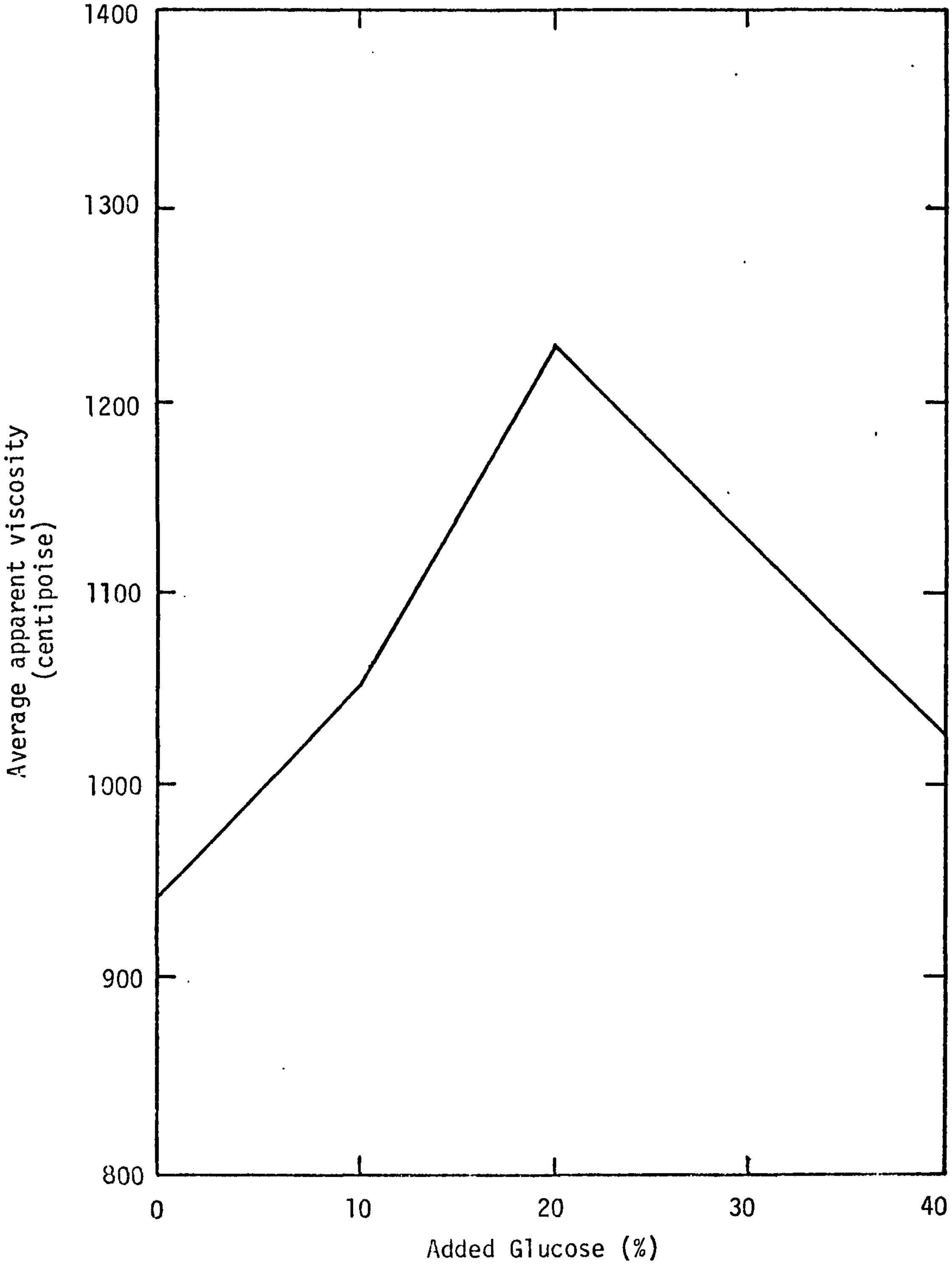

Figure 8. Average apparent viscosity with increasing quantities of glucose

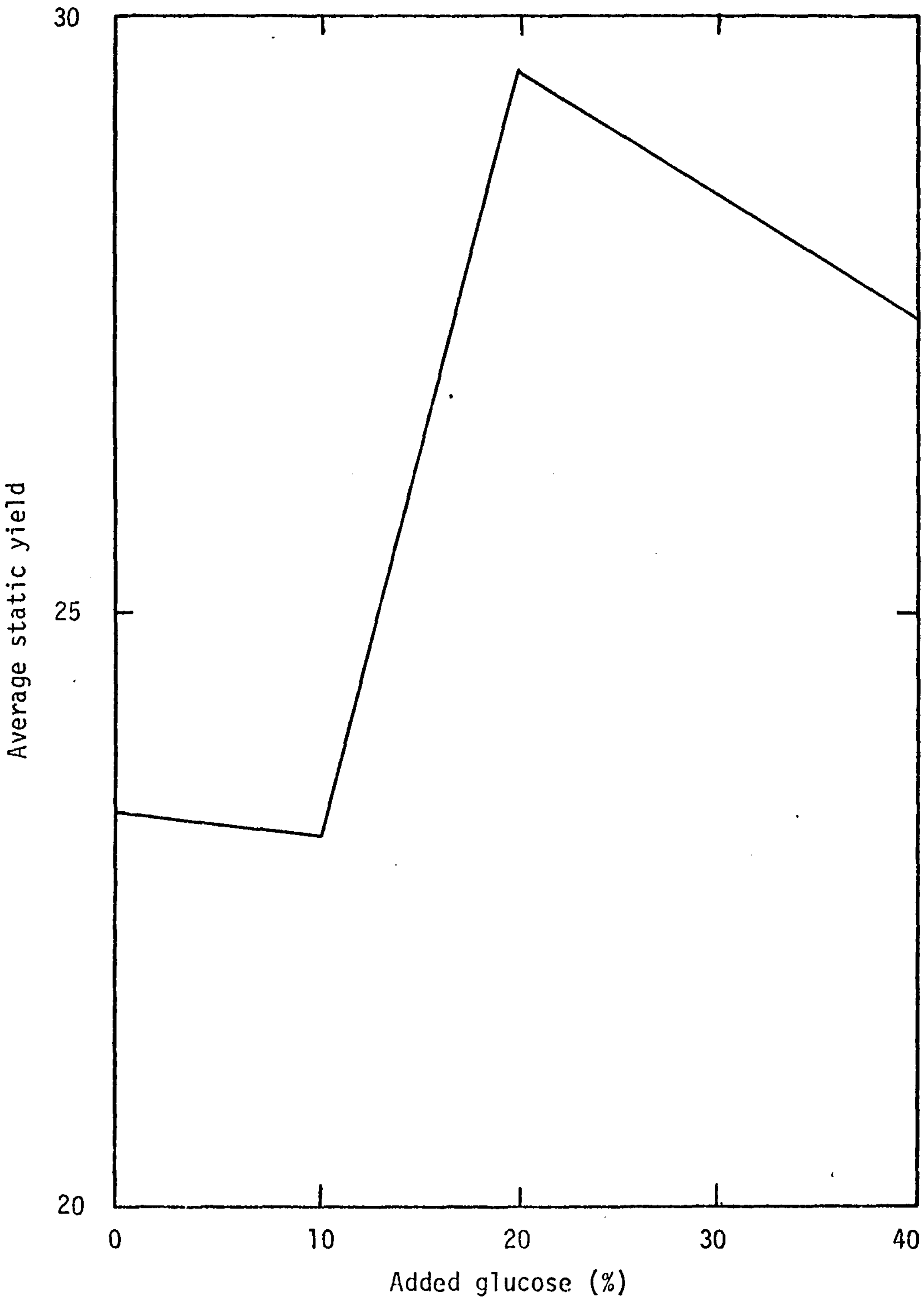

Figure 9. Average static yield with increasing quantities of glucose

Maltose-Sweet Potato Mixtures

Sensory Evaluations

Daily and averaged sensory panel rankings are presented in Table 8. No significant differences were found with a two-way analysis of variance between group mean ranks and increasing quantities of maltose. Using the regression technique, no significant linear, quadratic, or cubic effects were found between group mean taste panel ranks and increasing amounts of maltose (Appendix J). With 20 percent additions of maltose, average taste panel rank increased, leveled off at 30 percent additions, and increased when 40 percent additions of maltose were made, indicating a slightly more moist mixture (Figure 10).

Significant differences ($P < .05$) were found with the Friedman Test on daily sensory ranking data on the third day of the evaluations, and highly significant differences ($P < .005$) were found on the first and fourth days (Table 8).

Using the Multiple Comparison method (Table 9) with a .05 level of significance, the control sample was evaluated on the first day as more dry than the samples which had additions of maltose. Significant differences on the third day were found between control samples and samples which had 20 percent additions in maltose; the control sample was ranked more dry. On the fourth day of the sensory evaluations, significant differences were observed between control samples and samples to which 20 and 30 percent additions of maltose had been made and between 40 percent and 20 and 30 percent additions of maltose. The control sample tended to be more moist than samples with 20 and 30 percent

Table 8

Daily and Average Taste Panel Ranks* for Increasing Quantities of Maltose

Subject No.	First Day Percent Increase				Second Day Percent Increase				Third Day Percent Increase				Fourth Day Percent Increase				Fifth Day Percent Increase			
	0	20	30	40	0	20	30	40	0	20	30	40	0	20	30	40	0	20	30	40
1	-	-	-	-	3	2	4	1	3	2	1	4	3	4	1	2	3	4	1	2
2	1	3	2	4	2	1	4	3	4	1	3	2	3	1	4	2	3	4	2	1
3	1	3	4	2	-	-	-	-	1	4	2	3	3	2	1	4	3	2	4	1
4	1	2	4	3	1	2	4	3	1	3	4	2	2	4	3	1	3	4	2	1
5	-	-	-	-	1	2	3	4	2	3	1	4	3	1	2	4	4	2	1	3
6	1	3	2	4	4	1	3	2	2	3	1	4	3	2	1	4	2	4	1	3
7	-	-	-	-	1	3	2	4	4	3	2	1	3	1	2	4	4	2	3	1
8	1	2	3	4	3	1	4	2	3	2	4	1	4	2	1	3	4	2	1	3
9	-	-	-	-	1	3	2	4	2	3	4	1	3	1	2	4	2	1	3	4
10	1	3	4	2	-	-	-	-	1	4	2	3	3	2	1	4	2	4	1	3
11	-	-	-	-	3	2	4	1	1	2	4	3	3	1	2	4	1	3	2	4
12	1	2	3	4	4	1	2	3	1	3	4	2	3	1	2	4	2	4	1	3
13	1	3	2	4	4	1	3	2	4	2	3	1	4	2	1	3	3	1	2	4
14	1	3	2	4	-	-	-	-	1	4	3	2	3	2	1	4	2	1	3	4
15	-	-	-	-	2	3	4	1	1	3	4	2	2	3	1	4	2	3	1	4
16	4	1	3	2	-	-	-	-	1	2	3	4	3	2	1	4	2	4	1	3
17	1	4	2	3	-	-	-	-	2	4	3	1	4	1	2	3	4	3	1	2
18	-	-	-	-	1	3	2	4	2	4	1	3	2	4	1	3	4	1	3	2
19	1	4	2	3	-	-	-	-	1	4	2	3	3	1	2	4	1	2	3	4
20	-	-	-	-	4	2	3	1	1	2	3	4	1	3	2	4	2	3	4	1
21	2	4	1	3	-	-	-	-	1	3	4	2	2	3	1	4	3	4	1	2
$\overline{X}$	1.3	2.9	2.6	3.2	2.4	1.9	3.2	2.5	1.9	2.9	2.8	2.5	2.9	2.1	1.6	3.5	2.7	2.8	2.0	2.6
N of Subjects	13				14				21				21				21			
Q Value	16.29 ($P < .005$)				6.25 ($P < .10$)				8.14 ($P < .05$)				25.97 ($P < .005$)				5.17 ($P < .25$)			

*Ranking: 1 = Most Dry; 4 = Most Moist

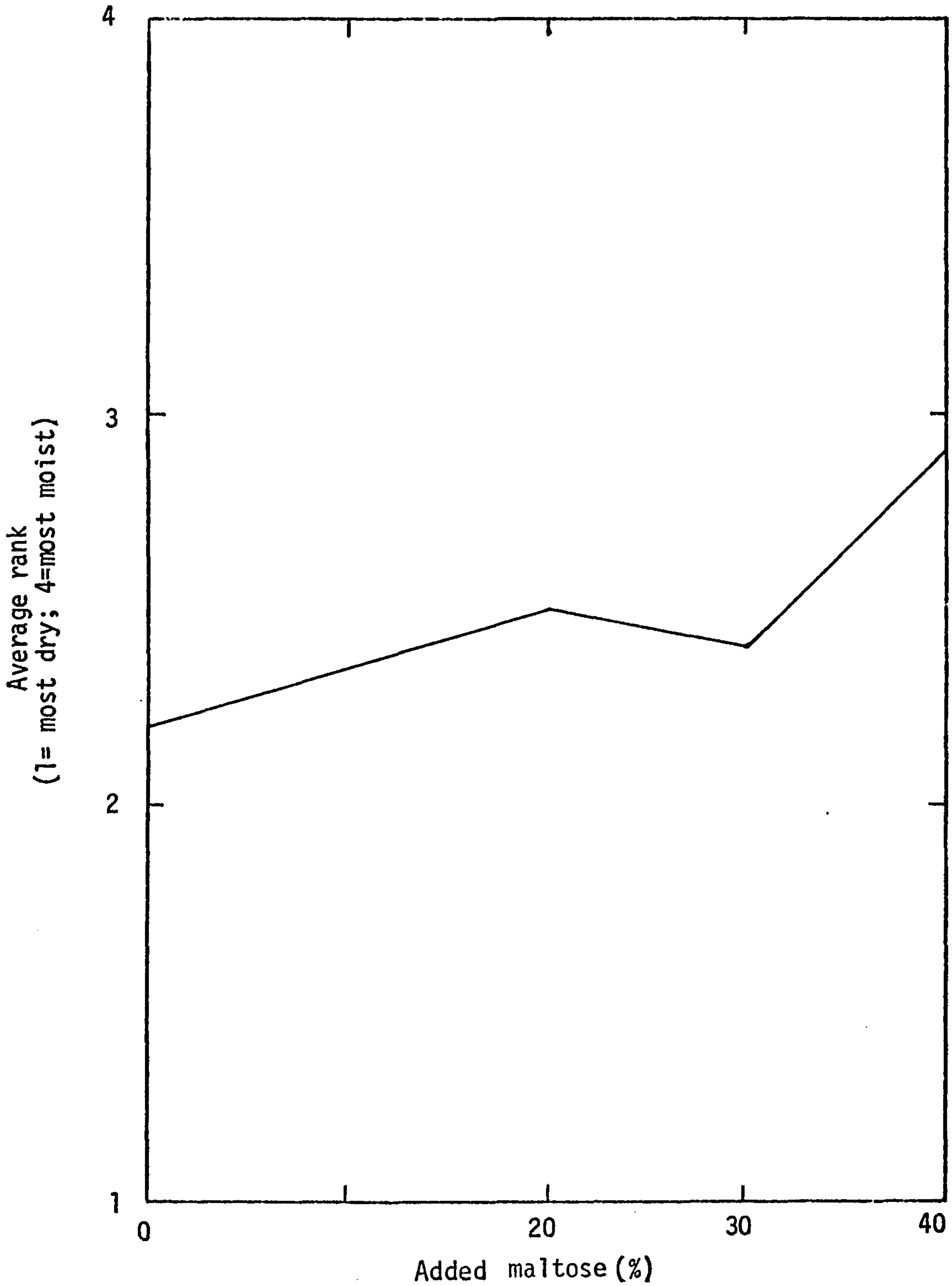

Figure 10. Average rank with increasing quantities of maltose

Table 9

Multiple Comparison of Mouthfeel Characteristics of

Maltose-Sweet Potato Mixtures*

Day	Percent Maltose Above Amount in Standard Sweet Potato			
	Control	20	30	40
First Day	More dry than 20, 30 or 40%	More moist than Control	More moist than Control	More moist than Control
Second Day	No Significant Differences			
Third Day	More dry than 20%	More moist than Control	No significant difference	No significant difference
Fourth Day	More moist than 20 or 30%	More dry than Control or 40%	More dry than Control or 40%	More moist than 20 or 30%
Fifth Day	No Significant Differences			

*.05 Significance Level

additions, and the sample with 40 percent additions of maltose was more moist than samples to which 20 and 30 percent increases of maltose had been made (Table 9).

Apparent Viscosity and Static Yield Measurements

Average daily apparent viscosity and static yield values are given in Appendix J. No significant differences were found between mean static yield or apparent viscosity values of various mixtures with a two-way analysis of variance (Appendix J). The response of apparent viscosity to increasing quantities of maltose is illustrated in Figure 11. Although no linear, quadratic, or cubic effects were found, increasing quantities of maltose tended to decrease apparent viscosity of the mixture (Figure 11).

No significant linear, quadratic, or cubic effects on average static yield were noted with increasing quantities of maltose (Appendix J). With 20 percent maltose additions, static yield increased slightly and then decreased with 30 percent additions. Static yield increased with 40 percent additions (Figure 12).

Sweet Potato Starch-Potato Mixtures (Heated)

Sensory Evaluations

Daily and average sensory panel rankings are given in Table 10. Mean group ranks are presented in Appendix K. Although no significant linear response was found for average ranks with increasing quantities of sweet potato starch, a significant ($P < .05$) quadratic and cubic effect was observed (Appendix V). As the percentage of starch

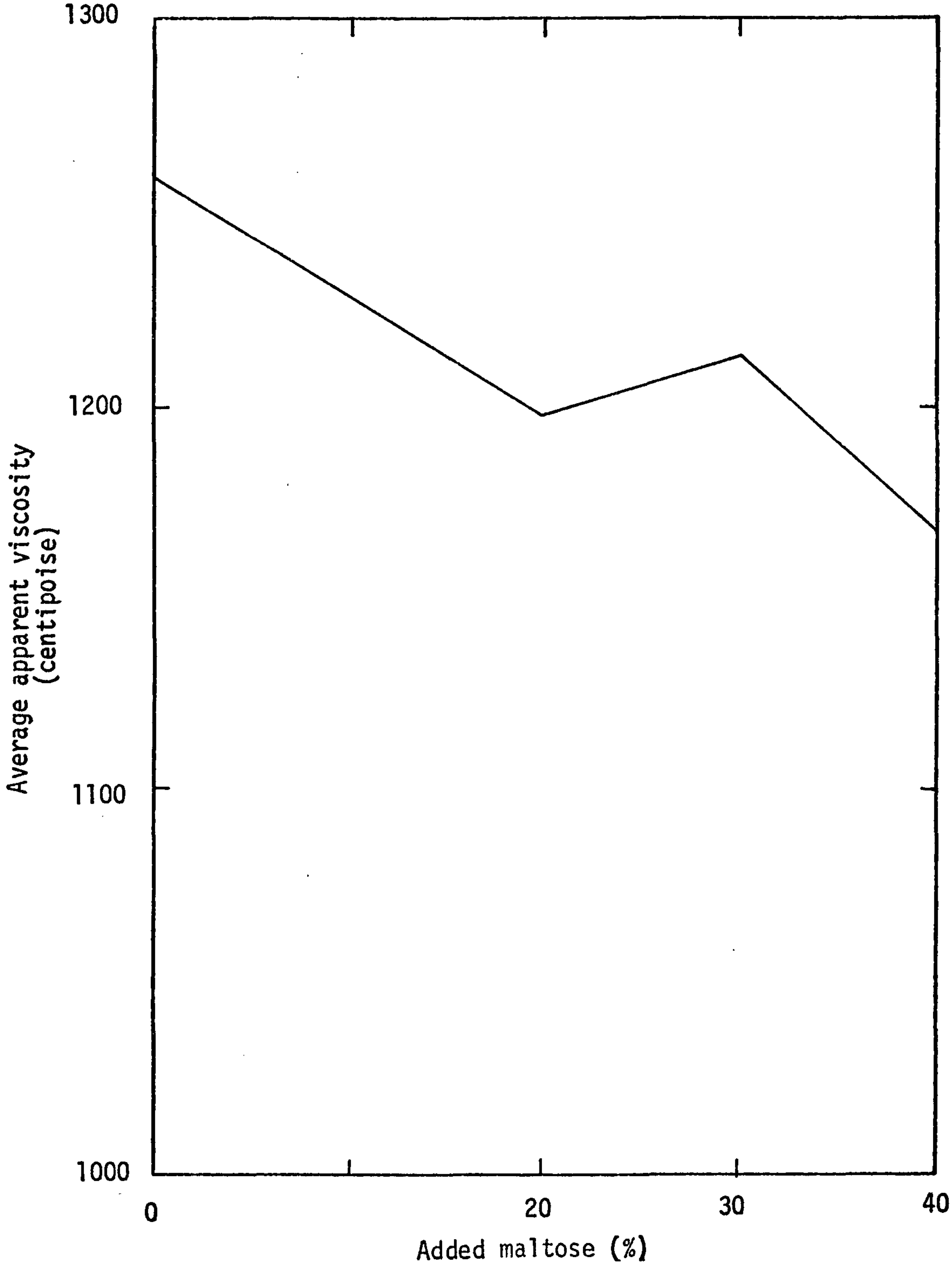

Figure 11. Average apparent viscosity with increasing quantities of maltose

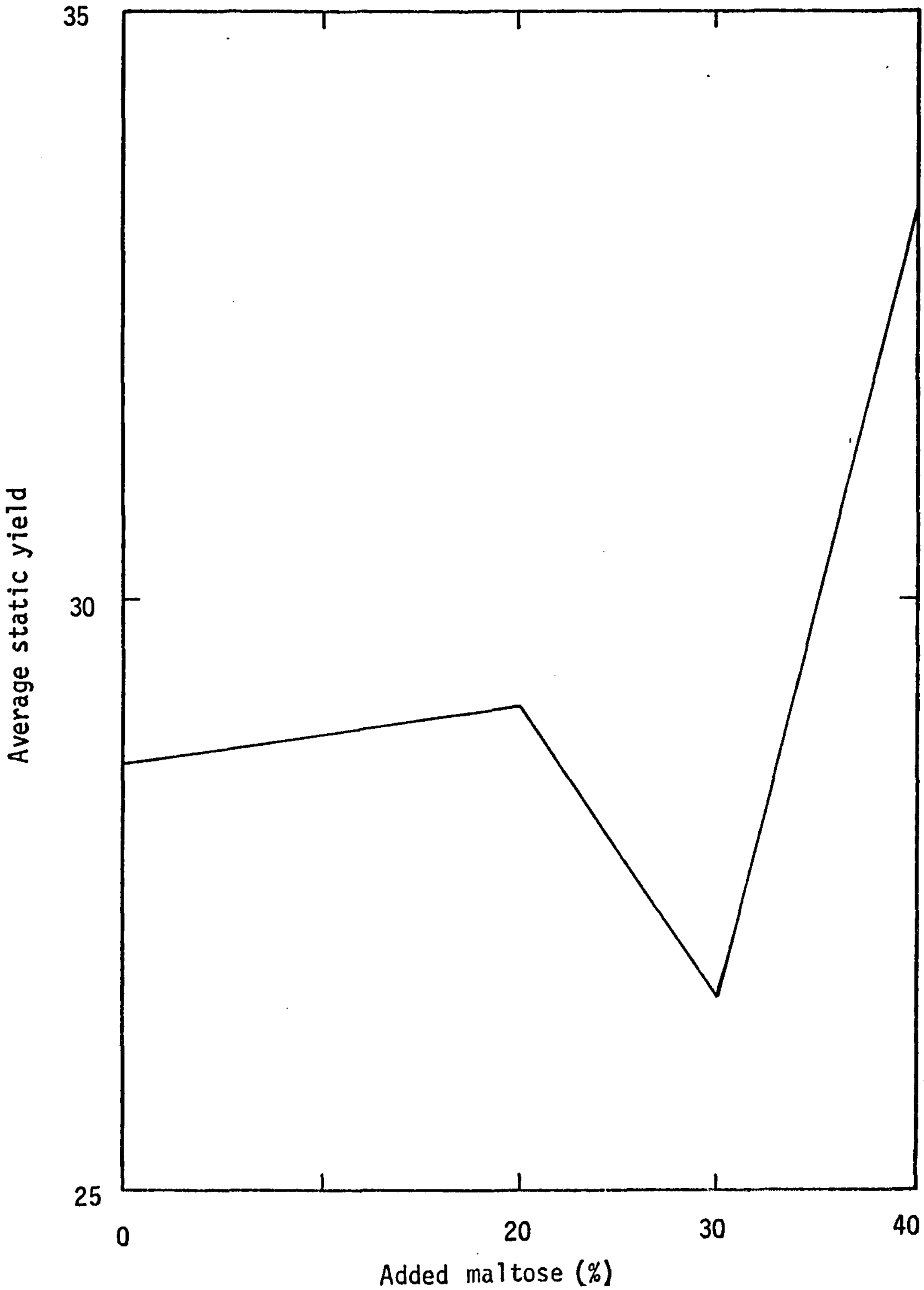

Figure 12. Average static yield with increasing quantities of maltose

Table 10

Daily and Average Taste Panel Ranks* for Increasing Quantities of Sweet Potato Starch (Heated)

	First Day				Second Day				Third Day				Fourth Day			
Subject	Percent		Increase		Percent		Increase		Percent		Increase		Percent		Increase	
No.	0	2	5	10	0	2	5	10	0	2	5	10	0	2	5	10
1	4	1	2	3	2	1	3	4	3	4	2	1	3	4	1	2
2	2	1	4	3	1	4	2	3	4	2	1	3	2	1	3	4
3	1	3	4	2	1	4	3	2	1	2	4	3	1	3	4	2
4	2	3	1	4	3	1	4	2	3	1	2	4	1	2	3	4
5	4	2	3	1	4	3	2	1	1	2	4	3	2	3	4	1
6	2	1	3	4	2	1	4	3	2	1	4	3	3	1	4	2
7	2	1	4	3	3	1	4	2	2	3	4	1	2	3	4	1
8	4	2	1	3	3	1	2	4	1	2	4	3	2	3	4	1
9	2	1	3	4	1	4	2	3	2	4	1	3	4	2	3	1
10	1	3	2	4	2	1	3	4	3	2	4	1	2	3	4	1
$\bar{X}$ Rank	2.4	1.8	2.7	3.1	2.2	2.1	2.9	2.8	2.2	2.3	3.0	2.5	2.2	2.5	3.4	1.9
N of Subjects	10				10				10				10			
Q Value	5.40 ($P < .25$)				3.00 ($P < .50$)				2.28 ($P < .75$)				7.56 ($P < .10$)			

*Ranking: 1 = Most Dry; 4 = Most Moist

increased, moist mouthfeel characteristic increased at first and then decreased (Figure 13).

Using the Friedman Test for daily ranking data, no significant differences were found for average daily ranks of mixtures (Table 10). As seen in Table 10, average ranks for the control sample (0 percent added starch) were fairly consistent. Average ranks for mixtures with different quantities of starch added showed considerable variation (Table 10).

Apparent Viscosity and Static Yield Measurements

Daily and average apparent viscosity and static yield values are presented in Appendix K. Significant ($P < .05$) differences were found between average apparent viscosity values of different mixtures with a two-way analysis of variance (Appendix K). Using a regression technique, a significant ($P < .05$) linear and quadratic response of apparent viscosity to increasing quantities of sweet potato starch was observed (Appendix K). Apparent viscosity of the mixture rose sharply with 2 percent additions of sweet potato starch. Five percent additions decreased apparent viscosity, and 10 percent additions caused a slight increase in apparent viscosity of mixtures (Figure 14).

Highly significant ($P < .01$) differences were found between average static yield values of mixtures (Appendix K). Using a regression technique, a highly significant ($P < .01$) linear and quadratic response of static yield to increasing quantities of sweet potato starch was observed (Appendix K). As the percentage of starch increased, static yield of mixtures increased sharply at first at 2 and 5 percent additions and then decreased slightly with 10 percent additions (Figure 15).

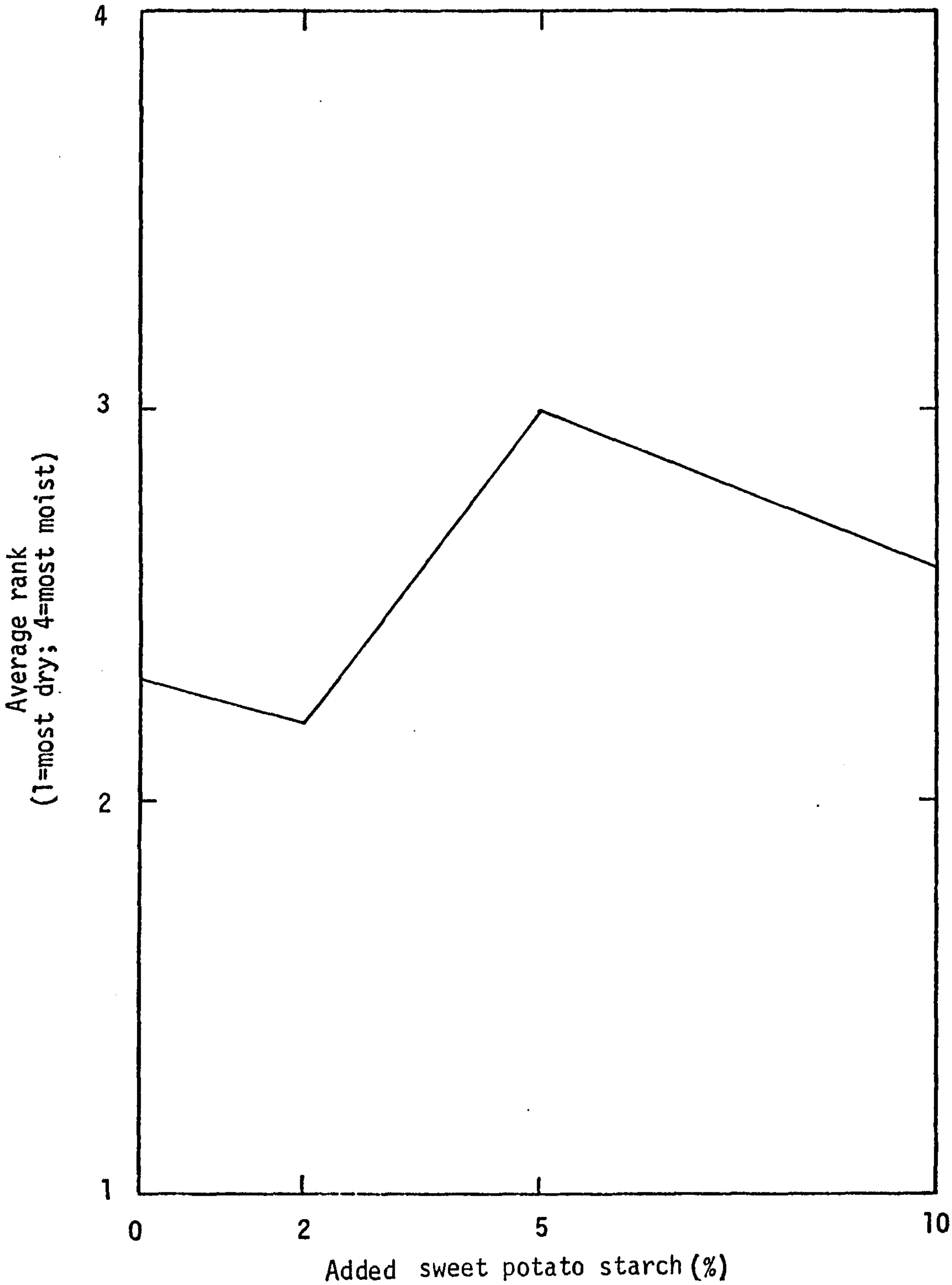

Figure 13. Average rank with increasing amounts of sweet potato starch (heated)

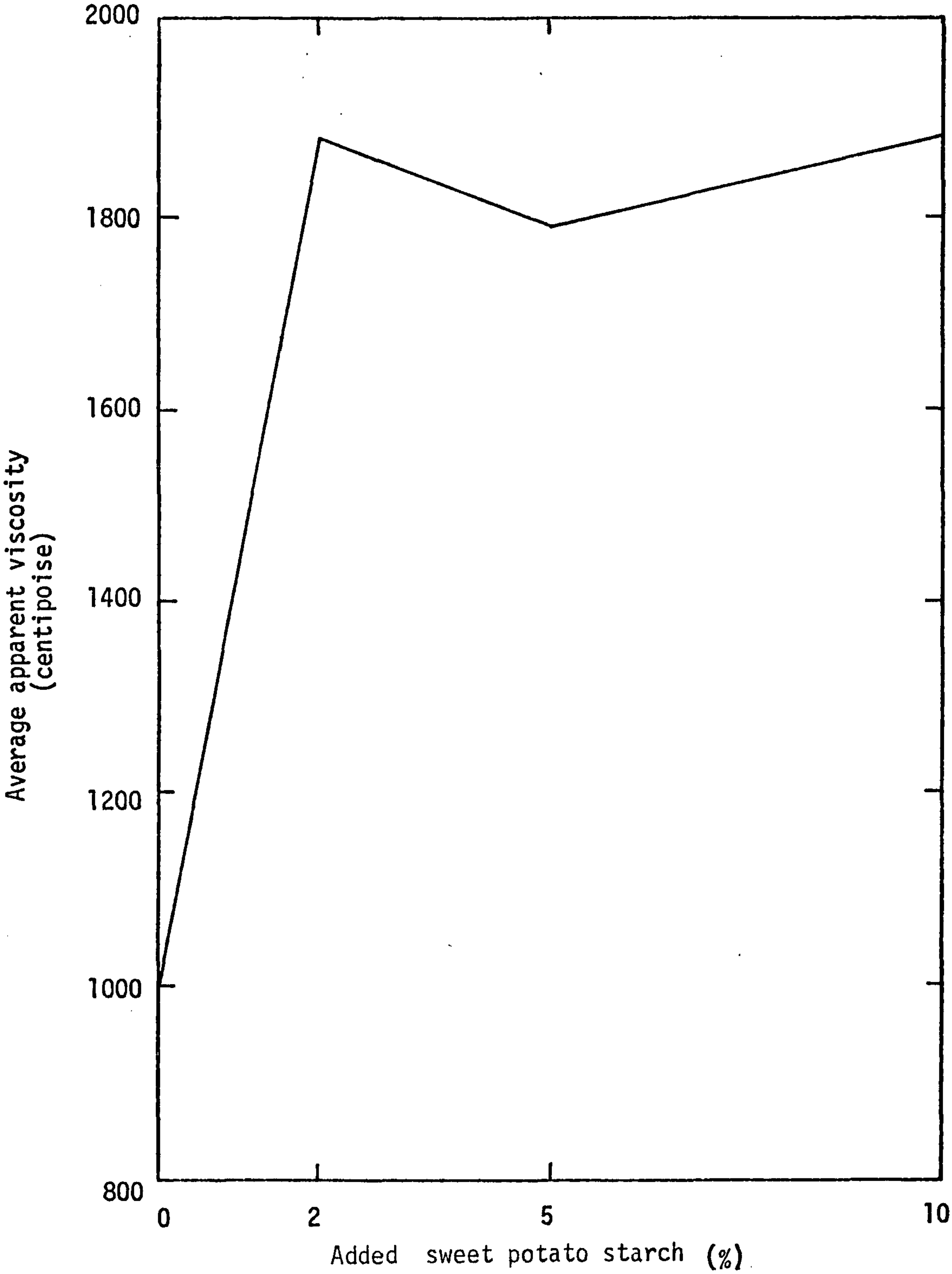

Figure 14. Average apparent viscosity with increasing quantities of sweet potato starch (heated)

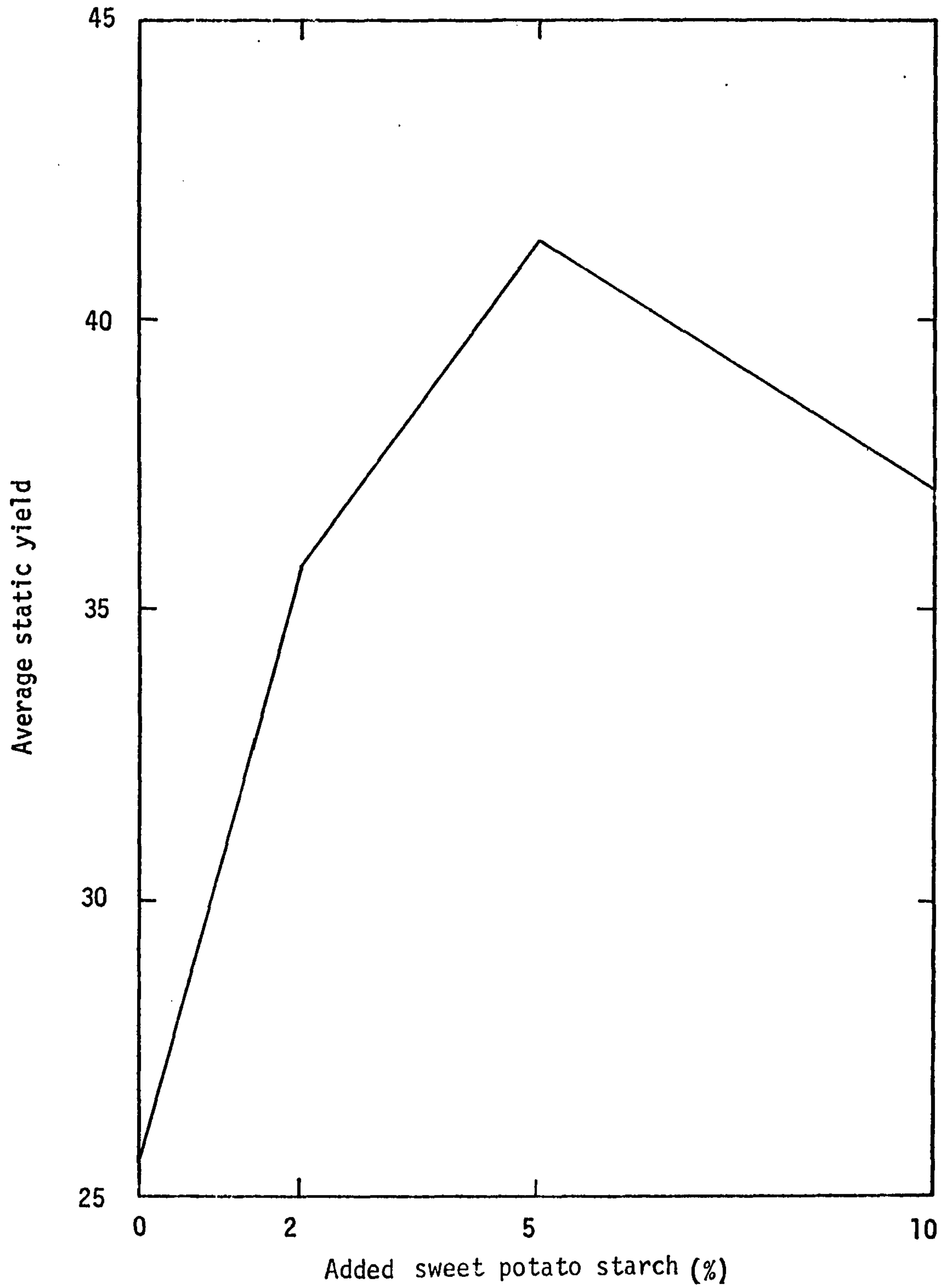

Figure 15. Average static yield with increasing quantities of sweet potato starch (heated)

Model System and Variations

To further determine the effects of variations in starch, maltose, and dextrin on apparent viscosity and static yield, a model system based on the starch, dextrin, maltose, sucrose, glucose, pectin, protein, fat, water, and fiber content of a cured, uncooked sweet potato was prepared. Compositional data for the model system and variations are presented in Appendix D. Only three components were varied in the mixtures, i.e., starch, dextrin, and maltose; all other components remained constant.

Due to difficulty in obtaining homogeneous mixtures, considerable variation in static yield and Haake readings were observed for duplicate samples (Appendix L). Mean static yield and apparent viscosity values (derived from Haake readings) were calculated and are presented in Table 11.

Mean static yield and apparent viscosity values were plotted against varying amounts of starch in Figures 16 and 17, respectively. When the quantity of starch was decreased and that of maltose increased (dextrin content remained constant) in samples 2, 3, and 4, there was a decrease in static yield and apparent viscosity of the mixtures. When the amount of maltose was held constant and the amount of starch decreased as dextrin increased (samples 8, 9, and 10), there was also a decrease in static yield and apparent viscosity of the mixtures. It was interesting to note in samples 8, 9, and 10 where dextrin had been increased at the expense of starch that static yield and apparent viscosity readings were lower than in samples 2, 3, and 4 where maltose was increased at the expense of starch (Figures 16 and 17).

Table 11

Mean Apparent Viscosity and Static Yield Values for the

Model System and Variations

Trial	Starch (gm)	Percent Increase or Decrease from Model System	Dextrin (gm)	Percent Increase or Decrease from Model System	Maltose (gm)	Percent Increase or Decrease from Model System	Mean Static Yield	Mean Apparent Viscosity (centipoise)
1*	13.68	0	1.93	0	2.48	0	15.0	1298.6
2	12.31	-10	1.93	0	3.85	+55	11.7	1020.4
3	10.94	-20	1.93	0	5.22	+110	7.3	603.0
4	9.57	-30	1.93	0	6.58	+165	2.8	208.7
5	13.68	0	2.12	+9.8	2.30	-7	11.1	974.0
6	13.60	-0.6	2.32	+20	2.16	-13	20.2	1797.2
7	13.63	-0.4	2.50	+30	2.01	-19	14.7	1090.0
8	13.00	-5	2.76	+43	2.48	0	6.7	405.8
9	12.31	-10	3.60	-87	2.48	0	5.7	347.9
10	11.63	-15	4.43	+130	2.48	0	2.4	150.8

*Model System

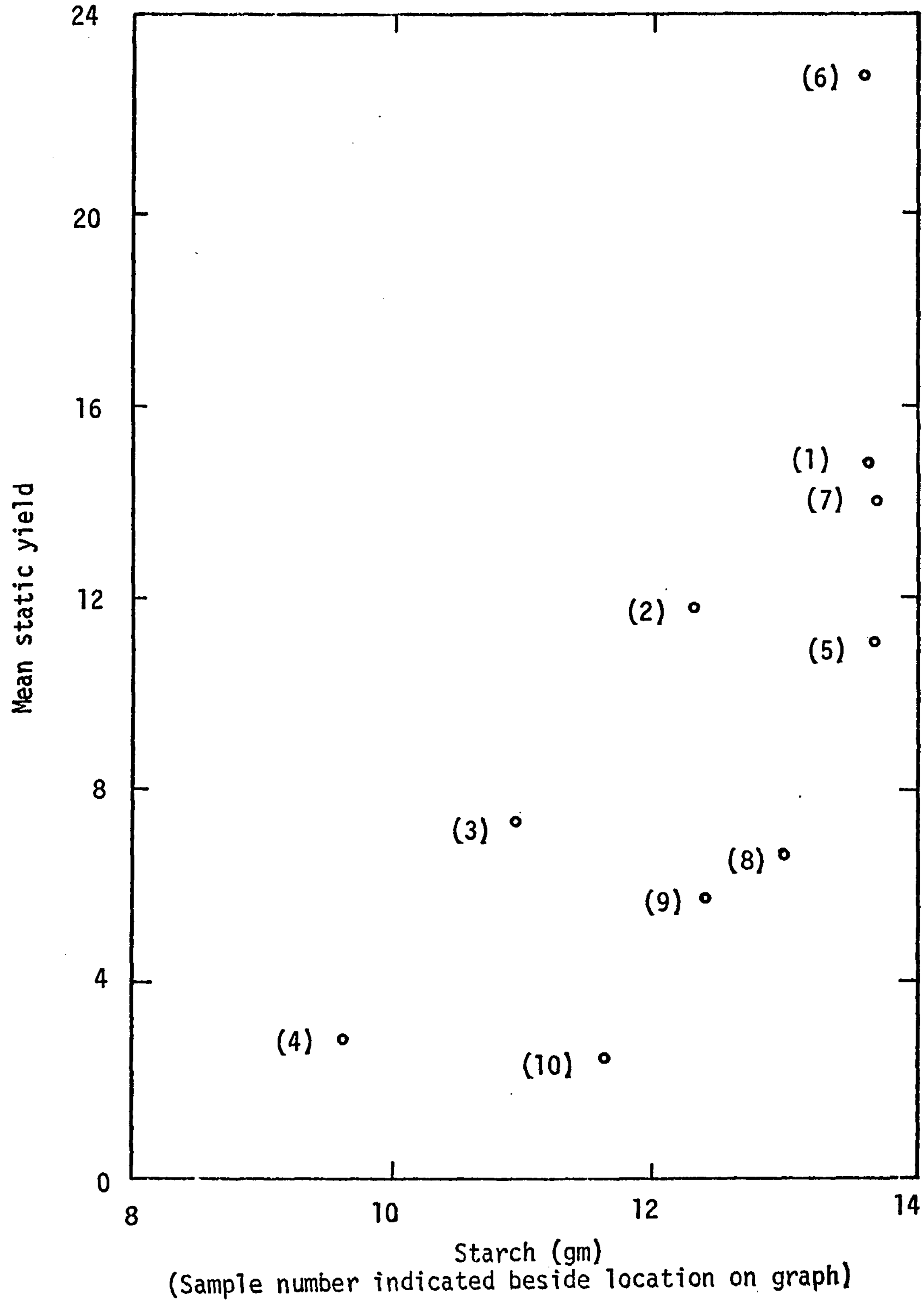

Figure 16. Mean static yield with varying amounts of starch

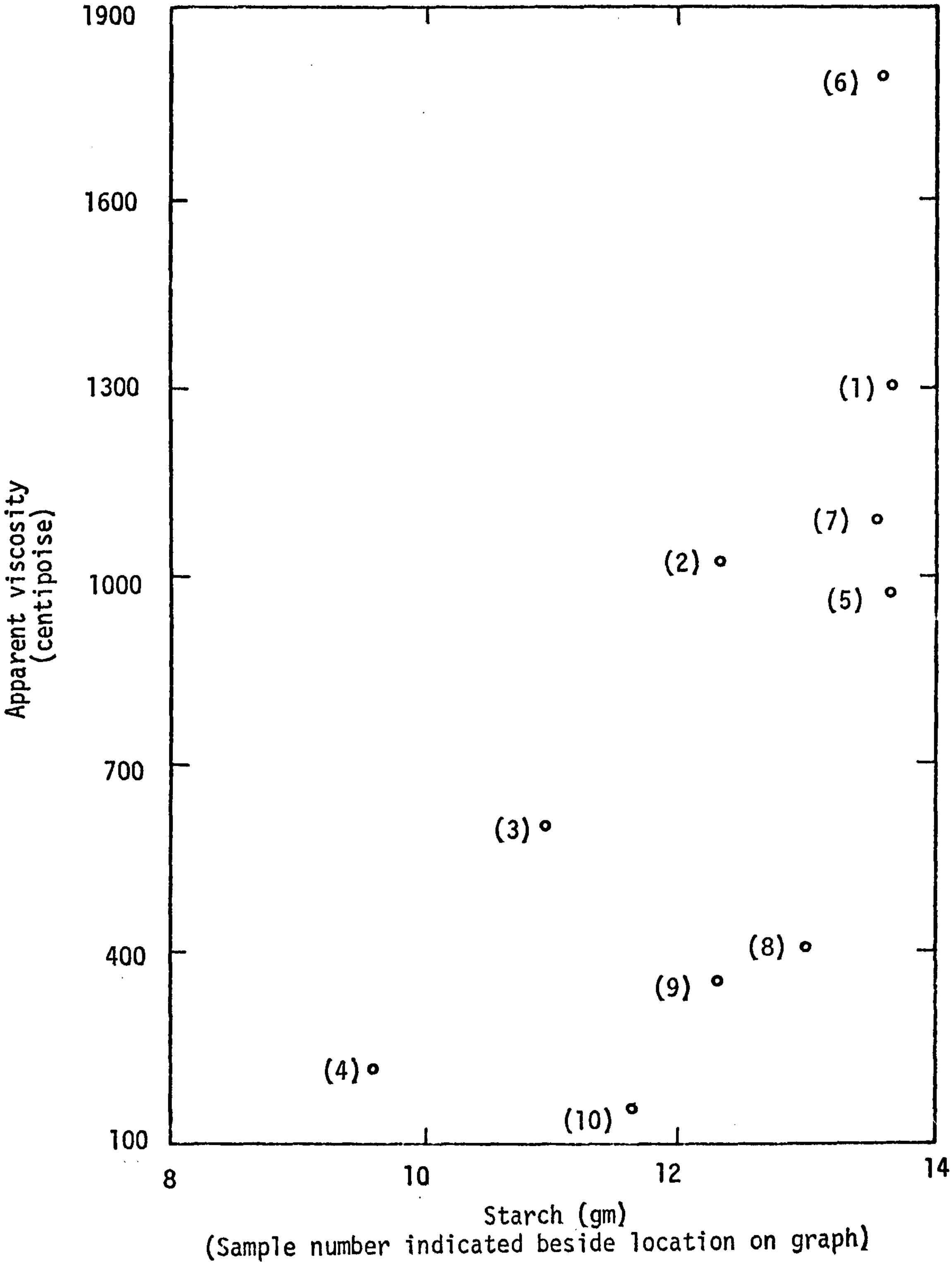

Figure 17. Mean apparent viscosity with varying amounts of starch

There appears to be a linear relationship between amount of starch and static yield and apparent viscosity of mixtures in samples 1 through 4 and 8 through 10. As the amount of starch decreased, static yield and apparent viscosity also decreased. The extraordinarily high static yield and apparent viscosity values of sample number 6 may possibly be attributed to heterogeneity of the mixture rather than to composition of the mixture.

Mean static yield and apparent viscosity values were plotted against varying amounts of maltose in Figures 18 and 19, respectively. A linear relationship was observed between the quantity of maltose and static yield for samples 1, 2, 3, and 4. As the amount of maltose increased, there was a decrease in static yield (Figure 18). A linear relationship was also seen between apparent viscosity values and quantity of maltose for samples 1, 2, 3, and 4. As the quantity of maltose increased in these samples, apparent viscosity decreased (Figure 19). The only variation in samples 1, 2, 3, and 4 was in the quantity of maltose and starch. As starch decreased, the quantity of maltose was increased (Table 11).

Mean static yield and apparent viscosity values were plotted against varying amounts of dextrin in Figures 20 and 21, respectively. A linear relationship was found between quantity of dextrin and static yield in some mixtures. For samples 5, 8, 9, and 10, when quantity of dextrin was increased, static yield decreased (Figure 18). In sample 5, maltose was decreased below the quantity in the model system and dextrin content was increased. In samples 8, 9, and 10, dextrins were increased,

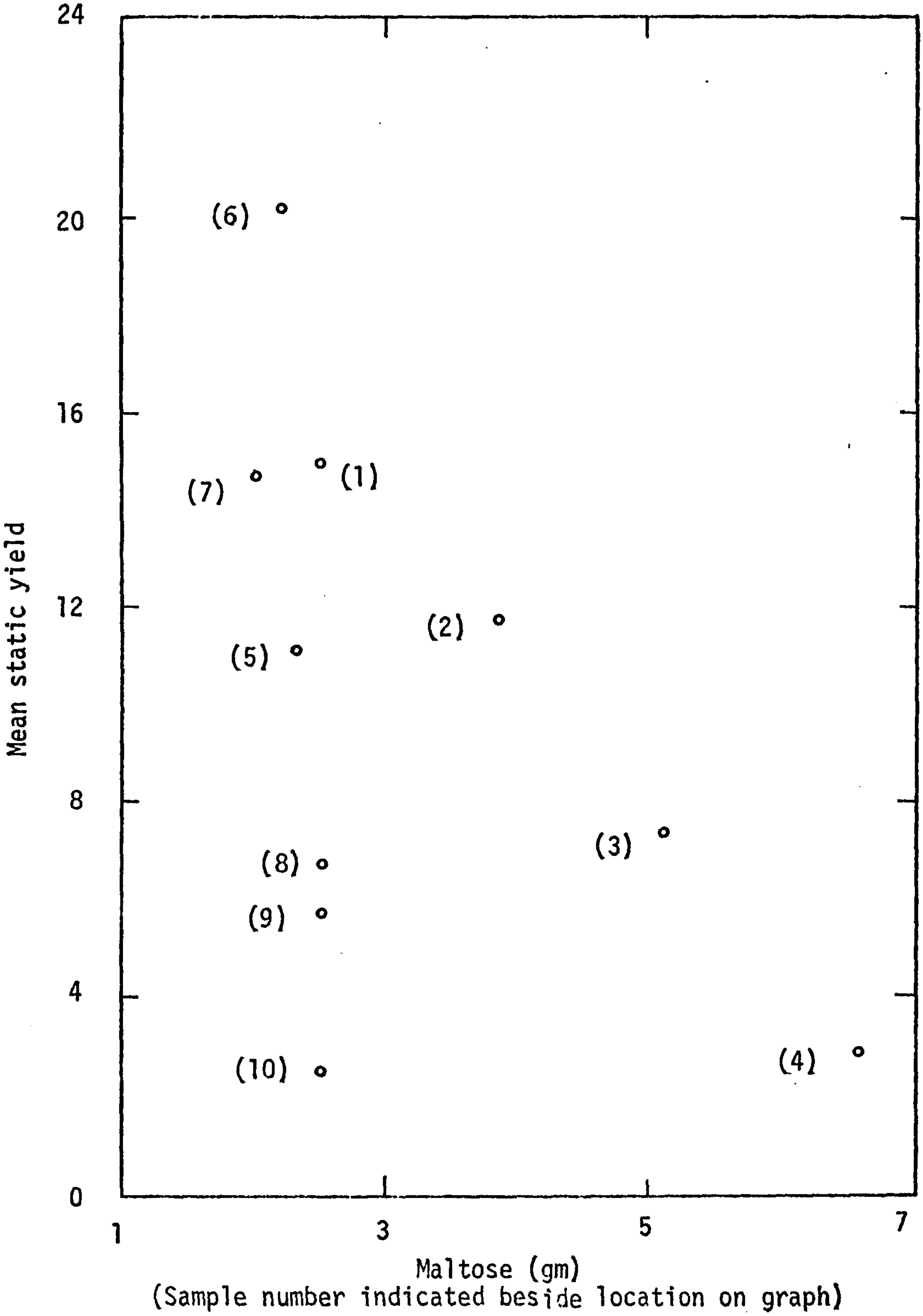

Figure 18. Mean static yield with varying amounts of maltose

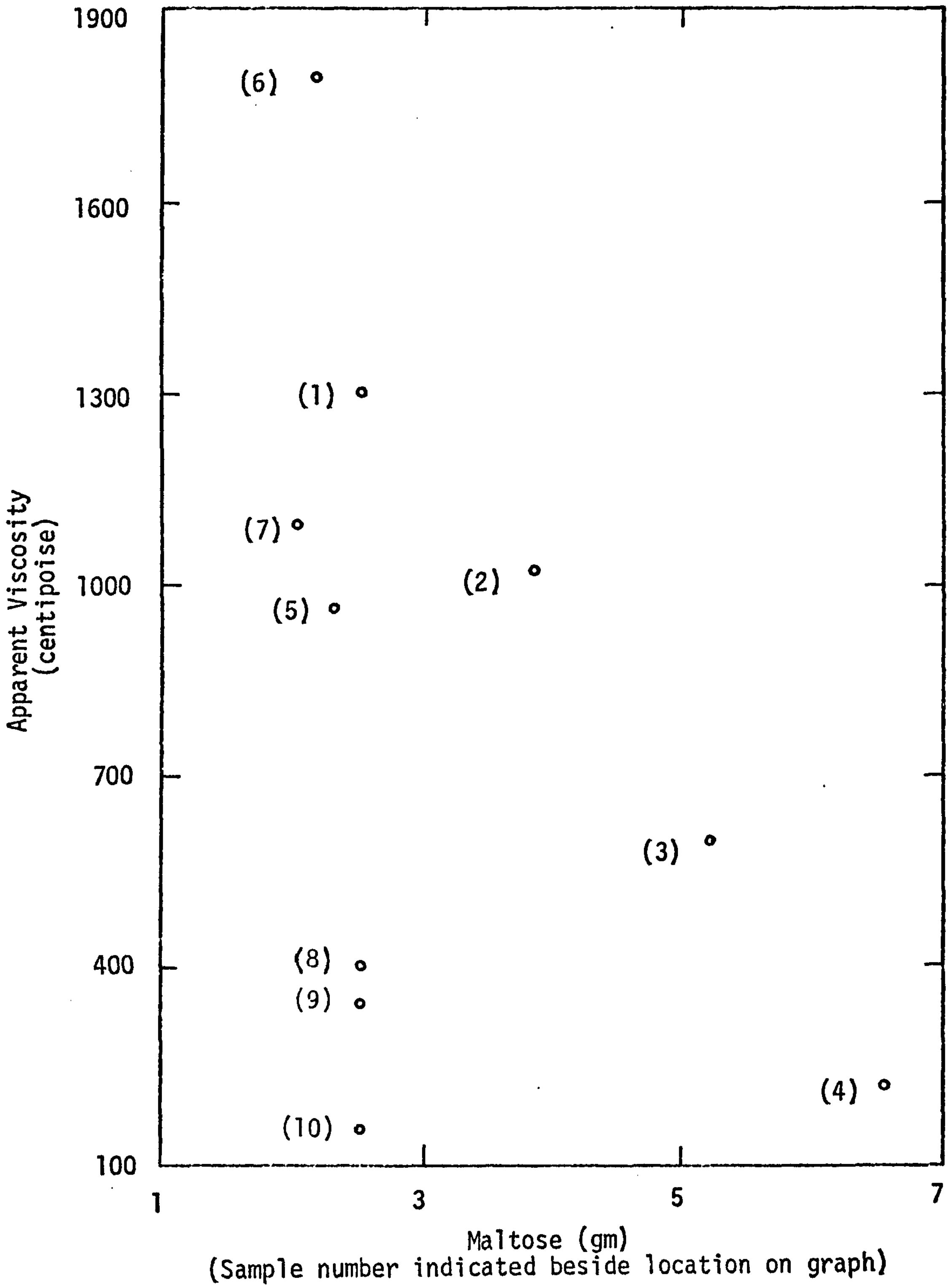

Figure 19. Apparent viscosity with varying amounts of maltose

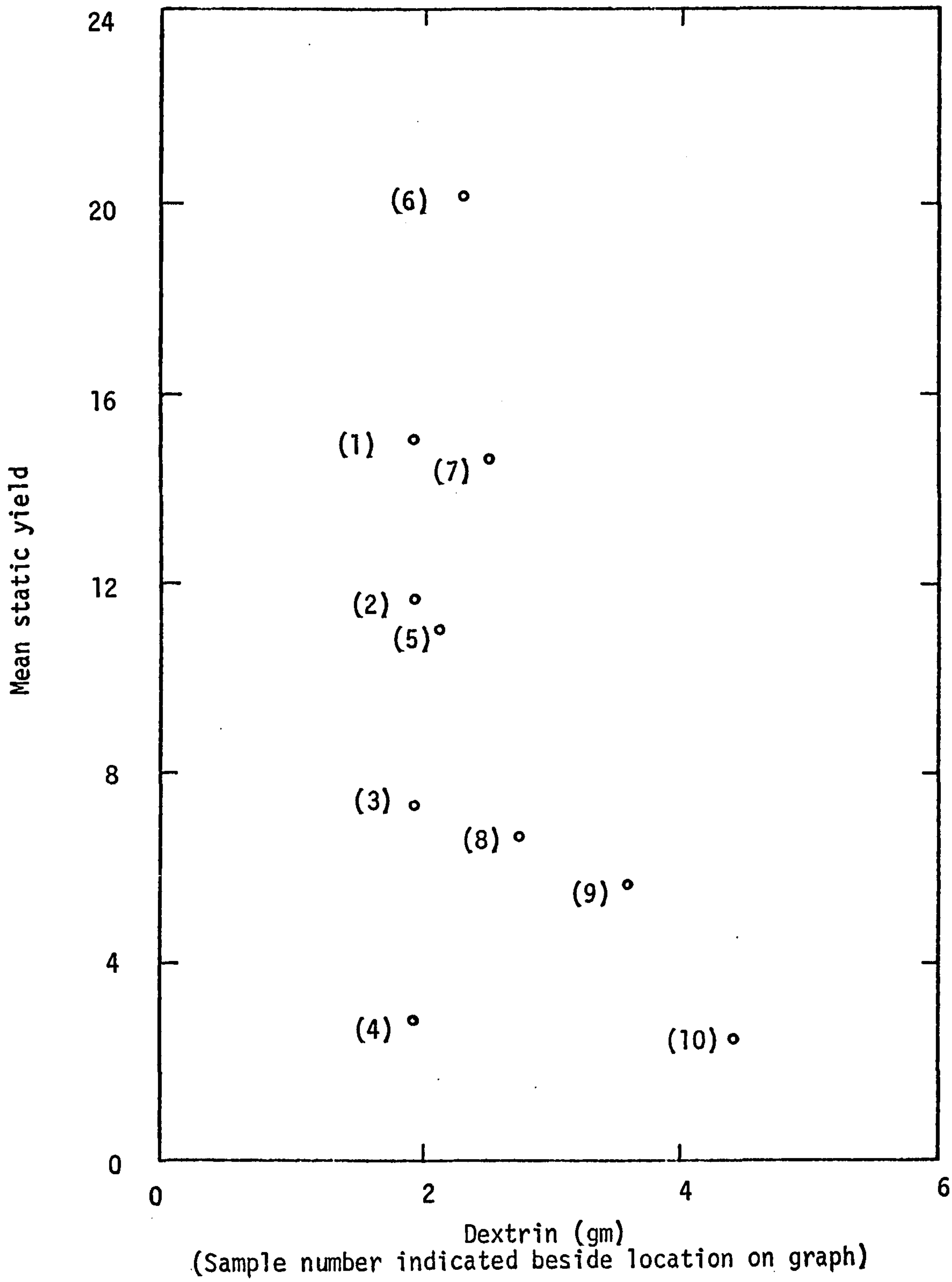

Figure 20. Mean static yield with varying amounts of dextrin

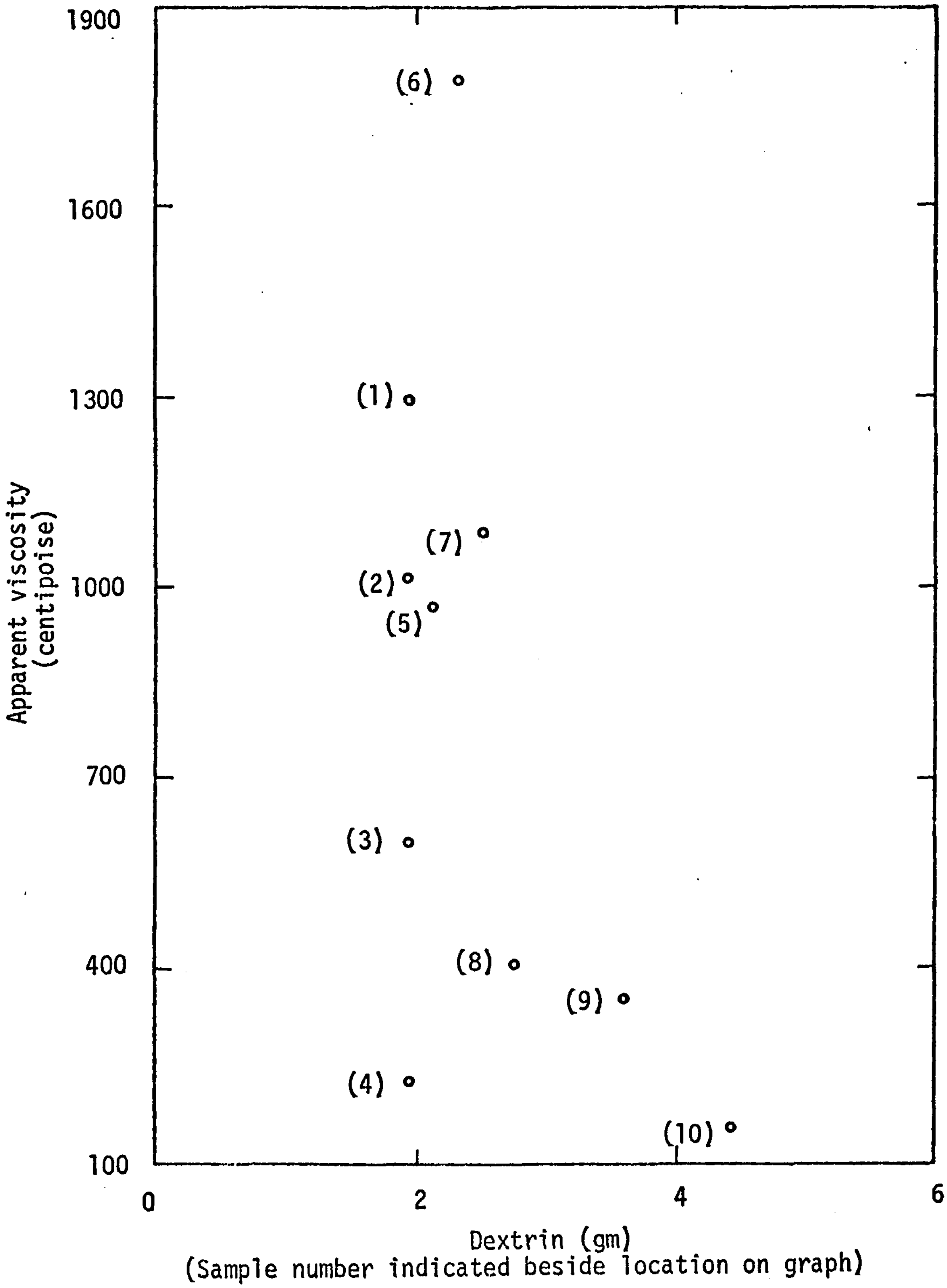

Figure 21. Apparent viscosity with varying amounts of dextrin

maltose remained the same as the amount in the model system, and starch was less than the quantity found in the model system (Table 11).

A linear relationship was also observed between the quantity of dextrin in samples 5, 8, 9, and 10 and apparent viscosity. As the quantity of dextrin increased, apparent viscosity decreased (Figure 21).

Although there is some indication that there is an inverse relationship between the amounts of dextrin and maltose and static yield and apparent viscosity, it must be emphasized that starch was being decreased in proportion to increases in dextrin or maltose. There is a clear relationship between apparent viscosity and static yield and the amount of starch, but in samples 1, 2, 3, and 4 where dextrin remained constant and samples 5, 8, 9, and 10 where maltose content changed little or none, the data indicate an independence of the two properties and dextrin or maltose content.

CHAPTER V

SUMMARY AND CONCLUSIONS

The effect of the quantity of certain carbohydrates, i.e., dextrin, maltose, glucose, and starch, on mouth sensations was tested by incorporating the carbohydrates into sweet potatoes which were then evaluated subjectively by a sensory panel. Sensory evaluations were conducted a minimum of four times on each sweet potato-carbohydrate mixture. The mixtures were objectively evaluated by a Brookfield viscosimeter for static yield and a Haake Rotovisco Model RV-1 Viscometer for apparent viscosity.

Five different series of sweet potato-carbohydrate mixtures were prepared. The amounts of added carbohydrates (above base level) were as follows: dextrin--25, 50, and 100 percent; glucose--10, 20, and 40 percent; maltose--20, 30, and 40 percent; unheated corn starch--10, 20, and 30 percent; heated sweet potato starch--2, 5, and 10 percent. Selection of the quantity of each type of carbohydrate used in the series was based on previous research by Walter et al. (Unpublished). When adding carbohydrates, the amount of carbohydrate reported by various investigators (Walter et al., Unpublished; Lambou, 1958; Hopkins & Phillips, 1937) was the base value; additions were made on the basis of percent increases over the base value which had been observed during processing. For example, Walter et al. (Unpublished) reported the base value in dehydrated sweet potato flakes for maltose as 12 percent by weight; during starch conversion the maltose content increased to 38 percent.

Sensory panel members were trained prior to evaluating the mixtures. Results of the triangle test given to the sensory panel indicated that they could identify the dry and moist mouthfeel characteristics being tested in the study.

Sensory evaluations of unheated corn starch-sweet potato mixtures revealed that increasing quantities of starch increased the dry mouthfeel characteristic. A significant linear response ($P < .02$) was found when the average sensory panel ranks were tested. Daily panel ranks were also consistent with average mean ranks for the series. Apparent viscosity and static yield were affected by the quantity of starch present. A highly significant ($p < .01$) linear response was found for the apparent viscosity and static yield with increasing quantities of corn starch; additions tended to decrease apparent viscosity and static yield of the mixtures. These data are not consistent with the inverse relationship observed between mouthfeel characteristics and apparent viscosity as reported by Rao et al. (1975). These investigators found that as moist mouthfeel sensation increased, apparent viscosity decreased. Since a positive relationship between static yield and apparent viscosity and moist mouthfeel was found in the present study, it is possible that the corn starch addition without subsequent heating tended to lubricate the mixtures resulting in a decrease in apparent viscosity and static yield. The increase in dry mouthfeel characteristics perceived by the sensory panel could possibly be explained by an "alum-like" taste reported by some panel members rather than a true change in mouthfeel sensations.

When increasing quantities of dextrin were added to sweet potatoes, no significant differences were found for mean average sensory panel ranks. Although significant differences were found for ranking data on some of the daily panel rankings, the differences were not consistent. For example, on the first day of the evaluations the control sample was ranked as most dry and on the third and fourth days the control sample was ranked as more moist than some samples with dextrin added. No significant differences were found in apparent viscosities of the different mixtures. It was interesting to note, however, that when the apparent viscosity data were graphed, there was a continued and steady decrease in the apparent viscosity with increasing amounts of dextrin (Figure 5). A significant ($P < .05$) linear response was found for the average static yield with increasing quantities of dextrin. As dextrin increased, static yield decreased.

No significant differences were observed for mean average sensory panel ranks of different sweet potato-glucose mixtures. Samples with no glucose added were ranked slightly higher, indicating a more moist mouthfeel than samples with glucose added. Significant differences were found between the mixtures for daily ranking data on some days. Data for these days were somewhat consistent in that the control sample which had no glucose added was perceived as more moist. The data indicate that additional amounts of glucose above that normally present in sweet potatoes do not impart a more moist mouthfeel. Although there is an indication that the quantity of glucose does increase slightly as sweet potatoes are cooked (Lambou, 1958), apparently the change in glucose content does not contribute to mouthfeel.

No significant differences were found between average apparent viscosity values of different glucose mixtures. A significant linear response ($P < .05$) was found between average static yield and increasing quantities of glucose. As glucose additions were made, apparent viscosity and static yield increased at first and then decreased.

No significant differences were found in group mean sensory panel ranks with increasing quantities of maltose; data indicated that mixtures with maltose added were ranked slightly higher (more moist) than the control sample. Daily panel data were not consistent. For example, on the first and third days of the sensory panel, the control sample was found to be more dry than samples which had 20 percent additions of maltose, and on the fourth day, the control sample was perceived as more moist than samples with 20 or 30 percent additions of maltose. No significant differences were found for apparent viscosity or static yield with increasing quantities of maltose.

A significant ($P < .05$) quadratic and cubic response was found for average sensory panel ranks with increasing quantities of sweet potato starch. As the percentage of starch increased, moist mouthfeel characteristics increased at first and then decreased. Due to similar ranks of mixtures on individual days, no significant differences were found for average daily ranks of the mixtures.

A significant ($P < .05$) linear and quadratic response of apparent viscosity and a highly significant ($P < .01$) linear and quadratic response of static yield to increasing quantities of sweet potato starch were observed. Apparent viscosity increased sharply at the 2 percent additions of starch, decreased slightly at the 5 percent additions, and then increased at the 10 percent additions. Static yield increased sharply at 2 and 5 percent additions and then decreased slightly with 10 percent additions of starch.

Both sensory panel ranking data and apparent viscosity values were somewhat consistent with the relationship reported by Rao et al. (1975). When the mixtures were ranked as more dry (2 and 10 percent additions of starch), apparent viscosity increased, and when sweet potato mixtures were ranked as slightly more moist (5 percent addition of starch), apparent viscosity decreased. The unique feature of this series was that the starch-sweet potato mixtures were heated following the addition of starch. The increased apparent viscosity observed with increasing quantities of starch could be attributed to gelatinization of the starch which tended to give a more firm and rigid structure. The more dry mouthfeel identified by the sensory panel with added sweet potato starch could be due to additional binding of water which takes place during gelatinization. Nelson (1973) suggested that molecules which have a large molecular size such as starch tend to bind water more tightly than smaller molecules. Although the same percentage of water was present in all sweet potato mixtures, the water was not as available for perception in the mixtures which had larger quantities of starch.

To further test the effects of variations in starch, maltose, and dextrin on apparent viscosity and static yield, a model system based on the protein, carbohydrate, fat, and water composition of a cured, uncooked sweet potato was prepared. Nine variations of the model system were made in which the dextrin, starch, and maltose content were varied; all other components remained constant. Due to difficulty in obtaining homogeneous mixtures, considerable variations in static yield and apparent viscosity measurements were observed for duplicate samples. Mean static yield and apparent viscosity values were plotted against varying amounts of starch, maltose, and dextrin. A linear relationship was found between quantity of starch in some samples and apparent viscosity and static yield. In samples where starch was decreased and dextrin content increased, there was a decrease in static yield and apparent viscosity.

When the quantity of maltose and dextrin were plotted against apparent viscosity and static yield, linear relationships were observed. As the quantity of maltose or dextrin increased, the static yield and apparent viscosity decreased. The relationship was observed only for samples in which the dextrin or maltose increases were accompanied with starch decreases; no other components were changed in the mixtures. Although there was some indication that an inverse relationship existed between amounts of dextrin and maltose and static yield and apparent viscosity, it appears that the primary carbohydrate component responsible for changes in the two properties was the quantity of starch.

Other data presented on the model system and variations indicate an independence of dextrin or maltose content and static yield and apparent viscosity.

Several conclusions can be drawn from the research completed:

1. Trained sensory panelists could identify the differences in mouthfeel of baked roots.
2. Addition of corn starch to baked sweet potatoes significantly increased the dry mouthfeel characteristics and decreased apparent viscosity and static yield.
3. Additions of dextrin to baked sweet potatoes did not significantly affect mouthfeel characteristics or apparent viscosity. Static yield significantly decreased as the quantity of dextrin increased.
4. Additions of glucose to baked sweet potatoes did not significantly affect mouthfeel characteristics or apparent viscosity. Static yield significantly increased at first and then decreased with increasing quantities of glucose.
5. Additions of maltose to baked sweet potatoes did not significantly affect mouthfeel characteristics, apparent viscosity, or static yield.
6. Additions of sweet potato starch to baked sweet potatoes which were subsequently heated significantly affected mouthfeel characteristic, apparent viscosity, and static yield. Moist mouthfeel increased at first and then decreased. Apparent viscosity and static yield increased and then decreased.

7. The primary carbohydrate component which exerted an influence on apparent viscosity and static yield in the model system and variations was starch. As starch was decreased with either increases of maltose or dextrin, apparent viscosity and static yield decreased.

Further research on the role of molecular size of carbohydrates should be focused on mixtures which have been heated following carbohydrate additions to sweet potatoes. Due to binding of water, heated samples may display characteristics which conform more closely to baked sweet potatoes. In further tests it would be desirable to limit the number of samples presented to panelists in order to reduce the possibility of "taste fatigue." It would also be advisable to retrain the sensory panel periodically during the sessions to insure recognition of the mouthfeel characteristics being studied.

Additional research on a model sweet potato system may provide information which would define more specifically the carbohydrates (or combination of carbohydrates) which impart the moist mouthfeel characteristic. An increased number of variations with only one or two changes in components in a sample would be desirable. The use of an inert filler, the presence or absence of which would not change textural characteristics, would allow changes in one type of carbohydrate without involving the possible interaction resulting from adjustment of several ingredients in the system.

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APPENDIX A

SOURCE OF CARBOHYDRATES

Carbohydrate Type	Manufacturer
Dextrin, Food Grade #8074 Buffalo	CPC International, Inc. Industrial Division Argo Cook County, Illinois 60501
Dextrin, Liqui-Dex Liquid	Clinton Corn Processing Co. (Division of Standard Brand, Inc.) Clinton, Iowa 52732
Maltose, U.S.P. Hydrous	Mallinckrodt Chemical Works New York, New York
Pectin, Fruit Sure-Jell	General Foods Corporation White Plains, New York 10625
Starch, Powdered Sweet Potato	Prepared at North Carolina State University as described in Appendix B
Starch, Powdered Corn #3401 Buffalo	CPC International, Inc. Industrial Division Argo Cook County, Illinois 60501
Glucose, U.S.P. Hydrous	Mallinckrodt Chemical Works New York, New York
Sucrose, U.S.P. Hydrous	Mallinckrodt Chemical Works New York, New York

APPENDIX B

PROCEDURE FOR EXTRACTION OF STARCH FROM SWEET POTATOES

Equal amounts (by weight) of distilled water and sliced sweet potatoes were placed in a 5-quart Waring blender. Sodium bisulfite was added in the amount of one percent of total weight. The mixture was blended for approximately three minutes at medium speed until they were thoroughly ground. The puree was strained through cheese cloth and the aqueous phase was collected in a 1000 ml beaker. The starch was allowed to settle to the bottom. After three hours, the supernatant was decanted and the starch was resuspended in distilled water and screened through a #140 sieve to remove any cell walls and fiber not previously removed. The starch-water mixture was placed in a refrigerator until the starch settled (approximately three hours), the top liquid was removed, and the starch was freeze dried on a Vertis Freeze Dryer for three hours at 25 microns pressure.

APPENDIX C

APPENDIX C-1

FOOD ALLERGY QUESTIONNAIRE

Name:______________________________ Campus Telephone__________________

Address:___________________________ Home Telephone____________________

You are being asked the following questions to determine whether you have any food allergies, food intolerances, or any dietary restrictions which might exclude you from taste panel participation involving certain foods and/or ingredients. The information will be strictly confidential and will be filed for use by researchers only.

Food Allergies: Do you presently have or have you had any allergic response to any type of food (for example: eggs, milk, lobster, wheat starch)?

Yes_____ No_____ If "yes," fill in the following blanks:

At what age did the allergic reaction occur? _____

Do you still have an allergy to the food? Yes_____ No_____

List the food items which cause the allergy:

Food Intolerances: Symptoms of intolerances include: gastric and/or intestinal discomfort and may include excess flatulence.

Do you have any intolerances? Yes_____ No_____. If "yes," what food items precipitate the symptoms? (Fill in):

____

Dietary Restrictions: Has a medical doctor placed any restrictions on your diet?

Yes_____ No_____. If "yes," what type of diet has he prescribed and specifically what foods should you avoid? (Fill in):

____

If you are asked to participate in a taste panel evaluation, you will not be asked to taste any foods or ingredients which you have listed above.

APPENDIX C-2

INFORMED CONSENT AGREEMENT

I, ________________________________, do hereby consent to voluntary participation in Mrs. Sarah S. Mills' research project. She, or her authorized representative, has orally:

1. Explained the procedures to be followed and identified those which are experimental.

2. Described the attendant discomforts and risks.

3. Described the benefits to be expected.

4. Described the appropriate alternative procedures.

Mrs. Sarah Mills has agreed to answer any inquiries I may have concerning the procedures and has informed me that I may contact the Clemson University Committee for the Protection of Human Subjects by calling (803) 656-2375. This Committee administers the University assurance with the United States Department of Health, Education, and Welfare (DHEW) covering the protection of human subjects.

I understand that I am free to withdraw my consent and discontinue my participation at any time. I have understood the above explanations and descriptions and freely give this consent.

________________________________	________________________________
Signature of Auditor-Witness to Oral Presentation and Signature	Signature

____
Signature of Person Obtaining Consent

APPENDIX C-3

VERBATUM TEXT

(READ TO EACH TASTE PANEL MEMBER)

The research project in which you are asked to participate is designed to determine which carbohydrate component in sweet potatoes tends to give it a moist mouthfeel or soft texture. The study may possibly have potential benefits to you and other taste panel members since identification of the carbohydrate component could help food processors to control the texture of canned and frozen sweet potatoes.

There will be an initial session for all taste panel members where you will be trained to detect differences in the texture of sweet potatoes. Moist and dry-type sweet potatoes will be sampled in the session. In subsequent trials, you will be asked to sample various carbohydrate mixtures which are similar to the proportions found in sweet potatoes canned by a standard process. Approximately ten different tasting sessions will be required to complete the necessary evaluations. No risk should be involved since the mixtures of carbohydrate being sampled will be composed of commonly used and approved food ingredients accepted by agencies of the United States government as being safe. The amounts of the carbohydrates in the mixtures are at safe levels as per generally accepted standards.

Your attendance at all taste panel sessions would be desirable; however, you will be free to withdraw your consent and discontinue your participation at any time.

Sarah S. Mills, Project Director

APPENDIX C-4

INSTRUCTIONS FOR TASTE PANEL MEMBERS

For the purposes of this test you are asked to distinguish dry mouthfeel from moist mouthfeel. Dry mouthfeel has been defined as pasty, mealy, and tending to cling to the mouth surface. Moist mouthfeel is slick to the mouth lining and easier to swallow. The samples you are asked to taste should be ranked by dryness as they compare to the dry standard sampled in the training session. Decide how the four coded samples compare in mouthfeel to the dry standard and rank them accordingly on the score sheet. Slide the product across the roof of the mouth with your tongue. Do not be confused by trying to detect moisture content in the sample. You may drink water between samples and the samples can be swallowed since taste is not a factor in how the samples rank. Please rank as nearly as you can even if you detect little differences in the samples. Feel free to indicate possible difficulty in ranking in the space provided for comments. Please do not discuss your participation in the panel evaluations with anyone else.

APPENDIX C-5

SCORE SHEET USED IN TRIANGLE EVALUATION

FOR SWEET POTATOES

Name:________________________________ Date:______________________

Directions: Two samples are alike and one is different.

1. Which sample is different? a b c (Circle one)

2. Is it more moist than the other two? Yes___ No___

APPENDIX C-6

SCORE SHEET USED FOR RANKING EVALUATIONS ON SWEET POTATO MIXTURES

Name:______________________________ Date:________________________________

Directions: Please rank the samples as they compare in mouthfeel to the dry standard. Place the three sample code opposite the rank.

	Rank	Sample Code
Most similar to dry standard	1	________
	2	________
	3	________
Most unlike dry standard	4	________

Comments:____

____

____

____

____

APPENDIX D

COMPOSITION BY WEIGHT OF MODEL SYSTEM AND VARIATIONS

Sample Number	Water	Protein	Fat	Fiber	Starch	Dextrin	Maltose	Sucrose	Glucose	Pectin	Total Carbo-hydrate (gm)	Total Weight (gm)
1*	74	1.8	.5	.9	13.68	1.93	2.48	3.3	.8	.4	22.6	99.8
2	74	1.8	.5	.9	12.31	1.93	3.85	3.3	.8	.4	22.6	99.8
3	74	1.8	.5	.9	10.94	1.93	5.22	3.3	.8	.4	22.6	99.8
4	74	1.8	.5	.9	9.57	1.93	6.58	3.3	.8	.4	22.6	99.8
5	74	1.8	.5	.9	13.68	2.12	2.30	3.3	.8	.4	22.6	99.8
6	74	1.8	.5	.9	13.60	2.32	2.16	3.3	.8	.4	22.6	99.8
7	74	1.8	.5	.9	13.68	2.50	2.01	3.3	.8	.4	22.7	99.9
8	74	1.8	.5	.9	13.00	2.76	2.48	3.3	.8	.4	22.7	99.9
9	74	1.8	.5	.9	12.31	3.60	2.48	3.3	.8	.4	22.9	100.1
10	74	1.8	.5	.9	11.63	4.43	2.48	3.3	.8	.4	23.0	100.2

*Model System

APPENDIX E

PROCEDURE FOR EXTRACTION OF FIBER FROM SWEET POTATOES

One kilogram of sweet potatoes was peeled and blended with an equal amount of distilled water in a 5-quart Waring blender at medium speed for three minutes. The resulting homogenate was filtered through a cheese cloth, and the sweet potato particles were placed in an enamel saucepan with equal parts of distilled water and heated to 88^{O}C. The potato mixture was cooled, and the pH was adjusted to 4.5 with an acetate buffer. With the addition of one gram of oligo glucosidase, the mixture was placed into an oven, stirred constantly, and held at 55^{O}C until a negative iodine test was obtained (approximately one week). The mixture was filtered through a cheese cloth, and the remaining particles were washed with distilled water. The fiber was resuspended in distilled water and heated to 90^{O}C to destroy any remaining enzyme. Following cooling, an acetate buffer was added to the suspension, and the pH was adjusted to 4.0. One gram of pectinase enzyme was added and the suspension held at 25^{O}C for 16 hours. After the fiber was filtered through a cheese cloth and washed with distilled water, it was dried in a vacuum oven for 24 hours at 65^{O}C and 30 in Hg.

APPENDIX F

APPENDIX F-1

DATA OBTAINED FROM FIRST TRIANGLE TESTS

PANELIST	TRIAL I	TRIAL II
1	Correct	Correct
2	Correct	Correct
3	Correct	Correct
4	Correct	Correct
5	Correct	Incorrect
6	Correct	Correct
7	Correct	Correct
8	Correct	Correct
9	Correct	Correct
10	Correct	Correct
11	Correct	Correct
12	Correct	Correct
13	Correct	Correct
14	Correct	Correct
15	Correct	Correct
16	Incorrect	Correct
17	Correct	Correct
18	Correct	Correct
19	Correct	Correct
20	Correct	Correct
21	Correct	Correct

TOTALS:	Correct	20	20
	Incorrect	1	1

42 Evaluations / 40 correct - 2 incorrect

APPENDIX F-2

DATA OBTAINED FROM SECOND TRIANGLE TEST

PANELIST		TRIAL I	TRIAL II
1		Correct	Correct
2		Incorrect	Correct
3		Correct	Correct
4		Correct	Correct
5		Correct	Correct
6		Correct	Correct
7		Correct	Correct
8		Correct	Correct
9		Correct	Correct
10		Correct	Correct
TOTALS:	Correct	9	10
	Incorrect	1	0

20 Evaluations /19 correct - 1 incorrect

APPENDIX G

APPENDIX G-1

ANALYSIS OF VARIANCE, REGRESSION COEFFICIENT AND STATISTICS FOR STATIC YIELD, APPARENT VISCOSITY, AND AVERAGE RANK FOR CORN STARCH (UNHEATED)

		Mean Squares		
Source	df	Static Yield	Apparent Viscosity	Average Rank[a]
Date	2	50.2	56406	----
Treatment	3	82.7	127719	.495
Linear	1	236.8**	316571**	1.293*
Quadratic	1	0.7	0.2	.022
Cubic	1	10.8	66585	.170
Error	6	6.0	13838	.179

[a]Degree of Freedom for Average Rank
For treatment was 3 and for error was 12.

**Highly significant (P<.01)

*Significant (P<.02)

APPENDIX G-2

AVERAGE DAILY TASTE PANEL RANKS, STATIC YIELD, AND APPARENT VISCOSITY VALUES FOR INCREASING QUANTITIES OF CORN STARCH (UNHEATED)

Amount Added Starch (gm/100)	Percent Increase	Day	Number of Subjects	Mean Daily Rank*	Group Mean Rank*	Daily Mean Static Yield	Group Mean Static Yield	Daily Mean Apparent Viscosity	Group Mean Apparent Viscosity
0.00	0	First	21	2.7	-	-	-	-	-
0.00	0	Second	21	2.3	3.0	27.3	26.5	997.2	1082.2
0.00	0	Third	21	3.4		22.5		1113.1	
0.00	0	Fourth	21	3.4		29.7		1136.3	
1.37	10	First	21	2.9	-	-	-	-	-
1.37	10	Second	21	2.8	2.5	16.0	20.4	626.1	803.9
1.37	10	Third	21	2.4		19.8		765.3	
1.37	10	Fourth	21	1.7		25.3		1020.4	
2.74	20	First	21	2.7	-	-	-	-	-
2.74	20	Second	21	2.6	2.5	19.1	18.9	927.7	858.5
2.74	20	Third	21	2.2		13.9		627.5	
2.74	20	Fourth	21	2.4		23.8		1020.4	
4.11	30	First	21	1.8	-	-	-	-	-
4.11	30	Second	21	2.2	2.1	11.2	13.7	510.2	579.8
4.11	30	Third	21	1.9		13.1		533.4	
4.11	30	Fourth	21	2.5		16.9		695.7	

*Ranking: 1 = Most Dry; 4 = Most Moist

APPENDIX H

APPENDIX H-1

ANALYSIS OF VARIANCE, REGRESSION COEFFICIENT AND STATISTICS FOR STATIC YIELD, APPARENT VISCOSITY, AND AVERAGE RANK FOR DEXTRIN

		Mean Squares		
Source	df	Static Yield	Apparent Viscosity	Average Rank[a]
Date	2	111.5	22723	----
Treatment	3	59.1	50372	.038
Linear	1	154.0**	149765	.001
Quadratic	1	20.4	75	.064
Cubic	1	2.8	1277	.048
Error	6	7.8	42618	.307

[a]Degree of Freedom for Average Rank
For treatment was 3 and for error 16.

**Highly significant (P<.01)

APPENDIX H-2

AVERAGE DAILY TASTE PANEL RANKS, STATIC YIELD, AND APPARENT VISCOSITY VALUES FOR INCREASING QUANTITIES OF DEXTRIN

Amount Added Dextrin gm/100 gm	Percent Increase	Day	Number of Subjects	Mean Daily Rank*	Group Mean Rank*	Daily Mean Static Yield	Group Mean Static Yield	Daily Mean Apparent Viscosity	Group Mean Apparent Viscosity
0.00	0	First	11	1.5		-	-	-	
0.00	0	Second	16	2.9	2.6	-	31.8	-	1306.4
0.00	0	Third	21	3.0		30.5		1553.7	
0.00	0	Fourth	21	3.2		29.2		1159.5	
0.00	0	Fifth	21	2.4		35.8		1205.9	
0.39	25	First	11	2.5		-	-	-	
0.39	25	Second	16	1.8	2.4	-	32.7	-	1213.6
0.39	25	Third	21	2.9		24.5		1159.5	
0.39	25	Fourth	21	1.9		32.8		1275.5	
0.39	25	Fifth	21	2.9		40.9		1205.9	
0.79	50	First	11	2.9		-	-	-	
0.79	50	Second	16	2.6	2.5	-	29.9	-	1167.2
0.79	50	Third	21	2.3		26.3		1020.4	
0.79	50	Fourth	21	2.0		27.3		1182.7	
0.79	50	Fifth	21	2.6		36.0		1298.6	
1.58	100	First	11	3.2		-	-	-	
1.58	100	Second	16	2.8	2.6	-	22.9	-	997.2
1.58	100	Third	21	1.8		21.0		788.5	
1.58	100	Fourth	21	2.9		19.0		881.2	
1.58	100	Fifth	21	2.1		28.8		1321.8	

*Ranking: 1 = Most Dry; 4 = Most Moist

APPENDIX I

APPENDIX I-1

ANALYSIS OF VARIANCE, REGRESSION COEFFICIENT, AND STATISTICS FOR STATIC YIELD, APPARENT VISCOSITY, AND AVERAGE RANK FOR GLUCOSE

Source	df	Mean Squares Static Yield	Apparent Viscosity	Average Rank[a]
Date	2	16.7	851	----
Treatment	3	30.6	43321	.445
Linear	1	45.0*	28108	.630
Quadratic	1	12.7	71704	.593
Cubic	1	34.1	30151	.113
Error	6		48475	.192

[a]Degrees of Freedom for Average Rank
For treatment was 3 and for error 12.

*Significant (P <.05)

APPENDIX I-2

AVERAGE DAILY TASTE PANEL RANKS, STATIC YIELD, AND APPARENT VISCOSITY VALUES FOR

INCREASING QUANTITIES OF GLUCOSE

Amount Added Glucose (gm/100 gm)	Percent Increase	Day	Number of Subjects	Mean Daily Rank*	Group Mean Rank*	Daily Mean Static Yield	Group Mean Static Yield	Daily Mean Apparent Viscosity	Group Mean Apparent Viscosity
0.00	0	First	21	3.3		-			
0.00	0	Second	21	2.8	3.0	24.3	23.3	881.2	943.1
0.00	0	Third	21	2.5		21.7		858.0	
0.00	0	Fourth	21	3.4		24.0		1089.9	
0.08	10	First	21	1.7		-		-	
0.08	10	Second	21	2.3	2.3	24.7	23.1	1066.7	1051.3
0.08	10	Third	21	2.8		19.5		1089.9	
0.08	10	Fourth	21	2.4		25.0		997.2	
0.16	20	First	21	1.9		-		-	
0.16	20	Second	21	2.9	2.3	27.5	29.6	1020.4	1229.1
0.16	20	Third	21	2.5		25.7		1182.7	
0.16	20	Fourth	21	2.1		35.5		1484.2	
0.32	40	First	21	3.1		-		-	
0.32	40	Second	21	2.1	2.4	27.8	27.5	1275.5	1028.1
0.32	40	Third	21	2.3		28.0		1066.7	
0.32	40	Fourth	21	2.2		26.7		742.1	

*Ranking: 1 = Most Dry; 4 = Most Moist

APPENDIX J

APPENDIX J-1

ANALYSIS OF VARIANCE, REGRESSION COEFFICIENT, AND STATISTICS FOR STATIC YIELD, APPARENT VISCOSITY, AND AVERAGE RANK FOR MALTOSE

Source	df	Mean Squares		
		Static Yield	Apparent Viscosity	Average Rank[a]
Date	2	8.3	31774	----
Treatment	3	23.6	4481	.353
Linear	1	15.3	11314	.813
Quadratic	1	25.3	19	.068
Cubic	1	30.2	2112	.178
Error	6	24.1	39486	.307

[a]Degrees of Freedom for Average Rank
For treatment 3 and for error 16.

APPENDIX J-2

AVERAGE DAILY TASTE PANEL RANKS, STATIC YIELD, AND APPARENT VISCOSITY VALUES FOR INCREASING QUANTITIES OF MALTOSE

Amount Added Maltose (gm/100 gm)	Percent Increase	Day	Number of Subjects	Mean Daily Rank*	Group Mean Rank*	Daily Mean Static Yield	Group Mean Static Yield	Daily Mean Apparent Viscosity	Group Mean Apparent Viscosity
0.00	0	First	13	1.3		-		-	
0.00	0	Second	14	2.4	2.2	-	28.6	-	1260.0
0.00	0	Third	21	1.9		28.4		1298.6	
0.00	0	Fourth	21	2.9		29.4		1345.0	
0.00	0	Fifth	21	2.7		27.9		1136.3	
0.50	20	First	13	2.9		-		-	
0.50	20	Second	14	1.9	2.5	-	29.1	-	1198.2
0.50	20	Third	21	2.9		21.3		881.2	
0.50	20	Fourth	21	2.1		29.9		1298.6	
0.50	20	Fifth	21	2.8		36.3		1414.6	
0.75	30	First	13	2.6		-		-	
0.75	30	Second	14	3.2	2.4	-	26.6	-	1213.6
0.75	30	Third	21	2.8		29.8		1136.3	
0.75	30	Fourth	21	1.6		26.9		1484.2	
0.75	30	Fifth	21	2.0		23.2		1020.4	
1.00	40	First	13	3.2		-		-	
1.00	40	Second	14	2.5	2.9	-	33.3	-	1167.2
1.00	40	Third	21	2.5		33.5		1113.1	
1.00	40	Fourth	21	3.5		29.7		950.8	
1.00	40	Fifth	21	2.6		36.7		1437.8	

*Ranking: 1 = Most Dry; 4 = Most Moist

APPENDIX K

APPENDIX K-1

ANALYSIS OF VARIANCE, REGRESSION COEFFICIENT, AND STATISTICS FOR STATIC YIELD, APPARENT VISCOSITY, AVERAGE RANK FOR POTATO STARCH (HEATED)

		Mean Squares		
Source	df	Static Yield	Apparent Viscosity	Average[a] Rank
Date	3	51.4	104499	----
Treatment	3	175.9**	740517*	.565
Linear	1	215.5**	974008*	.485
Quadratic	1	306.2**	664719*	.629*
Cubic	1	6.1	582822	.581*
Error	9	24.6	146508	.112

*Significant ($P < .05$)
**Highly significant ($P < .01$)

APPENDIX K-2

AVERAGE DAILY TASTE PANEL RANKS, STATIC YIELD, AND APPARENT VISCOSITY VALUES FOR INCREASING QUANTITIES OF SWEET POTATO STARCH (HEATED)

Amount Added Starch (gm/100 gm)	Percent Increase	Day	Number of Subjects	Mean Daily Rank*	Group Mean Rank*	Daily Mean Static Yield	Group Mean Static Yield	Daily Mean Apparent Viscosity	Group Mean Apparent Viscosity
0.00	0	First	10	2.4		24.5		1172.0	
0.00	0	Second	10	2.2	2.3	28.5	25.6	1148.0	998.2
0.00	0	Third	10	2.2		28.0		932.5	
0.00	0	Fourth	10	2.2		21.5		741.0	
0.27	2	First	10	1.8		38.0		1685.5	
0.27	2	Second	10	2.1	2.2	45.0	35.7	2582.0	1882.8
0.27	2	Third	10	2.3		33.5		2008.5	
0.27	2	Fourth	10	2.5		26.3		1255.0	
0.69	5	First	10	2.7		48.0		2128.0	
0.69	5	Second	10	2.9	3.0	42.0	41.3	1761.0	1791.1
0.69	5	Third	10	3.0		36.0		1267.0	
0.69	5	Fourth	10	3.4		39.0		2008.5	
1.37	10	First	10	3.1		42.5		2104.0	
1.37	10	Second	10	2.8	2.6	32.0	37.1	1626.0	1881.9
1.37	10	Third	10	2.5		40.5		2008.5	
1.37	10	Fourth	10	1.9		33.5		1817.0	

*Ranking: 1 = Most Dry; 4 = Most Moist

APPENDIX L

STATIC YIELD AND APPARENT VISCOSITY OF MODEL SYSTEM AND VARIATIONS

Sample Number	Starch (gm)	Dextrin (gm)	Maltose (gm)	Static Yield Trial A	Static Yield Trial B	Static Yield Mean Group	Haake Readings Trial A	Haake Readings Trial B	Haake Readings Mean Group	Mean Group Apparent Viscosity (Centipoise)**
1*	13.68	1.93	2.48	19.0 19.0	13.5 14.5	15.0	30.5 30.4	25.5 26.0	28.0	1298.6
2	12.31	1.93	3.85	14.8 13.8	9.5 8.7	11.7	26.0 26.0	18.0 18.0	22.0	1020.4
3	10.94	1.93	5.22	6.0 6.0	8.5 8.5	7.3	11.0 12.0	15.0 14.0	13.0	603.0
4	9.57	1.93	6.58	3.5 3.5	2.2 2.0	2.8	8.0 8.0	1.0 1.0	4.5	208.7
5	13.68	2.12	2.30	12.0 11.5	10.5 10.5	11.1	22.0 23.0	20.0 19.0	21.0	974.0
6	13.60	2.32	2.16	26.5 26.0	14.5 13.5	20.2	50.0 48.0	28.0 29.0	38.8	1797.2
7	13.68	2.50	2.01	14.2 13.8	15.0 15.5	14.7	20.0 20.0	27.0 27.0	23.5	1090.0
8	13.00	2.76	2.48	9.2 8.5	5.0 4.5	6.7	14.0 13.0	4.0 4.0	8.8	405.8

STATIC YIELD AND APPARENT VISCOSITY OF MODEL SYSTEM AND VARIATIONS--continued

Sample Number	Starch (gm)	Dextrin (gm)	Maltose (gm)	Static Yield Trial A	Static Yield Trial B	Static Yield Mean Group	Haake Readings Trial A	Haake Readings Trial B	Haake Readings Mean Group	Mean Group Apparent Viscosity (Centipoise)**
9	12.31	3.60	2.48	5.5 5.5	5.8 5.7	5.7	7.0 7.0	8.0 8.0	7.3	347.9
10	11.63	4.43	2.48	3.2 3.0	1.7 1.7	2.4	5.0 5.0	1.0 2.0	3.3	150.8

*Model system
**Computed from mean Haake reading