GUAR AND LOCUST BEAN GUMS AS PARTIAL REPLACERS OF ALL-PURPOSE FLOUR IN BREAD: AN OBJECTIVE AND SENSORY EVALUATION

by

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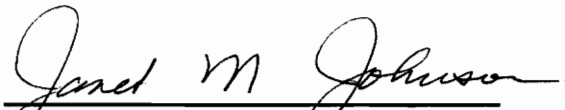

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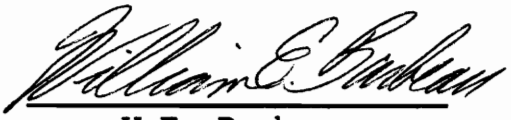

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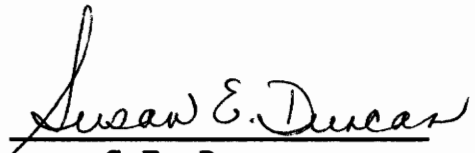

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(ABSTRACT)

The purpose of this research was to determine whether all-purpose flour could be partially replaced with locust bean gum (LBG) and guar gum, and produce an acceptable bread product.

A pilot study determined that up to 4% gum replacement for flour was feasible. All bread treatments were evaluated objectively by standing height, texture, color, and cell size. Moisture determinations were obtained for each bread variation. Sensory quality was examined by consumer testing. The amount of heat required to break the hydrogen bonds in amylopectin, indicative of bread staling, was measured by differential scanning calorimetry (DSC) for all bread treatments.

Two percent LBG replacement significantly increased standing height. Firmness of bread increased with an increase in gum; the 4% guar bread was significantly firmer. Crumb color was not significantly different for any of the five bread treatments. Crust color, however, was significantly

lighter for the control in comparison to the 2 and 4% guar, and 4% LBG breads. Two percent guar produced a more even cell size distribution throughout the bread crumb. For all 5 bread formulations moistures were not significantly different. Sensory evaluation determined a significant difference between the control and 4% LBG. The 4% LBG bread was preferred, although not significantly. Both gums were found to retard bread staling and 2% LBG was the most effective in lengthening the shelf life of the bread product.

Objective and sensory evaluation indicated both gums produced acceptable bread products for consumer consumption and possible use in further research.

I would like to dedicate this thesis to my beloved mother, Sieglinde Schwarzlaff, who passed away April 9, 1993, in memory of all the support, encouragement, friendship, and especially love she gave me the past 35 years.

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CHAPTER 1

INTRODUCTION AND OBJECTIVES

Bread, one of the oldest known foods to be consumed by man, dates back several thousand years. The discovery of leavened bread has been credited to the Egyptians (Dziezak, 1987; Trivedi et al., 1984) and ancient Babylonians (Dziezak, 1987), for yeast in bread making has been documented among hieroglyphics from ruins and in wall carvings around 2000 B.C., respectively (Dziezak, 1987). Despite its ancient history, bread is still one of the most common universal food products consumed today. Also, it has been recommended by the United States Department of Agriculture (USDA, 1990) that bread products and cereals of all types be consumed in quantities of 6 to 11 servings per day to meet nutritional requirements for good health.

In response, bread manufacturing has become highly specialized and a variety of breads are produced to satisfy the consumer (Bennion, 1990). Consumer acceptance is of great importance to the food industry, and thus, a bread of good quality is essential. Criteria such as appearance, flavor, texture, and loaf volume represent the quality of a bread product (Bennion, 1990; Campbell et al., 1979). Optimal quality of the final product can be achieved through

combination of constituents, ingredients, and processing (Bushuk, 1985).

Wheat flour, a major constituent of bread, contains proteins which possess a unique ability of forming a coherent mass called a gluten complex when wetted and mixed with water (Bennion, 1990; Pomeranz, 1988). The two groups of proteins responsible for gluten formation are the gliadins and the glutenins. Gliadins are known for their extensibility, whereas glutenins for their elasticity. Thus, in combination, they produce a viscoelastic dough. This viscoelasticity is important in dough formation. The starch, yeast, and other dough components must be able to mix and embed within the dough matrix, as well as the dough must be capable of retaining gas to produce a light, leavened product (Bushuk, 1985, Pomeranz, 1988). According to Marston and Wannan (1976), "The formation of elastic but extensible films of hydrated protein (gluten) capable of retaining gas under some pressure is the primary requirement in dough preparation". Gluten, essentially, can be classified as the framework of a wheat flour dough (Pomeranz, 1988).

The ability of wheat flour proteins to form gluten gives wheat "its prominence in the diet, rather than for a nutritive value" (Pomeranz, 1988). Unfortunately, there are children and adults who suffer from a permanent intolerance to gluten attributed to wheat as well as other cereal grains such as rye, barley, and possibly oats (Troncone and

Auricchio, 1991). These individuals experience serious intestinal problems such as steatorrhea and diarrhea with frequent foul-smelling, bulky stools, and occasional vomiting (Sampson, 1992; Zeman, 1983). Due to these detrimental conditions, children may experience failure to thrive and, for both children and adults, weight loss and irritability are typical along with malabsorption of nutrients such as protein, fat, carbohydrates and fat soluble vitamins (Zeman, 1983). Severe enterocyte damage is a pathological condition of the disease (Köttgen et al., 1988), and according to Sampson, MD. (1992), "Endoscopy reveals extensive villous atrophy of the small bowel which resolves when gluten is removed from the diet". This intolerance to gluten is called gluten-sensitive enteropathy (GSE) or celiac disease. Conservatively speaking, it is estimated that one out of every thousand individuals is susceptible to GSE. However, other individuals may actually be asymptomatic and thus the exact number of cases may be underestimated (Troncone and Auricchio, 1991). Some physicians and researchers consider GSE a food hypersensitivity, a delayed reaction to food, more commonly known as a food allergy in which there is abnormal immunologic response to gluten (Metcalfe, 1992; Sampson, 1992; Taylor, 1992), however, some argue this point due to the complexity and nature of the disease.

GSE is linked to the gliadin proteins found in wheat gluten (Cornell, 1988; DeRitis et al., 1988; Köttgen et al.,

1988; Troncone and Auricchio, 1991) and possibly the prolamin fraction of other cereals (Troncone and Auricchio, 1991). The exact pathogenesis of the disease is still unclear, but several theories have been postulated. One theory suggests that there is an enzyme deficiency (Troncone and Auricchio, 1991; Zeman, 1983), allowing toxic products of gliadin degradation to accumulate and damage the enterocytes; however, this enzyme has not been identified (Zeman, 1983). A second theory suggests that gluten or gliadin binds to surface receptors on the enterocytes (Köttgen et al., 1988; Troncone and Auricchio, 1991; Zeman, 1983). "Gluten has been shown to possess lectin-like properties with binding specificity for glycoproteins with high mannose glycans" (Köttgen et al., 1988). Also an immunologic basis has been supported, postulating that there is abnormal immune response to gliadin.

In response to the second theory, research has been carried out to determine if mannose containing compounds act as a preventive measure for GSE. Auricchio et al. (1987) found that mannan and mannose containing sugars do exhibit a protective effect by inhibiting gliadin binding.

The finding of mannose having a protective effect may be an alternative method of treatment, for a gluten-free diet is the method of treatment at this time. Speculating that the mannose containing compounds do provide an alternative treatment method for GSE, how can these compounds be

incorporated into wheat products? Since breads are one of the most universally consumed products, this proposal focused on incorporating such mannose containing compounds in bread.

Guar gum and locust bean gum are two galactomannan containing polysaccharides. Their use has become more prevalent in research due to their possible therapeutic value in treatment of some diseases. Both gums have been found to help lower serum insulin in diabetics (Ellis et al., 1981; Ellis et al., 1991; Morgan et al., 1985; Tsai and Peng, 1981) and blood lipids in hypercholesterolemic patients (Behall et al., 1984; Truswell, 1977; Zavoral et al., 1983). In addition, both gums have been incorporated into a variety of food products with much success (Dziezak, 1991; Glicksman, 1969; Tredger and Ransley, 1978). Apling et al. (1978) found that guar gum in high levels is most palatable in semi-moist foods such as bread. Presently, guar and locust bean gums are used as food additives in the United States and elsewhere.

The purpose of this study was to partially replace all-purpose flour in baked bread with guar and locust bean gums, and still produce an acceptable product for possible future use in humans with GSE, and thus provide an alternative method for treatment. The objectives were: 1) To determine what feasible amounts of gum can partially replace all-purpose flour and produce an acceptable bread product comparable to the control, and 2) To determine what effect guar and locust bean gums have on the quality characteristics

of a baked bread product as partial replacers of all-purpose flour. The hypothesis was that guar and locust bean gums will produce an acceptable bread product, comparable to the control, as partial replacers of all-purpose flour.

CHAPTER 2

REVIEW OF LITERATURE

2.00 BREAD INGREDIENTS

2.00a *Flour*

Wheat flour is a primary functional ingredient in bread making due to its unique ability of forming a viscoelastic dough. As mentioned earlier, this viscoelasticity is produced by the proteins known as gliadins and glutenins, found in wheat flour, when mixed with water. During mixing these proteins interact and form a gluten complex which stretches and coagulates during fermentation and baking respectively, helping to form the structure of the bread loaf along with other dough constituents (Penfield and Campbell, 1990).

To obtain a viscoelastic dough and the final structure of the bread loaf, the flour must have a high protein content of good quality (Bushuk, 1986). The flour must also be able to carry water, known as absorption, for dough formation. According to Jackel (1987), the greater the absorption the more favorable the production of a "top quality" bread product that has good texture and remains soft longer. Therefore, strong flours made from hard wheat are preferred. A strong flour, such as bread flour is high in protein (≥12%) and has a high water absorption; both characteristics are

needed in forming a viscoelastic dough required for good handling properties, good crumb characteristics, and good loaf volume of bread (Bushuk, 1986; Penfield and Campbell, 1990).

A correlation between protein content and loaf volume has been observed by Bushuk (1985); the greater the protein content, the greater the loaf volume. If a weak gluten flour such as soft wheat is used, a poor loaf volume will result as well as a poor quality product. Adjustments must be made in ingredient proportions, mixing methods, and techniques in bread preparation (Bennion, 1990) since the flour is lower in protein (Schiller, 1984). All-purpose flour, however, will produce an acceptable bread product (Bennion, 1990). Bushuk (1985) also observed that the quality of the protein also determines loaf volume. Poor quality flours produce low volume breads in comparison to high quality flours. Faridi et al. (1987) also state that loaf volume is correlated with protein content as well as the quality of the flour.

The protein content is dependent on agronomic and environmental factors, whereas protein quality is a genotypic trait; but is also affected by environmental conditions (Bushuk, 1985; Pomeranz, 1983). Protein contents of various flours are as follows: bread flour (hard wheat) - ~12%, all purpose (hard or soft wheat) - ~10.5%, and cake flour (soft wheat) - ~7.5% (Penfield and Campbell, 1990).

2.00b *Yeast*

Yeasts, unicellular fungi, are used in baked goods such as bread for leavening, changes in rheological properties and flavor (Reed and Nagodawithana, 1991), all contributing to a quality product. The functions of yeast are brought about by fermentation. Fermentation is a process by which yeast converts carbohydrates (simple sugars) into carbon dioxide, ethanol, and flavor compounds (Hoseney, 1986; Pyler, 1973) through enzymatic action produced by yeast cells (Bennion, 1990).

The gas, carbon dioxide, results in leavening of the bread. "To *leaven* means to 'make light and porous'" (Bennion, 1990). Therefore, the yeast must produce sufficient amounts of carbon dioxide, and the dough must be able to retain the gas produced, as well as the entrapped steam and air, in order to achieve a bread that is light and even in crumb (Bloksma and Bushuk, 1988). The carbon dioxide migrates through a "network of cellular compartments" (Lee, 1983), and results in expansion of the dough due to internal pressure. The internal pressure has been correlated with tension of the gas cell membrane (Hoseney et al., 1979). This internal pressure tends to affect every part of the dough, leading to dough expansion in all directions equally and an increase in volume (Hoseney et al., 1979).

Fermentation also affects the rheological properties of the dough. According to Hoseney et al. (1979), "Fermentation

transforms the dough from a highly mobile system to one with no spread", which was attributed to the yeast (Hoseney et al., 1979), the lowering of pH by carbon dioxide, ethanol formation, and action of expanding gas bubbles (Reed and Nagodawithana, 1991). Dough systems without yeast remain mobile. Yeast converts the dough from a "viscous flour component to one that is elastic", which is the same change in dough properties when oxidants are added (Hoseney, 1986). The yeast itself clearly demonstrates an oxidizing effect (Hoseney, 1986). Fermented doughs have increased resistance to deformation (Bloksma and Bushuk, 1988). According to Bloksma (1972), "Interchange reactions between chemical bonds, particularly compounds with thiol or mercapto groups (-SH), are required for permanent or viscous deformations of the protein network. Oxidation decreases the number of thiol groups available for these interchange reactions and, therefore, increases the resistance against deformation".

The development of dough is another important factor in bread making. Dough development is reflected by the initial increase in dough consistency, which changes continuously during mixing (Bloksma, 1972). Bloksma (1972) states, "The actual slow stretching of dough membranes during fermentation may add to dough development".

Another positive attribute of yeast is flavor. It is not the yeast itself that imparts flavor, but the by-products formed as a result of fermentation such as alcohols,

aldehydes, carbonyl compounds, ketones, and organic acids (Bennion, 1990; Lee, 1983; Reed and Nagodawithana, 1991). It is during baking that the aroma of bread comes about due to interactions between these compounds and other dough constituents such as amino acids and sugar (Reed and Nagodawithana, 1991). At high temperatures, sugar caramelization and Maillard browning occur. This is important in the development of crust flavor. According to Reed and Nagodawithana (1991), "The typical bread flavor is definitely formed in the crust, and removal of the crust soon after baking prevents diffusion of the flavor from the crust into the crumb, and the crumb will have no fermentation flavor". Therefore, the two essential steps for bread flavor production are fermentation and baking.

2.00c *Water*

Water, essential for all living organisms, is also essential in preparing food products such as bread. Water constitutes approximately 45% of weight in bread dough, and 35% in bread. Thus, water influences the quality of the end product (Leung, 1981; Marston and Wannan, 1976).

Flour proteins must be hydrated during mixing and the optimal amount of water is needed for dough preparation and handling properties (Campbell et al., 1979). If the moisture content of the dough is too low, 29%, the dough mixture has a tendency to be powdery and lacks resistance, and if above 30%

development of the dough takes place which exhibits resistance (Labuza, 1977). The consistency of the dough must be suitable for kneading and molding (Marston and Wannan, 1976). When flour proteins are wetted, they form a coherent mass called a gluten complex which is an essential component in bread making because of its viscoelastic properties (as mentioned earlier). As Labuza (1977) stated, "a well-developed dough is formed as moisture is increased until a dilution effect takes place and thereafter a decrease in dough resistance can be attributed to the lubricating action of water in the system that contributes to dough development".

In addition to dough development, water also acts as a solvent for such ingredients as salt and sugar normally found in most breads. For these ingredients to function properly they must first be dissolved. According to Campbell et al. (1979), water also acts as a "dispersion medium for yeast cells", and is essential for enzymatic activity to take place (Marston and Wannan, 1976).

Water also allows for starch gelatinization to occur during baking, which is responsible for forming the structure of bread. Along with gelatinization, water evaporation occurs. The evaporation of water helps regulate dough temperature, which is important for crust formation (Marston and Wannan, 1976). Crust formation is vital for color, flavor, and structure of the final product.

2.00d *Sugar*

Sugars are known for the sweetness they provide in many baked products. One of the oldest known sugars to be used is beet or cane sugar, even in bread making (Pomeranz and Finney, 1975). In addition to flavoring, sugars also possess important functions in bread making such as food for yeast, texture, appearance, and color of crust (Bennion, 1990; Pomeranz and Finney, 1975; Pyler, 1973). The bread dough sugars come from three different sources: 1) sugars that are initially present in flour, 2) sugars produced by enzymatic hydrolysis of oligosaccharides or polysaccharides, and 3) sugar added to the dough as an ingredient (Bennion, 1990; Pomeranz and Finney, 1975).

The main purpose of adding sugar (sucrose) to bread making is to provide carbohydrates as available food for the yeast to start and sustain fermentation (Pyler, 1973). Without added sugar fermentation would be slow from the very beginning, for the sugars from flour must be made available through amylolytic activity (Campbell et al., 1979). The optimum amount of sugar may contribute to an increase in volume in baked bread products, for sugar has a tenderizing effect on gluten which allows the dough to easily expand under pressure produced by the leavening gas (Bennion, 1990). It may also be a contributor to fine and even texture (Bennion, 1990; Myhre, 1970). However, the amount of sugar added must be carefully monitored for an excessive amount of

sugar (> 10% of the weight of flour (Campbell et al., 1979)) will actually retard fermentation (Bennion, 1990; Campbell et al., 1979). According to Campbell et al. (1979), this is attributed to "the osmotic effect of the dissolved solute on the yeast cells", which results in increased fermentation and proofing times (Bennion, 1990). Gluten development may also be affected by an excess amount of sugar. Sugar will compete with the gluten proteins for water, and thus decrease gluten development (Campbell et al., 1979).

Caramelization and Maillard browning are chemical reactions involving sugar. These two reactions happen during baking and result in crust color and flavor (Bennion, 1990; Shelton and D'Appolonia, 1985). As temperature increases, the outer surface of the baked bread becomes dry and allows caramelization to occur (Bennion, 1990). During caramelization, reducing sugars are hydrolyzed to monosaccharides and dehydrated by heat to active aldehydes, which in turn are polymerized by oven heat (Shelton and D'Appolonia, 1985). In Maillard browning, the reaction involves a reducing sugar and an amine, protein, and occurs at a lower temperature than caramelization (Shelton and D'Appolonia, 1985). The latter appears to be more important in formation of crust color (Shelton and D'Appolonia, 1985).

2.00e *Salt*

Common salt, generally, is another ingredient used in bread making. Its importance is often taken for granted. Salt actually is an essential ingredient in bread due to the many functions it possesses. Yeast fermentation is retarded with the addition of salt (Bennion, 1990; Campbell et al., 1979; Niman, 1981; Vetter, 1981). The yeast activity is lessened by an osmotic effect on yeast cells (Campbell et al., 1979) and is actually desirable to achieve control of fermentation. Vetter (1981) stated, "Salt acts as a biological buffer in a dough system, suppressing yeast activity to a controllable level but obviously not to a level that precludes its activity and concomitant leavening and flavor development".

Controlling fermentation, by the addition of salt, helps make the dough stronger (Hoseney, 1986; Penfield and Campbell, 1990) possibly by protecting the charged groups of the dough proteins (Hoseney, 1986; Penfield and Campbell, 1990). Dough strength is an important factor for it leads to a uniform baked product. According to Vetter (1981), "Uncontrolled fermentation would lead to variations in baked volume, grain and texture from the beginning to the end of the processing of a single dough".

In addition to controlled fermentation, salt also has a strengthening or firming effect on the gluten structure in bread dough, making it less sticky (Bennion, 1990; Bloksma and Bushuk, 1988; Campbell et al., 1979, Niman, 1981; Vetter,

1981). This effect helps to ensure good dough handling properties important for processing, and grain and texture of the bread product (Vetter, 1981). According to Bennion (1990), without salt the bread product may often be crumbly and become too light.

Flavor is another important function of salt. It not only imparts a saltiness to the bread, but also enhances flavors of other constituents and fermentation by-products (Niman, 1981; Vetter, 1981). Salt remedies blandness which is important for consumer acceptance (Niman, 1981; Pyler, 1973; Vetter, 1981).

2.00f *Fat*

Depending on the type of bread product, fat may or may not be added. Breads with no added fat tend to have a coarse grain with a tough bite (Tamstorf et al., 1986), which to the consumer is either desirable or undesirable. On the other hand, when fat is added to the bread formula the bread product becomes more tender, has a finer grain, has a greater loaf volume, and better keeping quality (Bennion, 1990).

Fat is known to retard the "setting" of the dough during baking which may be a contributing factor to the increase in loaf volume (Penfield and Campbell, 1990). During baking, the gluten structure becomes lubricated by the fat making it more extensible, and also slows the diffusion rate of carbon dioxide out of the dough, both resulting in an increase in

volume (Tamstorf et al., 1986). According to Tamstorf et al. (1986), the increase in loaf volume may actually contribute to the keeping quality of the bread since the crumb becomes finer plus more uniform. Penfield and Campbell (1990) stated that this effect may partially be indirect. Lipids are more likely to retard bread staling by complexing with starch. The so called complexed lipid-starch chains are thus not available for "starch-starch association" (Penfield and Campbell, 1990), reducing the reassociation of starch chains associated with firming of bread.

2.01 GUMS

Locust bean and guar are plant seed gums from the leguminous plants *Ceratonia siliqua L.* (carob tree) and *Cyamopsis tetragonolobus,* respectively. Both are galactomannan gums and are classified as hydrocolloids due to the hydrophilic or "water loving" properties they possess (Dziezak, 1991; Glicksman, 1969). These non-starch neutral polysaccharides contain polymers or sugar molecules known as galactose and mannose; hence the name galactomannan.

2.01a *Locust Bean Gum*

Locust bean gum (LBG) is contained in the endosperm of the seeds from the evergreen tree, known as the carob tree, which is indigenous to the Mediterranean area and is also grown in southern California. The seeds are about the size of

watermelon seeds and are found in pods approximately 4 to 12 inches in length (Glicksman, 1969). To obtain the gum, the seeds are removed from the pod and split lengthwise. The endosperm must then be separated from the germ, and is ground to a fine powder for commercial use. The typical composition of LBG is "galactomannan, 88%; pentosans, 3 - 4%, protein, 5 - 6%; cellulose, 1 - 4%; and ash, 1% (Glicksman, 1969). LBG has a molecular weight of approximately 310,000 and its backbone consists of β-1-4 linked D-mannopyranose units with usual branching on every fourth or fifth mannose group by single α-1-6 linked D-galactose units (Baker and Whistler, 1975; Glicksman, 1969), as shown Appendix A (Glicksman, 1969). The mannose to galactose ratio is 4:1.

2.01b *Guar*

Like LBG, Guar comes from the endosperm of the seeds produced by the pod-bearing plant *Cyamopsis t.* mentioned earlier, which is indigenous to India and Pakistan. It has also been successfully grown in Texas and Arkansas (Dziezak, 1991). The endosperm is separated from the germ and milled in a similar fashion as LBG to a fine particle size (Glicksman, 1969). Composition of guar is typically "galactomannan, 78 - 82%; water, 10 - 13%; protein, 4 - 5%; crude fiber, 1.5 - 2%; and ash, 0.5 - 0.9% " (Glicksman, 1969). Guar is known to have a molecular weight of 200,000 to 300,000. The structure of guar is identical to LBG with the exception of single

galactose units branching out in a ratio of one galactose unit per every two mannose units (Baker and Whistler, 1975; Elfak et al., 1977; Glicksman, 1969), as shown in Appendix A. The distribution of guar is more regular in comparison to LBG and has a ratio of mannose to galactose of ~ 2:1, although some researchers say a 3:2 ratio may be more realistic (Baines and Morris, 1987; McCleary, 1984).

2.01c *Properties and Applications*

Due to chemical and structural differences, despite being galactomannans, locust bean and guar gums have some different properties and applications, especially in food. Guar gum is soluble and hydrates readily in cold water (Dziezak, 1991; Sprenger, 1990), whereas LBG only dissolves when heated. Functional differences are exhibited as guar produces high viscosity when dissolved in cold water but, LBG must be heated and then cooled before maximum viscosity is achieved (Dziezak, 1991; Glicksman, 1969). The viscosity of LBG is little affected within a pH range of 3 - 11, for it is non-ionic (Glicksman, 1969). The same holds true for guar at a pH range of 4 - 10. In general, the viscosity of both gums is determined by "temperature, pH, time and concentration, degree of agitation, and particle size" (Dziezak, 1991) and combination with other ingredients such as sugar (Elfak et al., 1977).

Both gums, when combined with a gelling polysaccharide such as kappa-carrageenan, will increase the gelling strength and modify the gel structure (Dziezak, 1991; Glicksman, 1969). Guar gum, when combined with other gums or starches, has a great synergistic effect. Through tests, Carlson et al. (1962) found that the viscosity of a combination of guar and wheat starch cooked at high temperature was higher than the total thickening capacity of the two ingredients measured separately. The researchers (Carlson et al., 1962) attributed this to probable hydrogen-bonding between the two. Locust bean also has a synergistic effect related to elastic properties when combined with gums such as carrageenan and agar (Glicksman, 1969). Doublier and Launay (1981) found results, in regard to both gums, indicating that "entanglements play a dominant role in concentrated solutions" in relation to viscosity. LBG and guar in solution are classified as random coil polymers (Doublier and Launay, 1981; Robinson et al., 1982). The expansion and interaction of the random coils are dependent upon the concentration of the gums in solution. "In common with other 'random coil' polymers, the solution properties of guar gum undergo an abrupt change at a critical concentration, c*, which marks free transition from a dilute solution of polymer coils free to move independently, to an entangled network at higher polymer concentrations" (Baines and Morris, 1987). This polymer interaction of physical entanglement has been

observed by Robinson et al. (1982) and the researchers referred to them as hyperentanglements. The rheological properties of both gums have been studied and differences between their flow behavior have been observed (Alloncle et al., 1989; Doublier and Launay, 1981). Alloncle et al. (1989) and Doublier and Launay (1981) concluded that further research is needed to better describe the intricate macromolecular system they possess and how the degree of branching is related.

These functional abilities allow guar to be used mainly as a viscosity builder, stabilizer and water binder, and LBG as a thickener, stabilizer of emulsions and inhibitor of syneresis (Dziezak, 1991). Examples of food applications for guar would be: canned food and pet food, desserts, ice cream stabilizer, sauces, processed cheeses, baked goods, salad dressings and dry mixes (Dziezak, 1991; Glicksman, 1969). LBG is also used in canned foods, ice cream, desserts, cheese products, meat products, bakery products, sauces, and citrus juice products (Dziezak, 1991; Glicksman, 1969).

In addition to food applications, guar and locust bean gums have been shown to have a dietetic - therapeutic effect towards some illnesses. Studies carried out at the Gastroenterology Unit of the Medical Research Council, England (Jenkins et al., 1975), found pectin and guar gum to significantly lower serum cholesterol levels. This was also reported by Jenkins et al. (1980) and Kay and Truswell

(1977). Similar studies found LBG to lower cholesterol levels as well (Behall et al., 1984; Zavoral et al., 1983). Both gums have also been found to reduce blood glucose in diabetics (Blackburn et al., 1984; Jenkins et al., 1976; Morgan et al., 1985). In addition to blood glucose, guar (Blackburn et al., 1984; Ellis et al., 1981; Morgan et al., 1985) and locust bean (Tsai and Peng, 1981) gums have been found to reduce serum insulin levels. The exact therapeutic mechanism of the two gums is still under investigation for different theories have been hypothesized.

2.01d *Mechanism and Effects of Guar and Locust Bean Gums*

As just mentioned, guar and locust bean gums appear to have a therapeutic effect towards some diseases. The exact mechanisms responsible for this therapeutic effect are still unclear and remain controversial (Blackburn et al., 1984; Morgan et al., 1985). One hypothesis is that the action of the gums (polysaccharides) is related to the viscosity they possess (Edwards et al., 1987). The viscosity in turn delays gastric emptying (Blackburn et al., 1984) and therefore the delivery of nutrients to the small intestine is slowed down (Blackburn et al., 1984; Higham and Read, 1992).

The absorption rate of glucose from the small intestine appears to be reduced with the addition of gums in the diet, thus having a therapeutic effect towards diabetes (Morgan et al., 1985). Therefore, another hypothesis has been suggested

that the absorption rate of nutrients is reduced by these viscous polysaccharides (Blackburn et al., 1984; Morgan et al., 1985). This reduction in absorption has been attributed to the impairment of the substrate being mixed with digestive enzymes and a reduced nutrient contact rate with the absorptive layer of the small intestine (Higham and Read, 1992). According to Blackburn et al. (1984), it is likely that intestinal movements induce convection currents, which in turn may be responsible for forwarding nutrients from the bulk phase to the intestinal epithelial surface in normal circumstances. Diffusion plays an important role at this point in the unstirred water layer next to the epithelium (Blackburn et al., 1984). It has been proposed that the viscosity of the gums interferes with intestinal motility and increases resistance to diffusion by inhibiting the convection currents needed to bring the nutrients in contact with the epithelium (Blackburn et al., 1984). More research is needed in this area (Higham and Read, 1992). Should this be the case, that absorption is impaired, what are the consequences of long-term use of these gums?

The chronic effects of guar, locust bean and other gums have been observed by Melnick et al. (1983) in rats. Only a few reduced weight gains were found and no other effects on survival were noted. If any effects were present, apparently they were not significant enough to be evident at intake levels of 5% of the diet (Melnick et al., 1983). A similar

finding in regard to weight reduction, with use of guar gum, was found in humans by Uusitupa et al. (1989), but other unknown causes may have been contributing factors as well (Uusitupa et al., 1989). Higham and Read (1992) also concluded that guar gum even on short-term basis may contribute to weight loss.

In addition to weight reduction, a reduction in gastric inhibitory polypeptide levels have been observed after ingestion of guar, which possibly may elude to the decreased rate of amino acid absorption (Morgan et al., 1985). A decreased digestibility of protein and fat were also observed in rats fed viscous fibers, such as guar gum, even in the presence of increased digestive secretions (Ikegami et al., 1990). Higham and Read (1992) also found reduced fat absorption with terminal ileostomies. Thus, viscous fibers may actually inhibit pancreatic enzyme activity (Ikegami et al., 1990).

Guar gum has also been shown to increase bile acid and cholesterol secretions, which may affect fat soluble vitamin absorption (Uusitupa et al., 1989). It appears that LBG may bind bile acids, plus increase bile acid excretion; the formation of micelles is interfered with also (Zavoral et al., 1983). Uusitupa et al. (1989) found Vitamin A and E to be somewhat reduced with long-term use of guar, but concluded that it is unlikely that a deficiency will occur as long as adequate amounts of Vitamin A and E are consumed in the diet.

In regard to mineral balance, Behall et al. (1987) found that magnesium (Mg), manganese, iron (Fe) and zinc were not significantly affected by LBG. However, in long-term use, LBG may potentially lower calcium to a negative balance, and thus adequate amounts of calcium in the diet are recommended (Behall et al., 1987). Similarly, guar gum does not create a significant change in absorption of Na, K, Ca, Mg, or Fe, and zinc levels have actually been found to be higher (Uusitupa et al., 1989). The increased zinc levels have been attributed to the longer transit time, allowing for more complete absorption (Uusitupa et al., 1989).

Both LBG and guar gum are generally recognized as safe (GRAS status) when used in accordance of Title 21 Code of Federal Regulations (Maier et al., 1993), and appear to be safe even in long-term use as long as they are consumed in conjunction with a usual diet meeting the Recommended Dietary Allowance levels of all nutrients (Behall et al., 1987; Uusitupa et al., 1989). However, further research is needed in this area.

2.02 SENSORY EVALUATION

Sensory evaluation is a subjective method for measuring human responses to foods, beverages, tobacco, and even non-food items such as skin care lotions and other personal care products (Sidel et al., 1981). The idea of sensory evaluation dates back in history to when mankind started evaluating

products that could be used or consumed (Meilgaard et al., 1991). In the early 1900's, professional tasters and consultants became available in the business industry for grading foods, beverages and even cosmetics (Meilgaard et al., 1991). Over time sensory testing became an important tool for evaluating food quality, not only in the food industry, but food science research as well. This type of testing helps to answer questions such as appearance, smell and taste that are unattainable through the laboratory (Penfield and Campbell, 1990).

The type of sensory test used depends on the objectives of the study (Penfield and Campbell, 1990). Many types of tests are available such as difference testing which discriminates between or among samples, descriptive testing which scores product quality or describes the product, and affective testing where consumers rate acceptability of a product and/or preference (Penfield and Campbell, 1990). Acceptance and preference of a food product depends on the consumers overall impression of the food's quality, which is important for market potential.

2.02a *Consumer Testing*

Consumer testing is often used in product maintenance, product improvement/optimization, shelf-life testing, development of a new product(s), and assessment of market potential (Meilgaard et al., 1991). This type of testing

involves the selection of consumer panelists to represent only a sample of the population, and thus a minimum of 24 consumer responses is recommended by the Institute of Food Technologists (IFT) (Penfield and Campbell, 1990) in order to validly screen the product. Inexperienced consumers increase experimental error and therefore, large numbers are a necessity (Penfield and Campbell, 1990).

Central location is a tool often used for evaluating the development of a new product, and is conducted at a site where many potential consumers can be obtained at a central location by chance (Meilgaard et al., 1991). Consumers are asked to evaluate the product(s) by use of a scorecard which is developed to answer the test objective(s), yet easy enough for the consumer to understand and follow. Responses are then evaluated by statistical analysis.

2.03 BREAD STALING

The freshness and quality of a bread product is of utmost importance to the consumer. According to Sloan and Powers (1985), freshness is the major characteristic that women look for when buying bread. Unfortunately, after a certain length of storage, the crust no longer is crisp, but leather-like, and the crumb becomes firm with an unpleasant texture and stale flavor (Penfield and Campbell, 1990; Shelton and D'Appolonia, 1985). This change in bread characteristics is known as bread staling.

The change in the crust, according to Hoseney (1986) is attributed to water migrating from the crumb to the crust, thus making it tough and leather-like over time. The crumb, however, undergoes a different change which is much more complex and not fully understood. Bread staling has been associated with the starch component of the bread product. During baking, the starch granules swell due to a limited amount of water present in the product. According to Schoch (1965), a permanent gel network between granules is set up due to linear molecules diffusing from the swollen granules, and staling is due to the association of branched molecules within the swollen starch granules. The highly branched starch fraction is known as amylopectin and the linear fraction is amylose. According to Schoch's (1965) theory, during staling, the amylopectin recrystallizes (retrogrades) leading to firmness. Another theory by Pyler (1988) implies that amylose may also be involved, but that amylopectin is still the major contributor to bread staling.

The recrystallization of the starch can be reversed by heat, and other methods have been used to produce softer breads and longer retention of bread freshness over time (Hoseney, 1986). Surfactants, shortening, or flour pentosans are often added for their interaction with starch components making them less available for retrogradation (Hoseney, 1986; Penfield and Campbell, 1990). Also alpha amylase may be added to increase amylolytic action if the flour's natural enzyme

level is too low. The enzymatic action seems to maintain low rigidity of granules by attacking the cross-links holding the crystalline regions together (Penfield and Campbell, 1990). Through interaction with starch components, flour pentosans are also known to retard staling by making them less available for recrystallization (Penfield and Campbell, 1990).

One of the most common methods used to study bread staling is differential scanning calorimetry (DSC). This method measures the melting of the crystallized amylopectin. When heating a sample of bread in the DSC a thermogram is obtained which includes a so called "staling endotherm" (Eliasson, 1985). The endotherm in turn is used to calculate the amylopectin peak area/mg of the sample as an index to bread staling (Eliasson, 1985).

CHAPTER 3

MATERIALS AND METHODS

3.00 PURPOSE

The purpose of this study was to partially replace all-purpose flour in baked bread with guar and locust bean gums, and produce an acceptable product for possible future use in research to determine if guar and LBG have a protective effect in humans with GSE, and thus provide an alternative to a gluten-free diet.

3.01 EXPERIMENTAL DESIGN

The experimental design was a random incomplete block design of a 2 x 3 factorial. Two amounts of mannose type gums, locust bean and guar, were used as a partial replacement by weight for flour in bread. The control bread contained no gum. A pilot study determined if 1%, 2%, and 4% gum were feasible amounts to be used as partial replacers of all purpose flour. Objective measurements of the bread included standing height, compression, color, cell size and moisture to determine the effects of guar and locust bean gums as a partial replacement of all-purpose flour. Sensory evaluation was used to determine if a significant difference and preference existed between the control and 4% LBG. The 4%

LBG variation was chosen for it is a high mannan gum, and therefore have a greater protective effect for individuals with GSE. Differential Scanning Calorimetry (DSC) was also performed to determine enthalpy from bonding characteristics as an index to rate of staling in breads made with guar and LBG. The p value of 0.05 was used for significant difference.

3.02 BREAD

The selection of bread ingredients and methodology were adapted from Long (1991) with some modifications.

3.02a *Flour*

Enriched, bleached, presifted Gold Medal (General Mills, Inc., Minneapolis, MINN) all-purpose flour, with a protein and moisture content of 10.4% and 13.78% respectively, was used for all experimental bread formulation studies, physical and baking characteristic measurements, and consumer sensory testing. Five pound bags of flour were purchased from the same market shelf on the same day for the entire study.

3.02b *Yeast*

Fleischman's (Specialty Brands, a division of BURNS PHILP FOOD, INC., San Francisco, CA) rapid rise active dry yeast (7 gram packages) was used for all breads baked in the pilot study, objective evaluation of bread product characteristics, consumer sensory testing, and DSC. Yeast

packages from the same market shelf, with the same expiration date were purchased on the same day for the entire study.

3.02c *Water*

Local tap water at 20° C was utilized for preparation of bread dough for all tests and measurements.

3.02d *Sugar*

Domino (Domino Sugar Corporation, New York, NY) pure cane granulated sugar was purchased for preparation of all breads at one time from the same lot.

3.02e *Salt*

Richfood (Richfood, Inc., Richmond, VA) iodized salt was used for all bread preparations.

3.02f *Fat*

Parkay (Kraft, Inc., Glenview, IL) 100% vegetable oil margarine was used for all bread formulations.

3.02g *Milk*

Carnation brand (Carnation Company, Los Angeles, CA) non-fat dry milk was purchased in the form of 5 sealed 1 quart pouches of dry milk contained in one box and was used in all bread preparations.

3.02h *Gums*

TIC pretested guar 8/22 (lot# P.4015.A) and locust bean POR/A (lot# B.7225) gums were used in 2.0 and 4.0 grams per 100 grams of flour amounts to partially replace all-purpose flour in the experimental bread formulations. The gums were donated by TIC Gums, Inc. (Belcamp, MD).

3.02i BREAD FORMULA

For bread formulas see Appendix B.

3.02j MEASURING TECHNIQUES

Measurements (weights) of ingredients were obtained by use of an OHAUS gram balance scale (Model# CT 1200-5).

3.02k MIXING METHOD IN HOME BAKERY APPLIANCE

For all recipes, the water was measured first and poured into the Hitachi Home Bakery Appliance HB-B101 (National Headquarters: Compton, California) bread pan with the blade in place. Flour, dry ingredients, plus gums were weighed and placed into a plastic pitcher for mixing. The flour-gum mixtures were stirred 20 times with a fork, and then added to the water in the bread pan. The pre-weighed margarine was then placed on top of the flour-gum mixture, and the yeast was added last.

3.03 APPLIANCE: HITACHI HOME BAKERY

The Hitachi Home Bakery appliance HB-B101 (National Headquarters: Compton, California) was used for the dough preparation and baking of: 1) all pilot breads, 2) breads prepared for the objective measurements, and 3) breads evaluated by consumer testing. The bread making appliance was used to minimize variations in all bread products. The "rapid bread" setting, requiring 2 hours and 50 minutes for preparation of the bread, was used for all testing. The actions performed by the appliance were mixing, kneading, resting, heating, and cooling.

3.04 PILOT STUDY

The pilot study provided observational data on the feasibility of altering the all-purpose bread formula (Long, 1991) by replacing varying amounts (1%, 2%, 2.5%, 4%, 5%, and 15%) of all-purpose flour with guar and locust bean gums. All experimental breads from this pilot study were baked in the home bakery appliance.

3.05 OBJECTIVE EVALUATION OF BREAD PRODUCTS

3.05a *Index to Volume*

The index to volume of each bread variation was determined by standing height. The standing height of the bread was measured approximately 2 hours after baking. Metric ruler measurements of each loaf were taken by cutting each

bread loaf in half lengthwise by use of the indentation marks on 2 opposite sides of the bread left by the home bakery machine (Long, 1991) with a serrated bread knife. Each loaf was placed on a flat surface to obtain the measurements at three locations: center - by use of the machine made indentation marker, right and left heights - measurements were taken one inch from each side. The three measurements (center, right, left) were averaged to obtain a mean for each loaf. The measurement was done in triplicate (3 different loaves) for each treatment on three separate days.

3.05b *Compression (Texture)*

The Stevens-LFRA Texture Analyzer (Scarsdale, New York) was used for compression/texture analysis by testing the amount (grams) of force required to penetrate the bread product for a specified distance at a given speed.

Bread loaves were uniformly cut in half lengthwise, by previous method, approximately 2 hours after baking and placed on the circular disk of the Stevens Texture Analyzer. The top indentation of each bread loaf was used as a guide (marker) for placing the loaf half in such a position that the probe would penetrate the center of the loaf at this particular point. A 1 inch diameter circular plunger was used for compression with the distance set at 10 mm and speed at 2 mm/second to obtain a reading in grams per force. A second reading was obtained on the same loaf by moving the bread

sample down 1 inch from the first position in order to obtain a general texture measurement of the center of the loaf. Readings of each bread variation were replicated on three separate days.

3.05c *Color*

Color of internal crumb and external crust was measured by use of the Hunter Color Spectrophotometer (Reston, VA) for each bread variation. The instrument was calibrated before use as instructed in Appendix C. Delta E values were obtained for each treatment at least 2 hours after cooling. Once again bread loaves were cut in half lengthwise and whole bread halves were used in order to assure a complete fit over the aperture which supplied the light source. Measurements were taken on three separate days for each bread variation.

3.05d *Cell Size*

The cell size of each bread variation was visually measured by photocopying the respective loaf half according to the methodology given by Conforti (1989). After each bread had been cut lengthwise, approximately 2 hours after baking for standing height measurements, the same loaf half was utilized for photocopying. Loaf halves were carefully handled to prevent any damage to the cellular structure of the sample product.

A Monroe Photocopier Model #RL-945DX (Monroe Systems for Business, Co., New Jersey) was used for photocopying with the darkness setting set at normal. As instructed by Conforti (1989), a piece of transparent plastic wrap was carefully placed and smoothed, free from wrinkles to prevent interference, over the glass plate surface of the photocopier. Two copies were made for each bread variation on three separate days.

3.05e *Moisture*

Percent moisture for each bread variation was determined by use of a Brabender Moisture Tester (South Hackensack, New Jersey). The moisture tester was preheated for 1 hour to 130° C. Methodology was performed as instructed in the manual. Numbered teflon coated aluminum pans were used and pre-weighed by use of a Fisher Scientific balance scale Model #XL-500.

Bread loaves that had been cut lengthwise for objective measurements were wrapped with plastic wrap between testing and were prepared for moisture testing by slicing the loaf half 1 inch from back crust side towards the center. The slice, with the crust side, was then cut in half to obtain two 10 gram samples for each bread variation to represent an overall moisture content of each product. Once the ~10 gram samples were weighed, each pan + bread crumb sample was carefully placed into the Brabender oven for a total drying

time of 2 hours which was determined in the pilot study to be the time necessary to reach dry weight. After drying was complete, aluminum pans were placed inside a desiccator for 20 minutes to allow for cooling. Once cooled, pans + dried sample were re-weighed to obtain percent moisture by the following calculations:

1) weight of pan + weight of sample = weight of pan + sample

2) weight of pan + sample - weight of pan + dried sample = weight of moisture in the sample

3) weight of moisture in the sample / weight of sample x 100 = percent moisture

3.06 CONSUMER TESTING

Sensory evaluation by consumer testing was conducted to evaluate the consumer's response towards two different bread variations - control (basic white bread) and 4% LBG. Of the two gums, LBG and guar, and the percent amounts, 2% and 4%, 4% LBG was chosen because of a possible maximum protective effect towards Celiac disease. Locust bean may be more protective than guar gum for it is a high mannan (4:1 mannose to galactose ratio) gum, and 4% may be more beneficial in the effect than 2% (Barbeau, 1992).

3.06a *Consumer Tests - Paired Comparison and Preference*

Two consumer sensory tests were used in this study: paired comparison and preference. The paired comparison test

determined if there was a significant difference between the two bread products - control and 4% LBG. The preference test indicated which of the bread products, control and 4% LBG, was preferred and if the preference was indeed significant.

3.06b *Central Location Testing*

Central location testing was conducted at Burruss and Wallace Halls, Virginia Tech, Blacksburg, Virginia. This type of test location allowed the researcher to bring the product being tested to the potential consumer population. Areas were chosen that provided ample space available for displaying the products being evaluated, potential consumers, and easy access to the location, all of which are important in consumer evaluation.

3.06c *Preparation of Bread Samples and Testing Area*

Control and 4% LBG bread variations were prepared the morning of the testing dates. Bread loaves were cooled 2 hours after baking and cut in half lengthwise (with a serrated knife for uniform cutting) and sliced into 9 slices ~1.5 cm thick. Slices were cut in half and arranged in 4 rows onto large, labeled plastic trays lined with transparent plastic wrap, and then covered with another layer of transparent plastic wrap to insure freshness. Bread samples, plastic pitcher, napkins, paper cups, scorecards, and pencils were transported by car to test sites.

The test area included fluorescent lighting, a counter or table for displaying product samples being tested with available room for the other materials listed above, and enough space for consumer panelists to taste and evaluate products by use of a scorecard.

3.06d *Consumer Selection*

Consumers were selected by individual interest to participate in the study as a consumer panelist at both test sites, Burruss and Wallace Halls. Panelists, male and female, were either faculty, staff or students at Virginia Tech, Blacksburg, Virginia with varying unknown ages.

3.06e *Product Sampling and Evaluation*

Testing took place between 2:00 and 4:00 pm for the paired comparison test, and 3:00 and 5:00 pm for the preference test. Different times were due to scheduling conflicts with the test sites. Consumers were given a scorecard to read for instructions and evaluating the test products. For a sample of the scorecards used see Appendix D. The researcher was available for further instructions if needed and for questions. Each panelist was asked to taste one sample of each test product, evaluate, and provide non-verbal comments on the scorecard. Water was offered between samples. After scorecard completion, each consumer received a

thank you note (Appendix E) for appreciation of their interest and participation as a consumer panelist.

Completed scorecards were compiled according to location and test. Number of responses were then calculated and statistically analyzed by use of Roessler Statistical Tables (Roessler et al., 1978) for paired comparison and preference testing to determine significant differences and preferences, if any.

3.07 BREAD STALING BY DIFFERENTIAL SCANNING CALORIMETRY (DSC)

A Differential Scanning Calorimeter with micro-processor controller and data handling (Perkin-Elmer System-4, Norwalk, CT) was used to determine how guar and locust bean gum affect the rate of bread staling. Methodology was followed according to instructions outlined in the user manual.

Indium (3.85 mg) was used as the standard for calibration of the instrument on a daily basis. The reference sample was an empty stainless steel capsule. Standard and sample DSC parameters used are given in Appendix F. Fresh bread loaf variations (0, 2.0 and 4.0 grams gum per 100 grams all purpose flour) were made with both gums. After at least 2 hours of cooling, day 0, bread crumb samples of approximately 35 mg were placed into O-ring stainless steel capsules (Perkin-Elmer, Kit #319-0218, Norwalk, CT), weighed on a Perkin-Elmer AD-6 computerized micro-balance (Perkin-Elmer, Norwalk, CT), and with the lid tightly crimped into position

(Perkin-Elmer Quick Press and Spacer Insert), loaded into the DSC. The same process was followed for days 1,2,4,7 and 10 for each bread variation. Replications were in duplicate. All breads were tightly wrapped with transparent plastic wrap and placed into gallon size zip-lock bags throughout the duration of the testing period.

Thermograms were used to interpret the amount of H-bonding that had occured, indicative of staling, by plotting each thermogram for all bread variations and determining the baseline and height of the amylopectin peak. The obtained peak measurements were then used in the following calculations:

1) AREA = base line of peak (mm) x height of peak

2) PEAK AREA/mg = area / weight of the sample in mg

Mean peak area/mg values were obtained for all bread variations for each day as indicated earlier.

3.08 STATISTICAL ANALYSIS

Each of the following measurements were analyzed by analysis of variance (ANOVA) to determine significance and Duncan's test to determine which means (of all bread variations) were significantly different at $p < 0.05$: standing height, texture, color, moisture, and DSC values. The Statistical Analysis System (SAS), (SAS Institute 1989,

Cary, NC) was used on the IBM mainframe computer at Virginia Tech, Blacksburg, Virginia for analysis.

CHAPTER 4

RESULTS AND DISCUSSION

4.00 PURPOSE AND OBJECTIVES

The purpose of this research was to partially replace all-purpose flour in bread with guar and locust bean gums and produce an acceptable bread product. The objectives were to 1) determine what feasible amounts of gum could partially replace all-purpose flour and produce an acceptable bread product, and 2) determine what effect guar and LBG had on a bread product when used as partial replacers of all-purpose flour.

4.01 PILOT STUDY

Results of the pilot study clearly indicated that 1%, 2%, 2.5%, and 4% guar and LBG were feasible amounts as partial replacers of all-purpose flour in the control bread product. Five percent LBG, however, created a thicker, gummier dough which made it difficult for the home bakery bread machine to handle. Fifteen percent gum replacement was impossible for it produced a thick, gummy mass which the bread machine blade could not move. Therefore, to eliminate stress on the motor of the machine, the 4% gum level was chosen as the highest workable percent for this particular

study. Since the amount necessary for the protective effect of those with celiac disease is not known, a maximum gum level appropriate for the method was selected.

The pilot study was conducted for approximately 3 weeks and included all sample preparations, objective measurements, sensory evaluation, and DSC. As a result, the researcher became familiar with all methods, and all preparations for actual testing purposes.

4.02 OBJECTIVE EVALUATION OF BREAD PRODUCTS

Raw data in Appendix G.

4.02a *Index to Volume*

Mean standing height for each bread variation is recorded in Table 1. According to statistical analysis, the 2% LBG bread variation was significantly greater than the control bread, 4% LBG bread, and 4% guar bread. The 2% guar variation, however, was not significantly different from any of the bread variations, as shown in Figure 1. The control bread (no gum added) was used a standard/reference since all-purpose flour is known to produce an acceptable bread product (Bennion, 1990; Bushuk, 1985; Faridi et al., 1987).

The data suggested that standing height increased up to a critical gum level of this experiment (>2%). After the critical level was obtained, gum no longer enhanced the height of the bread product. Apling et al. (1978) had similar

TABLE 1. Mean standing height, texture and color values for breads with no gum added, 2% locust, 4% locust, 2% guar and 4% guar gum added bread treatments*.

TREATMENT	STANDING HEIGHT (cm)	TEXTURE (gms force)	COLOR (Δ E) CRUMB	CRUST
Control	17.6a^	88.3a	25.2a	51.2a
2% Locust	18.8b	86.8a	25.3a	53.4ab
4% Locust	17.3a	115.7ab	25.8a	55.4b
2% Guar	18.1ab	99.5a	25.1a	55.4b
4% Guar	17.4a	146.2b	24.7a	55.0b

*n = 3
^means in the same column with the same letter are not significantly different at $p<0.05$.

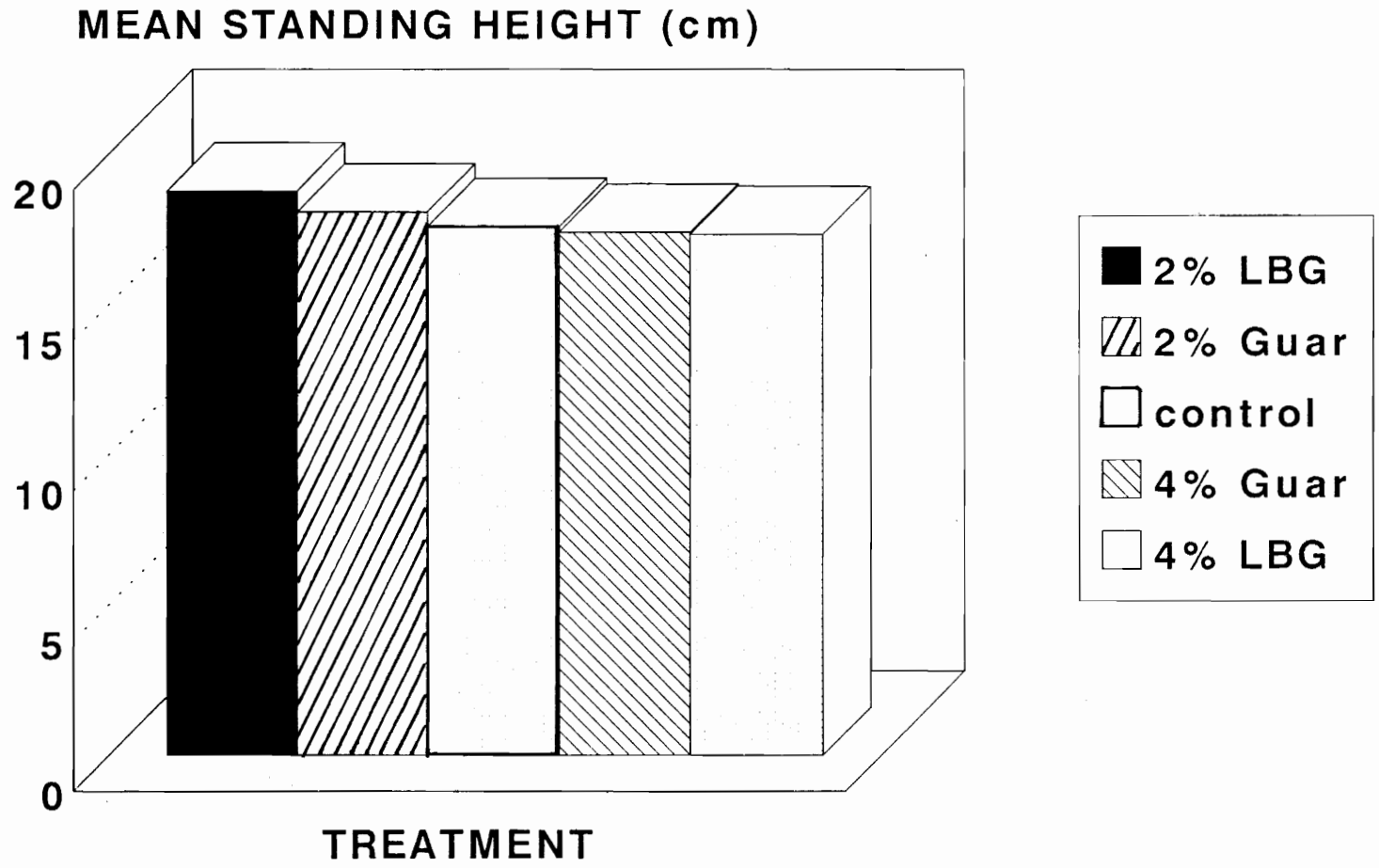


FIGURE 1. Mean standing height values for 2% LBG, 2% guar, control, 4% guar and 4% LBG.
*n = 3

results when using guar gum as a partial replacer of English flour, with 11.3% protein, in bread products. The researchers showed a clear improvement in loaf volume with the addition of 3% guar replacement, 6% guar replacement still had a good loaf volume, but 9% replacement was intermediate. Cawley (1964) also found guar gum to increase loaf volume, but to a greater extent than LBG which was in contrast to the results obtained in this study. The researcher attributed greater loaf volume with guar replacement due to its specific structure - "Straight chain of mannose residues with single unit galactose side-chains on every mannosan residue, but for LBG every 4th mannose is substituted, and thus the more substituents there are on the main chain the more effective is the polymer" (Cawley, 1964).

Also, while the amount of water was held constant in the bread formula, guar gum absorbed water differently than LBG (due to its structure) which may have resulted in behavior differences. The gums competed with the gluten for water. As gum concentrations were increased, competition for water with gluten was increased, and resulted in standing height differences. As mentioned earlier in the review of literature, water is an essential ingredient for gluten development.

4.02b *Texture*

As shown in Table 1, mean texture values revealed that bread with 4% guar replacement for flour was significantly firmer than the control (no gum), 2% LBG replacement, and 2% guar replacement, but not significantly different than the bread with 4% LBG replacement.

Both gums have been found to improve the texture of baked products usually giving a shorter, softer texture (Dziezak, 1991; Glicksman, 1969; Maier et al., 1993). The results obtained in this study, however, showed a firming effect with the addition of guar gum and LBG. A possible reason for this may be attributed to the type of flour used, i.e. all-purpose, and the bread formulation itself. Most research that has been done with the addition of gums in bread products includes bread flour or a flour with a higher protein content (11% or greater) than all-purpose flour (~10.5%). According to Apling et al. (1978), guar gum itself contributes to the final structure of the loaf by gums interacting with the starch components. Also, concentration of the gum has an effect on final texture as well. At higher concentrations the gum becomes more viscous, producing gumminess which in turn may actually produce a firmer texture. The 4% gum replacements were found to produce firmer textures in this study as given in Table 1. Water absorbancy capabilities of both gums may have influenced the texture as well.

4.02c *Color*

Mean Delta E values, given in Table 1, indicated that the crumb color for each bread variation was not significantly different. This outcome was expected.

However, the mean delta E value for the crust of the control bread was significantly lighter than 2% guar bread, 4% guar bread, and 4% LBG bread. The 2% LBG bread was not significantly different from any of the bread variations. A possible explanation for differences in crust color may be attributed to the fact that gums are sugars. Hydrolyzation of the gums to reducing sugars by enzymes provided by molds and yeast may have contributed to the darker crust colors. Also, the end of the gum's (guar and LBG) chain may act as a reducing sugar. The 2% LBG bread may not have been hydrolyzed to enough reducing sugars, due to its structure, to make a significant difference in crust color compared to all the other bread treatments. Reducing sugars readily react in the Maillard browning reaction to produce compounds responsible for the brown pigment of the non-enzymatic browning reaction. As mentioned earlier, the latter appears to be important in formation of crust color (Shelton and D'Appolonia, 1985).

4.02d *Cell Size*

Differences in cell size for each bread variation was determined by comparing photocopies of each bread loaf half as shown in Figures 2-6. The control bread had extra large

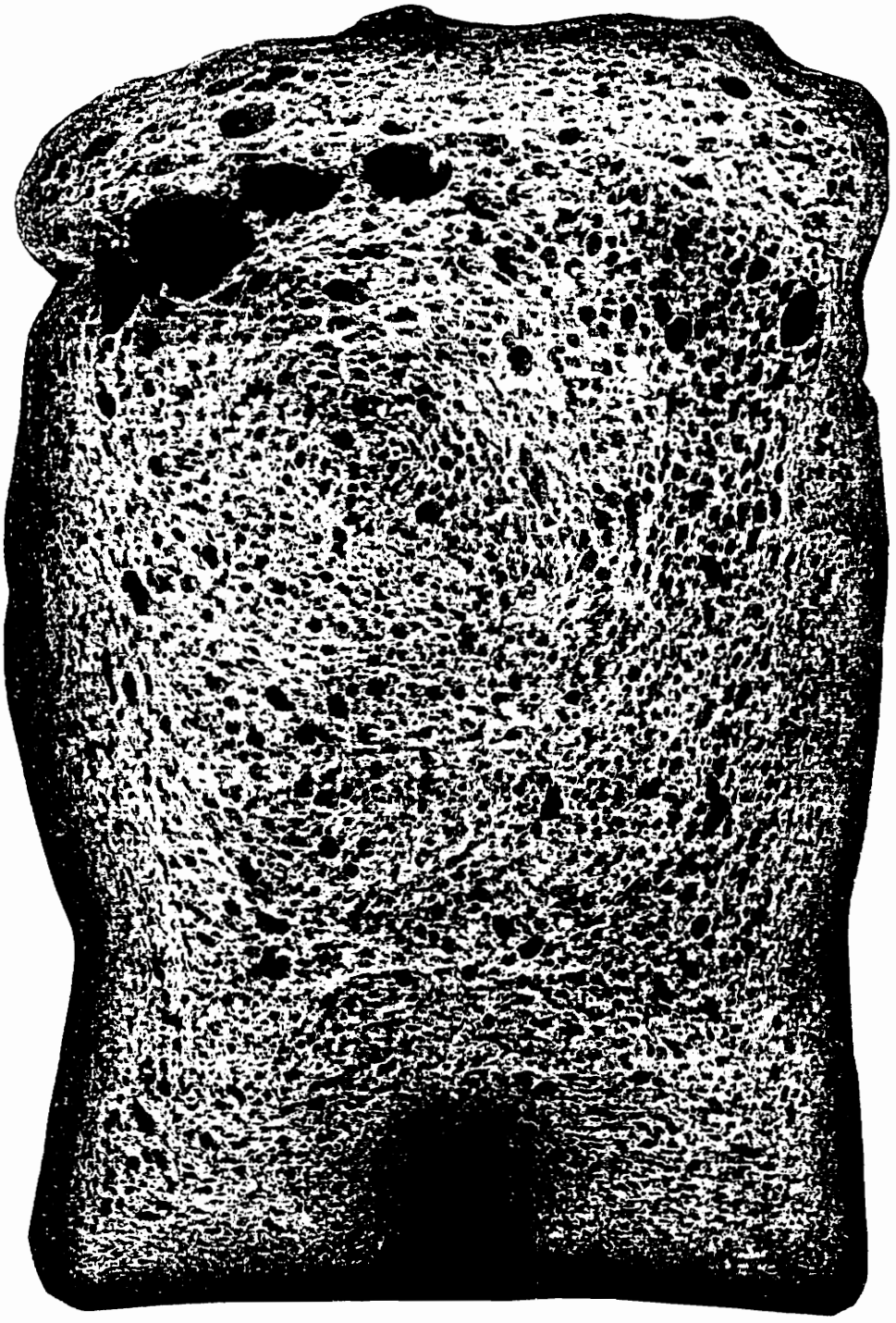


FIGURE 2. CONTROL CRUMB STRUCTURE.

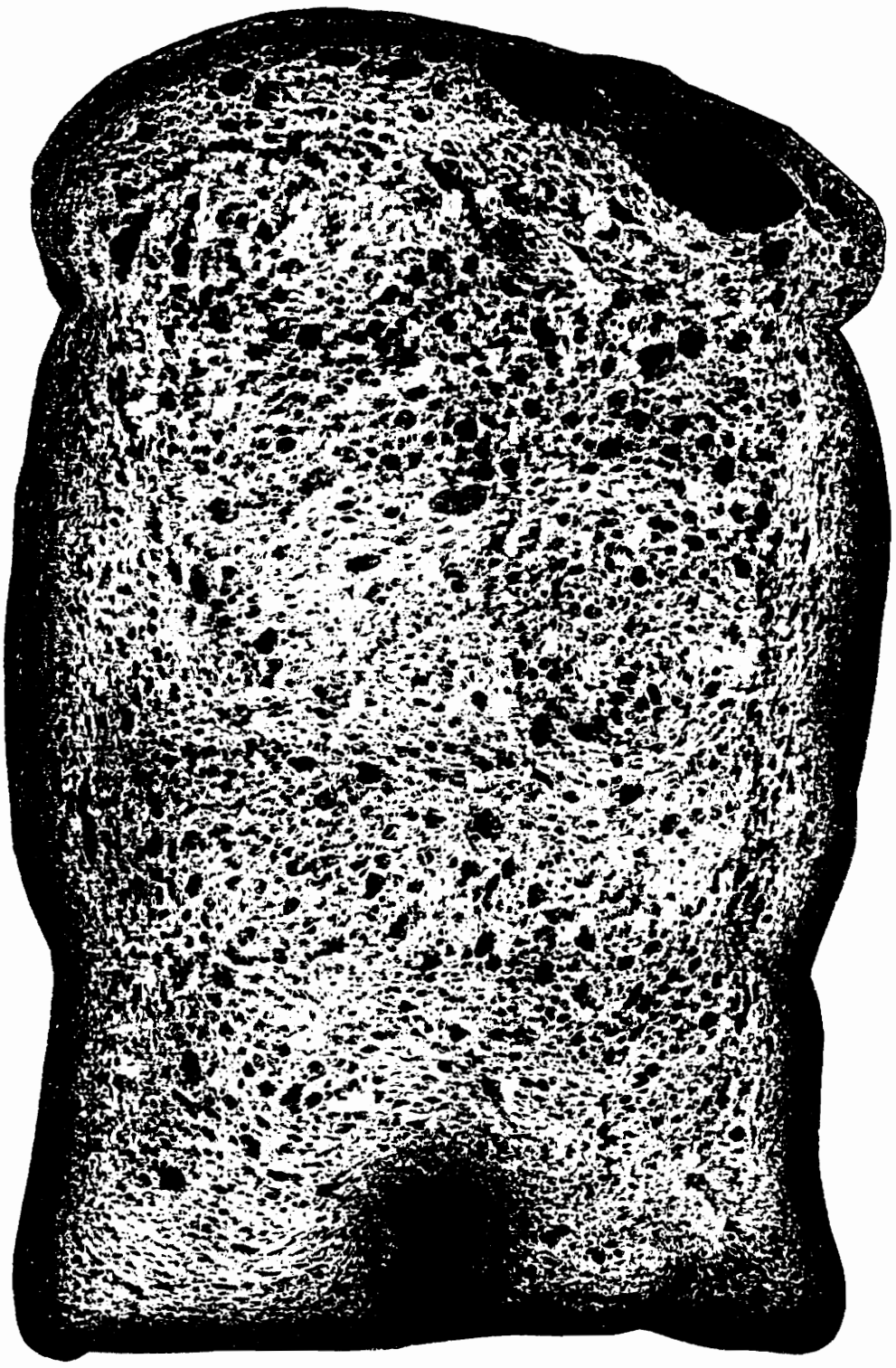


FIGURE 3. 2% LBG CRUMB STRUCTURE.

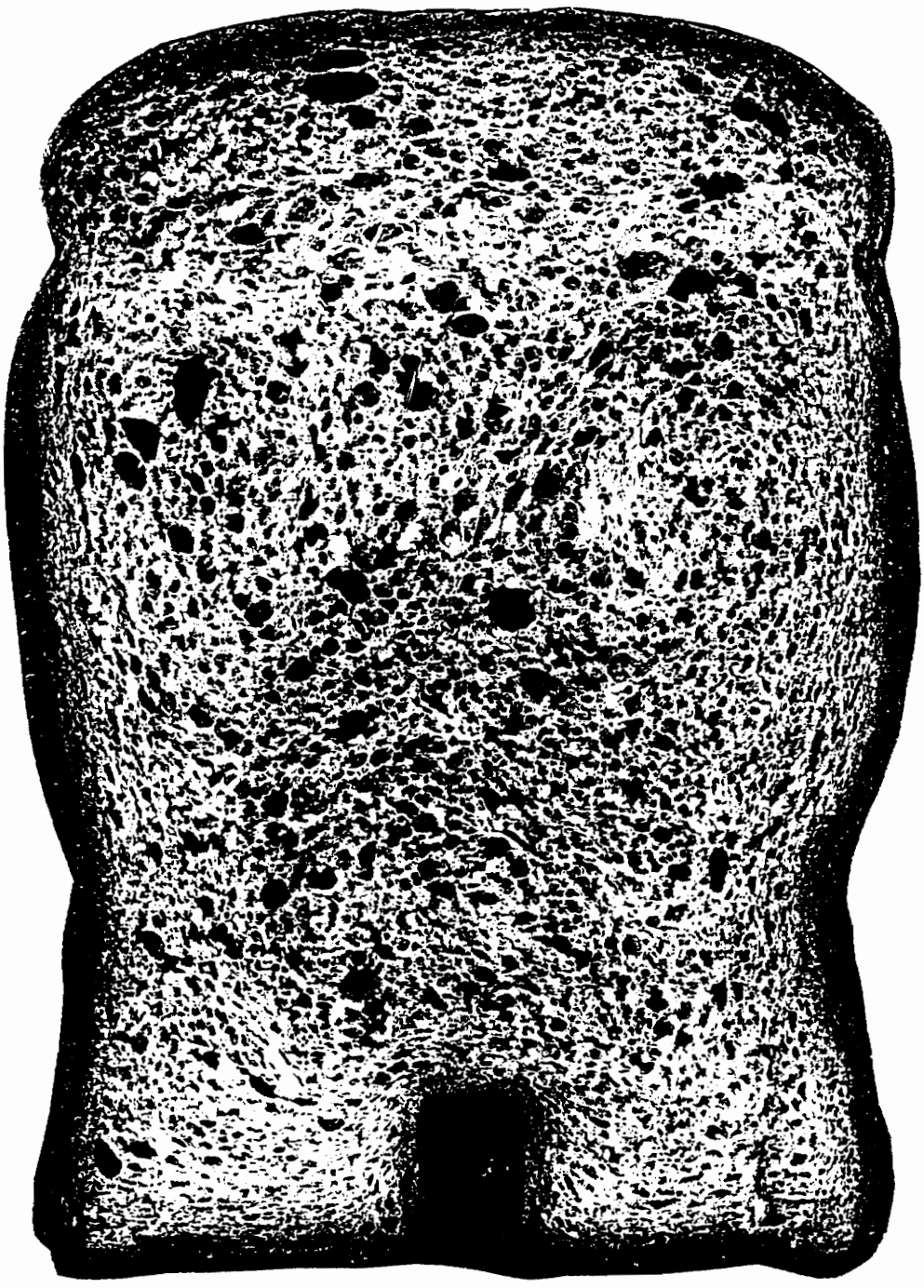


FIGURE 4. 4% LBG CRUMB STRUCTURE.

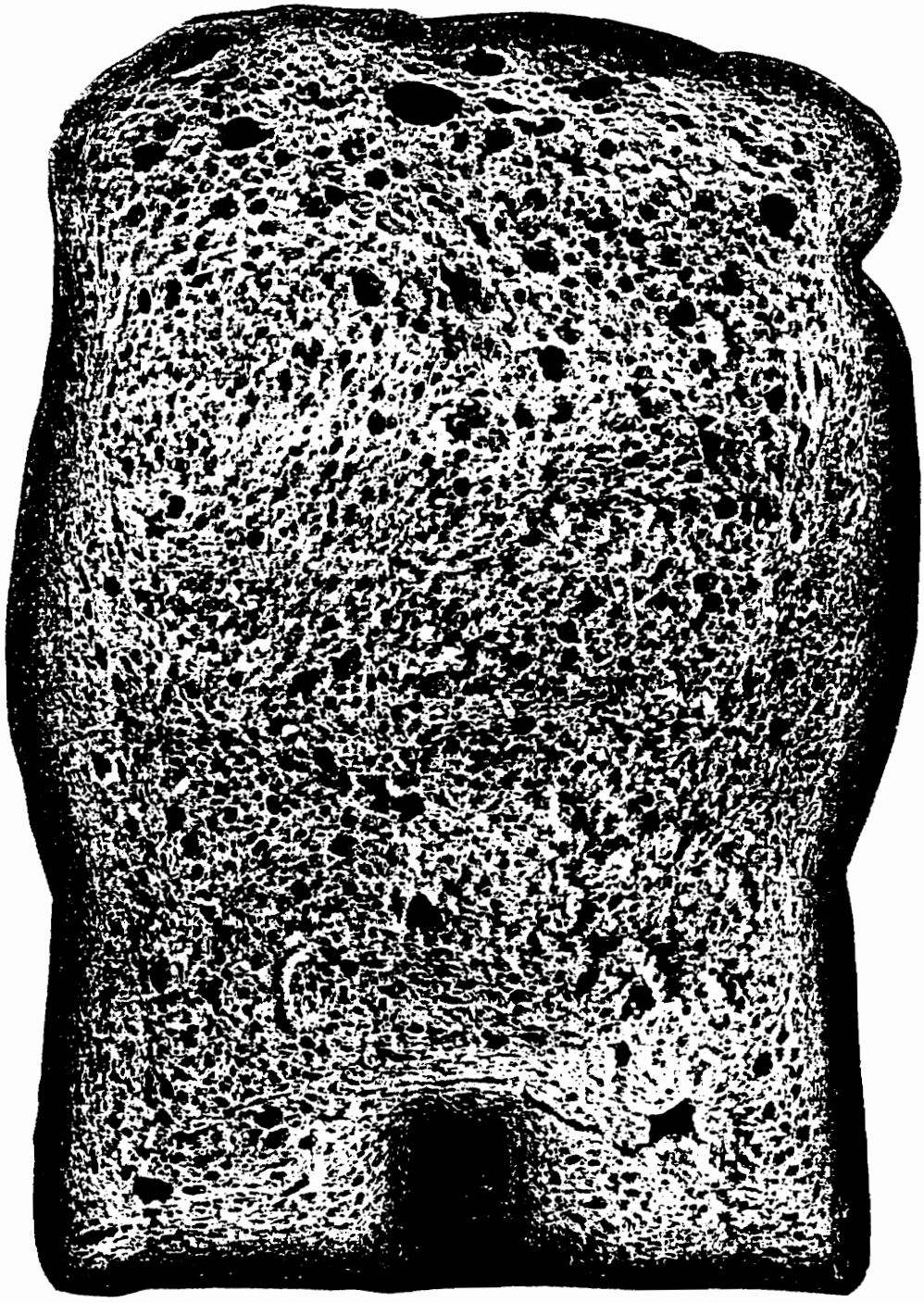


FIGURE 5. 2% GUAR CRUMB STRUCTURE.

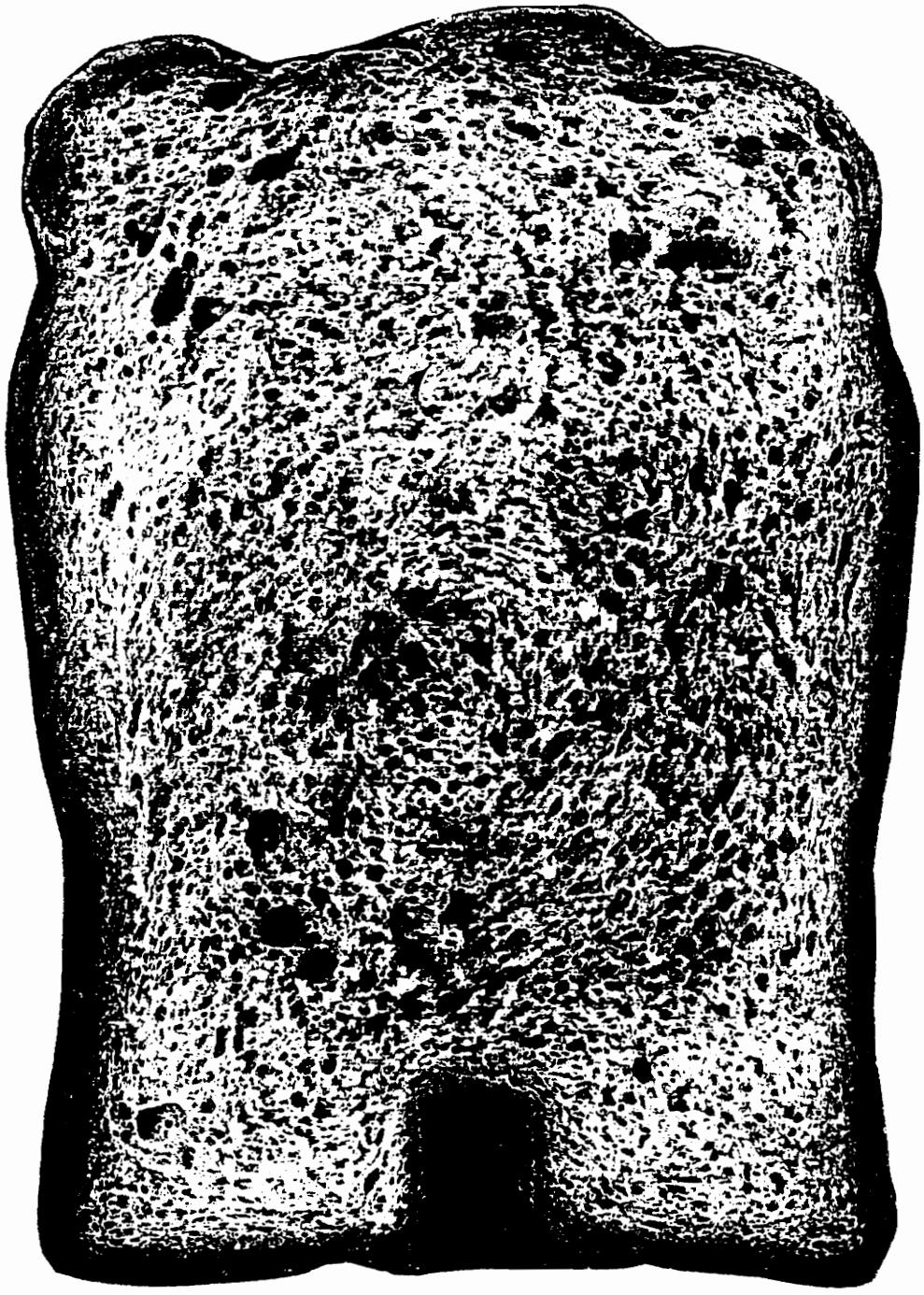


FIGURE 6. 4% GUAR CRUMB STRUCTURE.

cells at the top left corner, and the cells throughout the loaf were of various sizes and unevenly distributed (Figure 2). The 2% LBG bread (Figure 3) was similar to the control bread, as shown in Figure 7, with extra large cells at the top, various cell sizes, and uneven distribution. However, the 2% LBG bread appeared to have more large cells in general. The other bread variations were similar in appearance with various sized cells and uneven distribution, except for 2% guar bread having the most even distribution, as shown in Figure 8.

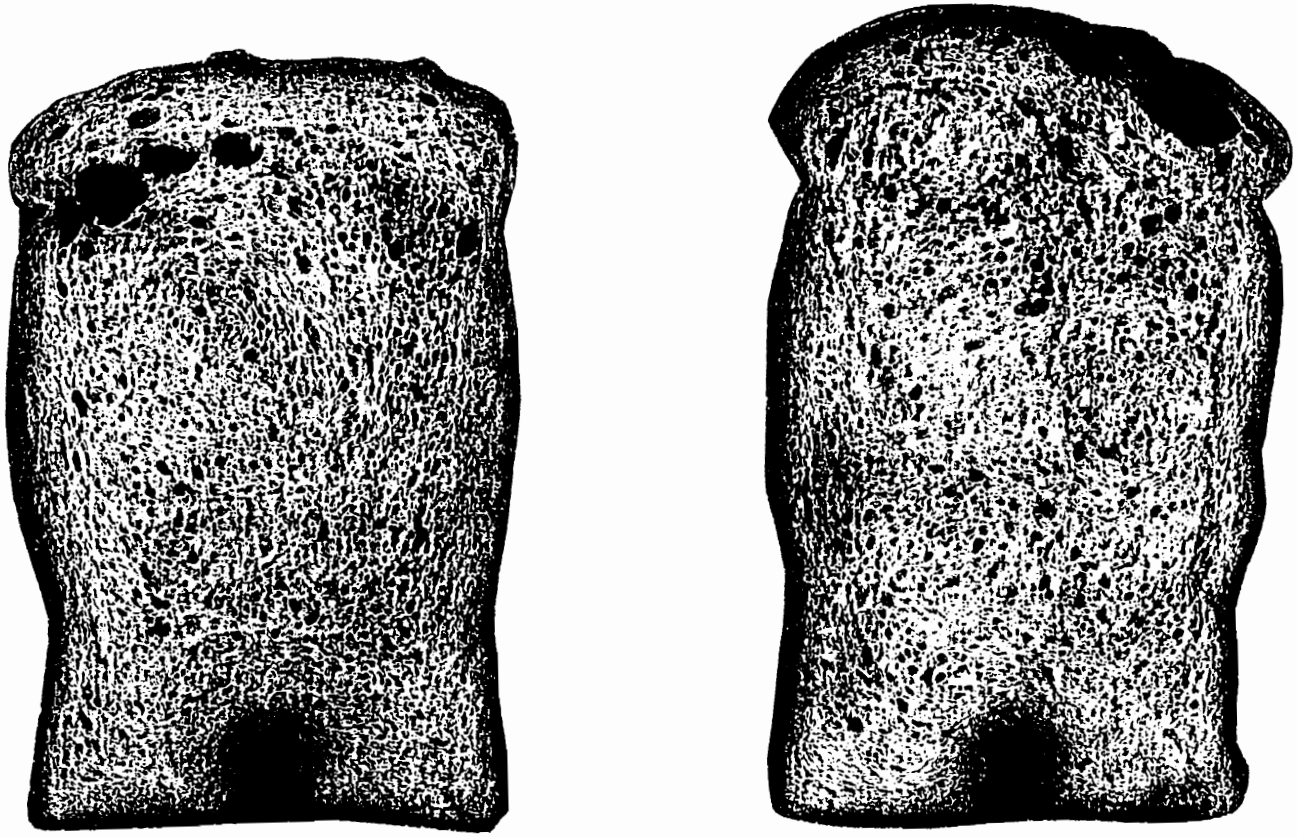
4.02e *Moisture*

Moisture contents of each bread variation were determined by use of a Brabender Moisture Tester (South Hackensack, New Jersey). Mean moisture contents are given in Table 2, below. The moisture contents of all bread variations

TABLE 2. Mean* percent moisture for control (no gum), 2% LBG, 4% LBG, 2% guar and 4% guar bread variations.

TREATMENT	PERCENT MOISTURE
Control	44.81
2% LBG	44.57
4% LBG	44.26
2% Guar	44.73
4% Guar	44.62

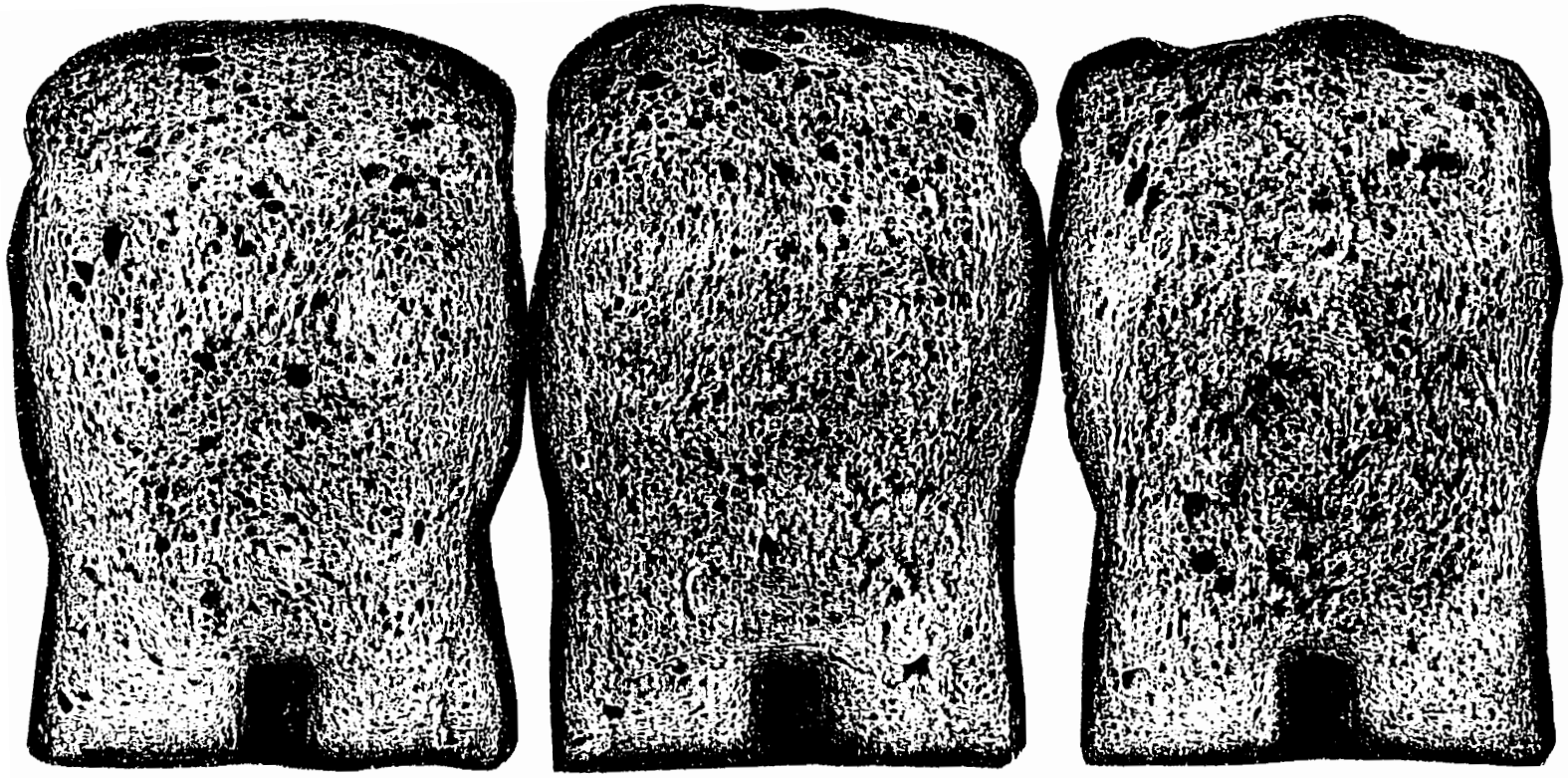
*n = 2



CONTROL

2% LBG

FIGURE 7. CONTROL AND 2% LBG CRUMB STRUCTURE.



4% LBG 2% GUAR 4% GUAR

FIGURE 8. 4% LBG, 2% AND 4% GUAR CRUMB STRUCTURES.

were not significantly different. According to Apling et al. (1978), the moisture content of a guar/wheat bread is approximately in the range of 45 to 48%, which was found to be true in this study as well.

4.03 CONSUMER TESTING (Raw data in Appendix H)

4.03a *Paired Comparison Test*

A paired comparison test (difference test) was done at 2 locations, Burruss and Wallace Halls, Virginia Tech, Blacksburg, Virginia between 2 and 4 pm. Consumers were recruited by a 24 hour advance invitation at a central location. A total of 24 responses came from Burruss Hall and 17 from Wallace Hall. Of the total responses obtained, Burruss and Wallace Halls had 17 and 12 correct responses, respectively, in identifying that the two samples (control and 4% LBG breads) were different. When combining the two locations, 29 responses were correct and 12 were incorrect, as shown in Table 3.

TABLE 3. Number of responses for consumer difference test* for bread with no gum and 4% LBG.

	NUMBER OF RESPONSES	
TEST	CORRECT	INCORRECT
Difference	29a	12

*n = 41
a - Significant at $p < .05$

The samples selected for paired comparison (difference) testing were control bread and 4% LBG bread based on the rationale that the 4% LBG bread may have a greater protective effect due to its high mannan composition. If gums added to breads are beneficial to celiac patients, the 4% LBG bread will provide maximum protection.

For 41 responses, 27 correct answers were necessary to establish a significant difference (Roessler Tables, Roessler et al., 1978). Therefore, a significant difference was found between the 2 bread products tested, 4% LBG and control treatments. Seventy-one percent of the responses were correct responses in identifying the two samples (control and 4% LBG breads) as being different, and 29% were incorrect (identified the two samples as the same), as shown in Figure 9.

In addition to product response, consumers were also asked to circle their gender (male/female). Out of the 41 consumer panelists, 34% (14) were male and 66% (27) were female (Figure 10). In regard to correct responses, 71% (10 out of 14) of the males had correct answers, and 70% (19 out of 27) of the females had correct answers. Therefore, gender did not play a significant role in product response in this particular study.

Comments were also part of the scorecard and 15 of the 41 consumer panelists responded. Most of the comments stated such as: difference in texture (5 responses), difference in

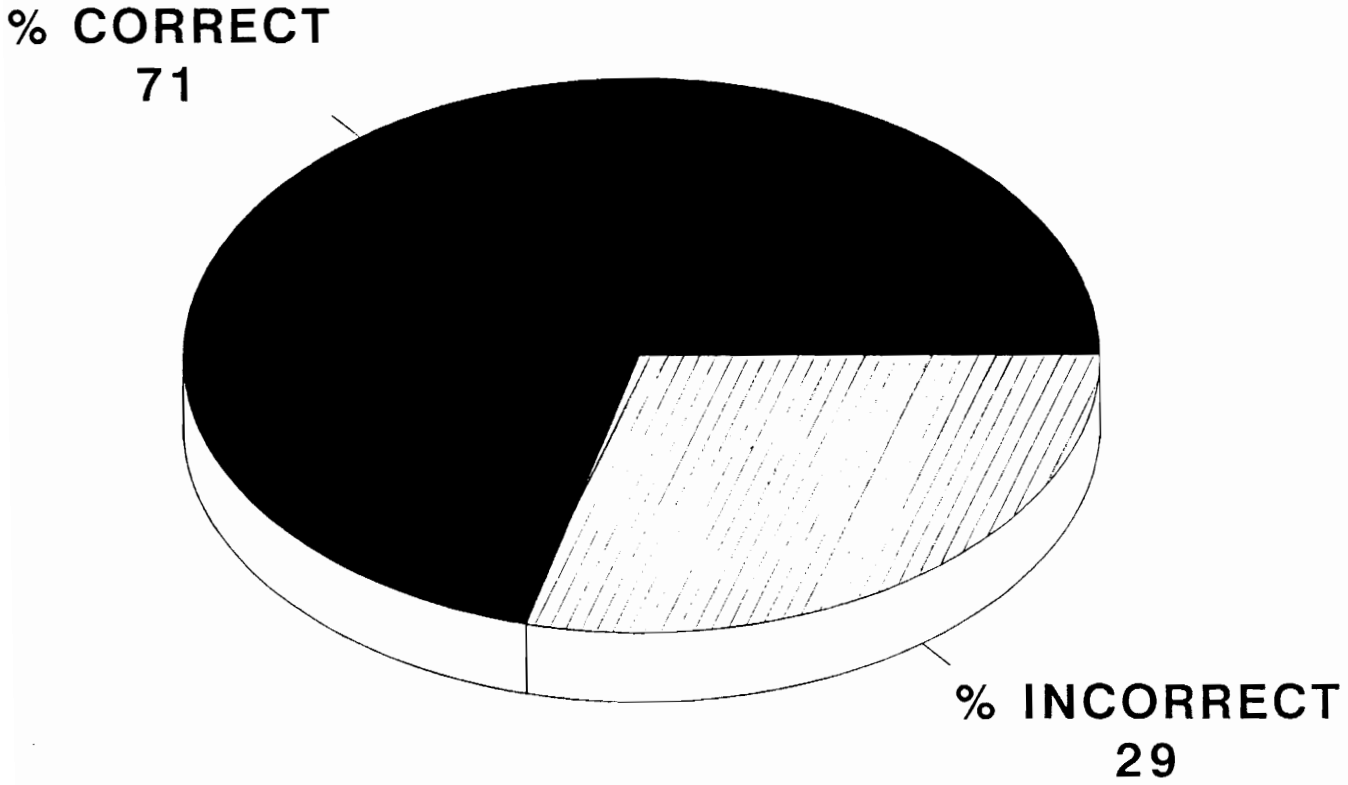


FIGURE 9. Percent correct and incorrect responses for difference test.

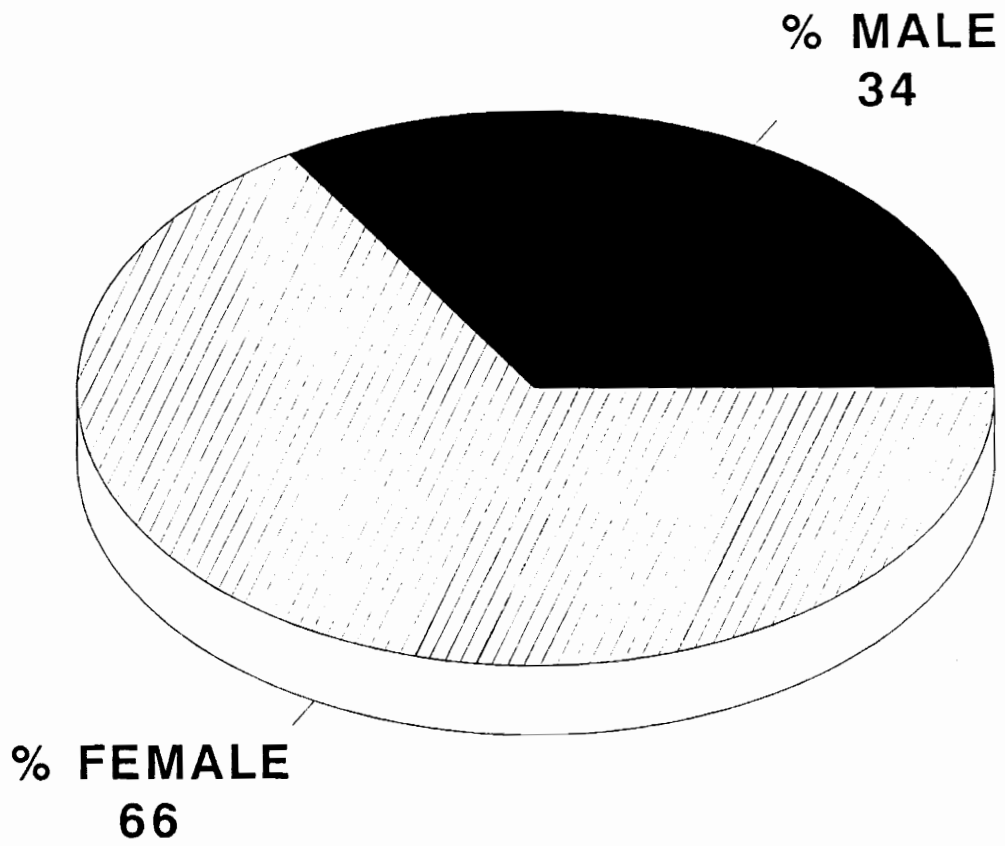


FIGURE 10. Percent male and female responses for difference test.

flavor (4 responses), both breads have the same color (5 responses), both are good breads (2 responses), 512 (control bread) seems less sweet than 780 (4% LBG bread) (1 response), 780 seems less sweet than 512 (1 response), and one tastes more like homemade bread (1 response).

4.03b *Preference Test*

A preference test was done at 2 locations, Burruss and Wallace Halls, Virginia Tech, Blacksburg, Virginia between 3 and 5 pm. Consumers were recruited by a 24 hour advance invitation at a central location testing. The samples selected for preference testing were control bread and 4% LBG bread based on the rationale established previously. Responses of the panelists indicated the 4% LBG bread was preferred over the control bread at Burruss Hall, and the control bread was preferred at Wallace Hall. Sixty-eight percent (15 out of 22) of the consumer panelists preferred the 4% LBG bread at Burruss, and 44% at Wallace Hall. In regard to the control bread, 32% of the consumer panelists preferred this treatment at Burruss, and 56% at Wallace. When the 2 locations were combined, 19 (61%) out of the total 31 consumers preferred the 4% LBG bread and 12 (39%) the control bread, (Table 4 and Figure 11).

TABLE 4. Number of responses for consumer preference test* for breads with no gum (control) and 4% LBG.

	NUMBER OF RESPONSES	
TEST	CONTROL	4% LOCUST
Preference	12a^	19a

*n = 31
^same letters are not significantly different at $p < 0.05$.

Out of 31 responses, 22 agreeing judgments were necessary to establish a significant difference (Roessler et al., 1978). Therefore, there was no significant difference among preference between the 2 treatments, control and 4% LBG breads.

In addition to product response, consumers were also asked to circle their gender (male/female). Of the 31 consumer panelists, 13% (4) were male and 87% (27) female, as shown in Figure 12. Three males (75%) and 16 females (59%) females preferred the 4% LBG bread. Therefore, gender may have some effect in preference, but the number of males available for testing was quite small and thus may not have been an adequate representation of gender in regard to preference for either bread product.

Comments were also part of the scorecard and 24 of the 31 consumer panelists responded. A major trend for a

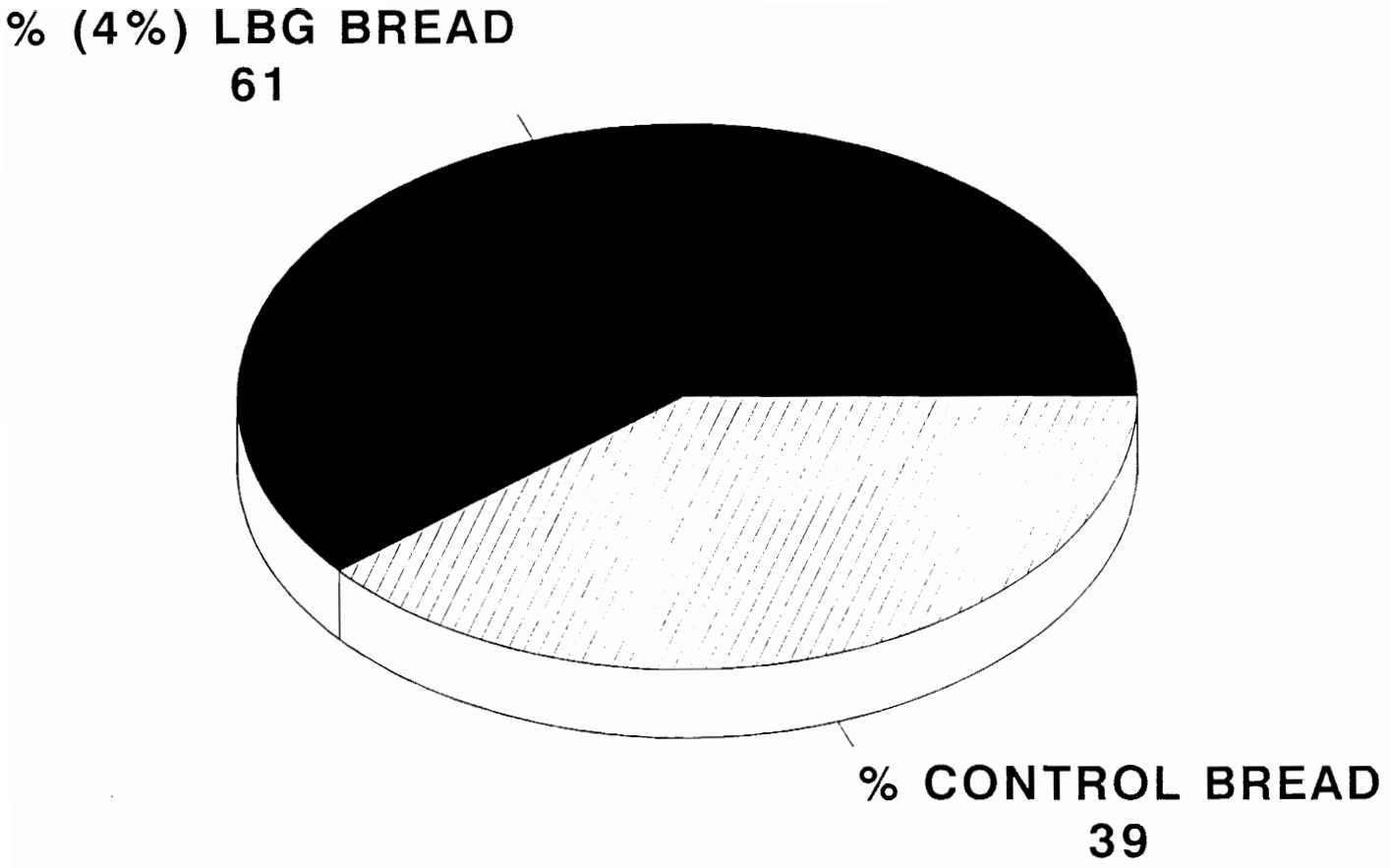


FIGURE 11. Percent responses for control and 4% LBG for preference test.

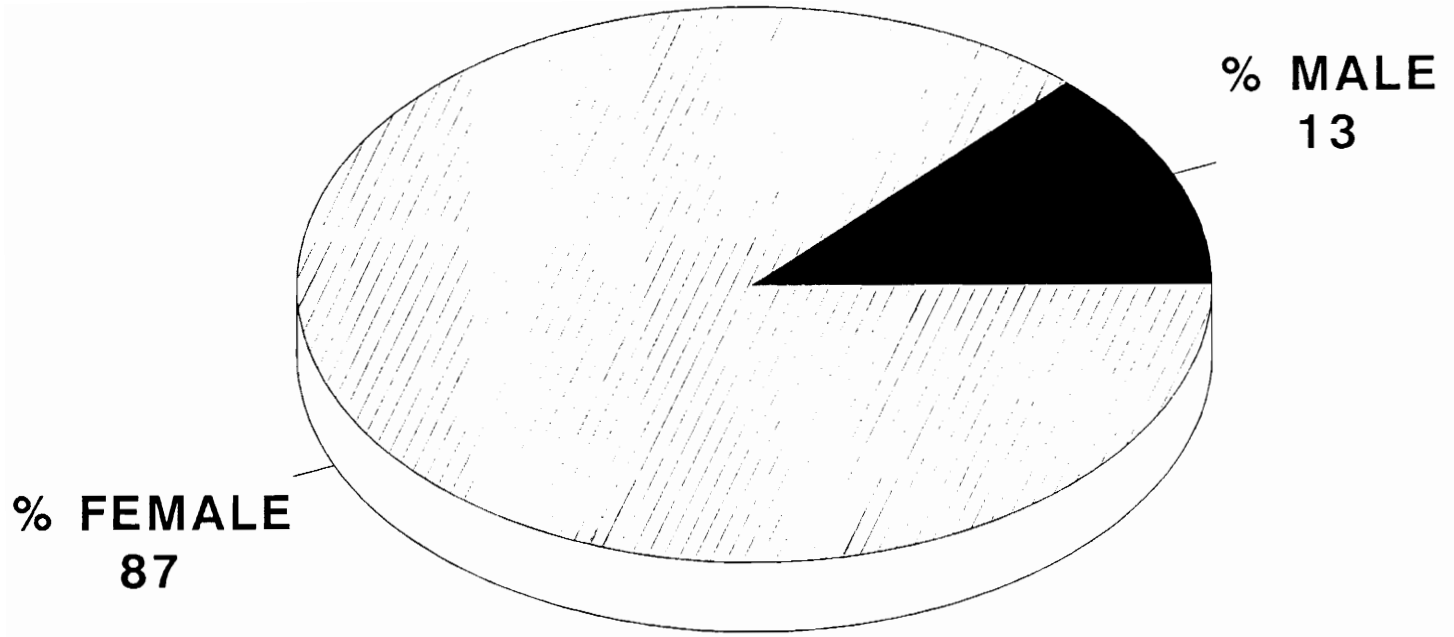


FIGURE 12. Percent male and female responses for preference test.

better/firmer texture (7 out of 16 consumer responses) and flavor (9 out of 16) were the deciding factors of preference for the 4% LBG bread. According to Szczesniak and Kahn (1971), texture plays an important role on people's feelings and attitudes towards food. Firmness is one of the most desirable qualities in bread products in addition to freshness and flavor (Sloan and Powers, 1985). In addition, 8 consumers commented on the 4% LBG bread being sweeter than the control. A possible explanation is that the 4% LBG bread was hydrolyzed to more reducing sugars and in turn gave it a sweeter taste.

4.04 BREAD STALING

Five bread treatments were prepared as given in the materials and methods, and cooled for 2 hours (day 0). Approximately 35 mg of bread crumb sample weights were placed into micro stainless steel capsules and heated up to 140° C in the DSC. Thermograms were labeled with treatment and day of storage. DSC samples were completed in duplicate and the same procedure was followed for days 1,2,4,7, and 10. Amylopectin is known to be the major contributor to bread staling (Pyler, 1988). Therefore, amylopectin peaks (peak 1) were monitored on the computer screen, plotted, and printed (Figures 13 - 17). The peak area/mg was used as an index to bread staling for all bread variations. As shown in Figure 18,

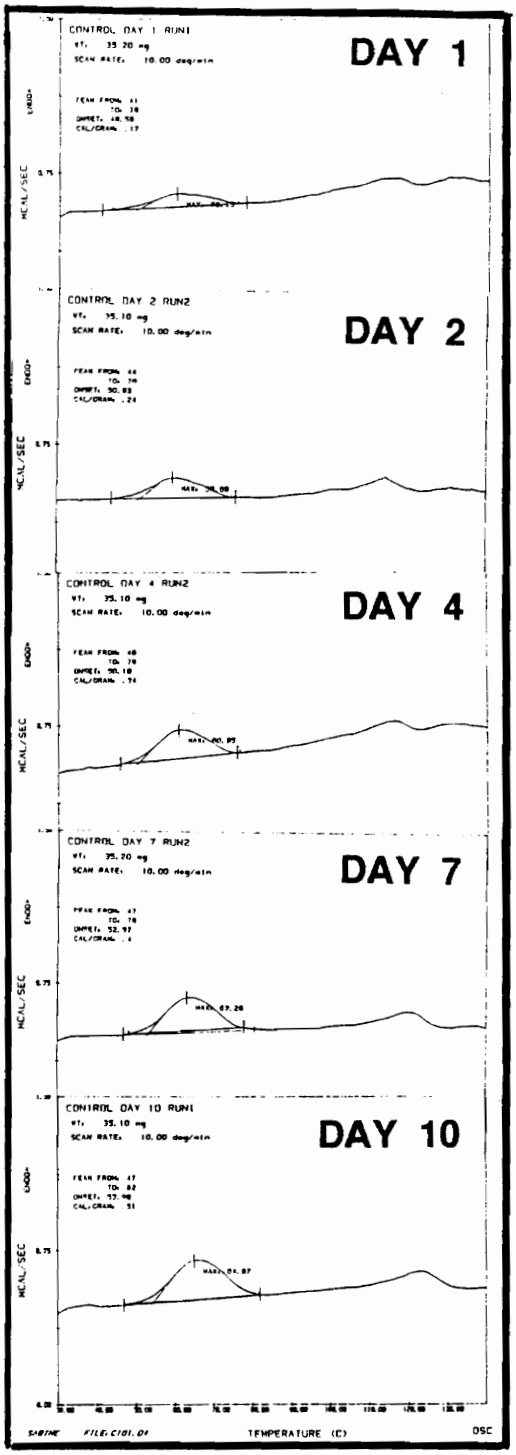


FIGURE 13. AMYLOPECTIN PEAKS FOR CONTROL DAYS 1,2,4,7 & 10.

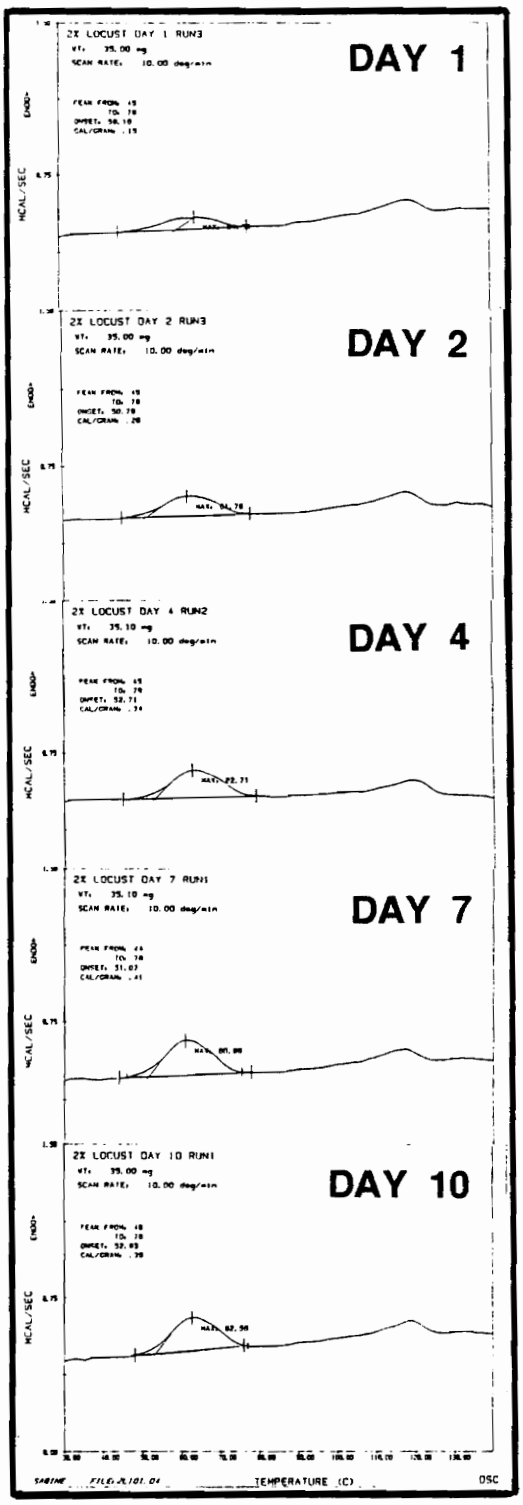


FIGURE 14. AMYLOPECTIN PEAKS FOR 2% LBG DAYS 1,2,4,7 & 10.

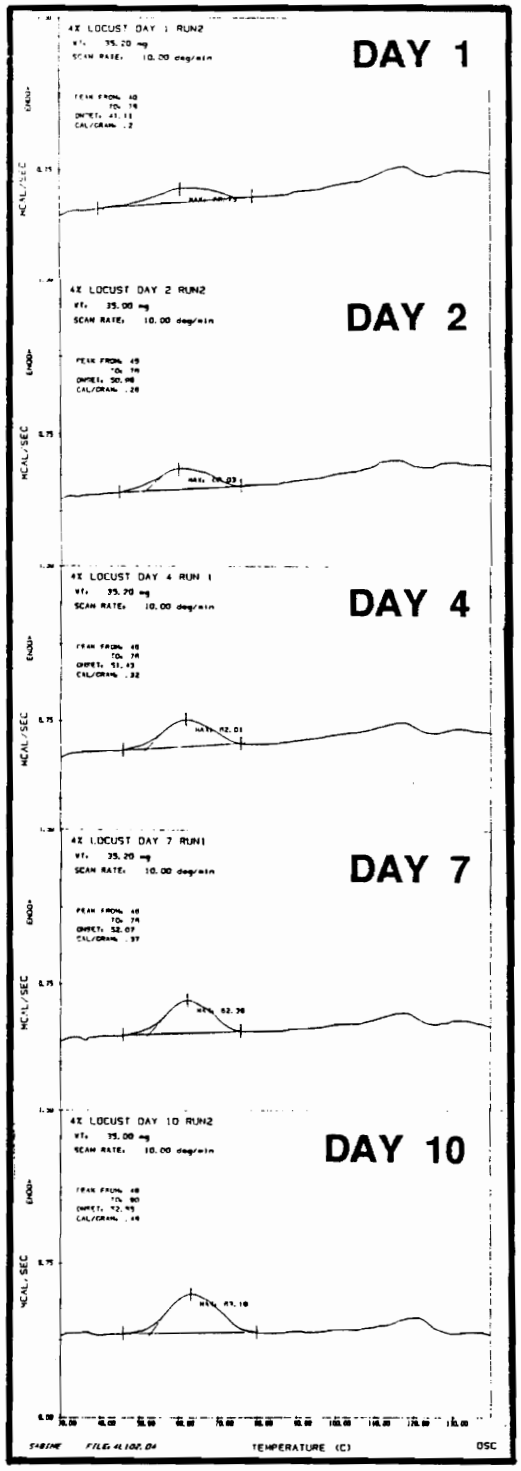


FIGURE 15. AMYLOPECTIN PEAKS FOR 4% LBG DAYS 1,2,4,7 & 10.

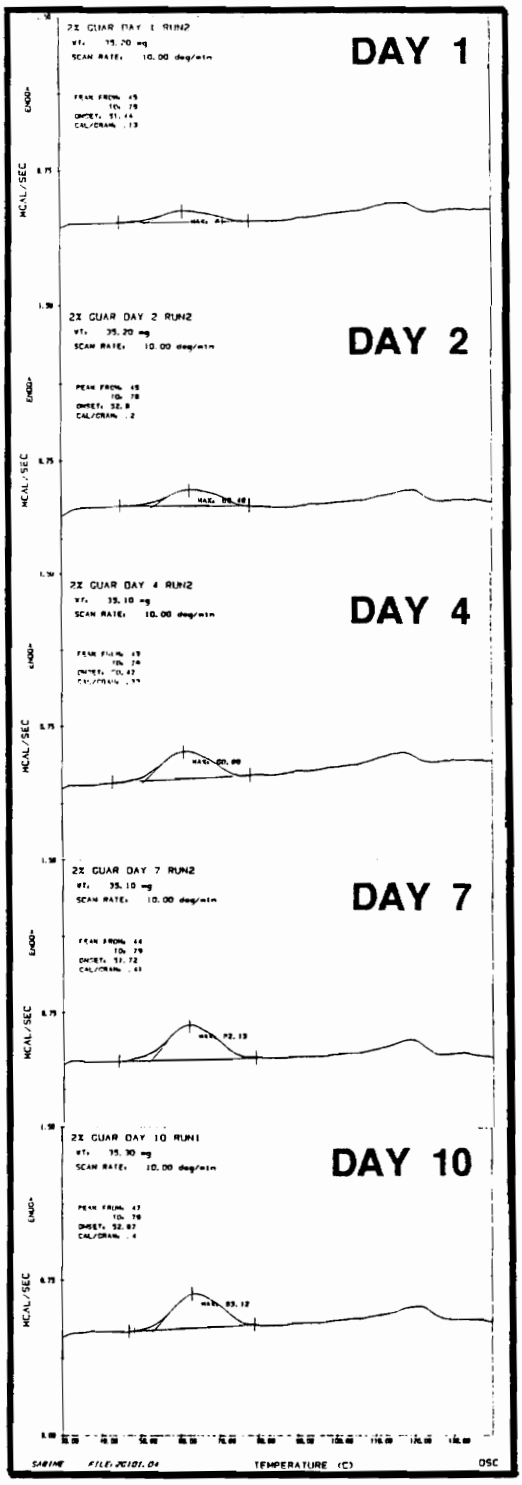


FIGURE 16. AMYLOPECTIN PEAKS FOR 2% GUAR DAYS 1,2,4,7 & 10.

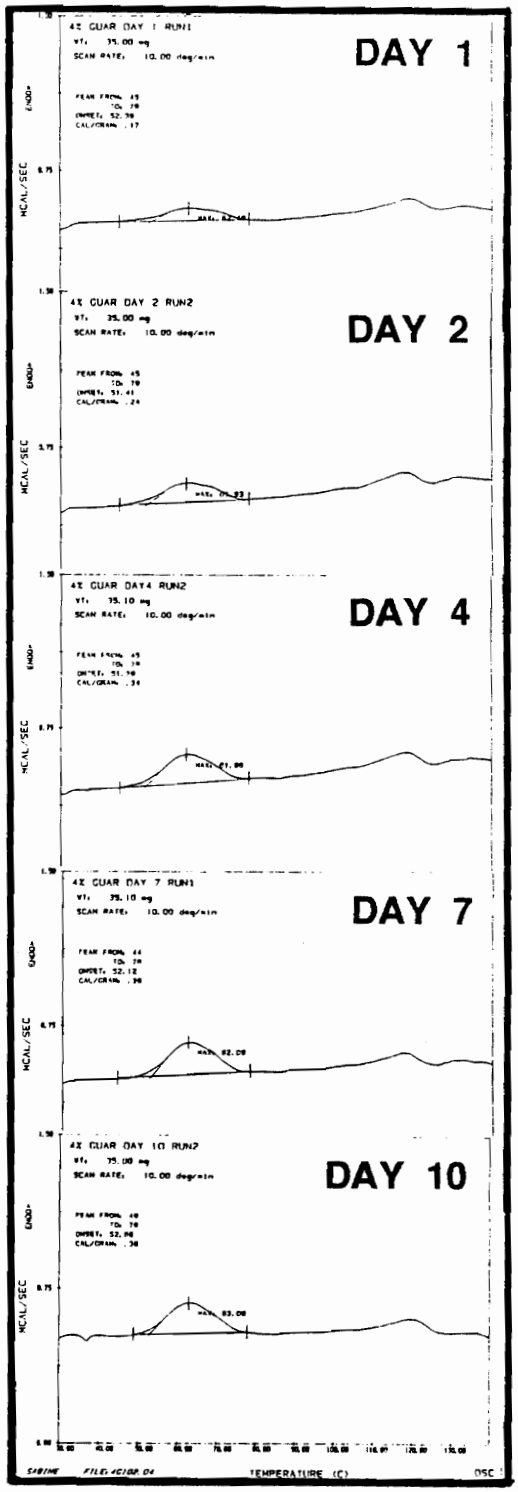


FIGURE 17. AMYLOPECTIN PEAKS FOR 4% GUAR DAYS 1,2,4,7 & 10.

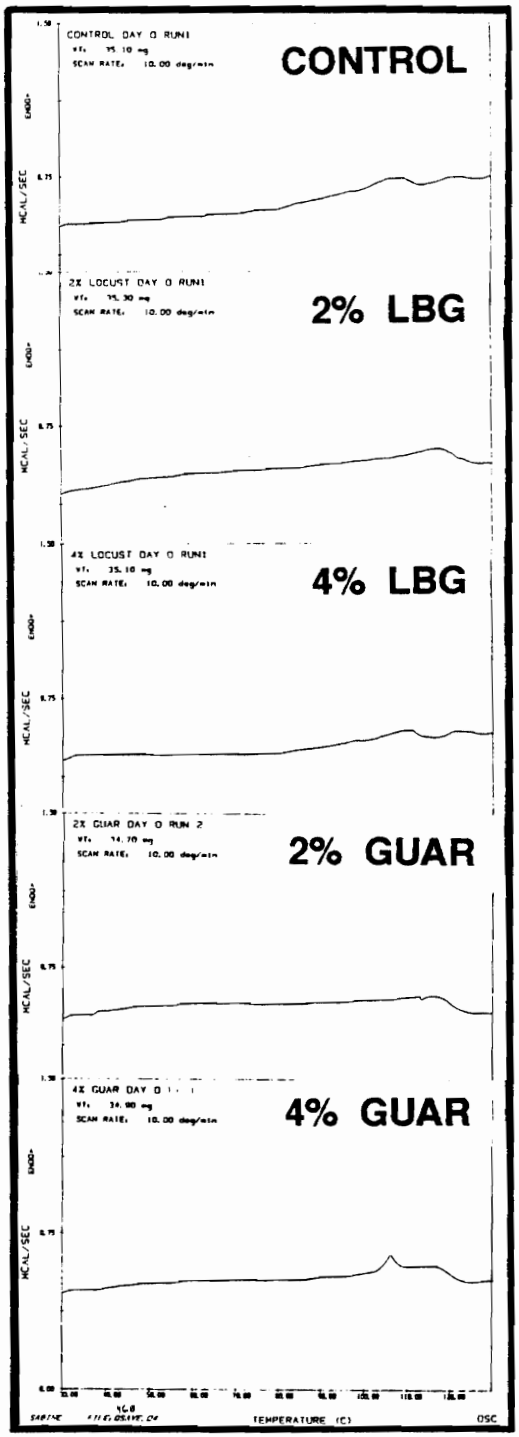


FIGURE 18. DSC DAY 0 THERMOGRAMS FOR CONTROL, 2% LBG, 4% LBG, 2% GUAR, and 4% Guar.

amylopectin peaks were not present on day 0, and thus, conclusively, bread staling had not occured as indicated by increased bonding of amylopectin. However, all bread treatments had an amylopectin peak day 1 and proceeded through day 10. Mean amylopectin peaks in peak area/mg (Table 5) were used as an index to staling. Peak area/mg increased with an increase in storage time for all treatments. Between days 1 and 2 bread staling was most rapid for all bread treatments (Figure 19), and continued moderately until day 4 with a leveling off of peak area/mg at days 7 through 10. The pattern of staling therefore did not change with any of the bread treatments. These findings were in agreement with bread staling results obtained by Czuchajowska and Pomeranz (1989).

The control bread had the highest staling (13.74 area/mg) on day 1 as shown in Table 5 and on Figure 19. Four percent LBG bread and 4% guar bread had an area/mg of 13.62 and 12.59, respectively. The 2% gum treatments were similar in having the lowest peak area/mg (guar = 10.94, LBG = 10.45) on day 1, with 2% LBG having the lowest area/mg of 10.45 and thus the least amount of staling. As storage time increased the control bread continued to have the greatest increase in peak area, 4% LBG bread trailed behind, and the 2% gum bread variations had the least (Figure 19). By day 10, control bread still had the highest amount of staling as measured by peak area of the thermogram (40.64 area/mg), next 4% LBG

TABLE 5. Mean area of amylopectin peaks per mg for control (no gum), 2% LBG, 4% LBG, 2% Guar, and 4% Guar bread variations* on days 1, 2, 4, 7 and 10.

TREATMENT	DAY 1	DAY 2	DAY 4	DAY 7	DAY 10
Control	13.71	21.33	28.13	33.84	40.64a^
2% Locust	10.45	17.87	24.80	31.67	31.33d
4% Locust	13.62	20.48	26.86	32.37	38.35b
2% Guar	10.94	16.95	25.95	32.87	33.64cd
4% Guar	12.59	19.47	25.90	33.24	33.29c

*n = 2

^means with the same letter are not significantly different at $p < 0.05$.

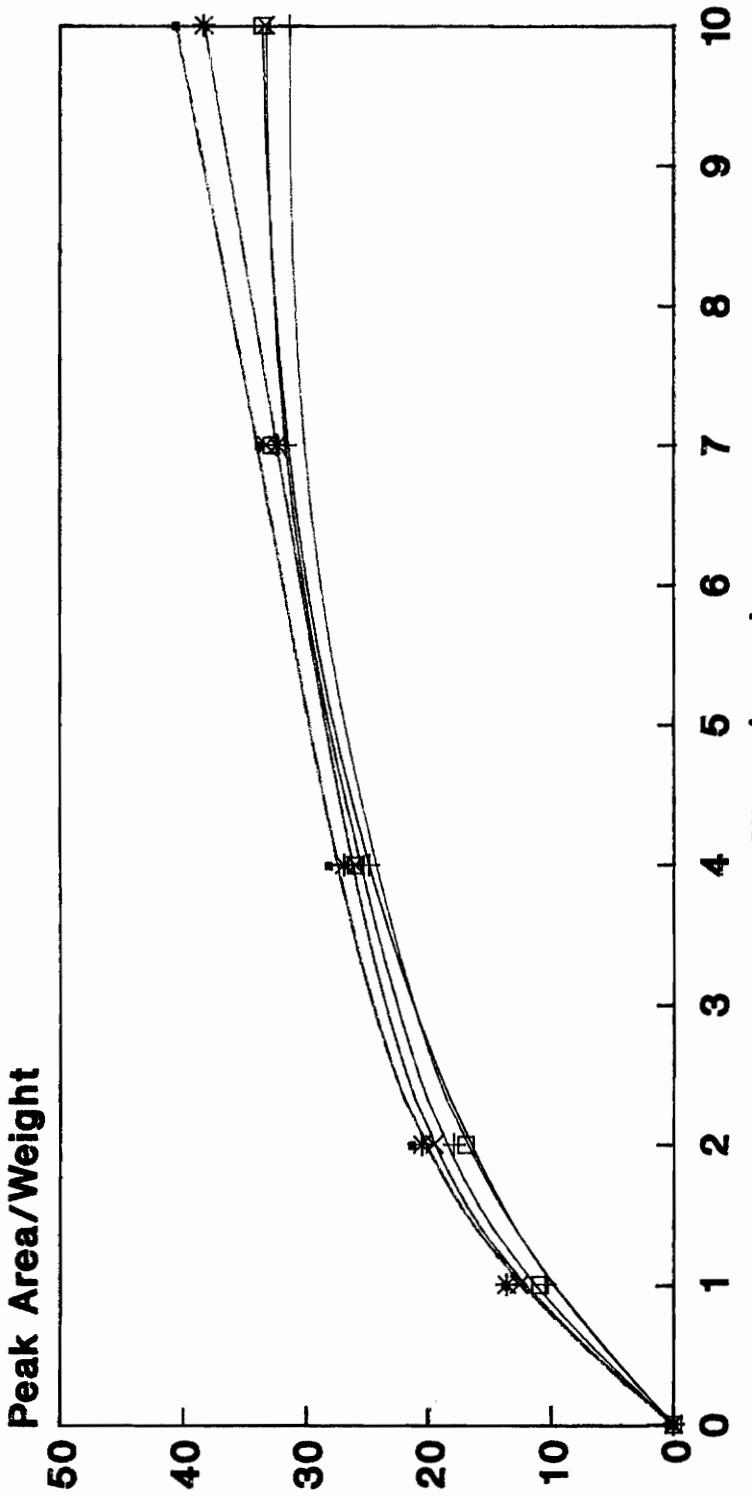


Figure 19. Mean peak area/mg for control, 2% LBG, 4% LBG, 2% Guar and 4% Guar breads on days 1, 2, 4, 7, and 10.

bread (38.35), and 2% LBG bread had the lowest (31.33), (Table 5 and Figure 19). The results indicated the following: the control bread treatment had greatest amount of staling, LBG and guar gum retarded staling, and 2% LBG replacement for all-purpose flour was the most effective in extending the shelf life of the bread product.

The gums increased or enhanced shelf life possibly by interacting with starch components of the bread through hydrogen bonding, and thus left them less available for starch recrystallization, known as retrogradation. Also, the water holding capacity of gums may have retarded bread staling by interfering with the starch-starch interactions normally associated with bread staling. Gums have been reported to give a longer shelf life in bread products, and therefore the results were consistent with other findings (Dziezak, 1991; Glicksman, 1969; Maier et al., 1993).

4.05 INSTRUMENTAL AND SENSORY AGREEMENT

Instrumental and sensory evaluation results of the control (no gum added) and 4% LBG replacement breads were compared. Both tests were in agreement for the following attributes: texture, crumb color and cell size. Seven out of 9 consumer panelists commented on the 4% LBG bread being firmer than the control bread, which was supported by analytical evaluation of texture using the Stevens Texture Analyzer. The crumb color of all bread variations was not

significantly different (see Table 1), and 5 out of 24 consumer panelists verbally commented on the likeness of the color between the two bread samples (control and 4% LBG replacement). In addition, 3 out of 24 consumers also remarked verbally that sample #780 (4% LBG bread) had more larger sized cells, which was appeared to be true when the photocopies of the control and 4% LBG breads were compared (Figure 7).

CHAPTER V

CONCLUSIONS

Conclusions for this study are as follows:

(1) Two and 4% guar gum and LBG were feasible amounts to be used as partial replacers of all-purpose flour in bread.

(2) The 2% LBG enhanced the index to volume, standing height, when incorporated into the bread product.

(3) Addition of gums produced a firmer texture. As the gum concentration increased, the firmness increased as well. The 4% guar bread treatment produced a significantly firmer texture as measured by compression.

(4) The crumb color was not significantly different for any of the bread treatments.

(5) Control bread was significantly lighter in crust color than 2% guar, 4% guar, and 4% LBG breads, but not the 2% LBG bread. Gums enhanced Maillard browning.

(6) Two percent LBG and control bread treatments were similar in having extra large cells at the top of the bread, various sized cells, and uneven distribution. However, 2% LBG bread appeared to have a greater amount of large cells. Two percent guar bread treatment had the most even cell distribution.

(7) Moisture content was not significantly different for any of the bread treatments.

(8) Consumer testing, by paired comparison and preference tests, established a significant difference between the 4% LBG and control bread treatments primarily attributed to the texture. The 4% LBG bread was preferred over the control bread, but not significantly.

(9) Sensory and instrumental results for the control (no gum) and 4% LBG breads were in agreement for texture, color, and cell size.

(10) Rapid bread staling, as suggested by increase in peak size for amylopectin, occurred at days 1 and 2 for all bread treatments. Staling was greatest for the control bread. Both gums retarded staling and 2% LBG was the most effective in extending or prolonging the shelf life of the bread product.

The purpose of this research was to determine whether all-purpose flour could be partially replaced by LBG and guar gums and produce an acceptable product. Objective and sensory evaluation indicated both gums produced bread products comparable to the control, and thus are acceptable for consumer consumption and possible use for further research.

CHAPTER VI

SUMMARY

The purpose of this research was to partially replace all-purpose flour with guar and locust bean gums, produce an acceptable bread, and evaluate the effects of both gums on the quality attributes of the bread product.

A pilot study determined 2% and 4% gum to be feasible amounts as partial replacers of all-purpose flour in a basic white bread formula used in this study. The five bread treatments consisted of no gum (control), 2% LBG, 4% LBG, 2% guar and 4% guar as partial replacers of all-purpose flour. All breads were measured objectively by standing height (cm), texture (grams per force), crumb and crust color (delta E), and cell size (photocopy). By use of a Brabender Moisture Tester, percent moisture content was determined for each bread treatment. Sensory analysis was examined by consumer testing. A paired comparison test was performed to determine if a significant difference existed between the control and 4% LBG breads. In addition, a preference test was carried out to determine a preference between the same 2 treatments. The amount of heat required to break the hydrogen cross-bonds, indicative of staling, was measured by DSC for all bread treatments. Thermograms were used to determine peak area/mg

for all breads on day 0,1,2,4,7, and 10. Peak area/mg was used as an index to measure bread staling.

Low gum levels (2%) enhanced standing height, and produced a more even cell structure with a small change in texture. Four percent gum amounts produced firmer textures, but the 4% guar made a significantly firmer bread. Crust color was darker with the addition of gums. Moisture content was similar for all bread treatments with no significant differences. Sensory evaluation confirmed a significant difference between control and 4% LBG breads, and the 4% LBG bread was preferred, although not significantly. Bread staling was retarded with the addition of gums, and 2% LBG replacement was the most effective.

Therefore, in conclusion, objective and sensory evaluation indicated that guar and locust bean gums, 2 and 4% gum treatments, produced acceptable (comparable to control variation) bread products for consumer consumption and possible use in further research.

CHAPTER VII

SUGGESTIONS FOR FURTHER RESEARCH

The partial replacement of all-purpose flour with 2% and 4% guar and locust bean gums proved to be successful in producing acceptable bread products by objective and sensory evaluation. Both gums were found to retard staling and thus extend the shelf life of the bread product.

Suggestions for further research include the following:

1) Determine optimum level of gum needed for greatest increase in standing height compared to the control.
2) Determine what effect the gums have on the dough: handling properties, elasticity, etc.
3) Further sensory analysis such as Quantitative Descriptive Analysis (QDA) to evaluate change in in quality attributes of bread products made with guar and locust bean gums.
4) Addition of mold inhibitor to bread treatments.
5) Microscopic observation of how gums interact with the starch components and
6) Incorporate 4% locust gum bread into diets of celiac patients, who are willing, to determine if LBG in a bread product produces a protective effect against gluten intolerance.

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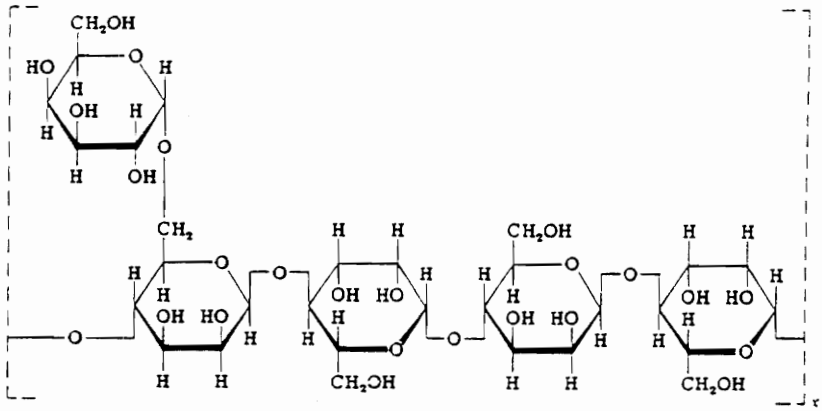
APPENDICES

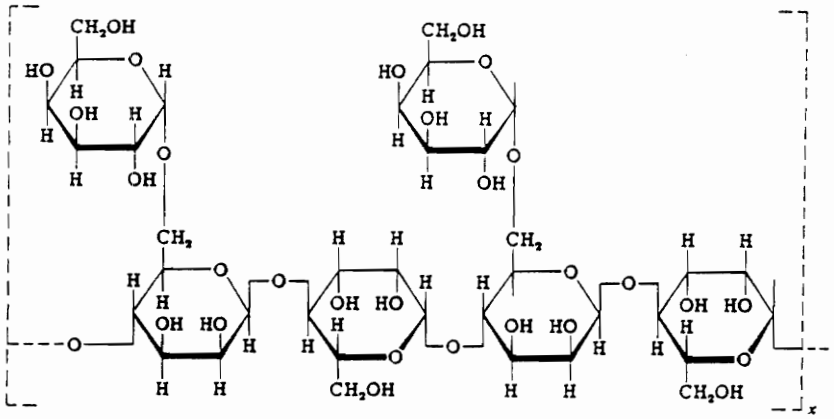
APPENDIX A

STRUCTURE OF LOCUST BEAN AND GUAR GUMS

STRUCTURE OF LOCUST BEAN AND GUAR GUMS*



LOCUST BEAN GUM



GUAR GUM

*Glicksman, M. 1969. Plant Seed Gums. In "Gum Technology in The Food Industry". Chap. 5, p. 134. Academic Press, Inc., NY.

APPENDIX B

BREAD FORMULAS

RAPID BREAD FORMULA OF CONTROL* (NO GUM), 2% AND 4% GUMS

		VARIATION	
INGREDIENT	CONTROL	2%	4%
Water	270.00 ml	270.00 ml	270.00 ml
Flour	375.00 g	367.50 g	360.00 g
Salt	6.40 g	6.40 g	6.40 g
Sugar	37.30 g	37.30 g	37.30 g
Dry Milk	7.60 g	7.60 g	7.60 g
Margarine	18.40 g	18.40 g	18.40 g
Dry Yeast	6.00 g	6.00 g	6.00 g
Gum (Guar or LBG)	0.00g	7.50 g	15.00 g

1. Attach blade to home bakery appliance bread pan.
2. Measure water into bread pan.
3. Into a mixing bowl measure: bread flour, salt, sugar, dry milk and gums. Stir and toss 20 times with a fork.
4. Add flour mixture to water in bread pan.
5. Measure and add margarine.
6. Measure and add yeast.
7. Place bread pan in bakery, close lid, plug onto outlet and program for "rapid bread", start and lock.
8. When buzzer sounds (2 hours and 50 minutes), remove bread from pan and place on cooling rack. Cool completely (at least 2 hours), then place in plastic bag or wrap with plastic wrap. Label.

* Adapted from Long (1991).

APPENDIX C

HUNTER LAB CALIBRATION AND OPERATION

HUNTERLAB COLORIMETER

Notes:

1. It is important that the standard tiles are treated with extreme care. They should be kept in the standards box when not in use. The uncalibrated white tile should be placed at the sample port during periods of nonuse, to help protect the interior of the sensor from dust.

2. Tiles should be placed shiny side toward sample port for reading.

To operate:

1. Obtain laptop computer from lab 329. (See Carolyn or Janet for the key).

2 Connect laptop. (Power supply, 2 cables from printer).

3. Connect power cord to SIU (sensor interface unit). Leave in the standby position until operations are ready to begin.

4. Turn power on to the computer, printer, and place SIU unit into the operate mode.

5. Follow the directions given by the computer: Place the black tile at the specimen port and press read <read>=F1. This will set the bottom of the scale and the following prompt will be displayed: "Zeroed" Place the white standard at the specimen port and press <read>=F1. This will set the top of the scale and the instrument will be in the measurement mode. Once the instrument is in the measurement mode read the white standard tile <read>=F1. LAB values will appear on the screen.

6. To get Delta E values: Follow steps 1-5 then press F8 (a menu of indices will appear). Press the numeric key 1. Then press the F2 key to obtain Delta E values. Delta E values should appear and white tile readings should appear in the standard and sample positions. Once this is done, place samples in the sample port and press read <read>=F1. This will give you LAB and Delta E values of samples based against the standard white tile.

7. Press F5 to print.

APPENDIX D

SENSORY SCORECARDS

Dear Consumer:

This is a sensory evaluation test being conducted for research purposes in the Department of Human Nutrition and Foods. All bread samples are made with FDA approved ingredients. Should you have any questions about this research, do not hesitate to ask.

SCORECARD

1) Please taste the 2 samples.

2) Determine if samples are the same or different.

3) Mark your response below.

_____ products same
_____ products different

Comments:

Please circle:

Male Female

Staff Student Faculty

Thank you for your participation!

Dear Consumer:

This is a sensory evaluation test being conducted for research purposes in the Department of Human Nutrition and Foods. All bread samples are made with FDA approved ingredients. Should you have any questions about this research, do not hesitate to ask.

SCORECARD

1) Please taste the product on the left first.

2) Taste the product on the right second.

3) Now that you've tasted both products, which one do you prefer? Please choose one.

_____780 _____512

Please comment on the reasons for your choice:

Please circle:

Male Female

Staff Student Faculty

APPENDIX E

SENSORY THANK YOU NOTE

Thank You!

As a consumer panelist you were terrific. Please note that your participation in this research project is of great value. Should you have any questions or concerns regarding this sensory evaluation test and/or how it was conducted please contact one of the following individuals listed below.

Sabine Schwarzlaff Principle Investigator	**552-6640** Phone
Dr. Janet Johnson Faculty	**231-6168** Phone

"HAVE A NICE DAY"

APPENDIX F

DSC PARAMETERS

Parameter	Indium Standard	Bread Samples
T Final	175	140
T Min	50	15
T Inc	15	10
T Initial	50	15
Y Range	5	5
Heating Rate	10	10
Cool Rate	320	320
Sample Wt	3.85 mg	? mg
Plot	N	N
S.A.Z.	N	N

Microprocessor Conditons
Press Set-up

Parameter	Indium Standard	Bread Sample
T Min	50	15
T Max	175	140
Heat Rate	10	10
Cool Rate	320	320
T Span	400	400

Modify Load Temp from 50 to 15 before starting bread samples.
Go to Load and Reset at the same time

Only load bread samples when the control light comes on after modification of the load temperature from 50 to 15.

APPENDIX G

OBJECTIVE RAW DATA

OBJECTIVE RESULTS

TREATMENT	TEST #	STANDING HEIGHT (cm)	TEXTURE	Δ E crumb	COLOR crust	MOISTURE (%)
Control	1	18.23	77.0	26.9	53.4	44.62
	2	17.80	98.0	24.2	49.4	45.00
	3	16.70	90.0	24.40	50.8	
Average		17.58	88.3	25.17	51.2	44.81
2% Locust	1	18.50	86.0	24.5	51.1	44.48
	2	18.97	88.5	24.9	55.0	44.66
	3	18.83	86.0	26.5	54.2	
Average		18.77	86.83	25.3	53.43	44.57
4% Locust	1	17.60	80.0	24.5	55.6	44.06
	2	17.80	108.5	26.2	56.0	44.46
	3	16.57	158.5	26.8	54.6	
Average		17.32	115.67	25.83	55.4	44.26
2% Guar	1	17.90	95.0	24.1	56.2	44.81
	2	17.77	97.0	25.8	54.9	44.64
	3	18.53	106.5	25.4	55.2	
Average		18.07	99.5	25.1	55.43	44.73
4% Guar	1	17.47	127.0	24.8	53.5	44.76
	2	16.83	150.0	24.3	55.6	44.47
	3	17.87	161.5	25.1	55.8	
Average		17.39	146.17	24.73	54.97	44.62

APPENDIX H

SENSORY RAW DATA

Sensory Results

PAIRED COMPARISON TEST

RESPONSE	NUMBER OF RESPONSES			
	Burrus		Wallace	
	Correct	Incorrect	Correct	Incorrect
Total	17	7	12	5
Gender				
Male	7	3	3	1
Female	10	4	9	4
Total	17	7	12	5
Position				
Faculty	8	4	5	2
Staff	8	3	3	3
Student	1	0	4	0
Total	17	7	12	5

Total Responses: Burrus + Wallace

Correct = 29
Incorrect = 12
Total = 41 responses

Out of 41 responses, 27 minimum correct answers are necessary to establish a significant difference. Therefore, a significant difference was found between the bread products, 4% locust bean gum and control treatments.

	Correct	Incorrect
Male	10	4
Female	19	8
Total	29	12
Faculty	13	6
Staff	11	6
Student	5	0
Total	29	12

Sensory Results

PREFERENCE TEST

NUMBER OF RESPONSES

	Burrus		Wallace	
RESPONSE	780	512	780	512
Gender				
Male	3	1	0	0
Female	12	6	4	5
Total	15	7	4	5
Position				
Faculty	1	1	1	2
Staff	14	6	1	3
Student	0	0	2	0
Total	15	7	4	5

Total Responses: Burrus + Wallace

4% locust - #780 = 19
Control - #512 = 12

Out of 31 responses, 22 miniumum agreeing judgements are necessary to establish a significant difference. So, there was **no** significant difference among preference between the two treatments. However, 19 **consumers preferred** the **4% locust** variety **(61%)**, whereas the other 12 **(39%) preferred** the **control** bread.

	780	512	Total
Male	3	1	4
Female	16	11	27
Total	19	12	31
Faculty	2	3	5
Staff	15	9	24
Student	2	0	2
Total	19	12	31

VITA

The author, Sabine Schwarzlaff, is a native of Blacksburg, Virginia, and was born in Radford, Virginia on October 12, 1957. She attended Gilbert Linkous Elementary School in Blacksburg, Virginia, and graduated from Blacksburg High School in 1976. Fall of 1976, the author began her undergraduate study at Virginia Tech, Blacksburg, Virginia in the Department of Human Nutrition and Foods, and in June 1980, received her B.S. degree in dietetics.

On October 1, 1980, the author began her career as a WIC Nutritionist for the Cumberland Plateau Health District. In 1990 she took a leave of absence for one semester from work to update her course work at Virginia Tech to become R.D. eligible once again.

July, 1991, the author moved back to Blacksburg, Virginia to begin her graduate study for a Master's degree in Foods after 11 years of work.

She is presently a Master's student and will give her thesis seminar, "GUAR AND LOCUST BEAN GUMS AS PARTIAL REPLACERS OF ALL-PURPOSE FLOUR IN BREAD: AN OBJECTIVE AND SENSORY EVALUATION" on August 6, 1993.

Sabine S Schwarzlaff