EFFECTS OF CORN BRAN ON THE QUALITY OF BAKED PRODUCTS

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CHAPTER I

INTRODUCTION

In recent years, there has been a markedly increased interest in the fiber content of foods and in the possible role of fiber in human nutrition. Fiber has long been recognized for its value in promoting regularity of bowel function by increasing both the bulk and the water content of the feces. More recent epidemiological evidence, however, suggests that fiber may be a protective factor against a variety of non-infectious diseases prevalent in Western society, including diverticular disease of the colon, ischemic heart disease, tumors of the large bowel, appendicitis, diabetes mellitus, gallbladder disease, venous disorders, hemorrhoids, and hiatus hernia (Burkitt, Walker, and Painter, 1974).

During this century, the fiber content of the Western diet has declined significantly. Fiber intake from fruits and vegetables has decreased by about 20%, while that from cereals and grains has decreased by as much as 50% (Scala, 1974). In addition, the introduction of advanced milling techniques has resulted in the production of highly refined wheat flour which contains little dietary fiber (Burkitt, Walker, and Painter, 1974).

Until the role of fiber in human nutrition is better understood, no specific recommendations for fiber intake can be developed. There is general agreement, however, that an increase in dietary fiber consumption would be beneficial. For this reason, there is a need to develop new methods of including fiber in the diet. A variety of nontraditional fiber sources are available commercially. Additional research is necessary to determine the feasibility of incorporating these high-fiber materials into food products.

Purpose and Objectives

The purpose of this research was to determine the effects of corn bran on the sensory and objective qualities of baked products. Sensory qualities included surface appearance, interior appearance, and eating characteristics. Objective qualities included tenderness, and fiber content. Specific objectives of the study were as follows:

1. To identify the effects of corn bran on the sensory and objective qualities of vanilla wafers.
2. To identify the effects of corn bran on the sensory and objective qualities of oatmeal cookies.
3. To identify the effects of corn bran on the sensory and objective qualities of wheat crackers.
4. To identify the effects of corn bran on the sensory and objective qualities of corn bread.
5. To make recommendations for future research in this field.

Hypotheses

The following hypotheses were postulated for this research:

H_1: There will be no significant differences in the individual quality characteristics of vanilla wafers when corn bran is substituted for all-purpose flour in the basic formula at levels of 0, 10, 20, and 30% by weight. The sensory quality characteristics include shape, surface color, top crust, cell distribution, cell size/shape, interior color, mouthfeel, flavor, and overall acceptability. The objective quality characteristics include tenderness and fiber content.

H_2: There will be no significant differences in the individual quality characteristics of oatmeal cookies when corn bran is substituted for all-purpose flour in the basic formula at levels of 0, 10, 20, and 30% by weight. The sensory and objective quality characteristics are the same as in H_1.

H_3: There will be no significant differences in the individual quality characteristics of wheat crackers when corn bran is substituted for whole wheat flour in the basic formula at levels of 0, 10, 20, and 30% by weight. The sensory quality characteristics include surface color, surface texture, interior texture, mouthfeel, flavor, and overall acceptability. The objective quality characteristics are the same as in H_1.

H_4: There will be no significant differences in the individual quality characteristics of corn bread when corn bran is substituted for all-purpose flour in the basic formula at levels of 0, 10, 20, and 30% by weight. The sensory quality characteristics include top crust, surface color, cell distribution, cell size/shape, crumb color, mouthfeel, flavor, and overall acceptability. The objective quality characteristics are the same as in H_1.

Assumptions

The following assumptions were made in this study:

1. The sensory evaluation panel will be trained to objectively detect and evaluate differences in each product.

2. Preparation of each product will occur in the same food research laboratory under controlled laboratory conditions.

Limitations

The following limitations were accepted in this study:

1. Only corn bran was used as a high-fiber material in this study; the corn bran was obtained from A. E. Staley Manufacturing Company, Decatur, Illinois.

2. Only four baked products were used to determine the effects of corn bran:

   a. Vanilla wafers

   b. Oatmeal cookies

   c. Wheat crackers

   d. Corn bread

Definition of Terms

The following terms were important to this research:

Crude fiber - the residue of plant food which remains after sequential extraction with solvent, dilute aqueous acid, and dilute aqueous alkali. Cellulose is the primary constituent of crude fiber (Trowell, 1976; Cummings, 1976).

Dietary fiber - the skeletal remains of plant cells which resist digestion by human gastrointestinal enzymes. It is composed primarily of non-digestible carbohydrates such as celluloses, hemicelluloses, pectic substances, gums, and mucilages, and of non-carbohydrate constituents such as lignin, plant lipids, unavailable nitrogen, and trace elements (Trowell, 1972a; Scala, 1974; Cummings, 1976).

Cellulose - a linear polymer of 1-4β-D-glucose units which forms the major structural polysaccharide in the plant cell wall (Southgate, 1976b; Eastwood, 1973).

Hemicelluloses - a mixture of linear and highly-branched polysaccharide polymers which contain various sugar residues, including xylose, arabinose, glucose, and mannose (Cummings, 1976; Eastwood, 1973).

Pectic substances - "A group of complex polysaccharides that are found in the middle lamellae, primary cell walls, and intercellular material of most plants" (Southgate, 1976b, p. 35). The principal component of this group is D-galacturonic acid.

Lignin - a complex non-carbohydrate polymer composed of phenylpropane units (Bing, 1976; Cummings, 1976).

Gums - "A complex group of highly branched uronic-acid-containing polymers, mainly of glucuronic and galacturonic acids, with neutral sugars such as xylose, arabinose, and mannose" (Cummings, 1976, p. 15).

Mucilages - a group of polysaccharides found combined with either the endosperm or the storage polysaccharides of plant seeds. They possess high water binding capacities and form reservoirs for water retention in the plant (Cummings, 1976; Eastwood, 1973).

Neutral-Detergent Fiber (NDF) - the components of the plant cell wall which are isolated by neutral-detergent solutions. The constituents of neutral-detergent fiber are cellulose, hemicellulose, and lignin. Neutral-detergent fiber appears to be the best estimate of total dietary fiber yet developed (Van Soest and Wine, 1967; Southgate, 1976a).

Acid-Detergent Fiber (ADF) - the plant cell-wall components which are isolated by acid-detergent solutions. The constituents of acid-detergent fiber are cellulose and lignin. Acid-detergent fiber provides a measure of the plant cell-wall materials indigestible by ruminant animals (Van Soest and Wine, 1967).

CHAPTER II

REVIEW OF LITERATURE

This chapter is a presentation of selected literature pertaining to the composition and physical properties of fiber, the role of fiber in health and disease, and the use of fiber in baked products.

Composition and Physical Properties of Fiber

In human nutrition, the term fiber is used to describe

> . . . a group of substances of plant origin which are found largely but not entirely in the plant cell wall and which are thought to be neither digested nor absorbed in the upper gastrointestinal tract (Cummings, 1976, p. 1).

Although there is not complete agreement regarding the specific substances which fall into this classification, the components of fiber appear to include cellulose, lignin, hemicelluloses, pectic substances, gums, mucilages, and various minor components.

The controversy surrounding the components of fiber has been further complicated by the lack of a practical and accurate procedure for analyzing the fiber content of foodstuffs. The original method of fiber analysis was developed in 1806 by Heinrich Einhof in an effort to estimate the nutritive value of animal feeds. In this method, the residue which remained after a sample had been sequentially extracted with solvent, dilute aqueous acid, and dilute alkali was called crude fiber (Van Soest and McQueen, 1973). The crude fiber method, however, is not a valid estimate of the true fiber in the human diet. Van Soest and McQueen (1973) reported that, on the average, only 50 to 80%

of the cellulose, 10 to 50% of the lignin, and 20% of the hemicelluloses are recovered after the acid and alkali sequential extraction. Consequently, the crude fiber method overestimates the proportion of fiber components which can be digested by man (Southgate, 1973). Crude fiber values reflect only one-fifth to one-half of the total fiber content of foods (Kelsay, 1978).

Despite its recognized deficiencies, the crude fiber method remains as the approved procedure of the Association of Official Analytical Chemists (AOAC) and is the basis for current nutrient labeling and advertising of fiber-containing foods (Van Soest, 1978). In addition, crude fiber values are the only index to the fiber content of foods reported in food composition tables. Although alternate methods of fiber analysis have been identified (Van Soest, 1963; Southgate, 1969; Van Soest and Wine, 1967), further research is needed to develop a suitable analytical procedure for the estimation of fiber in the human diet.

In order to establish a distinction between crude fiber and the actual indigestible matter in the human diet, Trowell (1972a, p. 138) proposed adoption of the term "dietary fiber," which he defined as "the skeletal remains of plant cells that are resistant to digestion by enzymes of man." In 1974, he expanded the scope of this term by identifying several groups of substances as components of dietary fiber. These included structural polysaccharides (celluloses, hemicelluloses, pectic substances, gums, mucilages), lignins, unavailable lipids (waxes, cutins), unavailable nitrogen, trace elements, and other unidentified substances (Trowell, 1974). Because it more accurately describes the true fiber content of foods in the human diet, the term dietary fiber is now widely used, particularly in discussions of the role of fiber in human nutrition.

The primary sources of fiber in the human diet are vegetables, fruits, wholegrain products, and nuts. The composition of dietary fiber in foodstuffs is not constant. Plant foods vary in their dietary fiber composition according to source, plant species, and physiological stage of growth (Van Soest, 1978). Consequently, the proportions of the various fiber components consumed are determined by the types and amounts of plant foods included in the diet (Southgate, 1976b). Table I shows the amounts of crude fiber, dietary fiber, and various fiber components in a selected group of foods.

TABLE I

FIBER CONTENTS (%) OF SELECTED FOODS

Food Item	Crude Fiber[a]	Dietary Fiber[b]	Cellulose[b]	Lignin[b]	Non-Cellulosic Polysaccharides[b]
Lettuce, raw	0.5	1.53	1.06	0.47	trace
Sweetcorn, cooked	0.7	4.74	0.31	0.12	4.31
Peaches, flesh and skin	0.6	2.28	0.20	0.62	1.46
Apple, flesh only	0.6	1.42	0.48	0.01	0.94
Flour, white, breadmaking	0.3	3.15	0.60	0.03	2.52
Flour, whole wheat	2.3	9.51	2.46	0.80	6.25
Peanuts	2.4	9.30	1.69	1.21	6.40

[a]U.S. Department of Agriculture, 1963.

[b]Southgate and Van Soest, 1978.

The physical properties which are generally attributed to fiber include bulk density, hydration capacity, cation exchange properties, and binding properties (Van Soest, 1978; Eastwood and Mitchell, 1976). Because dietary fiber is not a single substance of constant composition, these properties are, in fact, functions of its various components.

Cellulose is the major structural polysaccharide in the cell walls of plant tissues (Southgate, 1976b). One of the important properties ascribed to cellulose is the ability to absorb water. In the gastrointestinal tract, cellulose absorbs water, and thus increases stool bulk and weight. A bulkier stool is more easily propelled through the bowel, and regularity of bowel function is subsequently improved (Bing, 1976; Eastwood, 1974). Celluloses may differ in their abilities to induce bulk (Bing, 1976).

The hemicelluloses are a large group of polysaccharide polymers which, in conjunction with pectin, form the plant cell-wall matrix (Cummings, 1976). The hemicelluloses possess three physical properties which may be nutritionally significant: hydration capacity, ion binding capacity, and digestibility (Cummings, 1976). The hemicelluloses are digested to varying extents in the human gastrointestinal tract. As there are no enzymes capable of hemicellulose hydrolysis in the human gut, this digestion must occur as a result of bacterial fermentation. Holloway, Tasman-Jones, and Bell (1980) reported that as much as 97% of the hemicellulose component of dietary fiber may be digested.

Lignin is a highly insoluble non-carbohydrate substance which contributes to plant structure. It appears that lignin is present in the plant cell wall in smaller amounts than other plant polysaccharides (Cummings, 1976). It may also be more resistant to enzymatic digestion than other fiber components (Southgate, 1976b). Lignin possesses cation exchange properties. In the gastrointestinal tract, lignin has the ability to combine with organic materials such as free bile acids. When this occurs, these insoluble complexes cannot be absorbed and are excreted in the feces (Bing, 1976; Eastwood, 1974). This may promote transformation of liver cholesterol into new bile acids, resulting in reduced serum cholesterol levels and decreased probability of the development of gallstones or cardiovascular disease (Bing, 1976).

The pectic substances (pectin, pectic acid, and pectinic acid) are a group of complex polysaccharides found in the cell walls and intercellular layers of plant cells. Citrus fruit rinds and apples provide significant amounts of pectic substances in the human diet. The physical properties of these substances include the ability to form gels, cation exchange capacity, and digestibility. Another property which may have great nutritional significance is the ability to alter cholesterol metabolism. Various studies have reported that the administration of pectin supplements results in a reduction in serum cholesterol levels in man (Keys, Grande, and Anderson, 1961; Jenkins, Leeds, Newton, and Cummings, 1975; Jenkins, Reynolds, Leeds, Waller, and Cummings, 1979).

Plant gums and mucilages comprise a heterogeneous group of complex polysaccharides which are similar to the cell wall constituents in terms of biochemical and physical properties (Cummings, 1976; Southgate, 1976b). Like the pectic substances, these polysaccharides have the capacity to alter cholesterol metabolism. Studies have shown that guar gum significantly reduces serum cholesterol levels in human subjects (Fahrenbach, Riccardi, Saunders, Lourie, and Helder, 1965; Jenkins et al., 1975; Jenkins et al., 1979).

Role of Fiber in Health and Disease

For many years, human nutritionists considered fiber to be an unimportant component of the diet. The only recognized value of fiber was the relief of constipation and subsequent promotion of regular bowel function. In recent years, however, the role of fiber in health and disease has become a controversial topic in the field of nutrition.

Much of the recent interest in fiber is the result of epidemiological evidence associating low fiber intake with various diseases. While studying the geographical distribution of diseases, British investigators observed that certain diseases prevalent in Western populations were extremely rare in the developing countries of Africa. Because the typical Western diet has a low dietary fiber content, and the rural African diet contains much fiber, the investigators hypothesized that a deficiency of fiber in the diet may be a contributory factor in the etiology of these diseases (Painter, 1969; Burkitt, 1969; Painter and Burkitt, 1971; Burkitt, 1977).

Diverticular disease of the colon was largely unknown at the turn of this century; however, it is currently the most common colonic disorder in Western countries (Painter and Burkitt, 1971). The disease is characterized by small herniations in the intestinal mucosa which can fill with fecal matter and become infected. The development of diverticuli has been attributed to the increased intracolonic pressure required for movement of the small, firm stools which accompany a low-fiber diet (Painter, 1969; Painter and Burkitt, 1971). Bran supplementation has been effective in reducing intracolonic pressures and relieving symptoms in patients with diverticular disease (Painter and Burkitt, 1971; Painter, Almeida, and Colebourne, 1972; Brodribb and Humphreys, 1976).

Like diverticular disease, cancer of the colon and rectum is extremely rare in rural Africa. In Western Europe and North America, however, it is second only to lung cancer as the most common cause of cancer deaths (Burkitt, 1973). The environment of the colonic mucosa is determined by the content of the diet, particularly by the indigestible component. There is evidence that bile salts and other fecal constituents are degraded by colonic bacteria to form potential carcinogens (Burkitt, 1973). On a low-fiber diet, the increased transit time of the small fecal mass would provide additional time for degradation of fecal constituents. In addition, carcinogens would be exposed to colonic mucosa in concentrated forms for prolonged time periods. Dietary fiber functions to increase the water content and decrease the transit time of the feces; therefore, any carcinogenic substances might be diluted, and the exposure time of carcinogens to colonic mucosa would be reduced. It is also possible that dietary fiber alters the types and numbers of intestinal flora and thus inhibits carcinogen formation (Burkitt, 1971).

One of the major risk factors in the development of cardiovascular disease is the elevation of serum cholesterol levels. Research with both human and animal subjects has indicated that different types and components of dietary fiber can reduce serum cholesterol levels

(Keys et al., 1961; deGroot, Luyken, and Pikaar, 1963; Fahrenbach et al., 1965; Leveille and Sauberlich, 1966; Jenkins et al., 1975; Jenkins et al., 1979). The mechanism by which fiber exerts its hypocholesterolemic effects is not fully understood, and it appears that the mechanisms may differ between specific dietary fiber components. Three principal mechanisms have been proposed: alteration of intestinal absorption, metabolism, and release of cholesterol; alteration of hepatic metabolism and release of cholesterol; or alteration of peripheral metabolism of lipoproteins (Anderson and Chen, 1979). One theory suggests that certain dietary fiber components bind bile acids in the intestine and prevent their reabsorption. This reduces the bile acid pool, resulting in increased conversion of cholesterol to bile acids and a subsequent reduction of serum cholesterol levels. Therefore, a high-fiber diet may be a protective factor against the development of cardiovascular disease (Trowell, 1972b).

Dietary fiber has recently been advocated in the management of diabetes. Brodribb and Humphreys (1976) reported that oral glucose tolerance curves were lowered in diverticular disease patients receiving wheat bran supplements. The addition of guar and pectin to the diets of diabetic patients has produced significant reductions in postprandial plasma glucose and insulin levels (Jenkins, Leeds, Wolever, Goff, Alberti, Gassull, and Hockaday, 1976). Other studies have reported that high-carbohydrate, high-plant fiber diets may be beneficial in lowering postprandial glucose levels and insulin requirements in certain diabetic patients (Kiehm, Anderson, and Ward, 1976; Anderson and Ward, 1979). The specific mechanism by which dietary fiber alters carbohydrate absorption and/or metabolism has not been identified. It appears that the presence of dietary fiber in the gastrointestinal tract may slow carbohydrate absorption (Anderson and Chen, 1979).

There is some evidence to suggest that a high-fiber diet may be a beneficial tool in weight reduction. Mickelsen, Makdani, Cotton, Titcomb, Colmey, and Gatty (1979) reported that overweight college-age males consuming large amounts of reduced-calorie, high-fiber bread achieved significantly greater weight losses than those consuming enriched white bread. The researchers theorized that increased fiber consumption may promote a greater feeling of satiety and subsequently reduce food intake. It has also been reported that a high dietary fiber intake may reduce the apparent digestibility of energy (Southgate, 1973).

Use of Fiber in Baked Products

The increased attention which has been focused upon the role of fiber in health and disease has prompted researchers to investigate new methods of incorporating fiber into the diet. Approximately 80% of the flours and cereal products consumed in the United States are provided by wheat products, and these products comprise approximately 37% of the total carbohydrate in the diet (USDA, 1964). The dietary fiber content of wheat flour, however, is greatly reduced during the milling process. For these reasons, the substitution of high-fiber materials for a portion of the wheat flour in baked products would seem to be a feasible method of increasing dietary fiber consumption.

In recent years, a number of studies have been conducted to determine the feasibility of incorporating different types and levels of high-fiber materials into baked products. Several studies have investigated the use of commercially available cellulose and coated-cellulose products as dietary fiber sources. Pomeranz, Shogren, Finney, and Bechtel (1977) reported that acceptable bread was produced when several types of cellulose and coated-cellulose products were substituted for flour at levels of up to 7%. At substitution levels greater than 7%, mixing time, water absorption, and loaf volume were adversely affected. Several of the same cellulose products have been incorporated into white layer cakes (Zabik, Shafer, and Kukorowski, 1977) and sugar-snap cookies (Gorczyca and Zabik, 1979). Cakes in which 30% of the flour had been replaced with different types of cellulose or carboxymethylcellulose-coated cellulose were of high quality. Cakes prepared with pectin-coated cellulose, however, had decreased volumes and were of poor quality. Sugar-snap cookies of good quality were produced when 10% of the flour was replaced with each of the cellulose products. A comparison of the effects of different cellulose products at the 10% level of substitution showed some differences in physical parameters but no difference in sensory scores.

Cellulose has also been studied with regard to its applications as a metabolically inert bulking agent in foods. When cellulose is substituted for a portion of the flour in baked products, the caloric densities of the products are decreased, and the fiber contents are increased. Lee, Rust, and Reber (1969) and Brys and Zabik (1976) have demonstrated that microcrystalline cellulose can be incorporated into muffins, cookies, cakes, and biscuits with acceptable results.

Other studies have investigated the use of different varieties and levels of wheat bran as dietary fiber sources. Brockmole and

Zabik (1976) demonstrated that wheat bran and middlings could be successfully incorporated into white layer cakes. Cake volume was decreased only in cakes containing 12% bleached middlings. The incorporation of soft red wheat bran into white layer cakes at levels of up to 70% was investigated by Springsteen, Zabik, and Shafer (1977). Acceptable cakes were produced when wheat bran was substituted for 30% of the flour; however, higher substitution levels produced significantly decreased cake volumes and sensory scores. The researchers also reported that fineness of bran grind appears to be important in the successful incorporation of wheat bran into cake systems. The substitution of wheat bran for flour at levels of 10, 20, and 30% in a chiffon cake formula altered quality characteristics but did not adversely affect flavor or overall acceptability (Smith and Hawrysh, 1978). The effects of different varieties of wheat bran and of brans from other cereal grains on the quality of layer cakes were studied by Shafer and Zabik (1978). Brans from soft red wheat, soft white wheat, hard red wheat, commercial wheat, corn, soy, and oats were incorporated into layer cakes at the 30% level of substitution. All varieties of wheat bran produced acceptable results, as did corn bran. However, cakes prepared with oat bran and soy bran were unacceptable, due to low flavor scores.

Vratanina and Zabik (1978) investigated the possibility of producing high-fiber cookies by incorporating soft red and soft white wheat brans into sugar-snap cookies at substitution levels of 10, 20, and 30%. Flavor was adversely affected at the 30% level of substitution. Sensory data showed that bran affected only surface and interior color at the 10 and 20% substitution levels. On the basis of these results, the researchers concluded that bran substitution at the 10 and 20% levels was feasible. A subsequent study by the same researchers tested the theory that a flavored cookie could be substituted with higher levels of bran than a plain cookie, as the flavorings would mask the bran flavor. Results showed that oatmeal cookies in which 50% of the flour had been replaced with soft red and soft white wheat brans were well accepted by a consumer panel (Vratanina and Zabik, 1980).

Recent studies have identified several nontraditional plant fibers which have useful applications as dietary fiber sources. Oilseed flours have been incorporated into a variety of baked products to increase the protein contents of these products. These flours also contain significant amounts of crude fiber. Acceptable results were reported when soy flour (Sproul, 1975) and peanut flour (Sproul, 1975; Kuo, 1980; Melouk, 1981) were incorporated into muffins, cookies, butterscotch bars, and applesauce cake. Melouk demonstrated that both asparagus fiber and beet fiber could be substituted for 7% of the flour in orange drop cookies with acceptable results.

Brewer's spent grain, a principal by-product of the brewing industry, has also been investigated as a dietary fiber source in baked products. It is composed of the husk, bran, and embryo residues of the malt kernel and contains significant amounts of both protein and fiber (Prentice, Kissell, Lindsay, and Yamazaki, 1978; Prentice and D'Appolonia, 1977). Prentice and D'Appolonia (1977) reported acceptable results in consumer panel evaluation when brewer's spent grain was substituted for 5 to 10% of the flour in bread. At the 10% level of substitution, the crude fiber and acid-detergent fiber (ADF) contents were approximately doubled. Consumer panels also accepted sugar and specialty cookies prepared with brewer's spent grain at substitution levels of 15%. This corresponded to a fourfold increase in crude fiber and a threefold increase in dietary fiber (Prentice et al., 1978).

CHAPTER III

RESEARCH METHOD

The purpose of this study was to determine the effects of corn bran on the sensory and objective qualities of vanilla wafers, oatmeal cookies, wheat crackers, and corn bread, when substituted for wheat flour at levels of 10, 20, and 30%. The research design, data collection, and data analyses are outlined in this chapter.

Research Design

Experimental research was conducted to test the hypotheses of this study. In this type of research, the researcher deliberately and systematically manipulates the independent variable(s) under carefully controlled conditions and observes any subsequent changes in the dependent variable(s) (Best, 1981). In this study, the independent variable was the level of corn bran substitution. The dependent variables were the sensory and objective qualities of the four baked products. The conditions which were controlled with regard to product preparation included product ingredients, preparation procedures, preparation equipment, oven type, oven temperature, and baking time. The conditions which were controlled with regard to sensory evaluation included location, time of day, lighting, seating arrangement, and privacy in sample evaluation. Sensory evaluation of the products was performed by a trained sensory evaluation panel. Objective evaluations included tenderness and fiber content. Statistical analyses of the data were performed using the Friedman Test for Rank Analysis, Analysis of Variance, and a Duncan's Multiple range test.

Data Collection

Materials and Equipment

In the standard formula for each baked product, corn bran was substituted for wheat flour at levels of 0, 10, 20, and 30%, based on the weight of the flour. In the formula for vanilla wafers, oatmeal cookies, and corn bread, corn bran was substituted for all-purpose flour. In the formula for wheat crackers, corn bran was substituted for whole wheat flour.

Refined Corn Bran, Particle Size G-Fine, was obtained from the A. E. Staley Manufacturing Company, Decatur, Illinois. (The manufacturer's analysis of this product is presented in Table XVII in Appendix A.) The fiber analysis of this product is presented in Table II. All other ingredients were obtained from a local supermarket.

Major pieces of equipment used in this research included an electronic top-loading precision balance (Mettler PC4400, Delta Range), an electric mixer (Kitchen Aid, Model K45), an Atlas Noodle Maker Machine (Markato, Model 150 Lusso), an institutional deck oven (General Electric, Model CN50), an upright institutional refrigerator and freezer for ingredient storage, an Instron Universal Testing Instrument (Model 1122), and a Li-Cor Area Meter (Lambda Instrument Corp., Model LI-3100).

TABLE II

FIBER ANALYSIS OF CORN BRAN[a]

Fiber Component	Amount (%)
Neutral-Detergent Fiber (NDF)[b]	84.51
Acid-Detergent Fiber (ADF)[c]	21.19
Hemicellulose	63.32
Cellulose	20.68
Lignin	0.51

[a]Analyses were conducted at the Animal Sciences and Industry Nutrition Laboratory, Oklahoma State University.

[b]Composed of hemicellulose, cellulose, and lignin (Van Soest and Wine, 1967).

[c]Composed of cellulose and lignin (Van Soest and Wine, 1967).

Preliminary Product Development

Shafer and Zabik (1978) demonstrated the feasibility of increasing the fiber content of layer cakes by substituting corn bran for a portion of the flour. In order to expand the potential applications of corn bran substitution in baked products, four different baked products were chosen for this research. These products were vanilla wafers, oatmeal cookies, wheat crackers, and corn bread. Two cookie formulae were used, based on recommendations by Vratanina and Zabik (1980) and Melouk (1981) that a flavored cookie such as the oatmeal cookie may be a more feasible dietary fiber carrier than a bland cookie.

During preliminary experimentation, a standard formula for each baked product was chosen on the basis of flavor, baking quality, appearance, and suitability for corn bran incorporation. Ingredient measurements were converted to metric equivalents, and preparation procedures were standardized (see Tables XVIII, XIX, XX, and XXI in Appendix C). The corn bran substitution levels to be used in each product were determined on the basis of overall acceptability.

It was necessary to make some modifications in the original formulae. In the oatmeal cookie formula, raisins and nuts were omitted, and the amount of ground cloves was reduced from 1.9 grams to 1.0 grams. The wheat cracker formula was adapted for use in a conventional oven from a formula designed for use in a microwave oven. Vegetable shortening was used in place of margarine, and the amount of shortening was reduced from 84 grams to 56 grams. In order to achieve optimal product thickness, a noodle maker machine was used to roll the dough. The amount of water was increased to 63, 76, and 89 milliliters for corn bran substitution levels of 10, 20, and 30%, respectively, in order to improve dough handling.

Instrumentation

Based upon the examination of sensory evaluation instruments used in previous food product research, an instrument was developed to meet the specific objectives of this study (Appendix B). The instrument measured sensory quality characteristics in each of three categories: surface appearance, interior appearance, and eating characteristics. The individual sensory quality characteristics within the surface appearance and interior appearance categories varied slightly between products; however, the basic instrument was the same for all products.

The sensory test method used in the instrument was rank order. Ranking simplifies the work of the taste panel members, allows comparison of several samples at one time, and eliminates errors caused by the different scoring levels used by different taste panel members (Carlin and Harrison, 1978). The instrument was evaluated and approved by members of the Food, Nutrition and Institution Administration and Statistics graduate faculties.

Sensory Evaluation Panel Selection and Training

In this study, a trained sensory evaluation panel was used to measure differences in the sensory quality characteristics of baked products prepared with four substitution levels of corn bran. The sensory evaluation panel consisted of 11 panelists: nine females and two males. Panelists included university faculty, staff, and graduate students.

Screening and training sessions were conducted prior to the actual experiment, as recommended by Amerine, Pangborn, and Roessler, (1965) and Campbell, Penfield, and Griswold (1979). During a preliminary screening session, panelists were tested on their ability to recognize the four basic tastes (sweet, salty, sour, and bitter), identify 10 common odors, and differentiate between oatmeal cookie samples in a triangle test. All panelists completed these tests successfully. The purpose of the training session was threefold: to familiarize panelists with the quality criteria for each standard product, to develop a common understanding of terminology among the panelists, and to instruct panelists on the use of the sensory evaluation instrument. Each panelist received a list of the quality criteria for each standard product (Appendix B). These criteria were discussed as the panelists examined and tasted samples of each standard product. These lists were also posted in the sensory evaluation booths for reference during evaluation sessions. Written instructions for use of the sensory evaluation instrument were given to each panelist, and the instructions were discussed (Appendix B).

Experimental Procedures

Vanila Wafers. One day before preparation of the cookies for sensory evaluation, appropriate amounts of flour or flour-plus-corn bran for each of the four substitution levels were weighed. Each of the four portions was sifted twice, sealed in an airtight plastic container, and placed in the refrigerator for storage until preparation time.

On the morning of the sensory evaluation session, sufficient ingredients for four portions of the creamed mass were weighed together. Butter, shortening, and sugar were creamed together for six minutes on Speed 6 of the Kitchen Aid Mixer. Vanilla and salt were added, and the mixture was creamed for one additional minute at the same speed. Egg was added, and the mixture was beaten for three minutes on the same speed. Four portions of the creamed mass, each weighing 236.2 grams, were transferred to four glass mixing bowls. After being brought to room temperature, each of the individual flour mixtures was stirred into a portion of the creamed mixture. This was done using 60 hand strokes, rotating the bowl one quarter-turn after every

15 strokes. Using a #70 food server, the mixture in each bowl was portioned onto two 15 x 10 x 1 inch ungreased aluminum baking sheets. The cookies were then flattened to uniform size using the bottom of a glass (two inches in diameter) which had been sprayed with non-stick vegetable spray. Each batch of cookies (two baking sheets), representing one level of corn bran substitution, was baked in a preheated 375° F oven for 10 minutes. After baking, the cookies were removed immediately from the baking sheets and cooled on wire racks.

The formula for vanilla wafers provided sufficient dough for 34 cookies measuring approximately five centimeters in diameter. For the purposes of this study, however, only 30 cookies were baked.

Oatmeal Cookies. One day before preparation of the cookies for sensory evaluation, appropriate amounts of flour or flour-plus-corn bran, baking soda, and spices for each of the four substitution levels were weighed. Each of the four portions was sifted twice, sealed in an airtight plastic container, and placed in the refrigerator for storage until preparation time. Four portions of uncooked oats were also weighed, sealed in plastic bags, and placed in the refrigerator.

On the morning of the sensory evaluation session, sufficient shortening, sugars, egg, water, and vanilla for four portions of the creamed mass were weighed together. These ingredients were creamed together for one minute on Speed 4 and five minutes on Speed 6 of the Kitchen Aid Mixer. Four portions of the creamed mass, each weighing 299.0 grams, were transferred to four glass mixing bowls. After being brought to room temperature, each of the individual flour mixtures plus one portion of the uncooked oats was stirred into a portion of the creamed mixture. This was done using 60 hand strokes, rotating the bowl one quarter-turn after every 15 strokes. Using a #70 food server, the mixture in each bowl was portioned onto two 15 x 10 x 1 inch aluminum baking sheets which had been sprayed with non-stick vegetable spray. Each batch of cookies (two baking sheets), representing one level of corn bran substitution, was baked in a pre-heated 375°F oven for 11 minutes. After baking, the cookies were re-moved immediately from the baking sheets and cooled on wire racks.

The formula for oatmeal cookies provided sufficient dough for 41 cookies measuring approximately five centimeters in diameter. For the purposes of this study, however, only 30 cookies were baked.

Wheat Crackers. One day before preparation of the crackers for sensory evaluation, appropriate amounts of flour or flour-plus-corn bran and salt for each of the four substitution levels were weighed. Each of the four portions was sifted twice, sealed in an airtight plastic container, and placed in the refrigerator for storage until preparation time.

On the morning of the sensory evaluation session, the four indi-vidual flour mixtures were brought to room temperature and transferred to four glass mixing bowls. Four single portions of shortening were weighed, and each was placed in one of the mixing bowls. For each corn bran substitution level, the shortening was cut into the flour mixture for two minutes, using a standard pastry blender. The appro-priate amount of water was measured and sprinkled over the flour-shortening mixture, and the dough was stirred with a fork for one minute. The dough was then formed into a ball and divided into four equal portions. Each portion was rolled between the rollers of a noodle maker machine, as described in the preparation procedures (Appendix C). The sheets of dough were laid on a cutting board and cut into uniform pieces using a round cutter (two inches in diameter). The crackers were then transferred to a 15 x 10 x 1 inch ungreased aluminum baking sheet and pricked twice with the tines of a fork. Each batch of crackers (one baking sheet), representing one level of corn bran substitution, was baked in a preheated 375°F oven for 12 minutes. After baking, the crackers were cooled on wire racks.

The formula for wheat crackers provided sufficient dough for 43 crackers. For the purposes of this study, however, only 20 crackers were baked.

Corn Bread. One day before preparation of the corn bread for sensory evaluation, appropriate amounts of flour or flour-plus-corn bran, corn meal, sugar, salt, and baking powder for each of the four substitution levels were weighed. Each of the four portions was sifted twice, sealed in an airtight plastic container, and placed in the refrigerator for storage until preparation time.

On the morning of the sensory evaluation session, the four individual flour mixtures were brought to room temperature and transferred to four glass mixing bowls. For each corn bran substitution level, a single portion of milk, egg, and oil was measured. These ingredients were combined in a small bowl and stirred with a fork until well blended. This liquid mixture was added all at once to one of the flour mixtures and stirred 20 hand strokes, rotating the bowl one quarter-turn after every five strokes. The batter was then poured into an 8 x 8 x 2 inch square aluminum cake pan which had been sprayed with non-stick vegetable spray. Each batch of corn bread (one pan), representing one level of corn bran substitution, was baked in a preheated 400°F oven for 20 minutes. After baking, the loaf was cooled in the pan for several minutes and then removed and cooled on a wire rack. After trimming off the outside edges, the loaf was cut into 25 uniform squares, each measuring 1-1/2 x 1-1/2 inches.

Sensory Evaluation. The sensory evaluation panel convened at 11:00 a.m. for three days to evaluate each type of baked product. Three replications of one product were completed before evaluation of the next product began. Products were evaluated in the following order: vanilla wafers, oatmeal cookies, wheat crackers, and corn bread. Evaluation sessions took place in a sensory evaluation room adjacent to the food research laboratory. The room was equipped with separate carrels and received proper illumination and ventilation.

At each session, panelists received four coded samples of the product, representing the four corn bran substitution levels. Samples were presented to the panelists on white plates in a random arrangement. The computer was utilized to develop a system of random arrangement for sample presentation (Table III). Distilled water was provided for rinsing the mouth between samples. Panelists were asked to rank the samples against each other on a scale of 1 to 4 for each sensory characteristic. The number 1 was assigned to the sample which most closely matched the criteria for that product, while the number 4 was assigned to the sample which least closely matched the criteria. No ties were allowed.

TABLE III

EXAMPLE OF RANDOM ARRANGEMENT IN THE ORDER OF SAMPLE PRESENTATION TO SENSORY EVALUATION PANELISTS

Panelist No.	Order of Sample Presentation (% Corn Bran Substitution)			
1	0	20	30	10
2	30	0	10	20
3	10	20	0	30
4	30	0	20	10
5	10	0	20	30
6	20	0	10	30
7	10	0	30	20
8	20	10	0	30
9	0	30	10	20
10	30	0	10	20
11	0	10	20	30

Objective Evaluation. After each evaluation session, remaining product samples were sealed in plastic bags and frozen. One week later, the samples were thawed, and two samples from each substitution level at each evaluation session were randomly chosen for objective evaluation. Thus, tenderness evaluations were performed for each baked product during the week following its sensory evaluation. The Instron Universal Testing Instrument (Model 1122) was used to measure tenderness by shear force (kg/g) in each product. The Warner-Bratzler shear cell was used on the corn bread samples, while the Kramer shear cell was used on all other product samples. For vanilla wafer and corn bread samples, a scale load setting of 10 was used, and a scale load setting of 20 was used for oatmeal cookie and wheat cracker samples. A Li-Cor Area Meter (Model 3100) was used to determine tenderness by measuring the area under the peak (cm^2/g). Fiber contents of the products were also calculated.

Data Analyses

The Statistical Analysis System (SAS) (Barr and Goodnight, 1972) was employed for data analyses. In the analysis of the sensory evaluation data, the Friedman Test for Rank Analysis (Conover, 1980) was used to determine any significant differences between treatments. In the analysis of the objective evaluation data, Analysis of Variance (ANOVA) and a Duncan's Multiple range test (Snedecor and Cochran, 1973) were used to determine the location of significant differences.

CHAPTER IV

RESULTS AND DISCUSSION

Corn bran was incorporated into four baked products in order to increase the fiber contents of the products while maintaining acceptable organoleptic characteristics. The sensory characteristics of the products were evaluated by an 11-member trained attribute panel. Objective evaluations included tenderness by shear force (kg/g) and by measurement of the area under the peak (cm^2/g), and fiber content calculations. This chapter presents the data analyses to determine whether there were differences between the sensory and objective qualities of products incorporating corn bran and those without corn bran.

Sensory Evaluation

In each baked product, individual sensory quality characteristics in the categories of surface appearance, interior appearance, and eating characteristics were evaluated by means of ranking. Statistical analysis of the data was performed using the Friedman Test for Rank Analysis (Conover, 1980).

Vanilla Wafers

Results of the analysis of sensory evaluation data for vanilla wafers are presented in Table IV. The substitution of corn bran for

TABLE IV

MEAN RANKS AND CHI-SQUARE VALUES OF SENSORY EVALUATIONS[a] OF VANILLA WAFERS PREPARED WITH FOUR LEVELS OF CORN BRAN

	Mean Ranks[b]								
	Surface Appearance			Interior Appearance			Eating Characteristics		
Corn Bran Level	Shape	Surface Color	Top Crust	Cell Distribution	Cell Size/ Shape	Interior Color	Mouthfeel	Flavor	Overall Acceptability
0	1.50	1.41	1.59	1.63	1.56	1.31	1.66	1.50	1.47
10	2.16	1.97	2.06	2.09	2.19	1.94	1.81	1.78	1.84
20	3.03	3.00	3.13	2.75	2.81	2.97	2.69	2.97	2.88
30	3.31	3.63	3.22	3.53	3.44	3.78	3.84	3.75	3.81
X^2[c]	39.56	57.49	36.86	39.49	37.50	68.89	58.09	63.34	64.46
p	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001

[a]Mean ranks and chi-square values for three replications.

[b]Means for ranking values of 1, 2, 3, and 4 where 1 is closest to the criteria for the standard product and 4 is furthest from the criteria.

[c]Friedman chi-square value with df = 3.

all-purpose flour at levels of 10, 20, and 30% significantly ($p<0.05$) affected all sensory characteristics of this product, including shape, surface color, top crust, cell distribution, cell size/shape, interior color, mouthfeel, flavor, and overall acceptability. The mean ranks of each substitution level showed that all sensory characteristics decreased significantly as the level of corn bran substitution was increased (Table IV). Despite these results, the panelists commented that vanilla wafers at all substitution levels were acceptable. Although some panelists described the cookies at the 20 and 30% levels as having a dense, powdery mouthfeel and more pronounced corn flavor, most did not indicate that this was unpalatable.

Oatmeal Cookies

Results of the analysis of sensory evaluation data for oatmeal cookies are presented in Table V. In the surface appearance category, significant ($p<0.05$) differences between corn bran substitution levels were noted in the characteristics of shape and surface color; however, no significant difference due to corn bran substitution level was found in the top crust characteristic. The individual interior appearance characteristics of cell distribution and cell size/shape were not significantly ($p<0.05$) affected by corn bran substitution levels. Within this category, a significant ($p<0.05$) difference between substitution levels was identified only with regard to interior color. Data analysis indicated that mouthfeel was significantly ($p<0.05$) affected by level of corn bran substitution. No significant ($p<0.05$) differences due to corn bran level were noted in the other individual eating characteristics of flavor and overall acceptability;

TABLE V

MEAN RANKS AND CHI-SQUARE VALUES OF SENSORY EVALUATIONS[a] OF OATMEAL COOKIES PREPARED WITH FOUR LEVELS OF CORN BRAN

	Mean Ranks[b]								
	Surface Appearance			Interior Appearance			Eating Characteristics		
Corn Bran Level	Shape	Surface Color	Top Crust	Cell Distri-bution	Cell Size/ Shape	Interior Color	Mouthfeel	Flavor	Overall Acceptability
0	2.97	3.06	2.58	2.79	2.91	3.24	3.12	2.91	2.94
10	2.39	2.73	2.15	2.48	2.24	2.64	2.33	2.64	2.48
20	1.91	2.06	2.42	2.21	2.21	1.94	2.21	2.06	2.18
30	2.73	2.15	2.85	2.52	2.64	2.18	2.33	2.39	2.39
χ^{2c}	12.53	13.47	5.04	3.29	6.64	19.51	10.38	7.73	6.05
p	.0058	.0037	.1692	.3489	.0844	.0002	.0156	.0520	.1090

[a]Mean ranks and chi-square values for three replications.

[b]Means for ranking values of 1, 2, 3, and 4 where 1 is closest to the criteria for the standard product and 4 is furthest from the criteria.

[c]Friedman chi-square value with df = 3.

however, flavor was affected at a significance level very close to 0.05. In oatmeal cookies, all corn bran substitution levels were very well accepted by the panelists. Many commented that the oatmeal and spices in the cookies made it difficult to differentiate between the levels. The cookies prepared with 20 percent of the all-purpose flour substituted with corn bran received mean ranks closest to the standard criteria in all sensory characteristics except top crust.

Wheat Crackers

Results of the analysis of sensory evaluation data for wheat crackers are presented in Table VI. In the individual surface appearance characteristics of surface color and surface texture, the differences due to corn bran level were significant ($p \leq 0.05$). Interior texture was also significantly ($p<0.05$) affected at all corn bran substitution levels. Data analysis revealed that there were no significant ($p<0.05$) differences between corn bran substitution levels with regard to the three individual eating characteristics: mouthfeel, flavor, and overall acceptability. The crackers prepared with 10 percent corn bran substitution had mean ranks closest to the standard criteria in surface texture and flavor, while crackers at the 20 percent substitution level had mean ranks closest to the standard criteria in surface color and mouthfeel. The crackers prepared with 30 percent of the whole wheat flour substituted with corn bran received a mean rank closest to the standard criteria for overall acceptability. Panelist comments indicated that acceptable wheat crackers were produced at all levels of corn bran substitution, and that texture differences between the substitution levels were difficult to identify.

TABLE VI

MEAN RANKS AND CHI-SQUARE VALUES OF SENSORY EVALUATIONS[a] OF WHEAT CRACKERS PREPARED WITH FOUR LEVELS OF CORN BRAN

	Mean Ranks[b]					
	Surface Appearance		Interior Appearance	Eating Characteristics		
Corn Bran Level	Surface Color	Surface Texture	Interior Texture	Mouthfeel	Flavor	Overall Acceptability
0	3.32	3.13	3.32	2.55	2.45	2.68
10	2.22	1.97	2.13	2.55	2.29	2.45
20	2.13	2.26	2.13	2.42	2.55	2.45
30	2.32	2.65	2.42	2.48	2.71	2.42
X^2[c]	17.13	14.11	17.83	0.21	1.72	0.79
P	.0007	.0028	.0005	.9756	.6319	.8510

[a]Mean ranks and chi-square values for three replications.

[b]Means for ranking values of 1, 2, 3, and 4 where 1 is closest to the criteria for the standard product and 4 is furthest from the criteria.

[c]Friedman chi-square value with df = 3.

Corn Bread

Results of the analysis of sensory evaluation data for corn bread are presented in Table VII. In corn bread, increasing levels of corn bran substitution significantly ($p<0.05$) affected all individual sensory characteristics, including top crust, surface color, cell distribution, cell size/shape, crumb color, mouthfeel, flavor, and overall acceptability. The mean ranks for these characteristics revealed that, as the level of corn bran substitution increased, all sensory characteristics significantly ($p<0.05$) decreased. Despite these results, many panelists commented that all levels of corn bran substitution were acceptable. Some panelists described the corn bread as slightly coarse and dry at the 20 and 30% substitution levels. Other panelists, however, indicated that the only distinguishing characteristic at the higher substitution levels was the dark gold crumb color. None of the panelists described the corn bread as unpalatable at the higher substitution levels.

Objective Evaluation

Objective evaluations were performed on product samples from each level of corn bran substitution. These evaluations included determination of tenderness by shear force (kg/g) using the Instron Universal Testing Instrument No. 1122, and by measurement of the area under the peak (cm^2/g) using the Li-Cor Area Meter No. 3100. Calculations of the fiber content of each product were also determined. Analysis of Variance (ANOVA) and a Duncan's Multiple range test (Snedecor and Cochran, 1973) were used for statistical analysis of the data.

TABLE VII

MEAN RANKS AND CHI-SQUARE VALUES OF SENSORY EVALUATIONS[a] OF CORN BREAD PREPARED WITH FOUR LEVELS OF CORN BRAN

	Mean Ranks[b]							
	Surface Appearance		Interior Appearance			Eating Characteristics		
Corn Bran Level	Top Crust	Surface Color	Cell Distribution	Cell Size/ Shape	Crumb Color	Mouthfeel	Flavor	Overall Acceptability
0	1.43	1.40	1.77	1.63	1.23	1.33	1.47	1.27
10	2.23	2.30	2.27	2.43	2.00	2.10	2.00	2.07
20	2.77	2.70	2.60	2.57	2.90	2.93	2.97	3.00
30	3.57	3.60	3.37	3.37	3.87	3.63	3.57	3.67
X^{2c}	43.52	45.00	24.36	27.20	69.88	53.88	48.12	59.76
p	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001

[a]Mean ranks and chi-square values for three replications.

[b]Means for ranking values of 1, 2, 3, and 4 where 1 is closest to the criteria for the standard product and 4 is furthest from the criteria.

[c]Friedman chi-square value with df = 3.

Tenderness

The analysis of variance for tenderness by shear force (kg/g) and by area under the peak (cm^2/g) for each product are presented in Tables VIII and IX.

TABLE VIII

ANALYSIS OF VARIANCE FOR TENDERNESS BY SHEAR FORCE (kg/g)

Source	df	Mean Squares	F Value	Observed Significance Level
Vanilla wafers				
Date	2	.1545	19.48	.0002
Corn bran level	3	.0063	0.79	.5213
Day x corn bran level	6	.0411	5.19	.0076
Error	12	.0079		
Oatmeal cookies				
Date	2	1.4292	0.53	.6011
Corn bran level	3	34.9964	13.01	.0004
Day x corn bran level	6	6.7881	2.52	.0814
Error	12	2.6907		
Wheat Crackers				
Date	2	18.1766	6.22	.0140
Corn bran level	3	23.0222	7.87	.0036
Day x corn bran level	6	10.1359	3.47	.0318
Error	12	2.9234		
Corn Bread				
Date	2	.0018	0.23	.7951
Corn bran Level	3	.0058	0.74	.5508
Day x corn bran level	6	.0112	1.43	.2808
Error	12	.0079		

TABLE IX

ANALYSIS OF VARIANCE FOR TENDERNESS BY AREA UNDER THE PEAK (cm^2/g)

Source	df	Mean Squares	F Value	Observed Significance Level
Vanilla wafers				
Date	2	.0140	31.97	.0001
Corn bran level	3	.0010	2.32	.1270
Day x corn bran level	6	.0019	4.42	.0138
Error	12	.0004		
Oatmeal Cookies				
Date	2	.0060	0.18	.8390
Corn bran level	3	.3596	10.41	.0012
Day x corn bran level	6	.0414	1.20	.3704
Error	12	.0346		
Wheat Crackers				
Date	2	.0839	6.09	.0150
Corn bran level	3	.1340	9.71	.0016
Day x corn bran level	6	.0497	3.60	.0280
Error	12	.0138		
Corn Bread				
Date	2	.0090	1.05	.3797
Corn bran level	3	.0099	1.16	.3666
Day x corn bran level	6	.0063	0.73	.6345
Error	12	.0086		

Vanilla Wafers. Mean values for tenderness by shear force and by area under the peak were not significantly ($p<0.05$) affected by corn bran level (Table X). A significant difference was detected only between the standard and 30% levels for measured areas under the peak (Table X). Based upon these results, it appears that the substitution of corn bran for all-purpose flour at levels of up to 30% did not affect the tenderness of vanilla wafers. The analysis of variance for tenderness by shear force and by area under the peak (Tables VIII and IX) showed significant interactions between day and corn bran level. This indicated that the tenderness values for each corn bran substitution level differed significantly ($p<0.05$) between evaluation sessions. A comparison of the mean tenderness values of vanilla wafers from each of the three evaluation sessions is presented in Table XI. These differences may have been due to changes in the moisture content of the product samples occurring either before or after freezer storage.

TABLE X

MEAN VALUES FOR TENDERNESS EVALUATIONS OF VANILLA WAFERS[1]

Corn Bran Level	Tenderness: Shear Force (kg/g)	Tenderness: Area Under Peak (cm^2/g)
0	1.94[a]	0.37[b]
10	1.89[a]	0.38[a,b]
20	1.97[a]	0.38[a,b]
30	1.94[a]	0.40[a]
F	0.79	2.32
p	.5213	.1270

[1]Values within column having no letter in common are significantly ($p<0.05$) different.

TABLE XI

MEAN TENDERNESS VALUES FOR VANILLA WAFERS AT INDIVIDUAL EVALUATION SESSIONS

Evaluation Session	Corn Bran Substitution Level			
	0	10	20	30
1	2.28[a]	2.14	1.97	1.99
	0.45[b]	0.44	0.41	0.42
2	1.81	1.78	1.93	1.97
	0.35	0.35	0.35	0.42
3	1.74	1.75	2.00	1.88
	0.31	0.36	0.38	0.36

[a]Top value in each pair is Instron measurement (kg/g).

[b]Bottom value in each pair is Area Meter measurement (cm^2/g).

Oatmeal Cookies. Significant ($p<0.05$) differences due to corn bran level were identified in mean values for tenderness by shear force and by area under the peak (Table XII). As the level of corn bran substitution increased, both the force required to shear the cookies and the measured areas under the peak increased. Cookies with 30% corn bran substitution required the highest shear force (13.58 kg/g) and had the greatest area measurement under the peak (1.31 cm^2/g) (Table XII). Significant differences in shear force occurred between the standard and 10, 20, and 30% levels, the 10 and 30% levels, and the 20 and 30% levels. Significant differences in area under the peak measurements were identified between the standard and 20% levels, the standard and 30% levels, the 10 and 30% levels, and the 20 and

30% levels. This evaluation indicated that the tenderness of oatmeal cookies decreased as the level of corn bran substitution increased. The analysis of variance for tenderness by shear force and by area under the peak (Tables VIII and IX) showed no significant interaction between day and corn bran level.

TABLE XII

MEAN VALUES FOR TENDERNESS EVALUATIONS OF OATMEAL COOKIES[1]

Corn Bran Level	Tenderness: Shear Force (kg/g)	Tenderness: Area Under Peak (cm^2/g)
0	7.78[c]	0.72[c]
10	9.97[b]	0.95[b,c]
20	11.12[b]	1.06[b]
30	13.58[a]	1.31[a]
F	13.01	10.41
p	.0004	.0012

[1]Values within column having no letter in common are significantly ($p<0.05$) different.

Wheat Crackers. The mean values for tenderness by shear force and by area under the peak were significantly ($p<0.05$) affected by corn bran substitution levels (Table XIII). Both shear force and area under the peak measurements increased with increasing levels of corn bran substitution up to the 20% level. The force required to shear the crackers and the measured area under the peak were highest at the 20% level of corn bran substitution (Table XIII). Significant differences in shear force and area under the peak measurements occurred between the standard and 10% levels, the standard and 20% levels, and the 20 and 30% levels. These results indicated that the tenderness of crackers decreased with increasing levels of corn bran substitution up to the 20% level; the tenderness then increased between the 20 and 30% levels. Significant interactions between day and corn bran level were detected in the analysis of variance for tenderness by shear force and by area under the peak (Tables VIII and IX). This indicated that the tenderness values for each corn bran substitution level differed significantly ($p<0.05$) between evaluation sessions. A comparison of the mean tenderness values of wheat crackers from each of the three evaluation sessions is presented in Table XIV. These differences may have been caused by changes in the moisture contents of the samples occurring either before or after freezer storage.

Corn Bread. The tenderness by shear force values for corn bread (Table XV) represent averages for two top and two bottom crusts at each substitution level. No significant differences were identified in the mean values for tenderness by shear force or by area under the peak. Table XV shows that, as the level of corn bran substitution increased, both the force required to shear the corn bread and the measured area under the peak decreased; however, these decreases were not significant ($p<0.05$). Therefore, it appeared that as the substitution level of corn bran increased, the tenderness of corn bread

TABLE XIII

MEAN VALUES FOR TENDERNESS EVALUATIONS OF WHEAT CRACKERS[1]

Corn Bran Level	Tenderness: Shear Force (kg/g)	Tenderness: Area Under Peak (cm^2/g)
0	10.65[c]	0.72[c]
10	13.94[a,b]	0.99[a,b]
20	15.04[a]	1.07[a]
30	12.01[b,c]	0.86[b,c]
F	7.87	9.71
p	.0036	.0016

[1]Values within column having no letter in common are significantly ($p<0.05$) different.

TABLE XIV

MEAN TENDERNESS VALUES FOR WHEAT CRACKERS AT INDIVIDUAL EVALUATION SESSIONS

Evaluation Session	Corn Bran Substitution Level			
	0	10	20	30
1	10.98[a] 0.74[b]	13.30 0.95	13.72 1.00	12.35 0.86
2	11.52 0.78	10.34 0.76	13.34 0.89	11.18 0.86
3	9.46 0.65	18.18 1.25	18.08 1.32	12.50 0.87

[a]Top value in each pair is Instron measurement (kg/g).

[b]Bottom value in each pair is Area Meter measurement (cm^2/g).

actually increased slightly. It is possible that the addition of corn bran disrupted the gluten structure of corn bread, causing it to be slightly more tender. The analysis of variance for tenderness by shear force and by area under the peak (Tables VIII and IX) showed no significant interaction between day and corn bran level.

TABLE XV

MEAN VALUES FOR TENDERNESS EVALUATIONS OF CORN BREAD[1]

	Tenderness	
Corn Bran Level	Shear Force (kg/g)	Area Under Peak (cm^2/g)
0	1.57[a]	1.03[a]
10	1.57[a]	1.02[a]
20	1.55[a]	0.98[a]
30	1.51[a]	0.94[a]
F	0.74	1.16
p	0.5508	0.3666

[1]Values within column having no letter in common are significantly ($p<0.05$) different.

Fiber Content

This research was conducted in an effort to develop quality baked products with increased fiber contents over the standard products. A comparison of the dietary fiber contents of these products at four corn bran substitution levels is presented in Table XVI. In calculating these fiber contents, available data was used to estimate the dietary fiber contribution of product ingredients. The calculations were based on dietary fiber values of 3.45% for all-purpose flour (Anonymous, 1979), 9.51% for whole wheat flour (Table I), 5.63% for rolled oats (Jwuang and Zabik, 1979), and 84.51% for corn bran (Table II). The substitution of 30% of the flour with corn bran provided 1.12 grams of dietary fiber per vanilla wafer, 0.54 grams of dietary fiber per oatmeal cookie, 0.99 grams of dietary fiber per wheat cracker, and 0.95 grams of dietary fiber per corn bread square. By substituting 30% of the flour with corn bran, it was therefore possible to increase the dietary fiber content of certain products by as much as nine times.

TABLE XVI

CALCULATED AMOUNT OF DIETARY FIBER (g) PER PRODUCT SAMPLE AT FOUR CORN BRAN SUBSTITUTION LEVELS (%)

Product	Average Sample Size	Dietary Fiber (g) per Sample at Four Substitution Levels			
		0	10	20	30
Vanilla wafers	8.0g	0.12	0.47	0.80	1.12
Oatmeal cookies	9.5g	0.21	0.32	0.43	0.54
Wheat crackers	4.0g	0.30	0.53	0.76	0.99
Corn bread	2"x2"	0.12	0.40	0.68	0.95

Testing the Hypotheses

The first hypothesis (H_1) stated that there will be no significant differences in the individual quality characteristics of vanilla wafers when corn bran is substituted for all-purpose flour in the basic formula at levels of 0, 10, 20, and 30% by weight. Based upon the statistical analyses of subjective and objective evaluation data (Tablex IV and X), the researcher rejected H_1.

The second hypothesis (H_2) stated that there will be no significant differences in the individual quality characteristics of oatmeal cookies when corn bran is substituted for all-purpose flour in the basic formula at levels of 0, 10, 20, and 30% by weight. Based upon the statistical analyses of subjective and objective evaluation data (Tables V and XII), the researcher rejected H_2.

The third hypothesis (H_3) stated that there will be no significant differences in the individual quality characteristics of wheat crackers when corn bran is substituted for whole wheat flour in the basic formula at levels of 0, 10, 20, and 30% by weight. Based upon the statistical analyses of subjective and objective evaluation data (Tables VI and XIII), the researcher rejected H_3.

The fourth hypothesis (H_4) stated that there will be no significant differences in the individual quality characteristics of corn bread when corn bran is substituted for all-purpose flour in the basic formula at levels of 0, 10, 20, and 30% by weight. Based upon the statistical analyses of subjective and objective evaluation data (Tables VII and XV), the researcher rejected H_4.

CHAPTER V

SUMMARY, CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS

The purpose of this research was to determine the effects of corn bran on the sensory and objective qualities of vanilla wafers, oatmeal cookies, wheat crackers, and corn bread. Corn bran was substituted for wheat flour in the standard formula for each baked product at levels of 0, 10, 20, and 30% based on flour weight. Sensory evaluation of the products was performed by an 11-member trained attribute panel. Objective evaluations included tenderness and fiber content. Sensory evaluation data was analyzed using the Friedman Test for Rank Analysis, while Analysis of Variance (ANOVA) and a Duncan's Multiple range test were used in analysis of objective evaluation data.

A review of the literature has presented evidence that fiber may be a protective factor against the development of a variety of diseases common in Western populations. As a result of this evidence, there has been increased public awareness and interest regarding fiber in the human diet. As there is general agreement that an increase in dietary fiber consumption would be beneficial, there is a need to develop new methods of incorporating fiber into the diet. The feasibility of using nontraditional plant fibers to increase the dietary fiber content of baked products has been documented; however, more research is needed in this area. The lack of reported research employing corn bran as a source of dietary fiber provided justification for this study.

Summary and Conclusions

Vanilla Wafers

The first hypothesis (H_1) stated that there will be no significant differences in the individual quality characteristics of vanilla wafers containing different substitution levels of corn bran. Analyses of sensory and objective evaluation data indicated that while tenderness by shear force (kg/g) and by area under the peak (cm^2/g) were not significantly affected by increasing levels of corn bran substitution, all sensory characteristics decreased significantly. Based upon these results, the researcher rejected H_1.

The standard vanilla wafer has a mild flavor and pale color; therefore, any alterations in the appearance or eating characteristics of this product due to corn bran incorporation are readily apparent. Most panelists indicated, however, that all substitution levels of corn bran were acceptable in this product. It appears, then, that the sensory evaluations of vanilla wafers prepared with higher substitution levels of corn bran might be improved if these products were scored individually and not in comparison to the standard product.

Oatmeal Cookies

The second hypothesis (H_2) stated that there will be no significant differences in the individual quality characteristics of oatmeal cookies containing different substitution levels of corn bran. Analysis of sensory evaluation data showed that oatmeal cookies prepared with 20% of the all-purpose flour substituted with corn bran had mean ranks closest to the standard criteria for all sensory characteristics except top crust. The analysis of objective evaluation data indicated, however, that as the level of corn bran substitution increased, the tenderness of oatmeal cookies decreased. On the basis of these results, the researcher rejected H_2.

The distinct flavor and texture of the oatmeal cookie produced by the spices and rolled oats seem to mask any alterations in the appearance or eating characteristics of this product due to corn bran incorporation. It appears that the addition of corn bran produced a cookie which was thicker and chewier than the standard, and many of the panelists preferred this. Panelist comments did not indicate any difference in tenderness between substitution levels.

Wheat Crackers

The third hypothesis (H_3) stated that there will be no significant differences in the individual quality characteristics of wheat crackers containing different substitution levels of corn bran. Analysis of sensory evaluation data indicated that crackers prepared with 30% of the whole wheat flour substituted with corn bran received a mean rank closest to the standard criteria for overall acceptability. Analysis of objective evaluation data, however, showed that the tenderness of wheat crackers decreased as the level of corn bran substitution increased, up to the 20% level. Based upon these results, the researcher rejected H_3.

The coarse, crisp texture and toasted wheat flavor of this product seemed to mask any alterations in texture or eating characteristics caused by corn bran substitution. As the level of corn bran substitution increased, the crackers became more pale in color and less pronounced in their toasted wheat flavor; however, these alterations did not affect panelist acceptance of the product.

Corn Bread

The fourth hypothesis (H_4) stated that there will be no significant differences in the individual quality characteristics of corn bread containing different substitution levels of corn bran. Analyses of sensory and objective evaluation data indicated that, although tenderness of the product increased slightly with increasing levels of corn bran substitution, all sensory characteristics decreased significantly. On the basis of these results, the researcher rejected H_4.

Like the vanilla wafer, the standard corn bread has a mild flavor and pale color; therefore, any alterations in the appearance or eating characteristics of this product caused by corn bran substitution are readily apparent. Since many panelists indicated that all substitution levels of corn bran produced acceptable corn bread, the sensory evaluations of corn bread at higher substitution levels might be improved if these products were scored individually and not in comparison to the standard product. Several panelists also suggested that the acceptability of this product at higher substitution levels would be greatly improved if it were served warm with butter and honey.

Recommendations

The incorporation of corn bran into baked products appears to be a feasible method of providing additional fiber in the diet. Based upon the results of this research, corn bran incorporation is most successful in baked products which have distinctive flavors or textures which serve to minimize any noticeable flavor or texture changes caused by the corn bran. Further research is recommended to determine the feasibility of corn bran incorporation into other food systems typically low in dietary fiber such as casseroles, gravies and sauces, pasta products, snack foods, and dessert items. Additional research is also needed to investigate the possible applications of the incorporation of other nontraditional dietary fiber sources into food systems.

In order to provide more comprehensive information regarding the effects of corn bran on the organoleptic qualities of baked products, additional sensory and objective evaluations could be performed. Product evaluation by a consumer panel would provide additional information about product acceptability. Further objective evaluations might include moisture content, color measurement, volume, batter viscosity, and nutrient analysis.

Implications

Many nontraditional sources of dietary fiber are available commercially. Through further research, those materials which can be successfully incorporated into food systems will be identified. It is recommended that corn bran and other dietary fiber sources be used by manufacturers of processed foods such as convenience baked goods and baking mixes to supplement the fiber contents of these products.

As consumer awareness and interest increases concerning the role of fiber in human nutrition, nontraditional fiber sources should also be made available for consumer use. In order to promote consumer acceptance of these products, accurate and appealing educational materials must be developed to explain their benefits and possible uses in home food preparation.

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APPENDIXES

APPENDIX A

TYPICAL ANALYSIS (DRY BASIS) OF STALEY REFINED CORN BRAN

TABLE XVII

TYPICAL ANALYSIS (DRY BASIS) OF STALEY REFINED CORN BRAN

Component	Amount
Color/Form	Cream Colored Powder
Moisture	10%
Oil	2-4%
Protein	4-6%
Starch	4-6%
Ash	0.6%
Calories/gram	Less than 0.5
Fiber:	
Dietary	88-92%
Crude	17-18%
Particle Size:	
Regular	80% min. thru #20 Mesh
Fine	20% max. on #60 Mesh
Typical Microbiological Counts:	
Total Plate Ct.	20,000 max./gm
E. Coli	Negative
Molds	50 max./gm
Yeast	50 max./gm
Salmonella	Negative
Staphylococcus	Negative

APPENDIX B

SENSORY EVALUATION OF BAKED PRODUCTS

INSTRUCTIONS TO PANEL MEMBERS

At each session, you will be asked to sample and evaluate four formulations of the baked product. Please evaluate the visual characteristics of all samples before evaluating the eating characteristics. Samples should be evaluated in the order that the sample codes are listed (left to right) at the top of the scorecard. After examining or tasting the samples, rank them against each other on a scale of 1 to 4. The number 1 should be assigned to the sample which most closely matches the criteria for that product, while the number 4 should be assigned to the sample which least closely matches the criteria. A list of criteria for the product will be available at each booth in the sensory evaluation room. There can be NO TIES. If you find any other differences between samples or have any comments which might be helpful in the evaluation of these products, please indicate them on the lines provided.

Distilled water will be provided for rinsing purposes. Please use it to rid your mouth of the flavor of one sample before evaluating the next sample.

Be sure to include your name, judge number, and the date at the top of each sensory evaluation scorecard. Return the scorecards and pencils to the table in the outer room.

For at least one-half hour before evaluation sessions, please try to avoid smoking, eating, drinking coffee or tea, or chewing gum, as these may alter your sense of taste.

Thank you for volunteering your time and effort for my research project.

CRITERIA FOR STANDARD VANILLA WAFER

1. Surface Appearance
   a) Shape
      Round
      Symmetrical
   b) Surface Color
      Pale, creamy gold
      Uniform
   c) Top Crust
      Very slightly mounded; may be almost level
      Not sunken
      Slightly porous; may have very shallow indentations visible around edges, but no surface cracks or deep indentations
2. Interior Appearance
   a) Distribution of Cells
      Uniformly distributed throughout
      Not compact
   b) Size and Shape of Cells
      Uniform in size; small air cells
      Thin cell walls
      Some larger air cells may be present, but should be well distributed
   c) Crumb Color
      Pale, creamy gold
      Uniform
3. Eating Characteristics
   a) Mouthfeel
      Tender
      Slightly moist
      Not rough, coarse, or dry
   b) Flavor
      Mild, delicate
      Slightly sweet
   c) Overall Acceptability
      Overall satisfaction in eating each product based upon the above criteria

Name____________________________ Date____________________

SENSORY EVALUATION OF VANILLA WAFERS

Please rank order the four coded samples on a scale of 1 to 4. Remember: There can be NO TIES.

SAMPLE CODE ____ ____ ____ ____

1. Surface Appearance
   a) Shape ____ ____ ____ ____
   b) Surface Color ____ ____ ____ ____
   c) Top Crust ____ ____ ____ ____

   Comments:____

2. Interior Appearance
   a) Distribution of Cells ____ ____ ____ ____
   b) Size and Shape of Cells ____ ____ ____ ____
   c) Crumb Color ____ ____ ____ ____

   Comments:____

3. Eating Characteristics
   a) Mouthfeel ____ ____ ____ ____
   b) Flavor ____ ____ ____ ____
   c) Overall Acceptability ____ ____ ____ ____

   Comments:____

CRITERIA FOR STANDARD OATMEAL COOKIE

1. Surface Appearance
   a) Shape
      Round
      Symmetrical
   b) Surface Color
      Light, golden brown
      Uniform
   c) Top Crust
      Crinkled appearance with shallow surface cracks
      Porous
      Almost level; may be slightly sunken in center
2. Interior Appearance
   a) Distribution of Cells
      Uniformly distributed throughout
      Not compact
   b) Size and Shape of Cells
      Small air cells; may have a few larger cells but should be evenly distributed
      Fairly thin cell walls
   c) Crumb Color
      Light, golden brown
      Oatmeal flakes may appear lighter than rest of crumb
      Uniform
3. Eating Characteristics
   a) Mouthfeel
      Crisp on outside but somewhat chewy on inside
      Light and tender
      Slightly moist
   b) Flavor
      Moderately sweet
   c) Overall Acceptability
      Overall satisfaction in eating each product based upon the above criteria

Name______________________________ Date________________________

SENSORY EVALUATION OF OATMEAL COOKIES

Please rank order the four coded samples on a scale of 1 to 4. Remember: There can be NO TIES.

SAMPLE CODE ____ ____ ____ ____

1. Surface Appearance

   a) Shape ____ ____ ____ ____

   b) Surface Color ____ ____ ____ ____

   c) Top Crust ____ ____ ____ ____

   Comments:____

   ____

2. Interior Appearance

   a) Distribution of Cells ____ ____ ____ ____

   b) Size and Shape of Cells ____ ____ ____ ____

   c) Crumb Color ____ ____ ____ ____

   Comments:____

   ____

3. Eating Characteristics

   a) Mouthfeel ____ ____ ____ ____

   b) Flavor ____ ____ ____ ____

   c) Overall Acceptability ____ ____ ____ ____

   Comments:____

   ____

CRITERIA FOR STANDARD WHEAT CRACKER

1. Surface Appearance
   a) Surface Color
      Golden brown with uniformly distributed darker brown specks
   b) Surface Texture
      Slightly rough or coarse
2. Interior Appearance
   a) Interior Texture
      Flaky with visible layers
3. Eating Characteristics
   a) Mouthfeel
      Crisp
      Tender
      Light
   b) Flavor
      Mild toasted wheat flavor
   c) Overall Acceptability
      Overall satisfaction in eating each product based upon the above criteria

Name______________________________ Date________________________

SENSORY EVALUATION OF WHEAT CRACKERS

Please rank order the four coded samples on a scale of 1 to 4. Remember: There can be NO TIES.

SAMPLE CODE ____ ____ ____ ____

1. Surface Appearance

    a) Surface Color ____ ____ ____ ____

    b) Surface Texture ____ ____ ____ ____

    Comments:____

2. Interior Appearance

    a) Interior Texture ____ ____ ____ ____

    Comments:____

3. Eating Characteristics

    a) Mouthfeel ____ ____ ____ ____

    b) Flavor ____ ____ ____ ____

    c) Overall Acceptability ____ ____ ____ ____

    Comments:____

CRITERIA FOR STANDARD CORN BREAD

1. Surface Appearance
    a) Top Crust
        Level or slightly rounded top
        Moderately smooth surface
        Free from deep surface cracks
    b) Crust Color
        Golden brown
        Uniform
2. Interior Appearance
    a) Distribution of Cells
        Uniformly distributed throughout
        Not compact
    b) Size and Shape of Cells
        Medium-sized air cells
        Moderately thin cell walls
        Free from tunnels or large air cells
    c) Crumb Color
        Golden-yellow
        Uniform
3. Eating Characteristics
    a) Mouthfeel
        Tender
        Slightly moist
        Neither coarse, dry, nor gummy
    b) Flavor
        Mild, delicate, pleasing
        Characteristic toasted corn flavor
    c) Overall Acceptability
        Overall satisfaction in eating each product based upon the above criteria

Name____________________________ Date____________________

SENSORY EVALUATION OF CORN BREAD

Please rank order the four coded samples on a scale of 1 to 4. Remember: There can be <u>NO</u> <u>TIES</u>.

SAMPLE CODE	____	____	____	____
1. Surface Appearance				
a) Top Crust	____	____	____	____
b) Surface Color	____	____	____	____

Comments:____

____

2. Interior Appearance				
a) Distribution of Cells	____	____	____	____
b) Size and Shape of Cells	____	____	____	____
c) Crumb Color	____	____	____	____

Comments:____

____

3. Eating Characteristics				
a) Mouthfeel	____	____	____	____
b) Flavor	____	____	____	____
c) Overall Acceptability	____	____	____	____

Comments:____

____

APPENDIX C

FORMULAE AND PREPARATION PROCEDURES

TABLE XVIII

FORMULA FOR VANILLA WAFERS[a]

Ingredient	Measure
Butter	56.0 gm
Vegetable Shortening	56.0 gm
Granulated Sugar	66.7 gm
Vanilla	5.0 ml
Salt	4.7 gm
Egg	54.0 gm
All-purpose Flour[b]	137.5 gm

[a]Formula was adapted from Better Homes and Gardens New Cookbook, 1965, p. 184.

[b]Corn bran was substituted for all-purpose flour in the amounts of 10, 20, and 30% by weight.

1. Assemble equipment and ingredients. Preheat oven to 375°F. Weigh all ingredients.

2. Thoroughly cream butter, shortening, and sugar for six minutes on Speed 6. Add vanilla and salt, and mix one minute on Speed 6. Add egg, and beat well for three minutes on Speed 6. Stir in flour using 60 hand strokes.

3. Using a #70 food server, portion dough onto baking sheets. Spray bottom of a drinking glass with non-stick vegetable spray, and flatten cookies to uniform size.

4. Bake 10 minutes. Remove immediately from baking sheets, and cool on wire racks.

TABLE XIX

FORMULA FOR OATMEAL COOKIES[a]

Ingredient	Measure
Vegetable Shortening	84.0 gm
Brown Sugar	110.0 gm
Granulated Sugar	50.0 gm
Egg	27.0 gm
Water	32.0 ml
Vanilla	3.0 ml
All-purpose Flour[b]	55.0 gm
Salt	2.4 gm
Cinnamon	1.2 gm
Baking Soda	1.0 gm
Ground Cloves	1.0 gm
Uncooked Oats	120.0 gm

[a]Formula was adapted from Betty Crocker's Cookbook, 1974, p. 137.

[b]Corn bran was substituted for all-purpose flour in the amounts of 10, 20, and 30% by weight.

1. Assemble equipment and ingredients. Preheat oven to 375°F. Weigh all ingredients. Spray baking sheets with non-stick vegetable spray.

2. Thoroughly mix shortening, sugars, egg, water, and vanilla for one minute on Speed 4, then five minutes on Speed 6. Sift together flour and spices. Stir in flour mixture and oats using 60 hand strokes.

3. Using a #70 food server, portion dough onto baking sheets.

4. Bake 11 minutes. Remove immediately from baking sheets, and cool on wire racks.

TABLE XX

FORMULA FOR WHEAT CRACKERS[a]

Ingredient	Measure
Whole Wheat Flour[b]	133.3 gm
Vegetable Shortening	56.0 gm
Salt	2.4 gm
Water, cold	50.0 ml

[a]Formula was adapted from Microwave Baking and Desserts, 1980, p. 10.

[b]Corn bran was substituted for whole wheat flour in the amounts of 10, 20, and 30% by weight.

1. Assemble equipment and ingredients. Preheat oven to 375°F. Weigh all ingredients.

2. Combine flour and salt. Cut in shortening until particles are coarse (two minutes). Sprinkle water over mixture, and stir dough with fork for one minute. Form dough into ball, and divide into four equal portions. Roll each portion through rollers of a noodle maker machine: twice on Width 1, once on Width 2, and once on Width 3. Lay sheets of dough onto cutting board, and cut into uniform pieces using round cutter. Transfer crackers to baking sheet, and prick twice with tines of a fork.

3. Bake 12 minutes. Cool on wire racks.

TABLE XXI

FORMULA FOR CORN BREAD[a]

Ingredient	Measure
All-purpose Flour[b]	55.0 gm
Yellow Cornmeal	72.5 gm
Baking Powder	7.0 gm
Salt	2.4 gm
Granulated Sugar	24.0 gm
Egg, beaten	54.0 gm
Vegetable Oil	28.0 ml
Milk, whole	122.0 ml

[a]Formula was adapted from Oklahoma State University Food Preparation Manual, 1979, p. 90.

[b]Corn bran was substituted for all-purpose flour in the amounts of 10, 20, and 30% by weight.

1. Assemble equipment and ingredients. Preheat oven to 400°F. Weigh all ingredients. Spray baking pan with non-stick vegetable spray.

2. Sift combined dry ingredients into mixing bowl. Combine beaten egg, oil, and milk, and stir with fork until well blended. Add liquid ingredients all at once to dry ingredients. Stir, using 20 hand strokes. Pour batter into baking pan.

3. Bake 20 minutes. Cool loaf in pan for several minutes, then remove from pan, and cool on wire rack.

VITA 2

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