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THE PHYSICAL AND SENSORY PROPERTIES OF SNACK CRACKERS PREPARED WITH OAT AND WHEAT BRAN

A Thesis
Presented for the
Master of Science
Degree
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ABSTRACT

Adequate intake of dietary fiber is of increasing concern to Americans, especially with recommendations by nutritionists and health professionals to consume more complex carbohydrates and fiber. Scientific research supports health benefits from physiological effects of specific fiber types. Oat bran, in particular, has increased in popularity due to its cholesterol-lowering effects. Consumer interest in nutritionally-enhanced foods is growing as indicated by market reports. In response to increased demand for high fiber foods, a study was conducted to investigate the effects of adding bran to snack crackers. Physical and sensory properties of crackers containing oat or wheat bran at four flour replacement levels, 0, 10, 20, and 30%, were studied.

Physical parameters reflecting textural quality of crackers were measured and found to give varying results. Breaking strength was significantly affected ($p<0.01$) by bran level but not by type; crackers decreased in breaking strength as level of bran increased. Stack height decreased as level of bran increased in wheat bran crackers but flakiness was more constant for oat bran crackers. Water activity, which has been correlated with textural quality of snack foods, did not differ significantly among treatments.

Physical measurement of color attributes revealed significant ($p<0.001$) treatment effects. Lightness and yellowness decreased as bran level increased, especially for wheat bran crackers. Redness increased gradually in both oat and wheat crackers as bran level increased. Overall, color was more consistent across all bran levels for oat crackers than wheat crackers.

Crackers made with 10 and 20% bran were analyzed for fiber and found to range in total dietary fiber from 8.48 to 18.51 g/100g. Oat bran crackers contained less dietary fiber than wheat bran crackers at 10% but not 20% levels.

A 6-member, trained sensory panel found significant differences ($p<0.05$) among treatments for color, crispness, cohesiveness, and flavor. Oat bran crackers were more consistent for color than wheat bran crackers. Judges perceived oat bran crackers to be less cohesive than wheat bran crackers. As bran level increased cereal flavor was less intense for oat bran crackers. A 50-member consumer panel found no differences in acceptability or preference between 10% oat bran and 10% wheat bran crackers with hedonic and food action rating tests. Acceptability of both oat and wheat bran crackers was low, possibly due to poor textural quality of crackers.

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CHAPTER I

INTRODUCTION

Adequacy of dietary fiber has become an increasing concern during the last 15 years. U.S. Dietary Guidelines for Americans (U.S. Department of Agriculture/U.S. Department of Health and Human Services, 1985) brought public attention to the fiber issue with recommendations to consume more complex carbohydrates and foods with adequate starch and fiber. The definition of dietary fiber has been subject to debate with some researchers defining dietary fiber chemically and others defining it physiologically. Trowell (1974) defined dietary fiber as the remnants of plant cells that cannot be digested by endogenous enzymes in the human gastrointestinal tract.

Classification and chemical analysis of dietary fiber have taken many directions as researchers sought a reliable and accurate method. Several classification systems for dietary fiber exist. Classification by water solubility is a general system that is often used in literature (Slavin, 1987). Water-soluble and water-insoluble fibers have different physiological effects in the body and are credited with promoting many health benefits (Slavin, 1987). Dietary fiber may be effective in reducing the risks of diabetes, obesity, cardiovascular disease, and gastrointestinal disease (Burkitt, 1978; Kritchevsky, 1978; Van Itallie, 1978; Anderson and Ward, 1979).

Water-insoluble fiber is known to increase fecal bulk and decrease intestinal transit time (Anderson, 1985). High fiber diets were recognized initially in the early 1970's for a possible role in lowering the incidence of colon cancer and other gastrointestinal diseases (Burkitt, 1973). Major food sources of water-insoluble fiber are vegetables, wheat, and most grain fibers. Coarsely ground wheat bran is considered to be the most effective bulking agent in the gastrointestinal tract (Wyman et al., 1976; Anderson, 1985).

Water-soluble fiber functions physiologically to slow gastric emptying, decrease the rate of glucose absorption, and lower serum cholesterol (Reiser, 1984; Anderson, 1985; Schneeman, 1986). Major food sources of water-soluble fiber include fruits, legumes, oats, and barley. Oats were recognized in the early 1960's for cholesterol lowering benefits (DeGroot et al., 1963). Popular publications have alerted the public to health benefits derived from eating oat bran (SerVaas, 1982) and scientific research supports such claims. Oat bran has been observed to lower serum cholesterol (Kirby et al., 1981) and to enhance the effects of a fat-modified diet (Van Horn et al., 1986). However, scientists have not

determined the exact mechanism through which oat bran and other water-soluble fibers lower serum cholesterol (Anderson et al., 1984).

Reports on food consumption patterns in the U.S. indicate a growing concern over nutritional quality during the last decade due to interest in physical fitness and expanded public awareness of nutrition (Murray, 1978; Tanis, 1978; Payne, 1987). Consumers have become more knowledgeable about nutrition and have altered eating patterns in response to information (Hurt and Crocco, 1986). Awareness of dietary fiber was evidenced by increased sales of high fiber cereals (Tanis, 1978; Aaron and Stauffer, 1986).

Percentages of young families and working women have increased and influenced the food market as well. People from the "Baby Boom" generation represent a more sophisticated population segment with interest in quality health and nutrition (Tanis, 1978; Anonymous, 1980). Typically, households have two wage earners and have more money to spend on food. Due to career demands and less time to prepare meals, consumers are willing to spend more money on food products that offer nutritional advantages (Fensholt, 1983).

With changing consumer attitudes toward food, industries have responded by developing nutritionally-enhanced products and emphasizing health benefits in marketing approaches (Tauber, 1980; Hurt, 1983). Food industries have begun to recognize product development as an opportunity to implement U.S. Dietary Guidelines (U.S. Department of Agriculture/ U.S. Department of Health and Human Services, 1985) through products that contain reduced sodium, reduced fat, and more complex carbohydrate (Scala, 1979; Peters, 1980; Tauber, 1980). The number of new products fortified with fiber in grocery stores has greatly increased during the last two years (Payne, 1987). The importance of fiber as an ingredient in food product development has been noted recently (Vetter, 1984). Factors such as solubility and dispersibility as well as overall product acceptability must be considered in developing high fiber foods. Potential carriers for dietary fiber include breads, crackers, leavened cereal products, hot cereals, and cookies (McCormick, 1985).

Vratanina and Zabik (1980) investigated consumer acceptance of oatmeal cookies made with added bran. In general, high-fiber oatmeal cookies were well accepted by consumers who liked oatmeal cookies and consumed cookies frequently. The majority of consumers in the study indicated awareness of dietary fiber through having read, seen, or heard information about dietary fiber. Sixty percent of the participants said that they had

increased their family's fiber intake during the past year. College graduates, women aged 60 or above, and family incomes above $15,000 were positively correlated with fiber awareness and increased fiber intake.

Many food companies are developing high fiber products and emphasizing health benefits in marketing strategies (Hurt, 1983; Hurt and Crocco, 1986). Oat bran is available to consumers through several commercial cereal products. However, oat bran products are limited because the food industry has not found a satisfactory means to utilize the non-bran portion (Vetter, 1984).

Little research has been conducted on the use of oat bran in bakery products. Oat bran has been used as a flour replacement in layer cakes (Shafer and Zabik, 1978) but yielded cakes with poor flavor. Oat hulls have been used in muffins (Polizzoto et al., 1983) but had an adverse effect on mouthfeel and overall product acceptance. Combinations of oat and wheat brans and/or flours have been investigated in bakery products such as cookies, cakes, and bread (D'Appolonia and Youngs, 1978; Vratanina and Zabik, 1980) with moderate success in product acceptability.

The bakery industry has grown over the past five years due to several factors, including rise in dual-income households (Fensholt, 1983). Bakery product purchases tend to increase with number of wage earners in households. Rising sales of baked products were evidenced by a 4.1% increase in 1982 (Fensholt, 1983). A report from the U.S. Department of Commerce (1986) stated that the baking industry significantly expanded sales in the cookie/cracker sector during 1985. Per capita consumption for cookies was higher than crackers due to the recent introduction of "soft cookies". Although per capita consumption of crackers remained stable for 1985, market reports support the popularity of cracker products among Americans. In 1985, Simmons Market Research Bureau interviewed 19,000 consumers on usage of food products purchased at grocery stores and found that crackers ranked 14th in order of usage and that heavy users of crackers tended to be people between 35-44 years of age (Anonymous, 1985). Crackers are viewed as a more "nutritious" snack food than chips, cookies, or candy and newly introduced crackers containing whole-grain ingredients such as whole wheat flour, cracked wheat, and sesame seeds have been received well by consumers (Pehanich, 1984; Przybyla, 1984). Although "natural" snacks such as granola bars are available, many are high in sugar and fat and less desirable nutritionally (Tavone and Matthews, 1982).

Consumer interest in healthy snacks and high-fiber foods is evident but limited research on bakery products containing oat bran has been reported. Therefore, a study

was undertaken to investigate the effects of adding two types of bran, oat and wheat separately, to snack crackers. The objectives of the study were:

1. To evaluate sensory properties (crispness, color, cohesiveness, and flavor) of crackers made with varying levels of oat bran or wheat bran.
2. To study physical properties of crackers made with oat bran or wheat bran.
3. To assess acceptability of oat bran and wheat bran crackers.
4. To estimate total dietary fiber content of selected cracker treatments.

CHAPTER II

REVIEW OF LITERATURE

Research on the addition of fiber to food products varies according to type of fiber and food system. Little research has been reported on the use of oat bran in bakery products. McKechnie (1983) reviewed the use of oat products such as rolled oats, quick oats, steelcut oats, and oat flour in bakery foods. However, oat bran was not included which may be due to the current inability of the food industry to utilize the bran-less fraction of oats (Vetter, 1984). Some work has been reported on the use of oat protein concentrates as a protein supplement in food products and beverages (Cluskey et al., 1979). More research has been conducted on whole grains and bran from species of grain other than oats in bakery products. Wheat bran in bakery products has been studied extensively. Food systems used for experiments include cookies, cakes, bread, and crackers.

A definition for dietary fiber has been evolving over the last decade. Most researchers support a definition of dietary fiber in terms of chemical composition (Cummings, 1987). New developments in defining dietary fiber have influenced chemical analysis of fiber as well. Methodology for determining dietary content of foods has undergone many alterations as more accurate and reliable procedures have been developed (Slavin, 1987). Recently, researchers have focused much attention on the physiological effects and health benefits of fiber.

I. Use of Fiber in Bakery Products

Crackers

Research on crackers containing high-fiber ingredients is limited. Kahn and Penfield (1983) investigated the use of whole-grain flour from triticale, a high-protein hybrid of wheat and rye, in snack crackers. They studied substitution of all-purpose wheat flour with triticale flour at the 25, 40, 55, and 70% levels. Cracker products were evaluated for crispness, taste, overall acceptability, and protein content. Differences in crispness were not observed through sensory and objective tests. Researchers observed that the 25 and 40% crackers were rated as acceptable. Protein content of triticale crackers was significantly higher than reported values for saltines and whole-wheat crackers. Kahn and

Penfield demonstrated that whole-grain triticale flour may be used in snack crackers to produce desirable characteristics and an enhanced nutritional profile. Other research on crackers includes studies on water activity levels and effect on textural properties (Katz and Labuza, 1981) and protein enrichment in saltine crackers (Sathe et al., 1981).

Layer Cakes

Use of bran in bakery products other than crackers has been studied more extensively. Brockmole and Zabik (1976) incorporated different levels and combinations of bran and middlings into white layer cakes and tested physical and sensory properties. Substitution levels were 4, 8, and 16% bran, and 12% bleached or unbleached middlings, and 16% bran plus 12% bleached or unbleached middlings. Higher levels of bran and middlings increased batter viscosity, tenderness, and yellowness and redness color values. Only unbleached middlings decreased cake volume. Sensory panelists found cake flavor differences due to treatments but not objectionable. Layer cakes made with wheat bran and middlings appeared to be a successful product.

Shafer and Zabik (1978) investigated layer cakes prepared with 30% of the flour replaced by various brans. The brans used were: corn bran, soy bran, oat bran, and six types of wheat bran. Objective measurements conducted on cakes included tenderness, volume, moisture, and color. Sensory evaluation included cell uniformity, grain, texture, crumb color, and flavor. Researchers found that cakes containing non-wheat bran were significantly less acceptable than cakes containing wheat bran. Cakes prepared with wheat bran were more tender and moist than the control cake and non-wheat bran cakes. Specifically, oat bran cakes scored lowest in tenderness and flavor compared to all cakes. Soy bran cakes scored lowest in crumb color. The crumb of wheat bran cakes tended to be a red color while non-wheat bran cakes had a slightly green tinted crumb.

Shafer and Zabik concluded that all of the wheat bran cakes were acceptable at the 30% replacement level, but non-wheat bran cakes were considered unacceptable due to low flavor scores. One possible explanation may be due to storage of oat and soy brans at room temperature resulting in rancidity and off-flavors. Further investigation using lower levels of flour replacement and altered storage conditions is needed to determine if non-wheat brans can be incorporated into layer cakes successfully.

In a 1979 study, Jeltema and Zabik investigated fiber components in various brans and related these to cake quality. Brans used in the study were corn bran, oat bran, soy hulls, and six types of wheat bran. Researchers found that hemicelluloses significantly

affected cake quality. Water-insoluble hemicelluloses in particular improved cake volume, tenderness, and cell thickness, while water-soluble hemicelluloses had the opposite effect. Oat bran was low in water-insoluble hemicelluloses which may explain poor cake quality as reported in other studies. Oat bran may not be suitable in cakes, but perhaps can be incorporated successfully into other bakery products.

Muffins

Polizzoto et al. (1983) studied the effects of various brans at the 25% flour replacement level in muffins. Seven types of bran were used including alpha-cellulose, corn bran, oat hulls, rice bran, soy bran, and two types of wheat bran. All the brans were ground to specific particle size. Proximate analysis of muffins was conducted and visual characteristics and acceptability were evaluated. Researchers observed results similar to the findings of Shafer and Zabik (1978). Muffins prepared with the two wheat brans were most acceptable. Corn bran muffins were considered acceptable also. Researchers found that particle size influenced sensory evaluation and observed that flavor and mouthfeel affected overall acceptability of muffins greatly. Wheat bran and corn bran muffins may have scored higher because flavors were more familiar to panelists. Researchers observed that oat hull muffins had an unacceptable gritty mouthfeel. Oat hulls may not have much potential in bakery products due to their fibrous texture and low nutritional value (McKechnie, 1983).

Bread Products

Combinations of oat and wheat brans and/or flours have been studied in loaf bread. However, early researchers noted that oats interfered with gluten development and loaf volume in bread. Jones and Hutchinson (1945) observed that oat groats ground into flour and combined with wheat flour yielded bread of significantly lower volume. The researchers identified the oat bran portion as the factor responsible for decreased loaf volume and found that dry heat treatment of oat groats counteracted the effect. Cunningham et al. (1955) investigated chemical characteristics and cohesive properties of proteins found in oats and other grains. They found that oat proteins were claylike and noncohesive which interrupted gluten structure in the oat/wheat flour breads. The researchers noted that oat proteins had less moisture absorption capacity than wheat gluten thereby yielding less elastic dough and bread products of decreased structural quality.

Pomeranz et al. (1977) studied bread made with up to 15% of the flour replaced by various types of fiber including cellulose, oat hulls, and wheat bran. Loaf volume was noted to decrease at bran levels of 5% or more due to decreased gluten. Oat hulls produced an objectionable gritty texture as other researchers have reported.

D'Appolonia and Youngs (1978) investigated the effects of oat protein concentrate and oat bran on dough properties and bread quality in comparison to wheat bran. Flour blends were prepared with 10, 20, and 30% oat bran, oat protein concentrates, or wheat bran. The oat groats were heat treated before milling to help produce more stable doughs. Dough stability was measured with a farinograph. Oat bran and oat protein concentrate were observed to absorb more water than wheat bran. Dough stability was optimal for oat bran and wheat bran at all levels of flour replacement; dough stability was not satisfactory for oat protein concentrate at the 30% level. Loaf volume for breads containing oat bran and oat protein concentrate was lower at all levels of substitution than for breads containing wheat bran. Sensory panelists found the oat bran bread more acceptable at the 10 and 20% levels than wheat bran bread at like levels.

Oomah (1983) studied blends of wheat and oat flour in bread. Rheological properties and baking qualities were evaluated for two types of oat flour, commercial oat flour and laboratory-milled oat flour, in flour blends containing 5, 10, 15, 20, and 25% oat flour. The addition of oxidants and a dough conditioner was tested also. Loaf volume decreased with increasing oat flour content and 25% oat flour produced the greatest volume decrease. Loaf volume improved with laboratory-milled oat flour containing oxidants or the dough conditioner but not with commercial oat flour containing the same additives at 5 and 10% oat flour levels.

Cookies

Gorczyca and Zabik (1979) investigated the effects of adding different types of cellulose at 0 to 30% levels to sugar-snap cookies. Researchers found that cellulose absorbed more water producing a thicker, softer, less crisp cookie. Cookie color was lighter as cellulose level increased. Cookies made with 10% cellulose were the most acceptable to sensory panelists.

Jeltema et al. (1983) studied different sources of dietary fiber, wheat bran, oat bran, corn bran, navy bean hulls, and soy hulls, in sugar-snap cookies. Flour was replaced by 0 and 20% of the above mentioned sources of dietary fiber. Cookies were evaluated for color, top grain, spread, moisture, tenderness, and breaking strength. Sensory panelists

visually evaluated color, cell size and distribution, and texture. Visual evaluation of texture was not defined. Researchers measured fiber components such as cellulose, pectin, water soluble and insoluble hemicelluloses of the different brans and hulls and correlated these with cookie properties. Control cookies and cookies made with navy bean hulls were most desirable having large spread and minimal surface cracks. Type of bran affected color; wheat bran cookies were darker, more red and less yellow. Corn, wheat, and soy cookies were more tender than the other cookies but were not optimum in spread and top grain qualities. Moisture levels after baking differed among treatments with corn bran cookies retaining the most moisture ($p<0.05$). Sensory panelists found that lighter color cookies were more acceptable than darker cookies. Researchers found that most of the cookie properties correlated with fiber components, especially hemicellulose. Hemicellulose has a high water-binding capacity which produced less spread but increased moisture and tenderness in cookies.

In a study by Vratanina and Zabik (1978), high fiber cookies were prepared with 10, 20, and 30% red or white wheat bran. Higher levels of bran increased water retention and decreased spread. Bran components reduced the amount of free water in cookie dough necessary for spread. Researchers found that color differed significantly among cookie treatments. Lightness and yellowness decreased as level of bran increased. Red wheat bran decreased yellowness more than white wheat bran. Higher levels of bran produced more tender, less crisp cookies. Moisture content of the cookies was affected because wheat bran has a greater capacity to retain water. Sensory panelists found that flavor and mouthfeel were less acceptable at 30% bran levels.

In another study by Vratanina and Zabik (1980) oatmeal cookies were prepared with 50% of the flour replaced by white wheat bran or red wheat bran and various flavors added. When consumer acceptance was measured the researchers found that a cookie with oatmeal added was a successful vehicle for increasing fiber in the diet because the bran flavor was masked. Red wheat bran was slightly more preferred than white wheat bran.

Oomah (1983) studied blends of wheat and oat flour in cookies as well as bread. Up to 25% commercial oat flour or laboratory-milled oat flour was substituted for wheat flour in cookies and baking qualities were evaluated. Cookie spread increased with higher

levels of laboratory-milled oat flour, but cookie spread for those formulated with commercial oat flour did not differ significantly ($p<0.05$) from the control formulated with wheat flour.

II. Definitions of Dietary Fiber

Dietary fiber is described physiologically as cellular material of plants that resists enzymatic hydrolysis in the human digestive tract (Trowell, 1974). However, other food components that are not part of plant cell wall material may qualify as dietary fiber also. Gums, mucilages, and modified starches used by food industry resist human enzyme digestion (Slavin, 1987). Terms such as unavailable carbohydrate and indigestible residue have been used to expand the physiological definition of fiber (Bingham, 1987).

Chemical definitions of fiber are more practical in regard to analysis of dietary fiber content in foods (Bingham, 1987). Many researchers prefer the term nonstarch polysaccharides because it encompasses a wide range of fibers. Nonstarch polysaccharides include: soluble and insoluble fibers, pectins, gums, hemicelluloses, cellulose, and beta-glucans (Bingham, 1987). Including enzyme resistant starch under the chemical definition of dietary fiber is subject to debate among researchers (Bingham, 1987). Universal agreement on a chemical definition of dietary fiber has not been achieved; therefore, methods of measuring dietary fiber have varied greatly (Slavin, 1987).

III. Dietary Fiber Determination

Methodology for analysis of dietary fiber has undergone many changes recently. Originally, fiber content of foods was measured as crude fiber for which an acid and alkali treatment was used. However, the crude fiber method underestimated the total fiber content of foods and was deemed inappropriate for human nutrition studies(Slavin, 1987).

Van Soest (1978) contributed much to dietary fiber research by developing an extraction method that utilized a neutral detergent. Water-insoluble fibers were measured, but water-soluble fibers such as pectin and gums were not recovered and total dietary fiber was underestimated. Southgate introduced another approach that separated individual fiber components through chemical and enzymatic extractions (Schneeman, 1986). The Southgate procedure tended to yield dietary fiber values higher than other procedures due to inclusion of enzyme resistant starch (Slavin, 1987).

Other researchers proposed that mammalian enzymes be used in dietary fiber determination. Mammalian enzymes more closely mimic the treatment of dietary fiber in the gastrointestinal tract by removing starch and protein and leaving dietary fiber (Slavin, 1987). New methods using a combination of enzymatic and gravimetric techniques have been developed (Asp et al., 1983; Prosky et al., 1984). These methods were evaluated recently by the Food and Drug Administration through a collaborative interlaboratory study (Prosky et al., 1984). Results based on those methods were modified to reduce variation among samples and to achieve a reliable method. The modified method for total dietary fiber analysis has been accepted by the Association of Official Analytical Chemists (Prosky et al., 1985). However, little data on total dietary fiber content of foods have been generated with the new method. Currently available data on fiber content of foods have been generated by a variety of methods and conditions. Therefore, much work is needed to produce a usable data base on total dietary fiber (Schneeman, 1987).

In addition to chemical analysis of dietary fiber, food scientists are beginning to examine the effects of food processing on the content and form of fiber in foods. Several researchers have observed that heat processing of potatoes significantly increased the amount of enzyme resistant starch present (Varo et al., 1983; Jones et al., 1985). Bjorck et al. (1984) studied the effect of extrusion-cooking on wheat starch digestibility but found no significant differences in digestibility. Food processing may influence the physiological function of fiber in the body. Wyman et al. (1976) compared the effects of intestinal transit time in healthy humans. Cooked wheat bran was less effective in decreasing intestinal transit time than raw wheat bran.

IV. Physiological Effects of Dietary Fiber

Insoluble Fiber

Insoluble dietary fiber is known mainly for influencing the gastrointestinal tract. Adequate intakes of water-soluble fiber such as wheat bran have been proven to decrease intestinal transit time and increase fecal bulk, thereby decreasing constipation (Klurfield, 1987). Insoluble fiber may aid in the treatment of several gastrointestinal diseases such as diverticulosis, irritable bowel syndrome, and Crohn's disease (Klurfield, 1987; Mendeloff, 1987). The relationship between dietary fiber and gastrointestinal disease is not understood completely.

Epidemiological studies indicate that level of fiber intake influences the incidence of colon cancer among populations (Burkitt, 1973). However, animal studies on fiber and colon cancer suggest a complex relationship involving many factors (Jacobs, 1987). High fiber diets may have a detrimental effect on the gastrointestinal tract and increase the risk of gastric and colon cancer (Klurfield, 1987); therefore, increasing dietary fiber should be done prudently and through food sources instead of concentrated supplements (Jacobs, 1987; Schneeman, 1987).

Soluble Fiber

Water-insoluble fiber from oats and legumes appear to be effective in treating cardiovascular disease and diabetes. Recent research on the physiological effects of oat bran include data collected by Kirby et al. (1981) who fed 100 g of oat bran daily to eight hypercholesterolemic men. Average total serum cholesterol reductions of 13% were observed in seven of the subjects. Oat bran selectively lowered low density lipoproteins (LDL) but did not affect high density lipoproteins (HDL). Anderson et al. (1984) reported significant serum cholesterol reductions ($p<0.0005$) in 20 hypercholesterolemic subjects fed 100 g of oat bran per day. Van Horn et al. (1986) conducted research using 208 healthy adult volunteers who were placed on fat-modified diets along with 35 g of oat bran per day. Researchers observed that oat bran along with a low-fat diet had an enhancing effect ($p<0.05$) in reducing serum lipid levels. Proposed mechanisms for the cholesterol-lowering effect of oat bran include increased binding and fecal excretion of bile acids which results in more cholesterol entering the bile acid synthetic pathway with less cholesterol available for circulation (Kritchevsky, 1978; Kay, 1980). Soluble fiber may influence synthesis of cholesterol in the liver also (Anderson, 1985). Further research is needed to define the mechanism involved in the lipid lowering effect of oat bran.

High-fiber diets offer many benefits in management of diabetes; insoluble fibers have been shown to delay gastric emptying and decrease the rate of postprandial glucose absorption (Anderson et al., 1987). Many studies have been conducted on diabetic individuals consuming high-fiber diets with positive results of decreased insulin requirements, improved blood glucose control, and lower serum cholesterol and triglyceride levels (Anderson, 1985). High-carbohydrate, high-fiber (HCF) diets consisting of 60% carbohydrate, 20% protein, 20% fat, and 25 g dietary fiber per 1000

calories were developed by Anderson and his colleagues in the mid 1970's. The HCF diets have been accepted and tolerated well by diabetic individuals and have improved diabetes management (Anderson et al., 1987).

Obesity is another chronic health problem that appears to benefit from a high-fiber intake. Epidemiological surveys support increased incidence of obesity among Western populations due to decreased dietary fiber intake (Burkitt, 1973). Dietary fiber increases satiety and promotes weight loss and maintenance by limiting caloric intake (Van Itallie, 1978). High-fiber foods require more mastication and longer time for gastric emptying and therefore help prevent overeating (Klurfield, 1987).

CHAPTER III

MATERIALS AND METHODS

In order to test the effect of bran in snack crackers two types of bran, oat and wheat, were incorporated separately into crackers at three different levels. A control cracker was developed without oat or wheat bran for comparison. Moisture content of the doughs varied considerably due to type and level of bran. Experimentation was required to determine the appropriate level of water for each formulation.

I. Experimental Design

A 2 x 4 factorial arranged in a partially balanced incomplete block design was used (Table 1). Factors that were tested included two types of bran, oat and wheat, and four levels of flour replacement, 0, 10, 20, and 30%, giving 7 unique treatments but 8 experimental treatments. An incomplete block design was chosen because panelists could not evaluate all the treatments at one session. Eight blocks gave 4 complete replications for each of the 8 treatments. Each taste session was represented by a block. Order of presentation of crackers to sensory panelists was randomized for each panelist within a block to minimize positional bias.

II. Formula

Crackers were prepared according to a formula established by Casella (1966) as modified by Kahn and Penfield (1983). Oat bran replaced 10, 20, and 30% of the flour weight (Table 2). For comparison, a second type of cracker was prepared by replacing flour with wheat bran at 10, 20, and 30% levels. A control cracker containing no oat bran or wheat bran was prepared also. During preliminary testing, control crackers, oat bran crackers, and wheat bran crackers were made with Gold Medal all-purpose flour. Gold Medal flour was used because it yielded a suitable cracker dough with optimal gluten level and yielded crackers that were neither too tough or too fragile. All ingredients, except for the two brans, were obtained from a local supermarket. Oat bran was supplied by National Oats Company (Cedar Rapids, IA). Wheat bran (Dietfiber ® B) was supplied by Lauhoff Grain Company (Danville, IL).

Table 1 - Incomplete block[a] design for assigning treatments to blocks

	Treatment[b]							
	Oat bran,%				Wheat bran,%			
Block	0	10	20	30	0	10	20	30
1			X	X			X	X
2		X	X			X	X	
3	X	X	X	X				
4		X		X	X		X	
5	X	X			X	X		
6					X	X	X	X
7	X		X			X		X
8	X			X	X			X

[a] Blocks 1 - 8 were completed for physical and sensory studies.

[b] Level of flour replacement.

Table 2 - Formulas for crackers

		Amount, g						
			Oat bran, %			Wheat bran, %		
Ingredients	Source	Control	10	20	30	10	20	30
Flour	Gold Medal[b]	180.0	162.0	144.0	126.0	162.0	144.0	126.0
Baking soda	Arm & Hammer[b]	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Salt	Morton[b]	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Nonfat, dried buttermilk	Saco[b]	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Oat bran	National Oats[c]	—	18.0	36.0	54.0	—	—	—
Dietfiber B	Lauhoff Grain[d]	—	—	—	—	18.0	36.0	54.0
Vegetable shortening	Crisco[b]	56.0	56.0	56.0	56.0	56.0	56.0	56.0
Eggs	Kroger[b]	54.0	54.0	54.0	54.0	54.0	54.0	54.0
Water[a]		36.0	36.0	36.0	36.0	44.0	44.0	44.0

[a]Amounts of water added to oat and wheat bran formulations vary due to differences in water absorption of bran types. Water absorption was measured during preliminary studies and wheat bran absorbed 31.6% more water than oat bran.

[b]Obtained from local grocery store.

[c]Obtained from National Oats Co., Cedar Rapids, IA.

[d]Obtained from Lauhoff Grain, Danville, IL.

Amount of water required for cracker formulations was determined also because different types of fiber (such as water-soluble and water-insoluble) vary in water binding capacity (Sosulski and Cadden, 1982). Water binding capacity of several food fibers including oat bran and wheat bran has been researched. Chen et al. (1984) found that wheat bran had a higher water binding capacity than oat bran when tested by four different methods. Cunningham et al. (1955) observed water absorption differences due to grain species; wheat gluten has a higher moisture absorption capacity than oat proteins. During preliminary testing, the amount of water that oat bran and wheat bran absorb individually was measured. Fifteen ml of water were added to 5 g of each type of bran and then drained after a 1 min interval. This test was repeated 3 times and wheat bran was observed to absorb an average of 3.6 ml or 31.6% more water than oat bran. Water levels in wheat bran cracker formulations were adjusted accordingly in Table 2 to account for water absorption differences among cracker formulations.

Crackers were prepared according to the following steps: Flour, bran, baking soda, salt, and nonfat, dried buttermilk solids were sifted together into a mixing bowl. One hundred strokes with a pastry cutter were used to cut vegetable shortening into dry ingredients. Eggs and water were added and beaten for 1 min on speed 1 of Hobart mixer. Dough was gathered into a ball and kneaded for 1 min. Dough was rolled between two pieces of wax paper using metal guide bars of 0.12 cm thickness. Crackers were cut into 7 x 2.5 cm rectangles. Cracker dough was transferred to aluminum, air-cushioned baking sheets pricked uniformly. Crackers were baked for 11 min in a deck oven (General Electric Model CN50, Chicago Heights, IL) of 218 ° C with top heating element set on high and bottom heating element set on low. Crackers were cooled for 15 min on a wire rack at room temperature. The formula yielded a total of 40 crackers. Each baked cracker weighed approximately 3.2 g. Doughs were mixed on Day 1 (15 hrs before baking) and stored overnight in airtight, odor-free containers refrigerated at 6 ± 2° C. Crackers were baked in the morning of Day 2 and evaluated within 4 hrs of baking for physical and sensory attributes.

III. Physical Measurements

Previous research was considered in determining physical attributes of crackers to be evaluated. Bran retards gluten development in doughs (Cunningham, 1955) because the amount of gluten is decreased as flour is replaced by bran. Bran physically impedes and

weakens bonding of gluten strands which ultimately affects structure; therefore, breaking strength of crackers was measured. Flakiness in crackers may tend to decrease when bran is added because less gluten formation reduces the entrapment of air and fat necessary for flakiness. The height of a stack of crackers, which serves as an index to flakiness, was measured. Crackers were evaluated for color because researchers have noted differences in color attributes of bakery products with bran added (Jeltema et al., 1983). Variations in water binding capacity in different types of bran affects available water in a food system. Therefore, water activity in the crackers was measured.

Breaking Strength

Breaking strength has been used as a measurement of shortness and snapping properties of baked products such as cookies and crackers (Bourne, 1982) as well as tenderness in pie pastry (Stinson and Huck, 1969). Breaking strength may reflect crispness of crackers; therefore, breaking strength was measured by a Bailey Shortometer (Donald McIntyre, University of Minnesota, Minneapolis, MN). During preliminary work, breaking strength was tested with the Instron Universal Testing Machine (Canton, MA) but the instrument proved to be less sensitive when compared to the Bailey Shortometer because an appropriate load cell was not available. Breaking strength was defined as the force required to break cracker samples of 7 x 2.5 x 0.12 cm. A uniform sample was placed on a balance support, downward force exerted on the center of the sample, and maximum force required to break the sample recorded in ounces (Bailey, 1934). Measurements were taken on ten samples for each cracker treatment (Stinson and Huck, 1969).

Water Activity

Water activity of crackers was measured with a hygroline recorder (model VFB2) manufactured by Beckman Instruments, Inc. (Cedar Grove, NJ). A humidity sensor on the instrument equilibrates with the food sample in a closed environment, relative humidity of a food sample is measured and recorded on a scale as relative equilibrium moisture (r.e.m.). Water activity can be obtained by dividing r.e.m. values by 100. The instrument was standardized with 33% and 53% standards on 10-100% r.e.m. prior to taking readings. Two samples were tested for each treatment for each replication.

Water activity of snack foods has been studied in relation to textural quality and has been found to influence crispness of crackers. Crackers tend to become unacceptable at

water activity zones of 0.35 to 0.50 (Katz and Labuza, 1981). Water activity values were used to evaluate differences among cracker treatments due to level and type of bran. Water activity values were used also to evaluate whether laboratory crackers fell within acceptable water activity zones as cited in the literature.

Stack Height

The thickness of a stack of crackers or pastry indicates relative flakiness of the product (Campbell et al., 1979). Three crackers of uniform size were stacked one upon another and height of the stack measured in mm. Three sample sets were measured for each treatment.

Color

Color differences among cracker treatments were measured with the color/difference meter (model D25-2) manufactured by Hunter Associates Laboratory, Inc. (Reston, VA). Color is measured by numerical representation of the color response mechanisms of the human eye to light wavelengths. Dimensions for L (lightness), aL (redness), and bL (yellowness) were measured (Francis and Clydesdale, 1975) on laboratory crackers. Prior to color analysis, the instrument was standardized with a yellow tile (L = 77.0, aL = -1.6, bL = 21.0). Crackers were ground and uniform amounts placed in sample cups. Readings were taken on three cracker samples for each treatment.

Total Dietary Fiber

Crackers were analyzed for total dietary fiber by modification of a method by Prosky et al. (1985). Cracker samples (15 g) were pulverized, then dried in a Volatiles/Moisture Tester manufactured by C.W. Brabender Instruments, Inc. (Hackensack, N.J.) at 130°C for 50 min in preparation for fiber analysis. Fat was extracted from the samples by a Soxlet apparatus with ethyl ether (American Scientific Products, McGaw Park, IL) for 24 hrs. Samples were dried overnight in a 105°C drying oven. Appendix A outlines the procedure used for total dietary fiber analysis.

IV. Sensory Analysis

Crackers were evaluated by a sensory panel consisting of six judges. Panelists were trained to evaluate color, crispness, cohesiveness, cereal flavor, and non-cereal aftertaste.

A tentative scorecard was introduced and characteristics to be evaluated were discussed and refined. Technique for evaluating characteristics and anchors representing extremes of characteristics (Appendix B) were presented to panelists and discussed. A schedule of panel training sessions is located in Appendix B also. Data from the training sessions were evaluated statistically using two-way ANOVA. Each judge's scores for color, crispness, and cereal flavor were analyzed to determine if each judge was able to differentiate among cracker treatments (Cross et al., 1978). All judges were able to discern differences among treatments ($p<0.10$) for color and cereal flavor. Two of the judges were able to perceive differences ($p<0.10$) among treatments for crispness. Some judges may have had difficulty differentiating among samples due to lack of uniformity in cracker thickness. Midway through the training period an improved method for rolling dough to uniform thickness was developed. Additional time was spent discussing crispness and reviewing appropriate anchors. Panelists were trained to evaluate crispness by snapping the sample between fingers and at first bite of sample between incisors.

Cohesiveness and non-cereal aftertaste were incorporated into the scorecard midway through the training period at the suggestion of the panelists. Additional time was devoted to discussing these attributes and representative anchors. Based on the results of statistical analysis and feedback from the panel, it was concluded that the panelists were ready for data collection after 6 hours of training.

During the study, judges were seated in individual booths with white fluorescent ceiling lighting. The room was quiet, air-conditioned and relatively odor-free. Cracker samples were served in opaque, odor-free, wax paper envelopes coded with three-digit random numbers. Samples were presented simultaneously, but judges evaluated one sample at a time using a separate scorecard (Appendix C) for each sample and did not make comparisons among samples. Judges completely evaluated all attributes and were instructed to reclose samples in envelopes before proceeding to the next sample. Judges did not retaste or review previous samples.

The final scorecard (Appendix C) developed during the training period was an unstructured, 150 mm linear scale on which panelists responded by making a vertical mark (I.F.T. Sensory Evaluation Division, 1981). Instructions for scoring and cleansing were detailed on the scorecard. Panelists were encouraged to use the entire length of the scale when evaluating parameters of color, crispness, cohesiveness, and flavor. Aftertaste, if present, was evaluated and written comments were encouraged. Linear scales were

converted to numerical values by measuring responses in mm. The unit of measure for sensory analysis was defined as the mean evaluations of six trained judges with relatively similar scores.

V. Consumer Sensory Panel

Crackers were evaluated for acceptability by a 50 member consumer panel. Three weeks prior to testing, panelists were recruited (Appendix D) from faculty, students, and staff of the College of Human Ecology and the Department of Food Technology and Science. Two cracker treatments, 10% oat bran and 10% wheat bran, were presented to panelists because these treatments were more likely to be accepted by consumers. One set of crackers was presented to panelists and a hedonic and a food action rating test (Schutz, 1965) were used. The order of sample presentation was balanced and samples were coded with three-digit random numbers. Samples were served in white paper sandwich bags. Room temperature water was served in paper cups for rinsing between samples. The testing environment was similar to the environment for the trained sensory panel.

Instructions were included with the scorecard (Appendix E). Panelists were given the two crackers simultaneously but instructed to evaluate one sample at a time and not retaste samples. Crackers were evaluated for preference and acceptability on an eight-point hedonic scale and a six-point Fact scale. A questionnaire followed the scorecard (Appendix F) relating to demographics and cracker consumption practices. The results of the consumer panel were converted to ranking scores and significance analyzed by a t-test.

VI. Statistical Analysis

Data obtained from physical and sensory testing were analyzed via PROC GLM within SAS © (SAS Institute Inc., 1985). GLM was deemed appropriate for the analysis of the partially balanced incomplete block and for the sensory evaluation data since unequal sub-group members existed. Main effects of block, level, type, and the interaction of level x type were included in the mathematical model. Judge effect was not included in the study because the unit of measure for sensory analysis was defined as the mean evaluations of six trained judges with relatively similar scores. All tests of hypotheses were based upon type III sum of squares. For an incomplete block design type III sum of squares are without recovery of interblock information. Differences among quantitative levels, 0, 10, 20, and

30%, of bran were partitioned into linear, quadratic, and cubic components. The sum of squares for each component were obtained from the type III sum of squares within PROC GLM (Sanders, 1987).

CHAPTER IV

RESULTS AND DISCUSSION

Results are presented in sections according to type of data: physical, sensory, and consumer. Main effects including block, bran level, and bran type were analyzed as well as significant interactions between level and type. Analysis of variance tables are included to show overall significance and functionality of main effects and interactions. Graphs depicting the effects of treatments upon dependent variables are presented also. Tables of least-squares means with standard errors to show trends in physical and sensory measurements are located in Appendix G.

I. Physical Measurements of Texture

Mean square values for water activity are presented in Table 3. No significant differences due to treatment were found for water activity. Differences due to block were significant ($p<0.01$) which may be explained in part by the incomplete block experimental design. Different treatment combinations were used for each block thereby contributing to significant block differences. Experimental error was higher for water activity than for other physical measurements. Water activity may have been influenced by environmental conditions which could not be tightly controlled. Humidity and temperature fluctuated in the laboratory and crackers may have absorbed varying amounts of moisture as they were removed from the oven and cooled.

Least-squares means for water activity are presented in Appendix G, Table A-1. Water activity levels were below 0.35 for only two treatments, 10% oat bran and 10% wheat bran. All other treatments fell within zones of 0.35 to 0.50 at which range cracker crispness tends to become unacceptable (Katz and Labuza, 1981). Aside from the experimental error noted, bran absorbs and retains water within a food system, which may have contributed to a high water activity level and lack of crispness in the laboratory crackers.

Bran level significantly influenced ($p<0.01$) breaking strength of crackers as shown in Table 3, but bran type did not have a significant effect. Breaking strength decreased as level of bran increased (Appendix G, Table A-2) which may be due to physical impairment of gluten development and cracker structure by the bran (Cunningham, 1955). Stack

Table 3 - Analysis of variance for physical measurements of crackers prepared with oat or wheat bran at four flour replacement levels, 0, 10, 20 and 30%

Source of Variation	df	Mean squares		
		Water activity	Breaking strength	Stack height
Total	31			
Block	7	513.29 **	2.64	2.08
Level	3	54.38	37.35**	4.78*
Linear	1	11.13	99.97***	11.48**
Quadratic	1	100.04	4.60	0.56
Cubic	1	51.96	7.48	2.29
Type	1	1.90	1.06	10.23*
Level x type	3	8.27	0.48	3.58
Linear x type	1	9.25	0.28	6.88*
Quadratic x type	1	14.78	0.03	3.78
Cubic x type	1	0.76	1.14	0.10
Error	17	100.02	6.36	1.47

*p < 0.05

**p < 0.01.

***p < 0.001.

height of crackers (Table A-2) decreased in some cracker treatments as level of bran increased also indicating an interference with cracker structure. Crackers appeared to be more friable and have less structure with increasing bran levels. The effect of bran level on breaking strength was an inverse linear relationship as depicted in Figure 1; that is, breaking strength decreased as level of bran increased for both oat and wheat bran.

An interaction of level x type with a linear function influenced stack height of crackers significantly ($p<0.05$) as presented in Table 3. An inverse linear relationship existed between stack height and level of bran (Figure 2) for wheat bran but not for oat bran. The slope of the line for oat bran crackers appears close to zero slope (Figure 2), and apparently stack height was more constant for oat bran crackers. Generally, wheat bran crackers were thinner than oat bran crackers (Appendix G, Table A-3) possibly due to development of less gluten and therefore, less structure. Stack height reflects cracker flakiness; higher values indicate more layering and flakiness within crackers. Bran may have interfered with the ability of cracker dough to provide structure for air spaces and layering. Wheat bran doughs were noted to have more bran particles than oat bran doughs perhaps indicating more interruption of structure by the wheat bran. Visual observation of both brans revealed a possible difference in particle size. The wheat bran particles were smaller than oat bran which may explain a greater number of particles in the wheat bran doughs.

Results of physical measurements relating to cracker crispness were inconsistent. Katz and Labuza (1981) documented the relationship of water activity and crispness in crackers, but analysis of water activity revealed no significant differences due to treatment. Measurement of cracker breaking strength, which may be reflective of crispness, revealed a significant ($p<0.001$) relationship between bran level and breaking strength but bran type did not influence breaking strength. Differences in stack height due to treatment were significant ($p<0.05$); wheat bran crackers had less structure and were more crumbly or mealy as bran level increased.

II. Physical Measurement of Color

Mean squares for color measurement are presented in Table 4. An interaction of level x type significantly affected ($p<0.001$) lightness of crackers (Table 4). The function between level x type and lightness was an inverse linear relationship as represented by Figure 3. Lightness decreased as level of bran increased in crackers, especially with wheat

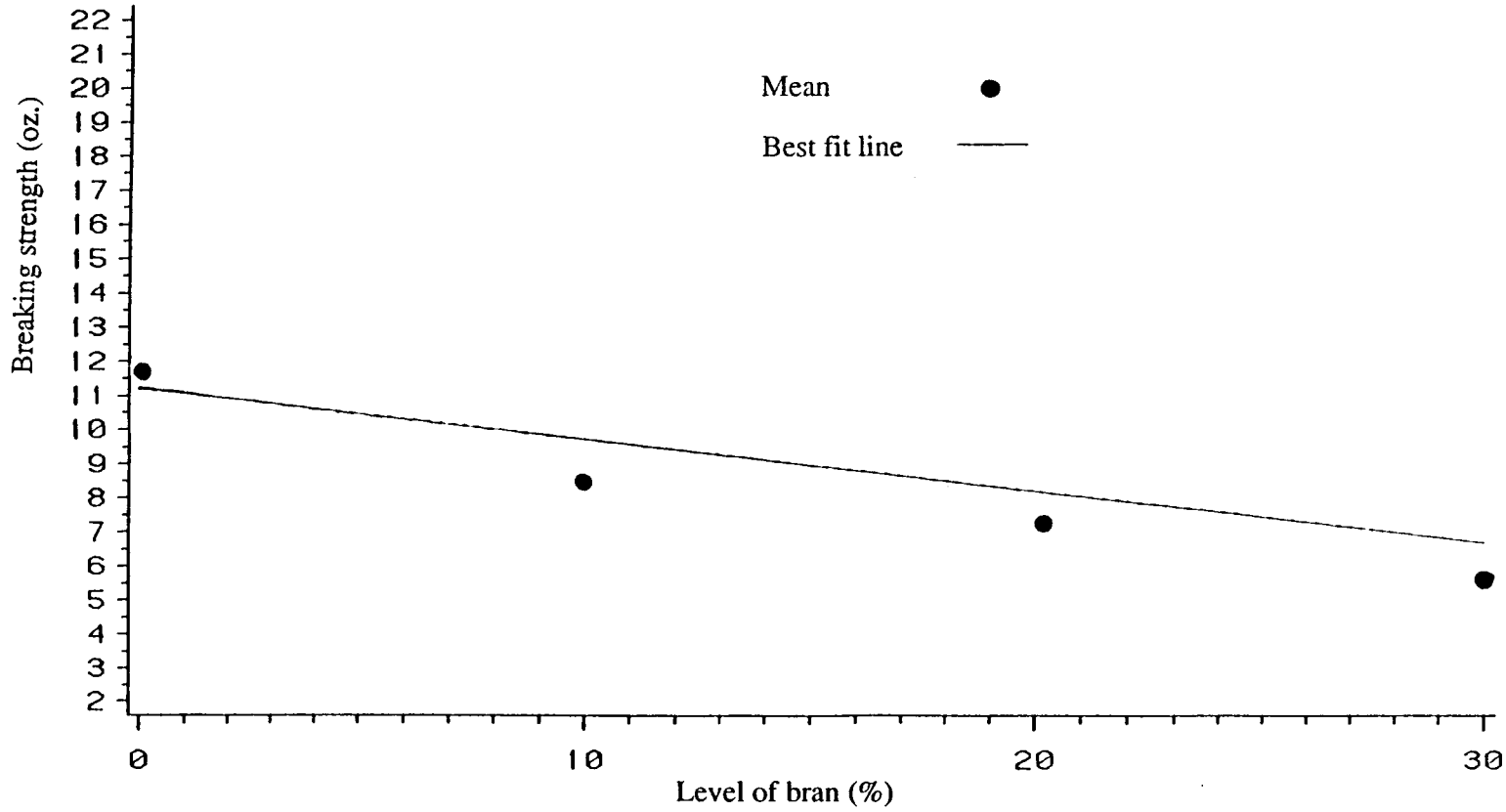


Figure 1 - Breaking strength of crackers due to level effect.

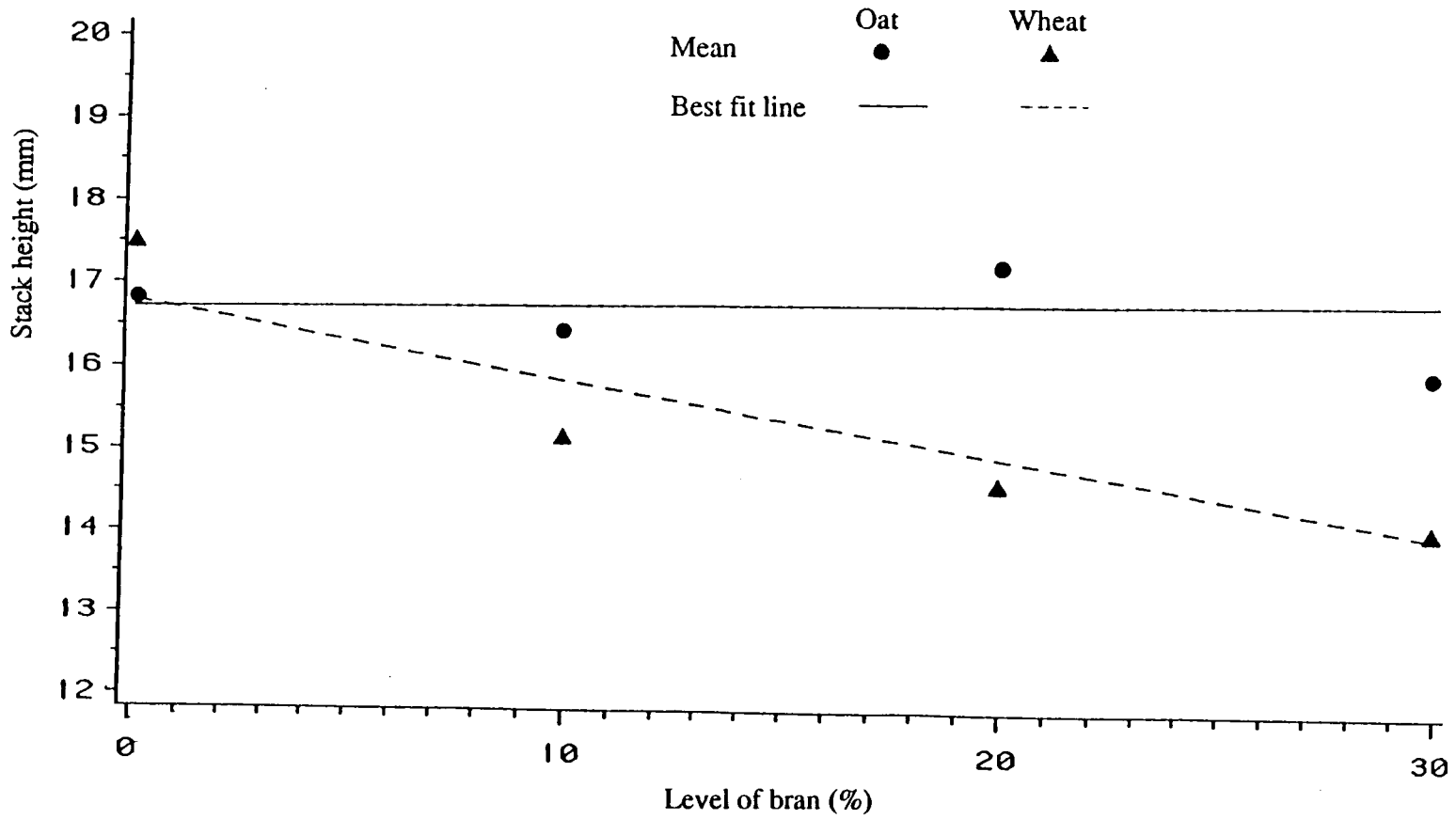


Figure 2 - Stack height of crackers due to interaction of level x type.

Table 4 - Analysis of variance for color measurement of crackers prepared with oat or wheat bran at four flour replacement levels, 0, 10, 20 and 30%

Source of Variation	df	Mean squares		
		Lightness	Redness	Yellowness
Total	31			
Block	7	6.38	1.66	0.20
Level	3	234.16***	5.31**	24.82***
Linear	1	697.36***	15.68***	73.00***
Quadratic	1	1.58	0.18	1.16**
Cubic	1	3.53	0.08	0.29
Type	1	335.00***	3.28	56.63***
Level x type	3	61.10**	0.59	10.89***
Linear x type	1	158.67***	0.42	27.97***
Quadratic x type	1	24.56	1.20	4.25***
Cubic x type	1	0.07	0.16	0.46
Error	17	7.98	1.11	0.13

**p < 0.01.

***p < 0.001.

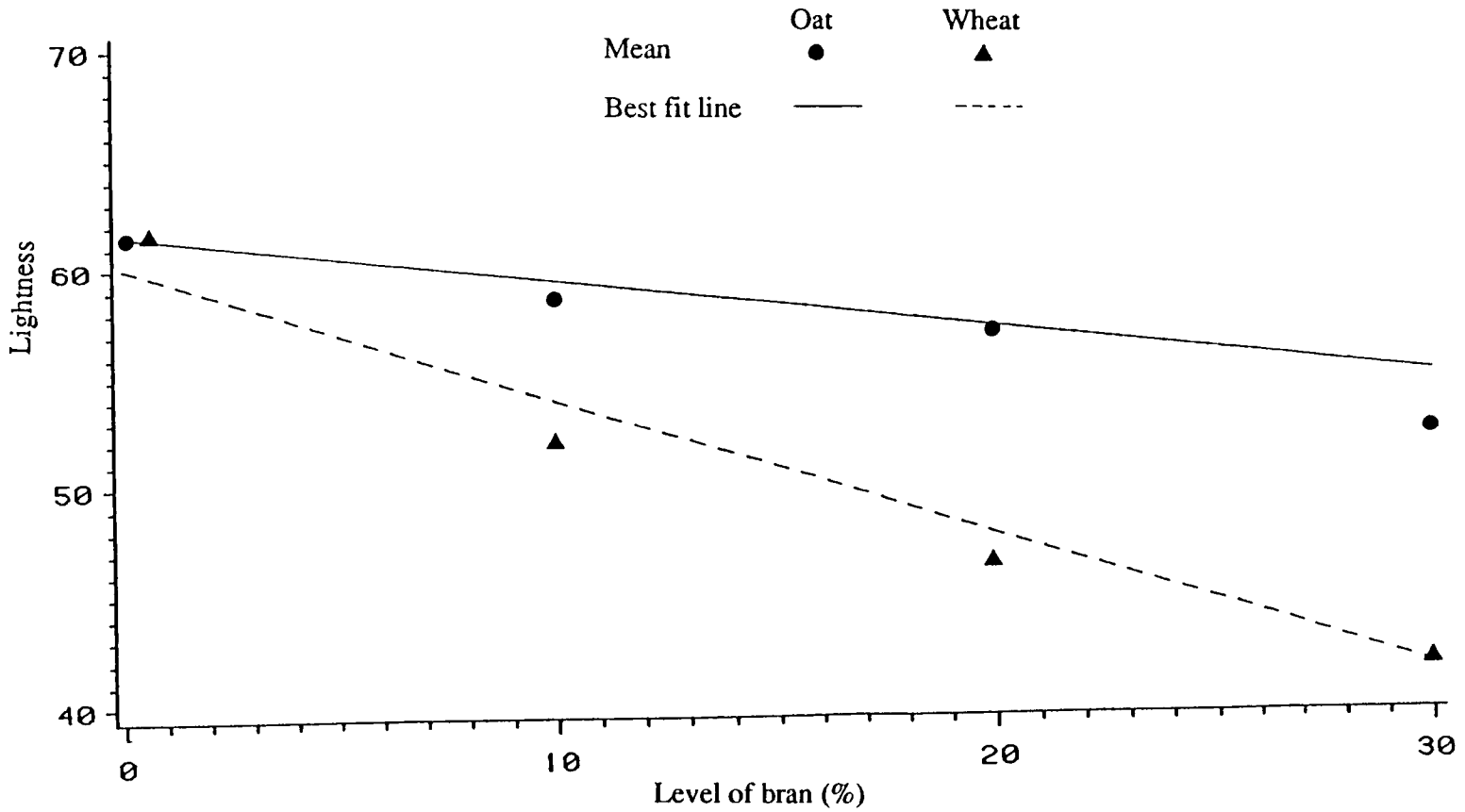


Figure 3 - Lightness of crackers due to interaction of level x type.

bran. Mean lightness values presented in Appendix G, Table A-4 indicate that wheat bran crackers were consistently darker in color than oat bran crackers as bran level increased. Other researchers have observed that cakes and cookies were consistently darker as fiber substitution increased (Vratanina and Zabik, 1978; Jeltema et al., 1983).

Level of bran substitution significantly influenced ($p<0.001$) redness of crackers (Table 4) but bran type did not have a significant effect. The relationship between bran level and redness was linear (Figure 4) with redness increasing as level of bran increased. Brockmole and Zabik (1976) found increases in redness as percentage of wheat bran increased at 4, 8, and 16% levels in layer cakes. Other researchers did not find significant redness differences in cookies due to bran substitution at 10, 20 and 30% levels or type of bran (Vratanina and Zabik, 1978). Visually wheat bran appears more red than oat bran so it is surprising that bran type did not significantly influence redness of crackers.

An interaction of bran level x bran type significantly affected ($p< 0.001$) yellowness in crackers (Table 4) and a quadratic function was present ($p<0.001$). Figure 5 illustrates an inverse quadratic treatment effect upon yellowness for both types of bran. Yellowness decreased as level of bran increased although the change was slight for oat bran. Yellowness appeared to be more constant for all levels of oat bran but differences in yellowness were pronounced in wheat bran crackers. Other researchers have found decreased yellowness in bakery products with wheat bran substitution (Shafer and Zabik, 1978; Vratanina and Zabik, 1978); little research has been conducted on oat bran in bakery products.

Analysis of cracker color attributes revealed that oat bran produced a more consistent cracker color, but wheat bran produced more dramatic changes in color. Oat bran may have potential in bakery products in which color is already acceptable and needs to be maintained while fiber content is increased. However, wheat bran provides a broader range of color in bakery products if consumers perceive a darker color as more nutritious and desirable in specific bakery products.

III. Estimation of Total Dietary Fiber

Estimations of total dietary fiber for selected cracker treatments are located in Table 5. Both types of bran, oat and wheat, were analyzed as well as two levels of bran crackers, 10% and 20%. The lower levels of bran substitution were tested because they were more likely to be accepted by consumers. A recent listing of the dietary fiber content of specific

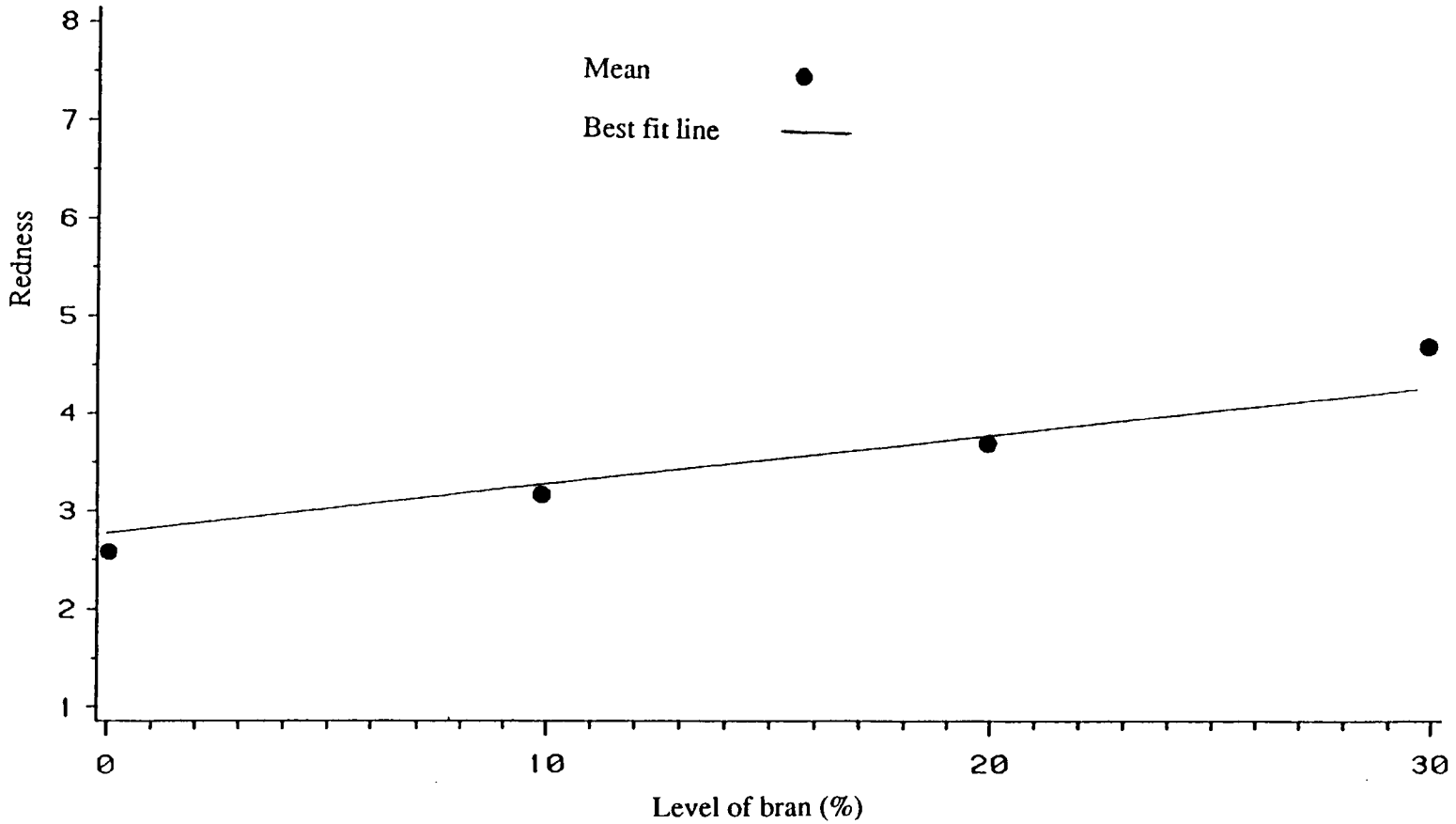


Figure 4 - Redness of crackers due to level effect.

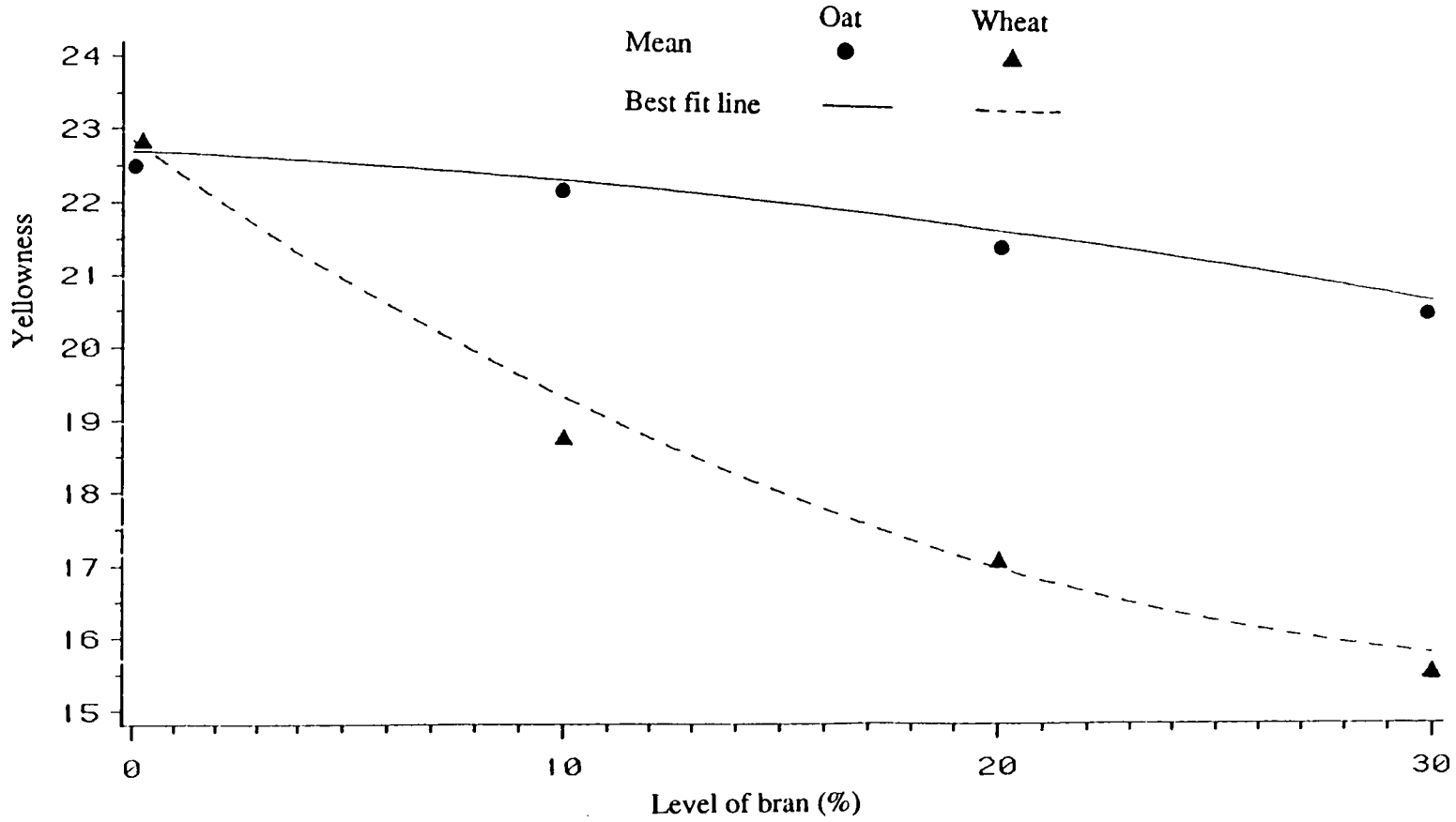


Figure 5 - Yellowness of crackers due to interaction of level x type.

Table 5 - Estimates [a] of total dietary fiber for selected cracker treatments and raw bran

Treatment	Total dietary fiber [b]
Oat bran crackers	
10%	8.48
20%	18.51
Wheat bran crackers	
10%	15.02
20%	18.37
Raw bran	
Oat	21.27
Wheat	48.99

[a] Estimates of 4 samples for each treatment.

[b] Reported as g /100g of cracker sample; one cracker ~ 3.2 g.

cereal products was published by the American Association of Cereal Chemists (Caldwell, 1987). Total dietary fiber was determined by AOAC/Prosky/AACC 32-5 or an equivalent method (Prosky, 1985). Total dietary fiber of oat bran from National Oats Co. was 22 g/100 g and Dietfiber B® wheat bran from Lauhoff Grain Co. was 44 g/100 g (Caldwell, 1987). Comparison of dietary fiber estimates of both brans to literature values revealed similar results. Total dietary fiber estimate for oat bran was very close to published values. Total dietary fiber estimate for wheat bran was slightly higher than the literature value. Differences may be due to laboratory technique, type of equipment used in analysis, or number of samples. Variability of the samples was not analyzed in this study. Further study on the total dietary fiber content of the crackers would include analysis of a larger number of samples and evaluation of sample variablity.

Comparison of dietary fiber estimates for cracker treatments revealed greater differences between oat and wheat bran crackers at the 10% levels but not at 20%. Fiber content differences between oat and wheat bran at 10% were probably due to less total dietary fiber of oat bran before incorporation into crackers. Lack of differences between oat and wheat at 20% levels may be due to saturation of the enzymes used for analysis. Twenty percent wheat bran crackers may have contained more total dietary fiber than estimated but perhaps larger amounts of enzymes were needed. At higher bran substitution levels, enzymes used for analysis may become more saturated and possibly larger amounts of enzymes may be required.

IV. Sensory Analysis

Initially, crackers were to be evaluated for color, crispness, cohesiveness, flavor, and aftertaste. Few judges gave responses to aftertaste, therefore it was dropped from the study because it was not a significant cracker attribute. As mentioned previously the mathematical model for analysis of sensory data included main effects of block, bran level, and bran type as well as interaction of level x type. Judge main effect was not included in the model because data were taken from the mean evaluations of six trained judges with relatively similar scores.

An interaction of level x type significantly affected ($p<0.001$) sensory perception of color (Table 6) and a quadratic function was present ($p<0.01$). Judges evaluated cracker color on a scale of light to dark. The quadratic effect of level x type on color is presented in Figure 6. Sensory panelists perceived wheat bran crackers to be darker as level of bran

Table 6 - Analysis of variance for sensory attributes of crackers prepared with oat or wheat bran at four flour replacement levels, 0, 10, 20 and 30%

Source of Variation	df	Mean squares			
		Color	Crispness	Cohesiveness	Flavor
Total	31				
Block	7	156.23	231.00	205.54	119.14
Level	3	4598.28***	524.48	229.60	2136.98***
Linear	1	13498.61***	1.95	117.24	6341.73***
Quadratic	1	269.79	1147.70	175.14	55.82
Cubic	1	26.42	423.78	396.43	13.41
Type	1	14176.62***	14.83	866.00	4648.17***
Level x type	3	2995.70***	1534.84	631.50	949.82***
Linear x type	1	8125.89***	3028.40*	1457.42*	1918.42***
Quadratic x type	1	761.80**	1153.60	47.94	791.02**
Cubic x type	1	99.40	422.50	389.15	140.02
Error	17	86.29	650.56	232.06	66.55

*$p < 0.05$

**$p < 0.01$.

***$p < 0.001$.

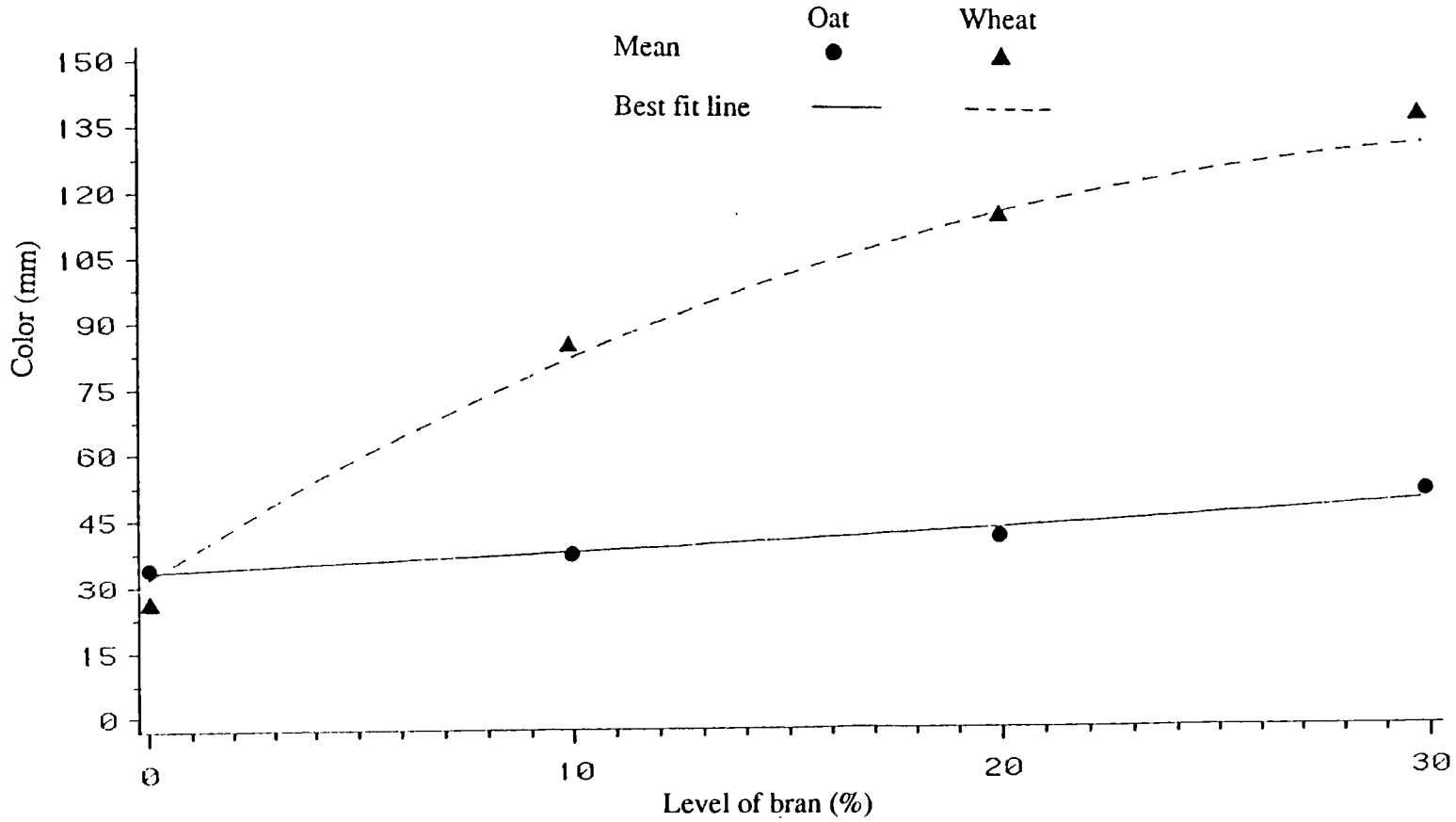


Figure 6 - Sensory analysis of cracker color due to interaction of level x type.

increased but differences seemed to be less perceptible at the 20 and 30% bran levels. Color became slightly darker with increasing level of bran in the oat bran crackers and the function may be quadratic also (Figure 6). These sensory results correspond with instrumental measurement of color in which level x type interaction significantly ($p<0.001$) affected lightness of crackers (Table 4, page 28). In both sensory and physical analysis of color the degree of color change was gradual for oat bran but more pronounced for wheat bran. Other researchers have reported similar color changes in fiber enriched bakery products with wheat bran producing greater color changes (Shafer and Zabik, 1978).

A level x type interaction with a linear function significantly affected ($p<0.05$) sensory perception of crispness (Table 6). However, graphic representation of crispness (Figure 7) indicates that significant differences were not present because the slope of the line was zero and the same for both bran types. The magnitude of standard errors (Appendix G, Table A-5) indicates that all means for crispness overlap. Crispness differences among treatments may not have been present or perhaps only slight differences existed. Experimental error was high (Table 6) possibly indicating that cracker treatments were inconsistent in textural quality due to humidity as discussed earlier in conjunction with water activity.

An interaction of level x type with a linear function significantly influenced ($p<0.05$) sensory evaluation of cohesiveness as observed in Table 6. The linear relationship between treatment and cohesiveness is depicted in Figure 8. The slopes of the lines for both types of bran appear to be relatively close to zero slope; therefore, sensory differences in cohesiveness may not be great. Wheat bran had a positive linear slope indicating crackers increased in cohesiveness while oat bran had a negative linear slope indicating crackers were less cohesive as bran level rose. Mean values presented in Appendix G, Table A-5 support the same trend in cohesiveness as shown by the graph. Judges evaluated cohesiveness using anchor extremes of slightly cohesive to very cohesive. In comparing sensory and physical data it is surprising that judges found wheat bran crackers to be more cohesive than oat bran crackers because stack height and breaking strength values were lower for wheat bran crackers than oat bran crackers (Appendix G, Table A-3) which would indicate less structure and cohesiveness for wheat bran crackers. However, earlier researchers observed interference of oats with gluten development in loaf bread (Jones and Hutchinson, 1945). Cunningham et al. (1955) reported that oat proteins were claylike, noncohesive, and interrupted gluten structure which may explain why sensory panelists found oat bran crackers less cohesive than wheat bran crackers.

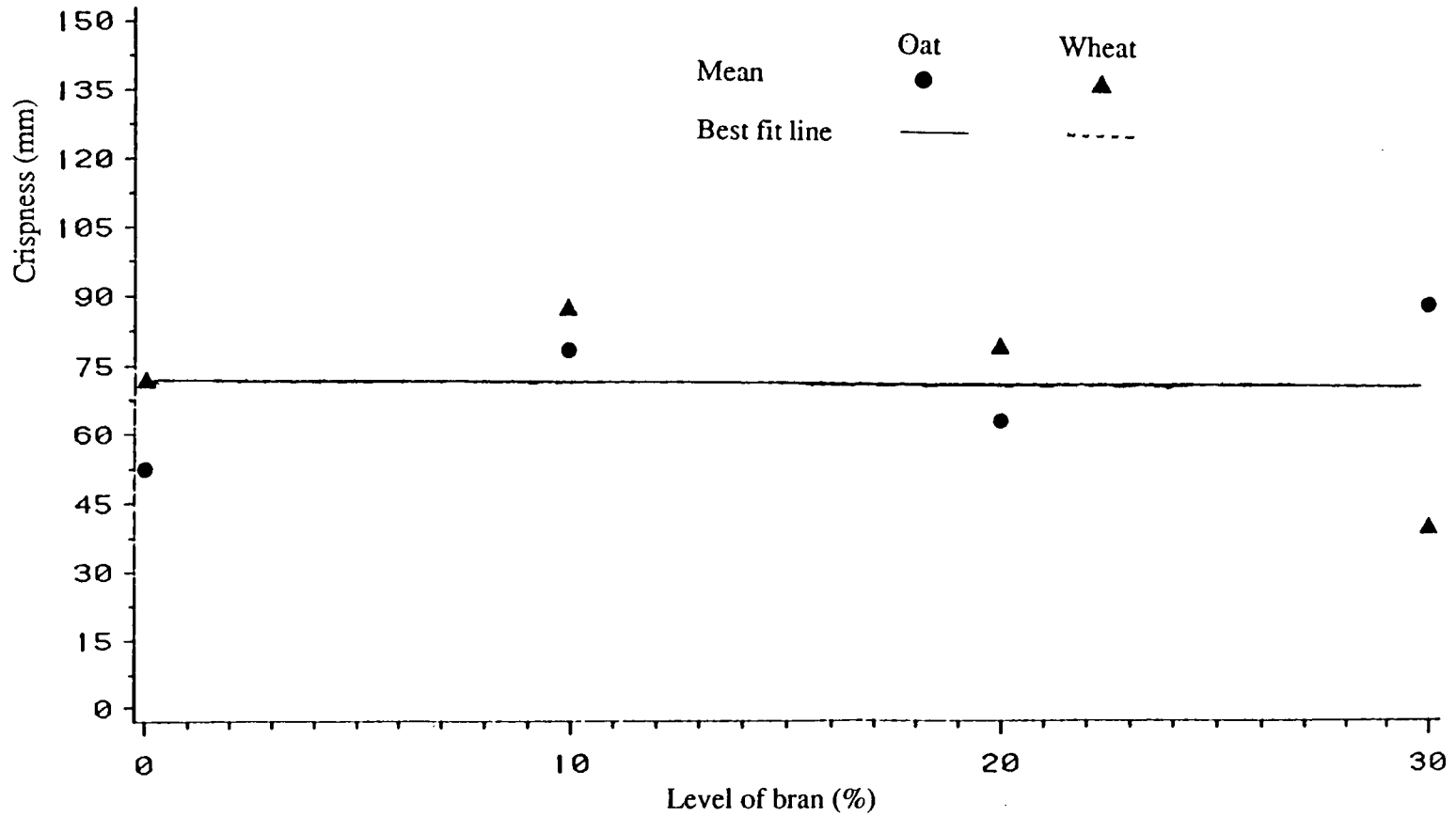


Figure 7 - Sensory analysis of cracker crispness.

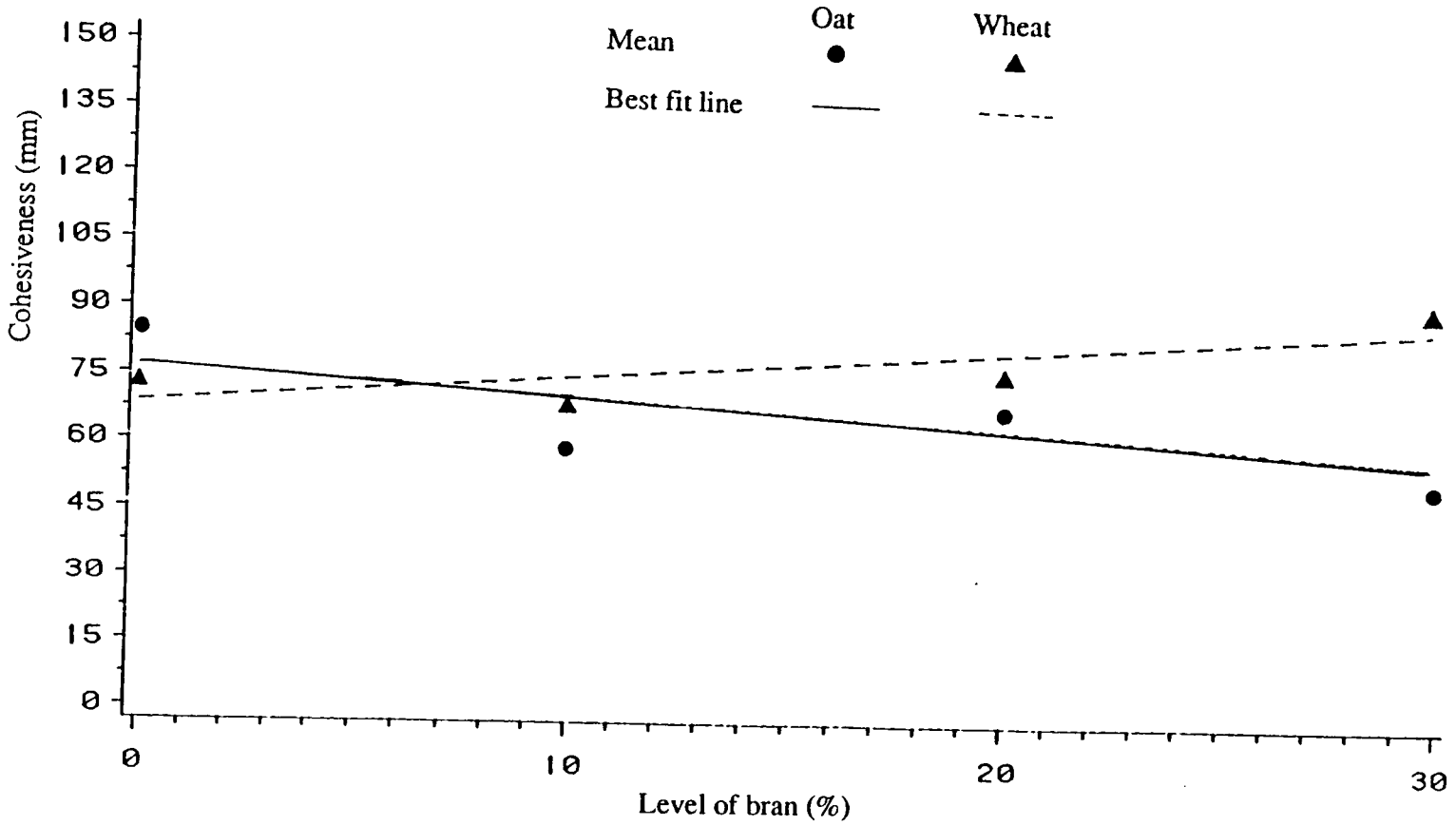


Figure 8 - Sensory analysis of cracker cohesiveness due to level x type interaction.

An interaction of bran level x bran type was significant ($p<0.001$) for cereal flavor (Table 6, page 35). Judges found that cereal flavor intensity increased as oat or wheat bran level increased (Appendix G, Table A-5). Figure 9 graphically represents the quadratic relationship between treatment and cracker flavor. Changes in flavor occurred gradually and were slight for oat bran and more pronounced for wheat bran. As mentioned earlier, few judges found aftertaste prominent in the crackers.

Analysis of sensory properties of crackers revealed significant differences ($p<0.001$) due to treatment for color and flavor attributes. Sensory analysis of color corresponded well with physical measurement of cracker color. A level x type interaction was found to significantly affect ($p<0.05$) perception of crispness and cohesiveness in crackers. However, sensory analysis of crispness and cohesiveness did not appear to correspond with physical measurements of texture. Peleg (1983) reported difficulties in correlating sensory and physical evaluation of textural attributes of food. Problems may arise due to differences in sensitivity between instrumental analysis and sensory analysis. Instruments strictly measure physical attributes of food and measurements tend to be uniform. Sensory panelists evaluate texture through a variety of methods including physical and psychological.

V. Consumer Panel Evaluation

Analysis of consumer panel data revealed that there were no significant differences in preference or acceptability between 10% oat bran and 10% wheat bran crackers. Mean scores (Table 7) for preference (hedonic scale) were in the middle range of the scale at the slightly dislike end. Mean scores for acceptability (FACT scale) were low with panelists not willing to purchase this type of oat bran or wheat bran cracker if offered commercially.

Many panelists expressed comments about the cracker samples. Some of the frequent comments were that crackers lacked crispness and were bland in flavor. Improvement of crispness through alternative baking methods such as humidity controlled ovens may increase acceptability of crackers. Added seasonings may improve the flavor as well. Bran levels greater than 10% would not be acceptable until textural and flavor characteristics are improved.

Results of the consumer panel questionnaire are in Appendix F. Out of a total of 50 consumer panelists, 72% were female and 28% were male. The majority of panelists

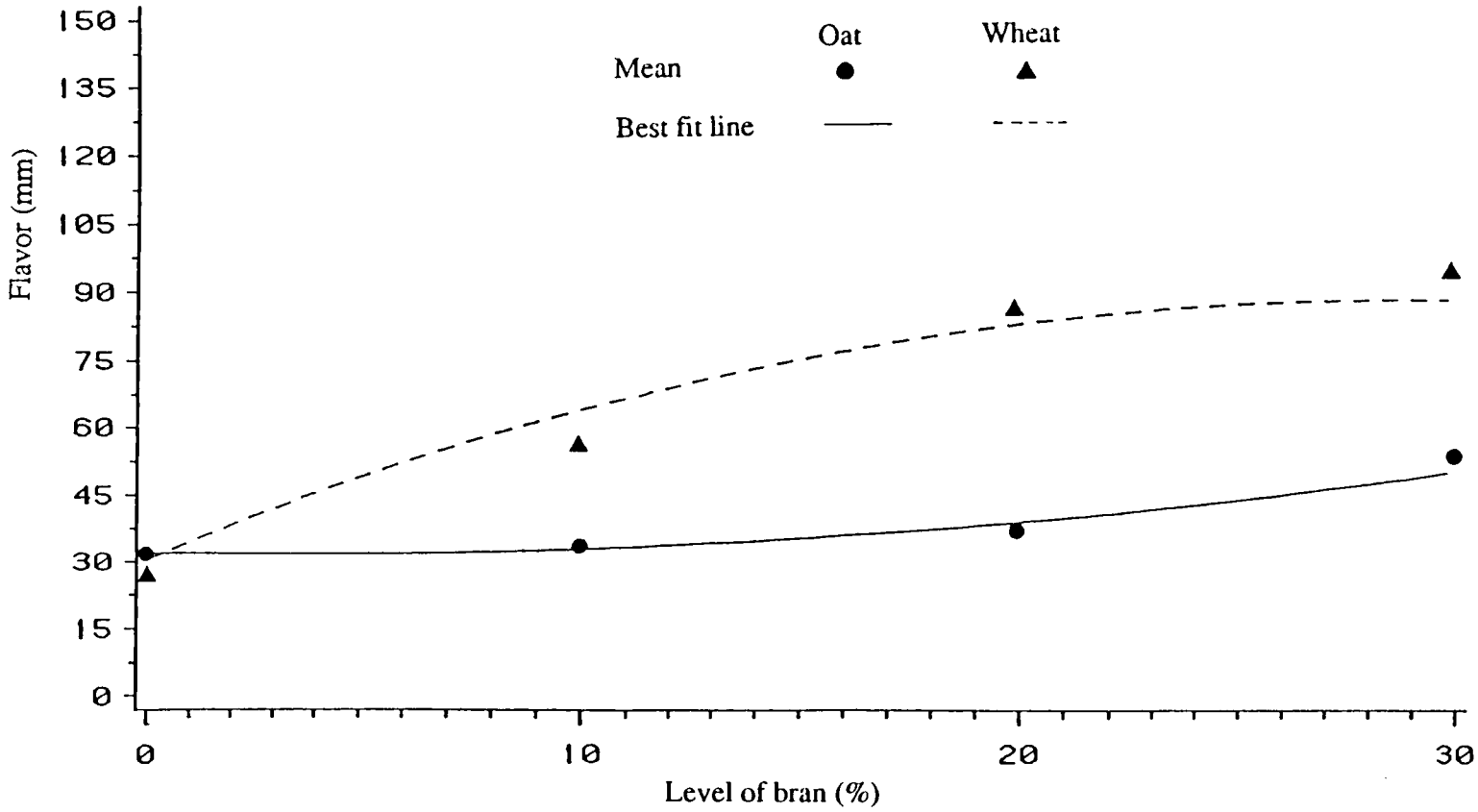


Figure 9 - Flavor of crackers due to interaction of level x type.

Table 7 - Hedonic and FACT scores[a,b] for crackers prepared with 10% oat or wheat bran

	Treatment	
Scale	Oat bran	Wheat bran
Hedonic[c]	4.36 ± 1.52	4.52 ± 1.50
FACT[d]	2.16 ± 1.35	2.34 ± 1.26

[a] Mean ± SD; no significant differences among means ($p>0.05$).

[b] Number of judges = 50.

[c] 1 = dislike extremely; 8 = like extremely.

[d] Food Action Rating Scale; 1 = I would never buy this; 6 = I would buy this often.

were between the ages of 18 and 34. Most of the panelists consumed crackers at least once a month and consumed crackers between meals. Fifty-six percent preferred whole grain crackers.

CHAPTER V

SUMMARY AND CONCLUSIONS

A study was conducted to investigate the effects of replacing flour with two types of bran, oat and wheat, at varying levels in snack crackers. Physical and sensory properties were measured and analyzed. Acceptability of the crackers was evaluated by a consumer panel.

Analysis of physical properties showed the water activity did not differ significantly among treatments. Water activity levels for most of the cracker variations were within zones at which textural quality begins to decline. Breaking strength, also indicative of cracker texture, was significantly affected ($p<0.01$) by bran level. Breaking strength of crackers decreased as level of bran increased indicating less structural resistance and possibly less crispness.

Standing height was affected significantly ($p<0.05$) by bran level and bran type. Standing height decreased as level of bran increased in wheat bran crackers. Standing height was more stable for oat bran crackers than wheat bran crackers as level of bran increased.

Physical measurement of color attributes, lightness, redness, and yellowness, revealed significant treatment effects. An interaction of level x type influenced cracker lightness significantly ($p<0.001$). Lightness decreased as bran level increased with the greatest change being observed in wheat bran crackers. Redness was significantly affected ($p<0.001$) by bran level. Redness gradually increased in crackers as bran level increased for both bran types. Yellowness was significantly influenced ($p<0.001$) by an interaction of level x type. Yellowness decreased as level of bran increased with the color change being more pronounced in wheat bran crackers. Overall, color was more constant in oat bran crackers than wheat bran crackers.

Fiber analysis of oat bran and wheat bran revealed estimates close to reported literature values; oat bran contained approximately 21.21 g/100 g and wheat bran contained 48.99 g/100 g. Fiber analysis of crackers made with 10 and 20% bran levels revealed the total dietary fiber content ranged from 8.48 to 18.51 g/100 g. Differences in fiber content between oat bran and wheat bran crackers were seen at 10% levels but not at 20% levels.

A trained sensory panel found differences due to treatment for color, crispness, cohesiveness, and flavor. An interaction of level x type significantly affected ($p<0.001$)

sensory perception of color. Sensory panelists noted that wheat bran crackers became darker as level of bran increased but the oat bran crackers remained more constant for color. A level x type interaction significantly affected ($p<0.05$) panelists' perception of crispness and cohesiveness. However, crispness differences may have been slight because differences among treatments were not observed graphically. Wheat bran crackers were considered more cohesive than oat bran crackers as bran level increased. An interaction of level x type significantly affected ($p<0.001$) cereal flavor; intensity increased gradually as bran substitution increased. Flavor was more constant in oat bran crackers.

A 50-member consumer panel found no significant differences in preference or acceptability between 10% oat bran and 10% wheat bran crackers. Scores for acceptability and preference tended to be low for both crackers.

The results of this investigation indicate that snack crackers are potential carriers of oat bran or wheat bran in a nutritionally-enhanced product. Although textural quality of crackers tended to decrease as bran level rose, altered baking conditions more similar to procedures used in cracker industries may improve cracker crispness and acceptability. Use of equipment for rolling and cutting cracker dough as well as band ovens which tightly control baking temperature and humidity (Matz, 1968) would help produce crackers of optimal textural quality. Oat bran crackers were more consistent in physical and sensory attributes than wheat bran crackers. The lowest level of bran substitution, 10%, produced crackers that were more acceptable in sensory attributes than higher levels of bran substitution. Bran substitution levels higher than 20% may not be acceptable to consumers due to greater intensity of cereal flavor and cracker color.

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APPENDIXES

APPENDIX A

Total Dietary Fiber Analysis

Principle of the assay is measurement of soluble and insoluble fibers through enzymatic digestion of starch and protein and gravimetric measurement of fiber. The procedure used in analysis was AOAC/Prosky/AACC 35-2 (Prosky et al., 1985).

Reagents

1. Phosphate buffer, 0.05 M, pH 6.0: Dissolve 0.875 g of Na_2HPO_4, anhydrous (Sigma Chemical Co., St. Louis, MO) and 5.26 g of NaH_2PO_4, anhydrous (Sigma) in 700 ml of distilled water. Dilute to one liter with water. Check pH and adjust if necessary with either NaOH or H_3PO_4.
2. Alpha-amylase (Sigma).
3. Sodium hydroxide solution, 0.171 N: Dilute 171 ml of 1.0 N NaOH solution (Sigma) to 1-l with water in a one liter volumetric flask.
4. Protease (Sigma).
5. Phosphoric Acid Solution, 0.205 M: Dilute 205 ml of 1.0 M H_3PO_4 solution (Sigma) to 1-l with distilled water in a one liter volumetric flask.
6. Amyloglucosidase (Sigma).
7. 95% Ethanol (v/v): technical grade.
8. 78% Ethanol: place 207 ml of water into one liter volumetric flask. Dilute to volume with 95% ethanol. Mix and bring to volume again with 95% ethanol if necessary. Mix.
9. Celite ®, Acid washed (Sigma).

Procedure

Samples were analyzed for fiber according to the following steps and blanks were run also to measure any contributions from reagents to residue. Four 1 g cracker samples from each cracker treatment to be analyzed were weighed to 0.1 mg on a Mettler AE 160 analytical balance (Mettler Instrumente AG, Greifensee, Switzerland). Samples were placed in plastic beakers manufactured by Tecator AB (Hoganas, Sweden) for use with the Fibertec System E. Fifty ml of phosphate buffer and 0.2 ml alpha-amylase enzyme were added and mixed well. Beakers were covered with aluminum foil, placed in a boiling water

bath, and incubated at 95°C for 30 min with periodic agitation. Solutions were cooled to room temperature and pH adjusted to 7.5 ± 0.1 with 10 ml of sodium hydroxide. To each solution was added 0.1 ml of Protease. Beakers were covered with aluminum foil and incubated at 60°C for 30 min with continuous agitation. Solutions were cooled to room temperature and pH adjusted to 4.5 ± 0.2 with 10 ml of phosphoric acid solution. Amyloglucosidase (0.3 ml) was added to each solution. Beakers were covered with aluminum foil and incubated at 60°C for 30 min with continuous agitation. Ethanol (95% concentration) preheated to 60°C was added in 280 ml volumes to each solution.

Solutions were allowed to precipitate at room temperature (25° C) for 5 days. Normally, 12 hrs are sufficient for precipitation of solutions, but due to limited access to the Fibertec, an interval of 5 days was used. Samples were filtered on the Fibertec System E manufactured by Tecator AB (Hoganas, Sweden). A filter aid, acid washed Celite® (0.5 g), was added to the crucibles and weighed prior to filtration. Residue collected in the crucibles was washed with 60 ml of 78% ethanol and 20 ml of 95% ethanol. Crucibles were dried overnight in 70° C vacuum oven, cooled, and weighed to the nearest 0.1 mg.

Calculations

$$\text{Blank} = \text{Average Wt. of Blank Residues (mg)} - \left[\left(\frac{\text{Average \% Protein in Blank Residues} + \text{Average \% Ash in Blank Residues}}{100} \right) \times \text{Average Wt. of Blank Residues (mg)} \right]$$

$$\%\ \text{Total Dietary Fiber} = \frac{\text{Average Wt. of Sample Residues (mg)} - \left[\left(\text{Average \% Protein in Sample Residues} + \text{Average \% Ash in Sample Residues} \right) \times \text{Average Wt. of Sample Residues (mg)} \right] - \text{Blank}}{\text{Average Wt. of Samples (mg)}} \times 100$$

Kjeldahl Method for Protein Determination

Principle of the assay is conversion of nitrogen in a food sample into ammonium sulfate through a digestion process. Ammonium sulfate is treated with a strong base and heated in a distillation rack. The liberated ammonia is distilled and collected in boric acid. Boric acid solution is titrated with a standard acid and percent nitrogen is calculated from titration data.

Reagents

1. Sodium sulfate (J.T. Baker Chemical Co., Phillipsburg, NJ).
2. Concentrated sulfuric acid (Fisher Scientific Co., Fair Lawn, NJ).
3. Copper sulfate (Mallinckrodt Chemical Works, St. Louis, MO).
4. Saturated boric acid solution (Fisher).
5. Mixed indicator: 2 parts 0.2% methyl red was mixed with 1 part 0.2% methylene blue.
6. Saturated sodium hydroxide solution (Fisher).
7. Hydrochloric acid (Fisher): standardized 0.1906 N.

Procedure

Residue from two samples of each cracker treatment and two blanks were analyzed for protein using the Kjeldahl method. Residue samples were placed into an extraction flask along with the following reagents: 10.0 g of sodium sulfate, 25 ml of concentrated sulfuric acid, 0.3 g of copper sulfate, a Hengar crystal (Hengar Company, Philadelphia, PA), and a 5 x 5 cm piece of paraffin (American Scientific Products, McGaw Park, IL) and 3 glass beads. Samples and blanks were digested on the Kjeldahl digesting rack and allowed to cool under a hood and 200 ml of distilled water were added to each. Sixty-five ml of saturated sodium hydroxide solution was added slowly to the Kjeldahl flasks containing digested sample. Erlenmeyer flasks were prepared for each sample and blanks with 65 ml of saturated boric acid solution and 2 to 3 drops of mixed indicator. Ammonia from the digested samples was distilled into the solution of boric acid. The boric acid solutions containing ammonia were titrated with standardized hydrochloric acid of 0.1906 N. The conversion factor of 6.25 was used to calculate protein content of the samples.

Ashing

The residue from two samples of each cracker treatment and two blanks was ashed in crucibles for 5 hours at 525° C. Samples were cooled in dessicator and weighed to nearest 0.1 mg.

APPENDIX B

Sensory Attributes, Verbal Anchors and Procedures for Evaluation

Attribute	Anchors	Procedure
Color	very pale-very dark	Before tasting, visually judge color of sample by mental comparison to extremes for color.
Crispness	slightly crisp-very crisp	Before tasting, snap sample in half with fingers and note snappiness; bite sample with incisors and evaluate crispness on first bite.
Cohesiveness	slightly cohesive-very cohesive	During mastication judge the amount of small particles present in the mouth.
Cereal flavor	mild-strong	During mastication judge the intensity of flavor present.
Aftertaste	none-strong	After swallowing sample, note any residual flavors if present such as metallic, bitter, or salty.

Extremes for Attributes Evaluate by Trained Panelist

Attribute	Lower Extreme	Brand	Higher Extreme	Brand
Color	saltine cracker	Kroger	high fiber cracker	Wasa Fiberplus
Crispness	stale saltine cracker[a]	Kroger	fresh saltine cracker	Kroger
Cohesiveness	whole wheat cracker	Carr's	graham cracker	Kroger
Cereal flavor	saltine cracker	Kroger	high fiber cracker	Wasa Fiberplus

[a]Crackers were steamed for 2 min in a covered steam basket.

Training Schedule for Panelist

Day	Activity
1	Project explained to panelists. Consent form (Appendix B) given to panelist and signed. Scorecard introduced to panelist and verbal extremes discussed. Anchors representing verbal extremes were presented to panelists for sampling and discussion. Panelists were presented with two laboratory crackers and practiced evaluating with scorecard.
2	Four laboratory crackers presented and evaluated using scorecard. Discussion followed and scorecard was adjusted according to panelists' input.
3	Four laboratory crackers presented to panelist and evaluated. Discussion followed and scorecard was adjusted according to panelists' input. Four more samples presented to panelists for further practice.
4	Anchors representing verbal extremes for cohesiveness and crispness reviewed and discussed with panelists. Four samples evaluated by each panelist.
5	Panelists practiced evaluating 4 cracker samples. Data from training sessions analyzed statistically to determine if panelists were competent and ready to begin the study.

Statement of Informed Consent

1. I have volunteered to be a member of a taste panel to test the addition of cereal brans in cracker systems. The research will be conducted by a graduate student and faculty member in the Department of Nutrition and Food Science at the University of Tennessee.

2. The purpose of this research is to evaluate differences in physical and sensory properties of crackers containing bran. This requires taste-testing of the products to evaluate sensory properties. Food-grade materials will be used. Standard methods of preparation of food samples will be followed. We anticipate no risk involved in tasting samples.

3. I have had the opportunity to discuss the procedure with the investigator and to ask questions.

4. I understand this testing involves multiple panel sessions and will require my participation for three weeks.

5. I understand that my performance as an individual will be treated as research data and will in no way be associated with me for other than identification purposes, thereby assuring confidentiality of my performance and responses.

6. I understand that I do not have to participate in this research, and that if I choose not to participate there will be no penalty. I further understand that I may withdraw my consent at any time without penalty.

7. If I have any questions concerning my rights as a research subject, injuries or emergencies resulting from my participation or any questions concerning this study, I understand that I can contact Jeannette Hitz.

I have read the above and signed this informed consent statement on

----------19----------

Signature----------

(PR/KSU 85)

APPENDIX C

Scorecard for Evaluating Crackers [a]

NAME:_____

DATE:_____

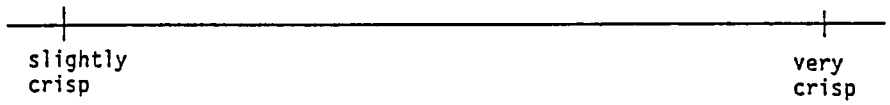
SAMPLE CODE:_____

1. Please evaluate the crackers using the attribute scales provided. Place a vertical line at the point on each scale that reflects your perception of each attribute for each cracker. Consider relation of sample to verbal anchors at end of scales.
2. Evaluate cracker samples in the order that scorecards are presented to you.
3. After evaluating a sample, place scorecard in brown envelope and reclose sample container. Use one scorecard per sample and completely evaluate all attributes for each sample before proceeding to the next. Do not compare samples.
4. Identify character of aftertaste (if present).
5. Write comments on the back of scorecard.
6. Rinse with water between samples.

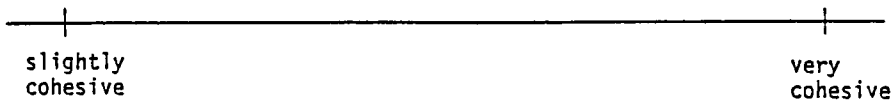
Color



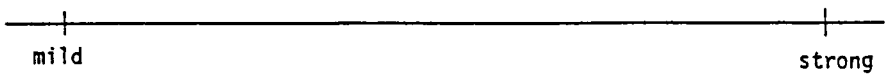
Crispness



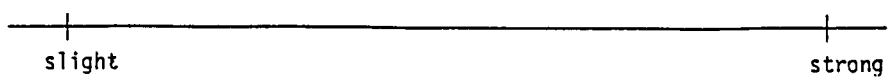
Cohesiveness



Cereal Flavor



Non-cereal Aftertaste (if any): _____



[a]On original, lines were 150mm in length.

APPENDIX D

THE UNIVERSITY OF TENNESSEE
KNOXVILLE

TO: College of Human Ecology Faculty, Graduate Students, and Staff

FROM: Jeannette Hitz, Graduate Student, NFS
Dr. Patricia Redlinger, Assistant Professor, NFS

DATE: August 5, 1987

RE: Volunteers for a Sensory Evaluation Panel

College of Human Ecology

Nutrition and Food Science

We are conducting a research project on the sensory characteristics of high fiber crackers and are looking for 50 volunteers to help with Phase II of the project. On Monday, August 24, a sensory evaluation panel will be conducted in the Sensory Lab (Room 16 of the Jesse Harris Building). Volunteers will be asked to complete a short questionnaire on their use of snack crackers and to taste two samples of crackers.

Testing will take place from 1:30 to 4:30 p.m. If you are willing to participate, please indicate the times that you would be available on the 24th and return the form to Jeannette Hitz, NFS Department. Include your campus phone number so that you can be notified of the time that you should come.

Your participation in this project would be greatly appreciated.

Thank you.

1215 West Cumberland Avenue, Room 229 / Knoxville, Tennessee, 37996-1900 / (615) 974-5445, 974-3491

Please return this form to Jeannette Hitz, NFS Department by August 14. You may put it in my mailbox across from room 229 or send it campus mail to NFS Department, room 229, Jesse Harris Building.

Name:_____

Campus address_____

_____

Campus phone_____

Please check all possible times that you could come on Monday, August 24. The test will take no longer than 20 minutes.

1:30 p.m._____

2:00 p.m._____

2:30 p.m._____

3:00 p.m._____

3:30 p.m._____

4:00 p.m._____

4:30 p.m._____

APPENDIX E

THANK YOU FOR AGREEING TO PARTICIPATE

IN THIS SENSORY EVALUATION STUDY

You will receive one set of cracker samples to test today. The scorecard is followed by a short questionnaire for you to answer. Please test the samples in the order given and rinse with water between samples. Do not retaste samples.

Jeannette Hitz
NFS Graduate Student

Panelist number_____

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

Cracker Preference Scorecard

Please indicate your preference for each cracker sample by checking the term that best describes your feeling toward the sample. Taste each cracker in the order given. Rinse with water between samples.

	Sample:	Sample:
	_____	_____
Like extremely	_____	_____
Like very much	_____	_____
Like moderately	_____	_____
Like slightly	_____	_____
Dislike slightly	_____	_____
Dislike moderately	_____	_____
Dislike very much	_____	_____
Dislike extremely	_____	_____

Please check the appropriate comment for each cracker sample.

I would buy this often	_____	_____
I would frequently buy this	_____	_____
I like this and would buy it now and then	_____	_____
I don't like this but would buy it occasionally	_____	_____
I would hardly ever buy this	_____	_____
I would never buy this	_____	_____

APPENDIX F

Panelist Questionnaire

Sex:

28% Male
72% Female

Age:

0 Less than 18 years
30% 18-24 years
36% 25-34 years
26% 35-44 years
8% Over 45 years

How often do you eat crackers?

44% Several times a week
40% Several times a month
16% Several times a year
0 Never

When do you consume crackers?

28% With meals mainly
71% Between meals mainly

What type of crackers do you prefer?

30% Plain crackers
56% Whole wheat or whole grain crackers
16% Highly flavored crackers such as cheese or bacon flavor

Have you ever made or eaten homemade crackers?

24% Yes
76% No

APPENDIX G

Table A-1 - Least squares means and standard errors for physical measurements for crackers prepared with oat or wheat bran at four flour replacement levels, 0, 10, 20, and 30%

Type	Level %	Physical measurements		
		Water activity [a]	Breaking strength [b]	Standing height [c]
Oat	0	0.40 ± 0.05	11.96 ± 1.36	16.93 ± 0.66
	10	0.34 ± 0.05	9.02 ± 1.36	16.56 ± 0.66
	20	0.36 ± 0.05	8.19 ± 1.36	17.32 ± 0.66
	30	0.36 ± 0.05	6.88 ± 1.36	16.18 ± 0.66
Wheat	0	0.39 ± 0.05	12.10 ± 1.36	17.51 ± 0.66
	10	0.31 ± 0.05	8.07 ± 1.36	15.15 ± 0.66
	20	0.35 ± 0.05	8.17 ± 1.36	14.74 ± 0.66
	30	0.38 ± 0.05	6.02 ± 1.36	14.36 ± 0.66

[a] Measurements made by a hygroline recorder and expressed as water activity; based on 4 replications with 2 samples per treatment for total of 8 observations/mean.

[b] Measurements made by a Bailey shortometer and expressed as force in ounces; based on 4 replications with 10 samples per treatment for total of 40 observations/mean.

[c] Measurements made by stacking 3 uniform crackers and expressed in mm; based on 4 replications with 3 samples per treatment for total of 12 observations/mean.

Table A-2 - Least squares means[a] for physical measurements for crackers prepared with four levels of bran when all types were pooled

	Physical measurements		
Bran level %	Water activity[b]	Breaking strength[c]	Standing height[d]
0	0.39 ± 0.04	12.03 ± 0.96	17.22 ± 0.46
10	0.32 ± 0.04	8.55 ± 0.96	15.85 ± 0.46
20	0.36 ± 0.04	8.18 ± 0.96	16.03 ± 0.46
30	0.37 ± 0.04	6.45 ± 0.96	15.27 ± 0.46

[a] Least squares means and standard errors.

[b] Measurements made by a hygroline recorder and expressed as water activity; based on 4 replications with 2 samples and 2 bran types for total of 16 observations / mean.

[c] Measurements made by a Bailey shortometer and expressed as force in ounces; based on 4 replications with 10 samples and 2 bran types for total of 80 observations / mean.

[d] Measurements made by stacking 3 uniform crackers and expressed in mm; based on 4 replications with 3 samples and 2 bran types for total of 24 observations / mean.

Table A-3 - Least-squares means[a] for physical measurements for crackers prepared with four levels of bran when all levels were pooled

	Physical measurements		
Bran type	Water activity [b]	Breaking strength [c]	Stack height [d]
Oat	0.36 ± 0.03	9.01 ± 0.68	16.75 ± 0.33
Wheat	0.36 ± 0.03	8.59 ± 0.68	15.44 ± 0.33

[a] Least-squares means and standard errors.

[b] Measurements made by a hygroline recorder and expressed as water activity; based on 4 replications with 2 samples and 4 bran levels for total of 32 observations / mean.

[c] Measurements made by a Bailey shortometer and expressed as force in ounces; based on 4 replications with 10 samples and 4 bran levels for total of 160 observations / mean.

[d] Measurements made by stacking 3 uniform crackers and measuring height expressed in mm; based on 4 replications with 3 samples and 4 bran levels for total of 48 observations/mean.

Table A-4 - Least-squares means[a] for color measurement for crackers prepared with oat or wheat bran at four flour replacement levels, 0, 10, 20, and 30%

Type	Level %	Color values		
		Lightness	Redness	Yellowness
Oat	0	61.63 ± 1.52	2.49 ± 0.57	22.56 ± 0.20
	10	59.58 ± 1.52	2.76 ± 0.57	22.29 ± 0.20
	20	58.04 ± 1.52	3.00 ± 0.57	21.56 ± 0.20
	30	53.51 ± 1.52	4.40 ± 0.57	20.70 ± 0.20
Wheat	0	61.98 ± 1.52	2.62 ± 0.57	22.95 ± 0.20
	10	52.53 ± 1.52	3.58 ± 0.57	18.99 ± 0.20
	20	46.64 ± 1.52	4.44 ± 0.57	17.25 ± 0.20
	30	41.72 ± 1.52	4.97 ± 0.57	15.63 ± 0.20

[a] Least-squares means and standard errors; based on 4 replications with 3 samples per treatment for total of 12 observations/mean.

Table A-5 - Least squares means [a] for sensory attributes [b] for crackers prepared with four levels of oat or wheat bran

Type	Level %	Sensory attributes			
		Color	Crispness	Cohesiveness	Flavor
Oat	0	34.30 ± 5.02	53.62 ± 13.77	83.33 ± 8.23	30.44 ± 4.40
	10	35.00 ± 5.02	78.61 ± 13.77	58.78 ± 8.23	33.83 ± 4.40
	20	43.43 ± 5.02	66.70 ± 13.77	70.99 ± 8.23	36.58 ± 4.40
	30	50.24 ± 5.02	88.05 ± 13.77	52.35 ± 8.23	53.76 ± 4.40
Wheat	0	26.94 ± 5.02	71.63 ± 13.77	74.59 ± 8.23	29.79 ± 4.40
	10	83.88 ± 5.02	87.39 ± 13.77	72.31 ± 8.23	58.41 ± 4.40
	20	111.28 ± 5.02	78.80 ± 13.77	76.59 ± 8.23	87.56 ± 4.40
	30	135.29 ± 5.02	42.88 ± 13.77	90.01 ± 8.23	90.19 ± 4.40

[a] Least-squares means and standard errors for 4 replications; number of judges = 6.

[b] 10 = very pale, slightly crisp, slightly crisp, slightly cohesive, mild; 150 = very dark, very crisp, very cohesive, strong.

VITA

Jeannette Louise Hitz was born in Atlanta, Georgia, on December 6, 1958. She attended Henderson Mill Elementary and Henderson High School, both in the Atlanta area. In 1977, she began her college career at North Georgia College in Dahlonega, Georgia. In 1978, she entered Georgia State University in Atlanta, and graduated cum laude in 1981 with a Bachelor of Science degree in Community Health Nutrition. From 1981 to 1985, she worked as a clinical dietitian at Forsyth Memorial Hospital in Winston-Salem, North Carolina. In September 1985, she accepted a teaching assistantship at the University of Tennessee, Knoxville, and began working on a Master of Science degree in Food Science. She received the degree in March 1988.

The author is a registered dietitian and a member of the American Dietetic Association, Omicron Nu, and the Institute of Food Technologists.