BRAN AND MIDDLINGS AS A SOURCE OF DIETARY FIBER IN LAYER CAKES

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
CANDACE LYNNE RAJCHEL
1975

ABSTRACT

BRAN AND MIDDLINGS AS A
SOURCE OF DIETARY FIBER
IN LAYER CAKES

By

Candace Lynne Rajchel

Medical studies have recently indicated that a relationship exists between a number of diseases and a lack of dietary fiber in the diet. In an attempt to increase the level of dietary fiber intake white layer cakes were prepared with seven substitution levels of bran and middlings for both 60 and 70% extraction flours. Substitution levels included 4, 8, and 16% bran, 12% midds bleached or unbleached, and 16% bran plus 12% midds bleached or unbleached. Flavored layer cakes including nut, spice, banana, and chocolate, were then prepared using substitution levels of 16% bran, 12% unbleached midds, and 16% bran plus 12% unbleached midds for a 70% extraction flour. In order to determine substitution levels consistent with high quality the white cake batter and all cakes were evaluated by both objective and subjective measurements.

The results of this study indicate that bran and midds may be successfully substituted for flour in the layer cake system. The batter viscosity increased as did the cake volumes with increasing substitution levels of fiber for flour

in the white cakes. Substitution of fiber in the white cake formula resulted in increased tenderness and the color scores of both the white batter and cake were affected in that yellowness and redness increased as lightness decreased. The quality characteristics of specific gravity, pH, symmetry, uniformity, shrinkage, moisture, and compressibility, as well as sensory scores, were not adversely affected by fiber substitutions in the white cake formula.

On the whole, the quality of the flavored cakes was not adversely affected by substitutions of fiber in the cake formulas for either the objective or subjective measurements. All sensory scores were 7 or better on a 10-point scale for all characteristics evaluated.

The fact that so few cake characteristics were affected by a fiber for flour substitution in the cake formula indicates that such substitutions may become a feasible method of increasing dietary fiber levels in the diet.

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Food Science and Human Nutrition

1975

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Dr. Mary Ellen Zabik for her guidance and help throughout the course of my graduate study and especially during the preparation of this manuscript.

I want to thank Mr. John Donelson and the USDA Soft Wheat Quality Research Laboratory in Wooster, Ohio for their help in the analysis of the flours. In addition, I am grateful to Dr. Everett Everson, Dr. Kusum Patel, and Miss Jean McFadden for their review of this paper.

I am also grateful for the use of the equipment borrowed from the departments of Agricultural Engineering, Biochemistry, and Crop and Soil Science and for the ingredients donated by Mennel Mills, Gerber, and Seymour Foods.

Finally, I want to thank my parents for their constant encouragement and finanacial support which made it possible for me to obtain this degree and Mr. Dean Brockmole for his never-failing interest and help.

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INTRODUCTION

Although fiber has been recognized as an important component of animal feeds, it has long been considered an insignificant part of the human diet. Fiber was considered necessary exclusively for the relief of constipation. During the past decade, however, fiber has been studied extensively and recent advances in the knowledge of its chemistry in addition to numerous epidemiological observations have led to the belief that fiber plays an essential role in the intestine and in maintaining man's health.

Since the epidemiological evidence appears to point an incriminating finger at the lack of foods containing fiber in the diet, it is essential to examine the effects of fiber on intestinal content and behavior. Cowgill and Anderson (1932) found that the addition of fiber-containing foods to the diet increased fecal bulk and improved bowel habits. Dietary fiber has also been shown to shorten transit time (McCance et al., 1953), that is, the time it takes for a food to pass through the digestive tract. The role that dietary fiber plays in the intestine has been correlated with epidemiological data to form the hypothesis which relates the prevalence of a wide group of diseases to a lack of fiber in the diet.

Much of the present interest in the role of dietary fiber

in relation to disease arises from the fact that both the source and the amount of fiber intake have changed during the past century. Between 1860 and 1960 fat consumption increased by less than 50% and sugar consumption more than doubled (Burkitt, 1973). In Britain in 1835 flour consumption was approximately 360lb/person/year. By 1880 it had dropped to 280lb/person/year and in 1970 to 145lb/person/year (Cummings, 1973). In the United States consumption of whole wheat flour has decreased from 160lb/capita in 1900 to less than 100lb/capita in 1970 (Scala, 1974). The fiber content of flour has also been reduced considerably since the beginning of the century due to a change in the milling process whereby flour is now more highly refined.

The evidence appears to substantiate the theory that an increase in dietary fiber intake would be very beneficial. Fiber which will need to be added to the daily diet to aid in disease prevention must be added to foods in an appealing manner in order to assure consumer acceptance of the product. Because fiber will need to be added to foods in amounts greater than that of the level of present food additives in order to be beneficial, it may have a significant effect on product quality characteristics.

Because flour is a major component of any baked product, these systems could become feasible fiber carriers. Possible products for such fiber supplementation would include cakes, cookies, crackers, doughnuts, pastry, muffins, and biscuits. However, due to the physical and chemical properties of the

fiber components, product quality may be impaired without a change in the product formulation.

The purpose of this research was to determine the differential effects of the incorporation of varying levels of bran and middlings on the physical and sensory quality characteristics of layer cakes.

REVIEW OF LITERATURE

Since the primary emphasis of this research was to investigate the effects of the addition of dietary fiber on layer cake quality characteristics, the need for dietary fiber in the diet and the composition of the dietary fiber constituents are reviewed in the first portion. The second portion of this review summarizes the formation of the layer cake structure.

Dietary Fiber

Cereals, fruits, and vegetables are the primary sources of fiber in the diet but a marked reduction in the consumption of these foods has occurred during the past century. Associated with this reduction is increased intake of foods low in fiber content such as animal products and sweetening agents as shown in Table 1.

Not only has flour and cereal consumption declined but technological advances in the milling process have caused a reduction in flour fiber content. Flour refining changed from stone-grinding to roller-milling in the 1880's. As a result of this change, the flour extraction rate dropped from 80% to 70% (Jones, 1958), while the fiber content was reduced by

Table 1. *Trends in annual per capita food availability* (Friend, 1967).

Food Source	1909-13	1925-39	1947-49	1957-59	1965
Meat, poultry, fish, lbs.	172	149	176	192	203
Eggs, lbs.	37	36	47	45	39
Dairy products, qts.	177	202	236	240	237
Fats & oils, lbs.	59	66	57	57	57
Fruit, lbs.	176	199	208	183	168
Potatoes, lbs.[1]	205	147	123	110	101
Other vegetables, lbs.	203	232	232	209	208
Flours & cereals, lbs.	291	204	171	148	147
Sugar & sweeteners, lbs.	89	110	110	106	112

[1]Includes sweet potatoes

nearly half (Pomeranz, 1964).

Fiber Deficiency Disorders

The close association between the incidence of certain diseases and their geographical distribution has led to the hypothesis that environment and diet play an important role in the development of these physical disorders. Many diseases are thought to be characteristic of Western civilization because they are rarely found in communities which exist on high residue diets and are common in the Western world which exists on a low residue diet. Cleave et al. (1969) drew attention to the relationship between some diseases and implicated the over-consumption of refined carbohydrates as a major causal factor. This relationship has been supported by a number of researchers for diverticular disease (Painter and Burkitt, 1971), atherosclerosis (Trowell, 1972), colonic cancer (Burkitt, 1971), and appendicitis (Walker et al., 1973). Stool bulk and content, transit time, bacterial flora, and intra-abdominal pressures are all markedly affected by dietary changes and particularly so by the removal of the unabsorbable fiber component from food. This over-consumption of refined carbohydrates, especially white flour and sugar, is characteristic of Western civilization.

Diverticular disease. The role of fiber in the diet is to act as a bulking agent. In the absence of bulk increased motor activity can develop in the sigmoid colon and the resulting high contractile pressures may cause the formation of an abnormal muscle. This muscle abnormality is the primary factor in the pathology of diverticular disease as seen in Figure 1 (Painter and Burkitt, 1971).

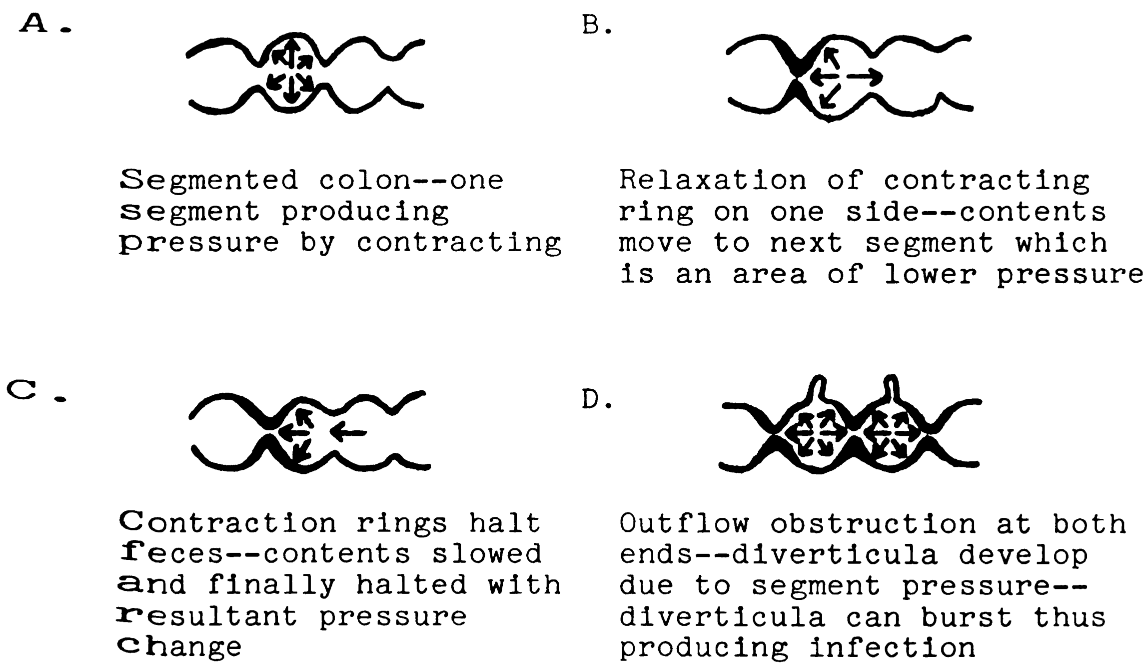

Figure 1. Pathogenesis of diverticular disease

Additions of fiber to the diet in the form of bran were found to relieve the symptoms of diverticulosis in 62 of the 70 patients for whom this dietary treatment was prescribed (Painter <u>et al</u>., 1972). The added fiber produced a less viscous stool due to the high water absorption capacity of the bran thereby curtailing segmentation and reducing the contractile pressures.

Atherosclerosis. A positive correlation has been found to exist between blood cholesterol levels and atherosclerosis and both have then been related to a lack of fiber in the diet. Studies conducted with human subjects indicate that for populations consuming a low fiber diet and which have high blood cholesterol levels, an increase in fiber intake significantly reduces these levels (deGroot et al., 1963). The hypothesis for this mechanism involves the increased bile acid excretion noted to occur with high fiber diets. Bile acids are secreted into the intestine during digestion to aid in the emulsification of fats after which they are reabsorbed into the system. Bile acids form complexes with the fiber components and the subsequent excretion of these complexes prevents reabsorption. To resupply bile acids necessary for further fat digestion, available cholesterol is converted to bile acids. The net effect of this reaction is the reduction of the size of the bile acid pool thereby lowering blood cholesterol levels. Leveille and Sauberlich (1966) showed that pectin reduced plasma cholesterol levels in rats from 128±3mg/100ml with a 1% cholesterol addition to a basal diet to 116±5mg/100ml when 1% cholesterol plus 5% pectin was added. Sundaravalli et al. (1971) found that plasma cholesterol in rats fed a basal diet plus 1.5% cholesterol was increased by 83mg/100ml over the basal diet fed alone while the same basal diet supplemented with 1.5% cholesterol and 20% cellulose decreased plasma cholesterol from 147 to 91mg/100ml.

Colonic cancer. The high incidence of colonic cancer in the Western world has been related to carcinogens produced by bacterial flora action on the bile acids. Fiber in the diet increases bile acid excretion; it also reduces the amount of fecal deoxycholate (Pomare and Heaton, 1973), a substance suspected of being carcinogenic in the human colon (Hill et al., 1971). Cancer development depends upon the time and concentration of a carcinogen in contact with a tissue. The decreased transit time induced by increased dietary fiber intake limits the time for this interaction to occur and the increased water content in the colon due to the high water absorption capacity of the fiber can dilute the concentration of the carcinogen. For these reasons the opportunity for colonic cancer formation is thought to be reduced.

Appendicitis. Short (1920) postulated that the increasing incidence of appendicitis cases seen in Britain was directly related to a fiber depleted diet. This theory has recently been substantiated by extensive epidemiological observations (Burkitt, 1971). Increased fecal viscosity can result in the development of fecaliths and segmentation of the appendix. It has been theorized that this obstruction causes increased intraluminal pressures with the resultant effect of bacterial infiltration to the appendix (Burkitt et al., 1974). At the turn of the century Van Zavalenburg (1904) hypothesized that bacterial invasion in the appendix gives rise to inflammation and subsequent disease. Based on the available evidence it would now appear that this hypothesis is what actually does occur (Burkitt, 1971).

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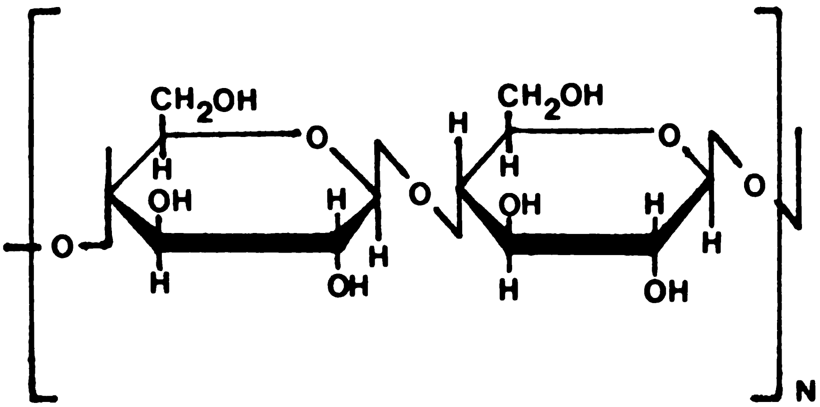
Crude fiber vs. dietary fiber

Crude fiber, the time-honored concept of fiber, is not equivalent to dietary fiber. Furthermore, it is dietary fiber that is believed to contribute to disease prevention (Trowell, 1972). Crude fiber is the material that remains after a food has been treated with sulfuric acid and sodium hydroxide. This remaining material is composed of the structural polysaccharide cellulose and lignin and is what is presently recorded in food composition tables as "fiber." However, dietary fiber encompasses not only the cellulose and lignin but also the other structural polysaccharides hemicellulose and pectin. These components can be determined by a number of methods (Southgate, 1969; Van Soest and Wine, 1967).

Dietary fiber components

Cellulose. Cellulose is the major structural polysaccharide in plant tissues; it is also the most abundant organic material found in nature. Cellulose is acid, alkali, and water insoluble but is attacked by the enzyme cellulase.

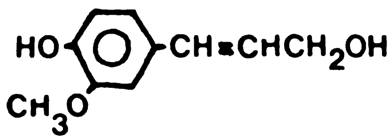
Cellulose is a chain structure composed exclusively of glucose molecules linked by β-(1→4) glycosidic linkages. It is believed that cellulose is not a branched molecule but rather is arranged in bundles of parallel chains, or fibers. These fibers are composed of both crystalline and amorphous regions. The molecules of the crystalline area are held together by hydrogen bonds between the hydroxyl groups.



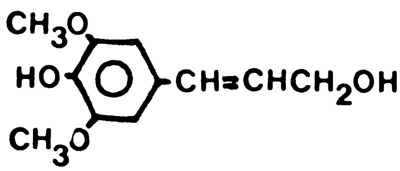
Portion of cellulose structure

A loose arrangement of the molecules is found in the amorphous regions of cellulose; this amorphous region readily adsorbs water and swells which accounts for the increased water absorption capacity of fiber.

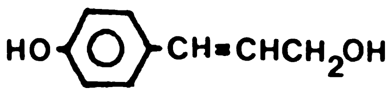
Lignin. Lignin is the second most abundant organic compound found in nature. It is a complex molecule formed by the polymerization of three alcohols--trans-coniferyl, trans-sinapyl, and trans-coumaryl. This polymerization occurs by free radical formation involving covalent bonding. Softwoods are especially abundant in coniferyl residues, hardwoods predominate in sinapyl residues, and grasses abound in coumaryl residues. Lignin has also been noted to increase in plant tissues as the plant ages.



t-coniferyl alcohol



t-sinapyl alcohol

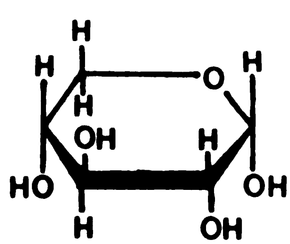


t-coumaryl alcohol

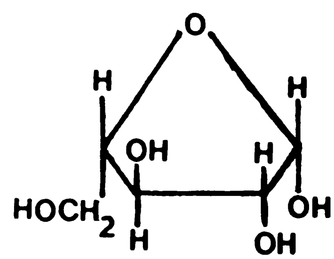
Hemicellulose. Hemicellulose is found in close association with cellulose and lignin in the plant tissue though it has not been clearly defined. Hemicelluloses are synthesized in plants as structural components of the cell wall and are found in the middle lamella.

The hemicelluloses have been divided into two categories for descriptive purposes. These categories are hemicelluloses or water-insoluble polysaccharides, and pentosans or water-soluble polysaccharides. However, Aspinall (1959) noted that classification according to solubility may lack precision in respect to chemical structure and biological function. Nonetheless, solubility is a widely used method of classification. By this definition the water-insoluble pentosans are classified as hemicelluloses.

The cereal hemicelluloses and pentosans are built of five and six carbon sugar units. The hemicelluloses are composed chiefly of anhydro-D-xylose units and are referred to as the cementing tissue of a plant (Smith and Montgomery, 1959). The monomeric units most common in the cereal pentosans are D-xylose and L-arabinose. The pentosans are highly



D-xylose

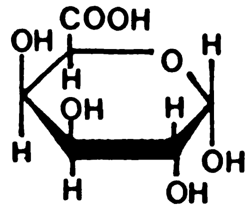


L-arabinose

branched polymers; they imbibe large quantities of water at room temperature and in turn exhibit high viscosities (Gilles, 1960).

<u>Pectic substances</u>. Pectic substances is a general term used to describe complex colloidal carbohydrate derivatives which occur in plants and contain a large proportion of anhydrogalacturonic units. Pectic substances are linear polymers of D-galacturonic acid linked by α-(1→4) glycosidic

bonds. The pectic substances include protopectin, pectinic acid, pectin, and pectic acid.



D-galacturonic acid

In the chain structure the carboxyl groups are partly esterified with methanol. The hydroxyl groups on C-2 and C-3 may also be acetylated. Many pectic substances have the sugars arabinose, galactose, glucose, xylose, or rhamnose covalently linked as side chains. Bhattacharjee and Timell (1965) found that rhamnose may also occur in the parent chain with the galacturonic acid linked by α-(1→2) bonds.

Dietary fiber in foods

The percent dietary fiber in most foods is relatively small. However, from the standpoint of the undigested food residue it is quite significant as shown in Table 2.

Table 2. Estimated composition of the cell wall polysaccharides in some foods (Southgate, 1969).

	Distribution of unavailable carbohydrate + lignin				
Fiber constituent	Wheat %	Rye %	Potato %	Apple %	Cabbage %
Cellulose	10.0	12.4	35.8	41.9	69.1
Lignin	23.3	9.9	32.0	24.8	6.4
Hemicellulose	65.0	77.7	32.1	32.3	24.3

Composition of the wheat kernel

Wheat produces dry fruits containing one seed which do not open at maturity to shed the seed. The seed consists basically of the germ, or embryo, and endosperm covered by a seed coat all of which is enclosed in a fruit coat or pericarp as seen in Figure 2.

Milling is the process that breaks down the wheat kernel into separate portions by a series of steps. The kernel is tempered for ease of milling and the bran is then broken off, the wheat germ is flaked, and the endosperm is powdered into different flours possessing varying characteristics.

Bran. Ideally, from the miller's standpoint, the bran encompasses the pericarp, seed coat, a thin layer of nucellar tissue that lies just inside the seed coat, and the aleurone

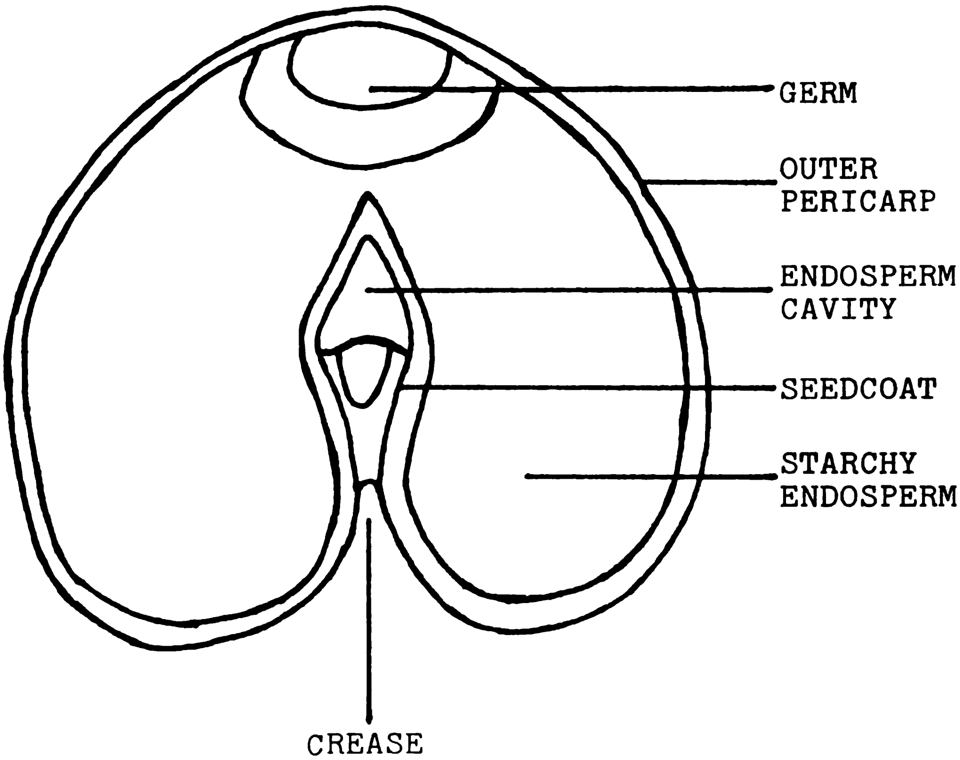


Figure 2. Cross section of a wheat kernel

layer, or outer layer of the endosperm. The bran accounts for approximately 14 1/2% of the wheat kernel (Wheat Flour Institute, 1964). Bran has traditionally been used as an animal feed but recent efforts have been intensified to promote the more extensive use of this mill product as a human food. When the bran and germ are not separated from the endosperm the resulting product is whole wheat flour. Whole wheat flour contains more of the essential nutrients required by man than the separated wheat fractions as seen in Table 3. The aleurone cells in the bran account for almost half of the bran weight and most of its protein content (Hutchinson and Martin, 1970). The amino acid pattern of bran indicates a

Table 3. Nutrient contribution of some wheat kernel constituents (Wheat Flour Institute, 1964).

Nutrient	Bran %	Endosperm %	Germ %
Protein	19	73	8
Pantothenic acid	50	43	7
Riboflavin	42	32	26
Niacin	86	12	2
Pyridoxine	73	6	21
Thiamine	33	3	64

lysine content significantly greater than that found in white flour; the biological value of white flour is limited by this low lysine content (Hutchinson et al., 1962). Crude wheat bran has a lysine content of 656 mg/100 g while all-purpose unenriched white flour has a lysine content of 242 mg/100 g (Bowes and Church, 1970). Therefore, if the protein present in bran were digestible the biological value of white flour could be substantially improved by a mixture of the white flour and bran. Hutchinson and Martin (1970) found that addition of bran to white flour in the diets of rats increased protein and essential amino acid intakes. When wholemeal bread was fed to human subjects the proteins of the whole wheat bread were found to be almost completely digested and absorbed (McCance and Walsham, 1948).

In addition to its increased nutrient value bran has been analyzed for percentage fiber constituents and was found to contain 23% pentosans and 21% cellulose (Frasar and Holmes, 1959).

Middlings. The middlings are an intermediate mill product. They are that part of the wheat after milling that is too poor for use as a flour but too good for sale as animal feed. The middlings consist of fine particles of wheat bran, wheat germ, wheat shorts, wheat flour, and other materials at the completion of milling, containing not more than 9.5% crude fiber (Wheat Flour Institute, 1965). Middlings differ from shorts only in that the shorts contain no more than 7% crude fiber.

Formation of the Layer Cake Structure

The formation of the layer cake structure is due primarily to the gelatinization of the starch granules present. Howard et al. (1968) demonstrated this principle by substituting pure starch for flour in layer cakes. However, other components in addition to starch have been found to be essential for the development of the cake structure. These components include soluble proteins, surface-active lipids, and polyvalent cations (Howard et al., 1968; Howard, 1972). These components may be contributed by milk and egg, fat, and egg, milk, and leavening agent, respectively. The functions of other cake ingredients have been described by O'Brien (1972) for emulsifiers, Wilson and Donelson (1963) for water, and Hunter et al. (1950) for sugar.

A properly mixed batter is an oil-in-water emulsion. The continuous phase is an aqueous sugar solution with suspended solids and gases (MacDonald, 1968). Most of the air is found in the continuous phase. Upon baking the cake batter changes from a fluid emulsion to a solid porous structure due to the gelatinization of the starch granules. In order to form a structure that will not collapse or shrink after removal from the oven the free water must be absorbed. However, in a high-ratio cake formulation (140% sugar based on the weight of the flour) the sugar competes with the starch for the available water and gelatinization may be impaired. Matz (1960) suggests that total liquid in the system should exceed the amount of sugar by 25 to 35%. This amount should be sufficient liquid to dissolve the sugar and provide for adequate starch gelatinization. Miller and Trimbo (1965) found that early starch gelatinization during baking prevents the formation of a sunken center in the layers.

A number of researchers have studied the effects of the various fractions of the flour in the cake system following a flour fractionation procedure. Many methods have been employed for flour fractionation (Sollars, 1958; Donelson and Wilson, 1960) but all methods give the same four fractions as a result of the process. These fractions include starch, gluten, water-solubles, and tailings. The tailings fraction is composed of damaged starch granules, proteins, and insoluble pentosans. MacMasters and Hilbert (1944) found the tailings fraction to be composed of 87 to 94% starch, 1 to 2% protein, 4% pentosan, 0.7% fatty compounds, and 0.3% ash. Yamazaki (1955) dispersed the tailings fraction in water and then fractionated this dispersion through a 325-mesh sieve to obtain "purified tailings." The purified tailings were found to contain 30 to 65% insoluble pentosans, 7 to 23% starch, and 0.5 to 3% total nitrogen.

Studies have shown that while the soluble pentosans have an improving effect in dough systems, it is the water-insoluble pentosans that show an improving effect in batter systems. Gilles (1960) found that water-insoluble pentosans added to a marginal quality soft wheat flour produced a yellow cake with quality characteristics more desirable than those of the control cake. Donelson and Wilson (1960) determined that the tailings fraction added to cake batters produced a cake with a significant increase in volume and improved grain and texture. Baldi et al. (1965) obtained similar results when they found increasing amounts of tailings up to an optimum level improved cake volume and internal structure. This optimum level was determined to be 9 to 15% of the weight of the flour for a high-ratio (125% sugar based on flour weight) cake formulation and 18% of the weight of the flour for a low-ratio (100% sugar based on flour weight) cake formulation. The optimum amount of tailings was significantly less for the high-ratio than for the low-ratio cakes. The reason for this result was theorized to be due to a greater swelling of the water-insoluble pentosans at the higher sugar-water level, compensating for the smaller amount of this fraction. This resulted in a stronger and more stable matrix. A high batter viscosity seems to be required to hold the shape and structure of the cake during baking (Miller and Trimbo, 1965). Therefore, any change in the cake formulation that allows for an increase in the batter viscosity will result in an improved baked product. The addition of the water-insoluble flour fraction to a flour used in cake baking may be such a formulation change.

EXPERIMENTAL PROCEDURE

This research was initiated to determine whether the fiber constituents of the wheat kernel could be satisfactorily substituted for white flour in a layer cake formulation. Preliminary experimentation indicated that partial substitution of bran and middlings for flour in a layer cake produced an acceptable product. In order to determine the effects of these substitutions all factors known to affect cake quality were carefully controlled.

Ingredient Procurement

Common lots of sugar, salt, shortening, non-fat dry milk, and baking powder were obtained from the Michigan State University Food Stores. The baking powder was special ordered to insure freshness. Common lots of soda, cocoa, vanilla, ground cloves, cinnamon, and mace, almond extract, chopped walnuts, brown sugar, and dried buttermilk were obtained from local commercial establishments. Bran, middlings, 50 and 70% flour extractions, and clears were obtained from Mennel Mills, Fostoria, Ohio. A partial proximate analysis, as well as pH, of the bran, middlings, and flours were also obtained from Mennel Mills and is found in the Appendices. Dried egg whites and dried whole eggs were procured from Seymour Foods, Inc.; canned mashed bananas were donated by Gerber Products Company.

Layer Cake Formulations

A standard high-ratio white cake formula and four flavored cake formulas including nut, spice, banana, and chocolate were prepared. Five replications of each variable were evaluated by both objective and subjective measurements. Variables prepared for evaluation in the white layer cake series included a control and substitutions of flour with 4, 8, and 16% bran, 12% bleached midds, 12% unbleached midds, 12% bleached midds plus 16% bran, and 12% unbleached midds plus 16% bran. The white cakes were prepared from a 60% extraction flour using the standard AACC formula, method 10-90 (Table 4). The series was then repeated using a 70% extraction flour.

Variables prepared for evaluation in the flavored cake series included a control and substitutions of flour with 16% bran, 12% unbleached midds, and 16% bran plus 12% unbleached midds. The flavored cake formulations were adapted for use in this study from popular cookbooks (Table 5). The flavored layers were prepared using a 70% extraction flour only.

Method of Preparation

The bran and middlings were ground to the same particle size as the control flours to eliminate mouthfeel differences using a Udy Cyclone Sample Mill, model MS. Particle sizing was done using a Roto-Tap Testing Sieve Shaker, model 4589 (Donelson and Yamazaki, 1972). The resulting particle size

Table 4. Formula for standard high-ratio white layers.

Ingredient	Amount	
	g	% (flour basis)
Flour	150.0	100.0
Sugar	210.0	140.0
Shortening	75.0	50.0
Non-fat Dry milk	18.0	12.0
Dried egg whites	13.5	9.0
Salt	4.5	3.0
Water	232.5	155.0
Baking powder[1]	7.87 - 8.25	5.5 - 5.75

[1]Added according to schedule based on barometric pressure as outlined in AACC method 10-90.

Table 5. Formulations for flavored layer cakes.

Ingredient	Nut[1]		Spice[2]		Banana[2]		Chocolate[3]	
	g	% flour	g	% flour	g	% flour	g	% flour
Flour	129.4	100.0	115.0	100.0	134.0	100.0	126.0	100.0
Sugar	133.4	103.1	100.0	87.0	166.7	124.4	225.0	178.6
Shortening	62.7	48.5	62.7	54.5	62.7	46.8	70.5	55.9
Whole dried egg	16.1	12.4	16.1	14.0	10.7	8.0	16.1	12.8
Dried buttermilk			61.0	53.0	40.7	30.4		
Non-fat dry milk	17.0	13.1					24.0	19.0
Salt	1.5	1.2	3.0	2.6	3.0	2.2	4.5	3.6
Soda			1.4	1.2	1.9	1.4	3.1	2.5
Baking powder	2.7	2.1	1.8	1.6	2.0	1.5		
Cocoa							28.1	22.3
Mashed banana					77.4	57.8		
Brown sugar			75.0	65.2				
Ground cloves			1.0	0.7				
Ground cinnamon			1.0	0.7				
Ground mace	0.1	0.1						
Chopped walnuts	31.0	24.0						
Almond extract	0.5	0.4						
Vanilla extract							3.8	3.0
Distilled water	180.0	139.1	180.0	156.5	140.0	104.5	218.0	173.0

[1] McCall's Cookbook. 1963. Random House, Inc., New York. Pg. 117.

[2] Better Homes and Gardens Pies and Cakes Cookbook. 1966. New York. Pgs. 54 and 57.

[3] Betty Crocker's Picture Cookbook. 1961. McGraw-Hill Book Co., New York. Pg. 145.

values are cited in the Appendices.

Flour Preparation

A 60% extraction flour was prepared for use in the white cakes by mixing 5 parts of 50% extraction flour with 1 part of clears for 30 minutes in a Liquid-Solids Blender, model S44EXAK-989. The 70% extraction flour from Mennel Mills was used in the second white layer cake series.

Due to an insufficient quantity of 70% extraction flour for use in the flavored cakes a 70% extraction flour was prepared for use in this series by combining 5 parts of 50% extraction flour with 2 parts of clears. This mixture was divided in half and each half mixed for 30 minutes in a Hobart mixer, model K-200. To insure adequate mixing half of the contents of each portion of this flour were remixed together for an additional 30 minutes.

To insure an even mixing of the different particle sizes of the bran and middlings these were also mixed in the Liquid-Solids Blender for 30 minutes before preparation of the flours for the variables studied.

Enough flour for each variable was prepared at the same time. The premixed flour, bran, and middlings were weighed to the nearest 0.1 g and mixed in the Liquid-Solids Blender for 30 minutes to insure an even distribution of the flour components.

Cake Mix Preparation

The dry ingredients for each cake layer were preweighed to the nearest 0.1 g and stored at 1.7°C until used. Cake ingredients for the white layers were stored in glass beakers and the ingredients for each flavored layer were packaged in polyethylene bags with the exception of the brown sugar and chopped nuts which were packaged separately. The mashed bananas were weighed to the nearest 0.1 g in glass sample jars and frozen at -17.7°C until the day before use. The frozen bananas were thawed at 8°C for 24 hours and warmed to room temperature prior to use in the cakes. Baking powder, shortening, vanilla, and almond extract were stored at room temperature in closed containers and weighed on each day of use. All dry ingredients were sifted into the mixing bowl.

White Cake Preparation

The white cakes were prepared according to AACC specifications, method 10-90. The preweighed dry ingredients, shortening, 60% of the distilled water, and baking powder were mixed in a Kitchen Aid mixer, model K5-A at low speed (145 rpm) for 1/2 minute. The bowl was scraped and mixing was continued for an additional 4 minutes at medium speed (249 rpm). Half of the remaining water was added and the batter mixed for 1/2 minute at low speed, scraped, and mixed 2 minutes at medium speed. The remaining water was added and the batter was again mixed for 1/2 minute at low speed, scraped, and then mixed for 2 minutes at medium speed.

Flavored Cake Preparation

All flavored cakes were mixed using the same mixer as that used for the white layers.

Nut Cakes. The preweighed dry ingredients, shortening, and 110-milliliters of distilled water were mixed at low speed for 1/2 minute. The bowl was scraped and the batter was mixed an additional 2 minutes at medium speed. The remaining water and almond extract were added and the batter mixed at low speed for 1/2 minute, the bowl was scraped, and the batter mixed 2 additional minutes at medium speed. Finally, the nuts were added and the batter mixed 10 seconds at low speed.

Spice Cakes. The preweighed dry ingredients, shortening, brown sugar, and 100-milliliters of distilled water were mixed at low speed for 1/2 minute. The bowl was scraped and the batter mixed for 2 minutes at medium speed. The remaining water was added and the mixing process was repeated.

Banana Cakes. The preweighed dry ingredients, shortening, thawed mashed bananas, and 90-milliliters of distilled water were mixed at low speed for 1/2 minute. The bowl was scraped and the batter was mixed for 2 minutes at medium speed. The remaining water was added and the mixing process was repeated.

Chocolate Cakes. The preweighed dry ingredients, shortening, and 118-milliliters of distilled water were mixed at low speed for 1/2 minute. The bowl was scraped and the batter was mixed 2 minutes at medium speed. The remaining water and vanilla were added and the mixing process was repeated.

Baking Procedure

Weighed to the nearest gram, 400, 425, and 450 g of batter were scaled into ungreased 8 in round two piece cake pans for the chocolate, white, and remaining flavored layers respectively. The cake layers were placed on the middle shelf of an Etco forced convection oven, model 186A, and baked for 25 minutes. The oven temperature was maintained at $178 \pm 3^{o}C$ by a Honeywell versatronic controller. After removal from the oven the cakes were allowed to cool in the pan for 30 minutes. They were then removed from the pan onto racks and allowed to cool an additional 30 minutes. Objective and subjective evaluations for each layer were obtained on their respective baking day.

Preparation of Samples

After volume measurements were obtained the layers were cut for evaluation (Figure 3). Specially manufactured cutters were used to cut samples for shear press evaluations. All samples were wrapped in Reynolon® Food Service Film to prevent dehydration. The cake remaining after samples were removed was ground in an Osterizer blender on high speed for

White Cake
Series

Flavored Cake
Series

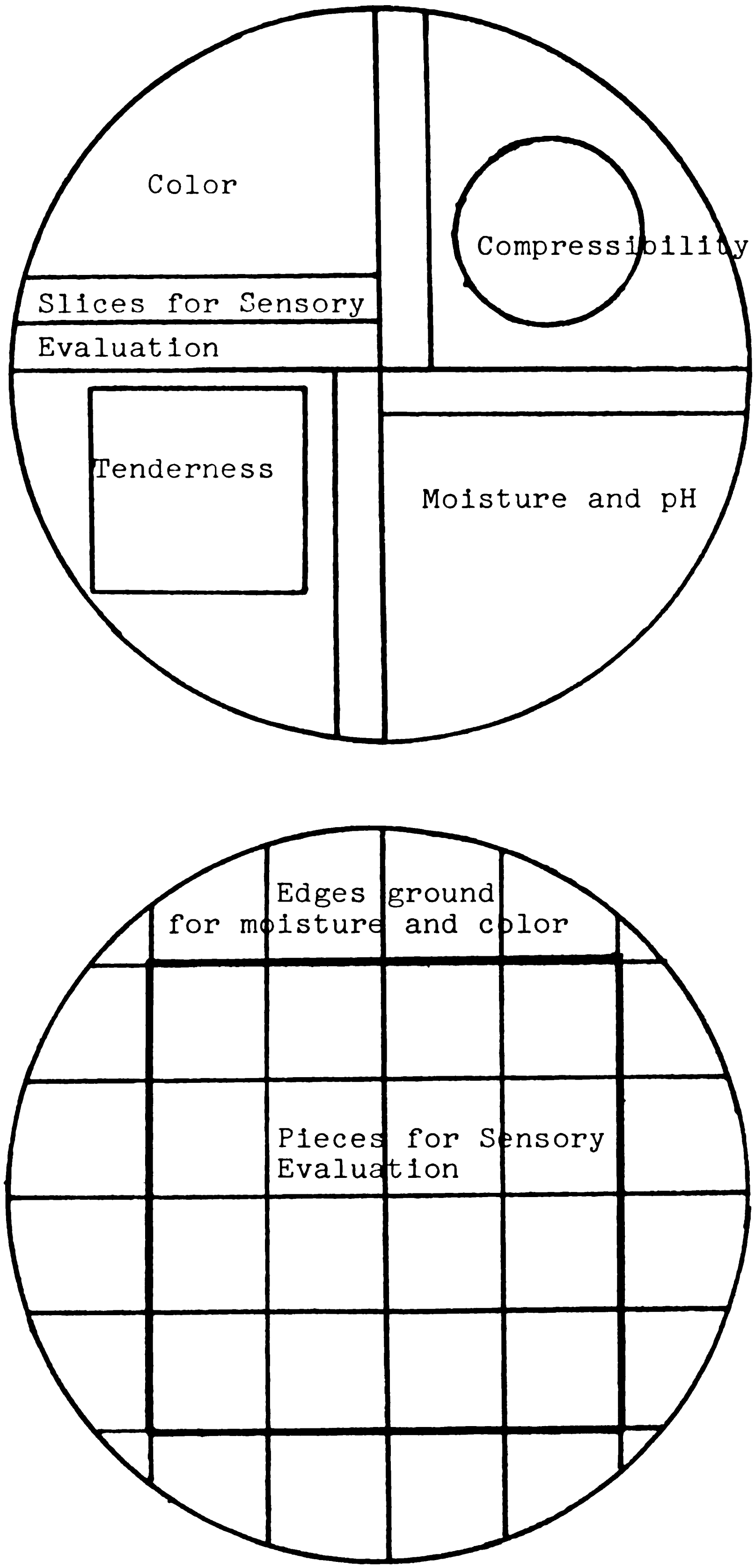


Figure 3. Cutting Diagram for Cakes

10 seconds for use in pH and moisture determinations of the white layers. In the case of the flavored layers all remaining cake was ground and both moisture and color determinations were done on ground samples.

Objective Measurements

Objective measurements were used to evaluate the quality characteristics of both the batter and the cake for the white layers and the cake for the flavored layers. Batter quality measurements included viscosity, specific gravity, pH, and color. Cake quality characteristics determined were pH, crumb color, volume, tenderness, compressibility, and moisture for the white layers, and crumb color, volume, and moisture for the flavored layers. In addition to these determinations the 16 flours used in the white cake series were analyzed for crude fat content and alkaline water retention capacity and were fractionated into 4 fractions to determine gluten, prime starch, tailings, and water-solubles.

Batter Viscosity. Batter viscosity was determined using a Brookfield Viscometer, model RVF-100, equipped with a No. 7 spindle rotating at 10 rpm. The spindle was submerged in a 250-milliliter sample in a 500-milliliter beaker. The reading was taken after the dial was allowed to make one complete revolution and the reading was then multiplied by the appropriate conversion factor to express viscosity in poise.

Specific Gravity. Batter specific gravity was determined by comparing the weights of equal volumes of batter and water at room temperature using the method of Platt and Kratz (1933).

pH. The batter and cake pH were determined using the method of Ash and Colmey (1973).

Color. The Hunter Color Difference Meter, model D25, equipped with a spherical head was used to determine the color of both crumb and batter samples. The instrument was standardized before use against a white tile (L=94.8; a_L=0.7; b_L=2.7) for the white layers, a yellow tile (L=83.0; a_L=-3.5; b_L=26.5) for the nut, spice, and banana layers, and a grey tile (L=21.5; a_L=-1.7; b_L=-0.1) for chocolate layers. One reading was taken for each batch of batter and each cake layer for the L, a_L, and b_L values.

Volume. Cake volume was determined using the AACC method 10-91 to obtain shrinkage and volume, symmetry, and uniformity indices.

Tenderness. Tenderness values were determined using the standard shear-compression cell of the Allo-Kramer Shear Press, model SP12, equipped with an electronic recorder, model E2EZ. Cake samples 5.73 cm square were weighed to the nearest 0.1 g and placed in the cell. The 3000-pound proving ring and a range of 5 pounds were used for each measurement. The cell assembly was cleaned between each determination. The tenderness value expressed as pounds force per gram for each layer was determined by a single measurement calculated according to the formula,

$$\text{Tenderness} = \frac{\text{Reading x Ring x Range}}{\text{Sample Weight x 100 x 100}}$$

Compressibility. The 3000-pound proving ring and a range of 5 pounds were used for this determination. The height of each cake sample was determined by averaging readings from a vernier caliper taken at 3 different points. The diameter remained constant at 5.23 cm. The sample was placed at the base of the shear press column, centered, and depressed by a flat plunger 5.23 cm in diameter to a uniform thickness of 0.7 cm. Each compressibility determination was calculated from a single trial and recorded as pounds force per cm compressed by substituting cm compressed for sample weight in the formula used to calculate tenderness.

Moisture. Cake moisture was determined by drying 2 g samples, weighed to the nearest 0.001 g, for 5 hrs at 90^{o}C under a vacuum of 27-in of Hg in a Hotpack vacuum oven, model 633. The samples were reweighed after cooling in a desiccator. Percentage moisture was calculated according to the formula,

$$\%\ \text{moisture} = \frac{\text{Wt. of moisture lost (g)}}{\text{Original sample wt. (g)}} \times 100$$

Crude Fat. Percentage crude fat in the flours was determined using acid hydrolysis followed by petroleum and ethyl ether extraction according to the AACC method 30-10.

Alkaline Water Retention Capacity (AWRC). AWRC as an indication of flour hydration properties was done on the flours by researchers at the USDA Soft Wheat Quality Lab, Wooster, Ohio according to the method by Yamazaki _et al_. (1968).

Flour Fractionation. The flours were fractionated into gluten, prime starch, tailings, and water-solubles by researchers at the USDA Soft Wheat Quality Lab, Wooster, Ohio according to the method by Donelson (1974).

Subjective Evaluation

Training sessions were held prior to taste panel evaluation to acquaint the panel members with the score cards. Sample score cards appear in the Appendices.

White Layers

The White layers were evaluated by a panel of 5 trained judges for internal characteristics following the method outlined in the AACC method 10-90.

Flavored Layers

The flavored layers were evaluated by a 12 to 15 member taste panel composed of faculty, staff, and graduate students in the Department of Food Science and Human Nutrition. Eight of these members were trained and participated in all evaluations. The cakes were examined for color, moisture, tenderness, texture, flavor, and general acceptability using a 10-point scale with 10 indicating the best value. Additional comments were noted.

Analysis of Data

The data were analyzed for variance and Duncan's Multiple Range Test (1957) was then used to sort out differences revealed by the analysis of variance.

RESULTS AND DISCUSSION

This study was designed to determine the effects of substituting various levels of wheat bran and midds for flour on the quality characteristics of a standard high-ratio white layer cake and four flavored cakes. Objective and subjective data were examined to ascertian the effect of these substitutions. All numerical data were subjected to analyses of variance and significant differences were pinpointed by use of Duncan's Multiple Range Test (1957). Tables of replicate means and standard deviations, as well as analysis of variance tables, accompany this discussion.

White Layers

A white layer cake formulation was chosen for fiber substitution studies because changes in the quality characteristics of a white cake are the most stringent test of flour performance. White layers were prepared with 60 and 70% extraction flours using the American Association of Cereal Chemists standard formula and preparation method.

Objective Measurements

Batter and cake quality characteristics were determined by employing a number of different objective tests.

Batter and Volume Parameters. Specific gravity, batter viscosity, and volume index means and standard deviations are presented in Table 6 and a summary of the analyses of variance for these parameters is presented in Table 7. Specific gravity is an indication of the amount of batter aeration. The desirable specific gravity of a layer cake is 0.65 to 0.75 (Ellinger and Shappeck, 1963). A specific gravity below this range is indicative of an overaerated batter while a specific gravity above this range is indicative of a dense batter which may result in a decreased volume. All white cakes, prepared by using the AACC standard formula and method, showed a specific gravity slightly above this range. However, substitutions of bran and/or midds in the cake formula revealed no significant changes in batter specific gravity.

A comparison of variable means for viscosity disclosed that cake batters prepared with increasing fiber substitution levels resulted in a significantly greater ($p<0.001$) viscosity. This increased viscosity could be due to the increased water absorption capacity of the fiber constituents as a result of their large molecular size (Gilles, 1960). Viscosity was also significantly greater ($p<0.001$) in the batters prepared with the 70% extraction flour. Collins and Sunderline (1940) demonstrated that a definite relationship exists between batter

Table 6. Means and standard deviations[1] for specific gravity, viscosity, and volume index values of white layers prepared with 60 and 70% extraction flours.

Variable	Specific Gravity		Viscosity (ps)		Volume Index (cm)	
	60%	70%	60%	70%	60%	70%
Control	$.79 \pm .01^{a}$	$.78 \pm .01^{a}$	380 ± 20^{a}	$584 \pm 92^{b,c,d,e}$	$10.4 \pm .2^{a,b}$	$10.5 \pm .3^{a,b}$
4% Bran	$.78 \pm .01^{a}$	$.78 \pm .02^{a}$	$524 \pm 78^{b,c,d}$	$488 \pm 33^{a,b}$	$10.7 \pm .3^{a}$	$10.9 \pm .4^{a}$
8% Bran	$.77 \pm .01^{a}$	$.76 \pm .01^{a}$	$536 \pm 46^{b,d}$	$788 \pm 163^{c,f}$	$10.5 \pm .1^{a}$	$10.2 \pm .3^{a}$
16% Bran	$.78 \pm .02^{a}$	$.77 \pm .03^{a}$	$512 \pm 33^{b,c}$	$528 \pm 59^{b,c,d}$	$10.6 \pm .5^{a}$	$10.5 \pm .4^{a}$
12% Midds Bleached	$.76 \pm 0^{a}$	$.76 \pm .01^{a}$	$680 \pm 94^{e,f}$	748 ± 149^{f}	$10.6 \pm .2^{b}$	$10.4 \pm .3^{b}$
12% Midds Unbleached	$.78 \pm .01^{a}$	$.77 \pm .01^{a}$	$592 \pm 66^{b,c,d,e}$	788 ± 143^{f}	$10.9 \pm .2^{a}$	$10.5 \pm .5^{a}$
16% Bran + 12% Midds Bleached	$.77 \pm .02^{a}$	$.77 \pm .01^{a}$	$640 \pm 40^{d,e}$	760 ± 133^{f}	$10.1 \pm .3^{b}$	$10.1 \pm .2^{b}$
16% Bran + 12% Midds Unbleached	$.77 \pm .01^{a}$	$.78 \pm .02^{a}$	$632 \pm 33^{c,d,e}$	952 ± 82^{g}	$10.6 \pm .4^{a,b}$	$10.4 \pm .3^{a,b}$

[1]Based on 5 replications.

[a]Averages superscripted by the same letter are not significantly different at the 1% level of probability (Duncan, 1957).

Table 7. Analyses of variance of specific gravity, viscosity, and volume indices of white layer cakes prepared with 60 and 70% extraction flours.

Source	df	Mean Squares		
		Specific Gravity	Viscosity	Volume Index
Total	79	0.00	267.94	0.13
Variables	7	0.00	1344.96***	0.44***
Flour	1	0.00	4061.25***	0.24
Interaction	7	0.00	342.68***	0.09
Within	64	0.00	82.70	0.10

***Significant at the 0.1% level of probability.

viscosity and cake structure. They found that thin batters were not viscous enough to hold the air incorporated during mixing or the gas liberated by the baking powder. Gas bubbles were found to be small, numerous, and evenly distributed in more viscous batters.

No significant differences were revealed for the volume indices of cakes prepared with 60 or 70% extraction flours but significant differences ($p<0.001$) did occur among variables. Substitutions of bleached midds for flour in two variables resulted in decreased cake volumes. However, significant differences were not noted among the other substitution levels. The effects of chlorine bleaching on wheat flour have been widely studied. The reaction of chlorine with flour produces three distinct changes: bleaching of the flour pigments, reduction of the pH, and chemical modification of the flour components (Kulp, 1972). Whistler and Pyler (1968) studied the effects of bleaching on isolated hemicellulose A. Hemicellulose is a constituent of dietary fiber found in both bran and midds. These researchers found that hemicellulose is rapidly depolymerized by chlorine and the rate of this reaction is most rapid with gaseous chlorine. The depolymerization results in a breakdown of high molecular weight compounds and may decrease the water absorption capacity as a result. Insufficient liquid absorption in the cake batter may result in decreased volumes or sunken centers in the cakes.

<u>Shrinkage and Symmetry and Uniformity Indices</u>. The mean values for shrinkage as well as the symmetry and uniformity

indices are presented in Table 8 and the analyses of variance for these data are presented in Table 9. The shrinkage is calculated as the difference between the diameter of the interior of the cake pan and the cake diameter after baking. The term "symmetry" has traditionally been used in the cake industry to indicate cake contour and "uniformity" is a measurement of the cake symmetry. Fiber substitutions for flour do not appear to affect these cake quality characteristics since the analyses of variance revealed no significant differences between flours or among variables.

Tenderness and Compressibility. Means and standard deviations for tenderness and compressibility scores are presented in Table 10. Tenderness values analyzed for variance revealed very highly significant differences among variables while analyses of compressibility values revealed significant differences ($p<0.05$) among variables and ($p<0.001$) between flours as seen in Table 11. Tenderness increased with increasing fiber substitution levels in the cakes. As the fiber substitution levels increase the total amount of starch, as well as the gluten-forming proteins, are diluted. This dilution of the basic components of the layer cake structure may result in a less rigid cake and, therefore, a more tender cake (Howard et al., 1968). As would be expected, cakes prepared with the 60% extraction flour required less force for compression than those prepared with the 70% extraction flour since the 70% extraction flour is a stronger flour. However, no trend was established to relate compressibility to

Table 8. Means and standard deviations[1] for shrinkage and symmetry and uniformity indices of white layer cakes prepared with 60 and 70% extraction flours.

Variable	Shrinkage		Symmetry Index		Uniformity Index	
	60%	70%	60%	70%	60%	70%
Control	1.3±.1	1.5±.5	0.3±.4	0.4±.5	0.1±.1	0.0±.1
4% Bran	0.9±.3	1.1±.2	0.1±.2	0.5±.3	0.0±.1	0.0±.1
8% Bran	1.1±.2	1.3±.1	0.3±.1	0.0±.4	0.1±.1	0.0±0
16% Bran	1.0±.3	1.2±.1	0.2±.2	0.1±.2	0.0±.2	0.0±.1
12% Midds Bleached	1.1±.2	1.5±.5	0.1±.3	0.4±.2	0.0±.1	0.0±.1
12% Midds Unbleached	1.1±.2	1.2±.1	0.3±.2	0.3±.3	0.0±.1	0.0±.1
16% Bran + 12% Midds Bleached	1.2±.4	1.1±.2	-0.2±.5	0.1±.3	0.0±.1	-0.1±.1
16% Bran + 12% Midds Unbleached	1.3±0	1.4±.2	0.1±.2	0.0±.3	0.0±.2	0.1±.1

[1]Based on 5 replications.

Table 9. Analyses of variance of shrinkage and symmetry and uniformity indices of white layer cakes prepared with 60% and 70% extraction flours.

Source	df	Mean Squares		
		Shrinkage	Summetry Index	Uniformity Index
Total	79	0.96	0.11	0.01
Variables	7	0.18	0.21	0.01
Flour	1	0.42	0.13	0.02
Interaction	7	0.06	0.16	0.02
Within	64	1.15	0.10	0.01

Table 10. Means and standard deviations[1] for tenderness and compressibility values of white layer cakes prepared with 60 and 70% extraction flours.

Variable	Tenderness		Compressibility	
	60%	70%	60%	70%
Control	$1.86 \pm .14^{a}$	$1.75 \pm .22^{a}$	$5.75 \pm .19^{w}$	$5.26 \pm .65^{w,x,y}$
4% Bran	$1.67 \pm .08^{b}$	$1.48 \pm .16^{b}$	$5.41 \pm .66^{w,x}$	$4.27 \pm .57^{z}$
8% Bran	$1.73 \pm .16^{b}$	$1.56 \pm .13^{b}$	$5.09 \pm .62^{w,x,y}$	$4.49 \pm .20^{y,z}$
16% Bran	$1.54 \pm .13^{b}$	$1.65 \pm .15^{b}$	$5.78 \pm .85^{w,x}$	$5.35 \pm .67^{w,x}$
12% Midds Bleached	$1.64 \pm .18^{b}$	$1.61 \pm .10^{b}$	$5.68 \pm .49^{w,x}$	$5.06 \pm .57^{w,x,y}$
12% Midds Unbleached	$1.61 \pm .12^{b}$	$1.58 \pm .13^{b}$	$5.14 \pm .54^{w,x,y}$	$5.31 \pm .49^{w,x}$
16% Bran + 12% Midds Bleached	$1.34 \pm .13^{c}$	$1.39 \pm .09^{c}$	$5.78 \pm .55^{w}$	$4.77 \pm .30^{x,y,z}$
16% Bran + 12% Midds Unbleached	$1.37 \pm .06^{c}$	$1.43 \pm .16^{c}$	$5.63 \pm .36^{w}$	$4.79 \pm .51^{x,y,z}$

[1]Average of 5 replications.

[a]Averages superscripted with same letter are not significantly different at the 1% level of probability (Duncan, 1957).

[w]Averages superscripted with same letter are not significantly different at the 5% level of probability (Duncan, 1957).

Table 11. Analyses of variance of tenderness and compressibility values of white layer cakes prepared with 60 and 70% extraction flours.

Source	df	Mean Squares	
		Tenderness	Compressibility
Total	79	0.04	0.44
Variable	7	0.19***	0.79*
Flour	1	0.03	7.67***
Interaction	7	0.03	0.41
Within	64	0.02	0.29

*Significant at the 5% level of probability.

*** Significant at the 0.1% level of probability.

percentage fiber substitutions. Compressibility is the amount of force necessary to compress a given size slice to a uniform height. High standard deviations were found for this measurement and may reflect differences in the textures of the layers. As a result, the compressibility measurement may not be indicative of cake quality.

Batter and Cake Color. Means and standard deviations for the L, a_L, and b_L values are presented in Table 12 and the analyses of variance for these data are presented in Table 13. Similar tables containing data for the cake color scores are presented in Tables 14 and 15. No significant differences were noted between flours for any of the batter measurement color scores but very highly significant differences were revealed among variables for the L, a_L, and b_L readings. As the percentage fiber substitution increased the L or lightness value decreased while the a_L or redness and the b_L or yellowness values increased. Similarly, no significant differences were revealed between the L and a_L color measurements of cakes prepared with either 60 or 70% extraction flour but a significant difference was revealed between the b_L values (yellowness) of cakes with the two types of flour. Very highly significant differences were revealed among variables for the L and a_L values while no significant differences were revealed among variables for the b_L measurement. As the percentage fiber substitution increased the lightness of the cake decreased while the redness increased. Cakes prepared with 60% extraction flour exhibited lower b_L values than the 70%

Table 12. Means and standard deviations[1] for L, a_L, and b_L values of white layer cake batter prepared with 60 and 70% extraction flours.

Variable	L (lightness) 60%	L (lightness) 70%	a_L (greeness) 60%	a_L (greeness) 70%	b_L (yellowness) 60%	b_L (yellowness) 70%
Control	$82.2 \pm .5^{a}$	$8.17 \pm .8^{a}$	$-3.6 \pm .5^{a}$	$-3.6 \pm .4^{a}$	$7.4 \pm .9^{a}$	$7.4 \pm .7^{a}$
4% Bran	$79.3 \pm .4^{b}$	$78.5 \pm .7^{b}$	$-2.9 \pm .4^{b}$	$-2.5 \pm .7^{b}$	$8.4 \pm .4^{b}$	$8.5 \pm .7^{b}$
8% Bran	$77.4 \pm .7^{b,c}$	$76.4 \pm .4^{b,c}$	$-2.3 \pm .2^{b,c}$	$-2.3 \pm .5^{b,c}$	$9.0 \pm .4^{b}$	$9.2 \pm .5^{b}$
16% Bran	$73.1 \pm .8^{d,e}$	$73.2 \pm .4^{d,e}$	$-1.3 \pm .3^{c,d,e}$	$-1.8 \pm 1.0^{c,d,e}$	$9.7 \pm .6^{c,d}$	$11.0 \pm 1.8^{c,d}$
12% Midds Bleached	$75.9 \pm .6^{b,c}$	$75.7 \pm .3^{b,c}$	$-2.6 \pm .4^{b}$	-2.5 ± 1.1^{b}	$10.3 \pm .9^{b,c}$	$10.5 \pm 2.5^{b,c}$
12% Midds Unbleached	$75.9 \pm .5^{c,d}$	$76.3 \pm 2.1^{c,d}$	$-2.3 \pm .3^{b,c,d}$	$-1.8 \pm 1.5^{b,c,d}$	$9.1 \pm .4^{c,d}$	$9.7 \pm .4^{c,d}$
16% Bran + 12% Midds Bleached	70.4 ± 1.0^{e}	$71.1 \pm .9^{e}$	$-0.9 \pm .7^{e}$	$-0.8 \pm .8^{e}$	$10.6 \pm .5^{d}$	$10.6 \pm .5^{d}$
16% Bran + 12% Midds Unbleached	$71.0 \pm .5^{e}$	70.2 ± 1.4^{e}	$-1.2 \pm .4^{d,e}$	$-1.2 \pm .5^{d,e}$	$10.7 \pm .1^{d}$	11.0 ± 1.3^{d}

[1]Average of 5 replications.
[a]Averages superscripted by the same letter are not significantly different at the 1% level of probability (Duncan, 1957).

Table 13. Analyses of variance of L, a_L, and b_L values of white layer cake batters prepared with 60 and 70% extraction flours.

Source	df	Mean Squares L	Mean Squares a_L	Mean Squares b_L
Total	79	17.94	1.12	1.99
Variables	7	153.81***	7.92***	14.81***
Flour	1	1.30	0.06	2.52
Interaction	7	0.94	0.21	0.45
Within	64	5.20	0.49	0.74

***Significant at the 0.1% level of probability.

Table 14. Means and standard deviations[1] for L, a_L, and b_L values[2] of white layer cakes prepared with 60 and 70% extraction flours.

Variable	L		a_L		b_L	
	60%	70%	60%	70%	60%	70%
Control	69.3 ± 1.6^{a}	68.9 ± 1.4^{a}	-2.9 ± 1.7^{a}	-3.4 ± 1.6^{a}	$10.8\pm.9$	11.7 ± 2.2
4% Bran	64.2 ± 2.5^{b}	63.9 ± 1.2^{b}	0.9 ± 2.0^{b}	-1.1 ± 2.3^{b}	10.6 ± 2.2	$12.2\pm.7$
8% Bran	60.3 ± 1.9^{c}	61.8 ± 2.3^{c}	$0.4\pm1.0^{b,c}$	$0.0\pm1.6^{b,c}$	$11.9\pm.9$	11.6 ± 1.8
16% Bran	54.6 ± 2.5^{e}	55.0 ± 1.1^{e}	$1.8\pm1.2^{c,d}$	$1.1\pm1.2^{c,d}$	13.5 ± 1.3	$13.3\pm.4$
12% Midds Bleached	58.2 ± 1.9^{d}	57.6 ± 3.4^{d}	$0.2\pm1.3^{b,c,d}$	$0.7\pm1.7^{b,c,d}$	11.3 ± 1.4	12.6 ± 2.5
12% Midds Unbleached	58.0 ± 2.5^{d}	58.2 ± 2.1^{d}	$0.1\pm1.6^{b,c}$	$0.1\pm1.0^{b,c}$	10.8 ± 2.0	$12.2\pm.7$
16% Bran + 12% Midds Bleached	$51.4\pm.8^{f}$	51.1 ± 1.6^{f}	1.9 ± 1.0^{d}	2.5 ± 1.5^{d}	11.0 ± 1.4	$13.6\pm.8$
16% Bran + 12% Midds Unbleached	48.8 ± 1.8^{f}	$5.12\pm.9^{f}$	2.7 ± 1.5^{d}	2.0 ± 1.4^{d}	11.4 ± 2.3	12.2 ± 2.1

[1]Average of 5 replications.

[2]L values for lightness, $-a_L$ values for greeness, $+a_L$ values for redness, b_L values for yellowness.

[a]Averages superscripted with same letter are not significantly different at the 1% level of probability for the L and a_L values (Duncan, 1957).

Table 15. Analyses of variance of L, a_L, and b_L values of white layer cakes prepared with 60 and 70% extraction flours.

Source	df	Mean Squares		
		L	a_L	b_L
Total	79	39.96	4.77	3.04
Variable	7	411.96***	30.25***	4.77
Flour	1	2.35	3.57	21.32**
Interaction	7	2.79	1.72	2.25
Within	64	3.93	2.34	2.65

** Significant at the 1% level of probability.
***Significant at the 0.1% level of probability.

extraction flour. The bran and midds used in these substitution levels were from a soft red wheat. Therefore, the bran and midds were dark and brownish-red in color which accounts for the decreased lightness and increased redness measurements in both the batter and the cake. The brown color imparted to the batter and cakes also accounts for the increased yellowness scores.

Moisture and Alkaline Water Retention Capacity. Means and standard deviations of percentage moisture and the value for the AWRC as determined by the USDA Soft Wheat Quality Laboratory are presented in Table 16. The analysis of variance of the percentage moisture data is given in Table 17. No significant differences were revealed by the analysis of variance among the variables and no trend for moisture retention appeared to be established. A highly significant difference did occur, however, between flours with the cakes prepared with the 60% extraction flour being more moist. AWRC values indicate that the flour retained more water as the levels of fiber substitution increased. It has been established that the fiber components of wheat have a high water absorption capacity (Gilles, 1960). This increased water absorption capacity correlates with the increasing AWRC values with increasing fiber substitution levels. Although the cakes prepared with increased fiber levels did not show an increase in moisture retention this could be accounted for by the fact that sugar and starch act in competition for the water thereby preventing the fiber components from being hydrated to their

Table 16. Means and standard deviations[1] for percentage moisture and single determination value for AWRC for white layer cakes prepared with 60 and 70% extraction flours.

Variable	% Moisture		% AWRC[2]	
	60%	70%	60%	70%
Control	28.1±.6	27.3±.9	54.6	54.9
4% Bran	27.5±.7	28.1±.3	56.7	56.6
8% Bran	28.6±1.1	27.9±.5	58.2	58.3
16% Bran	27.9±1.2	27.5±1.1	62.1	63.2
12% Midds Bleached	28.9±.6	27.7±1.9	60.5	59.6
12% Midds Unbleached	28.8±.4	27.0±.3	59.6	59.1
16% Bran + 12% Midds Bleached	28.0±1.5	26.4±2.1	69.1	69.3
16% Bran + 12% Midds Unbleached	28.4±1.4	27.7±.8	69.1	69.0

[1]Average of 5 replications.
[2]Data on 14% moisture basis.

Table 17. Analyses of variance for percentage moisture of white layer cakes prepared with 60 and 70% extraction flours.

Source	df	Mean Square % Moisture
Total	79	1.42
Variables	7	1.18
Flour	1	14.79**
Interaction	7	1.37
Within	64	1.24

** Significant at the 1% level of probability.

fullest potential.

pH. pH means are presented in Table 18. Although these values were not converted to the logarithm form to permit an analysis of variance the fiber substitutions for flour in the cake formula did not appear to affect the pH of either the batter or cake nor did the pH appear to be affected by the type of flour extraction used in the cakes.

Dietary Fiber by Difference. The percentage dietary fiber in the two flour extractions used to prepare the eight variables was calculated by difference as seen in Tables 19 and 20. Moisture, starch, protein, crude fat and ash were calculated as a percentage and subtracted from a total 100% to give an indication of the amount of dietary fiber contributed. All data was calculated on a 14% moisture basis. Raw data used in these calculations for the flour fractionation and crude fat values are found in the Appendices.

As the fiber substitution levels for the flour increased the dietary fiber contribution of the flour also increased. However, difficulties were encountered in two areas in the fractionation procedure used for the flours. First, the substitution level of 16% bran plus 12% midds did not fractionate well and the starch recovered at this level was of doubtful purity. Secondly, at this level of substitution the gluten dispersed upon hand kneading and a part of the tailings fraction adhered. Apparently this substitution level altered the density gradient thus making the procedure unsatisfactory for use. Although no data for starch is

Table 18. Mean values[1] for white cake batter and cake pH prepared with 60 and 70% extraction flours.

Variable	Batter 60%	Batter 70%	Cake 60%	Cake 70%
Control	7.1	7.1	7.1	7.0
4% Bran	7.1	7.1	7.0	6.9
8% Bran	7.1	7.1	6.9	6.9
16% Bran	6.9	7.1	6.8	6.9
12% Midds Bleached	7.1	7.1	6.9	6.9
12% Midds Unbleached	7.0	7.1	6.9	6.9
16% Bran + 12% Midds Bleached	7.1	7.1	6.7	6.7
16% Bran + 12% Midds Unbleached	7.1	7.0	6.8	6.8

[1]Average of 5 replications.

Table 19. Dietary fiber determinations by difference in 60% extraction flour.

Variable	Moisture %	Starch %	Protein %	Crude Fat %	Ash %	Dietary Fiber %
Control	14.0	73.3	9.7	1.5	0.5	1.0
4% Bran	14.0	62.6	9.9	1.9	0.8	10.8
8% Bran	14.0	55.4	10.1	2.3	1.0	17.2
16% Bran	14.0	35.0	10.6	2.8	1.5	36.1
12% Midds Bleached	14.0	51.9	10.6	2.2	1.1	20.2
12% Midds Unbleached	14.0	53.6	10.6	2.6	1.1	18.1
16% Bran + 12% Midds Bleached	14.0	----[1]	11.6	3.0	2.1	----
16% Bran + 12% Midds Unbleached	14.0	----	11.6	3.5	2.1	----

[1]Starch recovered by flour fractionation was of doubtful purity.

Table 20. Dietary fiber determinations by difference in 70% extraction flour

Variable	Moisture %	Starch %	Protein %	Crude Fat %	Ash %	Dietary Fiber %
Control	14.0	76.2	9.9	1.9	0.5	2.5
4% Bran	14.0	63.3	10.1	2.3	0.8	9.5
8% Bran	14.0	55.5	10.3	2.7	1.0	16.5
16% Bran	14.0	38.6	10.8	2.9	1.5	32.2
12% Midds Bleached	14.0	54.1	10.8	2.9	1.1	17.1
12% Midds Unbleached	14.0	54.5	10.8	2.4	1.1	17.2
16% Bran + 12% Midds Bleached	14.0	----[1]	11.7	4.0	2.1	----
16% Bran + 12% Midds Unbleached	14.0	----	11.7	4.1	2.1	----

[1]Starch recovered by flour fractionation was of doubtful purity.

available to calculate dietary fiber contributed at the highest substitution levels it would appear logical to assume that the percentage dietary fiber contributed would be greatest at this level. Dietary fiber by difference is an estimation of the level of dietary fiber present. This method may, however, overestimate the available carbohydrate or underestimate the structural polysaccharides of the plant cell wall. Some researchers have developed methods to report carbohydrate by determination (Southgate, 1969; Van Soest and Wine, 1967). It may also be possible to determine the fiber polysaccharides by gas-liquid chromatography (Sloneker, 1971).

The method of estimating the dietary fiber contributed by difference was chosen for this study over an analytical method of fiber determination because the primary purpose of this research was to observe the effects of fiber on cake quality rather than to study the amount of dietary fiber in terms of the individual constituents of fiber provided by such substitutions.

Sensory Evaluation

Sensory scores were determined by use of the AACC layer cake score card, method 10-90. This method called for a total sum of all individual characteristics evaluated and this sum total was then evaluated as an indication of cake quality. Quality characteristics evaluated to comprise this total score included cell uniformity, cell size, cell wall thickness, grain, moistness, tenderness, and softness, crumb color, and flavor. A breakdown of the scores for the individual characteristics evaluated appear in the Appendices.

Means and standard deviations of the sensory score totals appear in Table 21 and an analyses of variance for these data appear in Table 22. Very highly significant differences were revealed among the variables evaluated but no significant differences occurred between cakes prepared with different extraction flours. The taste panelists rated the control cakes as having the most desirable characteristics and the cakes with a flour substitution level of 16% bran plus 12% unbleached midds as having the least desirable characteristics. Many of the other variables were, however, rated as being equally as good and no clear cut trend was established for these intermediate substitution levels in the cakes.

The characteristics evaluated that contributed to low scores were crumb color and flavor. The bran and midds substitution changed the cake flavor but all taste panelists agreed that the flavor change was not objectionable. This data tends to indicate that consumer acceptance of cakes high in fiber content may be good. The visual characteristics of the white cakes prepared can be seen in Figure 4.

Table 21. Means and standard deviations[1] of sensory scores for white layers prepared with 60 and 70% extraction flours.

Variable	Sensory Scores[2] 60%	70%
Control	85.1±2.9[a]	83.7±4.5[a]
4% Bran	80.4±2.3[a,b]	82.0±1.2[a,b]
8% Bran	80.8±1.6[b,c]	79.0±3.6[b,c]
16% Bran	78.8±3.8[b,c]	78.2±2.8[b,c]
12% Midds Bleached	82.3±2.5[a,b,c]	78.9±2.8[a,b,c]
12% Midds Unbleached	83.1±5.4[a,b]	79.5±4.0[a,b]
16% Bran + 12% Midds Bleached	75.8±3.9[b,c]	79.1±2.4[b,c]
16% Bran + 12% Midds Unbleached	77.9±1.6[c]	75.1±5.7[c]

[1]Average of 5 replications.

[2]Total score 100 based on cell uniformity (10 pts), cell size (10 pts), cell wall thickness (10 pts), grain (16 pts), moistness (10 pts), tenderness (14 pts), softness (10 pts), crumb color (10 pts), and flavor (10 pts).

[a]Averages superscripted by same letter are not significantly different at the 1% level of probability (Duncan, 1957).

Table 22. Analysis of variance of sensory scores for white layer cakes prepared with 60 and 70% extraction flours.

Source	df	Mean Squares
Total	79	16.74
Variable	7	64.03***
Flour	1	26.45
Interaction	7	13.69
Within	64	11.75

***Significant at the 0.1% level of probability.

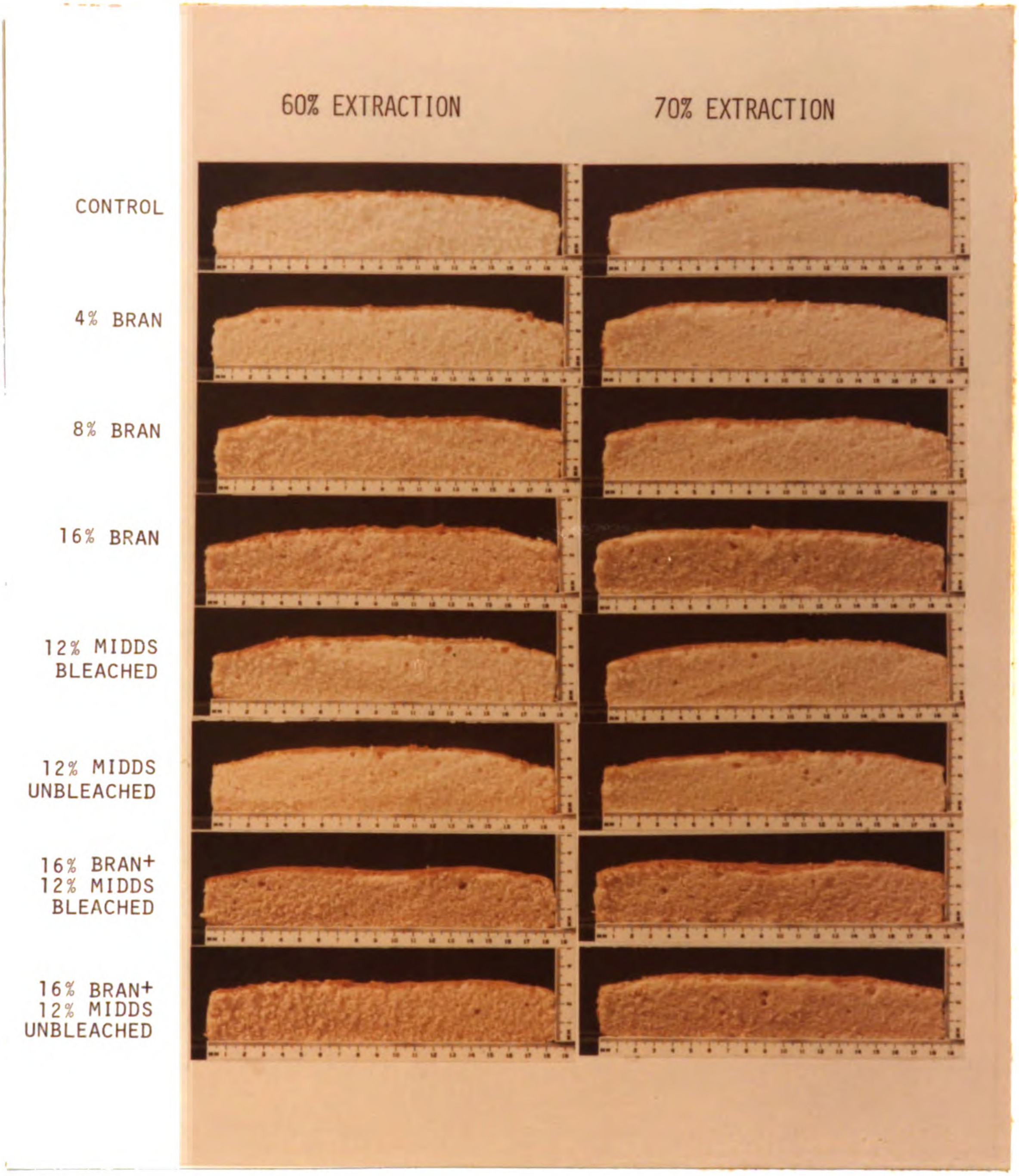


Figure 4. The color and appearance of white layer cakes prepared with increasing substitution levels of bran and midds for flour.

Flavored Layers

Because objective and subjective data collected after preparation of the white layers indicated that quality characteristics were not greatly impaired by the substitution of bran and midds for flour in the cake formula four flavored cakes including nut, spice, banana, and chocolate were chosen for further study. All flavored layers were prepared using a 70% extraction flour.

Objective Measurements

Due to a minimum amount of flour, batter characteristics were not evaluated. The primary evaluation of the flavored layers was sensory but objective data related to volume, color, and moisture were collected.

Shrinkage and Volume-Related Indices. Means and standard deviations for shrinkage and volume, symmetry, and uniformity indices for all four flavored layers are presented in Table 23 while analyses of variance of these data are presented in Table 24. The only significant differences revealed by the analyses of variance were for the volume index for the banana ($p<0.05$) and chocolate ($p<0.01$) layers. The volume index was highest for the control cakes of the banana series while the control cake and the variable containing the bran substitution exhibited volume indices slightly higher than the other

Table 23. Means and standard deviations[1] for shrinkage and volume, symmetry, and uniformity indices of flavored layer cakes.

Variable	Shrinkage	Volume Index	Symmetry Index	Uniformity Index
NUT				
Control	$2.3\pm.2^{a}$	$8.6\pm.3^{a}$	0 ± 0^{a}	$0.1\pm.3^{a}$
16% Bran	$2.3\pm.1^{a}$	$8.6\pm.1^{a}$	$0\pm.1^{a}$	$0.1\pm.2^{a}$
12% Midds	$2.1\pm.3^{a}$	$8.8\pm.4^{a}$	$0\pm.1^{a}$	$0\pm.1^{a}$
16% Bran + 12% Midds	$2.1\pm.3^{a}$	$8.6\pm.4^{a}$	0 ± 0^{a}	$0.2\pm.3^{a}$
SPICE				
Control	$1.7\pm.4^{a}$	$9.3\pm.4^{a}$	$0\pm.1^{a}$	$0.8\pm.1^{a}$
16% Bran	$2.1\pm.2^{a}$	$9.1\pm.2^{a}$	$0\pm.1^{a}$	$0.6\pm.1^{a}$
12% Midds	$1.8\pm.4^{a}$	$9.2\pm.5^{a}$	$-0.1\pm.1^{a}$	$0.6\pm.1^{a}$
16% Bran + 12% Midds	$1.7\pm.4^{a}$	9.7 ± 1.1^{a}	$0\pm.1^{a}$	0.4 ± 0^{a}
BANANA				
Control	$1.8\pm.2^{a}$	$11.3\pm.4^{x}$	$0\pm.2^{a}$	$0.7\pm.1^{a}$
16% Bran	$1.6\pm.4^{a}$	$10.5\pm1.1^{x,y}$	$0\pm.1^{a}$	$0.5\pm.3^{a}$
12% Midds	$1.7\pm.2^{a}$	$10.2\pm.5^{y}$	$0\pm.1^{a}$	$0.5\pm.1^{a}$
16% Bran + 12% Midds	$1.5\pm.2^{a}$	$9.9\pm.9^{y}$	$0\pm.2^{a}$	$0.6\pm.4^{a}$
CHOCOLATE				
Control	$1.7\pm.3^{a}$	$11.0\pm.3^{a}$	$0\pm.1^{a}$	$0.4\pm.3^{a}$
16% Bran	$1.5\pm.5^{a}$	$10.8\pm.6^{a}$	$0\pm.1^{a}$	$0.2\pm.6^{a}$
12% Midds	$1.6\pm.5^{a}$	$9.5\pm.7^{b}$	0 ± 0^{a}	$-0.1\pm.7^{a}$
16% Bran + 12% Midds	$1.6\pm.3^{a}$	$9.6\pm.7^{b}$	$0\pm.1^{a}$	$-0.4\pm.8^{a}$

[1] Average of 5 replications.

[a] Averages superscripted with the same letter are not significantly different at the 1% level of probability (Duncan, 1957).

[x] Averages superscripted with the same letter are not significantly different at the 5% level of probability (Duncan, 1957).

Table 24. Analysis of variance of shrinkage and volume, symmetry, and uniformity indices for flavored layer cakes.

Source	df	Mean Squares			
		Shrinkage	Volume Index	Symmetry Index	Uniformity Index
NUT					
Total	19	0.06	0.11	0.00	0.04
Variables	3	0.07	0.03	0.00	0.02
Within	16	0.06	0.13	0.00	0.05
SPICE					
Total	19	0.14	0.40	.01	0.14
Variables	3	0.18	0.36	.02	0.19
Within	16	0.14	0.40	.01	0.13
BANANA					
Total	19	0.06	0.79	0.00	0.08
Variables	3	0.09	1.91*	0.00	0.08
Within	16	0.05	0.59	0.00	0.08
CHOCOLATE					
Total	19	0.15	0.79	0.00	0.43
Variables	3	0.02	3.03**	0.00	0.55
Within	16	0.17	0.36	0.00	0.40

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

variables in the chocolate series. The banana and chocolate cakes contain a greater percentage of sugar based on the weight of the flour than the nut and spice cakes. A volume decrease resulting with increased levels of fiber substitution may be due to an imbalance of moisture during the baking process since the sugar competes with the other cake ingredients for the water.

Cake Color. L, a_L, and b_L color score means and standard deviations are presented in Table 25 for all four flavored cakes. Analyses of variance of these data are presented in Table 26. Very highly significant differences were revealed among variables in the nut, spice, and banana cakes for the lightness value. As the percentage fiber substitution increased the lightness of the cakes decreased. The bran and midds were brownish-red in color and imparted this darkness to the cakes. However, no significant differences occurred in the lightness of the chocolate cakes at increased fiber substitution levels.

Very highly significant differences were revealed in all flavored cakes for the a_L or redness color score. As the percentage fiber substitution increased the redness similarily increased. This again may be due to the fiber constituents imparting their red color to the cake crumb.

Significant differences ($p<0.05$) were revealed for the b_L or yellowness score in the spice and chocolate layers only. As the percentage fiber substitution increased the yellowness of the cake decreased.

Table 25. Means and standard deviations[1] for color scores of flavored layer cakes.

Variable	L (lightness)	a_L (redness)	b_L (yellowness)
NUT			
Control	$65.3\pm.9^{a}$	$0.8\pm.4^{a}$	$16.5\pm.6^{a}$
16% Bran	$54.9\pm.7^{b}$	$3.6\pm.2^{b}$	$16.6\pm.5^{a}$
12% Midds	$58.0\pm.7^{c}$	$2.9\pm.2^{c}$	$16.2\pm.2^{a}$
16% Bran + 12% Midds	$50.6\pm.7^{d}$	$4.7\pm.2^{d}$	$16.0\pm.2^{a}$
SPICE			
Control	52.8 ± 2.7^{a}	$4.2\pm.6^{a}$	$16.5\pm.3^{x}$
16% Bran	$47.5\pm1.1^{b,c}$	$5.5\pm.3^{b}$	$16.1\pm.2^{x}$
12% Midds	$49.9\pm1.4^{a,b}$	$4.7\pm.3^{a}$	$16.0\pm.7^{x,y}$
16% Bran + 12% Midds	46.1 ± 0.9^{c}	$5.7\pm.3^{b}$	$15.5\pm.3^{y}$
BANANA			
Control	56.5 ± 1.5^{a}	$3.4\pm.5^{a}$	$14.7\pm.9^{a}$
16% Bran	48.6 ± 1.5^{b}	$5.1\pm0^{b,c}$	$15.0\pm.5^{a}$
12% Midds	49.9 ± 1.4^{b}	$4.6\pm.7^{b}$	$15.4\pm.4^{a}$
16% Bran + 12% Midds	44.7 ± 0.7^{c}	$5.7\pm.2^{c}$	$14.9\pm.2^{a}$
CHOCOLATE			
Control	19.3 ± 1.3^{a}	$6.0\pm.5^{a}$	$6.2\pm.7^{x}$
16% Bran	$19.4\pm.5^{a}$	$5.1\pm.1^{b}$	$5.7\pm.5^{x}$
12% Midds	$19.5\pm.6^{a}$	$4.7\pm.2^{b,c}$	$5.6\pm.5^{x}$
16% Bran + 12% Midds	$19.0\pm.2^{a}$	$4.3\pm.2^{c}$	$4.9\pm.3^{y}$

[1]Average of 5 replications.

[a]Averages superscripted with same letter are not significantly different at the 1% level of probability (Duncan, 1957).

[x]Averages superscripted with same letter are not significantly different at the 5% level of probability (Duncan, 1957).

Table 26. Analyses of variance of color scores for flavored layer cakes.

Source	df	Mean Squares		
		L	a_L	b_L
NUT				
Total	19	30.72	2.15	0.23
Variables	3	191.60***	13.18***	0.40
Within	16	0.56	0.07	0.19
SPICE				
Total	19	9.26	0.56	0.28
Variables	3	43.45***	2.67***	0.81*
Within	16	2.85	0.16	0.18
BANANA				
Total	19	20.12	0.92	0.33
Variables	3	120.66***	4.83***	0.40
Within	16	1.27	0.19	0.32
CHOCOLATE				
Total	19	0.52	0.49	0.45
Variables	3	0.24	2.67***	1.42*
Within	16	0.57	0.08	0.27

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.
***Significant at the 0.1% level of probability.

Moisture. Means and standard deviations for moisture determinations of all four flavored cakes are presented in Table 27 and analyses of variance of these data are given in Table 28. Significant differences ($p<0.05$) were revealed by the analysis of variance for the nut and banana cakes only. In both cases the variable prepared with midds retained more moisture than the variable prepared with bran. The composition of the midds varies with each milling process (Wheat Flour Institute, 1965). Because the composition of the midds is uncertain it is difficult to relate their presence to the cakes exhibiting the greatest water retention. More research is needed in this area to ascertain the interaction between midds and other cake ingredients.

Sensory Evaluation

All flavored layers were evaluated organoleptically for the characteristics of color, moisture, tenderness, texture, flavor, and general acceptability. Each characteristic was evaluated on a 10-point scale, with 10 being optimum. Means and standard deviations of these sensory scores are given in Table 29. Analyses of variance of these data are given in Table 30. Very highly significant differences for color were revealed in the nut and banana layers whereby color acceptability was decreased by fiber substitution in the nut layers but was improved by fiber substitution in the banana layers. Fiber substitutions changed the crumb color

Table 27. Means and standard deviations[1] for moisture determinations of flavored layer cakes.

Variable	% Moisture
NUT	
Control	$26.4\pm0.9^{x,y}$
16% Bran	25.2 ± 1.1^{y}
12% Midds	27.1 ± 0.4^{x}
16% Bran + 12% Midds	$26.0\pm0.7^{x,y}$
SPICE	
Control	23.9 ± 1.2^{x}
16% Bran	24.2 ± 1.3^{x}
12% Midds	24.2 ± 1.3^{x}
16% Bran + 12% Midds	23.7 ± 0.7^{x}
BANANA	
Control	$24.7\pm1.5^{x,y}$
16% Bran	23.4 ± 1.5^{y}
12% Midds	26.3 ± 1.4^{x}
16% Bran + 12% Midds	24.2 ± 0.7^{y}
CHOCOLATE	
Control	22.9 ± 2.3^{x}
16% Bran	22.9 ± 1.7^{x}
12% Midds	23.2 ± 1.5^{x}
16% Bran + 12% Midds	23.5 ± 1.5^{x}

[1]Average of 5 replications.

[x]Averages superscripted with same letter are not significantly different at the 5% level of probability (Duncan, 1957).

Table 28. Analyses of variance of moisture determinations for flavored layer cakes.

Source	df	Mean Squares
NUT		
Total	19	1.12
Variable	3	3.23*
Within	16	0.72
SPICE		
Total	19	1.20
Variable	3	0.33
Within	16	1.36
BANANA		
Total	19	2.60
Variable	3	7.27*
Within	16	1.73
CHOCOLATE		
Total	19	2.82
Variable	3	0.37
Within	16	3.28

*Significant at the 5% level of probability.

Table 29. Means and standard deviations[1] for sensory scores[2] of flavored layer cakes.

Variable	Color	Moisture	Tenderness	Texture	Flavor	General Acceptability
NUT						
Control	$8.4\pm.6^{a}$	$8.2\pm.2^{a}$	$7.3\pm.4^{a}$	$7.2\pm.5^{a}$	$9.2\pm.3^{a}$	$7.5\pm.2^{a}$
16% Bran	$8.0\pm.3^{b}$	$8.1\pm.2^{a}$	$8.0\pm.2^{a,b}$	$7.6\pm.5^{a}$	$8.6\pm.3^{b}$	$7.6\pm.1^{a}$
12% Midds	$8.1\pm.5^{b}$	$8.1\pm.5^{a}$	$7.7\pm.4^{a,b}$	$7.3\pm.4^{a}$	$8.4\pm.2^{b}$	$7.4\pm.3^{a}$
16% Bran + 12% Midds	$8.5\pm.4^{a}$	$8.6\pm.3^{a}$	$8.4\pm.5^{b}$	$7.5\pm.4^{a}$	$8.4\pm.4^{b}$	$7.6\pm.4^{a}$
SPICE						
Control	$8.2\pm.2$	$7.8\pm.3^{a}$	$8.0\pm.5^{a}$	$7.8\pm.5^{a}$	$8.6\pm.3^{a}$	$7.6\pm.4^{a}$
16% Bran	$8.3\pm.3$	$8.1\pm.5^{a}$	$8.3\pm.3^{a}$	$7.5\pm.5^{a}$	$8.6\pm.4^{a}$	$7.6\pm.6^{a}$
12% Midds	$8.5\pm.3$	$8.2\pm.5^{a}$	$8.4\pm.5^{a}$	$7.8\pm.4^{a}$	$8.5\pm.5^{a}$	$7.6\pm.6^{a}$
16% Bran + 12% Midds	$8.7\pm.5$	$8.2\pm.5^{a}$	$8.4\pm.4^{a}$	$7.9\pm.4^{a}$	$8.1\pm.2^{a}$	$7.6\pm.8^{a}$
BANANA						
Control	$6.7\pm.7^{a}$	$8.5\pm.2^{a}$	$8.3\pm.6^{a}$	$7.7\pm.4^{x}$	$8.9\pm.3^{x}$	$8.0\pm.4^{a}$
16% Bran	$8.3\pm.4^{b}$	$8.4\pm.3^{a}$	$8.5\pm.5^{a}$	$7.6\pm.5^{x}$	$8.7\pm.2^{x}$	$7.8\pm.3^{a}$
12% Midds	$8.1\pm.4^{b}$	$8.0\pm.4^{a}$	$8.1\pm.7^{a}$	$7.3\pm.4^{x}$	$9.4\pm.3^{y}$	$7.8\pm.5^{a}$
16% Bran + 12% Midds	$7.9\pm.7^{b}$	$8.2\pm.2^{a}$	$8.1\pm.7^{a}$	$6.6\pm.6^{y}$	$8.6\pm.6^{x}$	$7.3\pm.7^{a}$
CHOCOLATE						
Control	$9.0\pm.4^{a}$	$7.4\pm.5^{a}$	$9.0\pm.3^{a}$	$8.5\pm.3^{a}$	$9.6\pm.3^{x}$	$8.6\pm.3^{a,b}$
16% Bran	$9.0\pm.1^{a}$	$8.0\pm.5^{a}$	$9.1\pm.3^{a}$	$8.4\pm.2^{a}$	$9.4\pm.2^{x}$	$8.9\pm.4^{a}$
12% Midds	$9.0\pm.2^{a}$	$7.9\pm.4^{a}$	$9.2\pm.3^{a}$	$8.6\pm.3^{a}$	$9.2\pm.5^{x,y}$	$8.6\pm.5^{a,b}$
16% Bran + 12% Midds	$8.9\pm.2^{a}$	$8.2\pm.7^{a}$	$9.0\pm.3^{a}$	$8.1\pm.4^{a}$	$8.7\pm.5^{y}$	$8.0\pm.1^{b}$

[1] Average of 5 replications.
[2] 10-point scale with 10 being optimum.
[a] Averages superscripted with same letter are not significantly different at the 1% level of probability (Duncan, 1957).
[x] Averages superscripted with same letter are not significantly different at the 5% level of probability (Duncan, 1957).

Table 30. Analyses of variance for sensory scores of flavored layer cakes.

Variable	df	Mean Squares					
		Color	Moisture	Tenderness	Texture	Flavor	General Acceptability
NUT							
Total	19	.07	.16	.29	.19	.18	.08
Variables	3	.32***	.33	.92**	.17	.63**	.04
Within	16	.02	.13	.16	.20	.09	.09
SPICE							
Total	19	.13	.21	.20	.18	.17	0
Variable	3	.22	.24	.14	.13	.22	0
Within	16	.12	.21	.21	.20	.16	0
BANANA							
Total	19	.74	.10	.35	.37	.21	.27
Variable	3	3.00***	.22	.17	1.14*	.61*	.36
Within	16	.31	.08	.39	.23	.13	.25
CHOCOLATE							
Total	19	.05	.34	.08	.11	.27	.21
Variable	3	.01	.54	.04	.22	.68*	.71**
Within	16	.60	.31	.09	.09	.19	.11

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.
***Significant at the 0.1% level of probability.

of the nut cakes from creamy white to tan while crumb color of the banana cakes changed from grey to tan.

No significant differences were revealed in any of the cakes for the moisture evaluation and tenderness was affected by fiber substitution in the nut layers only. Tenderness was significantly decreased ($p<0.01$) in the variable containing the substitution of both bran and midds as compared to the control.

Significant texture differences ($p<0.05$) were revealed in the banana layers only. The control layer and the layer substituted with the 16% bran were scored as having significantly better texture than the layer containing the substitution of 16% bran plus 12% midds.

Flavor was unaffected by fiber substitutions in the spice layers but was significantly different in the nut ($p<0.01$), banana ($p<0.05$), and chocolate ($p<0.05$) layers. Flavor was slightly impaired at any fiber substitution level in the nut cakes; however, flavor was scored highest in the cakes substituted with 12% midds for the banana layers. Chocolate cake flavor was slightly impaired at only the 16% bran plus 12% midds level of flour substitution. However, in all cases, no score was below 8 on a 10-point scale.

Significant differences ($p<0.01$) in general acceptability were revealed for the chocolate layers only. The cake containing a 16% bran substitution was the most acceptable chocolate layer while the cake containing a flour substitution of 16% bran plus 12% midds was least acceptable. Nevertheless, all of these cakes had average general acceptability scores of 7 to 9.

An overall review of sensory scores tends to indicate that flavored layer cakes prepared with fiber substitutions for flour result in good quality products.

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the feasibility of incorporating dietary fiber into a baked product system while maintaining the original product quality. The baked product chosen for this research was layer cakes.

White layer cakes were prepared from 60 and 70% extraction flours with increasing substitution levels of bran and middlings using a standard white layer cake formulation. Substitution levels included 4, 8, and 16% bran, 12% middlings either bleached or unbleached, and the combination of 16% bran with either 12% bleached or unbleached middlings to approximate whole wheat flour. Flavored cakes were also prepared from a 70% extraction flour employing levels of 16% bran, 12% unbleached middlings, and the combination of the 16% bran plus 12% unbleached middlings. The flavors prepared were nut, spice, banana, and chocolate. The bran and middlings were ground with a cyclone mill to the same particle size as the control flour to eliminate mouthfeel differences.

Physical characteristics of the white cake batters examined were specific gravity, viscosity, color, and pH. Cake quality characteristics examined were volume indices, moisture, tenderness, compressibility, color and pH. Physical characteristics of the flavored cakes examined were volume indices, moisture, and color. Organoleptic studies were also conducted on all cake variables.

Objective measurements of the quality characteristics of the white cakes indicated that specific gravity of the batter and uniformity, symmetry, and shrinkage of the cakes were not significantly changed by either the flour extraction or the level of dietary fiber used. High fiber replacement levels in the 70% extraction flour appeared to form a more viscous batter than any of the batters prepared with the 60% extraction flour. Cakes prepared with the 60% extraction flour showed greater moisture retention than those prepared with 70% extraction flour. The level of dietary fiber used, however, did not affect moisture retention of the cake. The volume index was not adversely affected except by substitutions containing the bleached midds. Substitution of fiber in the cake formulations resulted in increased tenderness values but no trend for compressibility was established. Both the batter and cakes prepared with increased levels of dietary fiber had higher yellowness and redness but decreased lightness values. Sensory data scores showed that the incorporation of bran and midds into the layer cakes did not adversely affect the quality characteristics of the product. Out of a possible 100 points all cakes were scored 75 or above.

Objective measurements of the quality characteristics of the flavored cakes indicated that volume was slightly impaired in the banana and chocolate cake layers as the fiber substitution levels increased. This was attributed to the higher sugar levels in these cakes and the fact that sugar acts in competition for the water. As the percentage fiber substitution increased the lightness value decreased in the nut, spice, and banana layers. The redness value increased in all four flavored layers as fiber substitution levels increased while the yellowness value decreased in only the spice and chocolate layers. Moisture retention was affected in the nut and banana cakes where the substitution of 12% midds retained the greatest amount of water. This may have been due to the chemical interaction of the midds with the other cake ingredients but further research is necessary to pinpoint the cause. Sensory data indicated that bran and midds incorporation into the layer cakes did not affect cake quality. All characteristics evaluated were rated 7 or better on a 10-point scale.

From an evaluation of the data obtained in this investigation, it can be concluded that dietary fiber in the form of bran and midds can be increased in layer cakes without adversely affecting the cake quality characteristics.

PROPOSALS FOR FURTHER RESEARCH

Although the results of this study indicate that substitution of wheat bran and middlings for flour in a layer cake system is a feasible method of increasing dietary fiber intake, further investigation is warranted. The following research areas are proposed:

1. The effect of fiber substitutions in other cake formulations needs to be studied. The effects of ingredient changes, especially changes in the water level and/or the addition of emulsifiers, need further investigation.

2. Fiber substitutions in other baked products, such as cookies, biscuits, or pastry, need to be studied. In order to increase the intake of dietary fiber in the diet a variety of fiber carriers need to be available for consumption.

3. Studies concerning the effects of the substitution of levels of fiber greater than 16% bran plus 12% midds need to be conducted on cakes as well as other baked products.

4. The effect of dietary fiber on the absorption of vitamins and minerals needs to be investigated. Controlled feeding studies would indicate whether or not fiber constituents decrease nutrient absorption and utilization in the body.

5. Studies are needed to determine the effect of fiber substitutions on product stability and shelf life. The increased lipid levels at high fiber substitution levels may cause rancidity to occur at an increased rate.

6. Finally, investigations into the physical and chemical characteristics of middlings need to be made. Only then can the interactions of midds with the other baked product ingredients be clearly understood.

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APPENDICES

APPENDIX I

PROXIMATE ANALYSIS OF BRAN, MIDDLINGS, AND FLOURS OBTAINED FROM MENNEL MILLS

Identification	Moisture %	Protein %	Ash %	pH
Bleached Patent 50% Extraction	13.6	8.85	0.36	4.75
Bleached Straight Grade 70% Extraction	13.3	9.45	0.51	5.05
Bleached Clears	12.7	11.70	0.95	5.25
Wheat Midds Unbleached	12.3	15.55	4.80	----
Wheat Midds Bleached	12.3	15.55	4.80	----
Wheat Bran Unbleached	13.1	14.55	6.60	----

APPENDIX II

AVERAGE PARTICLE SIZE[1] OF FLOUR AND CYCLONE MILLED BRAN AND MIDDS

PARTICLE SIZE in	60% Flour Extraction %	70% Flour Extraction %	Bran %	Midds Bleached %	Midds Unbleached %
.0232	0	0	0	0	0
.0165	0	0	0	0	0
.0116	55	64	69	48	56
.0058	22	27	30	51	43
.0029	21	8	1	1	1
.0017	2	1	0	0	0

[1]Average of 5 replications.

APPENDIX III

TASTE PANEL EVALUATION OF WHITE LAYER CAKES CHARACTERISTICS

Internal Factors (100 points)		Score (Points)
A. Cells (30 points)		
1. Uniformity (10 points)	a) Even (normal)	10
	b) Slightly uneven	6
	c) Uneven	2
2. Size (10 points)	a) Dense (normal)	10
	b) Close	8
	c) Slightly open	6
	d) Open	4
3. Thickness of walls (10 points)	a) Thin (normal)	10
	b) Slightly thick	6
	c) Thick	2
B. Grain (16 points)		
1. Silky (normal)		16
2. Harsh		10
3. Coarse (corn bread)		8
C. Texture (34 points)		
1. Moistness (10 points)	a) Gummy	6
	b) Moist (normal)	10
	c) Slightly dry	8
	d) Dry	4
2. Tenderness (14 points)	a) Very tender (normal)	14
	b) Tender	12
	c) Slightly tough	10
	d) Tough	4
3. Softness (10 points)	a) Soft (normal)	10
	b) Slightly firm	8
	c) Firm	4
D. Crumb Color (10 points)		
1. Bright white (normal)		10
2. White		8
3. Slightly dull		8
4. Slightly creamy		8
5. Creamy		6
6. Slightly dull and slightly creamy		4
E. Flavor (10 points)		
1. Normal (no off-flavor due to flour)		10
2. Foreign		10
	TOTAL	100

APPENDIX IV

TASTE PANEL EVALUATION OF FLAVORED LAYER CAKE CHARACTERISTICS

Quality Factors	Scoring Scale			
Color	10 9 Very desirable	8 7 6 Moderately desirable	5 4 3 Slightly desirable	2 1 Very undes.
Moistness	10 9 Very desirable	8 7 6 Moderately desirable	5 4 3 Slightly desirable	2 1 Very undes.
Tenderness	10 9 Very desirable	8 7 6 Moderately desirable	5 4 3 Slightly desirable	2 1 Very undes.
Texture	10 9 Very desirable	8 7 6 Moderately desirable	5 4 3 Slightly desirable	2 1 Very undes.
Off-flavor	10 9 Very desirable	8 7 6 Moderately desirable	5 4 3 Slightly desirable	2 1 Very undes.
General Acceptability	10 9 Very desirable	8 7 6 Moderately desirable	5 4 3 Slightly desirable	2 1 Very undes.

Comments:

APPENDIX V

SCORING OF INDIVIDUAL CHARACTERISTICS BY TASTE PANEL MEMBERS FOR WHITE LAYER CAKES PREPARED WITH 60% EXTRACTION FLOUR

Variable	Uniformity	Size	Wall Thickness	Grain	Moistness	Tenderness	Softness	Crumb Color	Flavor
Control	6.9±0.7	8.7±0.2	8.2±0.4	15.4±1.0	9.0±0.6	10.8±0.8	7.7±0.9	9.2±0.0	9.1±1.2
4% Bran	5.5±0.9	7.5±0.7	7.3±0.9	14.5±0.5	9.0±0.4	11.6±0.8	8.3±0.8	7.3±0.2	9.5±1.1
8% Bran	6.5±0.4	7.8±0.9	7.6±0.8	13.4±1.0	9.6±0.3	12.0±0.6	8.6±0.5	6.4±0.3	9.0±1.4
16% Bran	4.9±0.9	7.1±1.1	7.7±1.2	13.4±0.5	9.7±0.5	12.6±0.6	9.1±0.7	5.8±0.4	8.5±1.4
12% Midds Bleached	6.0±1.5	7.8±0.9	8.6±0.4	13.8±1.0	9.3±0.7	12.5±0.6	9.3±0.6	6.4±0.3	8.6±1.3
12% Midds Unbleached	5.8±0.9	7.9±0.9	8.2±1.7	15.0±1.6	9.8±0.4	12.9±0.5	9.2±0.3	6.2±0.5	8.1±1.1
16% Bran + 12% Midds Bleached	6.5±0.4	7.1±1.2	7.6±1.1	13.1±0.7	9.9±0.2	12.8±0.9	9.0±0.9	5.4±0.2	4.4±2.2
16% Bran + 12% Midds Unbleached	6.3±1.1	7.7±1.0	7.3±0.9	13.7±1.1	9.8±0.2	13.0±0.2	9.4±0.5	5.4±0.4	5.2±1.8

APPENDIX VI

SCORING OF INDIVIDUAL CHARACTERISTICS BY TASTE PANEL MEMBERS FOR WHITE LAYER CAKES PREPARED WITH 70% EXTRACTION FLOUR

Variable	Uniformity	Size	Wall Thickness	Grain	Moistness	Tenderness	Softness	Crumb Color	Flavor
Control	5.4±0.9	7.5±0.5	8.1±0.7	15.5±0.7	9.3±0.6	11.2±1.8	8.4±0.8	8.3±0.3	10.0±0.0
4% Bran	6.6±1.0	7.4±0.7	8.3±0.8	13.8±1.0	9.0±0.7	12.2±0.5	8.9±0.4	7.2±0.8	8.6±2.2
8% Bran	6.3±0.4	7.4±0.9	8.1±0.7	13.6±0.8	9.4±0.5	11.8±1.1	8.6±0.6	6.3±0.2	7.6±2.5
16% Bran	6.3±0.7	7.1±0.9	7.7±0.7	13.6±1.2	9.5±0.5	12.5±0.2	8.9±0.6	5.5±0.2	7.0±1.1
12% Midds Bleached	6.8±1.6	7.4±1.0	8.6±1.0	13.8±0.5	9.2±0.6	12.0±0.5	8.6±0.6	5.9±0.7	6.7±1.6
12% Midds Unbleached	6.7±1.0	7.8±0.8	8.4±1.5	14.0±0.6	9.4±0.4	12.0±0.4	8.7±0.5	6.2±0.5	6.2±1.3
16% Bran + 12% Midds Bleached	7.4±1.0	7.4±1.0	8.3±0.3	8.2±1.1	14.3±1.1	9.6±0.6	12.5±0.3	5.2±0.1	4.4±1.5
16% Bran + 12% Midds Unbleached	6.1±1.1	7.2±1.5	7.9±0.7	13.6±0.8	9.7±0.3	12.6±1.0	8.8±0.7	5.3±0.2	3.9±2.3

APPENDIX VII

RESULTS OF FLOUR FRACTIONATION PROCEDURE FOR 60 AND 70% EXTRACTION FLOURS[1]

Variable	Starch %		Tailings %		Gluten %		Water Solubles %	
	60%	70%	60%	70%	60%	70%	60%	70%
Control	73.3	72.6	12.3	13.6	10.3	9.1	4.1	4.7
4% Bran	62.6	63.3	22.2	22.3	10.8	9.9	4.3	4.3
8% Bran	55.4	55.5	30.4	30.3	9.9	10.0	4.4	4.2
16% Bran	35.0	38.8	51.7	48.0	9.0	8.2	4.2	5.3
12% Midds Bleached	51.9	54.1	34.8	31.7	8.9	8.8	4.5	4.9
12% Midds Unbleached	53.6	54.5	33.0	31.5	9.0	9.4	4.4	4.5
16% Bran + 12% Midds Bleached	----	----	----	----	5.7	4.6	5.3	5.8
16% Bran + 12% Midds Unbleached	----	----	----	----	6.0	6.8	5.0	5.5

[1]All data on 14% moisture basis.

APPENDIX VIII

CRUDE FAT ANALYSES OF 60 AND 70% EXTRACTION FLOURS[1]

Variable	Crude Fat - %	
	60%	70%
Control	1.50	1.88
4% Bran	1.93	2.26
8% Bran	2.31	2.70
16% Bran	2.80	2.94
12% Midds Bleached	2.22	2.87
12% Midds Unbleached	2.59	2.42
16% Bran + 12% Midds Bleached	3.03	3.98
16% Bran + 12% Midds Unbleached	3.48	4.07

[1]All data on 14% moisture basis.