# WHEAT, CORN AND OAT BRANS AS SOURCES OF DIETARY FIBER IN BREAD SYSTEMS

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DIETARY FIBER IN BREAD SYSTEMS

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TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

| Table | | Page |
|---|---|---|

LIST OF FIGURES

| Figure | | Page |
|---|---|---|

# CHAPTER I

## INTRODUCTION

During the past decade, there has been a renewed interest in the fiber content of the foods and the effects of dietary fiber intake on man. Fiber was once an undesirable portion of foods that was largely removed in processing. The current trend is to incorporate it back into food products. As a result, consumers are attempting to include more dietary fiber in their diets with the belief it may prevent certain diseases associated with modern Western civilization (Trowell, 1972; Burkitt, 1973; Burkitt, Walker and Painter, 1974).

In the Refined Carbohydrate Foods and Disease, edited by Burkitt and Trowell (1975), the following diseases are discussed as the result of low dietary fiber intake: appendicitis, diverticular disease of the colon, benign and malignant tumors of the large bowel, ulcerative colitis, Crohn's disease, varicose veins, deep vein thrombosis, hemorrhoids, hiatus hernia, gallstones and colecystitis, ischemic heart disease, diabetes, obesity, dental decay, peridontal disease and duodenal ulcer. These diseases are still rare in rural communities of developing countries (Burkitt, Walker and Painter, 1972). In fact, before the twentieth century, historical studies indicate these diseases were also rare in Western civilization (Burkitt, 1975). It has been suggested that the removal of fiber from carbohydrate foods and the excess consumption of refined cereal and sugar may cause these Western diseases (Cleave, Campbell and Painter, 1969).

While a fiber-depleted diet may not be the only factor responsible for these diseases, it may be a causative factor contributing in varying degrees to the previously mentioned diseases. Burkitt (1975) suggests that probably the best solution is the addition of fiber to food. Diets high in dietary fiber, especially wheat bran, have been shown to effectively alleviate symptoms of diverticular disease (Painter, Almeida and Colebourne, 1972). Wheat bran also reduces stool transit time and increases stool bulk (Truswell and Kay, 1976). The intake of certain plant fibers, such as rolled oats, pectin, guar and Bengal gram, have been shown to effectively lower serum cholesterol concentrations in human subjects (De Groot, Luyken and Pikaar, 1963; Anderson and Chen, 1979; Judd and Truswell, 1981).

Since the cost of fresh fruits and vegetables continues to rise, processed foods have become an inexpensive solution to increasing dietary fiber intake of man (Scala, 1974). Fiber can be added to bread products both to increase dietary fiber content and to reduce caloric value. Acceptable bread products have been produced from wheat flours with 7% of the flour replaced with microcystalline cellulose or wheat bran (Pomeranz, Shogren, Finney and Bechtel, 1977). Actually, little is known about the effects of different grain fibers on bread systems. Pomeranz et al. (1977, p. 40) suggests further studies are needed to discover "an ideal fiber material (in terms of functional breadmaking properties) that would eliminate or at least minimize crumb-structure disrupting effects."

## Purpose and Objectives

The purpose of this study is to compare the effects of wheat bran, corn bran, oat bran and corn-oat bran on the sensory and objective qualities of various bread systems. The objectives of the study are as follows:

1. To determine the effect of wheat bran, corn bran, oat bran and corn-oat bran on the sensory and objective qualities of Anadama bread.

2. To determine the effect of wheat bran, corn bran, oat bran and corn-oat bran on the sensory and objective qualities of banana nut bread.

3. To determine the effect of wheat bran, corn bran, oat bran and corn-oat bran on the sensory and objective qualities of bran rolls.

4. To determine the effect of wheat bran, corn bran, oat bran and corn-oat bran on the sensory and objective qualities of whole wheat English muffins.

5. To develop acceptable bread systems using 1-g NDF calculations.

6. To make recommendations for further studies in this area.

## Hypotheses

The following hypotheses are postulated for this research:

$H_1$: There will be no significant differences in the sensory and objective qualities of Anadama bread when all-purpose flour is replaced with the appropriate amounts of wheat bran, corn bran, oat bran and corn-oat bran to yield 1-g NDF per serving. The sensory evaluation of

Anadama bread includes the attributes of top crust, shape of top crust, crust color, structure of cells, texture, crumb color, moisture, flavor and overall acceptability. The objective qualities that are evaluated include baking loss, height, index to volume and nutritional composition.

$H_2$: There will be no significant differences in the sensory and objective qualities of banana nut bread when all-purpose flour is replaced with the appropriate amounts of wheat bran, corn bran, oat bran and corn-oat bran to yield 1-g NDF per serving. The sensory evaluation of banana nut bread includes the same attributes as in $H_1$, excluding texture. The objective qualities are the same as in $H_1$.

$H_3$: There will be no significant differences in the sensory and objective qualities of bran rolls when all-purpose flour is replaced with the appropriate amounts of wheat bran, corn bran, oat bran and corn-oat bran to yield 1-g NDF per serving. The sensory evaluation of bran rolls includes the attributes of top crust, crust color, structure of cells, crumb color, moisture, mouthfeel, flavor and overall acceptability. The objective qualities that are evaluated are the same as in $H_1$.

$H_4$: There will be no significant differences in the sensory and objective qualities of whole wheat English muffins when all-purpose flour is replaced with the appropriate amounts of wheat bran, corn bran, oat bran and corn-oat bran to yield 1-g NDF per serving. The sensory evaluation of whole wheat English muffins includes the attributes of top crust, crust color, side walls, structure of cells, texture, crumb color, moisture, mouthfeel, flavor and overall accepability.

The objective qualities evaluated are the same as in $H_1$, with the addition of diameter.

## Assumptions and Limitations

The following assumptions were made for this study:

1. A trained taste panel will evaluate the bread products as instructed.

2. The experiments will be conducted under controlled environmental conditions.

Limitations for this study are identified as follows:

1. Only four baked products will be investigated:

   a. Anadama bread

   b. Banana nut bread

   c. Bran rolls

   d. Whole wheat English muffins

2. Only three brans will be used:

   a. Wheat bran obtained from Shawnee Milling Company, Shawnee, Oklahoma.

   b. Corn bran, regular grind, obtained from A. F. Staley Manufacturing Company, Decatur, Illinois

   c. Oat bran obtained from Quaker Oats Company, Barrington, Illinois.

## Definitions of Terms

Crude Fiber (CF) - the residue from a food sample that remains after sequential extraction with solvent, dilute acid and dilute alkali. This residue is composed primarily of lignin and cellulose (Southgate, 1975; Trowell, 1976; Anonymous, 1979).

Dietary Fiber - defined as plant cell-wall materials that are indigestible by the secretions of the human digestive system. It consists mainly of unavailable carbohydrates, such as pectins, celluloses, hemicelluloses, gums and mucilages; includes non-carbohydrate substances such as lignin, nitrogen-containing compounds, complex unavailable lipids and trace elements (Trowell, 1972; Scala, 1974; Southgate, 1977; Van Soest and Robertson, 1977).

Unavailable Carbohydrate - refers to all plant polysaccharides resistant to enzymatic hydrolysis in the human digestive system (Southgate, 1973; Cummings, 1976).

Cellulose - an unbranched polymer of glucose residues linked together with B 1-4 glucosidic linkages. It is insoluble in water or other solvents, and is dissolved by concentrated solutions of alkali (Windholz, 1976).

Hemicellulose - a polysaccharide component that constitutes the secondary plant cell wall thickening, extracted with dilute alkali. They are complex polymers of xylose, arabinose, glucuronic acid, galactose, mannose and sometimes other saccharide polymers. Hemicelluloses have water-holding capacity and can bind actions (Van Soest and McQueen, 1973; Southgate, 1975; Anderson and Chen, 1979).

Pectins - complex polysaccharides that are found in the middle lamellae, primary cell walls and intercellular materials of most plants. Pectins can form gels and have water-holding capacity. The basic structure of pectin is a polymer of galacturonic acid with side chains of galactose, arabinose, xylose, rhamose and fucose (Cummings, 1976; Anderson and Chen, 1979).

Lignin - an aromatic complex polymer consisting of substituted phenylpropane units of various alcohols. It is regarded as the main non-carbohydrate fraction in the plant cell wall and is resistant to microbial and chemical degradation (Van Soest and McQueen, 1973; Southgate, 1975; Huang, Gopalakriskna and Nichols, 1978).

Mucilages - polysaccharide components of plant tissues that are extracted with hot water and have water-holding capacity (Bing, 1976; Anderson and Chen, 1979).

Gums - branched polymers of glucuronic and galacturonic acids with side branches of neutral sugars such as xylose, arabinose and galactose; are water-soluble substances of the cell wall of endosperm and germ (Meyers and Calloway, 1977; Anderson and Chen, 1979).

Neutral Detergent Fiber (NDF) - an organic residue left after treatment with hot neutral detergent solution; a measurement of the total components of the cell wall, including lignin, cellulose and hemicellulose (Van Soest and McQueen, 1973; Southgate, 1975, 1977; Van Soest and Robertson, 1977).

Acid Detergent Fiber - an organic residue left after treatment with boiling acid containing detergent. It represents mainly crude lignin and cellulose fraction of plants (Southgate, 1975, 1977; Van Soest and Robertson, 1977).

Bran - a portion of a kernel of cereal or grain that functions as a container for the endosperm and germ; the remainder with germ after the milling process of grains that in the past was used only for animal feed (Griswold, 1962; Vail, Phillips, Rust, Griswold and Justin, 1973).

## CHAPTER II

## REVIEW OF LITERATURE

Pertinent literature to the understanding of the role of dietary fiber in nutrition and food product development is presented in this chapter. The epidemiological relationships and theoretical assumptions about fiber and certain diseases, as well as the methodologies and terminology in the evaluation of dietary fiber will be discussed. Recent studies to evaluate the effect of different types and levels of fiber on the physical characteristics and the quality of various baked products will be reviewed.

### Dietary Fiber and Disease Relationships

For many years, fiber has been surrounded by mystery and ignorance. Where proteins, fats and carbohydrates have been extensively studied, dietary fiber has been historically disregarded and categorized as indigestible and of negligible nutritive value (Burkitt, 1977). In the last decade, there has been research on fiber and its role in health, as well as "what it actually is and how many kinds of it there are" (Galton, 1976, p. 120). Fiber is a very complex substance that needs further investigation and definition.

Fiber has been synonymously referred to as bran, roughage, bulk and residue. In 400 B.C., Hippocrates identified bran as a laxative (Colmey, 1978). Actually, bran is the hard outer protective coating of a kernel of grain and the by-product of the milling process of grains and cereals. Roughage is defined as a rough or coarse substance that serves as a stimulus to peristalsis (Guralnik, 1973). Bulk is the measure of water-holding capacity of some foods beyond the colon; and the term "residue" is often used by the medical profession to refer to anything that might add mass to the stool (Monte, 1981). Currently, dietary fiber is the accepted term used to refer to fiber fractions of plant foods.

Dietary fiber has been classified into three categories according to physiological related claims: definite value, probable value and possible value (Anonymous, 1979). The definite value of fiber is relieving constipation problems, and the probable value is in the treatment of diverticular disease. The possible value relates to reducing serum cholesterol levels and prevention of certain diseases such as hemorrhoids, varicose veins, ischemic heart disease, colon-rectal cancer, diabetes, appendicitis, obesity, gallstones, phlebitis, dental caries, irritable bowel, ulcerative-colitis and harmful effects of some toxic substances.

The majority of epidemiological evidence that associates fiber and disease comes principally from developing countries in Africa (Trowell, 1972; Burkitt, 1973; Burkitt et al., 1974). After visiting five continents and comparing epidemiological evidence, Burkitt suggests that four stages lead to the correlations of Westernization of diets and certain diseases (Burkitt and Trowell, 1975). First stage: the primitive diet is largely unprocessed starches and plant foods; diseases associated with Western civilization are rare. Second stage: as Westernization of diet begins, obesity and diabetes become common among advantaged groups. Third stage: with the moderate Westernization of diets, constipation, hemorrhoids, varicose veins and appendicitis are common clinical problems. Fourth stage: in the advanced Westernization of diets, thromboembolic disease, ischemic heart disease (IHD), diverticular disease, hiatus hernia and cancer of the colon became common.

Table I summarizes the differences in prevalence of certain diseases between African populations and the United States (Burkitt et al., 1974). Burkitt (1973) observes the high fiber-containing foods of rural Africans and correlates the adoption of Western customs with the rise in frequency of these diseases. The per capita consumption of fiber in the American diet has decreased in this century; fiber from fruits and vegetables has declined by 20% and from cereals and grains by as much as 50% (Scala, 1974; Heller and Hackler, 1978). There has been a 90% drop in fiber consumption between 1880 and 1960 which corresponds with the changes in milling techniques introduced in 1880 and the reduction in fiber content of wheat flour (Trowell, 1972; Burkitt, 1973). Cleave, Campbell and Painter (1969) present evidence that excess refined cereal and sugar consumption may cause obesity, diabetes mellitus, coronary heart disease and other Western diseases.

The composition of the average Western diet is compared to the diets of the average Trappist monk, the Yeminite and the Bedouin in Table II (Groen, 1973). All three groups that are compared to the Western diet have higher intakes of carbohydrates and lower intakes of fat and cholesterol. The fiber contents of the Western diet is lower than the other groups. Groen (1973) has found that when saturated fat in the diet is replaced by bread or polyunsaturated fat, serum

TABLE I

PREVALENCE OF CERTAIN DISEASES[a]

| Condition | In the United States | In Africa |
|---|---|---|
| Ischemic heart disease | Responsible for a third of all deaths | Virtually unknown. Incidence just beginning to increase slowly in large cities. |
| Appendicitis | The most frequent of abdominal emergencies | Virtually unknown in rural areas. Incidence starting to rise in more westernized communities |
| Diverticular disease | The most common disease of the colon. | Almost unknown |
| Gallstones | Present in some 10% of the adult population. | Exceedingly rare. |
| Varicose veins | Present in over 10% of the adult population. | Present in probably 0.1% of those living in a traditional manner. Increasing with adoption of western customs. |
| Deep vein thrombosis and resultant pulmonary embolism | These make hospital life increasingly hazardous. | Very rare. |
| Hiatus hernia | Demonstrable in nearly half the population over the age of 50 years. | Almost unknown. |
| Hemorrhoids | " " " " " " | Rare or very rare according to degree of westernization. |
| Cancer of the colon and rectum | Second only to lung cancer as a cause of death from neoplasms. | Rare |
| Obesity | Nearly half the adult population is markedly overweight. | Rare amongst those living wholly on traditional diets. Becomes common with urbanization and adoption of western foods. |

[a]Burkitt et al., 1974, p. 71.

TABLE II

COMPARISON OF THE COMPOSITION OF AVERAGE WESTERN, TRAPPIST MONKS, YEMENITE AND BEDOUIN DIETS[a,b]

| Ingredient | Western | Trappist Monks | Yemenite | Bedouin |
|---|---|---|---|---|
| Bread | 150 | 600 | 500 | 750 |
| Butter, margarine and cream | 125 | 25 | 10 | *[c] |
| Meat | 100-200 | -[d] | 100 | 10-25 |
| Egg | 50 | - | 50 | 5 |
| Cheese | 30 | 0[c] | - | 5 |
| Milk | 150 | 250 | - | * |
| "Leben" (buttermilk) | - | 250 | 150 | * |
| Fruit | 300 | 300 | 200 | * |
| Vegetables | 300 | 300 | 200 | 50 |
| Legumes | 0 | 100-150 | 30 | * |
| Potatoes, macaroni, and rice | 100 | 500 | 100 | 100 |
| Honey, sugar, chocolate, cakes | 100 | 5 | 25 | 25 |
| Oil | - | 30 | 10 | 10 |
| Protein: | | | | |
| Total | 85(15)[e] | 110(14) | 88(15) | 63(11) |
| Vegetable | 30 | 70 | 58 | 58 |
| Animal | 55 | 40 | 30 | 5 |
| Carbohydrates: | | | | |
| Total | 250(45) | 480(64) | 355(65) | 410(74) |
| Mono- & disaccharides | 115 | 40 | 40 | 20 |
| "Starch" | 135 | 440 | 315 | 390 |
| Fat: | | | | |
| Total | 100(40) | 78(21) | 48(19) | 38(15) |
| Saturated fatty acids | 50 | 18 | 18 | 8 |
| Oleic acid | 32 | 40 | 20 | 12 |
| Linoleic acid | 9.5 | 5.0 | 6.5 | 9.0 |
| Cholesterol (g) | 0.55 | 0.16 | 0.40 | 0.04 |
| Fiber | 5 | 13 | 8 | 7 |
| Energy (MJ/d) | 9.4 | 13.4 | 9.2 | 9.4 |

[a]Groen, 1973, p. 160.

[b]Values of the composition of the diet are: g/diet.

[c]These ingredients are not always included in the diet.

[d]A dash (-) indicates values are not given.

[e]Values in parentheses indicate the energy content (%).

cholesterol levels are reduced and excretion of neutral steroids and bile acids in the stools is increased. Burkitt et al. (1974) explains:

> Calorie intake, speed of passage through the intestine, levels of intracolonic pressure, number and type of fecal bacteria, as well as levels of serum cholesterol and changes in bile salt metabolism are related to amount of dietary fiber consumed (p. 1068).

Spiller and Kay (1979) explain the relationship of fiber and digestive function in two ways: 1) fiber is involved in stool bulk and consistency, prevention of treatment of constipation, as well as normalization of the whole gut transit; and 2) intraluminal pressure and muscular hypertrophy are reduced by some fiber in diverticular disease. The astronaut is an example of an individual who consumes refined foods which cause fewer and smaller stools; when an astronaut is fed a diet almost free of fiber, the results are extreme constipation with five or six days elapsing between bowel evacuation (Wintz, Graff, Gallagher, Markin and Seedman, 1965).

It is generally recognized that certain amounts of dietary fiber have laxative effects. Bran functions as a laxative in patients with diverticular disease and those with delayed bowel activity (Findlay, Smith, Mitchell, Anderson and Eastwood, 1974). When compared to oat bran, frequency in bowel movements per day are higher than those of wheat bran and raffinose, and wet and dry fecal weights are increased by wheat bran (Meyers and Calloway, 1977). The laxative effect is caused by the mechanical stimulus of distention due to large amounts of residue present in the colon and the water-holding capacity of different fibers (Monte, 1981).

Diverticular disease is the "outpouching" of the intestinal wall that is the result of a fold of muscle in the interior wall that pushes outward to the external wall; diverticulitis results when the pouch or diverticula fills with fecal matter and becomes infected (Mayer, 1975; Leveille, 1976). Diverticular disease is the most common disease of the large intestine in North America and Great Britain (Latto, Wilkinson and Gilmore, 1973).

In the past, low residue diets have been used to treat diverticular disease. It was presumed that the low residue diet will allow healing because it did not irritate the bowel. People consuming high residue diets tend to pass large, soft and non-odorous stools which contrasts with the small, fetid stools of low residue diets (Cleave et al., 1969; Burkitt et al., 1974). Bran is therapeutically recommended in the treatment of constipation, diverticular disease and other colonic disorders (Painter et al., 1972). Bran increases dry weight of the stool, even when the dosage is small, less than 2-g crude fiber per day; 16-g wheat bran per day can approximately double the stool weight after three weeks of treatments (Eastwood, Kirkpatrick, Mitchell, Bone and Hamilton, 1973). A high fiber diet of 15 to 35-g wheat bran per day relieves gastrointestinal symptoms of diverticular disease; consequently, high fiber diets are shown to effectively manage diverticular disease of the colon (Painter et al., 1972).

Clinical investigators suggest that diverticular disease develops from the slow movement of small, hard and dry stools through the intestine which increases pressure in the colon (Leveille, 1976). Increased dietary fiber reduces pressure by the absorption of water to form softer stools and decrease transit time. Swiftly passed soft stools cause less strain and do not promote the formation of diverticulae (Painter and Burkitt, 1971).

Diverticular disease is related to appendicitis, hiatus hernia, varicose veins and gallstones (Latto et al., 1973; Brodribb and Humphreys, 1976). In one study, 73% of 110 patients with diverticular disease had some evidence of varicose veins (Latto et al., 1973). Cleave et al. (1969) postulate local pressure as a causative factor, while Burkitt suggests an alternative explanation. The alternative explanation is intra-abdominal pressure that is raised naturally when straining to eliminate a stool (Burkitt, 1972; Burkitt et al., 1974).

Varicose veins might result from raised intra-abdominal pressure transmitted down the veins of the leg (Burkitt, 1977). Varicose veins affect 15% of the United States population (Latto et al., 1973). Interestingly, communities who squat during elimination seem to have lower prevalence for varicose veins (Burkitt, 1972).

Hiatus hernia is a condition almost unknown in less civilized countries (Burkitt and James, 1973). Diverticular disease and hiatus hernia are closely associated, and the fiber depleted diet is suggested as a common cause (Burkitt and James, 1973). Increased intra-abdominal pressure favors the dilation of hemorrhoidal veins and might contribute to the production of hiatus hernia (Burkitt et al., 1974).

"It is probable that almost all metabolic functions affected by dietary fiber can be related to the colon" (Mendeloff, 1976, p. 322). Cancer of the colon, varicose veins, diverticular disease and constipation are all more common in the female (Burkitt, 1972). The American male has six times the chance of contracting intestinal cancer than the male in lesser developed communities (Scala, 1974). The lack of dietary fiber is associated with colonic cancer (Burkitt, 1971). Dietary fiber possibly can work as a preventative mechanism for colonic cancer in three ways: 1) altering the composition of microflora in the colon and inhibiting the production of potential carcinogens; 2) accelerating the elimination of carcinogens; and 3) increasing water content in the colon and reducing the concentration of potential carcinogens (Leveille, 1976). Briefly, lack of dietary fiber can cause harmful substances to be held against the bowel mucose in concentrated form for long periods (Burkitt, 1971; Burkitt et al., 1972).

Fiber inhibiting the reabsorption of bile is currently being studied. Communities with diets high in plant foods tend to have lower serum cholesterol concentrations; people in undeveloped countries exhibit lower blood cholesterol concentrations than their counterparts (Leveille, 1976; Anonymous, 1977). Some fiber fractions are believed to increase bile salt excretion (Anonymous, 1977; Kritchevsky, 1977). Bran decreases bowel transit time, and it reduces the bacterial degradation and bile acid concentration in the intestinal contents (Heaton and Pomare, 1974). Cholesterol is the primary precursor of bile acids and salts, and bile acid excretion is the major elimination method of internally produced cholesterol. Blood cholesterol levels are lowered by decreasing transit time and increasing bile acid excretion, which leads to reduced absorption of dietary cholesterol and reduced absorption of bile salts (Scala, 1974; Anonymous, 1979). Hypercholesteremia is a major risk factor associated with atherosclerosis. It is possible that added dietary fiber could help prevent atherosclerosis by reducing serum cholesterol levels.

Different plant fibers have different metabolic effects and physical actions. The hypocholesterolemic effect of rolled oats was first observed in rats (De Groot, Luyken and Pikaar, 1963). De Groot et al. (1963) had demonstrated that 140-g rolled oats per day reduced plasma cholesterol levels an average of 11% in 21 healthy male volunteers during a three week experimental period. Cholesterol levels have been reduced an average of 8% when 125-g rolled oats per day was consumed by staff members of a university (Judd and Truswell, 1981). Water-soluble fibers such as pectin, guar and Bengal gram have shown hypocholesterolemic effects; most water insoluble fibers such as cellulose nad wheat bran do not influence serum cholesterol levels in humans or animals (Jenkins, Leeds, Newton and Cummings, 1975; Anderson and Chen, 1979). The United States Department of Agriculture Human Nutrition Laboratory has conducted a study where 26-g wheat bran and corn bran daily elevated high density lipoprotein (HDL) cholesterol, but the study has not been reported in detail (Monte, 1981). In another study, low density lipoprotein (LDL) concentrations were selectively lowered by 100-g oat bran per day intake; however, HDL cholesterol concentrations were not altered (Kirby, Anderson, Sieling, Rees, Chen, Miller and Kay, 1981).

Two hypotheses are suggested implicating the relationship of fiber, heart disease and diabetes. The first hypothesis states that dietary fiber protects individuals against ischamic heart disease (IHD), and the second hypothesis states that a prolonged consumption of fiber depleted starch contributes to the development of diabetes mellitus in susceptible genotypes such as obese people (Trowell, 1972). The removal of fiber from the diet seems to raise serum cholesterol levels which often leads to coronary heart disease. Subgroups with lower incidence of IHD and lower serum cholesterol levels are strict vegetarians, lacto-ovo-vegetarians and Seventh Day Adventists (Trowell, 1972).

Cholesterol metabolism is involved in IHD and in gallstones. Heaton (1976, p. 125) believes "coronary heart disease is a disease of involuntary overnutrition caused mainly by taking food and drinks which have been depleted of fiber." Furthermore, it is suggested that eating refined fiber-depleted foods, especially sugar, causes the secretion of bile over-saturated with cholesterol which is the metabolic defect behind cholesterol gallstone formation (Burkitt and Trowell, 1975).

The hypothesis that dietary fiber is an important factor in obesity is postulated by Trowell (1973). Cleave et al. (1969) contend that the only cause of obesity is the consumption of refined carbohydrates, and the treatment is dilution with natural carbohydrates and added fiber in the diet. Four reasons fiber seems to interfere with energy intake are by: 1) displacing available nutrients from the diet; 2) requiring chewing which slows intake; 3) stimulating secretion of gastric juice and saliva which promotes satiety; and 4) reducing the absorptive efficiency of the small intestine (Heaton, 1973). No studies have proven these reasons. To provide physiological basis for the control of non-obese body weight, Southgate and Durnin (1970) postulate that increased physical activity and increased consumption of whole unpeeled potatoes may result in decreased absorption by increased sensations of satiety from increased amounts of unabsorbed protein, fat and unavailable carbohydrates in the gut.

It is also suggested that dietary fiber may have clinical application in the prevention and treatment of adult-onset diabetes mellitus, hypoglycemia and obesity (Spiller and Kay, 1979). Researchers have compared the influence of whole apples, apple puree and apple juice on satiety, plasma glucose and serum insulin changes (Haber, Heator, Murphy and Burroughs, 1977). The study demonstrates when carbohydrates and plant fibers are consumed at the same time, less hyperglycemia follows than when the same amount and type of carbohydrates are consumed without the addition of fiber. It also demonstrates that when carbohydrates are consumed with plant fibers, the rise in blood glucose and insulin concentrations are significantly lower than when the same carbohydrate foods are eaten without fibers (Haber et al., 1977). Some studies indicate that glucose tolerance may be improved on a long-term basis in normal individuals (Wapnick, Wicks, Kanenogoni and Jones, 1972; Brodribb and Humphreys, 1976).

Observation of diabetic patients consuming added plant fibers in their diets indicate reduced hyperglycemia and glycosuira, which may allow insulin doses to be reduced (Jenkins, Leeds, Wolever, Goff, Alberti, Gassull and Hockaday, 1976; Jenkins, Hockaday, Howarth, Apling, Wolever, Leeds, Bacon and Dilawari, 1977). The therapeutic application of high fiber diets for treating insulin-requiring diabetic patients has some support (Kiehm, Anderson and Ward, 1976). An editorial in the Journal of the American Medical Association (Ricketts, 1976, p. 2321) suggests that "physicians and nutritionists might do well to start modest trials with fiber supplements for diabetic patients who need to diminish glucose levels after meals."

There is some evidence that refined foods contribute to dental decay by sticking to the teeth (Bing, 1976). Cleave et al. (1969) believes that coarse fiber, caused by the processing of white flour and over-consumption of sugar, removed the natural cleansing of teeth and hardening of gums. It is still questionable whether dental decay, obesity and diabetes are related to the fiber-depleted diet. As for Crohn's disease and ulcerative colitis, more studies are needed to establish the possible relationship with dietary fiber (Spiller and Freeman, 1981).

Certain plant fibers appear to have detoxifying effects when fed with certain drugs and chemicals (Ershoff, 1974). Extensive studies have been conducted with alfalfa meal, amaranth and other plant fibers by Ershoff (1974). Further investigations are needed to thoroughly explain the relationships of dietary fiber to certain diseases (Burkitt, 1977; Anonymous, 1979). Epidemiological evidence seems to suggest the fiber deficient diet as a cause, but better quantitative data is needed to establish a causal relationships. One problem in studying dietary fiber is selecting an appropriate experimental model (Hegsted, 1977). Most of the diseases associated with fiber depleted diet do not commonly occur in animals, and long-term controlled studies on humans are not feasible. If human subjects are used, epidemiological evidence becomes confused by the inability to separate various dietary factors from modifications in lifestyle. Furthermore, there is a good possibility that different populations and even individuals utilize fiber differently. Some researchers find cooked wheat bran has less effects on the gastro-intestinal track than raw bran, but bulking effect is independent of particle size (Wyman, Heaton, Manning and Wicks, 1976). More studies are needed to establish the role of fiber in medicine and nutrition. There are many controversies that remain unsolved and need further investigation.

## Terminology and Analysis of Fiber

At the present time, there is not an established minimum intake for fiber, but one of the Dietary Guidelines for Americans is to eat foods with adequate starch and fiber (Spiller and Kay, 1979). Fiber terminology is often incorrectly used and not understood. The growing interest in the epidemiological relationships of fiber with certain diseases has emphasized the need for standardized terminology and methodology for assessing the fiber content of foods. Van Soest and McQueen (1973) identified current problems in the chemistry and estimation of fiber as:

> 1) conflicting concepts of what constitutes fiber; 2) the definition of lignin, cellulose, and hemicellulose; 3) achieving separation of lignin from interfering matter; 4) the isolation of indigestible fiber and its relation to the true fiber of food; and 5) the failure of hemicellulose, cellulose, and lignin to be chemically similar in different plant materials (p. 123).

"We do not really know what 'dietary fiber' is and cannot measure it" (Hegsted, 1977, p. 45).

Fiber content of foods has been assessed in two ways: as crude fiber and as dietary fiber. For over 100 years, crude fiber has been a term that represents the major fiber constituents, at least in animal feeds. It represents the end product of a fiber extraction technique developed in 1806 by Einhof (Cummings, 1976).

Crude fiber corresponds to modern cell wall values which are the sum of cellulose, hemicellulose and lignin. According to Spiller and Kay (1979, p. 2102), "crude fiber bears no consistent quantitative relationship to dietary fiber and use of this procedure should be abandoned." The primary cell wall components of crude fiber are cellulose and lignin. According to Van Soest and McQueen (1973), the crude fiber method is underestimated fiber content in foods because 80% of the hemicellulose and 50% to 90% of the lignin in lost during analysis. Hemicellulose is the main constituent of fiber in cereals (Van Soest and Robertson, 1977).

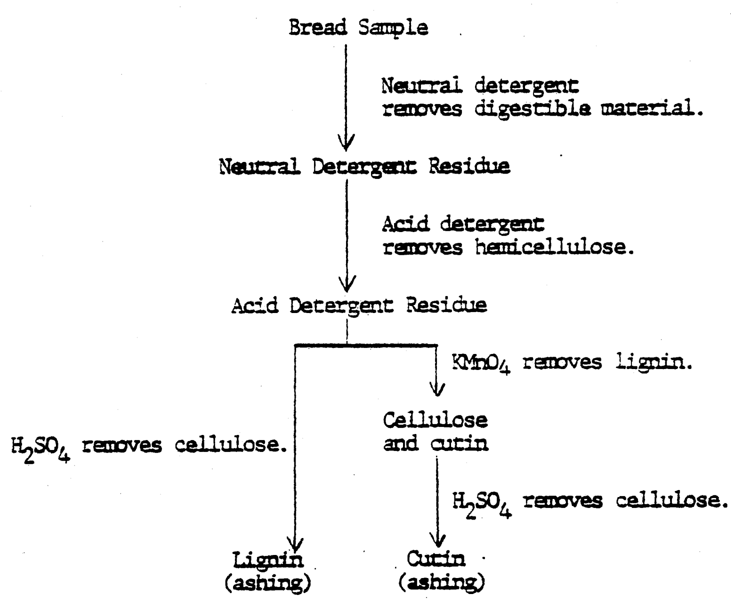
Trowell (1972) used the term "dietary fiber" to represent the plant polysaccharides and lignin which are resistant to digestive enzymes in the upper gastrointestinal tract. Dietary fiber is the sum of the unavailable carbohydrates and lignin (Southgate, 1973). The term implies biological determination of the fiber content in a food sample by the residue remaining in the feces. However, some dietary fiber may be metabolized by microorganisms in the lower intestinal tract. It is also possible that measurements on fecal excretion of fiber may give inaccurate results.

Godding (1976, p. 1129) proposed a new term, "edible fiber," defined as "polysaccharides, related polymers and lignin, which are resistant to hydrolysis by digestive enzymes of man." Unlike dietary fiber, edible fiber is a broader term that is meant to include all types of fiber suitable for human consumption whether from traditional or nontraditional food sources. Nontraditional examples are pharmaceutical preparations and the cellulose from wood that has been introduced in commercial breads. Plantix is another alternative term suggested for dietary fiber (Trowell et al., 1978). Since there are different chemical and nutritional views of fiber, the definition of fiber is still controversial; however, dietary fiber is the currently accepted term used to describe total fiber content in the diet (Van Soest and Robertson, 1977).

The main components in which nutritionists and researchers are interested are cellulose, hemicellulose, lignin and pectin. It is unknown which of these components of fiber is most beneficial in the diet, and each has been shown to have varied chemical and physiological affects (Kelsay, 1978). At present, there is no universally accepted method of determination of total fiber in foods. Furthermore, there is limited data on the fiber content in foods and the available indexes are usually crude fiber values.

One of the first extraction procedures for the determination of cellulose, hemicellulose and lignin in foods was developed by Southgate (1969). This procedure is often called the crude fiber (CF) method. Haber et al. (1977) believe the CF method is time-consuming and does not accurately isolate the main components of fiber. Van Soest and Wine (1967) studied the use of detergents in both acid and neutral solutions to determine the fiber in animal feeds. They developed the neutral detergent fiber (NDF) method for determining fiber content. The NDF method is a more rapid and accurate chemical method than the CF method (Baker and Holden, 1981). In 1978, the American Association of Cereal Chemists (AACC) accepted the NDF method as an official method of fiber content determination (Baker and Holden, 1981).

The schematic summary (Figure 1) illustrates the residue after extractions with neutral and acid detergents in the fiber determination of a bread sample (Mongeau and Brassard, 1979). NDF value includes mainly hemicellulose, cellulose and lignin. It provides a measurement for the total components of the cell wall without including pectins. The acid detergent fiber (ADF) includes cellulose and crude lignin. Cellulose is calculated by subtracting lignin from ADF. Hemicellulose is calculated by subtracting ADF from NDF (Van Soest and McQueen, 1973). The fiber analysis of corn bran, oat bran and wheat bran are determined by the NDF and ADF methods for this study and is discussed in Chapter III.




Source: Mongeau and Brassard, 1979, p. 439.

Figure 1. Schematic Summary of Fiber Determination of a Bread Sample

The importance of standardized methodology for assessing the fiber content is partially the result of varying chemical and physical properties of the components of fiber. No appropriate enzymes are secreted in the human digestive tract to attack cellulose, hemicellulose and pectin (Van Soest and McQueen, 1973). Cellulose is the most abundant organic compound in nature (Huang et al., 1978). Hemicellulose derived its name from its intimate association with cellulose. The main physiological action of cellulose and hemicellulose are their water-holding capacity, which reportedly increases fecal weight (Southgate and Durnin, 1970; Huang et al., 1978). Another important property of hemicellulose is its ion-binding capacity (Mongeau and Brassard, 1979).

Pectin is reported to increase excretion of fecal sterols and lipids, bind cations and bile acids and cause hypocholesterolemic affects (Kelsay, 1978). Unlike cellulose and hemicellulose, pectin is water-soluble (Belo and De Lumen, 1981).

Many polysaccharides swell in water to form gels. Pectins, gums and mucilages have high affinities for water and form gels in the small intestine (Anderson and Chen, 1979). Some gums are used in bulk-forming laxatives. The food industry uses various gums as thickeners, emulsifiers and stabiliziers. Guar gum emphasizes the classification and terminology problems in fiber determination. Guar gum is a mucilage, yet it is also a major storage polysaccharide (Cummings, 1976). Guar gum has water-binding and stabilizing properties and is added to sauces, dressing, ice cream, pie filling and dog foods.

Lignin, cutin, protein and mineral constituents are the major non-carbohydrate components of the plant cell wall (Van Soest, 1978).

Lignin is insoluble in strong acid and alkali, and it is not digested or absorbed in the colon (Anderson and Chen, 1979). Lignin may delay or impair the small intestine absorption of certain nutrients such as bile acid (Van Soest and McQueen, 1973; Eastwood, 1974). Food high in lignin may cause constipation (Huang et al., 1978). Cutin is a portion of crude lignin that is an undigestible plant lipid. Cutin may account for the fecal fat of individuals on high fiber diets (Cummings, 1976).

The mineral components of fiber are important. Although phytic acid is not a true fiber fraction, it acts as a phosphorus storage reserve in immature plants (Van Soest, 1978). The phytates may cause losses of iron and zinc in the feces and bind cations (Cummings, 1976). Calcium pectates in vegetables and legumes are available forms of calcium. Silicon is found in most cereals, especially rice. Silicon could act as a binder for other elements such as iron. Other trace elements may be in a form unavailable in the cell wall and may also cause binding to the cation exchange on the fiber surface. The presence of these non-carbohydrate components and their natural association with fiber suggests that dietary fiber cannot be limited to plant polysaccharides and lignin.

## Dietary Fiber and Bread Products

Public and commercial interest in recent studies of fiber has stimulated the introduction of high fiber breads and other foods. High fiber bread is a newcomer that entered the retail market in the middle 1970's when Burkitt's (1972) findings were first publicized. Bread is an excellent vehicle to increase dietary fiber consumption, and high fiber bread is usually low calorie. Variety breads such as rye, wheat, raisin and bran are currently 24% of total bakery sales, and the percentage is expected to increase to 31% in two years; these new breads sell from 15% to 20% above white bread prices (Mrdeza, 1978). Historically, white bread has been a symbol of wealth and nobility, but today dark breads are becoming somewhat of a contemporary status symbol (Mrdeza, 1978).

Supplementation of breads and other processed foods with dietary fiber assures increased fiber in the diet of man. Almost everyone eats bread at meals. Mendeloff (1976) believes it is consistent with the ideas of energy conservation to eat more cereal grains and less beef. Colmey (1978) suggests that cereal brans can be added to many foods where whole grain flavor, color and texture might complement the food systems. In a study of the metabolic effects of plant fibers, the human subjects found oat bran to be palatable when incorporated in hot cereal, muffins, breads and other prepared foods (Kirby et al., 1981).

Fiber can also act as a carrier for other products, as a binder to impart shape or as a vehicle for texture (Scala, 1974). Powdered cellulose, called "Solka-Flock," is currently being incorporated in meat systems (Anonymous, 1976). "Solka-Flock" allows greater moisture and fat retention which binds nutrients that are sometimes lost in cooking.

Initially, the first studies to evaluate the effects of fiber on the quality of baked products were conducted with cellulose. To reduce caloric value, cellulose is added to several baked products (Lee, Rust and Reber, 1969; Pratt, Reber and Klocbow, 1971; Brys and Zabik, 1976). Lee et al. (1969) substitutes microcrystalline cellulose (MCC) for flour in muffins and cookies and adds MCC to mashed potatoes to prepare an acceptable reduced calorie diet. The subjective evaluation of exterior appearance and palatability for muffins decreases significantly ($p<0.05$) as MCC level is increased, and mean values of volume of muffins decrease with each increased level of MCC (Lee et al., 1969). Flavor and texture scores decrease with each increased level of MCC. Mashed potatoes are substituted with MCC up to 18% level without undesirable changes in appearance (Lee et al., 1969). Brys and Zabik (1976) attempt to determine the level of MCC that will provide a good quality cake (0, 20%, 40%, 60%) and biscuits (0, 20%, 40%, 50%), with significant calorie reduction. With increased levels of MCC, biscuit quality decreases. Cakes with 20% MCC replaced for flour receive the highest scores in all characteristics except color. Cakes with 60% MCC are too moist and gummy. In another study, cakes with 30% pectin-coated cellulose replaced for flour are of poor quality and described as compact, gummy, soggy, doughy and slightly grey (Zabik, Shafer and Kuborowski, 1978). The other cakes with various types of added cellulose are found to be of high quality with 30% of the flour replaced and "feasible carriers of dietary fibers which contribute to lacation" (Zabik et al., 1978, p. 1431).

Corn bran, oat bran, amaranth grain flour, soybean hulls and various high fiber flours are available as dietary fiber sources that can be added to breads and other food products. The most abundant and available source of dietary fiber is wheat bran, which is a by-product of the milling process. Wheat bran and middlings have been incorporated in white, flavored and chiffon cakes (Brockmole and

Zabik, 1976; Springsteen, Zabik and Shafer, 1977; Smith and Hawrysh, 1978). Acceptable banana, chocolate, nut and spice cakes are prepared by replacing 16% of the flour in the formulas with wheat bran (Rajchel, Zabik and Everson, 1975). Consumer panelists find little difference in acceptability between control oatmeal cookies and cookies with 50% of the flour replaced with either red or white wheat bran (Vratanina and Zabik, 1975). Shafer and Zabik (1978) show that wheat, corn, oat and soy brans can be successfully incorporated in layer cakes. The corn bran layer cake has the largest volume but the lowest flavor scores. Also, flavor scores tend to increase as the panelists become accustomed to the taste of the brans. Cochran (1982) replaces flour with corn bran at levels of 10%, 20% and 30% in the formulas for vanilla wafers, oatmeal cookies, corn bread and wheat crackers.

Consuming products made with high fiber flours can increase both fiber and protein content in the diet. Melouk (1981) and Sproul (1975) have studied the affects of different high fiber flours on various baked products. Melouk has studied the effects of white skinned peanut flour, citrus flour, beet fiber and asparagus fiber on the functional and eating qualities of orange drop cookies. Peanut flour substitution up to the 15% level and beet fiber and asparagus fiber up to the 7% level of substitution in cookies are acceptable, but the citrus flour is not acceptable because it leaves a bitter aftertaste.

Sproul (1975) has studied the effects of soy flour, cottonseed flour and peanut flour on the quality of muffins, butterscotch bars and applesauce cake. Instead of all-purpose flour, whole wheat flour was used because "it has an interesting texture and flavor" (Sproul, 1975, p. 24). The products with 25% of the flour replaced with soy and peanut flours are acceptable, while the cottonseed flour products are not acceptable.

Colmey (1978) states that bread is a suitable carrier for dietary fiber because it is a sensitive product and functional differences are quickly seen. Acceptable bread products are produced from wheat flours with 7% replacement of flour with MCC and fine wheat bran (Pomeranz, Shogran, Finney and Bechtel, 1977). At levels above 7%, Pomeranz et al. (1977, p. 40) reported weakness in the cell walls of the bread products and suggested "further studies are needed to establish the mechanism and mode of the crumb disrupting effect." The structure of cells in bread is acceptable with as much as 7% of the flour replaced by guar but is not acceptable at levels above 10% (Apling, Khan and Ellis, 1978). Bran fiber ingredients substituted at levels above 12% cause distinct differences in volume, color, grain and texture of bread, including off-flavor. It is suggested that bread texture is associated with the particle size of the added fiber, and with the added fiber there is a need for holding increased water in the dough system (Anonymous, 1976).

Brewer's spent grain is not a fiber, but it is a by-product of the brewing industry that is high in dietary fiber and protein because of the barley bran and husk content. Prentice and D'Appolonia (1977) study the functionality and consumer acceptance of brewer's spent grain in bread and show that it is practical to replace 5% to 15% of the flour in bread with brewer's spent grain, especially if the consumers are aware of the possible benefits of increased fiber and protein levels. Chocolate chip, oatmeal and raisin cookies are acceptable with 15% of the flour in the cookies replaced with brewer's spent grain (Prentice, Kissell, Lindsay and Yamazak, 1978).

Bread is an important source of carbohydrates, the vitamin B complex, essential fatty acids and other nutrients (Groen, 1973). It has been demonstrated that the diets low in saturated fats and sugar, but with a high consumption of bread, can produce low serum cholesterol levels.

The first commercial bread with added fiber bread to be marketed is "Less" by Ort's, Incorporated of Layales, Maryland, in 1976 (McCormick, 1976). "Less" is a white bread developed to reduce calories rather than incorporate fiber. The increasing interest of the consumer in dietary fiber led to the introduction of "Fresh Horizons" by the ITT Continental Baking Company of Rye, New York (McCormick, 1976). "Contours," "Vim," and "Sunbeam High Fiber Wheat Bread" are other high fiber and reduced calorie breads that are marketed. Table III illustrates how these new added fiber breads compare nutritionally (McCormick, 1976).

These first high fiber breads have added cellulose to increase dietary fiber content. "Sunbeam High Fiber Wheat Bread" has an ingredient declaration which identifies stone ground wheat, natural bran and "added purified plant fiber" as the source of crude fiber (McCormick, 1976). Except for the "Sunbeam" bread and two varieties of "Fresh Horizons," the baking industry seems to agree on the term "alpha-cellulose" for ingredient information (Anonymous, 1976). The two varieties of "Fresh Horizons" incorporate powdered cellulose. There is a need to standardize definitions of fiber source for literature references and consumer information for product labeling. Table III

TABLE III

NUTRITIONAL COMPARISON OF THE NEW HIGH FIBER BREADS[a]

| | Breads | | | | |
|---|---|---|---|---|---|
| | Less | Fresh Horizons White/ Wheat | Contour | Sunbeam | Vim White/Wheat |
| Serving, slices | 2 | 2 | 2 | 2 | 2 |
| Wt. per serving | 45 g | 2 oz | 45 oz | 2 oz | 1½ oz/1½ oz |
| Calories | 80 | 100 | 90 | 150 | 80/90 |
| Protein, g | 5 | 5 | 4 | 5 | 3/3 |
| Carbohydrate, g | 15 | 19 | 16 | 29 | 14/17 |
| Fat, g | 1 | 1 | 1 | 1 | 1/1 |
| Fiber, refers to flour wt. | 3 | 4.25 g | 3 g | 2.1% | 6.5%/7.5% |
| Percent U.S. RDA: | | | | | |
| Protein | 8 | 8 | 6 | 8 | 4/4 |
| Vitamin A | *[b] | 0 | * | * | */0 |
| Vitamin C | * | 0 | * | * | */0 |
| Thiamin | 10 | 15 | 10 | 15 | 10/6 |
| Riboflavin | 6 | 10/8 | 6 | 8 | 6/6 |
| Niacin | 8 | 10 | 8 | 10 | 6/6 |
| Calcium | 6 | 10 | 6 | 4 | 4/4 |
| Iron | 6 | 10 | 6 | 8 | 6/6 |
| Phosphorus | 8 | -[c] | - | - | - |
| Loaf size, oz | 16 | 16 | 16 | 16 | 16 |

[a]McCormick, 1976, p. 13.

[b]"*" indicates less than 2% U.S. RDA.

[c]"-" indicates no claim, or not stated.

illustrates some of the confusion in fiber determination and future problems in labeling high fiber food products. "Fresh Horizons" and "Contour" report grams of fiber, while "Sunbeam" and "Vim" give percentage of fiber, and "Vim" reports an unclassified "3." It is assumed that crude fiber is the mode of fiber determination, but it is not clearly stated and may not be the case (McCormick, 1976).

In reviewing new trends in specialty breads, Mrdeza (1978, p. 699) states that, "we must make certain the consumer is provided with the best tasting, most healthful and nutritious products that our modern technology can provide." Standardized definitions and methodology to access dietary fiber is necessary for the establishment of future labeling provisions concerning fiber. Scala (1974, p. 35) states that "Perhaps the Food and Nutrition Board will someday recommend the equivalent of an RDA for fiber." Added fiber is a factor in the development of future food products, and NDF calculations per serving may be the method of dietary fiber determination in these new products. The decade of the 1920's brought forth enhanced awareness and studies about fiber; however, many controversies still remain. Possibly, some of the confusion about fiber will be clarified by research in the decades of the 1980's.

# CHAPTER III

## METHOD

Dietary fiber encompasses many different plant components, including cellulose, lignin, pectins, gums and brans. Different fiber components have different physical and chemical properties. The purpose of this study is to compare the effects of wheat, corn and oat brans on the sensory and objective qualities of various bread products. This chapter includes the research design, experimental preparation procedures of samples, subjective and objective evaluations, including taste panel selection and training, instrumentation and data collection and analysis methods.

### Type of Design

> Experimental design is the blueprint of the procedures that enable the researcher to test hypotheses by reaching valid conclusions about relationships between independent and dependent variables (Best, 1981, p. 68).

The independent variables or treatments are the four bran variations replacing a portion of all-purpose flour in Anadama bread, banana nut bread, bran rolls and whole wheat English muffins. The dependent variables are subjective evaluations by the taste panel and the objective determinations of the bread systems.

The experimental design used in this research is split-plot, which is a special kind of incomplete block design with whole plots or whole blocks subdivided into distinct subunits (Steel and Torrie, 1980). The whole plot treatment factor represents panelists, and the subplot treatment factor represents bran types in the bread systems.

The conditions of the research are controlled by the procedures used in the preparation of the breads, including ingredients, food research equipment, mixing methods, storage procedures and time and temperature of baking. Sensory evaluation of the bread products is conducted at the same time of day and in the same room where noise, privacy, lighting and room temperature are controlled.

Random assignment of the presentation order of the samples to the panel members eliminates the possibility of systematic bias and minimizes the effects of extraneous variables (Best, 1981). Table IV illustrates the random assignment in the order of sample presentation for each panelist for sensory evaluation.

Two simultaneous studies are being conducted. The two researchers are using the same four bread systems, the same formulas with different levels of all-purpose flour replaced, the same food research facility, the same taste panelists for sensory evaluation of the bread systems and the same time schedule for experiments. In this study, the researcher is studying the effects of 1-g NDF wheat, corn, oat and corn-oat brans per serving on the subjective and objective qualities in Anadama bread, banana nut bread, bran rolls and whole wheat English muffins. The second researcher is studying the effects of 0%, 10%, 20% and 30% all-purpose flour replaced with amaranth grain flour in the same four bread systems.

In the simultaneous sensory evaluation of the samples for both studies, the possible effect of extraneous variables are dealt with by the two researchers by using sandwich packs for the samples, color coding and random assignment. Each sample is presented in a china foam sandwich pack coded with alternating letters of the Greek alphabet. The sandwich packs are opaque, covered containers that allow the taste panelists to evaluate only one sample at a time. The panelists are requested to discard each sample after sensory evaluation.

TABLE IV

EXAMPLE OF RANDOM ASSIGNMENT IN THE ORDER OF SAMPLE PRESENTATION TO EACH PANELIST FOR SENSORY EVALUATION

| Panelist No. | Order of Sample Presentation[a] | | | |
|---|---|---|---|---|
| | First | Second | Third | Fourth |
| 1 | WH | CR | CO | OA |
| 2 | CO | OA | CR | WH |
| 3 | OA | CO | CR | WH |
| 4 | WH | CO | OA | CR |
| 5 | OA | CR | CO | WH |
| 6 | CO | OA | WH | CR |
| 7 | OA | CR | CO | WH |
| 8 | CO | WH | CR | OA |

[a]The letters represent the bran variations order of sample presentation in one replication of one experiment: WH - Wheat Bran, CR - Corn, CO - Corn-Oat, OA - Oat.

For each panelist, four separate score cards for each study are arranged in a randomly assigned order of sample presentation, as illustrated by the example in Table IV. The score cards and sandwich packs are coded in two different colors to distinguish the two studies. Alternately, the two studies are presented first and second to prevent systematic bias that might develop for the samples with amaranth grain flour or the varieties of bran. After evaluating the first set of samples, the panel is asked to leave the tasting room and obtain a tray with the second set of samples and score cards from a counter in the adjoining food research laboratory.

## Preparation of the Breads

### Preliminary Studies

Anadama bread, banana nut bread, bran rolls and whole wheat English muffins are products developed for a related study in the department. Corn bran was incorporated successfully in over 30 different food systems, as illustrated in the corn bran exchange list (Table V). Using the exchange list, 12 human subjects consumed self-selected foods in which some of the foods selected were replaced by experimental food systems with added corn bran. An additional 20-g NDF corn bran was consumed in foods normally eaten. Cochran (1982) has studied the effects of corn bran on the sensory and objective qualities of vanilla wafers, oatmeal cookies, wheat crackers and corn bread. The four bread products chosen for this research has been shown to be palatable and generally acceptable by the subjects in the related study.

TABLE V

CORN BRAN EXCHANGE LIST

| Food Product | Serving Size | NDF Corn Bran per Serving (grams) |
|---|---|---|
| **Breads** | | |
| Anadama bread | 1 slice (16 slices per loaf) | 2.5 |
| Bagel | 1-3 inch bagel | 2.0 |
| Banana nut bread | 1 slice (12 slices per loaf) | 2.5 |
| Bran rolls | 1 roll | 2.0 |
| Buttermilk cornmeal waffles | 1-5 inch waffle | 3.9 |
| Coffee cake | 3-inch cube | 3.0 |
| Corn bread | 2-inch cube | 2.0 |
| Corn muffins | 1 muffin | 3.0 |
| Corn tortillas | 1-5 inch tortilla | 1.0 |
| Pastry | 1/8 pie | 2.9 |
| Sticky buns | 1 bun | 2.0 |
| Whole wheat crackers | 1 cracker | 0.8 |
| Whole wheat English muffin | 1/2 muffin | 2.5 |
| Whole wheat pretzel | 1-2 inch pretzel | 2.0 |
| **Desserts** | | |
| Butterscotch brownie | 1-2 inch brownie | 3.0 |
| Carrot cake | 1-3 inch cube | 7.0 |
| Cheesecake | 1 slice (15 slices per cake) | 6.0 |
| Chocolate brownie | 1-2 inch brownie | 3.0 |
| Chocolate cream filling | 1/8 pie | 2.9 |
| Chocolate cream pie | 1/8 pie | 5.8 |
| Chocolate éclair | 1 eclair | 3.9 |
| Lemon refrigerator cookies | 1-2 inch cookie | 0.5 |
| Oatmeal cookies | 1-2 inch cookie | 0.3 |
| Vanilla wafers | 1-2 inch wafer | 1.0 |
| **Entrées** | | |
| Chicken quiche florentine | 1-3 inch cube | 4.5 |
| Chicken broccoli chowder | 1 cup | 6.5 |
| Chilli | 1 cup | 7.1 |
| Crab quiche | 1/8 pie | 2.9 |
| Individual meat loaf | 6 oz. | 9.0 |
| Meatballs | 4 oz. | 4.5 |
| Quiche Lorraine | 1/8 pie | 2.9 |
| Spinach quiche | 1/8 pie | 2.9 |
| Tuna salad | 1/2 cup | 3.0 |
| Tuna sandwich on Anadama bread | | 8.0 |
| Tuna sandwich on whole wheat English muffin | | 8.0 |
| **Master Mix** | | |
| Blueberry muffin | 1 muffin | 2.0 |
| Cinnamon muffin | 1 muffin | 3.0 |
| Gingerbread | 1-2 inch square | 3.5 |
| Pancakes | 1-5 inch pancake | 3.0 |
| Peanut butter cookies | 1-2 inch cookie | 1.5 |

It has been suggested that cereal brans be added to foods with wholegrain flavor and complementary texture and color (Colmey, 1978). Since wheat bran is an abundant source of dietary fiber that is available in supermarkets and health food stores and is currently incorporated in specialty breads commercially, wheat bran is used in this research along with other brans. Products with wheat bran are arbitrarily considered standard products.

Oat bran is selected for this research for its acceptability in preliminary tests and for further information about its effects on the quality of food systems. Human subjects in a metabolic study of the effects of fiber found oat bran palatable when incorporated in breads and muffins (Kirby et al., 1981).

The researchers of these twin studies recognize the need for standardized terminology and amounts in determining fiber content of food products. Fiber exchange lists with NDF determinations per serving size (number-grams NDF per serving) is a suggested alternative. According to Conroy's (1982) study on nutrition labeling, dietitians surveyed preferred total carbohydrates displayed by measurements of sugar, starch and fiber. Of 126 dietitians surveyed, 48% preferred measuring units per serving. The bread systems in this study have 1-g NDF bran per serving.

## Materials

A detailed description of materials and food research equipment are listed in Appendix A. Special equipment developed for this research include a proofing box, English muffin rings and 6-3/4 inch wires. The proofing box consists of the Cres-Cor Crescent closed transport cart with a Corning bun warmer in the bottom. The bun warmer is set at 250°F, and a two gallon pan of hot water is placed inside. The proofing box remains at about 95°F - 100°F and keeps the proofing breads free from draft in a controlled humid environment. The rings used for shaping and rising the English muffins are 2-inch lengths cut from poly-vinyl choride 4-inch pipe. A glass water goblet base fits exactly inside the rings and is used to flatten and remove the English muffins from the rings. Steel tag wires (4-5/8-inch in length with 1/2-inch red marks on top) placed in the center of Anadama bread after shaping into a loaf indicates when the loaf has risen one-inch above the top of the bread pan (approximately 45 minutes). The wire is removed, and the bread is baked after the loaf rises to the red mark on the wire.

Wheat bran, corn bran and corn-oat bran combination (50:50 ratio) are replaced for all-purpose flour in the bread systems. Table VI represents the fiber analysis of the brans. The flour is replaced with the calculated quantity of each bran for a 1-g NDF bran per serving. Grams NDF bran per serving is calculated with the following formula:

If: g = grams bran replaced for flour in formula
% = percentage NDF
# = number of servings in formula
Then: $(g \times \%) \div \# = g$ NDF per serving.

## Procedures

The formula and preparation procedure for Anadama bread, banana nut bread, bran rolls and whole wheat English muffins are in Appendix B. For each bread system, three replications are made during one week.

For each bread and replication, various information including coding, order of preparation, placement in oven, timing, weights and heights are recorded on data sheets illustrated in Appendix C. The order of preparation, placement in oven and baking pans are alternated for each replication of each bread. All bread systems are placed in zip locked storage bags, labeled and frozen 30 minutes after samples are cut for objective tastes.

TABLE VI

FIBER ANALYSIS OF VARIOUS FIBER SOURCES

| Fiber Source | Neutral Detergent Fiber (NDF)[b] % | Acid Detergent Fiber (ADF)[c] % | Lignin % | Cellulose % | Hemi-Cellulose % |
|---|---|---|---|---|---|
| Corn bran, refined (regular grind) | 85.45 | 19.61 | .37 | 19.58 | 65.84 |
| Oat bran | 19.52 | 2.01 | 1.49 | .94 | 17.51 |
| Wheat bran | 46.87 | 11.87 | 2.57 | 9.67 | 35.00 |

[a]Fiber analyses are conducted in a chemistry laboratory at Oklahoma State University. Values are the averages obtained from the fiber analysis of four samples.

[b]NDF is composed of lignin, cellulose and hemicellulose (Van Soest and McQueen, 1973; Southgate, 1975, 1977; Van Soest and Robertson, 1977).

[c]ADF is composed of lignin and cellulose (Southgate, 1975, 1977; Van Soest and Robertson, 1977).

Anadama Bread. Anadama bread is an old Northeastern United States one-bowl bread recipe recognized for its molasses flavor and the texture imparted by corn meal. Corn bran is similar in texture and flavor to corn meal.

Preliminary experiments indicate amounts calculated in excess of 1-g NDF oat bran per serving of Anadama bread is not acceptable; hence, 1-g NDF bran per serving is selected as the amount of bran added in the breads. Pomeranz et al. (1977) suggests acceptable bread is produced when 7% flour is replaced by wheat bran and MCC. Table VII indicates the percentage of all-purpose flour replaced by bran in Anadama bread, banana nut bread, bran rolls and whole wheat English muffins. In Anadama bread, all-purpose flour is replaced by about 9% wheat bran, 24% oat bran and 14% corn-oat bran to yield 1-g NDF per serving, which are higher percentages than previously found acceptable by other researchers (Pomeranz et al., 1977).

One day prior to the preparations of the replications of Anadama bread, 110-g flour, bran, salt and margarine for each variation are weighed to the nearest 0.01-g. These ingredients are stored in covered bowls and refrigerated. The remaining flour and molasses are weighed and stored at room temperature. On the morning of each experimental day, yeast and hot tap water are weighed and measured before incorporating into the dry ingredients.

Anadama bread is weighed before shaping and after cooling to determine moisture loss from baking. The loaf is sliced in half, and two measurements of heights are taken and averaged for each variation. Using a cutting guide, half of each loaf is sliced into eight slices. The center slice is placed in a sandwich bag. Then this center slice and the remaining half loaf are placed in a zip locked storage bag, labeled and frozen 30 minutes after cutting.

TABLE VII

PERCENTAGE OF ALL-PURPOSE FLOUR REPLACED BY BRAN[a]

| Bran | Percentage of A.P. Flour Replaced by Bran | | | |
|---|---|---|---|---|
| | Anadama Bread | Banana Nut Bread | Bran Rolls | Whole Wheat English Muffins |
| Wheat | 8.78 | 15.34 | 9.10 | 9.96 |
| Corn | 4.63 | 7.84 | 4.81 | 5.23 |
| Oat | 24.08 | 46.95 | 25.00 | 27.84 |
| Corn-Oat | 13.54 | 24.43 | 14.02 | 15.46 |

[a]Percentage calculations are based on 1-g NDF per serving for the breads.

The end slices of the Anadama bread are discarded. The remaining four slices are vertically sliced in half, and each half slice of bread is placed in a color coded sandwich pack. The researcher of the second study randomly distributes all samples for the panelists for sensory evaluation.

Banana Nut Bread. In preliminary tests, oat bran and corn bran complemented the flavor and appearance of banana nut bread. Similar to cakes, banana nut bread is leavened by baking powder. Acceptable banana, chocolate, nut and spice cakes have been incorporated with 16% wheat bran (Rajchel, Zabik and Everson, 1975). Layer cakes are successfully incorporated with 30% flour replacement with wheat bran, corn bran, oat bran and soy bran (Shafer and Zabik, 1978). Table VII indicates that in banana nut bread, flour is replaced by about 47% oat bran and 24% corn-oat bran, which are higher percentages than previously found acceptable by other researchers. Oatmeal cookies are acceptable by consumers, however, with as much as 50% flour replacement with wheat bran (Vritanina and Zabik, 1980). In sensory evaluation, panelists find oatmeal cookies, with 10%, 20% and 30% corn bran substitution levels acceptable (Cochran, 1982).

The week before the preparations of the replications of banana nut bread, the pecans for all replications are coarsely ground with the Kitchen Aide mixer food grinder attachment. Then 12 55-g packages of pecans are weighed and refrigerated in a sealed Tupperware container. Also, on the same day, the bananas for all replications are mashed in the blender, with the "blend" setting for one minute. The mashed bananas are weighed into covered containers and frozen. One day prior to each replication, the flour, bran, sugar, salt and margarine are weighed, placed in a covered mixing bowl and refrigerated. On the day of the experiments, the frozen bananas are thawed in the microwave oven for 12-minutes with the defrost setting. The baking powder, milk and beaten eggs are weighed and combined with the dry ingredients on the experimental day.

The banana nut bread is weighed before baking and after baking. The procedure for measuring, slicing and freezing banana nut bread is the same method as described for Anadama bread; however, banana nut bread is sliced into 12 slices and both end slices are discarded.

Bran Rolls. As presented in Table VII, the highest percentages of all-purpose flour replaced in the bran rolls are 9% with wheat bran, 25% with oat bran and 14% with corn-oat bran. Bran rolls are developed from a bran refrigerator dough recipe (London, 1972). The morning prior to each replication of the bran roll experiment, the ingredients are weighed, combined to prepare the dough batter and refrigerated overnight in a Rubbermaid covered bowl. On the morning of the experiment, the bran rolls are prepared according to the formula in Appendix B.

Two bran rolls are weighed after cooling, and an average weight is recorded. The rolls are sliced in half for sensory evaluation. Three rolls from each bran variation are placed in zip locked storage bags and frozen for objective tests.

Whole Wheat English Muffins. The percentage of all-purpose flour replaced in the whole wheat English muffin is approximately 10% with wheat bran, 5% with corn bran, 28% with oat bran and 16% with corn-oat bran. The effects of bran and other types of fibers on English muffins has not been studied. English muffins are sprinkled with corn meal before baking. As mentioned previously, corn bran is similar in texture and flavor to corn meal. In Appendix E, the criteria for whole wheat English muffins includes such characteristics as tender yet chewy, bland in flavor and slightly dry. These are characteristics sometimes considered unacceptable with high percentages of fiber in baked products.

On the day before the replication of each experiment, the whole wheat flour and the all-purpose flour for the English muffin systems are weighed, combined and divided. Half of the flour mixtures, the bran variations and salt are combined in a covered bowl. The honey and margarine are weighed and placed in separate covered containers. All pre-measured ingredients are refrigerated overnight. On the experimental day, the yeast is weighed and combined according to the procedure in Appendix B.

For objective evaluation, the weights of three cooled whole wheat English muffins for each variation are averaged and recorded. Three English muffins are sliced in half horizontally. Diameter is measured, averaged and recorded. Three different English muffins are sliced in half vertically. Height is measured, averaged and recorded. For subjective evaluation, panelists evaluate half of an English muffin that has been split horizontally and vertically. Two other English muffins are split horizontally in halves and frozen.

## Subjective Tests

### Instrumentation

The instrument developed to evaluate the breads (Appendix D) is a modified magnitude estimation scale. High and low limits are not specified, and there are no limiting endpoints (Moskowitz, 1974). Magnitude estimation allows the panelists to express small and large differences in sensory evaluation (Moskowitz, Fishken and Ritacco, 1979). The vertical lines used on the scales of the score cards (Appendix D) have been recommended by Holsinger (1980). The vertical lines for scales in this study are 5-cm in length.

The modified estimation scale have been used by Cathey (1981) to access the effects of collagen levels in beef patties and beef loaves.

The instrument for subjective evaluation of the breads has been evaluated for content validity, clarity and format and accepted by graduate faculty members of the Food, Nutrition and Institution Administration Department and the Statistics Department at Oklahoma State University.

### Selection and Training of Sensory Evaluation Panel

Three training sessions on sensory evaluation are conducted before starting the experiment. Instructions and forms used in the training sessions are included in Appendix D. Potential panelists who volunteered for the simultaneous studies are asked to identify 10 common odors, distinguish four basic tastes and differentiate samples of banana nut bread in a triangle test. The volunteers are familiarized with the criteria for the standard bread systems (Appendix D), the score cards and the method of sample presentation. After completion of the tests and training sessions, eight panelists are considered trained in the sensory evaluation of Anadama bread, banana nut bread, bran rolls and whole wheat English muffins. The eight panelists included graduate students, University faculty and staff.

## Objective Tests

The objective tests used to evaluate the effects of wheat, corn and oat brans on the quality of breads include measures of baking loss, height, index to volume and nutritional analyses. Baking losses are determined by weighing before baking and after baking (Appendix C). Heights of samples are measured after preparation.

The interior appearance and size of the bread systems are recorded by photograph prints. The photograph prints are made by placing samples of the breads on a photocopy machine. A Xerox photocopy machine is used in this study. Using a planimeter from the Agronomy Department, the photograph prints are traced to measure area as an index to volume. The procedure for measuring index to volume with a planimeter is described in The Experimental Study of Foods, by Griswold (1962). Food Values of Portions Commonly Used by Bowes and Church (1970) is used for nutritional analyses of the bread systems. The nutritional analyses of the brans and formulas are included in Appendix E.

## Data Analyses

Analysis of variance range procedures is used to analyze data. Duncan's multiple range tests for separation of means are used to determine the location of significant differences in analysis of sensory evaluation data and objective evaluation data (Steel and Torrie, 1980). The objective measures analyzed are the measures of baking loss, height, diameter and index to volume. The Statistical Analysis System (SAS) is used for calculations (Barr and Goodnight, 1972).

# CHAPTER IV

## RESULTS AND DISCUSSION

The purpose of this study is to determine the effects of the four bran variations on the sensory and objective qualities of the bread systems. All-purpose flour is replaced by wheat bran, corn bran, oat bran and corn-oat bran with appropriate amounts calculated to yield 1-g NDF per serving in Anadama bread, banana nut bread, bran rolls and whole wheat English muffins. Sensory qualities are evaluated by an eight-member trained panel. Objective evaluations include measures of baking loss, height, diameter and index to volume, photocopies and nutritional analyses. This chapter presents the data analyses to assess the differences in the bread systems attributed to bran type.

### Subjective Evaluation

For sensory evaluation of the bread systems, the instrument developed and utilized is the modified magnitude estimation scale (Appendix D). The vertical scales for each attribute are 5-cm in length. All scales are measured from bottom to top with larger numbers indicating desirable, more intense levels of the attributes. After sensory evaluation, the marks on the scales are measured to the nearest 0.10 centimeter and affixed with the designated values. F tests from the analysis of variance and Duncan's multiple range tests are then calculated from these designated values (Steel and Torrie, 1980).

Anadama Bread

The analysis of variance with corresponding F tests for Anadama bread is presented in Table VIII. There are significant ($p<0.05$) differences among the average mean scores for shape of top crust, structure of cells, texture, crumb color, moisture, flavor and overall acceptability due to the bran type in Anadama bread. Significant differences in mean scores are not found due to bran type for top crust and crust color. The attributes of texture, moisture, flavor and overall acceptability have significant ($p\leq0.005$) panelist by bran (PxB) interactions. Shafer and Zabik (1978) report that flavor scores increase as panelists become accustomed to the taste of bran. The differences among the average mean scores in PxB interactions may be attributed to the panelists becoming familiar with the flavor of the brans.

The results of Duncan's multiple range tests for separation of means are shown in Table IX. For shape of crust and crumb color, there are two groups indicated due to bran type. The group with the higher average mean scores includes Anadama bread with corn, oat and corn-oat brans. Wheat bran Anadama bread is in the group with lower average mean scores. For crumb color, bread with corn bran does not distinctly belong to either group.

For structure of cells, moisture, mouthfeel and flavor, average mean scores are in two groups (Table IX). Oat bran Anadama bread shows higher average mean scores for these attributes. The second group which has lower average mean scores includes Anadama bread with wheat, corn and corn-oat brans. For mouthfeel, tests are not able to distinguish which group includes Anadama bread with corn-oat bran.

TABLE VIII

ANALYSIS OF VARIANCE FOR SENSORY EVALUATION OF ANADAMA BREAD

| Attribute | Source | df | Sum of Squares | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Top Crust | Date | 2 | 3.78 | 2.73 | 0.0996 |
| | Panelist | 7 | 31.29 | 6.46 | 0.0016 |
| | Error (a) | 14 | 9.69 | | |
| | Bran | 3 | 0.54 | 0.23 | 0.8774 |
| | PxB | 21 | 17.93 | 1.08 | 0.3946 |
| | Error (b) | 48 | 37.78 | | |
| Shape of Top Crust | Date | 2 | 5.49 | 3.16 | 0.0737 |
| | Panelist | 7 | 38.70 | 6.36 | 0.0017 |
| | Error (a) | 14 | 12.17 | | |
| | Bran | 3 | 17.62 | 8.99 | 0.0001 |
| | PxB | 21 | 10.57 | 0.77 | 0.7382 |
| | Error (b) | 48 | 31.35 | | |
| Crust Color | Date | 2 | 1.95 | 1.74 | 0.2121 |
| | Panelist | 7 | 50.81 | 12.91 | 0.0001 |
| | Error (a) | 14 | 7.87 | | |
| | Bran | 3 | 3.84 | 1.78 | 0.1627 |
| | PxB | 21 | 11.74 | 0.78 | 0.7275 |
| | Error (b) | 48 | 34.39 | | |
| Structure of Cells | Date | 2 | 2.19 | 1.04 | 0.3796 |
| | Panelist | 7 | 45.97 | 6.25 | 0.0018 |
| | Error (a) | 14 | 14.71 | | |
| | Bran | 3 | 14.97 | 6.31 | 0.0011 |
| | PxB | 21 | 23.28 | 1.40 | 0.1651 |
| | Error (b) | 48 | 37.94 | | |
| Texture | Date | 2 | 6.63 | 3.54 | 0.0569 |
| | Panelist | 7 | 63.96 | 9.77 | 0.0002 |
| | Error (a) | 14 | 13.10 | | |
| | Bran | 3 | 29.74 | 14.47 | 0.0001 |
| | PxB | 21 | 28.06 | 1.95 | 0.0284 |
| | Error (b) | 48 | 32.89 | | |
| Crumb Color | Date | 2 | 4.05 | 2.86 | 0.0906 |
| | Panelist | 7 | 32.18 | 6.50 | 0.0015 |
| | Error (a) | 14 | 9.91 | | |
| | Bran | 3 | 10.46 | 3.33 | 0.0271 |
| | PxB | 21 | 14.87 | 0.68 | 0.8346 |
| | Error (b) | 48 | 50.27 | | |

TABLE VIII (Continued)

| Attribute | Source | df | Sum of Squares | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Moisture | Date | 2 | 1.57 | 0.89 | 0.4324 |
| | Panelist | 7 | 70.65 | 11.48 | 0.0001 |
| | Error (a) | 14 | 12.31 | | |
| | Bran | 3 | 18.54 | 8.66 | 0.0001 |
| | PxB | 21 | 45.27 | 3.02 | 0.0008 |
| | Error (b) | 48 | 34.24 | | |
| Mouthfeel | Date | 2 | 2.64 | 2.91 | 0.0874 |
| | Panelist | 7 | 63.15 | 19.91 | 0.0001 |
| | Error (a) | 14 | 6.34 | | |
| | Bran | 3 | 19.01 | 6.00 | 0.0015 |
| | PxB | 21 | 35.34 | 1.59 | 0.0917 |
| | Error (b) | 48 | 50.72 | | |
| Flavor | Date | 2 | 3.48 | 2.66 | 0.1046 |
| | Panelist | 7 | 77.13 | 16.90 | 0.0001 |
| | Error (a) | 14 | 9.13 | | |
| | Bran | 3 | 15.56 | 7.91 | 0.0002 |
| | PxB | 21 | 41.29 | 3.00 | 0.0008 |
| | Error (b) | 48 | 31.46 | | |
| Over-All Acceptability | Date | 2 | 3.17 | 2.50 | 0.1177 |
| | Panelist | 7 | 87.77 | 19.84 | 0.0001 |
| | Error (a) | 14 | 8.85 | | |
| | Bran | 3 | 21.68 | 10.61 | 0.0001 |
| | PxB | 21 | 34.77 | 2.43 | 0.0056 |
| | Error (b) | 48 | 32.70 | | |

For texture, there are two groups of average mean scores (Table IX). Anadama bread with wheat bran belongs to the first group and has higher average mean scores. The second group with lower mean scores includes bread with corn, oat and corn-oat brans.

Three groups are indicated for overall acceptability of Anadama bread (Table IX). The first group which has the highest average mean

TABLE IX

DUNCAN'S MULTIPLE RANGE TESTS FOR DIFFERENCES DUE TO BRAN TYPE IN SENSORY ANALYSIS OF ANADAMA BREAD[a]

| Bran | Mean Values of Attributes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Exterior Appearance | | | Interior Appearance | | | | Palatability | | |
| | Top Crust | Shape of Crust | Crust Color | Structure of Cells | Texture | Crumb Color | Moisture | Mouthfeel | Flavor | Over-All Acceptability |
| Wheat | 3.52 | $2.98^{B}$ | 3.77 | $3.28^{B}$ | $4.28^{A}$ | $3.44^{B}$ | $3.29^{B}$ | $3.18^{B}$ | $3.11^{B}$ | $3.05^{C}$ |
| Corn | 3.67 | $3.87^{A}$ | 3.93 | $2.89^{B}$ | $3.33^{B}$ | $3.92^{AB}$ | $3.40^{B}$ | $3.17^{B}$ | $3.06^{B}$ | $2.82^{C}$ |
| Oat | 3.72 | $3.94^{A}$ | 4.32 | $3.96^{A}$ | $3.33^{B}$ | $4.24^{A}$ | $4.42^{A}$ | $4.25^{A}$ | $4.07^{A}$ | $4.06^{A}$ |
| Corn-Oat | 3.66 | $4.05^{A}$ | 4.02 | $3.16^{B}$ | $3.79^{B}$ | $4.25^{A}$ | $3.66^{B}$ | $3.68^{AB}$ | $3.50^{B}$ | $3.54^{B}$ |

[a]For each attribute, means not having the same letter (A, B or C) are significantly different ($p<0.05$). Means with the same letter are similar and not significantly different. Means for attributes without letters are not significantly different from each other.

scores includes Anadama bread with oat bran. The middle group includes the bread with corn-oat bran. The third group which has lower average mean scores includes bread with wheat and corn brans. Panelists liked the flavor and aroma imparted by molasses in Anadama bread. On the 1 to 5-cm scales of the instrument, all means for the attributes of Anadama bread are in the upper desirable portion of the scale or greater than 2.5-cm.

Anadama bread has approximately 9% of the flour in the formula replaced by wheat bran, 5% by corn bran, 24% by oat bran and 14% by corn-oat bran (Table VII). Other researchers found flour replaced by above 12% bran results in differences in volume, color, grain and texture of the bread, including off-flavor (Anonymous, 1976; Apling et al., 1978). Anadama bread with 24% of the flour replaced by oat bran has the highest mean scores for structure of cells, flavor and overall acceptability. Apparently, the grain, texture and flavor of Anadama bread with flour replaced with as much as 24% oat bran are not affected. Several panelists note the compact cell structures around the edges and the large air pockets in the center of the wheat bran, corn bran and corn-oat bran variations, while the oat variation has more desirable cell distribution. Photocopies which support panelists' statements are included in the objective evaluation section of this chapter. Pomeranz et al. (1977) reports corresponding results of weakness in cell walls and crumb disrupting affect with above 7% of the flour replaced by wheat bran and MCC. Anadama bread with 9% of the flour replaced by wheat bran scored the highest means for texture in this research.

Banana Nut Bread

In banana nut bread, the flour is replaced by approximately 15% wheat bran, 8% corn bran, 47% oat bran and 24% corn-oat bran (Table VII). Acceptable banana and nut cakes are produced by replacing 16% of the flour with wheat bran (Rajchel et al., 1975). Successful layer cakes are produced when 30% of the flour is replaced by wheat bran, corn bran, oat bran and soy bran. The flour in oatmeal cookies has been successfully replaced by 30% corn bran and 50% wheat bran (Vratanina and Zabik, 1980; Cochran, 1982).

The analysis of variance with corresponding F tests for sensory evaluation of banana nut bread are shown in Table X. Significant ($p<0.05$) differences among the average mean scores are observed for top crust, crust color, structure of cells, crumb color, flavor and overall acceptability due to bran type. For shape of crust, moisture and mouthfeel, there are no significant differences among the average mean scores due to bran type. The attributes of top crust, crust color and overall acceptability have significant ($p<0.05$) panelist by bran interactions.

The results of Duncan's multiple range tests for separation of means due to bran type are shown in Table XI. For top crust, crust color, crumb color and overall acceptability, average mean scores are in two groups. For top crust, crust color and crumb color, banana nut bread with corn, oat and corn-oat brans are in the group with higher average mean scores, and bread with wheat bran is in the group with lower average mean scores. For overall acceptability, bread with oat and corn-oat brans are in the group with higher average mean scores,

TABLE X

ANALYSIS OF VARIANCE FOR SENSORY EVALUATION OF BANANA NUT BREAD

| Attribute | Source | df | Sum of Squares | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Top Crust | Date | 2 | 9.78 | 2.13 | 0.1552 |
| | Panelist | 7 | 25.09 | 1.56 | 0.2255 |
| | Error (a) | 14 | 32.08 | | |
| | Bran | 3 | 10.05 | 4.33 | 0.0088 |
| | PxB | 21 | 40.58 | 2.50 | 0.0045 |
| | Error (b) | 48 | 37.13 | | |
| Shape of Crust | Date | 2 | 0.30 | 0.10 | 0.9034 |
| | Panelist | 7 | 83.11 | 8.01 | 0.0005 |
| | Error (a) | 14 | 20.76 | | |
| | Bran | 3 | 1.58 | 0.77 | 0.5186 |
| | PxB | 21 | 17.00 | 1.17 | 0.3141 |
| | Error (b) | 48 | 33.09 | | |
| Crust Color | Date | 2 | 13.98 | 3.93 | 0.0441 |
| | Panelist | 7 | 65.98 | 5.30 | 0.0039 |
| | Error (a) | 14 | 24.87 | | |
| | Bran | 3 | 14.95 | 5.26 | 0.0032 |
| | PxB | 21 | 43.39 | 2.18 | 0.0130 |
| | Error (b) | 48 | 45.44 | | |
| Structure of Cells | Date | 2 | 5.02 | 4.52 | 0.0306 |
| | Panelist | 7 | 91.20 | 23.46 | 0.0001 |
| | Error (a) | 14 | 7.78 | | |
| | Bran | 3 | 8.99 | 3.62 | 0.0195 |
| | PxB | 21 | 16.74 | 0.96 | 0.5210 |
| | Error (b) | 48 | 39.73 | | |
| Crumb Color | Date | 2 | 32.32 | 14.83 | 0.0003 |
| | Panelist | 7 | 40.22 | 5.27 | 0.0041 |
| | Error (a) | 14 | 15.26 | | |
| | Bran | 3 | 21.30 | 5.87 | 0.0017 |
| | PxB | 21 | 25.25 | 0.99 | 0.4874 |
| | Error (b) | 48 | 58.08 | | |
| Moisture | Date | 2 | 4.29 | 1.97 | 0.1765 |
| | Panelist | 7 | 45.09 | 5.92 | 0.0024 |
| | Error (a) | 14 | 15.24 | | |
| | Bran | 3 | 2.57 | 0.55 | 0.6510 |
| | PxB | 21 | 27.28 | 0.83 | 0.6707 |
| | Error (b) | 48 | 74.98 | | |

TABLE X (Continued)

| Attribute | Source | df | Sum of Squares | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Mouthfeel | Date | 2 | 3.56 | 1.77 | 0.2072 |
| | Panelist | 7 | 46.74 | 6.63 | 0.0014 |
| | Error (a) | 14 | 14.11 | | |
| | Bran | 3 | 7.60 | 2.15 | 0.1060 |
| | PxB | 21 | 38.72 | 1.57 | 0.0996 |
| | Error (b) | 48 | 56.48 | | |
| Flavor | Date | 2 | 13.33 | 16.00 | 0.0002 |
| | Panelist | 7 | 84.82 | 29.09 | 0.0001 |
| | Error (a) | 14 | 5.83 | | |
| | Bran | 3 | 11.35 | 3.77 | 0.0164 |
| | PxB | 21 | 28.70 | 1.36 | 0.1857 |
| | Error (b) | 48 | 48.14 | | |
| Over-All Acceptability | Date | 2 | 6.52 | 6.61 | 0.0095 |
| | Panelist | 7 | 75.67 | 21.94 | 0.0001 |
| | Error (a) | 14 | 6.90 | | |
| | Bran | 3 | 10.22 | 3.74 | 0.0171 |
| | PxB | 21 | 36.48 | 1.91 | 0.0330 |
| | Error (b) | 48 | 43.76 | | |

and bread with wheat bran is in the group with lower average mean scores. For overall acceptability, bread with corn bran does not belong to either the group with lower or the group with higher average mean scores.

For structure of cells and flavor, there are two groups indicated (Table XI). Banana nut bread with oat bran belongs to the group with higher average mean scores. The group with lower average mean scores includes bread with wheat and corn brans. The average mean scores for banana nut bread with corn-oat bran is not separated distinctly into either the group with higher or the group with lower average mean

TABLE XI

DUNCAN'S MULTIPLE RANGE TESTS FOR DIFFERENCES DUE TO BRAN TYPE IN SENSORY ANALYSIS OF BANANA NUT BREAD[a]

| | Mean Values of Attributes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Exterior Appearance | | | Interior Acceptance | | | Palatability | | |
| Bran | Top Crust | Shape of Crust | Crust Color | Structure of Cells | Crumb Color | Moisture | Mouthfeel | Flavor | Over-All Acceptability |
| Wheat | 2.76$^{B}$ | 3.48 | 2.74$^{B}$ | 2.87$^{B}$ | 2.23$^{B}$ | 3.25 | 2.51 | 2.92$^{B}$ | 2.74$^{B}$ |
| Corn | 3.44$^{A}$ | 3.65 | 3.51$^{A}$ | 3.05$^{B}$ | 3.47$^{A}$ | 3.47 | 2.75 | 3.04$^{B}$ | 2.93$^{AB}$ |
| Oat | 3.43$^{A}$ | 3.40 | 3.80$^{A}$ | 3.65$^{A}$ | 3.18$^{A}$ | 3.71 | 3.20 | 3.77$^{A}$ | 3.51$^{A}$ |
| Corn-Oat | 3.60$^{A}$ | 3.73 | 3.51$^{A}$ | 3.42$^{AB}$ | 3.22$^{A}$ | 3.50 | 3.12 | 3.51$^{AB}$ | 3.43$^{A}$ |

[a]For each attribute, means not having the same letter (A, B or C) are significantly different ($p<0.05$). Means with the same letter are similar and are not significantly different. Means for attributes without letters are not significantly different from each other.

scores. As mentioned previously, the corn-oat bran is a 50:50 ratio of corn and oat brans.

Literature shows bread texture to be associated with particle size of the added fiber (Anonymous, 1976). In this study, the particle size of the wheat bran is larger than the oat and corn brans, and the wheat bran type breads are arbitrarily considered the standard products. The banana nut bread with wheat bran generally has lower average mean scores for all attributes with significant differences (Table XI). Panel members identify brown flecks in the bread with wheat bran. Most panelists indicated, however, that all four bran types are acceptable in banana nut bread. On the 1-cm to 5-cm scales, all average mean scores are in the upper desirable portion of the scale or greater than 2.5-cm.

## Bran Rolls

The analysis of variance with corresponding F tests for bran rolls is shown in Table XII. There is significant ($p<0.05$) difference among the average mean scores for all attributes due to bran type and due to panelist by bran interaction. Shafer and Zabik (1978) have shown that flavor scores and panelist preferences for bran increase as panelists become accustomed to the taste of the bran. For example, in the sensory evaluation of the wheat bran rolls, panelists note a coarse texture and grainy appearance with brown flecks, but the same panelists later comment about the very good texture, color and overall appearance. Again, the wheat bran rolls are arbitrarily considered the standard products. Wheat bran is available in supermarkets and has been incorporated in breads that can be purchased by consumers.

TABLE XII

ANALYSIS OF VARIANCE FOR SENSORY EVALUATION OF BRAN ROLLS

| Attribute | Source | df | Sum of Squares | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Top Crust | Date | 2 | 2.72 | 3.01 | 0.0816 |
| | Panelist | 7 | 38.50 | 12.17 | 0.0001 |
| | Error (a) | 14 | 6.33 | | |
| | Bran | 3 | 38.77 | 15.27 | 0.0001 |
| | PxB | 21 | 33.99 | 1.91 | 0.0323 |
| | Error (b) | 48 | 40.63 | | |
| Crust Color | Date | 2 | 0.97 | 0.67 | 0.5296 |
| | Panelist | 7 | 40.38 | 7.91 | 0.0006 |
| | Error (a) | 14 | 10.21 | | |
| | Bran | 3 | 17.09 | 8.95 | 0.0001 |
| | PxB | 21 | 34.75 | 2.60 | 0.0032 |
| | Error (b) | 48 | 30.57 | | |
| Structure of Cells | Date | 2 | 8.17 | 5.53 | 0.0170 |
| | Panelist | 7 | 59.53 | 11.51 | 0.0001 |
| | Error (a) | 14 | 10.34 | | |
| | Bran | 3 | 12.63 | 5.70 | 0.0020 |
| | PxB | 21 | 39.76 | 2.76 | 0.0036 |
| | Error (b) | 48 | 35.47 | | |
| Crumb Color | Date | 2 | 4.41 | 3.74 | 0.0500 |
| | Panelist | 7 | 27.11 | 6.56 | 0.0014 |
| | Error (a) | 14 | 8.26 | | |
| | Bran | 3 | 34.25 | 17.36 | 0.0001 |
| | PxB | 21 | 28.60 | 2.07 | 0.0189 |
| | Error (b) | 48 | 31.56 | | |
| Moisture | Date | 2 | 0.22 | 0.22 | 0.8023 |
| | Panelist | 7 | 62.33 | 18.46 | 0.0001 |
| | Error (a) | 14 | 6.75 | | |
| | Bran | 3 | 5.14 | 3.15 | 0.0332 |
| | PxB | 21 | 27.54 | 2.41 | 0.0059 |
| | Error (b) | 48 | 26.07 | | |
| Mouthfeel | Date | 2 | 0.74 | 0.35 | 0.7103 |
| | Panelist | 7 | 33.89 | 4.58 | 0.0075 |
| | Error (a) | 14 | 14.79 | | |
| | Bran | 3 | 17.20 | 6.52 | 0.0009 |
| | PxB | 21 | 47.27 | 2.56 | 0.0036 |
| | Error (b) | 48 | 42.24 | | |

TABLE XII (Continued)

| Attribute | Source | df | Sum of Squares | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Flavor | Date | 2 | 6.39 | 4.29 | 0.0353 |
| | Panelist | 7 | 51.40 | 9.85 | 0.0002 |
| | Error (a) | 14 | 10.43 | | |
| | Bran | 3 | 10.73 | 6.28 | 0.0011 |
| | PxB | 21 | 41.05 | 3.43 | 0.0002 |
| | Error (b) | 48 | 27.36 | | |
| Over-All Acceptability | Date | 2 | 6.40 | 3.51 | 0.0581 |
| | Panelist | 7 | 51.68 | 8.10 | 0.0005 |
| | Error (a) | 14 | 12.77 | | |
| | Bran | 3 | 16.83 | 17.01 | 0.0001 |
| | PxB | 21 | 32.53 | 4.70 | 0.0001 |
| | Error (b) | 48 | 15.83 | | |

The results of Duncan's multiple range tests for separation of means due to bran type in sensory evaluation of bran rolls is shown in Table XIII. For the attribute of top crust, average mean scores are in two groups. The group with higher average mean scores includes wheat, corn and corn-oat bran rolls. Oat bran rolls are in the group with lower average mean scores for top crust.

For crust color, moisture, flavor and overall acceptability, the average mean scores are separated into two groups (Table XIII). For crust color, flavor and overall acceptability, corn and corn-oat bran rolls are in the first group with higher average mean scores, while wheat and oat brans are in the second group with lower average mean scores. For moisture, corn bran rolls are in the first group, while

TABLE XIII

DUNCAN'S MULTIPLE RANGE TESTS FOR DIFFERENCES DUE TO BRAN TYPE IN SENSORY ANALYSIS OF BRAN ROLLS[a]

| Bran | Mean Values of Attributes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Exterior Appearance | | Interior Appearance | | | Palatability | | |
| | Top Crust | Crust Color | Structure of Cells | Crumb Color | Moisture | Mouthfeel | Flavor | Over-All Acceptability |
| Wheat | $3.93^{A}$ | $3.25^{B}$ | $2.94^{B}$ | $3.08^{C}$ | $3.70^{B}$ | $2.85^{B}$ | $3.31^{B}$ | $3.23^{B}$ |
| Corn | $4.05^{A}$ | $4.31^{A}$ | $3.51^{A}$ | $4.53^{A}$ | $4.27^{A}$ | $3.90^{A}$ | $3.97^{A}$ | $4.18^{A}$ |
| Oat | $2.56^{B}$ | $3.65^{B}$ | $2.64^{B}$ | $3.75^{B}$ | $3.72^{B}$ | $3.44^{A}$ | $3.40^{B}$ | $3.36^{B}$ |
| Corn-Oat | $4.09^{A}$ | $4.16^{A}$ | $3.46^{A}$ | $4.49^{A}$ | $3.94^{AB}$ | $3.88^{A}$ | $4.07^{A}$ | $4.05^{A}$ |

[a]For each attribute, means not having the same letter (A, B or C) are significantly different ($p<0.05$). Means with the same letter are similar and are not significantly different. Means for attributes without letters are not significantly different from each other.

wheat and oat bran rolls are in the second group. Tests are not able to distinguish which group, first or second, includes corn-oat bran rolls. Again, corn-oat bran is a 50:50 ratio of corn and oat brans. For the attribute of moisture, corn bran rolls and oat bran rolls are in different groups of average mean scores.

For the attribute of mouthfeel, there are two groups of average mean scores indicated in Table XIII. The group with higher average mean scores is corn, oat and corn-oat bran rolls. Wheat bran rolls are in the group with lower average mean scores.

Bran rolls have about 9% of the flour replaced by wheat bran, 5% by corn bran, 25% by oat bran and 14% by corn-oat bran (Table VIII). The 5% corn and the 14% corn-oat bran rolls show higher average mean scores for most attributes, including structure of cells, crumb color and overall acceptability (Table XIII). Researchers find crumb disrupting effects, differences in texture, grain and color, as well as less overall acceptability for breads with greater than 12% of the flour replaced by bran (Anonymous, 1976; Pomeranz et al., 1977; Apling et al., 1978). Panelists in this study observe that the 25% oat bran roll crumbles easily and seems heavy, but has good mouthfeel and flavor.

## Whole Wheat English Muffins

In the formula for whole wheat English muffins, all-purpose flour is replaced by approximately 10% wheat bran, 5% corn bran, 28% oat bran and 16% corn-oat bran (Table VII). The analysis of variance with corresponding F tests for the sensory evaluation of whole wheat English muffins is shown in Table XIV. For crust color, texture, crumb

TABLE XIV

ANALYSIS OF VARIANCE FOR SENSORY EVALUATION
OF WHOLE WHEAT ENGLISH MUFFINS

| Attribute | Source | df | Sum of Squares | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Top Crust | Date | 2 | 0.34 | 0.24 | 0.7918 |
| | Panelist | 7 | 37.11 | 7.49 | 0.0007 |
| | Error (a) | 14 | 9.90 | | |
| | Bran | 3 | 0.95 | 0.53 | 0.6617 |
| | PxB | 21 | 12.33 | 0.99 | 0.4878 |
| | Error (b) | 48 | 28.37 | | |
| Crust Color | Date | 2 | 1.01 | 1.42 | 0.2746 |
| | Panelist | 7 | 19.66 | 7.87 | 0.0006 |
| | Error (a) | 14 | 5.00 | | |
| | Bran | 3 | 4.57 | 5.65 | 0.0021 |
| | PxB | 21 | 5.73 | 1.01 | 0.4667 |
| | Error (b) | 48 | 12.93 | | |
| Side Walls | Date | 2 | 2.30 | 2.38 | 0.1290 |
| | Panelist | 7 | 31.13 | 9.21 | 0.0003 |
| | Error (a) | 14 | 6.76 | | |
| | Bran | 3 | 2.48 | 2.64 | 0.0603 |
| | PxB | 21 | 34.48 | 5.23 | 0.0001 |
| | Error (b) | 48 | 15.08 | | |
| Structure of Cells | Date | 2 | 0.59 | 0.26 | 0.7715 |
| | Panelist | 7 | 49.78 | 6.40 | 0.0016 |
| | Error (a) | 14 | 15.55 | | |
| | Bran | 3 | 2.74 | 1.27 | 0.2946 |
| | PxB | 21 | 24.95 | 1.66 | 0.0749 |
| | Error (b) | 48 | 34.43 | | |
| Texture | Date | 2 | 2.95 | 1.21 | 0.3286 |
| | Panelist | 7 | 49.61 | 5.79 | 0.0026 |
| | Error (a) | 14 | 17.13 | | |
| | Bran | 3 | 36.88 | 22.52 | 0.0001 |
| | PxB | 21 | 29.23 | 2.55 | 0.0037 |
| | Error (b) | 48 | 26.20 | | |
| Crumb Color | Date | 2 | 4.69 | 3.87 | 0.0460 |
| | Panelist | 7 | 29.56 | 6.97 | 0.0011 |
| | Error (a) | 14 | 8.49 | | |
| | Bran | 3 | 15.74 | 25.48 | 0.0001 |
| | PxB | 21 | 13.68 | 3.16 | 0.0005 |
| | Error (b) | 48 | 9.89 | | |

TABLE XIV (Continued)

| Attribute | Source | df | Sum of Squares | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Moisture | Date | 2 | 0.79 | 0.34 | 0.7159 |
| | Panelist | 7 | 37.53 | 4.64 | 0.0071 |
| | Error (a) | 14 | 16.19 | | |
| | Bran | 3 | 3.24 | 1.36 | 0.2659 |
| | PxB | 21 | 1.02 | 1.02 | 0.4606 |
| | Error (b) | 48 | 38.13 | | |
| Mouthfeel | Date | 2 | 2.54 | 1.03 | 0.3815 |
| | Panelist | 7 | 102.35 | 11.88 | 0.0001 |
| | Error (a) | 14 | 17.23 | | |
| | Bran | 3 | 16.51 | 8.99 | 0.0001 |
| | PxB | 21 | 30.00 | 2.33 | 0.0078 |
| | Error (b) | 48 | 29.39 | | |
| Flavor | Date | 2 | 2.86 | 2.56 | 0.1128 |
| | Panelist | 7 | 57.50 | 14.71 | 0.0001 |
| | Error (a) | 14 | 7.82 | | |
| | Bran | 3 | 5.91 | 3.37 | 0.0261 |
| | PxB | 21 | 25.83 | 2.10 | 0.0172 |
| | Error (b) | 48 | 28.12 | | |
| Over-All Acceptability | Date | 2 | 2.66 | 2.06 | 0.1644 |
| | Panelist | 7 | 61.69 | 13.64 | 0.0001 |
| | Error (a) | 14 | 9.04 | | |
| | Bran | 3 | 9.00 | 8.18 | 0.0002 |
| | PxB | 21 | 24.93 | 3.24 | 0.0004 |
| | Error (b) | 48 | 17.61 | | |

color, mouthfeel and overall acceptability, average mean scores are significantly ($p<0.05$) different due to bran type in the English muffins. There are no significant differences among the average mean scores for top crust, side walls, structure of cells and moisture. Table XIV shows significant ($p<0.05$) panelist by bran interactions for the attributes of side walls, texture, mouthfeel, flavor and overall acceptability.

The results of Duncan's multiple range tests for separation of means due to bran type of whole wheat English muffins is presented in Table XV. For crust color, texture and crumb color, two groups of mean scores are indicated. For texture and crumb color, the group with higher average mean scores includes English muffins with corn, oat and wheat brans. Wheat bran English muffins are in the second group with lower average mean scores. For crust color, English muffins with corn and oat brans are in the group with higher average mean scores, and wheat bran English muffins are in the second group. Tests are unable to separate the average mean scores for crust color of the corn bran English muffins into one of the distinct groups.

For mouthfeel, the average mean scores are divided into three groups (Table XV). Oat bran English muffins are in the first group with highest average mean scores. Corn bran English muffins are in the second group. Average mean scores for corn-oat bran English muffins are not distinctly in either the first or second group for mouthfeel. Two panelists comment that they could not identify the corn-oat bran in the whole wheat English muffins and have made remarks that perhaps bran was omitted from the formula. For mouthfeel, wheat bran English muffins are in the third group with lowest mean scores.

For the attribute of flavor, there are two groups of mean scores (Table XV). Oat bran English muffins are in the group with the higher average mean scores. The second group with lower average mean scores includes whole wheat English muffins with wheat, corn and corn-oat brans.

For overall acceptability, three groups of average mean scores are indicated for whole wheat English muffins (Table XV). Oat bran

TABLE XV

DUNCAN'S MULTIPLE RANGE TESTS FOR DIFFERENCES DUE TO BRAN TYPE IN SENSORY ANALYSIS OF WHOLE WHEAT ENGLISH MUFFINS[a]

| | Mean Values of Attributes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Exterior Appearance | | | Interior Appearance | | | | Palatability | | |
| Bran | Top Crust | Crust Color | Side Walls | Structure of Cells | Texture | Crumb Color | Moisture | Mouthfeel | Flavor | Over-All Acceptability |
| Wheat | 4.00 | $3.84^{B}$ | 3.95 | 3.94 | $2.74^{B}$ | $3.35^{B}$ | 3.59 | $2.89^{C}$ | $3.60^{B}$ | $3.38^{C}$ |
| Corn | 4.11 | $4.26^{A}$ | 4.05 | 3.61 | $3.90^{A}$ | $4.35^{A}$ | 3.99 | $3.53^{B}$ | $3.70^{B}$ | $3.63^{CB}$ |
| Oat | 4.25 | $4.43^{A}$ | 4.20 | 3.56 | $4.31^{A}$ | $4.24^{A}$ | 3.88 | $4.04^{A}$ | $4.25^{A}$ | $4.19^{A}$ |
| Corn-Oat | 4.01 | $4.12^{AB}$ | 3.76 | 3.51 | $4.19^{A}$ | $4.24^{A}$ | 4.07 | $3.67^{AB}$ | $3.78^{B}$ | $3.93^{AB}$ |

[a]For each attribute, means not having the same letter (A, B or C) are significantly different ($p<0.05$). Means with the same letter are similar and are not significantly different. Means for attributes without letters are not significantly different from each other.

English muffins are in the first group with highest average mean scores. No bran-types of English muffins are distinctly separated into the second group of middle average mean scores. Tests are unable to distinguish whether the corn-oat bran English muffins belong to the first or second group. Wheat bran English muffins are in the third group with lowest average mean scores. Tests are unable to distinguish whether corn bran English muffins belong to the second or third group.

## Objective Evaluation

F tests from the analysis of variance and Duncan's multiple range tests for separation of means are used to analyze the measures of baking loss, height, diameter and index to volume of the bread systems (Steel and Torrie, 1980). Table XVI shows the results of Duncan's multiple range tests for differences due to the bran type in Anadama bread, banana nut bread, bran rolls and whole wheat English muffins. Table XVI should be read vertically and not compared horizontally. Each bread system is studied individually based on type of bran added and is not meant to be compared to other bread systems.

The nutritional analyses of corn and oat bran and the formulas for the bread systems are included in Appendix E. The nutritional compositions of the bread systems with each bran variation are presented and discussed in this chapter.

The appearance of the breads is recorded by photocopying. The photocopies illustrate appearance, cell distribution, texture and

TABLE XVI

DUNCAN'S MULTIPLE RANGE TEST FOR DIFFERENCES DUE TO BRAN TYPE IN OBJECTIVE EVALUATION[a]

| Bran | Attribute | Anadama Bread | Banana Nut Bread | Bran Rolls | Whole Wheat English Muffins |
|---|---|---|---|---|---|
| Wheat | Baking Loss (g) | 73.33 | 76.27 | 6.33 | 12.33 |
| Corn | | 58.23 | 73.90 | 6.03 | 10.97 |
| Oat | | 70.80 | 77.00 | 6.27 | 11.00 |
| Corn-Oat | | 68.27 | 75.33 | 5.47 | 12.03 |
| Wheat | Diameter (cm) | | | | 9.77 |
| Corn | | | | | 9.77 |
| Oat | | | | | 9.50 |
| Corn-Oat | | | | | 9.83 |
| Wheat | Height (cm) | 10.80$^{A}$ | 6.43$^{B}$ | 5.03$^{A}$ | 3.37$^{B}$ |
| Corn | | 10.10$^{B}$ | 6.87$^{A}$ | 5.10$^{A}$ | 3.77$^{A}$ |
| Oat | | 10.07$^{B}$ | 6.40$^{B}$ | 4.30$^{B}$ | 3.30$^{B}$ |
| Corn-Oat | | 10.53$^{AB}$ | 6.00$^{C}$ | 4.90$^{A}$ | 3.43$^{B}$ |
| Wheat | Index to Volume ($cm^2$) | 120.79 | 64.72 | 29.22 | 72.52 |
| Corn | | 111.70 | 65.59 | 27.71 | 70.35 |
| Oat | | 123.06 | 65.37 | 27.28 | 66.65 |
| Corn-Oat | | 126.20 | 64.07 | 26.62 | 73.81 |

[a]For each attribute, average means not having the same letter (A, B or C) are significantly different ($p<0.05$). Means with the same letter are similar and not significantly different. Means for attributes without letters are not significantly different from each other.

size of the bread systems. Metric scales with centimeter units are included to indicate size.

Anadama Bread

The analysis of variance with corresponding F tests for objective evaluation of Anadama bread is presented in Table XVII. Figures 2, 3, 4 and 5 are photocopies of Anadama bread with 1-g NDF bran. are no significant differences ($p<0.05$) observed in baking loss and index to volume. Means for height differ significantly ($p<0.05$) due to type of bran and date of replication. The bread systems in this study are prepared in a food research laboratory; however, it is not possible to control room humidity. According to Griswold (1962), humidity may affect the speed of fermentation and height achieved by loaves, as well as volume of bread systems.

TABLE XVII

ANALYSIS OF VARIANCE FOR OBJECTIVE EVALUATION OF ANADAMA BREAD

| Attribute | Source | df | Mean Square | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Baking Loss | Date | 2 | 503.87 | 4.22 | 0.0718 |
| | Bran | 3 | 393.83 | 2.20 | 0.1893 |
| | Error (a) | 6 | 358.47 | | |
| Height | Date | 2 | 1.085 | 7.26 | 0.0250 |
| | Bran | 3 | 1.129 | 5.04 | 0.0445 |
| | Error (a) | 6 | 0.448 | | |
| Index to Volume | Date | 2 | 136.12 | 1.11 | 0.3877 |
| | Bran | 3 | 336.64 | 1.84 | 0.2410 |
| | Error (a) | 6 | 366.54 | | |

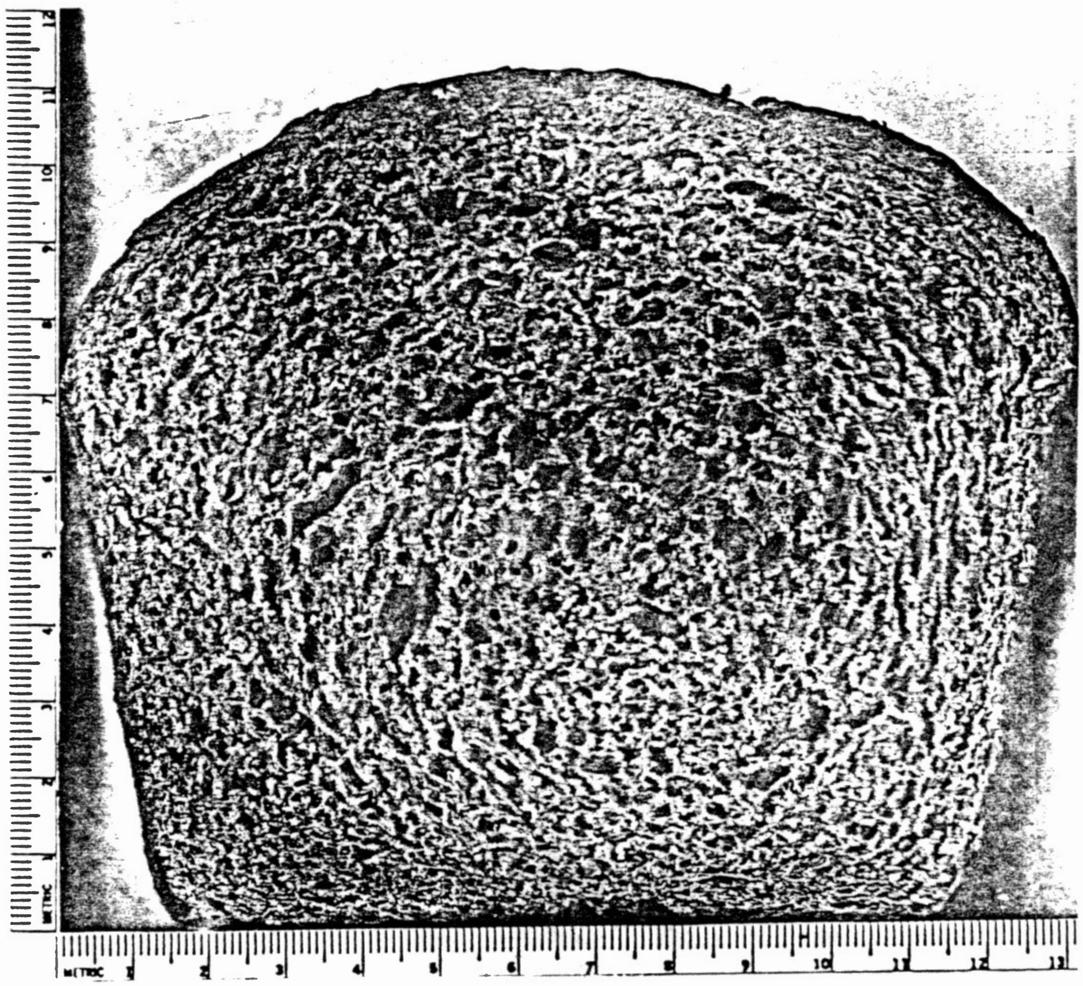


Figure 2. Photocopy of a Slice of Anadama Bread With 1-g NDF Wheat Bran

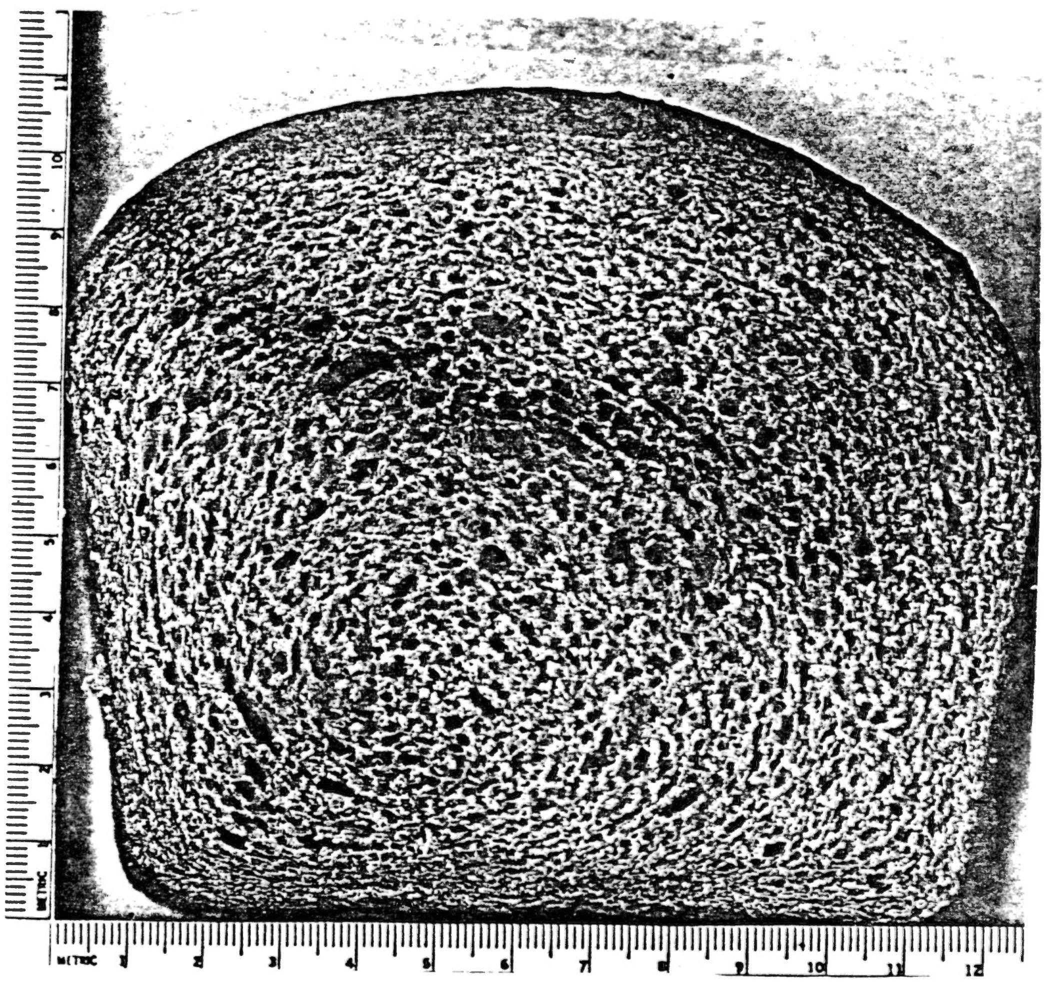


Figure 3. Photocopy of a Slice of Anadama Bread With 1-g NDF Corn Bran

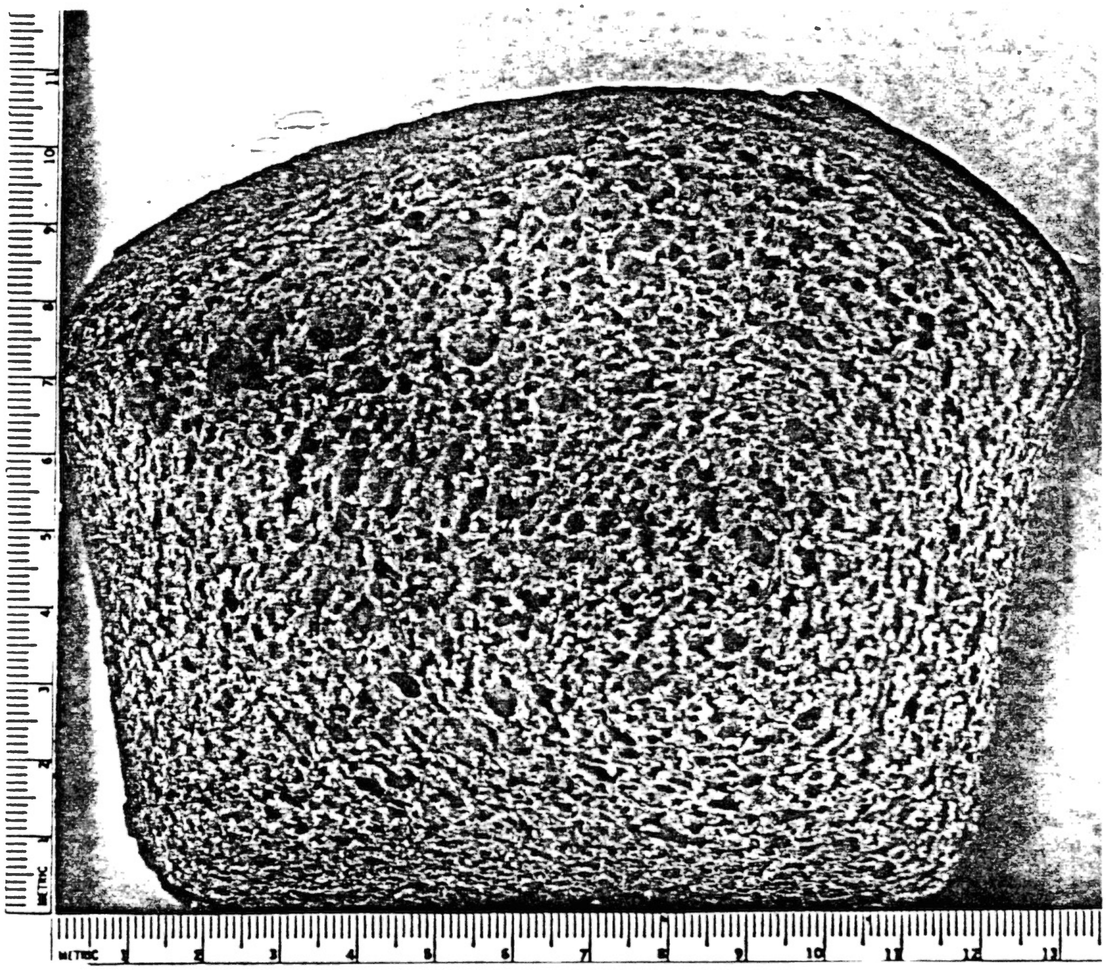


Figure 4. Photocopy of a Slice of Anadama Bread With 1-g NDF Oat Bran

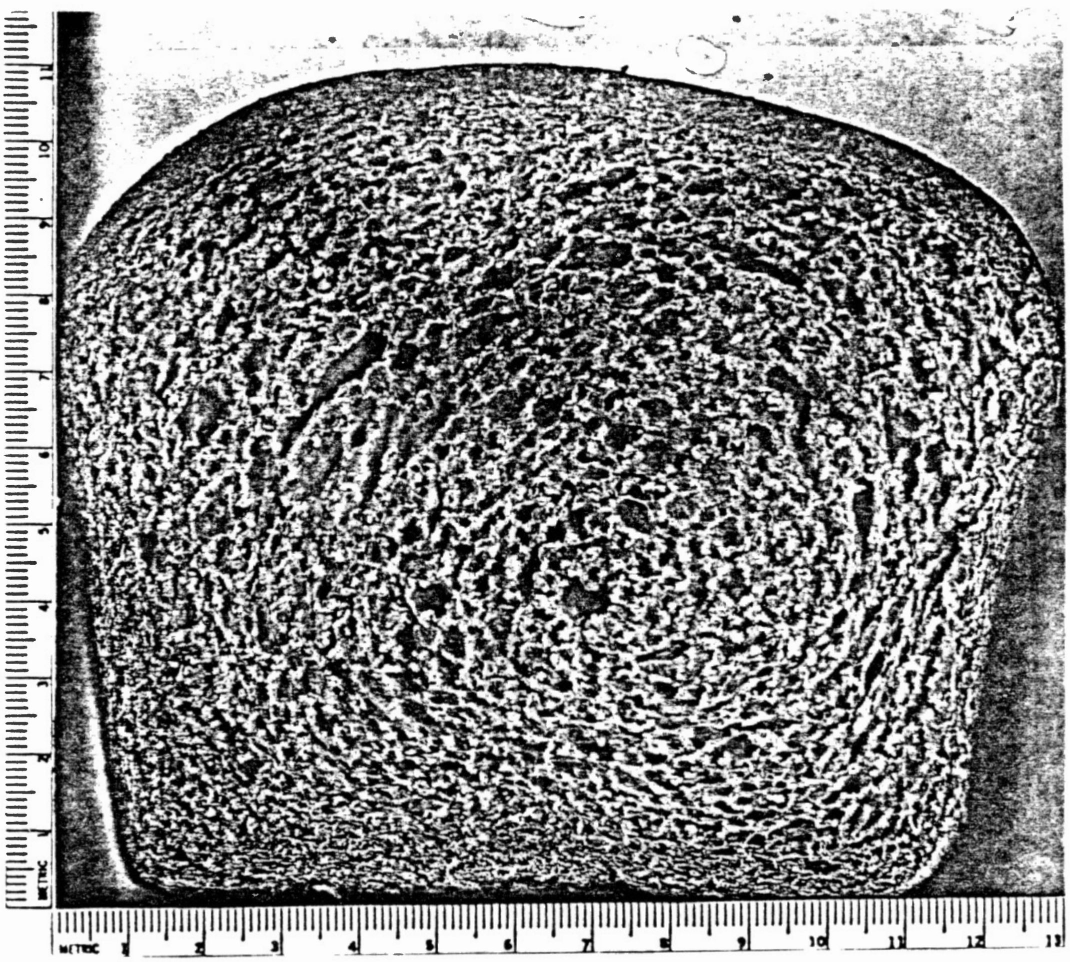


Figure 4. Photocopy of a Slice of Anadama Bread With 1-g NDF Corn-Oat Bran

Table XVI illustrates Duncan's multiple range tests for separation of means due to bran type. The average means for height are separated into two groups. Wheat bran Anadama bread is in the group with the highest average means. The group with lower average means includes Anadama bread with corn and oat brans. Tests are unable to decipher whether Anadama bread with corn-oat bran belongs to one of the other group. Pomeranz et al. (1977) reports that volume decreased in bread by the dilution of gluten when flour is replaced at levels above 7% by wheat bran. Results in this study support the results reported by Pomeranz et al. (1977) which state that height decreases as percentage of flour replaced by bran increases.

Bread is an important source of carbohydrates, the vitamin B complex, including thiamin, riboflavin and niacin and other nutrients (Groen, 1973). The nutritive composition of Anadama bread is presented in Table XVIII. In addition to the added 1-g NDF bran, each bran roll has 0.1-g dietary fiber from other ingredients in the formula. Calories per slice average between 117.9 and 119.8. High fiber breads available to consumers in the marketplace are compared nutritionally in Table III (Chapter II). The calories per slice and weight per serving compare closely to Anadama bread, but the high fiber breads in Table III are higher in fiber content and lower in carbohydrate values. The method of fiber determination is not recorded in Table III and possibly may not be NDF or the dietary fiber calculations of Anadama bread. This study is not to add maximum amounts of fiber, but rather to show the possibility of incorporating 1-g NDF of different fibers.

TABLE XVIII

NUTRITIVE COMPOSITION OF ANADAMA BREAD

| | Bran[a] | | | |
|---|---|---|---|---|
| | Wheat | Corn | Oat | Corn-Oat |
| Weight per slice, g | 43.1 | 41.8 | 43.6 | 43.5 |
| Calories | 118.3 | 117.9 | 119.8 | 118.8 |
| Protein, g | 3.1 | 2.9 | 3.5 | 2.7 |
| Carbohydrate, g | 23.0 | 22.5 | 22.4 | 22.5 |
| FIBER, g | 1.1 | 1.1 | 1.1 | 1.1 |
| Fat, g | 1.8 | 1.7 | 2.1 | 1.9 |
| Sodium, mg | 133.8 | 114.6 | 114.6 | 114.6 |
| Potassium, mg | 56.2 | 33.2 | 29.4 | 31.3 |
| Calcium, mg | 22.6 | 20.2 | 23.6 | 21.9 |
| Magnesium, mg | 16.9 | 13.1 | 5.7 | 6.2 |
| Phosphorus, mg | 57.9 | 31.5 | 31.6 | 31.6 |
| Iron, mg | 1.4 | 1.1 | 1.4 | 1.2 |
| Thiamin, mcg | 131.5 | 120.3 | 162.5 | 141.4 |
| Riboflavin, mcg | 92.9 | 87.9 | 98.8 | 93.4 |
| Niacin, mg | 1.5 | 1.1 | 1.0 | 1.0 |
| Ascorbic acid, mg | trace | trace | trace | trace |
| Vitamin A, iu | 57.8 | 57.8 | 57.8 | 57.8 |
| Vitamin D, iu | 0 | -[b] | - | - |

[a]The food values of Staley refined corn bran and Quaker oat bran are calculated from the typical analyses in Appendix E. Wheat bran is calculated from the food values of Bowes and Church (1970).

[b]A dash (-) indicates sparseness of reliable data.

In Table III, values for sodium, potassium and phosphorus are not stated. Values for sodium and potassium are higher for the wheat bran Anadama bread; however, adequate values for sodium and potassium in corn bran are not available (Appendix E). The oat bran Anadama bread is highest in thiamin (162.5-mcg) and riboflavin (98.8-mcg).

Banana Nut Bread

The analysis of variance with corresponding F tests for objective evaluation of banana nut bread is presented in Table XIX. Figures 6, 7, 8 and 9 are photocopies of slices of banana nut bread with 1-g NDF bran. While average means baking loss and index to volume are not significantly different, average means for height differ significantly at the $p<0.001$ level due to bran type.

TABLE XIX

ANALYSIS OF VARIANCE FOR OBJECTIVE EVALUATION OF BANANA NUT BREAD

| Attribute | Source | df | Mean Square | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Baking Loss | Date | 2 | 68.80 | 4.88 | 0.0551 |
| | Bran | 3 | 16.09 | 0.76 | 0.5557 |
| | Error (a) | 6 | 42.28 | | |
| Height | Date | 2 | 0.045 | 1.98 | 0.2192 |
| | Bran | 3 | 1.129 | 33.05 | 0.0004 |
| | Error (a) | 6 | 0.068 | | |
| Index to Volume | Date | 2 | 0.634 | 0.04 | 0.9636 |
| | Bran | 3 | 4.23 | 0.17 | 0.9155 |
| | Error (a) | 6 | 50.91 | | |

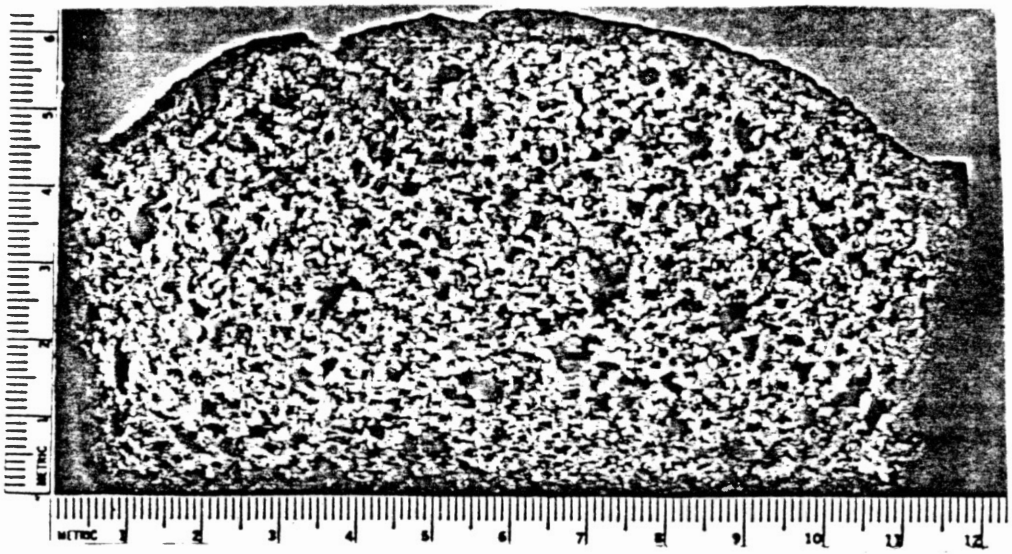


Figure 6. Photocopy of a Slice of Banana Nut Bread With 1-g NDF Wheat Bran

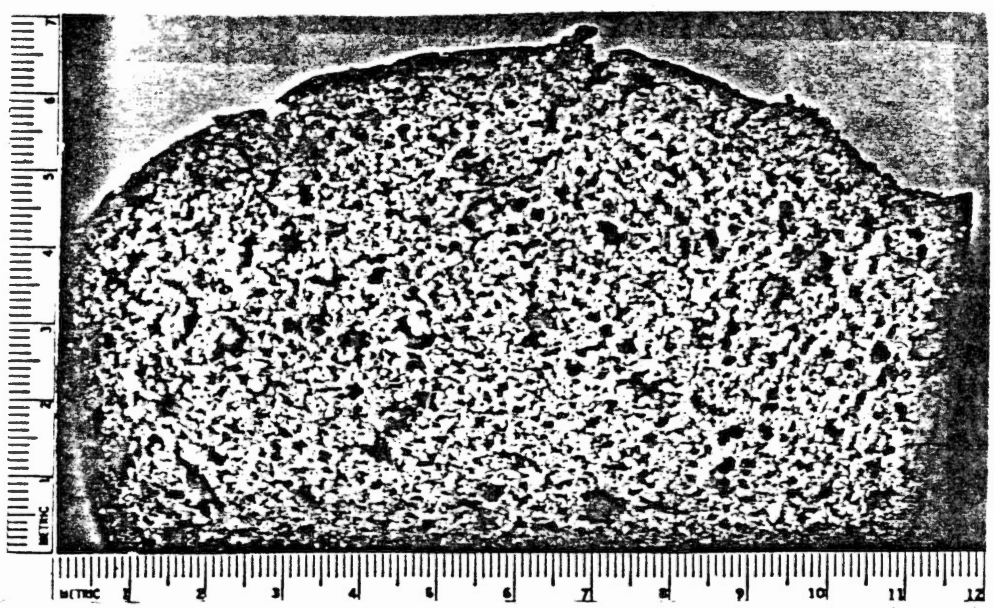


Figure 7. Photocopy of a Slice of Banana Nut Bread With 1-g NDF Corn Bran

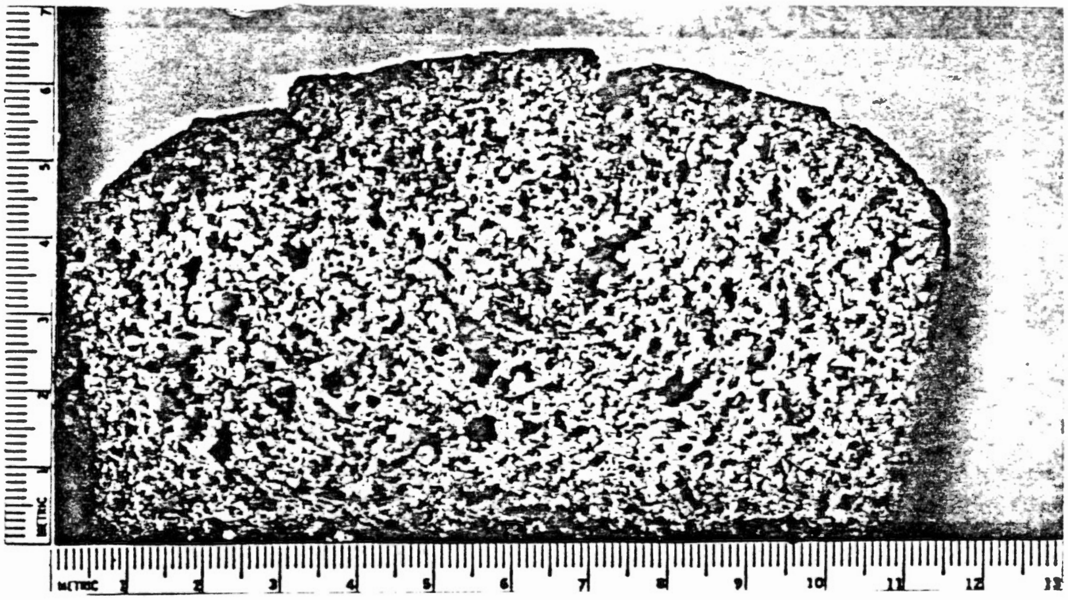


Figure 8. Photocopy of a Slice of Banana Nut Bread With 1-g NDF Oat Bran

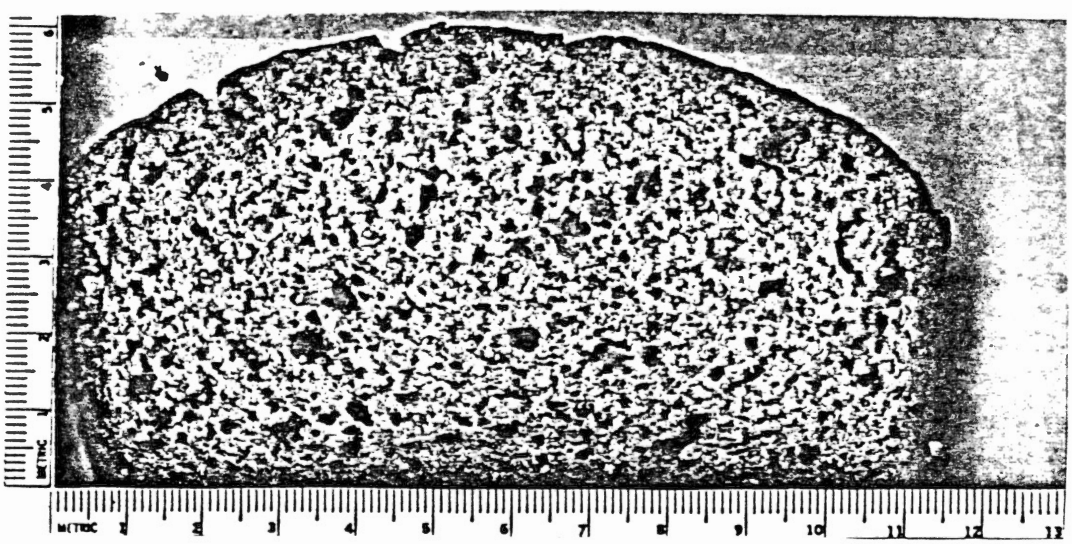


Figure 9. Photocopy of a Slice of Banana Nut Bread With 1-g NDF Corn-Oat Bran

Shafer and Zabik (1978) report larger volumes in layer cakes with corn bran when compared to oat and soy brans. Banana nut bread is a quick bread similar to layer cakes. Both are leavened with baking powder. The average mean heights for banana nut bread is separated into three groups (Table XVI). In this study, banana nut bread with corn bran has the larger mean height and corn-oat bran had the lower mean height; however, banana nut bread with wheat and oat brans are in the middle group for average mean height.

The nutritive composition of banana nut bread is shown in Table XX. In addition to the added 1-g NDF bran, each slice of banana nut bread has 0.2-g dietary fiber from other ingredients. Calories per slice range from 163.3 to 165.2 calories. Like Anadama bread, the banana nut bread with wheat bran has the highest values for potassium (140.3-mg) and also highest in magnesium (15.7-mg), phosphorus (106.1-mg) and niacin (1.1-mg) than the other bran types of bread. Banana nut bread with oat bran is highest in values for thiamin (160.2-mcg) and riboflavin (99.7-mcg).

## Bran Rolls

The analysis of variance with corresponding F tests for objective evaluation of bran rolls is presented in Table XXI. Photocopies of bran rolls with 1-g NDF bran are illustrated in Figures 10, 11, 12 and 13. Average mean height differs significantly at the $p<0.005$ level. In Table XVI, two groups of average mean heights are indicated. The group with higher average mean heights includes wheat, corn and corn-oat bran rolls. Oat bran rolls are in the group with lower average mean heights.

TABLE XX

NUTRITIVE COMPOSITION OF BANANA NUT BREAD

| | Bran[a] | | | |
|---|---|---|---|---|
| | Wheat | Corn | Oat | Corn-Oat |
| Weight per slice, g | 60.8 | 61.2 | 60.7 | 60.7 |
| Calories | 163.7 | 163.3 | 165.2 | 165.1 |
| Protein, g | 3.8 | 3.6 | 4.1 | 3.9 |
| Carbohydrate, g | 27.6 | 27.1 | 26.9 | 27.0 |
| FIBER, g | 1.2 | 1.2 | 1.2 | 1.2 |
| Fat, g | 4.6 | 4.8 | 5.2 | 5.0 |
| Sodium, mg | 172.9 | 172.7 | 172.6 | 172.6 |
| Potassium, mg | 140.3 | 117.3 | 113.5 | 115.4 |
| Calcium, mg | 38.9 | 36.5 | 40.0 | 38.2 |
| Magnesium, mg | 15.7 | 5.5 | 4.5 | 5.0 |
| Phosphorus, mg | 106.1 | 79.8 | 79.9 | 79.8 |
| Iron, mg | 1.1 | 0.9 | 1.0 | 0.9 |
| Thiamin, mcg | 129.1 | 118.0 | 160.2 | 139.1 |
| Riboflavin, mcg | 93.8 | 88.8 | 99.7 | 94.2 |
| Niacin, mg | 1.1 | 0.7 | 0.6 | 0.7 |
| Ascorbic acid, mg | 1.7 | 1.7 | 1.7 | 1.7 |
| Vitamin A, iu | 355.1 | 355.1 | 355.1 | 355.1 |
| Vitamin D, iu | 5.6 | 5.6 | 5.6 | 5.6 |

[a]The food values of Staley refined corn bran and Quaker oat bran are calculated from the typical analyses in Appendix E. Wheat bran is calculated from the food values of Bowes and Church (1970).

The nutritive composition of bran rolls is presented in Table XXII. In addition to the added 1-g NDF bran, each bran roll has 0.1-g dietary fiber from other ingredients. Calories per roll are between 169.2 and 171.2. Wheat bran rolls are highest in potassium (59.5-mg), magnesium (17.1-mg), phosphorus (59.1-mg) and niacin (1.5-mg). Oat bran rolls are highest in thiamin (162.9-mcg) and riboflavin (106.9-mcg).

TABLE XXI

ANALYSIS OF VARIANCE FOR OBJECTIVE EVALUATION OF BRAN ROLLS

| Atttribute | Source | df | Mean Square | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Baking Loss | Date | 2 | 1.42 | 3.50 | 0.0982 |
| | Bran | 3 | 1.40 | 2.30 | 0.1768 |
| | Error (a) | 6 | 1.21 | | |
| Height | Date | 2 | 0.0017 | 0.03 | 0.9663 |
| | Bran | 3 | 1.20 | 16.55 | 0.0026 |
| | Error (a) | 6 | 0.145 | | |
| Index to Volume | Date | 2 | 3.44 | 0.36 | 0.7132 |
| | Bran | 3 | 10.95 | 0.76 | 0.5565 |
| | Error (a) | 6 | 28.83 | | |

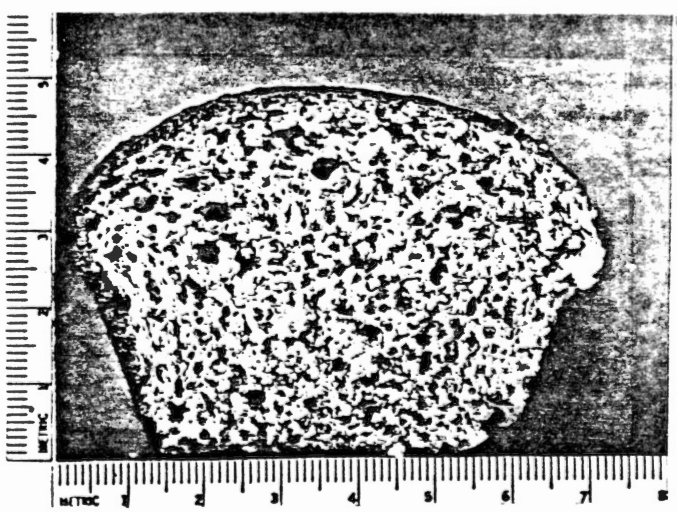


Figure 10. Photocopy of a Bran Roll With 1-g NDF Wheat Bran

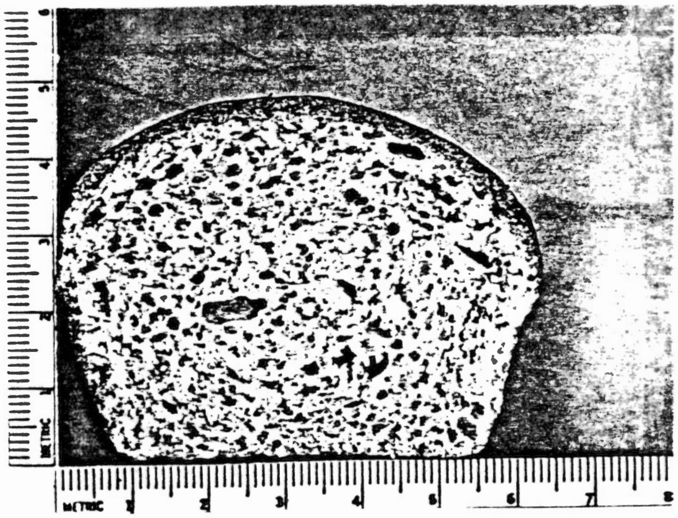


Figure 11. Photocopy of a Bran Roll With 1-g NDF Corn Bran

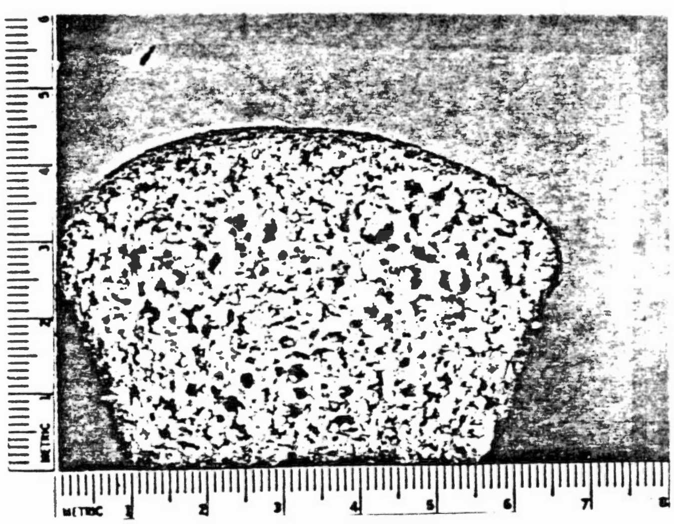


Figure 12. Photocopy of a Bran Roll With 1-g NDF Oat Bran

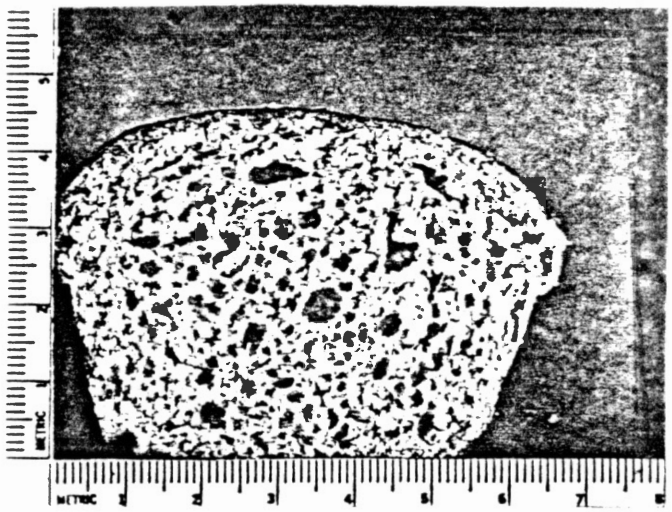


Figure 13. Photocopy of a Bran Roll With 1-g NDF Corn-Oat Bran

TABLE XXII

NUTRITIVE COMPOSITION OF BRAN ROLLS

| | Bran[a] | | | |
|---|---|---|---|---|
| | Wheat | Corn | Oat | Corn-Oat |
| Weight per roll, g | 46.7 | 47.0 | 46.7 | 47.5 |
| Calories, g | 169.7 | 169.2 | 171.2 | 170.2 |
| Protein, g | 3.4 | 3.3 | 3.2 | 2.9 |
| Carbohydrate, g | 24.1 | 23.6 | 23.4 | 23.5 |
| FIBER, g | 1.1 | 1.1 | 1.1 | 1.1 |
| Fat, g | 6.9 | 6.9 | 7.2 | 7.1 |
| Sodium, mg | 150.0 | 149.8 | 149.7 | 149.8 |
| Potassium, mg | 59.5 | 36.5 | 32.7 | 34.6 |
| Calcium, mg | 9.6 | 7.2 | 10.7 | 8.9 |
| Magnesium, mg | 17.1 | 6.9 | 5.9 | 6.4 |
| Phosphorus, mg | 59.1 | 34.3 | 38.1 | 34.4 |
| Iron, mg | 1.2 | 0.9 | 1.1 | 1.0 |
| Thiamin, mcg | 131.8 | 120.6 | 162.9 | 141.8 |
| Riboflacin, mcg | 100.9 | 95.9 | 106.9 | 101.4 |
| Niacin, mg | 1.5 | 1.0 | 0.9 | 1.0 |
| Ascorbic acid, mg | 0 | 0 | 0 | 0 |
| Vitamin A, iu | 320.0 | 320.0 | 320.0 | 320.0 |
| Vitamin D, iu | 13.5 | 13.5 | 13.5 | 13.5 |

[a]The food values of Staley refined corn bran and Quaker oat bran are calculated from the typical analyses in Appendix E. Wheat bran is calculated from the food values of Bowes and Church (1970).

Whole Wheat English Muffins

The analysis of variance for objective evaluation of whole wheat English muffins is shown in Table XXIII. Figures 14, 15, 16 and 17 are photocopies of whole wheat English muffins with 1-g NDF bran per muffin half. There are no significant differences in baking loss, diameter or index to volume; however, average mean heights differ significantly at the $p<0.05$ level due to bran types. As shown in Table XVI, English muffins are separated into two groups of average means for height. The English muffins with corn bran have the highest mean value (3.77-cm) in height. The group with lower average mean heights includes English muffins with wheat, corn and corn-oat brans. During sensory evaluation, panelists comment that even though the oat and corn-oat variations of whole wheat English muffins had good height, muffins with corn bran are taller and thicker in proportion to the size of the other English muffins.

The nutritive composition of whole wheat English muffins is presented in Table XXIV. In addition to the added 1-g NDF bran, each English muffin half has 0.2-g dietary fiber from other ingredients in the formula. The calories per English muffin half are between 132.2 and 134.2. English muffins with wheat bran have the greatest values for potassium (87.1-mg), sodium (193.3-mg), magnesium (24.7-mg), phosphorus (80.0-mg) and niacin (1.7-mg). English muffins with oat bran have the highest values for thiamin (191.3-mcg) and riboflavin (101.2-mcg).

TABLE XXIII

ANALYSIS OF VARIANCE FOR OBJECTIVE EVALUATION OF WHOLE WHEAT ENGLISH MUFFINS

| Attribute | Source | df | Mean Square | F Value | Observed Probability Level |
|---|---|---|---|---|---|
| Baking Loss | Date | 2 | 5.61 | 1.35 | 0.3285 |
| | Bran | 3 | 4.46 | 0.71 | 0.5786 |
| | Error (a) | 6 | 12.49 | | |
| Diameter | Date | 2 | 0.322 | 2.02 | 0.2138 |
| | Bran | 3 | 0.197 | 0.82 | 0.5275 |
| | Error (a) | 6 | 0.478 | | |
| Height | Date | 2 | 0.0267 | 0.86 | 0.4705 |
| | Bran | 3 | 0.387 | 8.29 | 0.0149 |
| | Error (a) | 6 | 0.093 | | |
| Index to Volume | Date | 2 | 57.35 | 2.16 | 0.1968 |
| | Bran | 3 | 88.28 | 2.21 | 0.1872 |
| | Error (a) | 6 | 79.75 | | |

## Testing the Hypotheses

The first hypothesis ($H_1$) states that there will be no significant differences in the sensory and objective qualities of Anadama bread when wheat bran, corn bran, oat bran and corn-oat bran are replaced for all-purpose flour with the appropriate amounts of bran to yield 1-g NDF per serving. Based on results of subjective and objective evaluations, the researcher rejects $H_1$.

The second hypothesis ($H_2$) states that there will be no significant differences in sensory and objective qualities of banana nut bread when wheat bran, corn bran, oat bran and corn-oat bran are replaced for

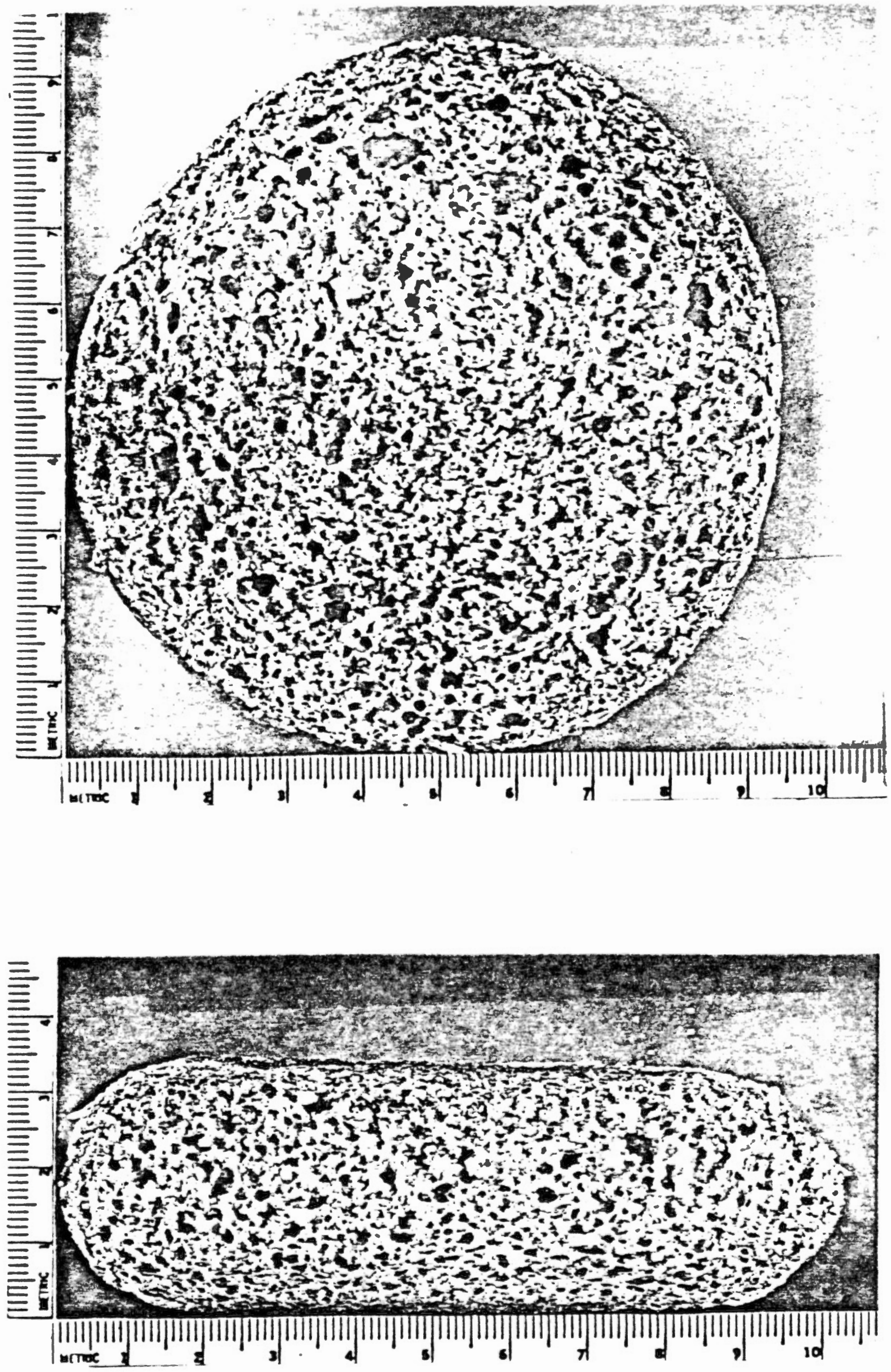


Figure 14. Photocopies of Horizontally and Vertically Cut Whole Wheat English Muffin Halves With 1-g NDF Wheat Bran

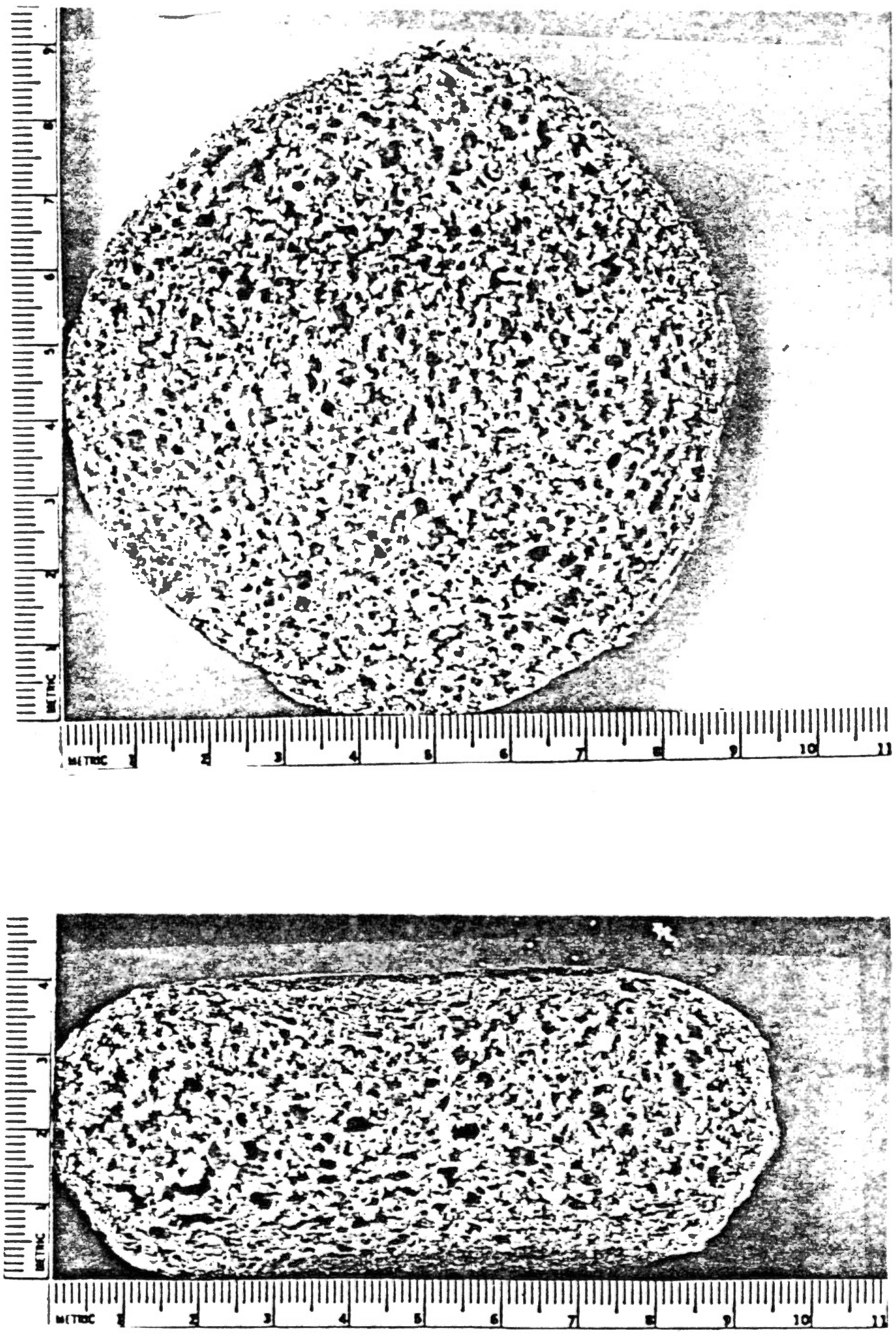


Figure 15. Photocopies of Horizontally and Vertically Cut Whole Wheat English Muffin Halves With 1-g NDF Corn Bran

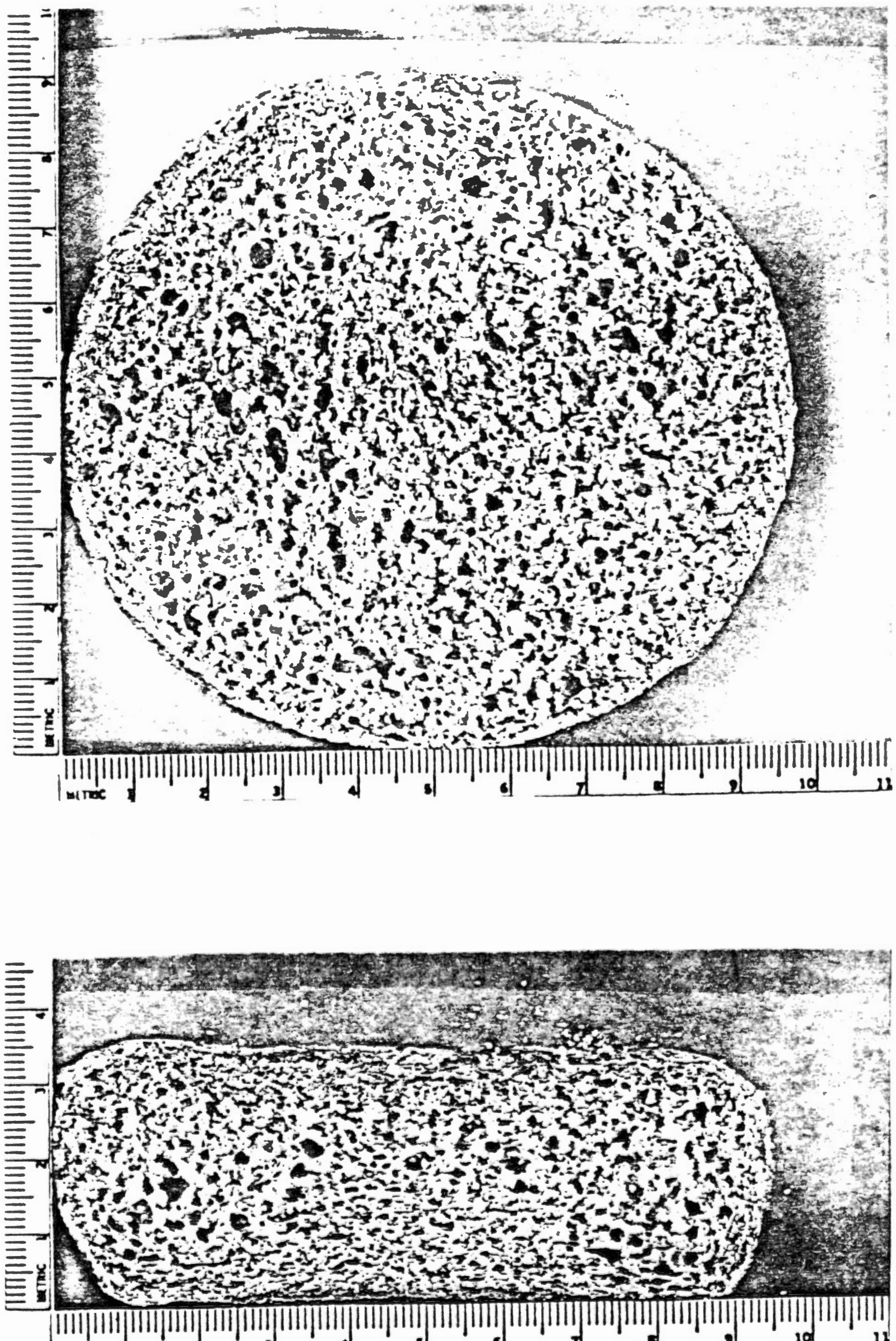


Figure 16. Photocopies of Horizontally and Vertically Cut Whole Wheat English Muffin Halves With 1-g NDF Oat Bran

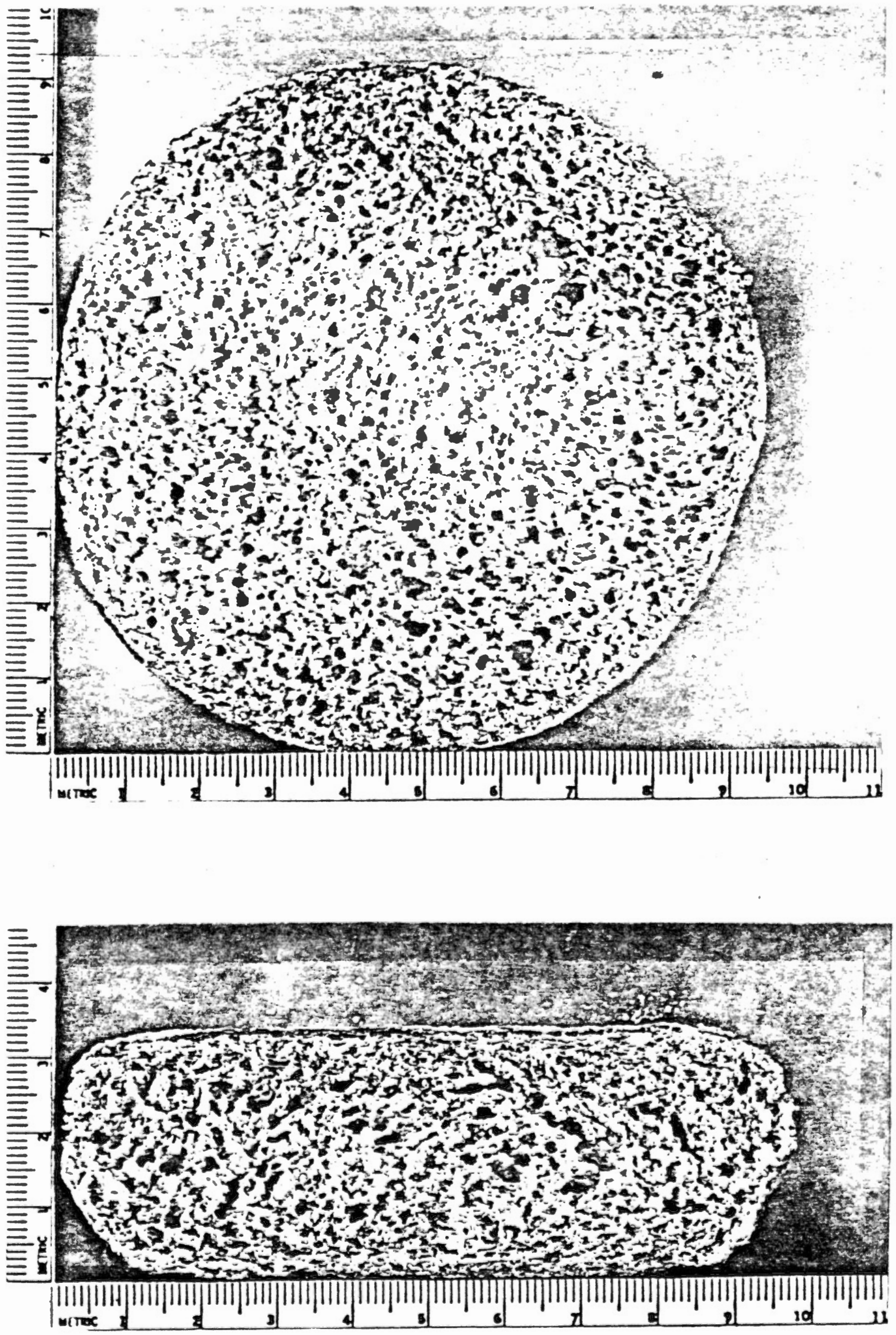


Figure 17. Photocopies of Horizontally and Vertically Cut Whole Wheat English Muffin Halves With 1-g NDF Corn-Oat Bran

all-purpose flour with the appropriate amounts of bran to yield 1-g NDF per serving. Based on results of subjective and objective evaluations, the researcher rejects $H_2$.

TABLE XXIV

NUTRITIVE COMPOSITION OF WHOLE WHEAT ENGLISH MUFFINS

| | Bran[a] | | | |
|---|---|---|---|---|
| | Wheat | Corn | Oat | Corn-Oat |
| Weight per muffin half, g | 44.8 | 45.5 | 45.5 | 45.0 |
| Calories | 132.7 | 132.2 | 134.2 | 133.2 |
| Protein, g | 3.8 | 3.6 | 4.2 | 3.9 |
| Carbohydrates, g | 24.1 | 23.6 | 23.5 | 23.6 |
| FIBER, g | 1.2 | 1.2 | 1.2 | 1.2 |
| Fat, g | 2.7 | 2.7 | 3.1 | 2.9 |
| Sodium, mg | 193.3 | 174.1 | 174.1 | 174.1 |
| Potassium, mg | 87.1 | 64.1 | 60.3 | 62.2 |
| Calcium, mg | 16.7 | 14.3 | 17.8 | 16.1 |
| Magnesium, mg | 24.7 | 14.5 | 13.4 | 13.9 |
| Phosphorus, mg | 80.0 | 53.6 | 53.8 | 53.7 |
| Iron, mg | 1.3 | 1.0 | 1.3 | 1.1 |
| Thiamin, mcg | 160.3 | 149.2 | 191.3 | 170.2 |
| Riboflavin, mcg | 95.2 | 90.2 | 101.2 | 95.7 |
| Niacin, mg | 1.7 | 1.3 | 1.2 | 1.2 |
| Ascorbic acid, mg | 0.1 | 0.1 | 0.1 | 0.1 |
| Vitamin A, iu | 92.8 | 92.8 | 92.8 | 92.8 |
| Vitamin D, iu | 0 | -[b] | - | - |

[a]The food values of Staley refined corn bran and Quaker oat bran are calculated from the typical analyses in Appendix E. Wheat bran is calculated from the food values of Bowes and Church (1970).

[b]A dash (-) indicates sparseness of reliable data.

The third hypothesis ($H_3$) states that there will be no significant differences in the sensory and objective qualities of bran rolls when wheat bran, corn bran, oat bran and corn-oat bran are replaced for all-purpose flour with the appropriate amounts of bran to yield 1-g NDF per serving. Based on results of subjective and objective evaluations, the researcher rejects $H_3$.

The fourth hypothesis ($H_4$) states that there will be no significant differences in the sensory and objective qualities of whole wheat English muffins when wheat bran, corn bran, oat bran and corn-oat bran are replaced for all-purpose flour with the appropriate amounts of bran to yield 1-g NDF per serving. Based on results of the subjective and objective evaluations, the researcher rejects $H_4$.

# CHAPTER V

# SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND IMPLICATIONS

Recent studies showing dietary fiber intake may prevent certain diseases associated with Western civilization has stimulated the introduction of high fiber breads and other food systems (Cleave et al., 1969; Burkitt et al., 1972; 1974; Trowell, 1972; Burkitt, 1973). Pertinent literature suggests that bread is an excellent vehicle to increase dietary fiber and to reduce caloric value. Little is known about the effects of many nontraditional sources of dietary fiber on bread making (Pomeranz et al., 1977).

Cereal brans, which are processing by-products, can impart whole grain flavor and texture in food systems (Scala, 1974; Colmey, 1978). Some researchers have studied the effects of different percentages of all-purpose flour replaced with wheat bran, corn bran and oat bran in cookies, cakes, muffins, crackers, cornbread and other breads (Rajchel et al., 1975; Brockmole and Zabik, 1976; Springsteen et al., 1977; Smith and Haurysh, 1978; Shafer and Zabik, 1978; Cochran, 1982). A review of literature showed the need for standardized definitions and methodology for dietary fiber determinations, as well as the need for further studies to determine the effects of different dietary fiber sources on bread systems.

The purpose of this research is to determine the effects of wheat bran, corn bran, oat bran and corn-oat bran (50:50 ratio) on the sensory and objective qualities of various bread systems. Anadama bread, banana nut bread, bran rolls and whole wheat English muffins are the bread systems chosen in this study. The independent variables are the four bran types replacing all-purpose flour with the amounts of bran calculated for 1-g NDF per serving. The dependent variables are the subjective evaluations by an eight member trained taste panel and objective evaluations, which include measures of baking loss, height, diameter and index to volume, and nutritional analyses.

A summary of Duncan's multiple range tests for separation of means attributed by bran type for sensory and objective evaluation is presented in Table XXV. The summary of results should be read vertically and not compared horizontally. The study of each bread system is a separate study based on type of bran rather than a comparison of bread systems.

## Summary and Conclusions

### Anadama Bread

The first hypothesis ($H_1$) states that there will be no significant differences in the sensory and objective qualities of Anadama bread when all-purpose flour is replaced by the appropriate amounts of the four bran types to yield 1-g NDF per serving. Average mean scores for shape of crust, structure of cells, texture, crumb color, moisture, flavor, overall acceptability and height differ significantly ($p<0.05$) due to bran type (Table XXV). Caloric values per

TABLE XXV

SUMMARY OF DUNCAN'S MULTIPLE RANGE TESTS DUE TO BRAN IN SENSORY AND OBJECTIVE EVALUATIONS[a]

| Bran | Attribute | Anadama Bread | Banana Nut Bread | Bran Rolls | Whole Wheat English Muffins |
|---|---|---|---|---|---|
| Wheat | Top Crust | | $2.76^{B}$ | $3.93^{A}$ | |
| Corn | | | $3.44^{A}$ | $4.05^{A}$ | |
| Oat | | | $3.43^{A}$ | $2.56^{B}$ | |
| Corn-Oat | | | $3.60^{A}$ | $4.09^{A}$ | |
| Wheat | Shape of Crust | $2.98^{B}$ | | | |
| Corn | | $3.87^{A}$ | | | |
| Oat | | $3.94^{A}$ | | | |
| Corn-Oat | | $4.05^{A}$ | | | |
| Wheat | Crust Color | | $2.74^{B}$ | $3.25^{B}$ | $3.84^{B}$ |
| Corn | | | $3.51^{A}$ | $4.31^{A}$ | $4.26^{A}$ |
| Oat | | | $3.80^{A}$ | $3.65^{B}$ | $4.43^{A}$ |
| Corn-Oat | | | $3.51^{A}$ | $4.16^{A}$ | $4.12^{AB}$ |
| Wheat | Structure of Cells | $3.28^{B}$ | $2.87^{B}$ | $2.94^{B}$ | |
| Corn | | $2.89^{B}$ | $3.05^{B}$ | $3.51^{A}$ | |
| Oat | | $3.96^{A}$ | $3.65^{A}$ | $2.64^{B}$ | |
| Corn-Oat | | $3.16^{B}$ | $3.42^{AB}$ | $3.46^{A}$ | |
| Wheat | Texture | $4.28^{A}$ | | | $2.74^{B}$ |
| Corn | | $3.33^{B}$ | | | $3.90^{A}$ |
| Oat | | $3.33^{B}$ | | | $4.31^{A}$ |
| Corn-Oat | | $3.79^{B}$ | | | $4.19^{A}$ |
| Wheat | Crumb Color | $3.44^{B}$ | $2.23^{B}$ | $3.08^{C}$ | $3.35^{B}$ |
| Corn | | $3.92^{AB}$ | $3.47^{A}$ | $4.53^{A}$ | $4.35^{A}$ |
| Oat | | $4.24^{A}$ | $3.18^{A}$ | $3.75^{B}$ | $4.24^{A}$ |
| Corn-Oat | | $4.25^{A}$ | $3.22^{A}$ | $4.49^{A}$ | $4.24^{A}$ |
| Wheat | Moisture | $3.29^{B}$ | | $3.70^{B}$ | |
| Corn | | $3.40^{B}$ | | $4.27^{A}$ | |
| Oat | | $4.42^{A}$ | | $3.72^{B}$ | |
| Corn-Oat | | $3.66^{B}$ | | $3.94^{AB}$ | |
| Wheat | Mouthfeel | $3.18^{B}$ | | $2.85^{B}$ | $2.89^{C}$ |
| Corn | | $3.17^{B}$ | | $3.90^{A}$ | $3.53^{B}$ |
| Oat | | $4.25^{A}$ | | $3.44^{A}$ | $4.04^{A}$ |
| Corn-Oat | | $3.68^{AB}$ | | $3.88^{A}$ | $3.67^{AB}$ |

TABLE XXV (Continued)

| Bran | Attribute | Anadama Bread | Banana Nut Bread | Bran Rolls | Whole Wheat English Muffins |
|---|---|---|---|---|---|
| Wheat | Flavor | $3.11^{B}$ | $2.92^{B}$ | $3.31^{B}$ | $3.60^{B}$ |
| Corn | | $3.06^{B}$ | $3.04^{B}$ | $3.97^{A}$ | $3.70^{B}$ |
| Oat | | $4.07^{A}$ | $3.77^{A}$ | $3.40^{B}$ | $4.25^{A}$ |
| Corn-Oat | | $3.50^{B}$ | $3.51^{AB}$ | $4.07^{A}$ | $3.78^{B}$ |
| Wheat | Overall Acceptability | $3.05^{C}$ | $2.74^{B}$ | $3.23^{B}$ | $3.38^{C}$ |
| Corn | | $2.82^{C}$ | $2.93^{AB}$ | $4.18^{A}$ | $3.63^{BC}$ |
| Oat | | $4.06^{A}$ | $3.51^{A}$ | $3.36^{B}$ | $4.19^{A}$ |
| Corn-Oat | | $3.54^{B}$ | $3.43^{A}$ | $4.05^{A}$ | $3.93^{AB}$ |
| Wheat | Height | $10.80^{A}$ | $6.43^{B}$ | $5.03^{A}$ | $3.37^{B}$ |
| Corn | | $10.10^{B}$ | $6.87^{A}$ | $5.10^{A}$ | $3.77^{A}$ |
| Oat | | $10.07^{B}$ | $6.40^{B}$ | $4.30^{B}$ | $3.30^{B}$ |
| Corn-Oat | | $10.53^{AB}$ | $6.00^{C}$ | $4.90^{A}$ | $3.43^{B}$ |

[a]For each attribute, means not having the same letter (A, B or C) are significantly different ($p<0.05$). Means with the same letter are similar and not significantly different. Means for attributes without letters are not significantly different from each other.

slice of Anadama bread vary slightly due to bran type; however, Anadama bread with oat bran is higher in thiamin and riboflavin, according to nutritive analyses (Table XVII). Based on these results, the researcher rejects $H_1$.

For the majority of attributes tested in sensory evaluation, the average mean scores for Anadama bread with 24% oat bran (1-g NDF oat bran) are higher than bread with the other brans. Photocopies (Figures 2-5) illustrate the compact cell structure around the loaf edges and large air pockets in the center in Anadama bread with about 9%

wheat bran, 5% corn bran and 14% corn-oat bran, as noted by the panelists. These results correspond with the findings of other researchers (Pomeranz et al., 1977; Apling et al., 1978) for cell wall weakness and crumb disrupting effect when flour is replaced with above 12% wheat bran. For texture, Anadama bread with 9% wheat bran is in the group with the higher average mean scores (Table XXV). Anadama bread with about 24% oat bran is in the group with the higher mean scores for cell structure. For overall acceptability, Anadama bread with oat bran is in the group with highest mean scores. Panelists like the molasses flavor of Anadama bread. It is possible that the molasses flavor complemented or even disguised the brans in Anadama bread. Flavor scores and preferences for brans seem to increase as panelists became accustomed to the taste of the bran (Shafer and Zabik, 1978).

Banana Nut Bread

The second hypothesis ($H_2$) states that there will be no significant differences in sensory and objective qualities of banana nut bread when all-purpose flour is replaced with the appropriate amounts of the four bran types to yield 1-g NDF per serving. In statistical analyses of sensory and objective attributes, there are significant differences among the average mean scores in banana nut bread due to bran type for top crust, crust color, structure of cells, crumb color, flavor, overall acceptability and height (Table XX). Based on these results, the researcher rejects $H_2$.

For structure of cells and flavor, banana nut bread with oat bran is in the group with higher average mean scores. For the attributes of top crust, crust color and crumb color, banana nut bread with corn, oat and corn-oat brans are in the group with higher average mean scores. Banana nut bread with oat and corn-oat brans are in the group with higher average mean scores for overall acceptability.

Texture has been previously associated with particle size (Anonymous, 1976). In this study, wheat bran has the largest particle size, and the wheat bran variations are considered the standard breads. Even though panelists identify brown flecks in banana nut bread with wheat bran, the attributes of mouthfeel, moisture and texture do not show significant differences among the average mean scores due to bran (Table XXV). In objective evaluation of height for banana nut bread, the bread with corn bran shows the highest average means for height (Table XXV).

Breads are an important source of B complex vitamins, and breads higher in riboflavin, niacin and thiamin are desirable (Groen, 1977). According to nutritional analyses, banana nut bread with wheat bran is higher in potassium, magnesium, phosphorus and niacin. With oat bran, banana nut bread is higher in thiamin and riboflavin.

## Bran Rolls

The third hypothesis ($H_3$) states that there will be no significant differences in the sensory and objective qualities of bran rolls when all-purpose flour is replaced with the appropriate amounts of the four bran types to yield for 1-g NDF per serving. As shown in Table XXV, top crust, crust color, structure of cells, crumb color, moisture, mouthfeel, flavor, overall acceptability and height differ significantly ($p<0.05$) due to bran type in the formula for bran rolls. While calories per roll vary only slightly due to bran type, nutritive values for potassium, magnesium, phosphorus and niacin are greater in wheat bran rolls, and values for thiamin and riboflavin are greater in oat bran rolls. Based on these objective and subjective results, the researcher rejects $H_3$.

By objective analysis, average mean heights are greater for wheat, corn and corn-oat bran rolls than for oat bran rolls (Table XXV). During sensory evaluation, panelists comment that the oat bran roll crumbles easily, but has good mouthfeel and flavor. The flour in the formula for bran rolls is replaced with approximately 25% oat bran, 5% corn bran, 14% corn-oat bran and 9% wheat bran. Other researchers find the same crumb disrupting affect, differences in texture and grain, and less acceptability with greater than 12% flour replaced with wheat bran (Pomeranz et al., 1977; Apling et al., 1978). For the attributes of crust color, structure of cells, flavor and overall acceptability, oat bran rolls and wheat bran rolls are less desirable. The corn bran rolls and corn-oat bran rolls have more desirable mean values for all attributes tasted in sensory evaluation.

## Whole Wheat English Muffins

The fourth hypothesis ($H_4$) states that there will be no significant differences in the sensory and objective qualities of whole wheat English muffins when all-purpose flour is replaced with the appropriate amounts of the four bran types to yield for 1-g NDF per serving. In sensory evaluation, the attributes of crust color, texture, crumb color, mouthfeel, flavor and overall acceptability differ significantly ($p<0.05$) due to bran type in whole wheat English muffins.

In objective evaluation, average means cooking loss, diameter and index to volume are not significantly different due to bran type in English muffins; however, average mean height differ significantly at the $p<0.01$ level (Table XIV). The corn bran type of English muffin has the greater height. Based on these results, the researcher rejects $H_4$.

As mentioned previously, breads are good sources of the B complex vitamins and other nutrients (Groen, 1977). The nutritional analysis of whole wheat English muffins with wheat bran show higher values for potassium, sodium, magnesium, phosphorus and niacin, while English muffins with oat bran have higher values for thiamin and riboflavin. In considering the sensory attributes of mouthfeel, flavor and overall acceptability, English muffins with oat bran are in the group with highest average mean scores. Comments by panelists indicate that whole wheat English muffins with the four bran variations are all excellent products.

## Recommendations

Bread systems appear to make excellent vehicles to increase dietary fiber. Based on the results of this research, wheat bran, corn bran, oat bran and corn-oat bran are acceptable additions in Anadama bread, banana nut bread, bran rolls and whole wheat English muffins in amounts of 1-g NDF per serving. A replication of this study with other objective evaluations, including tests for tenderness, moisture content and color, should be conducted to strengthen present conclusions. To judge the value of these breads in the food industry, a consumer panel would be helpful in evaluating product acceptability as well as of packing types and labeling formats for the new products.

Further studies are needed to study the effects of different dietary fibers on other food systems, such as meat extenders, convenience mixes, frozen entrees, chips and cereals. It is recommended that studies be conducted to compare the effects of dietary fibers with 1-g, 2-g, 3-g and 4-g NDF per serving.

## Implications

Supplementation of breads and other processed foods with different sources of dietary fibers make available and promote assurance of increased fiber content in the diet of the average consumer. Currently, wheat bran and cellulose are the most utilized sources of dietary fiber in the commercial market. In this research, oat bran and corn bran, which are relatively new sources of dietary fiber, have been shown to be palatable and acceptable in various bread systems. There are many other nontraditional sources of dietary fiber that warrant research.

Enrichment of products with dietary fiber is an important factor to consider in the development of future food products. Fiber exchange lists with NDF determinations per servings offer a solution to the need for standardized terminology and methodology for dietary fiber determination in foods. Such exchange lists might be useful to food technologists, dietitians in health care and other food service institutions, nutritionists, government officials, developing labeling and packaging regulations, educators and consumers.

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# APPENDIXES

APPENDIX A

MATERIALS

# Materials

## Ingredients

C and H pure cane granulated sugar
Clabber Girl double acting baking powder
Consumers IGA bananas
Consumers IGA TV Grade A large eggs
Consumers IGA TV homogenized whole milk
Crisco vegetable shortening
Del Cerro pecans
Fleischmann's corn oil margarine
Fleischmann's active dry yeast
Gold Metal all-purpose flour
Grandma's dark, rich robust style molasses
Morton iodized salt
Pillsbury's Best whole wheat flour
Quaker oat bran
Shawnee Best yellow corn meal
Shawnee Multi-Use wheat bran
Staley refined corn bran (regular grind)
Sue Bee Clover honey
Vegelene pan coating

## Supplies

Amoco all-plastic china foam 5-inch sandwich packs
Glad sandwich bags
Glass water goblet
Handi-Wrap plastic film
Poly-vinyl chloride 4-inch pipe for English muffin rings
Reynolds Wrap aluminum foil
Rubbermaid (12 cup) covered bowls
Stainless steel (12 cup) bowls
Tin finish quality steel tag wire (12-inch length)
Tupperware (1 pint) covered containers
Ziploc storage bags (gallon size)
50-ml and 100-ml graduated cylinders

## Food Research Equipment

Cres-Cor Cresent closed transport cart
Corning bun warmer (Model No. E.-1310)
Cooper thermometer
Galaxie Osterizer Blender (Model 848-31H)
General Electric conventional deck oven (Model CN50)
Hobart upright freezer (Model H1)
Kitchen Aid mixer (Model K45)
Lasico planimeter (Model N101A)
Mettler PC4400 digital top loading balance

Food Research Equipment (Continued)

Mirro Timer
Presto 11 inch Fry Pan-Griddle (Model KC 17AT)
Presto 12 inch Fry Pan-Griddle (Model KC 17AT)
Tappan Microwave Time-Saver (Model 10/02016)
Xerox photocopy machine (Model 3100)

# APPENDIX B

# FORMULAS AND PREPARATION PROCEDURES

FORMULA AND PREPARATION PROCEDURE FOR ANADAMA BREAD[a]

| Ingredient | Weight (g) |
|---|---|
| Salt | 4.0 |
| Active dry yeast | 7.0 |
| Margarine | 28.0 |
| Molasses | 82.0 |

[a]Formula is adapted from The American-International Encyclopedic Cookbook (London, 1972, p. 78).

| Variation[b] | Bran (g) | All-Purpose Flour (g) | Water, Tap (ml) |
|---|---|---|---|
| Wheat | 34.1 | 388.4 | 240 |
| Corn | 18.7 | 403.8 | 210 |
| Oat | 82.0 | 340.5 | 255 |
| Corn- | 9.4 | | |
| Oat | 41.0 | 372.1 | 245 |

[b]Bran variation and all-purpose flour weights are based on calculations for 1-g NDF per serving.

1. Weight flour for each variation.
2. Place 110g flour, bran, salt and undissolved yeast in mixing bowl. Blend in margarine for 60 seconds at medium speed.
3. Add very hot tap water (110°F) and molasses to dry ingredients in mixing bowl. Beat 3 minutes at medium speed.
4. Stir in remaining flour with 25 strokes reserving 27.5g to flour board.
5. Turn out onto lightly floured board. Knead 7 minutes.
6. Place in greased aluminum bowl, turning to grease top. Cover with cloth. Let rise in proofing box one hour.
7. Preheat oven to 204°C. (400°F).
8. Punch dough. Let rest 2 minutes. Roll out to 11x9 inch rectangle. Shape into loaf. Place in greased 9 1/4 x 5 1/4 x 2 3/4 inch bread pan.
9. Place 4 5/8 inch wire in center of loaf. Let loaf rise in proofing box uncovered until loaf has risen 1 inch above edge of bread pan (within 1/2 inch of top of wire) about 45 minutes.
10. Bake at 204°C. (400°F.) for 30 minutes. Remove from pan immediately and cool on wire rack one hour. Makes 1 loaf with 16 slices.

## FORMULA AND PREPARATION PROCEDURE FOR BANANA NUT BREAD[a]

| Ingredient | Weight (g) |
|---|---|
| Sugar | 133.3 |
| Baking powder | 9.9 |
| Salt | 3.0 |
| Margarine | 75.3 |
| Bananas, mashed | 200.0 |
| Eggs, beaten | 108.0 |
| Milk, whole | 64.0 |
| Pecans, chopped coarsely | 55.0 |

[a]Formula is adapted from a recipe on the package of Nabisco 100% Bran Cereal.

| Variation[b] | Bran (g) | All-Purpose Flour (g) |
|---|---|---|
| Wheat | 25.6 | 166.9 |
| Corn | 14.0 | 178.5 |
| Oat | 61.5 | 131.0 |
| Corn- | 7.0 | |
| Oat | 30.8 | 154.7 |

[b]Bran Variation and all-purpose flour weights are based on calculations for 1-g NDF per serving.

1. Preheat oven to 177°C. (350°F.).
2. Combine flour, bran, sugar, baking powder and salt in large bowl.
3. With pastry blender, cut in margarine until particles are the size of small peas.
4. Add mashed bananas, beaten eggs and milk. Stir 25 strokes just until blended.
5. Pour into a greased 9x5x3 inch bread pan.
6. Bake at 177°C. (350°F.) for 55 minutes.
7. Cool 10 minutes; then remove to rack to cool completely. Makes 1 loaf with 12 slices.

# FORMULA AND PREPARATION PROCEDURE FOR BRAN ROLLS[a]

| Ingredient | Weight (g) |
|---|---|
| Shortening | 50.0 |
| Sugar | 37.5 |
| Salt | 3.0 |
| Water, 100°C. (210°F.) | 56.0 |
| Active dry yeast | 3.5 |
| Water, 30°C. (85°F.) | 56.0 |
| Eggs, beaten | 27.0 |

[a]Formula is adapted from The American-International Encyclopedic Cookbook (London, 1972, p. 88).

| Variation[b] | Bran (g) | All-Purpose Flour (g) |
|---|---|---|
| Wheat | 17.1 | 187.9 |
| Corn | 9.4 | 195.6 |
| Oat | 41.0 | 164.0 |
| Corn- | 4.7 | |
| Oat | 20.5 | 179.8 |

[b]Bran variation and all-purpose flour weights are based on calculations for 1-G NDF per serving.

1. Measure shortening, sugar, bran and salt in mining bowl. Add 56g boiling (100°C.) water. Beat 60 seconds at medium speed. Scrape sides of bowl.

2. Soften yeast in lukewarm (30°C.) water. Add yeast and beaten eggs to bran mixture. Beat 60 seconds at medium speed.

3. Sift flour into dough batter. Beat 60 seconds at medium speed. Place in covered bowl and refrigerate over-night.

4. Remove dough from refrigerator and weigh 8 portions at 53g each. Shape portions into balls and place in greased muffin pans. Let rise 1½ hours in proofing box.

5. Preheat oven at 218°C. (425°F.). Bake rolls 15 minutes. Makes 8 bran rolls.

# FORMULA AND PREPARATION PROCEDURE FOR WHOLE WHEAT ENGLISH MUFFINS[a]

| Ingredient | Measure |
|---|---|
| Whole wheat flour | 120.0g |
| Active dry yeast | 7.0g |
| Water, 30°C. (85°F.) | 60.0ml |
| Salt | 6.0g |
| Honey | 21.0g |
| Margarine | 45.0g |
| Yellow corn meal | |

[a]Formula is adapted from a recipe on the package of Harrington's Hogdson Mill Wheat Bran.

| Variation[b] | Bran (g) | All-Purpose Flour (g) | Half Flour Mixture (g) | Water (ml) |
|---|---|---|---|---|
| Wheat | 34.1 | 342.4 | 231.2 | 225 |
| Corn | 18.7 | 357.8 | 239.9 | 215 |
| Oat | 82.0 | 294.5 | 207.3 | 240 |
| Corn- | 9.4 | | | |
| Oat | 41.0 | 326.1 | 223.1 | 235 |

[b]Bran variation and all-purpose flour weights are based on calculations for 1-g NDF per serving.

1. Combine whole wheat flour and all-purpose flour. Divide flour mixture in half and separate.

2. Dissolve yeast in 60ml lukewarm (30°C.) water.

3. Combine half flour mixture, salt and bran in mixing bowl. Add dissolved yeast, remaining lukewarm water and honey to dry ingredients in mixing bowl. Beat 2 minutes at medium speed.

4. Place dough batter in bowl and cover with foil. Let rise 1½ hours in proofing box.

5. Add melted shortening, remaining half flour mixture and risen dough in mixing bowl. Using dough hook attachment, knead about 5 minutes until all dough clings to hook and cleans sides of bowl.

6. Place 8 greased English muffin rings on an ungreased baking sheet. Sprinkle bottoms of each ring with about ½ teaspoon corn meal.

7. Weight 8 portions of dough at 102g each. Shape into muffin rings and flatten top of dough with bottom of water goblet. Let rise 30 minutes in proofing box.

8. Preheat two electric griddles to 191°C. (375°F.) for 30 minutes.

9. Invert ring and press English muffin with water goblet onto ungreased griddle. Bake covered 10 minutes on the first side and 10 minutes on the other side. Cool 30 minutes on wire rack. Makes 8 English muffins.

# APPENDIX C

## DATA SHEETS

Date________________________

Product______________________________

Oven temperature______________________

Time in oven__________________________

Time out of oven______________________

Time in proofer_______________________

| | Wheat 1 | Corn 2 | Oat 3 | Corn-Oat 4 |
|---|---|---|---|---|
| 1. Code | ______ | ______ | ______ | ______ |
| 2. Order of preparation | ______ | ______ | ______ | ______ |
| 3. Placement in oven | ______ | ______ | ______ | ______ |
| 4. Weight before cooking | ______ | ______ | ______ | ______ |
| 5. Weight after cooking | ______ | ______ | ______ | ______ |
| 6. Height of sample | ______ | ______ | ______ | ______ |
| 7. Diameter of sample | ______ | ______ | ______ | ______ |
| 8. First time in proofer (bowl) | ______ | ______ | ______ | ______ |
| 9. Second time in proofer (loaf or English muffin) | ______ | ______ | ______ | ______ |
| 10. Time in oven or on grill | ______ | ______ | ______ | ______ |
| 11. Time out oven or off grill | ______ | ______ | ______ | ______ |

Date____________________

Product____________________

Oven temperature____________________

Time in oven____________________

Time out of oven____________________

| | Wheat 1 | Corn 2 | Oat 3 | Corn-Oat 4 |
|---|---|---|---|---|
| 1. Code | ______ | ______ | ______ | ______ |
| 2. Order of preparation | ______ | ______ | ______ | ______ |
| 3. Placement in oven | ______ | ______ | ______ | ______ |
| 4. Weight before cooking | ______ | ______ | ______ | ______ |
| 5. Weight after cooking | ______ | ______ | ______ | ______ |
| 6. Height of sample | ______ | ______ | ______ | ______ |
| 7. Diameter of sample | ______ | ______ | ______ | ______ |

APPENDIX D

SENSORY EVALUATION OF BREAD SYSTEMS

# Instructions to Panel Members

At each session, you will be asked to sample and evaluate eight formulations of baked products. Please evaluate the visual characteristics of all samples before evaluating the eating characteristics. Samples should be evaluated in the order that the sample codes are listed (left to right) at the top of the scoresheet. After examining or tasting the samples, rank the sample on the vertical scale corresponding to the characteristic you are evaluating. A list of criteria for that product will be available at each booth in the sensory evaluation room. If you find any other differences between samples or have any comments which might be helpful in the evaluation of these products, please indicate them on the lines provided.

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

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

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

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

## Criteria for Standard Anadama Bread

1. Exterior Appearance:
    a) Top crust: relatively thin; mottled
    b) Shape of top crust: well-rounded; free from cracks or bulges
    c) Crust color: even brown
2. Interior Appearance:
    a) Structure of cells: uniformly distributed and not compact, large cells with thick cell walls
    b) Texture: smooth, not grainy
    c) Crumb color: golden cast or glow
    d) Moisture: slightly moist
3. Palatability:
    a) Mouthfeel: moderately tender
    b) Flavor: rich, appealing flavor with a hint of molasses, not sour or yeasty
    c) Overall acceptability: overall satisfaction in eating each product based upon the above criteria

## Criteria for Standard Benana Nut Bread

1. Exterior Appearance:

    a) Top crust: pebbled; thin and crisp

    b) Shape of crust: slightly rounded top

    c) Crust color: golden brown

2. Interior Appearance:

    a) Structure of cells: uniformly distributed air cells, not compact, medium-sized air cells, moderately thin cell walls, free of tunnels or large air cells

    b) Crumb color: light brown

    c) Moisture: slightly moist, not soggy

3. Palatability:

    a) Mouthfeel: tender, slightly moist, not gummy

    b) Flavor: sweet, nutty, banana flavor

    c) Overall acceptability: overall satisfaction in eating each product based upon the above criteria

## Criteria for Standard Bran Rolls

1. Exterior Appearance:

   a) Top crust: rounded, symmetrical shape; pebbled surface

   b) Crust color: golden brown

2. Interior Appearance:

   a) Structure of cells: evenly distributed air cells, medium to large size cells

   b) Crumb color: light, speckled

   c) Moisture: slightly moist crumb

3. Palatability:

   a) Mouthfeel: tender, not dry

   b) Flavor: sweet, mild, nutty flavor, not sour or yeasty

   c) Overall acceptability: overall satisfaction in eating each products based upon the above criteria

Criteria for Standard Whole Wheat

English Muffin

1. Exterior Appearance:

   a) Top crust: flat

   b) Crust color: gently rounded, light colored

   c) Side walls: uneven golden brown; sprinkled with corn meal

2. Interior Appearance:

   a) Structure of cells: unevenly distributed; not compact, medium to large air cells

   b) Texture: smoth, not grainy

   c) Crumb color: light brown

   d) Moisture: slightly dry

3. Palatability:

   a) Mouthfeel: relatively tough and chewy

   b) Flavor: bland and somewhat sour

   c) Overall acceptability: overall satisfaction in eating each products based upon the above criteria

## Instrument

DATE: ____________________

NAME: ____________________ CODE: ____________________

### SENSORY EVALUATION OF ANADAMA BREAD

| TOP CRUST | SHAPE OF TOP CRUST | CRUST COLOR | STRUCTURE OF CELLS | TEXTURE |
|---|---|---|---|---|
| Relatively thin, mottled | Well-rounded; free from cracks or bulges | Even brown | uniform distribution; not compact, large cells | smooth, not grainy |
| Thick, not mottled | Flat; cracked and/or bulging | Uneven color | Uneven; compact | coarse, grainy |

| CRUMB COLOR | MOISTURE | MOUTHFEEL | FLAVOR | OVER-ALL ACCEPTABILITY |
|---|---|---|---|---|
| Golden cast | slightly moist | moderately tender | rich, not sour or yeasty | acceptable |
| muted color | dry | tough | flat, sour yeasty | not acceptable |

COMMENTS: ____________________________________________

____________________________________________

Instrument

NAME: ____________________

DATE: ____________________

CODE: ____________________

SENSORY EVALUATION OF BANANA NUT BREAD

**TOP CRUST**
pebbled; thin and crisp
not pebbled; thick

**SHAPE OF CRUST**
slightly rounded
flat

**CRUST COLOR**
golden brown
muted brown

**STRUCTURE OF CELLS**
uniform distribution; not compact medium size
uneven; compact; small or large cells

**CRUMB COLOR**
light brown
dull brown

**MOISTURE**
slightly moist
soggy

**MOUTHFEEL**
tender; slightly moist; not grainy
tough; soggy; gummy

**FLAVOR**
sweet, nutty
too sweet or sour

**OVER-ALL ACCEPTIBILITY**
acceptable
not acceptable

COMMENTS: ____________________

Instrument

NAME: ______________________________

DATE: ____________________

CODE: ____________________

## SENSORY EVALUATION OF BRAN ROLLS

**TOP CRUST**

rounded, symmetrical; pebbled

flat, not pebbled

**CRUST COLOR**

golden brown

dull brown

**STRUCTURE OF CELLS**

uniform distribution; medium to large size

uneven distribution; small or large cells

**CRUMB COLOR**

light, speckled

dark

**MOISTURE**

slightly moist

dry

**MOUTHFEEL**

tender, not dry

tough, dry

**FLAVOR**

mild, sweet and nutty

strong, yeasty, sour

**OVER-ALL ACCEPTABILITY**

acceptable

not acceptable

COMMENTS: ____________________________________________________________

Instrument

NAME: ______________________________ DATE: ______________________________

CODE: ______________________________

SENSORY EVALUATION OF WHOLE WHEAT ENGLISH MUFFIN

| TOP CRUST | CRUST COLOR | SIDE WALLS | STRUCTURE OF CELLS | TEXTURE |
|---|---|---|---|---|
| flat | uneven golden brown | gently rounded; light colored | uneven distribution; not compact; medium size | smooth, not grainy |
| slanted; with mounds | even color | flat sides | even compact; small or large cells | grainy |

| CRUMB COLOR | MOISTURE | MOUTHFEEL | FLAVOR | OVER-ALL ACCEPTABILITY |
|---|---|---|---|---|
| light brown | slightly dry | tender and chewy | bland and somewhat sour | acceptable |
| dark brown | soggy | tough | strong yeasty, sour | not acceptable |

COMMENTS: ______________________________________________________________

______________________________________________________________

# M E M O R A N D U M

DATE June 3, 1982

TO Taste Panel Members

FROM Mary-Patrice Lesieur & Debbie Matejek

SUBJECT Dates for Taste Panel

I would like to apologize for this late change in dates. Below is the finalized schedule.

TRAINING: June 7 & 8

TASTING: June 9,10,11
June 14,16,18
June 21,23, 25
June 28,30
July 1.

Each day we will start at 2:00 p.m. If you have a conflict with any of these days, please contact me and see if we can work something out.

Thank you for volunteering your time for our research.

# BASIC TASTE IDENTIFICATION

Name______________________________

Instructions: In front of your are 6 cups containing weak water solutions of chemicals representing the basic taste sensations. One or more of these may be a blank or a repeat. Your task is to identify the dominant taste in each cup.

Please rinse your mouth with water before you taste each sample. For each sample, please record on the ballot below if the sample is tasteless or has a sweet, salty, sour, or bitter taste.

| Sample Code | Taste Description |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |

# ODOR IDENTIFICATION

Name__________________________________

<u>Instructions</u>: Ten bottles are presented which contain a common household odor. Please sniff each sample. Record the name or description of the odor below. Wait approximately 15 seconds between samples.

| Sample Code | Odor Description |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

# TRIANGLE TEST

Name________________________________ Date______________________

Product______________________________

Two of the samples are identical; one is different. Taste the samples and identify the one that is different.

| Code | Check the odd sample |
|---|---|
| __________ | ________ |
| __________ | ________ |
| __________ | ________ |

Describe the difference: ________________________________________

______________________________________________________________

______________________________________________________________

# APPENDIX E

# NUTRITIONAL ANALYSES

TABLE XXVI

TYPICAL ANALYSIS (DRY BASIS) OF STALEY REFINED CORN BRAN[a]

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

[a]Cochran, 1982, p. 64.

TABLE XXVII

TYPICAL COMPOSITION OF QUAKER OAT BRAN[a]

| Component | Amount |
|---|---|
| Moisture | 9.24% |
| Fat | 8.68% |
| Protein | 20.11% |
| Carbohydrates | 57.14% |
| Calories: | |
| Total Energy/gram | 3.87 |
| Estimate Available Calories/gram | 3.29 |
| Fiber: | |
| Dietary | 1.40% |
| Crude | 1.87% |
| Thiamin, mg/100g | 1.16 |
| Riboflavin, mg/100g | 0.41 |
| Niacin, mg/100g | 0.81 |
| Iron, mg/100g | 5.74 |
| Calcium, g/100g | 0.08 |
| Phosphorus, g/100g | 0.70 |

[a]Hurt, 1982.

## Explanatory Notes Concerning Tables

1. The principal source of data is Food Values of Portions Commonly Used (Bowes and Church, 1970).

2. The food values of Staley refined corn bran and Quaker oat bran are calculated from the typical analyses in Appendix E.

3. Shawnee wheat bran is similar in composition to the national averages for wheat bran. Wheat bran values are calculated from Bowes and Church (1970).

4. Baking powder values are calculated from Nutritive Value of Foods, Home and Garden Bulletin No. 72 (1977).

5. Blank spaces indicate significant data is not available.

6. Dashes (--) indicate sparseness of reliable data.

# TABLE XXVIII

## NUTRITIVE COMPOSITION OF INGREDIENTS IN ANADAMA BREAD

| Ingredient | g | CAL g | PRO g | CHO g | FIB g | FAT g | Na mg | K mg | Ca mg | Mg mg | P mg | Fe mg | THI mcg | RIB mcg | NIA mg | ASC mg | VIA iu | VID iu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Salt | 4 | 0 | 0 | 0 | | 0 | 1547.1 | 0.2 | 10.1 | | 0 | tr | 0 | 0 | 0 | 0 | 0 | |
| Yeast | 7 | 19.7 | 2.6 | 2.7 | | 0.1 | 3.6 | 139.9 | 3.1 | 4.1 | 90.4 | 1.1 | 163.1 | 387.7 | 2.6 | tr | tr | |
| Margarine | 28 | 200.0 | 0.2 | 0.2 | | 22.6 | 276.0 | 6.0 | 6.0 | | 4.0 | 0 | | | | 0 | 924.0 | 0 |
| Molasses | 82 | 188.6 | -- | 49.2 | | -- | 0 | 0 | 237.8 | | 57.4 | 4.9 | -- | -- | -- | -- | -- | 0 |
| Subtotal | | 408.3 | 2.8 | 52.1 | 0 | 22.7 | 1826.7 | 146.1 | 257.0 | 4.1 | 151.8 | 6.0 | 163.1 | 378.7 | 2.6 | tr | 924.0 | 0 |
| Wheat Bran | 34.1 | 72.6 | 5.5 | 21.1 | 16.0 | 1.6 | 306.9 | 382.3 | 40.6 | 167.1 | 435.1 | 5.1 | 245.5 | 119.4 | 7.2 | 0 | 0 | |
| Flour | 388.4 | 1412.4 | 41.0 | 295.5 | 1.1 | 3.9 | 7.1 | 370.8 | 63.6 | 98.9 | 339.0 | 11.3 | 1694.9 | 988.7 | 13.8 | 0 | 0 | |
| + Sub | | 1893.3 | 49.3 | 368.7 | 17.1 | 28.2 | 2140.7 | 899.2 | 361.2 | 270.1 | 925.9 | 22.4 | 2103.5 | 1486.8 | 23.6 | tr | 924.0 | 0 |
| ÷ 16 | | 118.3 | 3.1 | 23.0 | 1.1 | 1.8 | 133.8 | 56.2 | 22.6 | 16.9 | 57.9 | 1.4 | 131.5 | 92.9 | 1.5 | tr | 57.8 | 0 |
| Corn Bran | 18.7 | 9.4 | 1.1 | 1.1 | 16.0 | 0.8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | - |
| Flour | 403.8 | 1468.4 | 42.6 | 307.3 | 1.1 | 4.0 | 7.3 | 385.5 | 66.1 | 102.8 | 352.4 | 11.8 | 1762.1 | 1027.9 | 14.3 | 0 | 0 | |
| + Sub | | 1886.1 | 46.5 | 360.5 | 17.1 | 27.5 | 1834.0 | 531.6 | 323.1 | 209.9 | 504.2 | 17.8 | 1925.2 | 1406.6 | 16.9 | tr | 924.0 | 0 |
| ÷ 16 | | 117.9 | 2.9 | 22.5 | 1.1 | 1.7 | 114.6 | 33.2 | 20.2 | 13.1 | 31.5 | 1.1 | 120.3 | 87.9 | 1.1 | tr | 57.8 | - |
| Oat Bran | 82.0 | 270.6 | 16.5 | 46.9 | 16.0 | 7.1 | -- | -- | 65.6 | -- | 57.4 | 5.7 | 951.2 | 336.2 | 0.7 | -- | -- | - |
| Flour | 340.5 | 1238.0 | 35.9 | 259.1 | 0.9 | 3.4 | 6.2 | 325.0 | 55.7 | 86.7 | 297.1 | 9.9 | 1485.6 | 866.6 | 12.1 | 0 | 0 | |
| + Sub | | 1916.9 | 46.5 | 358.1 | 16.9 | 33.2 | 1832.9 | 471.1 | 378.3 | 90.8 | 506.3 | 21.6 | 2599.9 | 1581.5 | 15.4 | tr | 924.0 | 0 |
| ÷ 16 | | 119.8 | 3.5 | 22.4 | 1.1 | 2.1 | 114.6 | 29.4 | 23.6 | 5.7 | 31.6 | 1.4 | 162.5 | 98.8 | 1.0 | tr | 57.8 | - |
| Corn Bran | 9.4 | 4.7 | 0.6 | 0.6 | 8.0 | 0.4 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | - |
| Oat Bran | 41.0 | 135.3 | 8.3 | 23.4 | 8.0 | 3.6 | -- | -- | 32.8 | -- | 28.7 | 2.4 | 475.6 | 168.1 | 0.3 | -- | -- | - |
| Flour | 372.1 | 1353.2 | 39.2 | 283.2 | 1.0 | 4.2 | 6.8 | 355.2 | 60.9 | 94.7 | 324.8 | 10.8 | 1623.8 | 947.2 | 13.2 | 0 | 0 | |
| + Sub | | 1901.5 | 42.7 | 359.3 | 17.0 | 30.9 | 1833.5 | 501.3 | 350.7 | 98.8 | 505.3 | 19.2 | 2262.5 | 1494.0 | 15.8 | tr | 924.0 | 0 |
| ÷ 16 | | 118.8 | 2.7 | 22.5 | 1.1 | 1.9 | 114.6 | 31.3 | 21.9 | 6.2 | 31.6 | 1.2 | 141.4 | 93.4 | 1.0 | tr | 57.8 | - |

## TABLE XXIX

## NUTRITIVE COMPOSITION OF INGREDIENTS IN BANANA NUT BREAD

| Ingredient | g | CAL g | PRO g | CHO g | FIB g | FAT g | Na mg | K mg | Ca mg | Mg mg | P mg | Fe mg | THI mcg | RIB mcg | NIA mg | ASC mg | VIA iu | VID iu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sugar | 133.3 | 513.2 | 0 | 132.3 | 0 | 0 | 0.4 | 0.7 | 6.7 | | 1.3 | 0.1 | 0 | 0 | 0 | -- | 0 | 0 |
| Baking Powder | 9.9 | 16.5 | tr | 0 | 0 | tr | 0 | 16.5 | 191.4 | 0 | 287.1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Salt | 3.0 | 0 | 0 | 0 | | 0 | 1160.3 | 0.1 | 7.6 | | | tr | 0 | 0 | 0 | 0 | 0 | |
| Margarine | 75.3 | 0 | 0 | 0 | | 0 | 742.2 | 16.1 | 15.2 | | 10.8 | tr | 0 | 0 | 0 | 0 | 2484.6 | 0 |
| Bananas | 200.0 | 170.0 | 2.2 | 44.4 | 1.0 | 0.4 | 2.0 | 740.0 | 16.0 | | 52.0 | 1.4 | 100.0 | 120.0 | 1.4 | 20.0 | 380.0 | |
| Eggs | 108.0 | 176.0 | 14.0 | 1.0 | 0 | 12.4 | 132.0 | 140.0 | 58.0 | 12.0 | 220.0 | 2.4 | 120.0 | 320.0 | 0.2 | 0 | 1280.0 | 54.0 |
| Milk, Whole | 64.0 | 42.5 | 2.3 | 3.2 | 0 | 2.3 | 32.0 | 92.4 | 75.6 | 8.4 | 54.1 | tr | 21.0 | 110.3 | 0.1 | 0.5 | 89.3 | 13.1 |
| Pecans | 55.0 | 385.0 | 5.0 | 7.2 | 1.1 | 40.2 | tr | 231.0 | 38.5 | | 176.0 | 1.1 | 396.0 | 60.5 | 0.6 | tr | 27.5 | |
| Subtotal | | 1303.2 | 23.5 | 188.1 | 2.1 | 55.3 | 2068.9 | 1236.8 | 409.0 | 20.4 | 801.3 | 5.0 | 637.0 | 610.8 | 2.3 | 20.5 | 4261.4 | 67.1 |
| Wheat Bran | 25.6 | 54.5 | 4.1 | 15.9 | 12.0 | 1.2 | 2.3 | 287.0 | 30.5 | 125.4 | 326.7 | 3.8 | 184.3 | 89.6 | 5.4 | 0 | 0 | |
| Flour | 166.9 | 606.8 | 17.6 | 127.0 | 0.5 | 1.7 | 3.0 | 159.3 | 27.3 | 42.5 | 145.6 | 4.9 | 728.2 | 424.8 | 6.0 | 0 | 0 | |
| + Sub | | 1964.5 | 45.2 | 331.0 | 14.6 | 58.2 | 2074.2 | 1683.1 | 466.8 | 188.3 | 1273.6 | 13.7 | 1549.5 | 1125.2 | 13.7 | 20.5 | 4261.4 | 67.1 |
| ÷ 12 | | 163.7 | 3.8 | 27.6 | 1.2 | 4.6 | 172.9 | 140.3 | 38.9 | 15.7 | 106.1 | 1.1 | 129.1 | 93.8 | 1.1 | 1.7 | 355.1 | 5.6 |
| Corn Bran | 14.0 | 7.0 | 0.8 | 0.8 | 12.0 | 0.6 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Flour | 178.5 | 649.2 | 18.8 | 135.8 | 0.5 | 1.8 | 3.2 | 170.4 | 29.2 | 45.4 | 155.8 | 5.2 | 779.0 | 454.4 | 6.3 | 0 | 0 | |
| + Sub | | 1959.4 | 43.1 | 324.7 | 14.6 | 57.7 | 2072.1 | 1407.2 | 438.2 | 65.8 | 957.1 | 10.2 | 1416.0 | 1065.2 | 8.6 | 20.5 | 4261.4 | 67.1 |
| ÷ 12 | | 163.3 | 3.6 | 27.1 | 1.2 | 4.8 | 172.7 | 117.3 | 36.5 | 5.5 | 79.8 | 0.9 | 118.0 | 88.8 | 0.7 | 1.7 | 355.1 | 5.6 |
| Oat Bran | 61.5 | 203.0 | 12.4 | 35.1 | 12.0 | 5.3 | -- | -- | 49.2 | -- | 43.1 | 3.5 | 713.4 | 252.2 | 0.5 | -- | -- | -- |
| Flour | 131.0 | 476.4 | 13.8 | 99.7 | 0.4 | 1.3 | 2.4 | 125.1 | 21.4 | 33.3 | 114.3 | 3.8 | 571.7 | 333.5 | 4.6 | 0 | 0 | |
| + Sub | | 1982.6 | 49.7 | 322.9 | 14.5 | 61.9 | 2071.3 | 1361.9 | 479.6 | 53.7 | 958.7 | 12.3 | 1922.1 | 1196.5 | 7.4 | 20.5 | 4261.4 | 67.1 |
| ÷ 12 | | 165.2 | 4.1 | 26.9 | 1.2 | 5.2 | 172.6 | 113.5 | 40.0 | 4.5 | 79.9 | 1.0 | 160.2 | 99.7 | 0.6 | 1.7 | 355.1 | 5.6 |
| Corn Bran | 7.0 | 14.0 | 0.4 | 0.4 | 6.0 | 0.3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Oat Bran | 30.8 | 101.6 | 6.2 | 17.6 | 6.0 | 2.7 | -- | -- | 24.6 | -- | 21.6 | 1.8 | 357.3 | 126.3 | 0.3 | -- | -- | -- |
| Flour | 154.7 | 562.4 | 16.3 | 117.7 | 0.4 | 1.6 | 2.8 | 147.5 | 25.3 | 39.4 | 135.0 | 4.5 | 674.9 | 393.7 | 5.5 | 0 | 0 | |
| + Sub | | 1981.2 | 46.4 | 323.8 | 14.5 | 59.9 | 2071.7 | 1384.4 | 458.9 | 59.8 | 957.9 | 11.3 | 1669.2 | 1130.8 | 8.1 | 20.5 | 4261.4 | 67.1 |
| ÷ 12 | | 165.1 | 3.9 | 27.0 | 1.2 | 5.0 | 172.6 | 115.4 | 38.2 | 5.0 | 79.8 | 0.9 | 139.1 | 94.2 | 0.7 | 1.7 | 355.1 | 5.6 |

TABLE XXX

NUTRITIVE COMPOSITION OF INGREDIENTS
IN BRAN ROLLS

| Ingredient | g | CAL g | PRO g | CHO g | FIB g | FAT g | Na mg | K mg | Ca mg | Mg mg | P mg | Fe mg | THI mcg | RIB mcg | NIA mg | ASC mg | VIA iu | VID iu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shortening | 50.0 | 439.3 | | | | 49.3 | | | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sugar | 37.5 | 144.4 | 0 | 37.3 | 0 | 0 | 0.1 | 0.2 | 1.9 | | 0.4 | 0 | 0 | 0 | 0 | -- | 0 | 0 |
| Salt | 3.0 | 0 | 0 | 0 | | 0 | 1160.3 | 0.1 | 7.6 | | 0 | tr | 0 | 0 | 0 | 0 | 0 | |
| Yeast | 3.5 | 9.9 | 1.3 | 1.4 | | 0.1 | 1.3 | 70.0 | 1.6 | 2.1 | 45.2 | 0.6 | 81.6 | 189.4 | 1.3 | tr | tr | |
| Eggs | 27.0 | 44.0 | 3.5 | 0.3 | 0 | 3.1 | 33.0 | 35.0 | 14.5 | 3.0 | 55.0 | 0.6 | 30.0 | 80.0 | 0.1 | 0 | 320.0 | 13.5 |
| Subtotal | | 637.6 | 4.8 | 39.0 | 0 | 52.5 | 1194.7 | 105.3 | 25.6 | 5.1 | 103.9 | 1.2 | 111.6 | 269.4 | 1.4 | 0 | 320.0 | 13.5 |
| Wheat Bran | 17.1 | 36.4 | 2.7 | 10.6 | 8.0 | 0.8 | 1.5 | 191.7 | 20.4 | 83.8 | 204.5 | 2.6 | 123.1 | 59.9 | 3.6 | 0 | 0 | 13.5 |
| Flour | 187.9 | 683.2 | 19.8 | 143.0 | 0.5 | 1.9 | 3.4 | 179.3 | 30.7 | 47.8 | 164.0 | 5.5 | 819.8 | 478.2 | 6.7 | 0 | 0 | |
| + Sub | | 1357.2 | 27.3 | 192.6 | 8.5 | 55.2 | 1199.6 | 476.3 | 76.7 | 136.7 | 472.4 | 9.3 | 1054.5 | 807.6 | 11.7 | 0 | 320.0 | 13.5 |
| : 8 | | 169.7 | 3.4 | 24.1 | 1.1 | 6.9 | 150.0 | 59.5 | 9.6 | 17.1 | 59.1 | 1.2 | 131.8 | 100.9 | 1.5 | 0 | 320.0 | 13.5 |
| Corn Bran | 9.4 | 4.7 | 0.6 | 0.6 | 8.0 | 0.4 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Flour | 195.6 | 711.2 | 20.6 | 148.8 | 0.5 | 2.0 | 3.6 | 186.7 | 32.0 | 49.8 | 170.7 | 5.7 | 853.4 | 497.8 | 6.9 | 0 | 0 | |
| + Sub | | 1353.5 | 26.0 | 188.4 | 8.5 | 54.9 | 1198.3 | 292.0 | 57.6 | 54.9 | 274.6 | 6.9 | 965.0 | 767.2 | 8.3 | 0 | 320.0 | 13.5 |
| : 8 | | 169.2 | 3.3 | 23.6 | 1.1 | 6.9 | 149.8 | 36.5 | 7.2 | 6.9 | 34.3 | 0.9 | 120.6 | 95.9 | 1.0 | 0 | 320.0 | 13.5 |
| Oat Bran | 41.0 | 135.3 | 8.3 | 23.4 | 8.0 | 3.6 | -- | -- | 32.8 | -- | 28.7 | 2.4 | 475.6 | 168.1 | 0.3 | -- | -- | -- |
| Flour | 164.0 | 596.4 | 17.3 | 124.8 | 0.4 | 1.6 | 3.0 | 156.6 | 26.8 | 41.7 | 143.1 | 4.8 | 715.7 | 417.4 | 5.8 | 0 | 0 | |
| + Sub | | 1369.3 | 25.6 | 187.2 | 8.4 | 57.7 | 1197.7 | 261.9 | 85.2 | 46.8 | 304.4 | 8.4 | 1302.9 | 855.0 | 7.5 | 0 | 320.0 | 13.5 |
| : 8 | | 171.2 | 3.2 | 23.4 | 1.1 | 7.2 | 149.7 | 32.7 | 10.7 | 5.9 | 38.1 | 1.1 | 162.9 | 106.9 | 0.9 | 0 | 320.0 | 13.5 |
| Corn Bran | 4.7 | 2.4 | 0.3 | 0.3 | 4.0 | 0.4 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Oat Bran | 20.5 | 67.7 | 4.1 | 11.7 | 4.0 | 1.8 | -- | -- | 16.4 | -- | 14.4 | 1.2 | 237.8 | 84.1 | 0.2 | -- | -- | -- |
| Flour | 179.8 | 654.0 | 19.0 | 136.8 | 0.5 | 1.8 | 3.3 | 171.7 | 29.4 | 45.8 | 157.0 | 5.2 | 784.8 | 457.8 | 6.4 | 0 | 0 | |
| + Sub | | 1361.7 | 23.4 | 187.8 | 8.5 | 56.5 | 1198.0 | 277.0 | 71.4 | 50.9 | 275.3 | 7.6 | 1134.2 | 811.3 | 8.0 | 0 | 320.0 | 13.5 |
| : 8 | | 170.2 | 2.9 | 23.5 | 1.1 | 7.1 | 149.8 | 34.6 | 8.9 | 6.4 | 34.4 | 1.0 | 141.8 | 101.4 | 1.0 | 0 | 320.0 | 13.5 |

# TABLE XXXI

## NUTRITIVE COMPOSITION OF INGREDIENTS IN WHOLE WHEAT ENGLISH MUFFINS

| Ingredient | g | CAL g | PRO g | CHO g | FIB g | FAT g | Na mg | K mg | Ca mg | Mg mg | P mg | Fe mg | THI mcg | RIB mcg | NIA mg | ASC mg | VIA iu | VID iu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Whole Wheat Flour | 120.0 | 400.0 | 16.0 | 85.2 | 2.8 | 2.4 | 4.0 | 444.0 | 49.0 | 136.0 | 446.0 | 4.0 | 660.0 | 140.0 | 5.2 | 0 | 0 | |
| Yeast | 7.0 | 19.7 | 2.6 | 2.7 | | 0.1 | 3.6 | 139.9 | 3.1 | 4.1 | 90.4 | 1.1 | 163.1 | 378.7 | 2.6 | tr | tr | |
| Salt | 6.0 | 0 | 0 | 0 | | 0 | 2328.6 | 0.2 | 15.2 | | 0 | tr | 0 | 0 | 0 | 0 | 0 | |
| Honey | 21.0 | 64.0 | 0.1 | 16.4 | 0 | 0 | | | 4.0 | | 3.0 | 0.2 | 2.0 | 14.0 | tr | 1.0 | 0 | 0 |
| Margarine | 45.0 | 321.4 | 0.3 | 0.3 | | 36.3 | 443.5 | 99.6 | 99.6 | | 6.4 | 0 | | | | 0 | 1484.9 | 0 |
| Subtotal | | 805.1 | 19.0 | 104.6 | 2.8 | 38.8 | 2779.7 | 683.7 | 170.9 | 140.1 | 545.8 | 5.7 | 825.1 | 532.7 | 7.8 | 1.0 | 1484.9 | 0 |
| Wheat Bran | 34.1 | 72.6 | 5.5 | 21.1 | 16.0 | 1.6 | 306.9 | 382.3 | 40.6 | 167.1 | 435.1 | 5.1 | 245.5 | 119.4 | 7.2 | 0 | 0 | 0 |
| Flour | 342.4 | 1245.2 | 36.1 | 260.6 | 0.9 | 3.4 | 6.2 | 326.9 | 56.0 | 87.2 | 298.8 | 10.0 | 1494.2 | 871.6 | 12.1 | 0 | 0 | |
| + Sub | | 2122.9 | 60.6 | 386.3 | 19.7 | 43.8 | 3092.8 | 1392.9 | 267.5 | 394.4 | 1279.7 | 20.8 | 2564.8 | 1523.7 | 27.1 | 1.0 | 1484.9 | 0 |
| ÷ 16 | | 132.7 | 3.8 | 24.1 | 1.2 | 2.7 | 193.3 | 87.1 | 16.7 | 24.7 | 80.0 | 1.3 | 160.3 | 95.2 | 1.7 | 0.1 | 92.8 | 0 |
| Corn Bran | 18.7 | 9.4 | 1.1 | 1.1 | 16.0 | 0.8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | - | -- | - |
| Flour | 357.8 | 1301.2 | 37.7 | 272.3 | 1.0 | 3.6 | 6.5 | 341.6 | 58.6 | 91.1 | 312.3 | 10.4 | 1561.4 | 910.8 | 12.7 | 0 | 0 | |
| + Sub | | 2115.7 | 57.8 | 378.0 | 19.8 | 43.2 | 2786.2 | 1025.3 | 229.5 | 231.2 | 858.1 | 16.1 | 2386.5 | 1443.5 | 20.5 | 1.0 | 1489.9 | 0 |
| ÷ 16 | | 132.2 | 3.6 | 23.6 | 1.2 | 2.7 | 174.1 | 64.1 | 14.3 | 14.5 | 53.6 | 1.0 | 149.2 | 90.2 | 1.3 | 0.1 | 92.8 | - |
| Oat Bran | 82.0 | 270.6 | 16.5 | 46.9 | 16.0 | 7.1 | -- | -- | 65.6 | -- | 57.4 | 5.7 | 951.2 | 336.2 | 0.7 | - | -- | - |
| Flour | 294.5 | 1070.8 | 31.1 | 224.1 | 0.8 | 2.9 | 5.4 | 281.1 | 48.2 | 75.0 | 257.0 | 8.6 | 1285.0 | 749.6 | 10.4 | 0 | 0 | |
| + Sub | | 2146.5 | 66.6 | 375.6 | 19.6 | 48.8 | 2785.1 | 946.8 | 284.7 | 215.1 | 860.2 | 20.0 | 3061.3 | 1618.5 | 18.9 | 1.0 | 1484.9 | 0 |
| ÷ 16 | | 134.2 | 4.2 | 23.5 | 1.2 | 3.1 | 174.1 | 60.3 | 17.8 | 13.4 | 53.8 | 1.3 | 191.1 | 101.2 | 1.2 | 0.1 | 92.8 | - |
| Corn Bran | 9.4 | 4.7 | 0.6 | 0.6 | 8.0 | 0.4 | -- | -- | -- | -- | -- | -- | -- | -- | -- | - | -- | - |
| Oat Bran | 41.0 | 135.3 | 8.3 | 23.4 | 8.0 | 3.6 | -- | -- | 32.8 | -- | 28.7 | 2.4 | 475.6 | 168.1 | 0.3 | - | -- | - |
| Flour | 326.1 | 1186.0 | 34.4 | 248.2 | 0.9 | 3.3 | 5.9 | 311.3 | 53.4 | 83.0 | 284.6 | 9.5 | 1423.2 | 830.2 | 11.6 | 0 | 0 | |
| + Sub | | 2131.1 | 62.3 | 376.8 | 19.7 | 46.1 | 2785.6 | 995.0 | 257.1 | 223.1 | 859.1 | 17.6 | 2723.9 | 1531.0 | 19.7 | 1.0 | 1484.9 | 0 |
| : 16 | | 133.2 | 3.9 | 23.6 | 1.2 | 2.9 | 174.1 | 62.2 | 16.1 | 13.9 | 53.7 | 1.1 | 170.2 | 95.7 | 1.2 | 0.1 | 92.8 | - |

2

# VITA

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Master of Science

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