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Peanut hull flour as dietary fiber in whole wheat bread

S. Masoud Kalantari

To the Graduate Council:

I am submitting herewith a thesis written by S. Masoud Kalantari entitled "Peanut hull flour as dietary fiber in whole wheat bread." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

J.L. Collins, Major Professor

We have read this thesis and recommend its acceptance:

Sharon L. Melton, John R. Mount

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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and recommend its acceptance:

Sharon L. Melton

John R Mount

Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

X

PEANUT HULL FLOUR AS DIETARY FIBER IN WHOLE WHEAT BREAD

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

S. Masoud Kalantari

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ABSTRACT

Peanut hull flour (PHF) was substituted for 0, 4, and 8% of the wheat flour in a formulation for whole wheat bread. Carboxymethyl cellulose and wheat gluten were added to all treatments to produce loaves with volume comparable to that of bread made with white wheat flour. The bread was produced, baked, and tested to determine the effect of PHF on some of its chemical components, physical characteristics, and organoleptic attributes.

Bread with 8% PHF had a higher and bread with 4% had a lower hardness value than bread with 0% PHF. As the length of storage time was increased, hardness of the bread increased.

Addition of PHF affected cohesiveness but not elasticity of the bread. However, both properties of the bread decreased as the period of storage was extended to 6 days.

The presence of PHF caused a darkening of the outer crust and the crumb of the bread. Bread with 8% PHF was darker than bread with 4% PHF. The crumb was lighter than the crust of bread containing a given percentage of PHF.

Bread with 4% PHF had a higher loaf volume than bread with 0% PHF, while bread with 8% PHF had a lower loaf volume.

As the level of PHF was increased, the amount of moisture, ash, crude fiber, and neutral detergent fiber was increased. On the other hand, the amount of crude protein, ether extract, and carbohydrate was decreased as the percentages of PHF was increased.

Aflatoxins were not detected in the PHF.

The sensory panel indicated that the presence of PHF affected some of the quality attributes of the bread. When the panel compared samples of bread with the three levels of PHF content to an imaginary loaf of ideal whole grain bread, the following general findings were apparent. In relation to the ideal bread, PHF at one or more levels caused the bread to possess a less smooth surface, have decreased moistness and graininess, exhibit a softer crumb, and be less preferred. Likewise, PHF at one or more levels caused the bread to be more gritty and sticky and have a harder crust than the ideal loaf.

PHF does seem to have potential as a source of dietary fiber when added to whole wheat bread. A 4% level of PHF should yield bread with more acceptable physical attributes than an 8% level of PHF. However, the panel indicated samples of bread with 4 and 8% PHF level were not different from each other when compared with an ideal loaf of whole grain bread.

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CHAPTER I

INTRODUCTION

Major interest in dietary fiber depletion and dietary fiber addition has appeared within the past several years. Early reports were authored by Burkitt (14), who observed that Africans with diets high in food-containing fiber had a low occurrence of many diseases of the large intestine. These diseases are more prominent in the United States and other countries where the dietary intake of fiber is low (14, 36).

Many researchers report that several diseases such as diverticular diseases, hemorrhoids, appendicitis, hiatus hernia, varicose veins, diabetes, obesity, coronary artery disease, cancer of the colon, and constipation are directly related to the lack of sufficient dietary fiber (14, 15, 38, 47, 73). Contrariwise, when the diet is rich in fiber, there is no occurrence of these diseases (3, 20, 28).

Fiber adds bulk to food material during passage through the intestinal tract by absorbing moisture. As a result, body wastes are eliminated more frequently (20, 30, 34).

Because of the need for more fiber in the diet of Americans, it is questionable which foods are adequate vehicles for supplying an increase in the amount of dietary fiber (14, 26, 47, 56). Foods which contain fiber should be consumed periodically so that fiber enters the body throughout the day (56).

One approach to increasing the amount of the fiber in the diet is to incorporate the fiber into food products. One such product is bread.

Various and diverse substances have been proposed as sources of dietary fiber; the list of substances include peanut hulls, pectin, lignin, and cellulose (46). White wheat flour contains practically no fiber; whole wheat flour and whole wheat bread contain 2.3 and 1.6% crude fiber, respectively (43).

Peanut hulls may be considered an excellent source of dietary fiber. According to Post (51), peanut hulls contain 47.23% crude fiber and 77.6% neutral detergent dietary fiber.

Due to a plentiful supply of peanut hulls and to the relatively high fiber content of hulls, it seemed feasible to investigate the value of peanut hull flour as a source of dietary fiber for bread, and to determine the effect of peanut hull flour on physical and chemical characteristics and acceptability of a whole wheat bread with peanut hull flour by a sensory panel.

CHAPTER II

REVIEW OF LITERATURE

I. Source of Peanuts

The peanut (or ground nut) is cultivated for food in tropical and subtropical countries (54). World peanut production in the shell in 1974 was estimated at 17 million metric tons with principle producing countries being Sudan, Nigeria, China, India, United States, and Brazil (4).

Production of peanuts in the United States is primarily in the Southeastern states. The peanut enterprise is the largest single income-producing crop in Georgia and the second largest in Alabama (62).

Peanuts are important and popular throughout the world for many reasons; it is high in protein content, rich in oil, and can be used as a fresh vegetable or in other products. About 50% of the peanuts currently consumed in the United States is processed into peanut butter, about 25% is processed into salted forms, and the remaining approximately 25% is processed into confectionary products (62).

II. Utilization of Peanut Hulls

For many years peanut hulls were wasted. The amounts of peanut hulls in the United States increased from 70,000 short tons in 1926 to over 360,000 short tons in 1976 (2, 17, 68). Peanut hulls have been used primarily as fuel or litter (12, 28, 70).

Some current uses of peanut hulls are (a) as roughage in feed for dairy and beef cattle (68), (b) as litter for poultry (11), (c) as soil fertilizer (12), and (d) as raw material for production of furfural, glucose, paper, and cardboard (12). However, these usages account for only a small amount of the total production of hulls. Therefore, additional uses should be explored. Peanut hulls have been proposed as a source of dietary fiber (46).

III. Physical Properties and Chemical Composition

Peanut hulls have a low density, specific volume of peanut hulls is about 0.048 g/cc/. and hulls absorb water at about 52% of their weight. Peanut hulls are fairly inert against microbial activity (12, 22).

Like other farm wastes (72), peanut hulls consist primarily of cellulose, 45%; lignin, 28%; and pentosan, 18%. The digestible nutrient value is about 25% and the crude protein is about 7%, and crude fiber is about 60%. Additional analyses indicate that the hull contains 0.75% titratable acidity, 3% ash, 0.03% phosphorus, 0.25% calcium, 90% dry matter, and 5% ether extract (39, 63).

Post (51) reported that peanut hulls contain 7.19% crude protein, 7.3% ether extract, 2.1% ash, 47.2% crude fiber, and 77.6% neutral detergent dietary fiber.

IV. Source of Dietary Fiber

Crude fiber is defined as the residue remaining after digestion with acid followed by base under specific conditions (67). Dietary fiber can be defined as the components of a food that are not hydrolyzed by enzymes as it passes through the digestive tract of monogastric animals (24, 46, 67). Dietary fiber is composed of substances that comprise the cell walls of plants (9, 58). Wheat bran is a major source of dietary fiber (9-12% crude fiber) (36). Vegetable dietary fiber is recognized as having important biological effects in the gastrointestinal tract (1, 20). Burkitt (14) stated that the fiber from starchy foods and cereals is of more value in restoring normal bowel function than the fiber from fruits and vegetables. Various substances are proposed as potential sources of dietary fiber. These include cereals and vegetables, brans, coconut residue, almond skins, peanut hulls, pectin, lignin, and cellulose (46).

V. Role of Dietary Fiber

During the past several years, interest has increased in fiber-containing foods and in the effects of fiber intake. Much of the recent investigation in dietary fiber has been conducted by Burkitt et al. (15). These researchers theorized that people with a low fiber intake tended to have a longer bowel transit time and a lower stool weight than people whose diet is high in fiber. A long bowel transit time is not desirable as it has been postulated that compounds such as certain bile acids present in the large intestine are more likely to have an adverse effect on the intestinal tract.

Briggs and Spiller (13) suggested that fiber could be considered a nutrient despite its indigestibility. It has benefits similar to those of other nutrients. Many scientists believe that dietary fiber is as important as the other components of the diet (46).

Dietary fiber adds bulk to the intestinal tract by absorbing moisture, and as a result, body wastes are eliminated more frequently. The greater the bulk and more frequent elimination of body wastes, it is believed, protect against several diseases (14, 15, 24, 37, 56). The following eight disease conditions have been reported by Burkitt et al. (15): appendicitis, diverticular disease, ischemic heart disease, gallstones, varicose veins, hiatus hernia, hemorrhoids, and colon cancer.

The high occurrence of colon cancer in western countries is believed to be the result of dietary changes (14). The low incidence of colon cancer results from high fiber intakes (56). Kelsay et al. (34) stated that colon cancer was far less common in Indians of North India than in Indians of South India, and it could be that the North Indians consumed a greater amount of substances such as roughage, cellulose, and vegetable fiber than the South Indians.

Tandon and Tandon (65) pointed out that stool weights and fiber intake of North Indians were greater than those from the western world. Studies showed that a high fiber intake in humans resulted in larger stool weight (31, 33). Radiological studies showed that brown bread passes from the stomach through the intestinal tract more rapidly than white bread. The amount of residue from brown bread was also greater than that of white bread (42).

Studies have provided evidence that dietary fiber can lower the serum cholesterol level; pectin being more effective than wheat bran (25, 48). When a diet containing 4 g of cholesterol per day was fed 10 days to girls aged 10-12 years, the addition of 100 g of cellulose lowered serum cholesterol levels (60).

The effect of fiber on serum glucose levels has not been studied extensively (34). However, Kiehm et al. (35) reported that diets high in dietary fiber and digestible carbohydrates (75% of calories) could control hyperglycemia in moderately diabetic patients (3). These diets also reduced serum cholesterol and triglyceride values.

Colon cancer may be due to action of bacteria in intestinal tract by converting bile acid to carcinogenic compounds (14, 37, 59). It is thought, therefore, that fiber binds bile acids in the colon so as to decrease prolonged periods of carcinogenic substances in contact with the bowel wall (14, 37) and consequently, reduces cholesterol absorption (59).

Fecal lipids were reportedly increased by fiber intake. The addition of 9 g of fiber (maize, wheat, vegetables) in man increased the amount of fatty acids and sterols which were expected in the stool (7). Schneeman (58) reported a loss of lipase activity when solka-floc (a commercial wood fiber), cellulose, or xylan were consumed. The loss of lipase activity may be due to the absorption of lipase by the fiber. This action retards digestion of fat causing it to appear in the stool. Energy absorption was reportedly decreased when fiber intake was increased. In one subject, calories were reduced when 80% extraction flour was compared to the feeding of 90% extraction flour (41). In a study at Michigan State University, one group of men consumed regular bread averaging an intake of 2,350 calories per day. Another group consumed a reduced calorie high fiber bread providing 1,975 calories per day. The loss of weight in the first group was 13.7 pounds, while the loss of weight for the subjects of the second group was 19.3 pounds (13). Kiehm et al. (35) stated that patients who changed their diets which contained a high level of fiber, initially had difficulty eating enough food to provide the same amount of calories as they had consumed previously. Thus, a high fiber diet might help to limit the tendency to overeat and reduce the chance of becoming a diabetic.

Dietary fiber affects the action of certain toxic materials. Rats fed a semipurified diet containing 5% FD&C Red No. 2 dye did not survive beyond 14 days. The addition of 10% pectin, cellulose, or alfalfa to the diet completely overcame toxicity of the dye (37).

VI. Adverse Effects of Dietary Fiber

Some researchers reported unpleasant side effects of dietary fiber (13, 49). Fiber has the capacity for binding certain minerals such as calcium, zinc, magnesium, copper, and iron, thereby decreasing availability of these minerals. Serum calcium levels were reduced in one study when subjects received 18 to 100 g of unprocessed bran per day (13). In another study, 20 g of unprocessed bran per day had no effect on serum calcium level (49). Magnesium, calcium, potassium, and phosphorus were absorbed more readily by human subjects when 69% extraction flour was fed, compared to the feeding of 92% extraction flour (40). Reinhold et al. (53) reported that zinc, iron, and phosphorus were increased in the fecal matter of two subjects when 10 g cellulose per day were fed for 14 days.

Phytic acid is present in some grains. Phytate rather than fiber impairs absorption of iron and zinc (37), and copper and manganese (16). Widdowson and McCance (75) stated that iron absorption from white bread was higher than from brown bread. Eastwood and Mitchel (19) reported that sodium, potassium, calcium, and magnesium were increased in the feces of subjects after ingestion of wheat bran. In one study, it was reported that whole meal bread and bran can bind with zinc, iron, and calcium *in vitro* (53). Schneeman (58) reported that the high fiber intake in the diet resulted in nitrogen and fat excretion in the fecal material.

VII. Consumption of Dietary Fiber

In the past 20 years, there has been a considerable decrease in the per capita consumption of fiber-containing foods such as whole wheat flour, cereals, and fruits and vegetables (24). According to Scala (55), there has been a decline of about 50% in the fiber intake from cereals and grain and about a 20% decline from fruits and vegetables in the United States during the past century. Between 1870 and 1970, fiber intake in the United Kingdom decreased by 83% when consumption of breads, potatoes, and flour containing less bran were reduced (73). Kritchevsky (37) reported the United States dietary fiber intake decreased by 42% between 1964 and 1974.

Some pathological conditions of the colon and cardiovascular disease in the industrialized countries clearly are associated with an inadequate dietary fiber intake (38). Many nutritionists are convinced of the beneficial effects of fiber in the daily diet, but there is no stated level of fiber that one should consume (13). There have been no research studies to determine the amount of fiber needed in the diet (56).

Deficiencies and excess amounts of dietary fibers have been blamed for various diseases and nutritional problems (13). Briggs and

Spiller (13) reported that the transit time decreased rapidly with increasing fecal weight of 140 to 150 g per day, but further increases did not alter transit time. Hoppert and Clark (31) recommended that one ounce of bran per day (40 mg of crude fiber per kilogram body weight) was sufficient, based on stools of normal size and consistency. The greater intakes had no benefit. One study suggested that 6 g of crude fiber per day would eliminate and prevent constipation (56).

Burkitt (14) reported that the addition of 2 g crude fiber daily to diets improves the gastrointestinal function. This amount of fiber can be obtained in 5 ounces of whole meal bread or in 8 pounds of white bread. He also stated the bread rich in fiber could become "the staff of life."

Researchers suggest that the amount of fiber in the diet should be considered for body weight, sex, age, and type of fiber ingested (13).

Controlled clinical research will be necessary to study the role of increased dietary fiber in the diet and scientists do not recommend large increases in fiber intake until more information is available (26).

VIII. Constituents of Dietary Fiber

The main components of dietary fiber of interest to nutritionists are cellulose, hemicellulose, lignin, and pectin (24, 36, 57). The ideal dietary fiber has a low level of substances such as protein, fats, digestible carbohydrate, minerals, and vitamins (46). Dietary fiber components are not uniform in all plants. Water-holding capabilities vary (36, 73). Morse (46) reported that several factors should be considered for dietary fiber characteristics. These factors include mineral content, bulk volume, particle size, solubility in water, solubility in gastric fluid, fermentability, bile acid-binding capacity, cation exchange capacity, surface area, influence of enzymes, and maillard reactions.

Among the dietary components, cellulose is an important and widely distributed substance. Cellulose is a linear chain composed of 3,000-100,000 glucan units (5, 37, 46). Cellulose has several advantages over other fibrous materials (46). These advantages include the absence of flavor and color, adequate length of fiber (0.5-4 mm), excellent storage properties, and a low or negligible level of microbial contamination. Most of all, it is a virgin material, not a waste or secondary product. Cellulose reportedly has the least bile salts binding ability (5, 37). In one study, addition of 16 g cellulose increased a stool weight about two-fold after three weeks of treatment. Cellulose is capable of holding water in the stool and as a result, dilutes the concentration of bile acid in the feces (18, 20). Addition of cellulose in rat diets decreased transit time, absorbed bile acids, and excreted and reduced blood cholesterol level (38).

Hemicellulose is a more complicated molecule than cellulose. It contains mostly xylose, arabinose, mannose, galactose, glucose, and rhamnose as well as glucuronic and galacturonic acids (37). Hemicellulose is hydrophilic and, consequently produces more bulk than cellulose (14, 18, 36).

Pectin is a substance present in the cell wall and intercellular layer of all plants. Pectin is composed of β, 1-4, D-galacturonic acid, D-galactose, L-arabinose, and L-fucose with molecular weight of between

60,000 and 90,000 (37, 74). Pectin is not hydrolyzed by humans or animals (excluding snail), but pectin-hydrolyzing enzymes are present in higher plants or microorganisms (74). Pectin has a high water-holding capacity, thereby increasing the rate and volume of fecal material produced. Like lignin, pectin has the capacity for binding bile acids; this action lowers the serum cholesterol level (25, 48, 59). Some vegetable fibrous materials and fruit pectin are instrumental in eliminating lipids and steroids from the digestive tract (34).

Lignin is another constituent of cell walls of plants. It is composed of a phenyl propane polymer with three major polymeric chains derived from 4-hydroxy phenyl propane, 4-hydroxy-3-methoxy phenyl propane, and 3,5-di-methyl-4-hydroxy phenyl propane. Its molecular weight is generally between 1,000 to 4,500 (37). Eastwood (18) and Kritchevsky (37) reported that lignin in general has a great binding ability. According to Kimura (36), lignin is quite a constipating compound.

IX. Contamination of Peanuts from Natural Sources

The microbiological condition of foods are very important in preparation, processing, storage, and handling. Some microorganisms are beneficial, while others cause spoilage and health hazards (21).

Molds such as Aspergillus parasiticus and A. flavus are common spoilage molds of products, including corn, rice, other grains, and peanuts. These molds produce toxic substances called aflatoxins. Aflatoxins are among nature's most powerful carcinogenic compounds. An amount of 0.001 g in the diet of experimental animals has produced cancer (76, 77).

According to Food and Drug Administration (FDA) regulations, peanuts and peanut products having more than 20 parts per billion (ppb) aflatoxins may not be used or sold for purposes of food and feed (76).

The detection of aflatoxins is based on their fluorescent properties. When an aflatoxin is illuminated by ultraviolet light, it fluoresces either a blue or green color (78).

The general method for detection of aflatoxins in food is to extract the toxin from products using an organic solvent such as chloroform or acetone. The toxin is separated from contaminants by thin layer chromatography (TLC). Aflatoxin can be eluted on the TLC plate, and then detected under an ultraviolet light for blue or green color light (76, 78).

X. Analysis of Dietary Fiber

Several techniques have been developed for fiber analyses in foods. These include the crude fiber analysis (69), Van Soest's detergent analysis for fiber (6, 23, 44), the buffered acid detergent analysis for fiber (6), and enzymatic determination of fiber (29, 57). These methods are unsatisfactory for determination of fiber content in food because they do not measure all components of dietary fiber (29, 69).

The most common analysis for fiber is the crude fiber analysis. Crude fiber analysis does not measure the true amount of indigestible materials in food products. The method determines cellulose primarily. About 50 to 90% of the cellulose, 20% of the insoluble hemicellulose, and 10 to 40% of the lignin is recovered by this method (57, 69).

Neutral detergent fiber analysis measures plant cell wall constituents other than pectins. The acid detergent analysis determines the amount of lignocellulose, insoluble minerals, and crude lignin. The amount of lignin is determined by ultraviolet absorption at 280 nm in 25% acetylbromide in acetic acid solution. The amount of cellulose is determined by subtracting the amount of lignin from the amount of acid detergent fiber, while hemicellulose is determined by subtracting the amount of acid detergent fiber from the amount of neutral detergent fiber (23, 45, 61, 69).

According to Schallerman (57), the neutral detergent fiber method determines only the amount of cellulose, lignin, and hemicellulose. Also, this method solubilizes lipids and proteins, while ethylene diamine tetra acetic acid (EDTA) removes minerals and heat gelatinizes starch.

The acid detergent fiber method determines only the amount of cellulose and lignin, but not hemicellulose (57, 61).

An enzyme method of fiber analysis has been developed recently. It is a simple *in vitro* method and determines the dietary fiber of foods by using pepsin and pancreatin enzymes (29). Gormley (24) reported that this technique is quite suitable for most fruits and vegetables, but, for starchy foods such as potatoes and brown bread, additional research is required to improve the method.

CHAPTER III

MATERIALS AND METHODS

I. Source of Peanut Hulls

Peanut hulls of the Runner-type were provided by the De Leon Peanut Company, De Leon, Texas. The hulls were used to prepare a flour for use in the experiments.

II. Preparation of Peanut Hull Flour

The hulls were separated from the debris by screening on hardware cloth having one-fourth inch openings, washed in a solution of sodium dodecyl sulfate (19 g/150 liters of water), rinsed in three changes of fresh water, and dried in a forced-air dehydrator at 150° C for 24 hours. The dried hulls were ground three times in a Wiley Mill to pass through a 40-mesh sieve. The ground material was sieved after each grinding operation. Finally, the flour which passed through the 40-mesh sieve was ground for 3 minutes in a Colloid Mill. The peanut hull flour (PHF) which passed through a 100-mesh sieve was removed for use.

III. Aflatoxin Assay on the Hulls

Into a 250 ml flask was placed 10 g peanut hull flour (PHF) and 100 ml chloroform which has been passed through a bed of sodium sulfate to remove water. The mixture was blended for 5 minutes and transferred into a separatory funnel. Chloroform solution was drawn from the separatory funnel and transferred to a 500 ml round bottom flask. Into the funnel, 100 ml of chloroform were added, shaken for 5 minutes, drawn off and transferred to the solution in the round bottom flask. The contents of the flask were evaporated to approximately 5 ml by use of a rotary evaporator. By using pasteur pipettes, the concentrated extract was transferred into a dram vial. Microliter samples of extract were spotted on a preheated TLC plate (heated at 110° C for 30 minutes). The samples consisted of 10 and 15 microliters of concentrated extract and an aflatoxin standard. The plate was placed into a developing tank containing chloroform : acetone : water (90 : 10 : 1) and held for 45 minutes. After being developed, the plate was air-dried for 5 minutes and observed under ultraviolet light (365 nm).

IV. Source of Ingredients for Making Bread

Whole wheat flour, sugar, and salt were obtained from a local grocery store. White wheat flour, wheat gluten, crumbled compressed yeast, dairy base (whey), yeast food (malt), and dough conditioning and oxidizing agents (potassium bromate, potassium azodicarbonamide, and other edible excipients) were obtained from Kern's Bakery, Knoxville, Tennessee. Carboxymethyl cellulose (CMC, type 7-HF) was obtained from Hercules Inc., Wilmington, Delaware.

V. Optimizing the Level of Carboxymethyl Cellulose and Wheat Gluten in Bread

Sponge and dough formulas were used for the production of bread with 0% PHF (Table 1), 4, and 8% PHF (Table 2). To determine the proper level of water required for the dough, several loaves of bread were baked

TABLE 1

EXPERIMENTAL RECIPE FOR WHOLE WHEAT BREAD

Ingredients	Amount	%, Based on Flour
Sponge:		
Whole wheat flour	273 g	39.7
White wheat flour	147 g	21
Salt	14 g	2
Sugar	21 g	3
Yeast food (malt)	3.5 g	0.5
Crumbled compressed yeast	21 g	3
Carboxymethyl cellulose (CMC)	14 g	2
Wheat gluten	21 g	3
Water	220.5 ml	63
Dough:		
Whole wheat flour	182 g	26
White wheat flour	98 g	14
Sugar	21 g	3
Dairy base (whey)	21 g	3
Calcium propionate	0.90 g	0.128
Vegetable shortening	21 g	3
Potassium bromate	45 ppm	-
Potassium bromate azodicarbonamide and other edible excipients	22 ppm	-
Water	93 ml	13.28

TABLE 2

EXPERIMENTAL RECIPE FOR WHOLE WHEAT BREAD
CONTAINING PEANUT HULL FLOUR (PHF)

Ingredients	Amount	%, Based on Flour
Sponge:		
Whole wheat flour	273 g	39.7
White wheat flour	147 g	21
Salt	14 g	2
Sugar	28 g	4
Yeast food (malt)	3.5 g	0.5
Crumbled compressed yeast	21 g	3
Carboxymethyl cellulose (CMC)	14 g	2
Wheat gluten	21 g	3
PHF	variable[a]	-
Water	variable[b]	-
Dough:		
Whole wheat flour	182 g	26
White wheat flour	98 g	14
Sugar	21 g	3
Dairy base (whey)	21 g	3
Calcium propionate	0.90 g	0.13
Vegetable shortening	21 g	3
Potassium bromate	45 ppm	-
Potassium bromate azodicarbonamide and other edible excipients	22 ppm	-
Water	93 ml	13.28

[a]PHF = 4% and 8% (flour basis).

[b]Water for 4% PHF content was used at 241.5 ml or 69%; for 8% PHF content at 262.5 ml or 75%.

containing three levels each of carboxymethyl cellulose (CMC), gluten, and peanut hull flour (PHF). The amount of water was determined by the trial and error method. Doughs were prepared with different levels of water and baked into loaves of bread. The different loaves were evaluated for presence of gas pockets and cracking, uniform crumb cells, loaf volume, and for other bread-like characteristics. The most desirable was selected and the amount of water used in its preparation was used to prepare bread for the experiment. Loaves of bread were baked in 2 replications for 27 treatments. The amount of ingredients for preparation of treatments included the following: 1, 2, and 3% CMC; 3, 5, and 7% gluten; and 0, 4, and 8% PHF.

VI. Design of Experiment

The experiment was a completely randomized block (3 x 3 x 3 x 2; level of CMC x level of gluten x level of PHF x replication) (32). The data were analyzed by analysis of variance using the Statistical Analysis System (SAS) of The University of Tennessee Computer Center (10).

VII. Conditions and Facilities for Preparing Dough and Baking Bread

The ingredients of the sponge were mixed together and held at 29° C for 75 minutes in a sponge tank. After holding, the sponge was placed into the Household Mixer (Model K-45) containing the dough ingredients (Tables 1 and 2). The materials were mixed at medium speed (N 4 setting) for 20 minutes. After the dough was allowed to develop, it was removed from the mixer, scaled into 500 g portions, and placed into greased pans. The dough was proofed for 90 minutes at 38-43° C and 95% relative humidity. The dough was baked in a Despatch Oven (Model 154-R) at 230° C for 25 minutes. The loaves of bread were removed from the pans onto wire racks and cooled in air.

VIII. Measurement of Specific Volume of Bread

Volume of loaves was obtained by use of the rapeseed displacement method (66). Volume was recorded as cubic centimeters. Specific volume was calculated by dividing the volume of bread by weight (grams) of the bread.

IX. Analysis and Use of Data for Specific Volume

Analysis of variance was used to analyze the data to determine the effect of the study variables on the various attributes of the bread. The mean values for specific volume and certain observed quality factors served to permit the selection of a combination of ingredients which were used to produce loaves of bread with maximum volume while possessing other desirable characteristics. Observed quality factors considered include the presence of voids in the loaf, degree of darkening of outer part of loaf and crumb, and size of cells constituting the crumb.

X. Preparation of Bread Containing the Selected Amounts of Carboxymethyl Cellulose (CMC) and Wheat Gluten

One combination of ingredients (CMC and gluten) was selected and utilized for each of the three levels of PHF. The three treatments were:

2% CMC, 3% gluten, and 0% PHF; 2% CMC, 3% gluten, and 4% PHF; and 2% CMC, 3% gluten, and 8% PHF. The loaves were prepared and baked according to the procedure presented in Section VII.

Experiment A

Loaves from each treatment were baked and sliced at 12 mm thickness, and the slices were packed in polyethylene bags and stored up to 6 days at approximately 22° C. The slices were analyzed at daily intervals for physical attributes, proximate analysis, and dietary fiber by procedures described below. Samples were prepared in three replications.

Experiment B

The loaves of each treatment were baked in four replications and cooled in air at 22° C. The loaves were used to measure specific volume and color.

Experiment C

Loaves of each treatment were baked for sensory evaluation one day prior to testing. The number of loaves baked was sufficient to provide samples for 63 panelists.

XI. Experimental Design and Analysis of Data

Experiment A

The experiment was a completely randomized block (3 x 7 x 3; levels of PHF x days of storage x replication) (32). Data were analyzed by analysis of variance using the Statistical Analysis System (SAS) of The University of Tennessee Computer Center (10). Orthogonal polynomials were used to partition among treatments, PHF, and days of storage (10).

Experiment B

The experiment was a completely randomized block (3 x 4; level of PHF x replication) (32). Data were analyzed by analysis of variance using the Statistical Analysis System (SAS) of The University of Tennessee Computer Center (10). Significance among means was determined by Duncan's Multiple Range Test (10).

XII. Physical Analyses for Experiment A

Texture

Textural characteristics of bread hardness, cohesiveness, elasticity (springiness), chewiness, and gumminess were determined daily on samples which were stored up to 6 days. The Instron Machine (Model 1132) was used to compress the center of a slice of the bread with a thickness of 12 mm. The bread was compressed 25% of its original thickness. A 5 kg load cell was used; the chart- and crosshead speeds were set at 10 cm per minute. Representative compression curves are presented in Figure 1. The first measurement was designated as curve S_1, and the second as curve S_2.

The peak force of curve S_1 was defined as hardness (first bite). The ratio of the area of curve S_2 to the area of curve S_1 was defined as cohesiveness. These areas were determined with a Polar Planimeter (Model 43772). Elasticity was defined as the distance the sample was compressed during the beginning of curve S_2 to the peak of curve S_2.

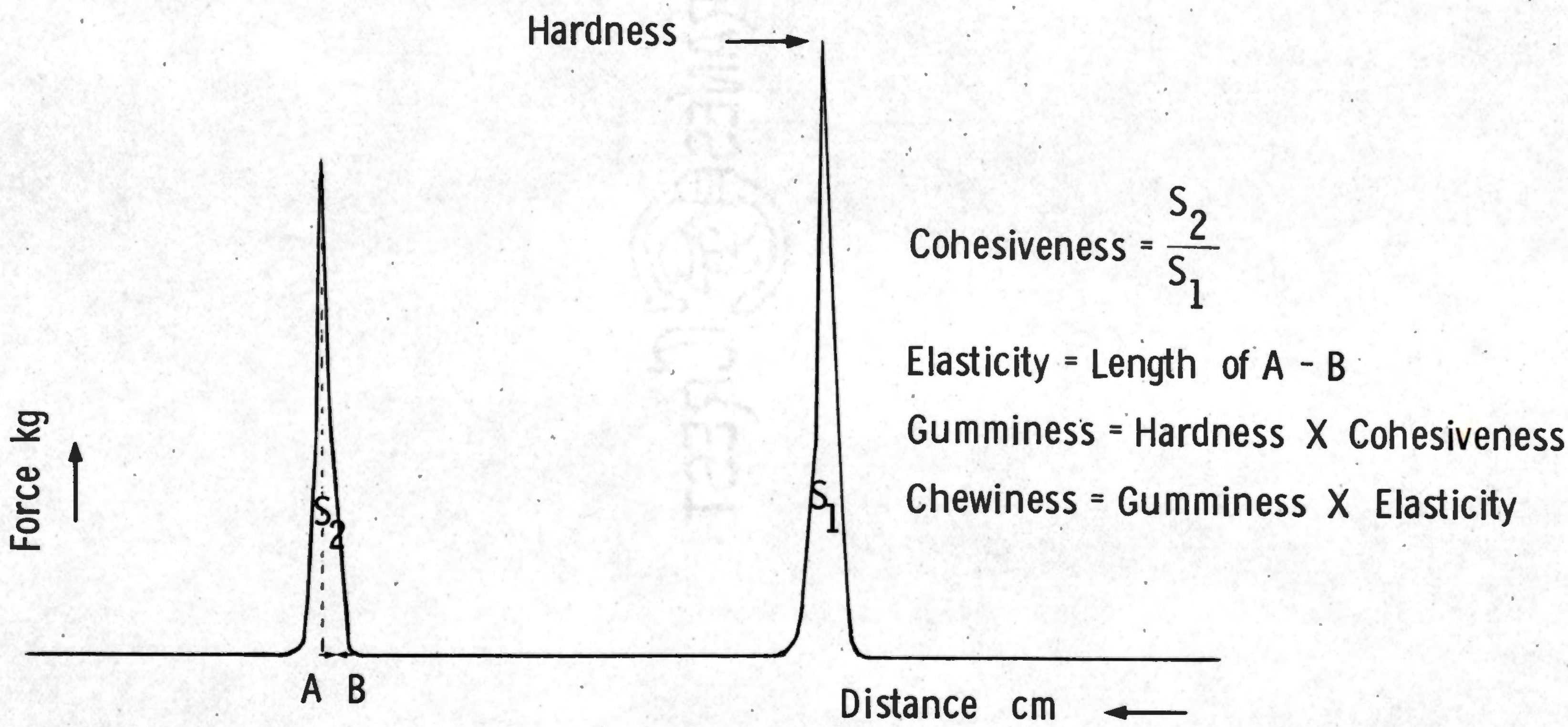

Figure 1. Texture profile for whole wheat bread obtained with the Instron machine.

The product of hardness and cohesiveness was calculated and recorded as gumminess. Finally, the product of gumminess and elasticity was calculated and reported as chewiness.

XIII. Physical Analyses for Experiment B

Specific Volume

Specific volume of the area of the bread was measured according to the procedures presented in Section VIII.

Color

L, "a," and "b" values were determined by the Hunter Colorimeter (Model D25D2M, Hunter Associates Laboratory, Fairfax, Virginia). An orange tile (L = 58.5, "a" = 29.4, "b" = 33.1) was used to standardize the instrument. Crust color values were taken from three predetermined areas each on the top, bottom, each side, and each end of the loaf. A cream-colored tile (L = 79.4, "a" = 2.4, "b" = 23.6) was used as the reference for standardizing the instrument for measuring crumb color. L, "a," and "b" values were read from three areas of the crumb. Each color value was averaged to obtain mean values of L, "a," and "b" for the top crust, bottom crust, side crust, end crust, and crumb.

XIV. Proximate Analysis

Samples prepared according to Experiment A (Section X) were analyzed for proximate analysis. The AOAC method (8) was followed. One measurement was made per replication. All measurements except for moisture, were reported on the moisture-free basis.

Moisture

Five g of freshly baked bread were dried by the vacuum oven method for moisture determination. Percentage of moisture content was calculated.

Crude Fat

Five g of oven-dried bread were extracted with petroleum ether on the Goldfisch Apparatus for 16 hours. Percentage of fat content (or ether extract) was calculated.

Crude Protein

Two g of oven-dried bread were analyzed by the Kjeldahl method. Nitrogen content was determined and percentage of crude protein was calculated by multiplying percentage of nitrogen by 6.25.

Crude Fiber

Two g of oven-dried and fat-extracted bread were analyzed. Percentage of crude fiber was calculated.

Ash

Two g of oven-dried bread were ashed in a Muffle Furnace at 650° C for 8 hours. Percentage of ash was calculated.

Carbohydrate

Carbohydrate content of bread was determined by subtracting the percentage of ash, crude fat, crude protein, and crude fiber from 100%. Percentage of carbohydrate was reported.

XV. Dietary Fiber Measurement

Measurements were made on samples prepared according to Experiment A (Section X). One measurement per replication was made. One g of oven-dried and fat-extracted bread was analyzed for amount of cell wall constituents by the neutral detergent fiber procedure (8). Percentage of neutral detergent fiber was reported.

XVI. Analysis of Data for Proximate Analysis and Dietary Fiber

Data for moisture, ash, crude protein, crude fat, crude fiber, carbohydrate, and dietary fiber contents were reported as means with $\pm$ one standard deviation.

XVII. Sensory Evaluation

The Consumer Texture Profile Technique (64) was used to evaluate quality attributes, color, and flavor of the sample of the bread for Experiment C (Section X). The criteria for judgments were listed on the score sheets, facsimiles of which are presented in Appendix Figures A-1 and A-2. Sixty-three panelists served as a consumer panel to evaluate the samples of bread containing 0, 4, and 8% PHF. Each panelist was asked to evaluate the samples on a 1-6 scale for all attributes, except overall preference, where 1 indicated the absence of the attribute and 6 indicated the presence of the attribute to a very high degree. For evaluation of preference, the value of 1 indicated that the sample was disliked very much and a score of 6 indicated that the sample was liked very much. Values of 2, 3, 4, and 5 indicated a measurement for the attribute intermediate between the extremes. Each panelist received one-half slice of bread and a strip of crust approximately 5 cm long. Water was provided for rinsing the mouth between the testing of samples. After testing the three experimental samples, each panelist was asked to evaluate an imaginary sample of an ideal whole grain bread. Each panelist evaluated a sample only one time.

XVIII. Analysis of Data for Sensory Scores

Data for organoleptic attributes were analyzed by the one-way classification of analysis of variance for a completely randomized block to determine the effect of the level of PHF on bread quality (Experiment C, Section X) (32). Significance among means was determined by Duncan's Multiple Range Test (10).

CHAPTER IV

RESULTS AND DISCUSSION

I. Optimum Level of Carboxymethyl Cellulose (CMC), and Wheat Gluten in Whole Wheat Bread

Data for specific volume of bread prepared with different levels of CMC, gluten, and PHF are presented in Table 3. The most desirable loaves of bread in terms of acceptable volume, uniform cell distribution and desirable texture were those prepared with 2% CMC and 3% gluten with 0, 4, and 8% PHF levels.

II. Textural Attributes of Whole Wheat Bread Containing the Optimum Amount of Carboxymethyl Cellulose and Gluten

The analysis of variance for the effect of PHF on hardness of bread is presented in Table 4. The effects of level of PHF and storage time (days) were significant at the 0.01 level and loaf within level of PHF was significant at the 0.05 level. The effect of the interaction between PHF and storage was significant at the 0.05 level. The linear and quadratic PHF comparison was significant at the 0.01 level. The linear, quadratic, and cubic days comparison were significant at the 0.01 level. Interactions between linear PHF comparison and the linear, quadratic, and cubic days comparison were significant at the 0.05 level.

The mean values for hardness of bread which was stored up to 6 days are presented in Table 5. The maximum hardness value (323 g force)

TABLE 3

SPECIFIC VOLUME[a] OF WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF), CARBOXYMETHYL CELLULOSE (CMC), AND GLUTEN

CMC, %	Gluten, %	Level of PHF, % 0	4	8
1	3	4.1	3.6	4.7
	5	5.0	3.6	4.4
	7	4.0	4.0	3.6
2	3	4.5	4.5	4.9
	5	4.6	4.9	4.8
	7	4.1	4.7	4.2
3	3	4.0	5.0	4.2
	5	4.7	4.5	4.8
	7	4.6	4.8	4.2

[a]Specific volume = cc/g.

N = 2.

TABLE 4

F-RATIOS OF ANALYSIS OF VARIANCE FOR EFFECT OF PEANUT HULL FLOUR (PHF) ON HARDNESS OF WHOLE WHEAT BREAD STORED UP TO 6 DAYS

Source	DF		F-Ratios	
Total	62		-	
PHF level	2		16.6**	
Linear (L)		1		14.1**
Quadratic (Q)		1		16.1**
Loaf (PHF) error a	6		1.9*	
Days (D)	6		62.9**	
Linear (L)		1		314.0**
Quadratic (Q)		1		17.3**
Cubic (C)		1		9.0**
Lack of fit		3		1.1^{NS}
PHF X Days	12		2.3*	
$L_{PHF} \times L_D$		1		3.5*
$L_{PHF} \times Q_D$		1		9.5*
$L_{PHF} \times C_D$		1		4.0*
Lack of fit		9		0.9^{NS}
Residual error (Mean square)	36		3015.8	

**Significant at the 0.01 level.

*Significant at the 0.05 level.

^{NS}Not significant at the 0.05 level.

TABLE 5

MEAN VALUES FOR TEXTURAL PROPERTIES OF WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

PHF, %	Time, days	Hardness, g force[a]	Cohesiveness[b]	Elasticity, mm[c]	Gumminess[d]	Chewiness[e]
0	0	82	0.87	4.5	71	321
	1	134	0.81	4.5	108	488
	2	199	0.78	4.3	155	667
	3	271	0.65	4.0	176	705
	4	296	0.59	4.0	174	997
	5	351	0.58	3.5	203	712
	6	457	0.57	3.5	260	911
	Means	256	0.69	4.0	164	686
4	0	73	0.82	4.5	60	268
	1	133	0.76	4.1	101	415
	2	153	0.74	4.0	113	452
	3	193	0.72	4.1	139	569
	4	257	0.69	4.0	177	709
	5	334	0.64	4.0	214	852
	6	448	0.61	4.0	274	1094
	Means	227	0.71	4.1	154	623
8	0	147	0.75	4.5	111	497
	1	190	0.73	4.3	139	596
	2	248	0.72	4.0	179	714
	3	260	0.70	3.8	182	691
	4	344	0.67	3.8	231	876
	5	361	0.63	3.8	227	864
	6	707	0.60	4.0	424	1696
	Means	323	0.69	4.0	213	848

[a]The height of the force peak on the first compression by the Instron machine.

[b]The ratio of the area under second force peak to area under first force peak.

[c]Distance the sample was compressed during the beginning of Curve B to the peak of Curve B. (Figure 1).

[d]Calculated value by multiplying values of hardness and cohesiveness.

[e]Calculated value by multiplying values of elasticity and gumminess.

resulted from use of 8% PHF. The minimum hardness value (227 g force) was found for bread containing 4% PHF. Bread containing 0% PHF exhibited a mean hardness value of 256 g force. Bread slices became harder as the period of time was extended.

The effects of PHF, days, and the PHF x days interaction on hardness of bread were partitioned with orthogonal polynomials. The three dimensional response surface is presented in Figure 2. Significant terms of the analysis of variance were included in a polynomial regression used to describe the response surface. The estimated equation for hardness is:

$$\widehat{\text{Hardness}} = 222.14 - 268.10(\text{PHF}) + 61.79(\text{PHF}^2) + 1.40(\text{days}) + 23.10(\text{days}^2) - 2.51(\text{days}^3) + 77.13(\text{PHF x days}) - 30.73(\text{PHF x days}^2) + 3.22(\text{PHF x days}^3).$$

The analysis of variance for effect of PHF on cohesiveness of the bread is presented in Table 6. The effect of PHF was significant at the 0.05 level. The effect of days and loaf within PHF level was significant at the 0.01 level. The effect of the interaction between PHF and days was significant at the 0.01 level. The quadratic PHF comparison and the linear days comparison were significant at the 0.01 level. Interactions between linear PHF comparison and the linear and quadratic days comparison were significant at the 0.01 and 0.05 levels, respectively. Interaction between quadratic PHF comparison and the linear days comparison was significant at the 0.01 level.

The mean values for cohesiveness of bread are presented in Table 5. The maximum cohesiveness value (0.71) was found for bread containing

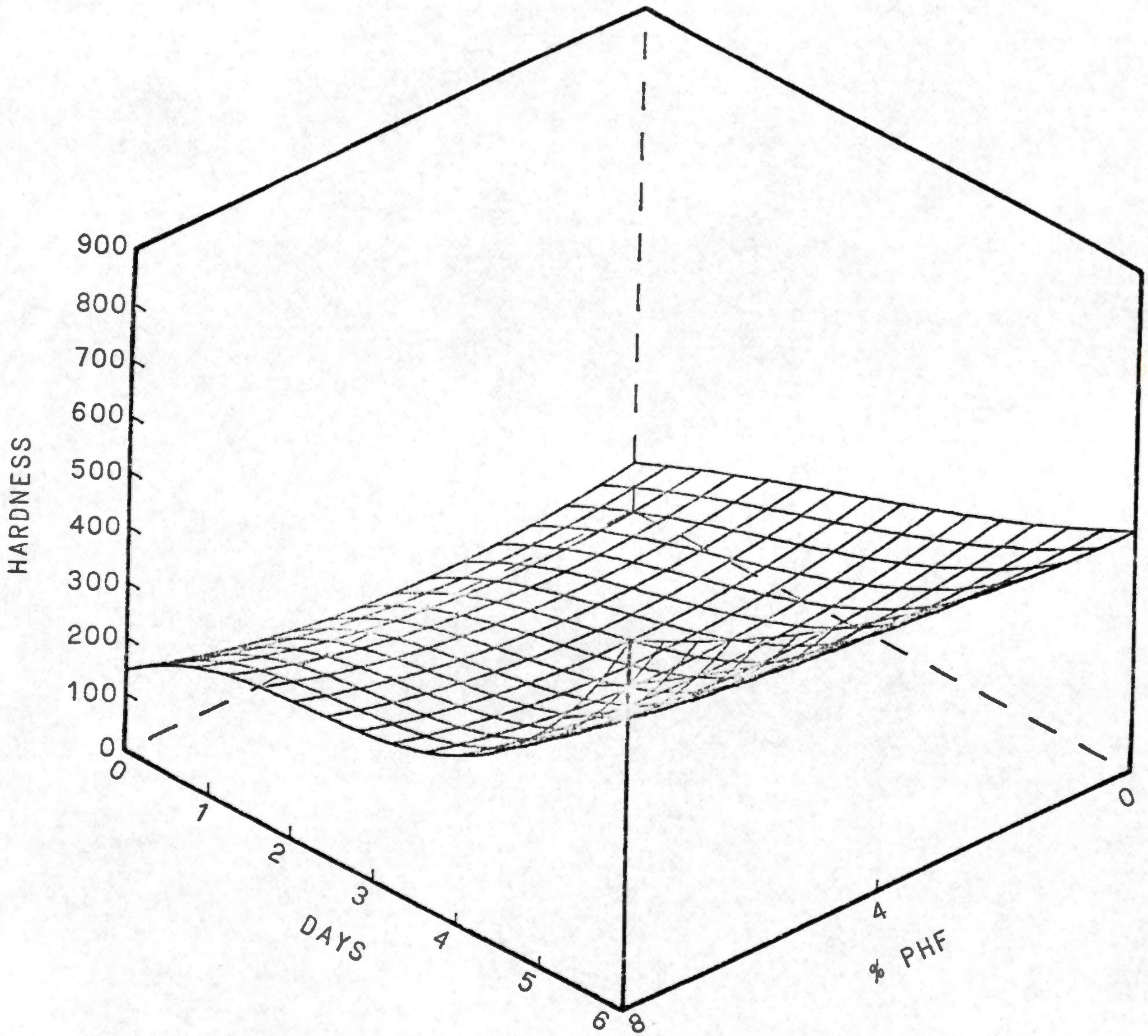

Figure 2. Three dimensional representation of the response surface for effect of peanut hull flour (PHF) on hardness of bread during 6 days storage.

TABLE 6

F-RATIOS OF ANALYSIS OF VARIANCE FOR EFFECT OF PEANUT HULL FLOUR (PHF) ON COHESIVENESS OF WHOLE WHEAT BREAD STORED UP TO 6 DAYS

Source	DF	F-Ratios
Total	62	-
PHF level	2	4.6*
Linear (L)	1	0.7^{NS}
Quadratic (Q)	1	7.9**
Loaf (PHF) error a	6	3.9**
Days (D)	6	78.4**
Linear (L)	1	310.2**
Quadratic (Q)	1	0.9^{NS}
Lack of fit	4	0.9^{NS}
PHF X Days	12	6.8**
L_{PHF} X L_D	1	33.6**
L_{PHF} X Q_D	1	6.8*
Q_{PHF} X L_D	1	7.9**
Q_{PHF} X C_D	1	0.1^{NS}
Lack of fit	8	0.8^{NS}
Residual error (Mean Square)	36	0.0011

**Significant at the 0.01 level.

*Significant at the 0.05 level.

^{NS}Not significant at the 0.05 level.

4% PHF level, however, the bread containing 0 and 8% PHF level was only slightly less cohesive with a value of 0.69. Generally, cohesiveness decreased daily at the three levels of PHF.

The effects of PHF, days, and the PHF x days interaction on cohesiveness of bread were partitioned with orthogonal polynomials. The three dimensional response surface showing the effect of PHF and storage on cohesiveness of the bread is presented in Figure 3. Significant terms of the analysis of variance were included in a polynomial regression used to describe the response surface. The estimated equation for cohesiveness is:

$$\widehat{\text{Cohesiveness}} = 1.10 - 0.12(\text{PHF}) - 0.16(\text{days}) + 0.01(\text{days}^2) + 0.76(\text{PHF} \times \text{days}) - 0.01(\text{PHF} \times \text{days}^2) - 0.01(\text{PHF}^2 \times \text{days}) + 2.57(\text{PHF}^2 \times \text{days}^3).$$

The analysis of variance for the effect of PHF on elasticity of bread is presented in Table 7. PHF did not affect elasticity of bread at the 0.05 level. Effect of loaf within PHF level and the effect of days were significant at the 0.05 and 0.01 levels, respectively. The linear and quadratic days comparison were significant at the 0.01 and 0.05 levels, respectively. The effect of the interaction between PHF and days was significant at the 0.01 level. The interaction between linear PHF comparison and the quadratic days comparison was significant at the 0.01 level. The interaction between quadratic PHF comparison and the linear days comparison was significant at the 0.05 level.

The mean values for elasticity of the sample of bread are presented in Table 5 (page 31). The values for elasticity ranged from

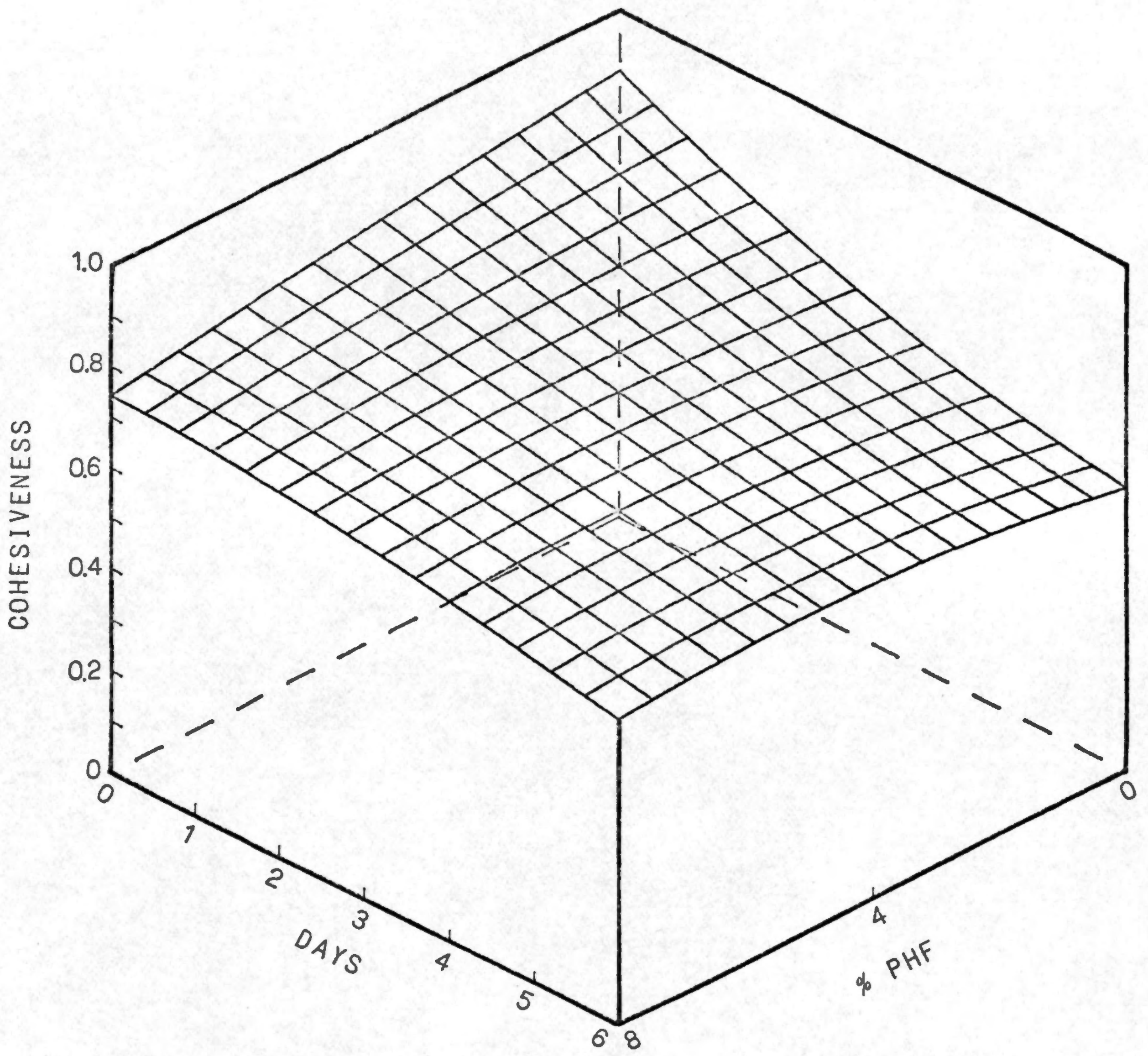

Figure 3. Three dimensional representation of the response surface for effect of peanut hull flour (PHF) on cohesiveness of bread during 6 days storage.

TABLE 7

F-RATIOS OF ANALYSIS OF VARIANCE FOR EFFECT OF PEANUT HULL FLOUR (PHF) ON ELASTICITY OF WHOLE WHEAT BREAD STORED UP TO 6 DAYS

Source	DF		F-Ratios	
Total	62		-	
PHF level	2		1.2NS	
Loaf (PHF) error a	6		3.1*	
Days (D)	6		20.6**	
Linear (1)		1		86.8**
Quadratic (Q)		1		6.1*
Lack of fit		4		0.6NS
PHF X Days	12		3.9**	
$L_{PHF} \times L_D$		1		1.9NS
$L_{PHF} \times Q_D$		1		16.2**
$Q_{PHF} \times L_D$		1		6.2*
Lack of fit		9		1.7NS
Residual error (Mean square)	36		0.0304	

**Significant at the 0.01 level.

*Significant at the 0.05 level.

NS Not significant at the 0.05 level.

4.0 mm for bread with 0 and 8% PHF to 4.1 mm for bread with 4% PHF. Elasticity of bread decreased with storage time at the three levels of PHF.

The effects of days and the PHF x days interactions on elasticity of bread were partitioned with orthogonal polynomials. The three dimensional response surface is presented in Figure 4. Significant terms of the analysis of variance were included in a polynomial regression which was used to describe the response surface. The estimated equation for elasticity is:

$$\widehat{\text{Elasticity}} = 4.75 - 0.16(\text{days}) - 0.02(\text{days}^2) + 0.02(\text{days x PHF}) + 0.02(\text{days}^2 \text{ x PHF}) - 0.02(\text{days x PHF}^2).$$

Data for gumminess and chewiness of bread were not analyzed by analysis of variance since these data were obtained by calculation from other textural data. The mean values for gumminess and chewiness of bread are presented in Table 5 (page 31).

Gumminess and chewiness of the bread slices increased with storage time within each level of PHF. Maximum values for these two attributes were found for bread which contained 8% PHF, and minimum values for bread which contained 4% PHF.

III. Crust and Crumb Color of Bread Containing Peanut Hull Flour

The F-ratios of the analysis of variance for the effect of PHF on Hunter L color values of the crust and crumb of bread are presented in Table 8. The Hunter L values of the crust and crumb of the bread were affected (0.01 level) by the level of PHF.

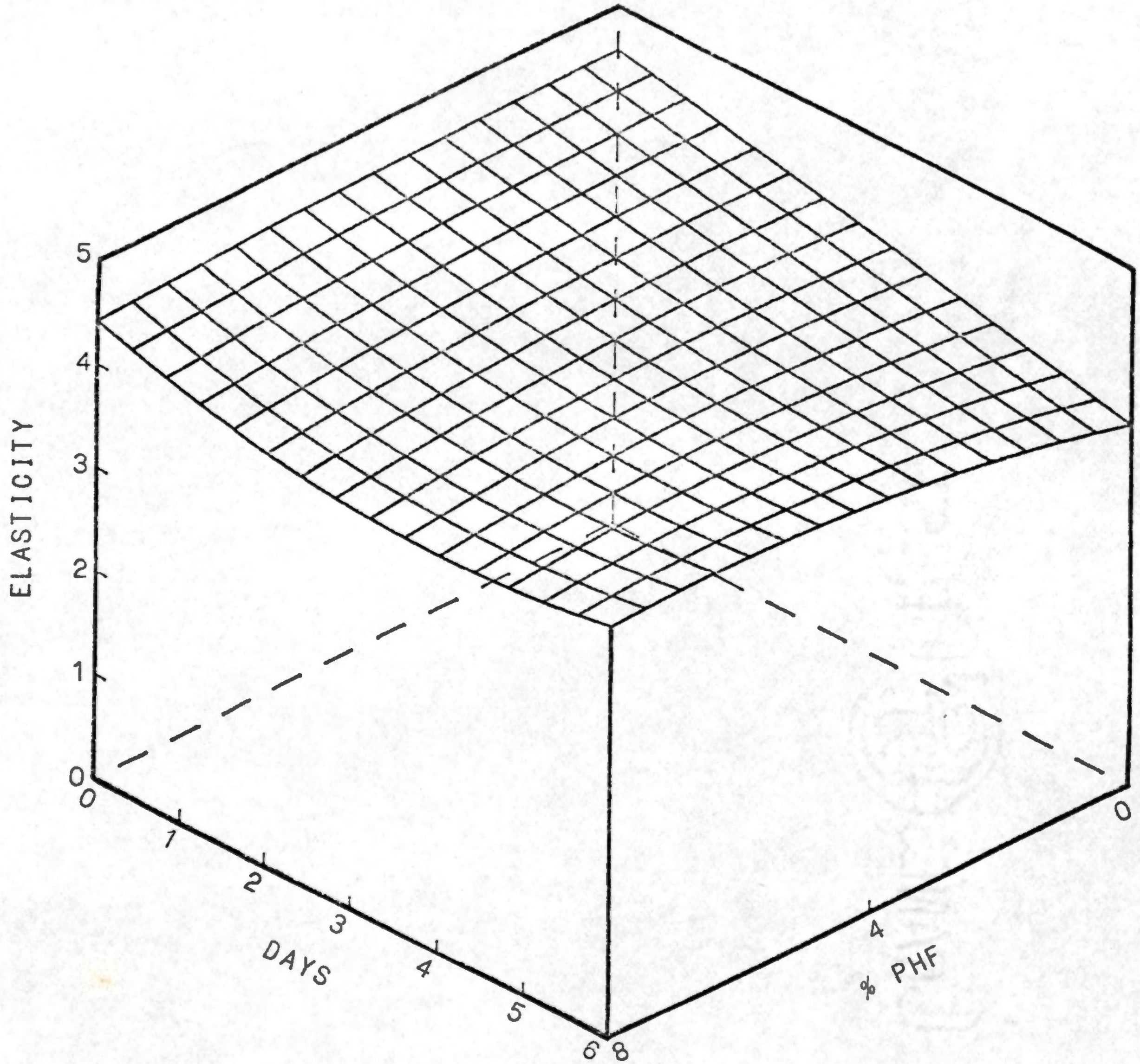

Figure 4. Three dimensional representation of the response surface for effect of peanut hull flour (PHF) on elasticity of bread during 6 days storage.

TABLE 8

F-RATIOS OF ANALYSIS OF VARIANCE FOR HUNTER L COLOR VALUES OF WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

Source	DF	External Area of Loaf				Crumb
		Top	Bottom	Side	End	
Total	11	-	-	-	-	-
PHF level	2	23.6**	380.8**	889.7**	1296.8**	34488.6**
Residual error (Mean square)	9	0.06	0.07	0.10	0.09	0.10

**Significant at the 0.01 level.

The mean Hunter L values are presented in Table 9. Bread containing 0% PHF was lightest and bread containing 8% PHF was darkest in all areas of the outer crust and the crumb. The top of the crust of breads containing 0 and 4% PHF was not different in Hunter L values. Also, the outer crust on the end of the loaf prepared with 4% and 8% PHF did not differ in Hunter L value. The crust from the bottom and sides, and the crumb exhibited Hunter L values which were different among breads prepared with 0, 4, or 8%. The crumb in bread with 0 and 4% PHF was considerably lighter (had higher Hunter L value) than the outer crust.

The F-ratios of the analysis of variance for the effect of PHF on Hunter "a" values of the outer crust and the crumb color are presented in Table 10. The values for all areas of the crust and the crumb were affected (0.01 level) by the level of PHF.

The mean Hunter "a" values are presented in Table 11. The crust from the top of bread had a slight amount of greenness. The crust from the bottom, sides, and ends of the loaves and the crumb were more red for bread containing 0% PHF than for bread containing 4 and 8% PHF. The Hunter "a" values of crust at the ends of the loaf were not different between bread containing 4 and 8% PHF. However, the "a" values for the top, bottom, and side crusts and the crumb were different between breads containing 4 and 8% PHF.

The F-ratios of the analysis of variance for the effect of PHF on Hunter "b" values for the crust and crumb are present in Table 12. The "b" value of the external areas and the crumb was affected (0.01 level) by the level of PHF.

TABLE 9

MEAN HUNTER L COLOR VALUES FOR WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

	External Area of Loaf				
PHF, %	Top[1]	Bottom[1]	Side[2]	End[3]	Crumb[1]
0	25.4[a]	42.4[a]	42.7[a]	42.5[a]	57.6[a]
4	25.0[a]	37.3[c]	35.9[b]	33.3[b]	46.5[b]
8	24.2[b]	38.5[b]	33.6[c]	33.5[b]	37.5[c]

[1]N = 12.

[2]N = 24.

[3]N = 8.

[a,b,c]Means within a column not followed by the same letter are different at the 0.01 level.

L = lightness - darkness (0 = black; 100 = pure white).

TABLE 10

F-RATIOS OF ANALYSIS OF VARIANCE FOR HUNTER "a" COLOR VALUES OF WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

		External Area of Loaf				
Source	DF	Top	Bottom	Side	End	Crumb
Total	11	-	-	-	-	-
PHF	2	47.6**	485.7**	237.9**	21.9**	2684.4**
Residual error (Mean square)	9	0.04	0.06	0.09	0.06	0.01

**Significant at the 0.01 level.

TABLE 11

MEAN HUNTER "a" COLOR VALUES FOR WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

PHF, %	External Area of Loaf				
	Top[1]	Bottom[1]	Side[2]	End[3]	Crumb[1]
0	-4.1[a]	11.0[a]	9.1[a]	6.6[a]	1.6[a]
4	-3.2[b]	7.7[b]	6.4[b]	5.4[b]	-2.6[b]
8	-2.7[c]	5.6[c]	4.3[c]	5.7[b]	-4.0[c]

[1]N = 12.

[2]N = 24.

[3]N = 8.

[a,b,c]Means within a column not followed by the same letter are different at the 0.01 level.

a = redness - greenness (+a = red; -a = green).

TABLE 12

F-RATIOS OF ANALYSIS OF VARIANCE FOR HUNTER "b" COLOR VALUES OF WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

Source	DF	External Area of Loaf				Crumb
		Top	Bottom	Side	End	
Total	11	-	-	-	-	-
PHF	2	79.5**	397.6**	495.1**	334.3**	11.6**
Residual error (Mean square)	9	0.04	0.05	0.05	0.06	0.02

**Significant at the 0.01 level.

The mean Hunter "b" values are presented in Table 13. Bread containing 0 and 4% PHF showed similar values for yellowness of the crumb, but bread with 8% PHF was slightly more yellow. Mean Hunter "b" values for top, bottom, sides, and ends of the crust were different among bread containing the three levels of the PHF.

From the Hunter L, "a," and "b" values, one may conclude that an increase in the amount of PHF caused parts of the crust and the crumb to become darker and exhibit less red coloration. An increase in percentage of PHF did not exhibit consistent effects on yellow coloration of the bread. Several researchers have reported that the addition of certain fibrous materials to bread caused darkening of the crust and the crumb (52, 71).

IV. Specific Volume of Bread

The analysis of variance for the effect of PHF on specific volume of bread is presented in Table 14. Specific volume was affected (0.01 level) by the level of PHF.

The mean values for specific volume of bread containing PHF are presented in Table 15. Bread containing 8% PHF had the lowest specific volume, while bread with 4% PHF had the highest specific volume.

Concerning loaf volume, Pomeranz (50) stated that the addition of cellulose to bread lowered volume and impaired crumb grain. Also, he suggested that the use of wheat gluten to bread is necessary to improve the dough strength which is weakened by the addition of fibrous materials. Other researchers (38, 52, 71) have reported a decrease in loaf volume with an increase in the fiber content of bread.

TABLE 13

MEAN HUNTER "b" COLOR VALUES FOR WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

	External Area of Loaf				
PHF, %	Top[1]	Bottom[1]	Side[2]	End[3]	Crumb[1]
0	7.9[c]	22.5[a]	21.1[a]	20.4[a]	16.3[b]
4	9.2[b]	18.3[c]	17.4[b]	15.7[c]	16.3[b]
8	9.6[a]	19.0[b]	16.4[c]	16.7[b]	16.7[a]

[1]N = 12.

[2]N = 24.

[3]N = 8.

[a,b,c]Means within a column not followed by the same letter are different at the 0.01 level.

b = yellowness - blueness (+b = yellow; -b = blue).

TABLE 14

ANALYSIS OF VARIANCE FOR SPECIFIC VOLUME OF WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

Source	DF	Sum of Squares	Mean Squares	F-Ratios
Total	11	0.82243	-	-
PHF	2	0.79595	0.39798	135.3**
Residual error (Mean Square)	9	0.02658	0.00295	-

**Significant at the 0.01 level.

TABLE 15

MEAN SPECIFIC VOLUME VALUES FOR WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

Level of PHF, %	Specific Volume, cc/g
0	4.73 ± 0.05[b]
4	4.99 ± 0.16[a]
8	4.36 ± 0.06[c]

[a,b,c]Means within a column not followed by the same letter are different at the 0.01 level.

N = 4.

A photograph of the bread with the three levels of PHF is presented in Figure 5. The overall shape of the loaf with 4% PHF is similar to that of the loaf with 0% PHF; the loaf with 8% PHF is somewhat different from the loaf with 0% PHF. The cells of the crust from the loaf with 4% PHF are obviously larger than the cells of the loaf with 0% PHF.

V. Components of Whole Wheat Bread Containing Peanut Hull Flour (PHF)

The proximate analysis of bread containing PHF is presented in Table 16. The percentages of crude protein, ether extract, and carbohydrate were decreased by increasing the level of PHF. However, some of the decreases were small. The percentages of moisture, ash, crude fiber, and neutral detergent fiber were increased by increasing the level of PHF.

Some of the values obtained for proximate analysis agree closely with published values for high fiber bread (52, 71). Volpe and Lehmann (71) reported that bread rich in fiber usually contains higher moisture levels (43-44%) than bread with no fiber.

VI. Results of Aflatoxin Determination on Peanut Hull Flour (PHF)

The PHF did not have aflatoxin. Post (51), in studying PHF as a potential source of dietary fiber, found no aflatoxin in PHF.

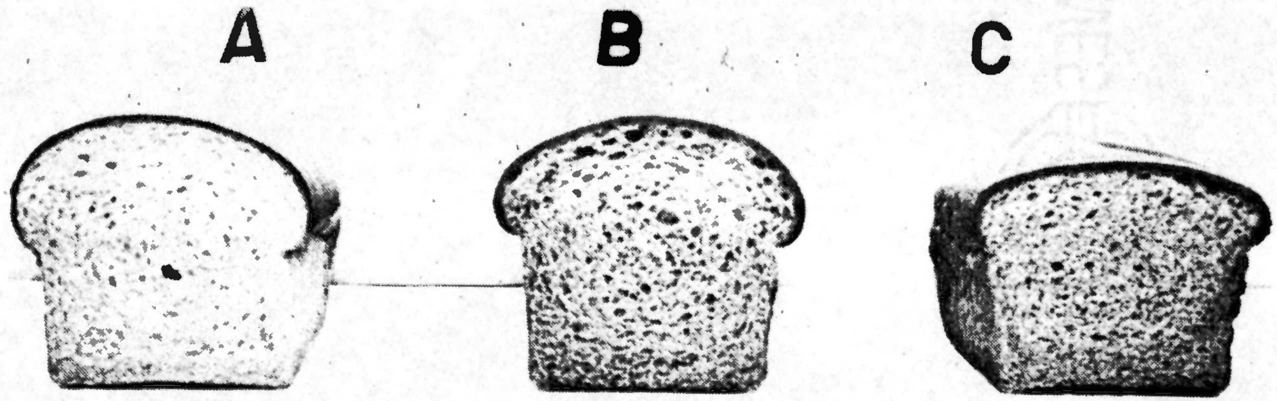

Figure 5. Visual comparison of whole wheat bread containing peanut hull flour (PHF): A = 0% PHF; B = 4% PHF; C = 8% PHF.

TABLE 16

AMOUNT[a] OF COMPONENTS OF THE WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

Components, %	Levels of PHF, %		
	0	4	8
Moisture	42.54 ± 0.24	43.21 ± 0.21	44.57 ± 0.28
Crude protein	16.84 ± 0.15	16.49 ± 0.25	16.15 ± 0.23
Ether extract	4.30 ± 0.20	4.25 ± 0.17	4.12 ± 0.12
Ash	1.54 ± 0.15	1.65 ± 0.23	1.74 ± 0.18
Crude fiber	2.22 ± 0.53	4.21 ± 0.30	6.15 ± 0.24
Neutral detergent fiber	10.63 ± 0.43	13.50 ± 0.44	16.48 ± 0.63
Carbohydrate	75.10	73.49	71.84

[a]Mean of 3 observations with ± one standard deviation and calculated on air-dried basis (excluding moisture values).

VII. Sensory Evaluation

The F-ratios of the analysis of variance for panel scores for certain quality attributes of whole wheat bread with PHF are presented in Table 17. The level of PHF had a significant effect on the scores given for all the attributes of the bread, except for chewiness. There were significant differences among the means of panelists, except for overall preference. The contrast section presents the level of difference between samples of bread containing PHF at each level and the imaginary ideal sample of whole grain bread.

The "ideal" sample was considered as a treatment along with those of 0, 4, and 8% PHF. Inclusion of the panel scores for the ideal samples for statistical analyses system was justified on the basis of comparison of the standard deviation of the respective sets of data. For all attributes evaluated, the standard deviation for the scores given for the ideal samples was similar to the standard deviations of scores given for the actual samples.

The mean panel scores for quality attributes of bread at each level of PHF versus those of an ideal brand are presented in Table 18. Scores for surface smoothness, moistness, hardness of the crust, and chewiness of bread containing 0% of PHF were not different at the 0.05 level from the scores for the same attributes of the ideal bread. Conversely, scores for graininess, grittiness, stickiness, and hardness of the crumb of bread with 0% PHF were different at the 0.01 level from the scores given the same attributes of the ideal bread.

Samples of bread with 4 and 8% PHF were less moist and more gritty, had a harder crust, were more sticky, and had a less hard crumb

TABLE 17

F-RATIOS OF ANALYSIS OF VARIANCE FOR PANEL SCORES OF QUALITY ATTRIBUTES OF WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

Source	DF	Surface-Smoothness	Moistness	Graininess	Grittiness	Hardness of Crust	Chewiness	Stickiness	Hardness of Crust	Overall Preference
Total	251	---	---	---	---	---	---	---	---	---
Panelist	62	1.5*	1.6*	1.8**	1.8**	2.3**	1.5*	1.5*	1.6**	1.2^NS
PHF	3	7.6**	6.6**	5.5**	9.0**	14.6**	0.1^NS	10.1**	8.2**	11.9**
Contrast:										
0% PHF vs. Ideal	1	2.4^NS	0.6^NS	13.3**	0.8^NS	0.9^NS	0.02^NS	29.3**	24.1**	5.5*
4% PHF vs. Ideal	1	2.6^NS	11.5**	10.3^NS	14.4**	17.7**	0.01^NS	12.6**	5.8*	21.0**
8% PHF vs. Ideal	1	8.5**	6.2*	0.5^NS	4.9*	32.8**	0.19^NS	7.7**	3.6*	29.4**
Residual error (Mean square)	186	1.7	1.2	1.3	1.0	1.5	1.5	1.3	1.1	0.9

**Significant at the 0.01 level.

*Significant at the 0.05 level.

NS Not significant at the 0.05 level.

TABLE 18

MEAN PANEL SCORES[a] FOR QUALITY ATTRIBUTES OF WHOLE WHEAT BREAD CONTAINING PEANUT HULL FLOUR (PHF)

Level of PHF, %	Surface-Smoothness	Moistness	Graininess	Grittiness	Hardness of Crust	Chewiness	Stickiness	Hardness of Crumb	Overall Preference
0	4.8[NS]	4.0[NS]	1.6**	1.5[NS]	3.0[NS]	3.0[NS]	3.1**	1.6**	5.2*
4	4.1[NS]	4.1**	2.3[NS]	2.3**	3.7**	3.1[NS]	2.7**	2.0*	4.6**
8	3.8**	4.3*	2.1[NS]	2.0*	4.0**	3.2[NS]	2.5**	2.2*	4.7**
Ideal loaf	4.4	4.7	2.2	1.6	2.8	3.0	2.0	2.5	5.6

[a]Mean scores of 63 panelists. Score for all factors except overall preference was 1 - 6 (1 = Not at all; 6 = Very much so) as presented in Appendix Figure A-1 and Figure A-2. Score for overall preference was 1 - 6 (1 = Dislike very much; 6 = Like very much).

**Score for whole wheat bread containing PHF is different from score for an ideal loaf at the 0.01 level.

*Score for whole wheat bread containing PHF is different from score for an ideal loaf at the 0.05 level.

[NS]Score for whole wheat bread containing PHF is not different from score for an ideal loaf at the 0.05 level.

when compared to the ideal bread. Graininess and chewiness of bread with each level of PHF were not different from an ideal bread. Surface smoothness of bread with 4% PHF was not different from that of the ideal bread, however, the attributes for bread with 8% PHF were scored as less smooth than that of an ideal bread.

Overall preference of bread containing 0% PHF was preferred less than an ideal bread, but only at the 0.05 level. However, breads with 4 and 8% PHF were preferred less than the ideal bread at the 0.01 level.

The Consumer Texture Profile for breads containing 0, 4, and 8% PHF and an ideal bread is presented in Appendix Figure A-3.

CHAPTER V

SUMMARY

Peanut hull flour (PHF) was added to the formulation for whole wheat bread to determine its effect on some of the chemical components, and physical and organoleptic attributes. PHF, a potential source of dietary fiber, was added at 0, 4, and 8% levels, based on weight of wheat flour in the recipe. The study was conducted in four parts as follows:

1. Part 1 involved investigation of physical properties (hardness, cohesiveness, elasticity, gumminess, and chewiness) of the bread as influenced by level of PHF and length of time that slices of bread were stored.

2. Part 2 consisted of an investigation to determine the effect of level of PHF on volume of loaves of bread and color of the outer crust and the crumb.

3. Part 3 involved measurement of some of the chemical components of the bread.

4. Part 4 was an evaluation of some organoleptic attributes of bread containing PHF by a consumer-type panel.

PHF affected hardness of the bread slices. Bread with 8% PHF had a higher and bread with 4% PHF had a lower hardness value than bread with 0% PHF. As the length of storage time was increased, the hardness of the slices of bread also increased.

The presence of PHF affected the cohesiveness of the bread. Cohesiveness decreased with storage time.

The presence of PHF did not cause a change in elasticity of the bread, but the length of storage time caused a decrease in elasticity.

Gumminess and chewiness of bread were related to the level of PHF in the bread. Bread with 8% PHF had the highest mean values for these measurements; bread with 4% PHF, the lowest.

The amount of PHF put into the bread had an effect on color of the outer crust and the crumb. As the level of PHF was raised, the outer crust and crumb became darker. The crumb was lighter than the crust. Generally, the degree of red coloration of the crust and crumb was reduced by increased levels of PHF. The presence of PHF caused only small changes in the degree of yellow coloration. With the addition of PHF, the top of the crust and the crumb became more yellow. Under the same conditions, other areas of the crust became less yellow.

Specific volume of the loaf was affected by PHF. Bread with 4% PHF had a higher and bread with 8% PHF had a lower specific volume than bread with 0% PHF.

A facsimile of loaves of breads containing 0, 4, and 8% PHF is presented in Figure 5 (page 50). The overall shape of the loaf with 4% PHF is similar to that of the loaf with 0% PHF; the loaf with 8% PHF is somewhat different from the loaf with 0% PHF. The cells of the crumb from the loaf with 4% PHF are obviously larger than the cells of the loaf with 0% PHF.

As the level of PHF was raised in the bread, the amount of moisture, ash, crude fiber, and neutral detergent fiber was increased. Conversely, the amount of crude protein, ether extract, and carbohydrate was decreased.

The PHF did not contain aflatoxin contamination.

The sensory panel indicated that the presence of PHF in bread affected some of the quality attributes. When the panel compared samples of bread with the three levels of PHF to an imaginary loaf of ideal whole grain bread, the following general findings were apparent. In relation to the ideal bread, PHF at one or more levels caused the bread to possess a less smooth surface, have decreased moistness and graininess, exhibit a softer crumb, and be less preferred. Likewise, PHF at one or more levels caused the bread to be more gritty and sticky and have a harder crust than the ideal loaf.

PHF does seem to have potential as a source of dietary fiber when added to whole wheat bread. A 4% level of PHF should yield bread with more acceptable physical attributes than an 8% level of PHF. However, the panel indicated samples of bread with 4 and 8% PHF were not different generally from each other when compared with an ideal loaf of whole grain bread.

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APPENDIX

INSTRUCTIONS TO THE SENSORY PANEL FOR EVALUATION OF WHOLE WHEAT BREAD WITH PEANUT HULL FLOUR

Instructions:

PLEASE READ THESE INSTRUCTIONS CAREFULLY BEFORE EVALUATING SAMPLES.

You will receive 3 samples of bread to evaluate for texture (how foods feel in mouth), and overall acceptability. These samples will be presented one at a time along with a score sheet. Each score sheet has a list of terms which are commonly used to describe textural properties in bread. Follow the instructions on the scoresheet and evaluate the samples by placing a check mark at the point to indicate the degree to which you feel this sample has the textural characteristics described by that term. After evaluating the 3 samples, describe how you think an <u>ideal</u> whole grain bread should be in terms of the supplied texture words using the same scale on a separate score sheet. It is very important to our test that you make a choice for each term. If you have any questions, please ask.

SAMPLE NUMBER: ___________

Name: ___________

Date: ___________

I. Place sample into mouth between tongue and palate and evaluate for:

Surface smoothness (degree to which surface is smooth; that is, not rough)

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

Moistness (degree to which sample is moist):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

II. Place sample between molar teeth, bite down, and evaluate for:

Hardness (force required to bite through sample):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

III. Place sample between molar teeth, chew and evaluate for:

Chewiness (number of chews required to hydrate sample and prepare for swallowing):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

Stickiness (degree to which sample sticks to teeth):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

IV. After chewing, swallow and evaluate for:

Graininess (degree to which mass contains small distinct particles: similar to popcorn husk - fine or coarse):

Not all all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

Grittiness (degree to which the sample contains small sand-like or grit-like particles):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

V. Place crust between teeth, bite down, and evaluate for:

Hardness (force required to bite through sample):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

VI. Evaluate for overall acceptability, taking in consideration flavor, texture, color:

Dislike ☐ ☐ ☐ ☐ ☐ ☐ Like

VII. Comments:

Figure A-1. Score sheet used for sensory evaluation of whole wheat bread containing peanut hull flour.

IDEAL WHOLE GRAIN BREAD

Think of what you consider as an ideal whole grain bread and evaluate using this score sheet. YOU WILL NOT GET A SAMPLE.

I. Place sample into mouth between tongue and palate and evaluate for:

Surface smoothness (degree to which surface is smooth; that is, not rough):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

Moistness (degree to which sample is moist):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

II. Place sample between molar teeth and bite down and evaluate for:

Hardness (force required to bite thorugh sample):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

III. Place sample between molar teeth, chew and evaluate for:

Chewiness (number of chews required to hydrate sample and prepare for swallowing):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

Stickiness (degree to which sample sticks to teeth):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

IV. After chewing, swallow and evaluate for:

Graininess (degree to which mass contains small distinct particles; similar to popcorn husk - fine or coarse):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

Grittiness (degree to which the sample contains small sand-like or grit-like particles):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

V. Place crust between teeth, bite down and evaluate for:

Hardness (force required to bite through sample):

Not at all ☐ ☐ ☐ ☐ ☐ ☐ Very much so

VI. Evaluate for overall acceptability taking into consideration flavor, texture, and color:

Dislike ☐ ☐ ☐ ☐ ☐ ☐ Like

VII. Comments:

Figure A-2. Score sheet used for sensory evaluation of an imaginary ideal loaf of whole grain bread.

Quality Attributes:

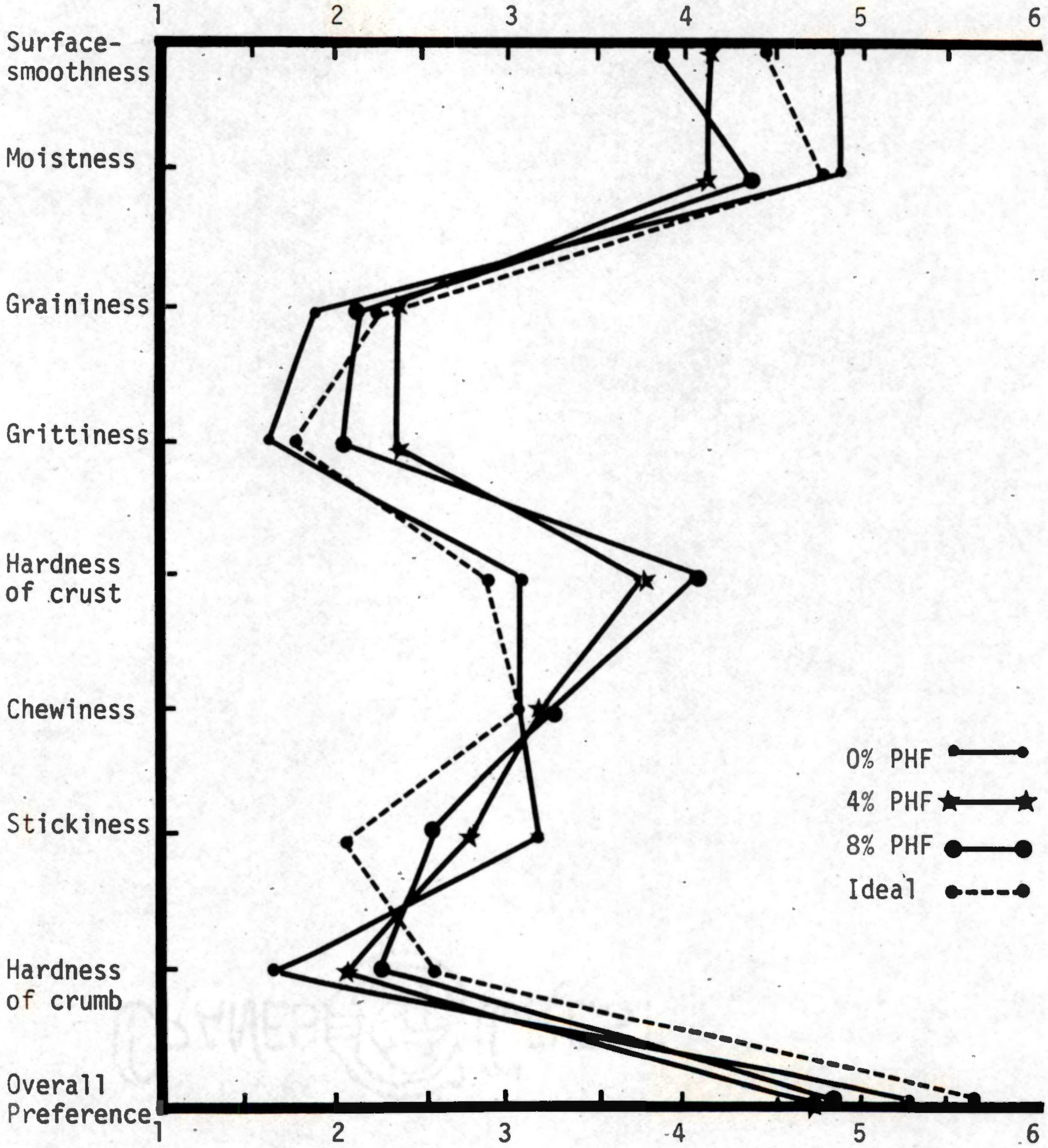

Figure A-3. Consumer Texture Profiles for bread containing peanut hull flour (PHF) and for an ideal bread. (Scale in footnote, Table 18; N = 63).

VITA

The author was born in Tehran, Iran. He attended elementary and high school in Tehran, Iran, and graduated in 1964. He received the Bachelor of Science degree in Chemistry in 1971 from Tehran, Iran. From October 1965, to August 1975, he was employed as a teacher of chemistry in Tehran high schools. He received the Bachelor of Science degree in Food Science and Technology from the University of Georgia in 1978. In September 1978, he was accepted as a graduate student at The University of Tennessee, Knoxville. In June 1980, requirements for the Master of Science degree with a major in Food Technology and Science were completed.