To the Graduate Council:

I am submitting herewith a thesis written by Alan R. Post entitled "Peanut Hull Flour as a Potential Source of Dietary Fiber." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

Jimmie L. Collins
Major Professor

We have read this thesis and
recommend its acceptance:

Hugh D. Payne

Sharon L. Melton

Accepted for the Council:

L. Evans Pell
Vice Chancellor
Graduate Studies and Research

B

Ag-VetMed
Thesis
79
.P678
cop. 2

PEANUT HULL FLOUR AS A POTENTIAL SOURCE OF DIETARY FIBER

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Alan R. Post

December 1979

1405023

DEDICATION

This work is respectfully dedicated to the memory of my mother, Gertrude Helen Post—educator, antiquarian, bibliophile, professor of classic values, and friend.

ACKNOWLEDGMENTS

The author wishes to express sincere appreciation and gratitude to his major professor, Dr. J. L. Collins, for his critical evaluation and especially for his direction and guidance throughout the course of this study. Sincere appreciation and thanks are expressed to Dr. S. L. Melton and Dr. H. O. Jaynes for serving on the graduate committee and for their helpful suggestions.

The author wishes to thank Dr. J. T. Miles, Department Head, for his understanding during the study.

Special thanks are extended to Ms. Ruth Hill and Ms. Linda Washam for their assistance and help throughout the study. Thanks are extended to Dr. W. B. Sanders and Mohammad Amiri for their assistance in the statistical analyses. Thanks are also extended to Dr. R. J. Lewis and Ms. Maralie Gaffron for their assistance in the atomic absorption spectroscopy work, to Ms. Ola Sanders and Ms. Joan Helm for their assistance in the sensory evaluation work, and to Dr. F. A. Draughon for her assistance in the aflatoxin determinations.

The author is appreciative of the contributions of Mr. G. C. Zekert who provided the peanut hulls used in this study.

I am also deeply indebted to Dr. and Mrs. Harold Post, Laurie S. Post, and Robert C. Post for their steadfast confidence, encouragement, and support.

ABSTRACT

The objectives of this investigation were to analyze a flour made from peanut hulls and to evaluate its potential as a source of dietary fiber.

Hulls produced a mean 27.50 grams of toasted Virginia-type hull flour (TVHF) and a mean 42.4 grams of toasted Runner-type hull flour (TRHF) per 100 grams of cleaned hulls.

The proximate composition of TVHF and TRHF was determined. The TVHF had 2.68 percent moisture, 6.74 percent crude protein, 0.83 percent ether extract, 2.94 percent ash, 47.33 percent crude fiber, and 39.34 percent nitrogen free extract. The TRHF contained 2.55 percent moisture, 7.19 percent crude protein, 0.52 percent ether extract, 2.07 percent ash, 47.23 percent crude fiber, and 40.33 percent nitrogen free extract.

Six macroelements and eight microelements were determined in TVHF and TRHF. The hull flours represent a potential source for calcium, phosphorus, and potassium. The concentration of lead in both flours was below the sensitivity limit of the atomic absorption spectrophotometer.

TVHF and TRHF yielded 7.64 percent and 9.06 percent soluble solids, respectively.

The water holding capacities for washed, acetone-dried flours were lower than those of TVHF and TRHF. The water holding capacity increased as the soaking time and temperature increased.

The oil holding capacity was affected by the type of material, but was not affected by soaking time and temperature.

The fibrous components in TVHF and in TRHF were, respectively, 61.49 and 58.76 percent lignocellulose for acid detergent fiber, 24.52 and 26.47 percent lignin, 78.45 and 78.26 percent lignocellulose in buffered acid detergent, 80.51 and 77.63 percent cell wall constituents, 21.41 and 22.37 percent soluble cell material in neutral detergent, 2.51 and 1.83 percent insoluble ash in neutral detergent, 19.02 and 18.87 percent hemicellulose, and 36.97 and 32.29 percent cellulose.

The washed, acetone-dried Virginia-type hull flour and the washed, acetone-dried Runner-type hull flour were, respectively, composed of 70.32 and 61.72 percent lignocellulose for acid detergent fiber, 28.28 and 25.22 percent lignin, 84.01 and 77.30 percent lignocellulose in buffer acid detergent, 81.94 and 76.57 percent cell wall constituents, 18.06 and 23.43 percent soluble cell material in neutral detergent, 2.10 and 1.67 insoluble ash in neutral detergent, 11.62 and 14.86 percent hemicellulose, and 42.04 and 37.16 percent cellulose.

The emulsifying capacity for one gram of flour ranged from 27.57 ml oil/g to 25.27 ml oil/g of dried sample of the toasted and washed, acetone-dried flours.

The cation exchange values ranged from 1.01 to 0.91 meq./g of dry sample weight. These values represent materials similar to resins of weak cation exchange capacity. The pH of the toasted flours were close to each other, ranging from 6.1 to 5.4.

The gross energy values for TVHF and TRHF were 4.574 and 4.566 Kcal/g, respectively.

Aflatoxins were not detected in either types of flour.

The Hunter L, "a," and "b" color values were dependent on the type of flour (Virginia- vs. Runner-type flours) and the treatment (untoasted vs. toasted).

The sensory panel did not show a preference for toasted or untoasted flours when evaluated for taste or aroma.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	3
	Availability and Usage of Peanut Hulls	3
	Dietary Fiber	4
	Kinds of Dietary Fiber and Analyses	5
	Nature and Properties of Dietary Fiber Components	10
	Clinical Aspects of Dietary Fiber	12
	Can One Get Too Much Dietary Fiber?	15
	Mold Contamination of Peanuts and Other Commodities	16
III.	MATERIALS AND METHODS	18
	Source and Preparation of Peanut Hull Flour	18
	Chemical Analyses of Peanut Hull Flour	19
	Determination of proximate analysis	19
	Energy determination	20
	Mineral composition	21
	Water holding, oil holding, and emulsifying capacities of the peanut hull flour	25
	Cation exchange capacity	27
	Aflatoxin detection	28
	Fiber analysis	29
	pH determination of peanut hull flours	33
	Determination of Color of Peanut Hull Flour	33
	Sensory Evaluation	33
	Statistical Analysis	34
IV.	RESULTS AND DISCUSSION	37
	Chemical Analyses of Peanut Hull Flour	37
	Determination of Color of Peanut Hull Flour	60
	Sensory Evaluation	64
V.	SUMMARY	69
REFERENCES		73
VITA		81

LIST OF TABLES

TABLE		PAGE
I.	A Comparison of Crude Fiber and Dietary Fiber in Certain Foods	7
II.	Basic Scheme for the Analysis of Fiber Using Detergents	9
III.	Amounts of Various Components of Flour Prepared from Toasted Peanut Hulls	38
IV.	Amounts of Certain Elements of Flour Prepared from Toasted Peanut Hulls	40
V.	F-Ratios of Analysis of Variance for Water Holding Capacities and Oil Holding Capacities for Different Types of Materials Prepared from Peanut Hulls	45
VI.	Mean Values for Water Holding Capacity for Different Materials Prepared from Peanut Hulls	46
VII.	Means for Type of Material × Soaking Time × Temperature Interaction for Water Holding Capacity	48
VIII.	Mean Values for Oil Holding Capacity for Different Materials Prepared from Peanut Hulls	49
IX.	Means for Type of Material × Soaking Time × Temperature Interaction for Oil Holding Capacity	51
X.	Mean Values for Fibrous Components of Different Materials Prepared from Peanut Hulls	52
XI.	Cation Exchange, pH, and Emulsifying Capacity of Flour Prepared from the Hulls of Virginia and Runner Peanuts	56
XII.	Caloric Content of Flour Prepared from Hulls of Virginia and Runner Peanuts	58

TABLE		PAGE
XIII.	F-Ratios of Analysis of Variance for Color of Flour Prepared from Untoasted or Toasted Hulls of Virginia- or Runner-Type Peanuts . . .	61
XIV.	Mean Hunter L Values for Type of Flour and Treatment	62
XV.	Mean Hunter "a" Values for Type of Flour and Treatment	63
XVI.	Mean Hunter "b" Values for Type of Flour and Treatment	65
XVII.	F-Ratios of Analysis of Variance for Taste and Aroma Scores of Flour Prepared from Untoasted and Toasted Hulls of Virginia- and Runner-Type Peanuts	66
XVIII.	Mean Values for Taste and Aroma for Different Types of Flour Prepared from Untoasted and Toasted Hulls of Virginia- and Runner-Type Peanuts	68

CHAPTER I

INTRODUCTION

The hypothesis concerning the role of dietary fiber in human nutrition and its relationship to disease of humans has attracted considerable attention in recent years. Studies have indicated a beneficial effect of plant fiber-containing materials in counteracting the toxic effects of a number of drugs, chemicals, and food additives (25,26,27).

The nutritional qualities of food products are usually described in terms of amounts of protein, carbohydrates, fats, vitamins, and minerals. The importance of fiber in the diet is less frequently mentioned, no doubt a result of the limited knowledge of dietary fiber (12).

A lower fiber intake has been reported to be associated with ischemic heart disease, diabetes, diverticular disease of the colon, appendicitis, cancer of the colon, and other diseases of the gastrointentional tract (13,14,59,60). Reportedly, these conditions are virtually nonexistant in populations subsisting on high fiber diets (14,31,32,42,51, 52,53,70,71,72,73,81).

Studies in both experimental animals and humans consuming diets high in plant fiber reveal a lower serum cholesterol level, thus suggesting that a relationship may exist between dietary fiber and freedom from atherosclerosis

(51,69,70). A definite value for including fiber in the diet would be to relieve constipation problems by increasing the water content of the stool (40,42,43).

Foods which contain significant amounts of fiber-containing materials are generally lower in caloric content. Diets for weight reduction encourage the consumption of various foods recognized as excellent sources of dietary fiber: these include raw vegetables and fruits, whole grain products, leguminous seeds, and nuts. The bulk resulting from consumption of these foods provides a feeling of satiety. Unfortunately, the higher prices of natural foods tend to limit consumption of some of these items (3, 5,37).

For fibrous materials to be noticeably beneficial in the diet, supplements in gram quantities would have to be incorporated into processed foods. The added material may alter the appearance, flavor and texture of many food products (18,80).

Little effort has been made to evaluate peanut hulls as a source of dietary fiber. Consequently, this study was undertaken to analyze a flour made from peanut hulls and to evaluate its potential as a source of dietary fiber.

CHAPTER II

REVIEW OF LITERATURE

I. AVAILABILITY AND USAGE OF PEANUT HULLS

Approximately 431,205 metric tons of peanut hulls are available as a by-product of the peanut-shelling industry (74). Peanut hulls accumulate in tremendous quantities at the shelling plants and are considered a liability rather than an asset (11,86). Most hulls are burned, but the industry has been notified by the Environmental Protection Agency that disposal which does not pollute the environment must be employed (31).

Peanut hulls are generally low in protein, ash, oil, and feeding value (86). Analysis shows the hulls to consist of 8.40 percent crude protein, 9.63 percent moisture, 3.55 percent ash, 1.83 percent ether extract, 63.53 percent crude fiber, 20.78 percent nitrogen-free extract, 39.95 percent cellulose, 68.25 percent acid detergent fiber, 29.85 percent acid detergent lignin, 77.15 percent cell wall constituents, 0.25 percent calcium, and 0.03 percent phosphorous (11,30, 74,75,86).

Peanut hulls are used as filler for fertilizers, mulch for growing plants, litter for poultry houses, abrasives for

polishing steel and aluminum, insulation for buildings, and high grade activated charcoal (11,86).

Peanut hulls have been used as roughage in cattle feed. Compared with other roughage materials, peanut hulls contain considerably more fiber and lignin. According to Utley et al. (74,75), changing the physical form of the unground peanut hulls from a coarse material to finely ground particles also changes the roughage characteristics and influences the digestibility of the diet. They found a slight reduction in crude fiber and cellulose digestibility in diets containing finely ground hulls.

Roughage is that portion of plant material which is not broken down by chemical action in the digestive system. This indigestible material is referred to as dietary fiber (68).

II. DIETARY FIBER

Dietary fiber has long been considered an insignificant part of the human diet because it was believed to contribute little nutritionally. However, there is evidence, primarily epidemiological, that fiber may have a direct effect upon some biochemical and physiological abnormalities of humans (15).

With the growing movement toward the use of natural foods and away from processed products, considerable

interest has developed in a theory that consumption of foods high in fiber such as bran, whole grains, and certain fruits and vegetables will prevent a variety of digestive and other diseases including cancer of the colon, hemorrhoids, diverticular disease, appendicitis, hiatus hernia, varicose veins, atherosclerosis, and ischemic heart disease (3,21,46). This theory is based on observations made by a number of British physicians that such diseases are virtually unknown among Africans living in rural villages. These diseases do occur in Africans who move to urban areas and, consequently, eat the typical low fiber, high fat, processed diet of Western man. Vegetarians and Trappist monks, two population groups exhibiting low serum cholesterol levels as well as low incidence of coronary artery disease, have been consuming diets with a high fiber content. In all of these epidemiological studies, the dietary fiber intakes have been underestimated. This is because the fiber content of the foods eaten by subjects is expressed in terms of crude fiber and not dietary fiber (31,32,44,46).

III. KINDS OF DIETARY FIBER AND ANALYSES

The primary plant materials of interest to nutritionists and health scientists are cellulose, hemicellulose, lignin, and pectin. Collectively, these materials are referred to as dietary fiber when consumed as a part of food (10,84).

Measurement of crude fiber is the only index of food fiber content available at the present time. The Association of Official Analytical Chemists (7) defines crude fiber as the material which is lost on ignition of the dried residue remaining after digestion with sulfuric acid and sodium hydroxide under specific conditions. It is a measure mainly of cellulose and lignin content (7,37,63). These two components constitute 50 percent or less of the total dietary fiber present in the food or feed product (Table I). For this reason, the terms "crude fiber" and "dietary fiber" are not interchangeable expressions.

Southgate (64) developed a detailed and time-consuming fractionation procedure for determination of cellulose, hemicellulose, and lignin in foodstuffs. This method provides data on the unavailable carbohydrates composition of the fiber (77,78).

The analytical methods for measuring amounts of fibrous materials developed by Goering and Van Soest (29) are simpler and easier than the method employed by Southgate (64). The method provides for the following determinations: the neutral detergent residue which includes plant cell materials minus the pectins; the acid detergent fiber which includes lignocellulose plus insoluble minerals; and the crude lignin from the acid detergent fraction. The hemicellulose content is determined by subtracting acid

TABLE I

A Comparison of Crude Fiber and Dietary Fiber in Certain Foods

Food	Crude Fiber g/100 g Food	Dietary Fiber g/100 g Food
Breads and cereals:		
White bread	0.2	2.72
Whole wheat bread	1.6	8.50
All bran cereal	7.8	26.7
Cornflakes	0.7	11.0
Puffed wheat	2.0	15.41
Puffed wheat, sugar coated	0.9	6.08
Vegetables:		
Broccoli tops, boiled	1.5	4.10
Lettuce, raw	0.6	1.53
Carrots, boiled	1.0	3.70
Peas, canned	2.3	6.28
Sweet corn, cooked	0.7	4.74
Fruits:		
Apples, without skin	0.6	1.42
Peaches, with skin	0.6	2.28
Strawberries, raw	1.3	2.12
Nuts:		
Brazil	3.1	7.73
Peanuts	1.9	9.30
Peanut butter	1.9	7.55

Reference 5, p. 36

detergent fiber from the neutral detergent fiber contents (Table II) (77,78).

Baker (8) developed a method using a hydrochloric acid-potassium chloride buffered solution which is less corrosive than the 1.0 N sulfuric acid solution used in the Goering and Van Soest (29) method. The buffered solution falls within the pH range of the human stomach digestive medium (Table II).

The Morrison (58) method measures lignin by ultraviolet absorption at 280 nm in 25 percent acetyl bromide in acetic acid. While this procedure is adequate for grasses and wheat bran, it has not proved to be of value for fruits and vegetables.

The term "dietary fiber" is variously defined in the literature as the remnants of vegetable cell walls which are not hydrolyzed by alimentary enzymes of humans, as unavailable carbohydrates and lignin, and as plant materials which are resistant to digestion by the secretions of the human gastrointestinal tract. Plant constituents usually considered as part of dietary fiber include hemicellulose, lignin, and cellulose. Additional components in this category include pectins, gums, cutin, some proteins, oligosaccharides, indigestible Maillard products and minerals (42,46).

TABLE II

Basic Scheme for the Analysis of Fiber Using Detergents

Fraction	Reagent	Treatment	Yield
Neutral-detergent residue (NDR)[a]	Na lauryl sulphate, EDTA pH 7.0	Boil 1 h	Plant cell wall pectins
Acid-detergent fiber (ADF)[a]	Cetryl trimethyl-ammonium bromide in 1 N-H_2SO_4	Boil 1 h	Lignocellulose + insoluble mineral
Lignin[a]	640 ml H_2SO_4/l	3 h, 20°C	Crude lignin
Cellulose[a]		Calculate as ADF-lignin	
Hemicellulose[a]	----	Calculate as NDR-ADF	
Buffered acid detergent fiber[b]	0.2 M HCl 0.2 M KCl Hexadecyltrimethyl ammonium bromide	Boil 1 h	Lignocellulose + insoluble mineral

[a]Reference 77, p. 124.

[b]Reference 8, p. 361.

IV. NATURE AND PROPERTIES OF DIETARY FIBER COMPONENTS

Cellulose is an important part of the cell walls of plant tissues. It is a water insoluble polysaccharide consisting of a long unbranched polymer of glucose units linked by β-1, 4 bonds, and containing from 3,000 to 100,000 glucose units. Cellulose is not attacked by enzymes of the digestive juices. The cellulose component of the dietary fiber provides the water retention properties (10, 22,63).

Cellulose fiber has the capacity to swell when exposed to water. During hydration the dry fiber absorbs water at the surface. As the wetting increases, the spaces between the fibers fill with entrapped water. Eventually, the system is saturated and additional water added to the system exists as free, unbound water. The weight of the hydrated materials may range from between 5 to 6 times the weight of the dry materials (21).

Lignin is a substance which makes up the principal part of the woody structure of plants. The term "lignin" refers to a group of indigestible substances which are not carbohydrates, but are composed of phenyl propane units. Unlike cellulose, lignin is capable of combining with bile acids to form insoluble complexes which are not absorbed in the intestine and thus inhibit cholesterol adsorption (4, 21,23,48,61).

Lignin acts as a weak cation-exchange resin in the digestive tract. Kirwan et al. (45) studied the cation exchange properties of two bran preparations. One of the preparations was composed of flake-like particles (coarse bran), whereas, the other preparation consisted of flour-like particles. Kirwan et al. (45) found that the cation exchange capacity of the coarse bran was 1.2 meq./g dry matter and that of fine bran was 0.7 meq./g, respectively. The cation exchange capacity changes with particle size and not with fiber or lignin content (54,55). The property of flour to act as a cation exchange could result in some undesirable effects. There is evidence that fiber fractions can bind appreciable amounts of dietary calcium, zinc, and iron in dephytinized whole meal bread and bran products (42).

The hemicellulose fraction is not regarded usually as an important part of the cell walls of plants. The hemicelluloses actually comprise a large group of carbohydrates, including the mucilages and gums, all of which are extractable from dry plant tissues by hot water. Molecularly hemicelluloses constitute a mixture of linear and branched chains of xylose, galactose, mannose, or other sugar units with uronic acids. The hemicelluloses are not hydrolyzed by the intestinal enzymes, but are readily broken down by the intestinal flora to form compounds that may be absorbed and yield energy to the body. It is now known that

bacterial action on hemicelluloses can produce quantities of volatile fatty acids such as acetic, propionic, and butyric acids. When absorbed, acetic and butyric acids follow the path of fatty acid metabolism, but propionic acid follows that of glucose metabolism (10,21,56,77,78).

V. CLINICAL ASPECTS OF DIETARY FIBER

The literature is filled with studies on the effects of dietary fiber on intestinal function (3,5,10,14,15,33,40, 42,53,56,60,70,71,72,81).

During this century, there has been an increase in the incidence of deaths due to diverticular disease. Diverticular disease is characterized by small blow-out type protrusion lesions of the large intestines. Statistical correlations indicate that people who have the disease are likely to have appendicitus, polyps of the bowel, hemmorrhoids and/or varicose veins (5,42). These associations indicate that heredity plays a role in the occurrence of the disease. Fiber apparently also plays a role (10).

The inclusion of fiber in the diet is essential for normal bowel function promoting regularity, softer stools, and rapid transit time (8). A classic study of this subject by McCance et al. (53) showed that, when six normal people consumed brown bread (1.82 percent crude fiber) mixed with barium, the brown bread left the stomach and passed through

the small intestines more rapidly, and left the colon 24 hours sooner than a similar amount of white bread (0 percent crude fiber).

One study with 310 subjects in Rhodesia showed that subjects consuming an African diet of unrefined carbohydrates had the shortest bowel transit time, and those consuming a Western diet of highly unrefined carbohydrates had the longest bowel transit time (40,42).

The value of fiber for relieving constipation lies in its ability to increase the water content of the feces, producing bulkier, softer, well-formed stools (14). Cereal fiber in the form of bran may be more effective than fruit and vegetables in treating constipation because of its lower coefficient of digestibility (43). Williams and Olmstead (84) reported that hemicelluloses were more effective than cellulose and lignin in increasing stool weight. Scala (63) stated that for each gram of fiber added to the diet, stool weight increased by about 15 grams.

Colonic cancer is the second-ranked cause of cancer mortality in the United States (63). Burkitt (15) theorized that fiber-depleted diets prolong the contact time between concentrated stool content and mucosa and that the same diets might favor growth of bacterial flora capable of forming carcinogens from the degradation of bile salts. Painter et al. (59,60) showed that stools from Western

communities, where bowel cancer is common, contained more bacteria capable of causing degradation of bile salts than did stools from Indians and Africans. Leveille, as quoted in reference (3), added to this theory by suggesting that a high-fiber diet could alter the colonic microflora so that production of carcinogens would be eliminated or inhibited.

Atheroma and ischemic heart disease are the most prevalent groups of diseases known to Western societies. Fifty percent of all deaths of people past the age of 45 can be directly attributed to heart disease (46).

Trowell (70) recently reviewed the effect of dietary fiber on blood cholesterol levels. He suggested that a high-fiber intake increases fecal steroid output and as this is the main pathway for cholesterol in humans, blood cholesterol is lowered and development of atheroma is retarded. He referred to fiber as a natural hypotholesteremic agent and made references to both animal and human experimental data to support this claim.

Moore (57) found that substitution of wheat straw for cellulose lowered cholesteremia and atherosclerosis in rabbits fed a semisynthetic diet containing 20 percent animal fat. The mechanism of action of the feed residue suggested that alfalfa or the wheat straw prevented the absorption of cholesterol or bile salts.

VI. CAN ONE GET TOO MUCH DIETARY FIBER?

At the present time there are no specified nutritional recommendations for dietary fiber in foodstuffs due to the lack of data regarding the requirement of fiber by the body (69). Consumption of as much as 10 tablespoons of bran per day, in addition to the regular diet could cause diarrhea and other digestive complaints. The high fiber diets of Africa and India are associated with high incidence of mineral deficiencies (15,37,42).

Fiber, by its sheer bulk, may reduce the total amount of food consumed resulting in the deficiency of certain nutrients and needed calories especially in areas where malnutrition is already existent (52,65,66).

Fiber provides three physiological obstacles to energy uptake which may help control obesity. Firstly, it displaces available nutrients from the diet. Secondly, it requires chewing which slows down and limits intake by promoting secretion of saliva and gastric juices. This, in turn, distends the stomach and promotes a feeling of fullness. Thirdly, fiber reduces the absorptive efficiency of the small intestines (3,63).

Scala (63) estimated that fiber derived from fresh fruits and vegetables has declined by about 20 percent, whereas, fiber derived from cereals and grains has decreased by as much as 50 percent. Most of the fiber is removed from

bread and cereals by milling, whereas, peeling and boiling reduces the intake from vegetables and fruits. Trowell (73) reported that the total fiber intake of the American diet decreased 37 percent from 1800 to 1970 AD.

At the present time, there is much confusion and many conflicting claims and reports in the literature related to the role of dietary fiber in the human body. The physiological mechanisms involved remain to be identified and clarified from experimental studies before the role of fiber in the human diet can be clearly defined.

VII. MOLD CONTAMINATION OF PEANUTS AND OTHER COMMODITIES

During storage of peanuts, corn, and other grain commodities control of molds is an important problem. Growth of mold on the peanuts, kernels and skins, is a direct result of excessive moisture present during the storage period. The molds can produce mycotoxins and one of the most toxic is aflatoxin, produced by Aspergillus flavus (52). This substance is a powerful heptatoxin and carcinogen (85). In general, A. flavus will not grow in equilibrium with less than 75 percent relative humidity (8 percent moisture) (86).

Peanuts and peanut products containing more than 20 parts per billion (ppb) aflatoxin may not be used or sold for food or feed according to Food and Drug Administration

regulations (85). Peanuts containing less than 20 ppb may be used or sold.

There are several methods for detecting aflatoxin. These include use of the black light test, the minicolumn test, thin layer chromatography (TLC), high pressure liquid chromatography (HPLC), and the duckling bioassay (85,86).

CHAPTER III

MATERIALS AND METHODS

I. SOURCE AND PREPARATION OF PEANUT HULL FLOUR

Peanut hulls of the Runner- and Virginia-types were used in this study. Hulls of the Runner-type were obtained from the DeLeon Peanut Company, Durant, Oklahoma. Hulls of the Virginia-type were obtained from the National Peanut Corporation, Suffolk, Virginia. Hulls of each type were received in 22.7 kilogram capacity burlap bags (87).

A flour was prepared from the hulls of both types. The hulls were separated from debris, washed in a solution of sodium dodecyl sulfate, and rinsed in three changes of fresh water. The hulls were dried in a forced-air dehydrator at 65°C and toasted one hour in a oven preheated at 149°C. Flour was prepared by grinding the hulls three times in a Wiley mill to pass a 40-mesh screen (18). Particle size of the flour was reduced further by grinding three minutes in a colloid mill. The flour which passed a 80-mesh sieve (0.177 mm opening) was removed for further analysis. Some of the flour used for sensory evaluation and color measurements was not toasted but dried in a forced air dehydrator at 65°C for three days. The two flour types

were stored in glass containers at 20°C through the experiment.

II. CHEMICAL ANALYSES OF PEANUT HULL FLOUR

A. Determination of Proximate Analysis

1. Crude protein. Total nitrogen was determined by the modified Kjeldahl method (7). Six samples consisting of two grams of the oven-dried Runner-type or Virginia-type hull flours were analyzed for total nitrogen content. Percentage of crude protein was calculated by multiplying percentage of nitrogen × 6.25. Results were expressed on a dry weight basis and air-dried basis.

2. Crude fat. The petroleum ether extract method was used to determine ether extract (1). A three-gram sample of the air-dried material was extracted with petroleum ether on the Goldfisch extractor for sixteen hours. Percentage of total lipid content was calculated. Six analyses were conducted for each sample.

3. Moisture. Moisture content of the flours was determined by drying two grams of flour to constant weight in a vacuum oven at 100°C and 200 torr (1). Six samples of flour of each peanut type were analyzed. Percentage of moisture was calculated.

4. Ash. Ash content of the flour was determined by ashing six, two-gram samples in a muffle furnace at 550°C for three hours (1). Percentage of ash was calculated.

5. Crude fiber. Crude fiber content of the flours was determined by digesting the samples with 1.25 percent solution of sulfuric acid and then with 1.25 percent solution of sodium hydroxide. The dried residue remaining after digestion was incinerated in a muffle furnace at 550°C for 20 minutes. Six, two-gram samples of the flour of each type were analyzed (7).

6. Nitrogen free extract. The nitrogen free extract was determined by subtracting the percentage of moisture, ash, crude protein, crude lipid, and crude fiber from 100 percent.

B. Energy Determination

The caloric value was determined with the Parr Oxygen Calorimeter (Parr Instrument Co., Moline, Ill.) (4). An 0.8-gram air-dried sample of each flour type was analyzed in triplicate. The energy value was determined by complete oxidation of the flour. Caloric value was determined by measuring the rise in temperature of a specific volume of water. The calculation used to determine calories in the bomb calorimeter was as follows:

$$\text{Kcal} = \frac{(Ft - It)\times(SF) - \text{Calories of wire} - \text{ml. } Na_2CO_3 - \text{Calories of Sulfur}}{\text{sample wt.} \times \text{dried matter}}$$

$$= \frac{\text{calories/g}}{1000} \qquad (1)$$

where Ft = Final temperature

It = Initial temperature

SF = Standard factor which is 1347

The net caloric content was calculated by subtracting the caloric value of protein, lipid and nitrogen free extract from the gross energy determinations (12).

C. Mineral Composition

Toasted Virginia- and Runner-type hull flours were analyzed for calcium, potassium, magnesium, sodium, chrominum, copper, iron, manganese, zinc, lead, aluminum, and molybdenum. The samples were prepared by ashing three, one-gram samples of each flour in a muffle furnace at 550°C for three hours. The ash was dissolved in 5 ml of concentrated hydrochloric acid and diluted with 25 ml deionized water. The mineral components were measured with an Atomic Absorption/Atomic Emission Spectrophotometer (Instrument Laboratory, model 551, Wilmington, Maine) (7,28,50).

A standard air-acetylene burner and single element hollow-cathode lamps were used for the detection of calcium, magnesium, lead, copper, iron, manganese, and zinc. Nitrous

oxide acetylene burner and single element hollow-cathode lamps were used for the detection of chromium and molybdenum. The detection of potassium, sodium, and aluminum employed the use of frame emission. An air acetylene flame was used for potassium and sodium determinations. A nitrous oxide acetylene mixture was used for aluminum determinations. The settings for the instrument and other experimental conditions were in accordance with manufacturer's specifications (24).

For some elements the sample solution was diluted with deionized water to bring the concentration of the element into the range of the instrument. A 0.1 to 10 ml dilution was prepared for calcium and magnesium determinations for toasted Virginia- and Runner-type hull flour samples. The final dilutions contained 1 percent (w/v) lanthanum solution to overcome interferences. For potassium determination a 0.5 to 10 ml dilution was prepared for toasted Virginia-type hull flour and a 0.1 to 10 ml dilution for toasted Runner-type hull flour samples. The final dilutions contained cesium chloride (1000 ug/ml) to overcome interferences. A 0.1 to 10 ml dilution was prepared for copper and sodium determination from both types of flour samples. A dilution of 1 to 5 ml was used for iron and manganese determinations. To calculate the mg/100 g of elements present in the flour samples, the following equation was used:

$$\text{dilution factor} = \frac{25}{\text{aliquot}} \times \text{final volume}$$

$$\text{mg/g of element} = \text{concentration of element from spectrophotometer} \times \frac{\text{dilution factor}}{1000} \div \text{Ash weight of sample}$$

$$\text{mg/g flour} = \left(\frac{\text{mg element}}{\text{g of ash}}\right)\left(\frac{\text{g of ash}}{\text{100 g flour}}\right)$$

$$\text{mg/100 g flour} = \text{mg/g flour} \times 100 \qquad (2)$$

The flours were analyzed for chloride and phosphorus by potentiometric and colorimetric procedures, respectively (7).

The chloride ion concentration was measured with a silver-silver chloride reference electrode and a silver indicating electrode (Fisher Scientific Co.). The electrodes were connected to a Fisher Accumet pH meter (model 600). A five gram air-dried sample of each flour was analyzed in triplicate. To this material, 200 ml of deionized water and 1 ml of concentrated nitric acid were added. A 0.1 N silver nitrate solution was added to the sample in small increments so that the voltage endpoint could be observed on the millivolt scale (7). The potential developed between the silver and its ions may be expressed in chloride ion concentration. The calculation used to measure the chloride ion concentration in the flour follows:

$$\text{meq. } Cl^- = \text{ml } AgNO_3 \times \text{N } AgNO_3$$

$$\text{g of } Cl^- = \text{meq. } Cl^- \times \left(\frac{.03546 \text{ g } Cl^-}{\text{meq. } Cl^-}\right)$$

$$\text{mg } Cl^-/g \text{ sample} = \frac{g\ Cl^-}{\text{wt. of samples in g}} \times \left(\frac{1000 \text{ mg } Cl^-}{g\ Cl^-}\right)$$

$$\text{mg } Cl^-/g \times 100 = \text{mg } Cl^-/100 \text{ g flour} \qquad (3)$$

The concentration of phosphorus was determined by ashing three, two-gram samples from each flour, four hours at 600°C. The ash was treated with 40 ml of concentrated hydrochloric acid (HCl), 0.5 ml concentrated nitric acid and 120 ml of deionized water. The solution was then brought to a boil. The solution was transferred to a 200 ml volumetric flask and diluted to volume with deionized water. An aliquot of sample containing 1.0 mg P was placed in a 100 ml volumetric flask. To this solution, 20 ml of molybdovanadate reagent were added and then the solution was diluted to volume with deionized water. The samples were allowed to stand ten minutes before reading the percentage absorbance at 400 nm on a Hitachi Spectrophotometer (model 100-60) against a 0.5 mg standard phosphorus solution (7). A phosphorus stock solution was prepared by dissolving 8.788 grams KH_2PO_4 in deionized water and diluting to one liter (2 mg P/mg). A working standard phosphorus solution was used to prepare a standard curve. This solution was prepared by diluting 50 ml stock solution to one liter (0.1 mg P/ml) (7). Aliquots of the standard solution containing 0.25, 0.50, 0.75, 1.00, 1.25, and 1.50 mg P/ml were placed in a 100 ml volumetric flask. To this solution,

20 ml of molybdovanadate reagent were added and the solution was diluted to volume with deionized water. The samples were allowed to stand ten minutes before reading the percentage absorbance at 400 nm on the spectrophotometer against a 0.5 mg standard phosphorus solution. The mg P/ml in the flour were determined from the linear regression line calculated from absorbance data from the known concentrations of phosphorus (7). To calculate mg P/100 g of flour the following equation was used:

$$\text{mg P/g} = \frac{(\text{mg P})}{\text{ml}} \left(\frac{200 \text{ ml}}{2 \text{ gram sample wt.}} \right)$$

$$\text{mg P/g} \times 100 = \text{mg P/100 g of flour} \qquad (4)$$

D. Water Holding, Oil Holding, and Emulsifying Capacities of the Peanut Hull Flour

The water holding, oil holding, and emulsifying capacities were determined on the Virginia- and Runner-type flours. Acetone dried flour was prepared from each type flour as follows: a 30-gram sample from each flour was washed with 300 ml of 40°C deionized water in a 500 ml beaker. The solution was filtered on a tared Gooch crucible and dried with an acetone rinse. The insoluble residue was washed free of soluble materials and protein. Three, one-gram samples from each flour were used to calculate the percentage loss of soluble material per gram of flour. Thus, four samples were tested: toasted Virginia-type hull flour

(TVHF), toasted Runner-type hull flour (TRHF), acetone-dried Virginia-type hull flour (ADVHF) and acetone-dried Runner-type hull flour (ADRHF) (55).

1. Water holding capacity (WHC). WHC of the dry material was determined on one gram samples of dry material under certain conditions of soaking, temperature, and centrifugation (20,21,55).

The capacity to hold water was determined by adding one gram of material to a 50 ml plastic centrifuge tube and an excess of deionized water (10 ml). The mixture was shaken by hand for one minute. The material was allowed to soak at 10°C, 37.8°C, and 65.6°C for 30, 90, and 150 minutes before centrifugation at 1000 × g for 60 minutes. The supernatant was discarded and the pellet weighed. The difference in weight between the wet and dry materials was defined as water holding capacity (20,21,54,55).

2. Oil holding capacity (OHC). OHC of the flours was determined in a manner silimar to that used for the water holding capacity determination, except vegetable oil (Wesson$^{T.M.}$ Oil) was used instead of deionized water. Sample size was 0.5 gram. The difference in weight between the bound oil and dry flour was calculated as oil-holding capacity of flour (16).

3. Emulsifying capacity (EC). The method of Webb et al. (83) was followed to determine EC. A blender jar with 250 ml capacity was used for emulsifying capacity determination. Two holes were drilled through the bottom of the plastic jar and copper electrodes were inserted. One larger hole was also drilled for the addition of oil. A one-gram sample of flour was blended into 30 ml of 5 percent NaCl solution for 30 seconds at 12,000 rpm. Then 20 ml of vegetable oil were added from a burettee and blended 30 seconds at 12,000 rpm. With continuous blending, oil was added slowly until the emulsion broke. The DC resistance increased sharply during emulsion breakdown. Emulsion breakpoint was measured by a volt-ohm meter (Micronta Multitester). The volume of oil was recorded and calculated as emulsifying capacity (ml oil/gram flour) (83). Three replicates were run for each flour type.

E. Cation Exchange Capacity (CEC)

The CEC was determined for flour of each type by the Helfferich method (35). Seven grams of oven-dried sample were converted to the hydrogen form by shaking with 250 ml of 2 N HCl for 16 hours in a stoppered Erlenmeyer flask. Five grams of the hydrated material were placed in a column (2.0 × 10.0 cm) and washed with 1000 ml deionized water to remove excess HCl. Water was passed through the column until the effluent became neutral. The material was

converted to the sodium form by passing 250 ml of 0.1 N NaOH through the column at 3-5 ml/min. Finally, 500 ml of deionized water were passed through the column to remove superfluous, nonbound sodium. The NaOH which did not react with the material was quantified by titration with 0.1 N HCl. The cation exchange capacity was calculated as:

$$CEC = \frac{100}{100 - w} \quad \frac{\text{meq. of NaOH - titrant used (meq.)}}{\text{wt. of hydrated material (g)}} \qquad (5)$$

where W = water content in weight percentage.

F. Aflatoxin Detection

A qualitative test was made on the flour for detecting the presence of aflatoxin. Three, 50-gram samples of toasted Virginia- and Runner-type hull flours were placed in a one-liter blender jar fitted with a screw cap, 100 ml of hexane were added, and the mixture was blended for one minute. A solution containing 100 ml of toluene-acetonitrile was added to the blender jar and blended for one minute. One ml of toluene-acetonitrile was added as the extracting solvent to millicolumns with a pipet. A vacuum was used to force the extract through the column rapidly while the aflatoxin remained on top of the column. A developing solution consisting of 97 parts chloroform, 2 parts methanol, 1 part acetone was prepared and 0.75 ml was added to column.

The millicolumns were prepared by packing with column-type silica gel (60-200 mesh). The columns were 90 mm long with glass wool plugs to hold the silica gel inside the glass tube. The glass tubing used was 6 mm I.D. × 200 mm.

The column was exposed under long wave ultraviolet light (365 nm) for the presence of aflatoxin, which is indicated by a sharp blue fluorescent band about 1 cm below the top of the column (38).

Standard columns were prepared using aflatoxin B_1 (Calbiochem-Behring Corp., LaJolla, California) to verify the method and to compare the columns prepared from both types of flour (38,39,79).

G. Fiber Analysis

1. Acid-detergent fiber (ADF) determination. The ADF method of Goering and Van Soest (29) was used to measure the amount of lignin and lignocellulose in the flour. One gram of vacuum-oven dried sample was weighed and placed into a 600 ml refluxing beaker. One hundred ml of cold (20°C) acid-detergent solution (20 grams of hexadecyltrimethyl-ammonium bromide in 1 liter 1.0 N sulfuric acid (H_2SO_4) were added to the beaker and the mixture was refluxed 60 minutes. The solution was filtered on a tared Gooch crucible set on the filter manifold. The filtered mat was broken up with a

glass rod while still in the crucible and washed twice with 90-100°C water. Washing was repeated with acetone until the filtrate was colorless. The ADF was dried at 100°C overnight, cooled in a desiccator, and weighed. ADF was calculated as:

$$ADF = (Wo - Wt)\ (100)/S \qquad (6)$$

where Wo = weight of oven-dry crucible including fiber;

Wt = tared weight of oven-dry crucible; and

S = oven-dry sample weight.

2. Acid detergent lignin (ADL) determination. ADL content (29) was determined on the ADF fraction previously described. One gram of asbestos (treated with 72 percent H_2SO_4 and ashed at 800°C) was added to the crucible containing the ADF. The contents of the crucible were covered with 72 percent H_2SO_4 (20°C) and stirred with a glass rod to form a smooth paste. The crucible was refilled with acid and stirred at hourly intervals as the acid drained. After three hours, the acid was drawn through the filter with the aid of vacuum and the filtered mat was washed with hot water until free of acid. The crucible and contents were dried at 100°C overnight, cooled in desiccator, and weighed. The crucible contents were ignited in a muffle furnace at 500°C for 2 hours, cooled to 100°C, and weighed. ADL was calculated as:

$$ADL = (L \times 100)/S \quad (7)$$

where L = loss upon ignition after 72 percent H_2SO_4 treatment; and

S = oven-dry sample weight.

3. Neutral-detergent fiber (NDF) determination. The flours were analyzed for amount of cell wall constituents by the NDF procedure (29). One gram of air-dried sample was weighed and placed into a 600 ml refluxing beaker. One hundred ml of cold (20°C) neutral-detergent solution (sodium lauryl sulfate, EDTA, pH 7) (29), 2 ml decahydronaphthalene, and 0.5 gram sodium sulfite were added to the beaker and the mixture was refluxed 60 minutes. The solution was filtered on a tared Gooch crucible set on the filter manifold. The filtered mat was broken up with a glass rod and washed twice with 90-100°C water. Washing was repeated with acetone until the filtrate was colorless. The NDF was dried at 100°C overnight, cooled in a desiccator, and weighed. The yield of NDF was expressed as a percentage of cell-wall constituents. An estimate of soluble cell material was made by subtracting this value from 100 percent. By ashing the residue in the crucible for three hours at 550°C, ash insoluble content in the neutral-detergent (NDF fraction) was determined.

4. Buffered acid-detergent fiber (BADF) determination. One gram of air-dried sample was weighed and placed into a 600 ml refluxing beaker. Seventy-five ml of buffered acid-detergent solution (20 g hexadecyltrimethylammonium bromide in 260 ml 0.2 M HCl and 1000 ml of 0.2 M potassium chloride, pH 2) (8) were added to the beaker and the mixture was refluxed 60 minutes. The solution was filtered through a tared Gooch crucible with an asbestos mat. The fiber was washed with 50 ml of boiling water followed with 25 ml of acetone. The BADF was dried at 110°C overnight, cooled in a desiccator, and weighed. BADF was calculated as:

$$\% \text{ BADF} = \frac{W_2 - W_1}{S} \times 100 \qquad (8)$$

where W_2 = dried weight of crucible, asbestos mat, plus fiber;

W_1 = dried weight of crucible and asbestos mat; and

S = oven-dried sample weight.

5. Cellulose and hemicellulose determination. The determination of cellulose was calculated by subtracting acid detergent fiber from the lignin content. The hemicellulose content was determined by subtracting the acid detergent fiber from the neutral detergent fiber (cell wall constituents).

H. pH Determination of Peanut Hull Flours

The pH was determined on four samples: TVHF, TRHF, ADVHF, and ADRHF.

One gram of the flour was weighed into a 50 ml beaker to which 25 ml of deionized water were added and allowed to stand for 30 minutes at room temperature with occasional agitation. The solids were allowed to settle. The pH was read on a Fisher Accumet pH meter (model 600) and recorded (5).

III. DETERMINATION OF COLOR OF PEANUT HULL FLOUR

Color measurements were made on peanut hull flour with a Hunter Color/Difference Meter (Model D25D2M, Hunter Associates Laboratory, Fairfax, Virginia). L, "a," and "b" values were recorded. The instrument was standardized against a standard beige tile (C2-138). The flour was placed into a cuvette with an optical glass bottom for color measurement. This procedure was replicated three times for each type of material measured: untoasted Virginia-type hull flour, untoasted Runner-type hull flour, toasted Virginia-type hull flour, and toasted Runner-type hull flour.

IV. SENSORY EVALUATION

The peanut hull flour was evaluated for taste and aroma by a panel of 12 people. The preference rating test

was used (49). The criteria for judgments were listed on the score sheet, Figure 1.

The scale used was an interval scale consisting of a horizontal line 15 cm long with anchor points 1.5 cm from each end. Each anchor point is labeled with an expression (Figure 1) (49). Each panelist recorded his/her evaluation by making a vertical line across the horizontal line at the point that best reflects his/her perception of taste or aroma (49). In addition, the preference for a specific sample was recorded for taste and aroma.

Numbers were assigned to the vertical lines made by the panelists and the data were analyzed statistically. Each panelist was provided approximately one gram of sample on a plastic spoon for taste evaluation. A test tube containing one gram sample was used for the aroma evaluation. Water was provided for rinsing the mouth between the tasting of samples. Testing was conducted between 10:00 and 11:00 a.m.

Samples were presented under red fluorescent light. The samples tested were similar to those used for color measurement. Three replications of the samples were evaluated on each of three separate days.

V. STATISTICAL ANALYSIS

All data, except for water holding capacity, oil holding capacity, sensory evaluations, and color measurements

Preference Rating Test

PLEASE READ: IF YOU DON'T UNDERSTAND, ASK QUESTIONS.

Product: Peanut flour Name: _____

Instructions: Please evaluate each sample for aroma and flavor by marking the horizontal line with a vertical line at a point to indicate your rating of each sample.

1. Aroma—You will receive the samples in a test tube. Take each sample, remove lid very quickly and sniff. Mark vertical lines on the horizontal line to indicate your rating of the aroma of each sample. Label each vertical line with the code number of the sample it represents.

Code numbers _____ _____ _____ _____

(bland) poor aroma — good (peanutty) aroma

Which do you prefer? _____
write in code number

2. Taste—You will receive the samples on a spoon, one at a time. Place entire spoon with flour in your mouth. Make vertical lines on the horizontal line to indicate your rating of the flavor of each sample. Label each vertical line with the code number of the sample it represents. Pull hatch for next sample.

Code numbers _____ _____ _____ _____

(bland) poor taste — good (peanutty) taste

Which did you prefer? _____
write in code number

Figure 1. Score sheet used for sensory evaluation.

were averaged and the means reported. The experiment for water and oil holding capacities was a factorial of a completely randomized block (4 × 3 × 3 × 3)—type of hulls used to prepare the flour, soaking period, temperature, and replication (41). The data were analyzed by analysis of variance using the Statistical Analysis System (SAS) of The University of Tennessee Computer Center (9).

The sensory evaluation and color data were analyzed by the SAS program. Where appropriate, significance among means was measured by Duncan's Multiple Range Test (9).

CHAPTER IV

RESULTS AND DISCUSSION

I. CHEMICAL ANALYSES OF PEANUT HULL FLOUR

A flour was prepared from the hulls of Virginia and Runner peanuts. One hundred grams of the hulls as received from the processor yielded, after the initial cleaning operation, 54.50 and 78.50 grams of Virginia and Runner hulls, respectively. The hulls used for the preparation of the flour produced a mean 27.50 grams of toasted Virginia hull flour (TVHF) and a mean 42.2 grams of toasted Runner hull flour (TRHF) per 100 grams of cleaned hulls. This flour passed an 80 mesh sieve (0.177 mm opening) and was used for further analyses.

The proximate composition of TVHF and TRHF is presented in Table III. The TVHF had 2.68 percent moisture, 6.74 percent crude protein, 0.83 percent ether extract, 2.94 percent ash, 47.33 percent crude fiber, and 39.34 percent nitrogen free extract. The TRHF contained 2.55 percent moisture, 7.19 percent crude protein, 0.52 percent ether extract, 2.07 percent ash, 47.23 percent crude fiber, and 40.33 percent nitrogen free extract.

The values agree fairly closely with published values for peanut hulls (11,74,75,86).

TABLE III

Amounts of Various Components of Flour Prepared from Toasted Peanut Hulls

Components, %	Toasted Virginia[a] Hull Flour	Toasted Runner[a] Hull Flour
Moisture	2.68 ± 0.33	2.55 ± 0.37
Crude Protein	6.74 ± 0.15 (6.88 ± 0.16)[b]	7.19 ± 0.11 (7.30 ± 0.11)[b]
Ether Extract	0.83 ± 0.02	0.52 ± 0.03
Ash	2.94 ± 0.06	2.07 ± 0.08
Crude Fiber	47.33 ± 0.59	47.23 ± 0.78
Nitrogen Free Extract	39.34 ± 0.23	40.33 ± 0.27

[a]Mean of 6 observations with ± one standard deviation and calculated on air dried basis.

[b]Values calculated on a dry matter basis.

Table IV presents the amounts (mg/100 g flour) of 14 elements assayed in the TVHF and TRHF.

The concentration of calcium in the TVHF and TRHF was found to be 361.84 and 401.33 mg/100 g, respectively. The recommended dietary allowance (RDA) for adults is 800 mg calcium/day (11,27). Peanut hull flour can, therefore, provide a significant amount of calcium to the human diet (80).

The amount of chloride present in both TVHF and TRHF was 7.10 mg/100 g. No RDA has been established for chloride in the diet.

TVHF and TRHF were found to contain 91.29 and 147.02 mg/100 g of potassium, respectively. No RDA has been set for potassium, although about 2.5 grams of the mineral are used by the body per day (18,66).

The magnesium concentration was 89.13 mg/100 g for TVHF, and 140.41 mg/100 g for TRHF. The RDA for magnesium is 300-400 mg/day (66).

The sodium content in TVHF and TRHF was 54.91 and 78.89 mg/g, respectively. No RDA has been established for sodium. A consensus among many nutritionists is that the American diet has too much sodium. A diet of 3-7 g/day is considered to be several times the daily requirement (18,66).

The concentration of phosphorus present in TVHF and TRHF was calculated from a standard curve represented by

TABLE IV

Amounts of Certain Elements of Flour
Prepared from Toasted Peanut Hulls

Element	Toasted Virginia-Type[a] Hull Flour (mg/100 g)	Toasted Runner-Type[a] Hull Flour (mg/100 g)
Macroelements:		
Calcium	361.84 ± 20.41	401.33 ± 11.29
Chloride	7.10 ± 0.10	7.10 ± 0.10
Potassium	91.29 ± 14.94	147.02 ± 1.39
Magnesium	89.13 ± 5.20	140.41 ± 6.11
Sodium	54.91 ± 9.46	78.89 ± 11.16
Phosphorus	687.25 ± 37.00	317.0 ± 6.00
Microelements:		
Chromium	0.27 ± 0.01	0.07 ± 0.01
Copper	19.16 ± 0.25	7.90 ± 2.29
Iron	35.62 ± 1.76	15.43 ± 0.65
Manganese	2.33 ± 0.13	3.27 ± 0.06
Zinc	9.84 ± 1.28	4.16 ± 0.56
Lead[b]	< 0.006 -	< 0.003 -
Aluminum	44.18 ± 3.82	20.37 ± 0.43
Molybdenum	0.12 ± 0.01	0.03 ± 0.01

[a]Mean value of triplicate determination for each element.

[b]Element below sensitivity limit of the instrument.

the equation Y = -0.0170 + 1.1661 x. The correlation coefficient was 0.9995. The x coordinate measured the absorbance while the Y coordinate measured the P mg/ml.

The amount of phosphorus found in TVHF and TRHF was 687.25 and 317.0 mg/100 g, respectively, which places the flours among the foods classified as fair sources of phosphorus such as beef and vegetables (46). The RDA for phosphorus is 800 mg/day (18,66).

The chromium content in TVHF and TRHF was 0.27 and 0.07 mg/100 g, respectively. There is no RDA established for chromium.

The results obtained for copper show 19.16 mg/100 g of copper in TVHF and 7.90 mg/100 g in TRHF. There is no RDA for copper, although 1.3-2.0 mg/day is generally recognized as being needed by adults (18,66).

The content of iron in TVHF and TRHF was found to be 35.62 and 15.43 mg/100 g, respectively. Both types of flour can be considered an excellent source of iron. The RDA for iron is 10-18 mg/day (18,66).

The manganese concentration found was 2.33 mg/100 g in TVHF and 3.27 mg/100 g in TRHF. A RDA has not been established for manganese, although 3-9 mg/g have been reported to be adequate.

The zinc concentration in TVHF and TRHF was found to be 9.84 and 4.16 mg/100 g, respectively. For a comparison,

the zinc concentration in nuts, cereals, and beans is reported to be in the range of 2-5 mg/100 g (66). The RDA for zinc is 15 mg/day (18,66).

The concentration of lead in both flours was below the sensitivity limit of the atomic absorption spectrophotometer. For this reason, no quantitative data for this element can be reported. This element causes lead toxicity in large doses. Lead has been found in high concentrations in plants and soils near highways due to discharges of lead from automobile engines, certain herbicides and pesticides. One cannot avoid eating traces of toxic elements found in our industrialized environment (66).

Aluminum and molybdenum are widely distributed in foods but in very small amounts. The microelement concentration is higher in the TVHF than in the TRHF. The nutritional needs for these elements are minute, and human deficiencies are not known. There is no information on the intake level of aluminum. A normal day's intake for molybdenum is about 0.1 to 0.4 mg/day. No RDA has been established for aluminum or molybdenum (44,66). The aluminum content in TVHF was 44.18 mg/100 g and in TRHF, 20.37 mg/100 g. The molybdenum content in TVHF was 0.12 mg/100 g and in TRHF, 0.03 mg/100 g.

Overall, the macroelements are in higher concentration in the TRHF. The differing concentrations of the elements

may be due to the varying soil conditions, the nutritional needs of the two species of peanut plants and the environmental conditions prior to processing and storage of the hulls at the shelling plant.

TVHF and TRHF yielded 7.64 percent and 9.06 percent soluble solids, respectively. By removing the soluble solids from the flour with deionized water and with an acetone rinse, a fibrous residue remained.

McConnell et al. (54) stated "The acetone-dried powder preparation (ADP) in certain respects would represent a form similar to that which would pass into the caecum, with disrupted anatomy and consisting of insoluble fibre." They attributed the ability of plant material to hold water in the human gastrointestinal tract to the water holding capacity of the ADP. They suggested that the ADP isolated from plant material would hold more water than the raw product.

Heller et al. (36) questioned this assumption and its physiological significance. They suggested that the water holding capacity be measured on a fresh weight or "as consumed" basis. ADP isolated from plant material would hold less water than the total, intact fresh material. This decrease in water holding capacity is attributed to the disruption of cellular structure and the loss of water soluble components.

The F-ratios from the analysis of variance for water and oil holding capacities are presented in Table V. The types of material measured were TVHF, acetone-dried Virginia hull flour (ADVHF), TRHF, and acetone-dried Runner-hull flour (ADRHF).

The water holding capacity was affected at the 0.01 level for the type of material, soaking time, and temperature (Table V).

The interactions for type of material × soaking time, type of material × temperature, and soaking time × temperature were significant at the 0.05 level. The interaction of type of material × soaking × temperature was significant at the 0.01 level.

The mean scores of water holding capacity for type of material, soaking time, and temperature are presented in Table VI. The mean water holding capacity values for type of material ranged from 3.12 to 2.93 g of water per gram of dry matter. TRHF ranked first in water holding capacity, binding 3.12 g of water per gram of dry matter. The ADRHF showed the least water holding capacity with 2.93 g of water per gram of dry matter. This agrees with the assumptions of Heller et al. (36) about ADP holding less water than a product on fresh weight or "as is basis." The mean water holding capacities for the acetone-dried fibers were lower than the TVHF and TRHF. Overall, the mean water

TABLE V

F-Ratios of Analysis of Variance for Water Holding Capacities and Oil Holding Capacities for Different Types of Materials Prepared from Peanut Hulls

Source	D.F.	Water Holding Capacity	Oil Holding Capacity
Total	107	---	---
A. Type of material	3	4.20**	68.33**
B. Soaking time	2	25.66**	2.40^{NS}
C. Temperature	2	75.58**	1.72^{NS}
A × B	6	3.04*	3.26**
A × C	6	2.42*	2.79*
B × C	4	3.21*	0.26^{NS}
A × B × C	12	3.19**	1.41^{NS}
RESIDUAL ERROR	72	0.052	0.023

*Significant at the 0.05 level.

**Significant at the 0.01 level.

^{NS}Not significant at the 0.05 level.

TABLE VI

Mean Values for Water Holding Capacity for Different Materials Prepared from Peanut Hulls

Type of Material		Soaking Time		Temperature	
Type	Grams Water/ Gram Flour	Minutes	Grams Water/ Gram Flour	°C	Grams Water/ Gram Flour
Toasted Virginia Hull Flour (TVHF)	3.08[ab]	30	3.00[b]	10	2.65[b]
Acetone-Dried Virginia Hull Flour (ADVHF)	2.97[ab]	90	2.84[c]	37.8	3.15[a]
		150	3.23[a]	65.6	3.28[a]
Toasted Runner Hull Flour (TRHF)	3.12[a]				
Acetone-Dried Runner Hull Flour (ADRHF)	2.93[b]				

[abc]Means within each variable not followed by the same letter are significant at the 0.01 level.

holding capacity increased in the materials as the soaking time and temperature were increased. TVHF and TRHF shows a greater water holding capacity than cereal and vegetable products such as maize, oatmeal, and potatoes (55).

The means for the interaction, type of material × soaking time × temperature, for water holding capacity are presented in Table VII.

The oil holding capacity was affected (0.01 level) by type of material. Specifically, the effect was due in part to a difference between the capacities of the TVHF and TRHF. The soaking time and temperature had no effect on the oil holding capacity. The interactions for type of material × soaking, and type of material × temperature were significant at the 0.01 and 0.05 level, respectively.

The mean scores of oil holding capacity for type of materials, soaking time, and temperature are presented in Table VIII. The mean oil holding capacity value for type of material ranged from 1.28 to 0.77 g vegetable oil per 0.50 g of dry matter. ADVHF and ADRHF ranked first in oil holding capacity, binding 1.21 and 1.28 g of oil per 0.50 g of dry matter, respectively. TRHF showed the lowest oil holding capacity, binding 0.77 g of oil per 0.50 g of dry matter. The means for oil holding capacity show a higher binding value for the acetone-dried fiber than the toasted flours. The means for oil holding capacity for

TABLE VII

Means[a] for Type of Material × Soaking Time × Temperature Interaction for Water Holding Capacity (grams water/1 gram flour)

Type of Material	Soaking Time (minutes)	Temperature, °C		
		10	37.8	65.6
Toasted Virginia Hull Flour (TVHF)	30	2.58	3.46	3.25
	90	2.65	2.65	2.92
	150	3.15	3.36	3.73
Acetone-Dried Virginia Hull Flour (ADVHF)	30	2.43	3.28	2.99
	90	2.10	3.08	3.46
	150	2.65	3.15	3.53
Toasted Runner Hull Flour (TRHF)	30	2.63	3.46	3.13
	90	2.85	2.81	2.98
	150	3.04	3.34	3.81
Acetone-Dried Runner Hull Flour (ADRHF)	30	2.54	2.90	3.31
	90	2.39	3.13	3.13
	150	2.76	3.13	3.08

[a]Means of 3 observations.

TABLE VIII

Mean Values for Oil Holding Capacity for Different Materials Prepared from Peanut Hulls

Type of Material		Soaking Time		Temperature	
Type	Grams Oil/ 0.5 Gram Flour	Minutes	Grams Oil/ 0.5 Gram Flour	°C	Grams Oil/ 0.5 Gram Flour
Toasted Virginia Hull Flour (TVHF)	0.92[b]	30	1.07[a]	10	1.08[a]
Acetone-Dried Virginia Hull Flour (ADVHF)	1.21[a]	90	1.00[a]	37.8	1.01[a]
Toasted Runner Hull Flour (TRHF)	0.77[c]	150	1.07[a]	65.6	1.04[a]
Acetone-Dried Runner Hull Flour (ADRHF)	1.28[a]				

[abc]Means within each variable not followed by the same letter are significant at the 0.01 level.

soaking time and temperature were not different. The means for the interaction, type of material × soaking time × temperature, for oil holding capacity are presented in Table IX.

The literature suggested that water holding capacity was a function of the cellulose and hemicellulose contents of the diet rather than the lignin or other components (18). It is hypothesized that the polysaccharide fraction which absorbs water and swells may have little capacity for absorbing organic materials such as bile acids (20).

The mean amounts of fiber for TVHF, ADVHF, TRHB, and ADRHF are presented in Table X. The acid detergent fiber (ADF) content is a measurement of lignocellulose. The ADVHF with 70.32 percent ADF had the highest amount of lignocellulose; TRHF with 58.76 percent of ADF had the lowest.

Acid-detergent lignin (ADL) content of the samples had a range of 3.76 percent. ADVHF possessed the highest lignin content with 28.28 percent and TVHF possessed the lowest content with 24.52 percent.

The buffered acid detergent content of the samples varied from 84.01 percent to 77.30 percent. The ADVHF had the highest amount of lignocellulose, while ADRHF had the lowest amount.

The means for the neutral detergent content of the samples for cell wall constituents varied from 81.94 to

TABLE IX

Means[a] for Type of Material × Soaking Time × Temperature Interaction for Oil Holding Capacity (grams oil/ 0.5 grams flour)

Type of Material	Soaking Time (minutes)	Temperature °C (mean grams) 10	37.8	65.6
Toasted Virginia Hull Flour (TVHF)	30	0.84	0.88	0.98
	90	0.96	0.82	0.88
	150	1.01	0.92	1.02
Acetone-Dried Virginia Hull Flour (ADVHF)	30	1.40	1.23	1.35
	90	1.30	1.14	1.10
	150	1.01	0.98	1.32
Toasted Runner Hull Flour (TRHF)	30	0.72	0.73	0.82
	90	0.81	0.73	0.74
	150	0.82	0.73	0.81
Acetone-Dried Runner Hull Flour (ADRHF)	30	1.45	1.39	1.05
	90	1.11	1.17	1.16
	150	1.54	1.44	1.21

[a]Means of 3 observations.

TABLE X

Mean Values for Fibrous Components of Different Materials Prepared from Peanut Hulls

Procedures for Fibrous Materials	Toasted Virginia Hull Flour[ab]	Toasted Runner Hull Flour[ab]	Acetone-Dried Virginia Hull Flour[c]	Acetone-Dried Runner Hull Flour[c]
Acid-Detergent Fiber for Lignocellulose	61.49 ± 0.60	58.76 ± 1.40	70.32 ± 0.54	61.72 ± 0.39
Acid-Detergent Lignin for Lignin	24.52 ± 1.02	26.47 ± 1.04	28.28 ± 0.39	25.22 ± 1.15
Buffered Acid Detergent for Lignocellulose	78.45 ± 0.99	78.26 ± 0.96	84.01 ± 1.02	77.30 ± 0.38
Neutral Detergent for Cell Wall Constituents	80.51 ± 1.64	77.63 ± 0.50	81.94 ± 0.76	76.57 ± 0.80
Soluble Cell Material in Neutral Detergent	21.41 ± 0.20	22.37 ± 0.50	18.06 ± 0.76	23.43 ± 0.80
Insoluble Ash in Neutral Detergent	2.51 ± 0.11	1.83 ± 0.10	2.10 ± 0.12	1.67 ± 0.20

TABLE X (continued)

Procedures for Fibrous Materials	Toasted Virginia Hull Flour[ab]	Toasted Runner Hull Flour[ab]	Acetone-Dried Virginia Hull Flour[c]	Acetone-Dried Runner Hull Flour[c]
Hemicellulose Determination	19.02 ± 0.50	18.87 ± 0.53	11.62 ± 1.13	14.86 ± 0.80
Cellulose Determination	36.97 ± 1.00	32.20 ± 1.00	42.04 ± 0.34	37.16 ± 0.81

[a]Values calculated on air-dried basis.

[b]Mean of 6 observations with ± one standard deviation.

[c]Mean of 3 observations with ± one standard deviation.

76.57 percent (Table X). The ADVHF had the highest amount of cell wall constituents while ADRHF had the lowest amount. The mean percentage of soluble cell material and insoluble ash in the neutral detergent fiber fraction are listed in Table X.

The means for hemicellulose determination varied from 19.02 percent to 11.62 percent. TVHF had the highest content, while ADVHF had the lowest content.

The amount of cellulose ranged from 42.04 to 32.20 percent. The ADVHF had the highest cellulose content, while the TRHF had the lowest content.

The acid detergent procedure produced higher mean values than the crude fiber (Table III, p. 38) determination. The buffered acid detergent determinations yielded higher values among the different flour materials than the acid detergent or crude fiber procedures.

The means show that the buffered acid detergent method does not remove as much cellulose from the samples as the other methods. The loss of cellulose is due to hydrolysis by sulfuric acid and sodium hydroxide used in the crude fiber procedure and by the 1.0 N sulfuric acid used in the acid detergent fiber method. The buffered acid detergent removes most of the starch and protein while breaking down very little of the cellulose. This method was developed in an effort to stimulate the conditions of the human digestive medium (7).

One can envision at least two reactions occurring with peanut hull flour when ingested into the gastrointestinal tract of man. Firstly, materials such as hemicellulose will absorb water and swell. Lignin, which is more hydrophobic, will not absorb water but will strongly absorb free bile acids. The other plant constituents of the plant fiber will exhibit reactions of various magnitudes between these two extremes (18).

Cation exchangers by common definition are soluble solid materials which carry exchangeable cations or anions. These ions can be exchanged for stoichiometrically equivalent amount of other ions of the same sign when the ion exchanger is in contact with an electrolyte solution (34,61). Helfferich (34) defined ion exchange capacity as the number of counter-ion equivalents in a specified amount of the material (meq./g dry matter). The cation-exchange capacities and pH measurements of peanut hull flours are presented in Table XI.

The cation ion-exchange values ranged from 1.01 to 0.91 meq./g of flour. The flour from the Virginia-type hulls had a slightly higher cation exchange capacity (1.01-1.00 meq./g) than similar flours of the Runner-type (0.97-0.91 meq./g). These values represent materials that are similar to weak cation exchange resins. The cation exchange capacity properties are mainly related to free carboxyl groups in

TABLE XI

Cation Exchange, pH, and Emulsifying Capacity of Flour Prepared from the Hulls of Virginia and Runner Peanuts

Types of Flour	Cation Exchange[a] Capacity (meq./g dry matter)	pH[a]	Emulsifying[a] Capacity (ml oil/gram dry matter)
Toasted Virginia Hull Flour	1.01 ± 0.03	5.5	25.60 ± 0.60
Acetone-Dried Virginia Hull Flour	1.00 ± 0.05	6.1	25.93 ± 0.83
Toasted Runner Hull Flour	0.97 ± 0.04	5.4	27.57 ± 0.91
Acetone-Dried Runner Hull Flour	0.91 ± 0.04	6.1	25.27 ± 0.90

[a]Mean of 3 observations with ± one standard deviation.

the hemicelluloses and lignin fraction (21). Thus, the peanut hull flour is capable of sequestering certain cations and anions. This would also depend on the chemistry of the fiber components. The pH values varied from 6.1 to 5.4. The acetone-dried material of both types of hulls had a pH of 6.1. The pH of the toasted flours was close to each other, ranging from 5.5-5.4. The absorption of water, minerals, and organic solvents by fibrous materials is pH dependent (21). This study did not attempt to correlate cation exchange capacities with pH of the materials.

The emulsifying capacity values of the peanut hull flours are presented in Table XI. Emulsifying capacity values ranged from 27.57 ml oil/g of flour to 25.27 ml oil/g of flour (dry basis). TRHF had the highest capacity, emulsifying 27.57 ml oil/g. ADRHF showed the lowest emulsifying capacity with 25.27 ml oil/g.

Feces consists of unabsorbed fiber, bacteria, water, and organic and inorganic substances in the form of an emulsion. Ershoff (26) suggested that the ability of fiber to form an emulsion would engulf some of the toxic materials in the mass and thus eliminate it from the gut. Thus, the emulsifying action of the fiber may remove harmful substances from the gut.

The gross energy determination and the net caloric content for TVHF and TRHF are presented in Table XII.

TABLE XII

Caloric Content of Flour Prepared from Hulls of Virginia and Runner Peanuts

Type of Flour	Gross Energy[a] Determination (Kcal/g)	Net Caloric[bc] Content (Kcal/g)
Toasted Virginia Hull Flour	4.574 ± 0.13	2.651
Toasted Runner Hull Flour	4.566 ± 0.20	2.604

[a]Mean value for 4 observations ± one standard deviation.

[b]Net caloric content calculated by subtracting the caloric value of protein, lipid, and nitrogen-free extract from the gross energy determination.

[c]The heats of combustion of the pure energy nutrients are 4.0 Kcal/g for protein and nitrogen-free extract and 9.0 Kcal/g for lipids.

The gross energy value from bomb calorimetry for TVHF and TRHF is 4.574 and 4.566 Kcal/g, respectively. The gross energy determination measures the three primary energy nutrients: carbohydrates, fats, and proteins. This was done by complete combustion in a bomb calorimeter (12).

The net caloric content, calculated by subtracting the caloric value of protein, lipid and nitrogen free extract from the gross energy determination, is 2.651 Kcal/g for TVHF and 2.604 Kcal/g for TRHF. The net caloric content is due to the unavailable carbohydrates which are not hydrolyzed by the intestinal secretions of man. The unhydrolyzable carbohydrates include the hemicelluloses, celluloses, lignin, and pectic substances (42,64,65). The factors used for the heats of combustion of the pure energy nutrients are 4.0 Kcal/g for protein and nitrogen free extract, and 9.0 Kcal/g for lipids (12,82).

The procedure of Holaday et al. (38,39) was used as a rapid screening method for the detection of aflatoxin on hulls of Virginia and Runner peanuts and their respective flours. The growth of Asperigillus flavus mold and the formation of aflatoxin usually occurs during the storage of the peanuts after removal from the soil. The detection technique was based on "millicolumn chromatrography." This method has a sensitivity for detecting the presence of aflatoxin at a level of 3-5 ppb. Aflatoxins were not

detected on either type of flour. The minicolumns showed no presence of a blue or bluish-green fluorescent band when exposed under long wave ultra-violet light which indicated presence of the toxin.

II. DETERMINATION OF COLOR OF PEANUT HULL FLOUR

The F-ratios of the analysis of variance for color of flour prepared from untoasted and toasted hulls of Virginia or Runner peanuts are presented in Table XIII.

The Hunter "L" values were affected by the type of flour (Virginia and Runner hull flours) and the treatment (untoasted and toasted) at the 0.01 level of significance. The interaction between the types of flour × treatment was affected at the 0.01 level.

The mean Hunter "L" values for Virginia and Runner hull flours are presented in Table XIV. Flour from Runner hulls was lighter. Toasting decreased the Hunter "L" value (causing darkening) of the flour. However, the small difference in the "L" values could not be observed with the eye.

The Hunter "a" values were affected (0.01 level) by type of flour, treatment, and type of flour × treatment (Table XIII). The mean Hunter "a" values (Table XV) for types of flour show very little redness in both samples. However, there was a significant difference between flour types at 0.01 level.

TABLE XIII

F-Ratios of Analysis of Variance for Color of Flour Prepared from Untoasted or Toasted Hulls of Virginia- or Runner-Type Peanuts

Source	D.F.	L	"a"	"b"
Total	11	---	---	---
A. Type of flour: Virginia vs. Runner	1	67.32**	81.00**	22.56**
B. Treatment: Untoasted vs. Toasted	1	105.19**	225.0**	0.06^{NS}
A × B	1	20.78**	36.0**	0.06^{NS}
Residual error (mean square)	8	0.064	0.003	0.013

^{NS}Not significant at the 0.05 level.

**Significant at the 0.01 level.

TABLE XIV

Mean Hunter L Values for Type of Flour and Treatment

Treatment	Type of Hull[1]		Treatment[2] (means)
	Virginia	Runner	
Toasted	62.70[ab]	63.23[a]	61.47[b]
Untoasted	60.53[c]	62.40[b]	62.97[a]
Type of Hull[2] (means)	61.62[b]	62.82[a]	

[abc]Means within each variable not followed by the same letter are significant at the 0.01 level.

[1]Means of 3 observations.

[2]Mean of 6 observations.

TABLE XV

Mean Hunter "a" Values for Type of Flour and Treatment

Treatment	Type of Hull[1]		Treatment[2] (means)
	Virginia	Runner	
Toasted	0.77[a]	0.87[a]	0.82[a]
Untoasted	0.07[c]	0.57[b]	0.32[b]
Type of Hull[2] (means)	0.42[b]	0.72[a]	

[abc]Means within each variable not followed by the same letter are significant at the 0.01 level.

[1]Mean of 3 observations.

[2]Mean of 6 observations.

The means for Hunter "a" show an increase in redness for toasting the flour. There was a significant difference between the treatments, toasted and untoasted flour, at the 0.01 level.

The type of hulls from which the flours were prepared had an effect (0.01 level) on the Hunter "b" value. The treatment and the interaction were not significant (Table XIII).

The means (Table XVI) for the types of flour show a difference at the 0.01 level for yellow coloration among the two flour types. Flour from Runner type hulls were the more yellow. There was no difference between toasted and untoasted flour. From a visual observation the flours were light brown or tan in color.

III. SENSORY EVALUATION

The F-ratios of the analysis of variance for panel evaluations of flavor by taste and aroma of TVHF, untoasted Virginia hull flour, TRHF, and untoasted Runner hull flour are presented in Table XVII.

The panelists did not prefer the flavor or aroma of any one of the types of flour over another. There was a difference (0.05 level) among panelists when scoring the flours for flavor. None of the other factors or interactions was significant in the evaluations of the flours.

TABLE XVI

Mean Hunter "b" Values for Type of Flour and Treatment

Treatment	Type of Hull[1]		Treatment[2] (means)
	Virginia	Runner	
Toasted	17.93[a]	18.23[a]	18.08[a]
Untoasted	17.93[a]	18.27[a]	18.10[a]
Type of Hull[2] (means)	17.93[b]	18.25[a]	

[abc]Means within each variable not followed by the same letter are significant at the 0.01 level.

[1]Mean of 3 observations.

[2]Mean of 6 observations.

TABLE XVII

F-Ratios of Analysis of Variance for Taste and Aroma Scores of Flour Prepared from Untoasted and Toasted Hulls of Virginia- and Runner-Type Peanuts

Source	D.F.	Taste	Aroma
Total	143	---	---
A. Type of Flour	3	1.21^{NS}	0.95^{NS}
B. Panelist	11	2.12*	1.13^{NS}
C. Reps (days)	2	0.23^{NS}	0.26^{NS}
A × B	33	0.49^{NS}	0.69^{NS}
A × C	6	0.60^{NS}	1.24^{NS}
Residual Error (Mean Square)	88	13.86	11.86

^{NS}Not significant at the 0.05 level.

*Significant at the 0.05 level.

Mean scores for taste and aroma are presented in Table XVIII. The scores ranged from 0.5 (bland) to 15.0 (peanutty) on the 15 cm scale (Figure 1, p. 35).

The data show no preference for toasted or untoasted types of flour on flavor and aroma. When individual panelists were asked for a preference for taste, 10 people or 31 percent chose toasted Runner hull flour as being the most flavorable. When individual panelists were asked for their preference of flour for aroma, 16 people or 44 percent chose untoasted Runner hull flour as having the highest aroma.

TABLE XVIII

Mean Values for Taste and Aroma for Different Types of Flour Prepared from Untoasted and Toasted Hulls of Virginia- and Runner-Type Peanuts

Type of Flour	Attributes[1]	
	Taste	Aroma
Untoasted Virginia Hull Flour	6.73[a]	6.25[a]
Toasted Virginia Hull Flour	5.80[a]	6.39[a]
Untoasted Runner Hull Flour	7.29[a]	7.26[a]
Toasted Runner Hull Flour	7.19[a]	7.30[a]

[a]Means within a column followed by the same letter are not significantly different at 5 percent level.

[1]A preference rating test using an interval scale consisting of a horizontal line 15 cm long with anchor points 1.5 cm from each end. Each anchor point is labeled, bland to peanutty.

CHAPTER V

SUMMARY

Little effort has been made to evaluate peanut hulls as a source of dietary fiber. Consequently, this study was undertaken to analyze a flour made from peanut hulls and to evaluate its potential as a source of dietary fiber.

Peanut hulls of the Virginia- and Runner-types were used in this study. A flour was prepared from the hulls to pass an 80-mesh seive (0.177 mm opening). Hulls produced a mean 27.50 grams of toasted Virginia-type hull flour (TVHF) and a mean 42.2 grams of toasted Runner-type hull flour (TRHF) per 100 grams of cleaned hulls.

The proximate composition of TVHF and TRHF was determined. The TVHF had 2.68 percent moisture, 6.74 percent crude protein, 0.83 percent ether extract, 2.94 percent ash, 47.33 percent crude fiber, and 39.34 percent nitrogen free extract. The TRHF contained 2.55 percent moisture, 7.19 percent crude protein, 0.52 percent ether extract, 2.07 percent ash, 47.23 percent crude fiber, and 40.33 percent nitrogen free extract.

Six macroelements and eight microelements were determined in TVHF and TRHF. The hull flours represent a potential source for calcium, phosphorus, and potassium.

The concentration of lead in both flours was below the sensitivity limit of the atomic absorption spectrophotometer.

TVHF and TRHF yielded 7.64 percent and 9.06 percent soluble solids. By removing the soluble solids from the flour with deionized water and acetone rinse, a fibrous residue remained. This influenced the water and oil holding capacity and the composition of the individual fibrous components.

The water holding capacity was affected by the type of materials, soaking periods, and temperature. The water holding capacities for washed, acetone-dried flours were lower than those of TVHF and TRHF. The water holding capacity increased as the soaking time and temperature increased.

The oil holding capacity was affected by the type of material, but it was not affected by soaking time and temperature. Oil holding capacity was higher for the washed, acetone-dried flours than for the toasted flours.

The fibrous components in TVHF and in TRHF were, respectively, 61.49 and 58.76 percent lignocellulose for acid detergent fiber, 24.52 and 26.47 percent lignin, 78.45 and 78.26 percent lignocellulose in buffered acid detergent, 80.51 and 77.63 percent cell wall constituents, 21.41 and 22.37 percent soluble cell material in neutral detergent, 2.51 and 1.83 percent insoluble ash in neutral

detergent, 19.02 and 18.87 percent hemicellulose, and 36.97 and 32.29 percent cellulose.

The washed, acetone-dried Virginia-type hull flour and the washed, acetone-dried Runner-type hull flour were, respectively, composed of 70.32 and 61.72 percent lignocellulose for acid detergent fiber, 28.28 and 25.22 percent lignin, 84.01 and 77.30 percent lignocellulose in buffer acid detergent, 81.94 and 76.57 percent cell wall constituents, 18.06 and 23.43 percent soluble cell material in neutral detergent, 2.10 and 1.67 percent insoluble ash in neutral detergent, 11.62 and 14.86 percent hemicellulose, and 42.04 and 37.16 percent cellulose.

The emulsifying capacity for one gram of flour ranged from 27.57 ml oil/g to 25.27 ml oil/g of dried sample of the toasted and washed, acetone-dried flours, respectively.

The cation ion exchange values ranged from 1.01 to 0.91 meq./g of dry sample weight. These values represent materials similar to resins of weak cation exchange capacity. The pH values of the toasted flours were close to each other, ranging from 6.1 to 5.4.

The gross energy values for TVHF and TRHF were 4.574 and 4.566 Kcal/g, respectively.

Aflatoxins were not detected in either types of flour.

The Hunter L, "a," and "b" color values were dependent on the type of flour (Virginia- vs. Runner-type flours) and the treatment (untoasted vs. toasted).

The sensory panel did not show a preference for toasted or untoasted flours when evaluated for taste or aroma.

REFERENCES

REFERENCES

1. A.A.C.C. 1976. "Approved Methods," American Association of Cereal Chemists. Vols. 1 and 2. St. Paul, Minn.

2. Anonymous. 1960. "Oxygen Bomb Calorimetry and Combustion Materials." Technical Manual 130, Parr Instrument Co. Moline, Ill.

3. Anonymous. 1975. Fiber—A new nutritional ingredient. Food Processing 36(1):24.

4. Anonymous. 1977. Dietary fiber as a binder of bile salts. Nutr. Rev. 35(7):183.

5. Anonymous. 1979. Dietary fiber. Food Technol. 33(1);35.

6. Antar, M. A., Ohlson, M. A., and Hodges, R. E. 1964. Changes in retail market food supplies in the U.S. in the last 70 years in relation to the incidence of coronary heart disease, with special references to dietary carbohydrates and essential fatty acids. Am. J. Clin. Nutr. 14:169.

7. A.O.A.C. 1975. "Official Methods of Analysis," 12th ed. Association of Official Analytical Chemists, Washington, D.C.

8. Baker, D. 1977. Determining fiber in cereals. Cereal Chem. 54(2);360.

9. Barr, A. J., and Goodnight, J. H. 1976. "A User's Guide to the Statistical Analysis System," Student Supply Stores, N.C. State University, Raleigh, N.C.

10. Bing, F. C. 1976. Dietary fiber in historical perspective. J. Am. Diet. Assoc. 69:498.

11. Birdsong, W. M. 1970. Peanut hulls—The growing need for new markets and research. J. Am. Peanut Research and Education Assoc. 2(1):39.

12. Bogert, L. J., Briggs, G. M., and Calloway, D. H. 1973. "Nutrition and Physical Fitness," W. B. Saunders Co., Philadelphia, Pa.

13. Burdick, D., Barton, F. E., and Amos, H. E. 1975. Performance of steers fed peanut hulls as roughage: weight gains and DDT residues. ARS-S-61. USDA. Washington, D.C.

14. Burkitt, D. P., Walker, A. R. P., and Painter, N. S. 1972. Effect of dietary fiber on stools and transit-times, and its role in the causation of disease. Lancet 2:1408.

15. Burkitt, D. P., Walker, A. R. P., and Painter, N. S. 1974. Dietary fiber and disease. J.A.M.A. 229:1068.

16. Childs, E. A., and Park, K. K. 1976. Functional properties of acylated glandless cottonseed flour. J. Food Sci. 41:713.

17. Childs, E., and Abajian, A. 1976. Physio-chemical characterization of peanut hull as a potential fiber additive. J. Food Sci. 41:1235.

18. Collins, J. L., and Sanchez, J. F. 1979. Effects of peanut shell flour on firmness, color and acceptance of peanut butter. J. Food Sci. 44:944.

19. Eastwood, M. A. 1969. Dietary fiber and serum lipids. Lancet 2:1222.

20. Eastwood, M. A. 1973. Vegetable fiber: its physical properties. Proc. Nutr. Soc. 32:137.

21. Eastwood, M. A. 1974. Dietary fiber in human nutrition. J. Sci. Fd. Agric. 25:1523.

22. Eastwood, M. A., Hamilton, T., Kirkpatrick, J. R., and Mitchell, W. D. 1973. The effects of dietary supple-nebts of wheat bran and cellulose on feces. Proc. Nutr. Soc. 32:20.

23. Eastwood, M. A., Anderson, R., Mitchell, W. D., and Robertson, J. 1976. A method to measure the absorption of bile salts to vegetable fiber of differing water holding capacity. J. Nutr. 106:1429.

24. Emmel, R. H., Sotera, J. J., and Stux, L. R. 1977. Atomic Absorption Manual—Standard Conditions for Flame Operation. Vol. 1. Instrumentation Laboratory, Inc., Wilmington, Me.

25. Ershoff, B. H. 1974. Anti-toxic effects of plant fiber. Am. J. Clin. Nutr. 27:1395.

26. Ershoff, B. H. 1974. Effects of diet on amaranth (FD and C Red No. 2) toxicity in the rat. J. Nutr. 104:937.

27. Ershoff, B. H. 1974. Nutritional effects of dietary fibers. J. Appl. Nutr. 26:22.

28. Galvao, L. C. A., Lopez, A., and Williams, H. L. 1976. Essential mineral elements in peanuts and peanut butter. J. Food Sci. 41:1305.

29. Goering, H. K., and Van Soest, P. J. 1970. Forage fiber analyses. Agriculture Handbook 379, USDA, Washington, D.C.

30. Hardinge, M. G., and Stare, F. J. 1954. Nutritional studies of vegetarians. II. Dietary and serum levels of cholesterol. Am. J. Clin. Nutr. 2:83.

31. Hardinge, M. G., Chambers, A. C., Crooks, H., and Stare, F. J. 1958. Nutritional studies of vegetarians. III. Dietary levels of fiber. Am. J. Clin. Nutr. 6:523.

32. Harris, H. D., and Bledsoe, R. W. 1951. "The Peanut—The Unpredictable Legume—A Symposium," The National Fertilizer Association, Washington, D.C. p. 89.

33. Harvey, R. F., Pomare, E. W., and Heaton, K. W. 1973. Effects of increased dietary fiber on intestinal transit. Lancet 2:1278.

34. Heaton, K. W. 1973. Food fiber as an obstacle to energy intake. Lancet 2:1418.

35. Helfferich, F. 1962. "Ion Exchange," McGraw-Hill Co., Inc., New York. p. 91.

36. Heller, S. N., and Hackler, L. R. 1977. Water-holding capacity of various sources of plant fiber. J. Food Sci. 42(4):1137.

37. Heller, S. N., and Hackler, L. R. 1978. Changes in the crude fiber content of the American diet. Am. J. Clin. Nutr. 31:1510.

38. Holaday, C. E., and Barnes, P. C. 1973. Sensitive procedure for aflatoxin detection in peanuts, peanut butter, peanut meal and other commodities. J. Agr. Food Chem. 21(4):650.

39. Holaday, C. D., and Lansden, J. 1975. Rapid screening method for aflatoxin in a number of products. J. Agr. Food Chem. 23(6);1134.

40. Holmgren, G. O. R., and Mynors, J. M. 1972. The effect of diet on bowel transit time. S. Afr. Med. J. 46:918.

41. Huntsberger, D. V., and Billingsley, P. 1977. "Elements of Statistical Inference." Allyn and Bacon, Inc., Boston, Mass.

42. Kelsay, J. L. 1978. A review of research on effects of fiber intake on man. Am. J. Clin. Nutr. 31:146.

43. Kelsay, J. L., Behalb, K. M., and Prather, E. S. 1978. Effect of fiber from fruits and vegetables on metabolic responses of human subjects I. Bowel transit time, number of defecations, fecal weight, urinary excretions of energy and nitrogen and apparent digestibilities of energy, nitrogen, and fat. Am. J. Clin. Nutr. 31:1149.

44. Keys, A., Anderson, J. T., and Grande, F. 1960. Diet type and blood lipids in man. J. Nutr. 70:257.

45. Kirwan, W. O., Smith, A. N., McConnell, A. A., Mitchell, W. D., and Eastwood, M. A. 1974. Action of different bran preparations on colonic function. Brit. Med. J. 4:187.

46. Kritchevsky, D. 1977. Dietary fiber: What it is and what it does. Food Prod. Dev. 11(5):111.

47. Kritchevsky, D., and Story, J. S. 1974. Binding of bile salts in vitro by non-nutritive fiber. J. Nutr. 104:458.

48. Kritchevsky, D., Tepper, S. A., and Story, J. A. 1974. Isocaloric, isogravic diets in rats III. Effect of non-nutritive fiber (alfalfa or cellulose) on cholesterol metabolism. Nutr. Reports Intern 9:301.

49. Larmond, E. 1977. "Laboratory Methods for Sensory Evaluation of Food," publication 1637. Canada Department of Agriculture, Ottawa.

50. Macleod, A. J. 1973. "Instrumental Methods of Food Analysis," Halsted Press, New York.

51. Mathur, K. S., Khan, M. A., and Sharma, R. D. 1968. Hypocholesterolaemic effect of Bengalgram; a long term study in man. Brit. Med. J. 1:30.

52. McCance, R. A., and Walsham, C. M. 1948. The digestibility and absorption of the calories, proteins, purines, fat and calcium in wholemeal wheaten bread. Brit. J. Nutr. 2:26.

53. McCance, R. A., Prior, K. M., and Widdowson, E. M. 1953. A radiological study of the rate of passage of brown and white bread through the digestive tract of man. Brit. J. Nutr. 7:98.

54. McConnell, A. A., and Eastwood, M. A. 1974. A comparison of methods of measuring "fibre" in vegetable material. J. Sci. Fd. Agr. 25:1451.

55. McConnell, A. A., Eastwood, M. A., and Mitchell, W. D. 1974. Physical characteristics of vegetable foodstuffs that could influence bowel function. J. Sci. Fd. Agr. 25:1457.

56. Mendeloff, A. I. 1975. Dietary fiber. Nutr. Rev. 33(11):321.

57. Moore, J. H. 1967. The effect of the type of roughage in the diet on plasma cholesterol and aortic atherosclerosis in rabbits. Brit. J. Nutr. 21:207.

58. Morrison, J. M. 1972. A semi-micro method for the determination of lignin and its use in predicting the digestibility of forage crops. J. Sci. Fd. Agric. 23:455.

59. Painter, N. S., and Burkitt, D. P. 1971. Diverticular disease of the colon: a deficiency disease of Western civilization. Brit. Med. J. 2:450.

60. Painter, N. S., Almeida, A. Z., and Colebourne, K. W. 1972. Unprocessed bran in treatment of diverticular disease of the colon. Brit. Med. J. 2:137.

61. Rasper, V. F. 1979. Chemical and physical properties of dietary cereal fiber. Food Technol. 33(1):40.

62. Samuelson, O. 1963. "Ion Exchange Separations in Analytical Chemistry," John Wiley and Sons, Inc., New York.

63. Scala, J. 1974. Fiber—the forgotten nutrient. Food Technol. 18:119.

64. Southgate, D. A. T. 1969. Determination of carbohydrates in foods. II. Unavailable carbohydrates. J. Sci. Food Agr. 20:331.

65. Southgate, D. A. T. 1973. Fibre and other unavailable carbohydrates and their effects on the energy value of the diet. Proc. Nutr. Soc. 32:133.

66. Southgate, D. A. T., and Durnin, J. V. G. 1970. Calorie conversion factor. An experimental reassessment of the factors used in the calculation of the energy value of human diets. Brit. J. Nutr. 24:517.

67. Spiller, G. A., and Amen, R. J. 1974. Role of dietary fiber in nutrition. Food Prod. Dev. 8(7):30.

68. Spiller, G. A., and Amen, R. J. 1975. Letter: Plant fibers in nutrition need for better nomenclature. Am. J. Clin. Nutr. 28(7):675.

69. Trowell, H. C. 1972. Crude fiber, dietary fiber and atherosclerosis. Atherosclerosis 16:138.

70. Trowell, H. C. 1972. Fiber: a natural hypocholesteremic agent. Am. J. Clin. Nutr. 25:464.

71. Trowell, H. C. 1972. Ischemic heart disease and dietary fiber. Am. J. Clin. Nutr. 25:926.

72. Trowell, H. C. 1973. Dietary fibre, ischemic heart disease and diabetes mellitus. Proc. Nutr. Soc. 32:151.

73. Trowel, H. 1976. Definition of dietary fiber and hypotheses that it is a positive factor in certain diseases. Am. J. Clin. Nutr. 29:417.

74. Utley, P. R., and McCormick, W. C. 1972. Level of peanut hulls as roughage source in beef cattle finishing diets. J. An. Sci. 34:146.

75. Utley, P. R., Hellwig, R. E., Butler, J. L., and McCormick, W. C. 1973. Comparison of unground, ground and pelleted peanut hulls as roughage sources in steer finishing diets. J. An. Sci. 37(2):608.

76. Van Soest, P. J. 1973. Feeds: collaborative study of acid detergent and lignin. J. Assoc. Offic. Agric. Chem. 56:4.

77. Van Soest, P. J., and McQueen, R. W. 1973. The chemistry and estimation of fiber. Proc. Nutr. Soc. 32:123.

78. Van Soest, P. J., and Robertson, J. B. 1977. What is fibre and fibre in food. Nutr. Rev. 35:12.

79. Velasco, J., and Morris, S. L. 1976. Use of water slurries in aflatoxin analysis. J. Agric. Food Chem. 24(1):86.

80. Vratanina, D. L., and Zabik, M. E. 1978. Dietary fiber sources for baked products in bran in sugar-snap cookies. J. Food Sci. 43(5);1590.

81. Walker, A. R. P. 1975. Effect of high crude fiber intake on transit time and the absorption of nutrients in South African Negro school children. Am. J. Clin. Nutr. 28:1161.

82. Watt, B. K., and Merrill, A. L. 1975. Composition of Foods. Agriculture Handbook 8, U.S.D.A., Washington, D.C.

83. Webb, N. B., Ivey, F. J., Craig, H. B., Jones, V. A., and Monroe, R. J. 1970. The measurement of emulsifying capacity by electrical resistance. J. Food Sci. 35:501.

84. William, R. D., and Olmsted, W. H. 1936. The effect of cellulose, hemicellulose and lignin on the stool: A contribution to the study of laxation in man. J. Nutr. 11:433.

85. Wilson, B. J., and Hayes, A. W. 1973. "Toxicants Occurring Naturally in Foods," National Academy of Sciences. Washington, D. C. p. 385.

86. Woodroof, J. G. 1973. "Peanuts: Production, Processing, Products," Avi Publishing Co., Westport, Conn.

87. Zekert, G. C. 1978. Private communication. Planters Peanuts, Suffolk, Va.

VITA

Alan Reed Post was born in New York City, New York, February 11, 1954. He attended John F. Kennedy High School in Silver Spring, Maryland; graduated June 1972; and entered the University of Maryland, College Park, in August 1972. In May 1977, he graduated from the University of Maryland, College Park, with a Bachelor of Science degree in food science and technology. In September 1977, he enrolled in the Department of Food Technology and Science at The University of Tennessee, Knoxville. In March 1979, he accepted a research assistantship in Food Technology and Science at the same institution. Since that time, he has been working to complete the requirements for the degree of Master of Science.