EFFECTS OF PLANT FIBERS ON THE QUALITY OF COOKIES

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CHAPTER I

INTRODUCTION

The nature of man's diet has changed markedly since life started millions of years ago. These changes have occurred as man became more modernized. This century has seen significant increase in protein and fat consumption, while total carbohydrate intake has decreased. At the same time, refined carbohydrates are depleted of many essential nutrients and dietary fiber. On the other hand, the unrefined carbohydrates in their natural form are rich in vitamins and other nutrients, and are the only source of dietary fibers. Data show that the consumption of fiber from cereals and grains has declined by as much as 50 percent, and fiber from fruits and vegetables has decreased by about 20 percent in this century (Scala, 1974).

In recent years, scientific research has focused attention on fiber and its role in human nutrition and health, and this research area continues to be the focus in many studies. There has been evidence that the low content of fiber in diets is related to many disorders, including coronary heart disease, diverticular disease, varicose veins, hiatus hernia, cancer of the colon, and obesity (Burkitt, Walker, and Painter, 1974). Burkitt, a British surgeon, called these disorders the western civilization diseases because of their rise in all economically developed countries.

The incidence of the diverticular disease is increasing in the United States (Scala, 1974). Clinical studies show that a high fiber diet, especially cereal fiber, is very effective in relieving the symptoms of the disease (Painter, Almeida, and Colebourne, 1972). It has been shown that diets high in fiber like wheat fiber lowers the blood cholesterol level and the mortality from coronary disease (Ranhotra, 1979). These studies have led to the introduction of several high fiber breads in the retail market. In addition, certain dietary fiber components have been added to other baked products to increase the fiber consumption (Pomeranz, Shogren, Finney, and Bechlel, 1977; Prentice, Kissell, Lindsay, and Yamazaki, 1978; Zabik, Shafer, and Kukorowski, 1977; Vratanina and Zabik, 1978; Gorczyca and Zabik, 1979). It appears that additional studies are needed on the incorporation of different types of natural fiber in baked products to evaluate its effect on the eating qualities, the properties and acceptability of the products.

Purpose and Objectives

The purpose of this study is to incorporate different types of plant fiber at different levels into a cookie system as an effort to increase its fiber content without altering the functional properties and eating qualities of the cookies. The objectives of the study are as follows:

1. To determine the effect of added different levels of high fiber peanut flour on the sensory and objective qualities of cookies.

2. To determine the effect of added different levels of high fiber citrus flour on the sensory and objective qualities of cookies.

3. To determine the effect of added different levels of beet fiber on the sensory and objective qualities of cookies.

4. To determine the effect of added different levels of asparagus fiber on the sensory and objective qualities of cookies.

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

Hypotheses

The following hypotheses were postulated for the study:

H_1: There will be no significant differences in the sensory and objective qualities of cookies when high fiber peanut flour was substituted for all-purpose flour in the basic formula at 0, 5, 10, and 15 percent by weight.

H_2: There will be no significant differences in the sensory and objective evaluations of cookies when high fiber citrus flour was substituted for all-purpose flour in the basic formula at 0, 3, 5, and 7 percent by weight.

H_3: There will be no significant differences in the sensory and objective evaluations of cookies when 0, 3, 5, and 7 percent of beet fiber was substituted for all-purpose flour by weight in the basic formula.

H_4: There will be no significant differences in the sensory and objective evaluations of cookies when 0, 3, 5, and 7 percent of asparagus fiber was substituted for all-purpose flour by weight in the basic formula.

Assumptions and Limitations

The following assumptions were made for this investigation:

1. A trained attribute panel will score the baked product as instructed.

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

Limitations identified in this study were as follows:

1. Only orange drop cookies will be used in the investigation.

2. Only four high fiber materials will be used.

   a. High fiber white skin peanut flour.

   b. High fiber citrus flour.

   c. Beet fiber.

   d. Asparagus fiber.

Definition of Terms

The following terms were utilized in this study:

Crude fiber - is what remained of plant cell-wall constituents after sequential extraction with ether, dilute acid, and dilute alkali. It is composed primarily of cellulose (Van Soest and McQueen, 1973; Cummings, 1976; Trowell, 1976).

Dietary fiber - is defined as the plant cell-wall materials that are resistant to the action of the human digestive system. It consists mostly of nondigestible carbohydrates, such as celluloses, hemicelluloses, pectic substances, gums, and mucilages; and also contains some noncarbohydrate substances such as lignin, plant lipids, nitrogenous compounds, and trace elements (Van Soest, 1978; Trowell, 1972, 1974; Southgate, 1977; Scala, 1974; Van Soest and Robertson, 1977).

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

Hemicelluloses - are components of the cell wall that consists of a wide variety of saccharide polymers which contain a mixture of pentose and hexose sugars (Spiller and Amen, 1976).

Pectic substances - are complex plant polysaccharides that are found in the middle lamellae, primary cell walls, and intercellular materials of most plants. The principal component of this complex is a polymer D-galacturonic acid in which the units are linked by B 1-4 glucosidic bonds (Spiller and Amen, 1976, Windholz, 1976).

Lignin - is a complex aromatic polymer that is very resistant to chemical degradation. The basic units of the polymer are joined by carbon-to-carbon bonds, unlike the glucosidic of the carbohydrates (Spiller and Amen, 1976).

Mucilages - are polysaccharide components that are extractable with water and possess water binding properties (Spiller and Amen, 1976).

Gums - are branched polymers of glucuronic and galacturonic acids with side branches of neutral sugars such as xylose, arabinose, and galactose, and are soluble in water (Windholz, 1976).

CHAPTER II

REVIEW OF LITERATURE

This chapter is a presentation of pertinent literature to provide an understanding of the scientific basis for the current increased interest in the role of dietary fiber. A review has been done on what might need to be accomplished in the development of a food system utilizing different types of plant fiber.

Fiber and Disease

Fiber, or "roughage" as grandparents referred to it in the past, is now more commonly called "dietary fiber." It had been neglected by nutritionists, and other than being considered as animal feed, the only significant use it has in the human diet is for the relief of constipation. Recently there has been renewed interest in the nutritional function of the fiber content of foods from plant origin in the human diet. This interest stems from the numerous scientific efforts and studies on the nutritional, chemical, and epidemiological nature of this complex material which has been reported during recent years.

Epidemiological observations by British investigators, who studied the geographical distribution of diseases, have proposed a relationship between the incidence of an array of various diseases ranging from diverticulosis and other gastrointestinal tract disorders to certain cardiovascular diseases and the over-consumption of refined carbohydrates, especially sugar and white flour (Burkitt, 1969; Burkitt et al., 1974; Trowell, 1972). They base their theory on the low or rare prevalence of these diseases in the developing countries of Africa where the consumption of dietary fiber is high, and the fact that the high occurrence of the diseases is in the western world where the dietary fiber intake is low.

Diverticular disease, which is characterized by inflamated protrusion lesions on the large intestine, was rare in Africa. Burkitt (1973 and 1977), Burkitt et al. (1972 and 1974), Painter (1969), Painter and Burkitt (1971) had described it as a deficiency disease of western civilization. They related its development to a low, dry stool and longer intestinal transit time which they stated was due to a low intake of dietary fiber. Painter (1973) reported that the inclusion of cereal fiber in the diet of patients with diverticulosis alleviated the symptoms of the disease.

Burkitt (1973) attributed hemorrhoids to the lack of dietary fiber in the diet, the consequent constipation, and the problem of strain to evacuate the lower bowel of food residues. In a study of transit time of food residues in 1200 people from different parts of the world, the authors concluded that the more refined the diet, the smaller and harder the stool and the longer the transit time (Burkitt et al., 1972).

In the seventies, cancer of the large bowel was one of the most common forms of malignancy and cause of death following lung cancer (Mayer, 1975). That was especially true in North America where the diet is high in animal fat and refined carbohydrates, but low in foods with high fiber content like whole grains, fruits, and vegetables. In contrast, cancer of the large bowel was rare in the rural African people, who consume great quantities of dietary fiber in their diet. Data on the consumption of crude fiber in the American diet between 1909 and 1975 indicated that the intake of fiber had declined (Heller and Hackler, 1978). Epidemiological evidence shows that the development of colon cancer is related to environmental factors, especially diet. It was also suggested that a small, hard, low-fiber stool, which moves at a slow speed through the intestines, leads to an increase in the number of the intestinal bacteria. These microorganisms break down the bile acids to carcinogenic compounds which might initiate cancer (Burkitt, 1971). A related research study suggested that a diet high in fiber may alter the composition of the intestinal bacteria and could possibly inhibit the production of potential carcinogens (Leveille, 1976). Eastwood and Hamilton (1968) showed that vegetable fiber can adsorb bile acids.

Atherosclerosis, a primary factor of most cardiovascular diseases in western countries, contributes to a high death rate of about 50 percent of middle aged men and older (Scala, 1974). The major characteristic of this disease is the deposition of different fatty materials in the arterial walls, mainly cholesterol. High blood cholesterol level is a high risk factor in the occurrence of atherosclerosis. Studies with humans and animals indicated that components of dietary fiber can reduce the circulating cholesterol levels significantly (De Groot, Luyken, and Pikaar, 1963; Mathur, Khan, and Sharma, 1968; Leveille and Sauberlich, 1966; Kritchevsky and Story, 1975). Other investigators concluded that the reduction in cholesterol level reduces the incidence of ischemic heart disease (Trowell, 1972). The fiber components bind bile acids which are needed for cholesterol absorption. The binding would inhibit the bile acid reabsorption, resulting in more conversion of cholesterol to bile acids, thereby the serum cholesterol level decreases; consequently, this lessens the incidence of atherosclerosis. Anderson and Chen (1979) indicated that including certain plant fibers in diabetic patients diets led to reductions in serum cholesterol levels and fasting serum triglycerides levels.

Diabetes has been linked to low fiber intake in some experimental studies. Brodribb and Humphreys (1976) claimed that dietary fibers may have a possible value in the prevention of diabetes. They observed that when wheat bran was added to the diet of diverticular disease patients, there was a decrease in their glucose tolerance curve. Similar reports showed that the addition of some fiber components to a carbohydrate meal decreased the blood glucose level in insulin-dependent diabetic patients (Jenkins, Goff, Leeds, George, Alberti, Wolever, Gassull, Derik, and Hockaday, 1976). In another study by Jenkins et al. (1978), it was observed that supplementing the diet of diabetic patients with guar crispbread led to a reduction in insulin dosage and glycosuria was also reduced for most of the patients. Other reports suggested that high carbohydrate, high-fiber (HCF) diets may be the right treatment for people with diabetes (Kiehm, Anderson, and Ward, 1976; Anderson et al., 1979).

Preliminary studies suggested that dietary fiber has an effect on controlling obesity. The continuous intake of a high-fiber bread in a weight reduction program for young men, helped them to maintain most of their weight loss during and after the program (Mickelsen, Makdani, Cotton, Titcomb, Colmey, and Gotty, 1979). This was explained by the fact that a high-fiber bread often contains fewer calories than normal bread; also it promotes an increased feeling of satiety and thereby reduces food consumption (Mrdeza, 1978).

Role of Fiber in Nutrition

Food fiber is a very complex substance which consists of several types of carbohydrates (cellulose, hemicellulose, pectins, mucilages, and gums) and lignin, a noncarbohydrate. It also contains small amounts of other constituents such as proteins, cutin, waxes, and other lipids. It has been suggested by Trowell (1974, 1976) that all these components collectively should be termed as dietary fiber or dietary fiber complex, and not be considered crude fiber which is mostly cellulose and some lignin. Crude fiber constitutes only about one-fifth to one-half of total dietary fiber (Scala, 1974). Therefore, the term dietary fiber is a more acceptable term than crude fiber in discussing the role of fiber in nutrition and health.

The composition and properties of plant fibers differ greatly depending on the plant type, species, and maturity. Bulk-density, hydration capacity, and binding capacity are some dietary fiber component properties which are of nutritional and physiological significance in the diet (Van Soest and McQueen, 1973; Eastwood and Mitchell, 1976; Schaller, 1977).

Cellulose, the major structural polysaccharide in the plant cell wall, has an important property in its bulk-inducing capacity. This fact was explained by the cellulose's great ability to absorb water, increase the human fecal weight, and subsequently improve the bowel function (Eastwood, 1973). It was postulated that different celluloses vary in the bulk-inducing properties according to their ability to absorb water; for instance, carrots are high in this respect (Bing, 1976). Fibers from strawberries and cucumbers have large water-holding capacity. Polymers of these fibers can hold more water than milk (Eastwood and Mitchell, 1974).

Hemicellulose, the cell-wall polysaccharide which is soluble in cold dilute alkali, has three important properties which could prove to be important in human physiology: capacity to hold water; capacity to bind ions; and digestibility. Hemicellulose is digested in the human gut to a greater extent than cellulose. Southgate and Durnin (1970) calculated the mean of digestion of both components as 87 and 2/10 percent and 29 and 4/10 percent for hemicellulose and cellulose, respectively. It was pointed out that hemicellulose is probably more readily broken down by the intestinal bacteria, thus forming compounds that could be absorbed and contribute energy to the body (Keys, Van Soest, and Young, 1969; Bing, 1976).

Pectin, a polysaccharide which is present in small amounts in the cell wall, and pectic substances are present in apple pulp (about 15 percent) and in the fluid of citrus (about 30 percent) (Spiller and Amen, 1976). The pectic compounds have the ability to form gel and the capacity to bind ions. Also, they are capable of altering cholesterol metabolism, and this property has received much attention in human nutrition. Studies with pectin and its effect on blood cholesterol level (Jenkins, Newton, Leeds, and Cummings, 1975; Truswell and Kay, 1975; Anderson, Grande, and Keys, 1973) showed a reduction in blood cholesterol level when a pectin supplement of between

15 and 35 g/day was taken. Furthermore, pectin was second to the reduction in dietary intake of cholesterol and fat in reducing the blood cholesterol level.

Plant gums and mucilages are neutral polysaccharides which are related to the cell wall constituents. They have similar properties to pectin in reducing the blood cholesterol level in man. A study by Jenkins, Newton, Leeds, and Cummings (1975) showed that these substances, especially guar-gum, are even more effective in lowering the blood cholesterol level than pectin.

Lignin is not a carbohydrate and is a highly insoluble component. It is present in the cell wall in smaller amounts than any of the other components. Lignin has a greater ion-binding capacity than any of the other types of fiber. It is capable of combining with bile-acids to form insoluble complexes which are not absorbed. As a consequence, there is an increase in bile acid fecal excretions, followed by lower cholesterol and fat absorption, and that leads to reduction in the cholesterol pool and perhaps less development of certain cardiovascular disorders (Bing, 1976). This property of lignin was also utilized in the treatment of diarrhea in patients following intestinal resection which involved bile acids (Eastwood and Girwood, 1968).

The variations, in the properties of dietary fiber components, has led to the need for the analysis of different plants and even the same plant at different ages, for their specific contents of fiber components. Methods for the determination of these components has been developed and modified for use with human foods (Southgate, 1969; Van Soest and Wine, 1967; Van Soest, 1973). These analytical methods show that fiber constitutes a significant part of many vegetables, fruits, and cereals. The research also show that these foods differ greatly in their relative contents of fibrous components. Unprocessed wheat bran was considered to be one of the richest sources of fiber (Bing, 1976). Table I shows the amount of dietary fiber in some plant materials contrasted to their crude fiber content. It was believed that by establishing a relationship between the chemical nature and physical properties and physiological behavior of dietary fiber through research, could help in estimating its biological qualities and values and lead researchers to the most effective sources of the dietary fiber which would be useful in formulating food systems enriched with these fibers (Rasper, 1979).

TABLE I

DIETARY FIBER AND CRUDE FIBER IN SELECTED FOODS (FRESH BASIS)*

Food	Total Dietary Fiber (%)	Crude Fiber (%)	Total Cellulose (%)	Non-cellulosic Polysaccharide (%)
Carrots (cooked)	3.7	1.0	1.48	2.22
Peas (raw)	7.8	1.2	2.1	5.3
Apple (flesh)	1.4	0.6	0.46	0.92
Strawberries (raw)	2.1	1.3	0.33	0.96
Flour (white wheat)	3.5	0.3	0.66	2.8
Flour (whole wheat)	11.0	2.3	2.2	7.9
Wheat bran	48.8	9.1	8.78	36.11
Peanuts	9.3	2.4	--	--

*Data from Ranhotra (1979) and Anonymous (1979).

Fiber in Baked Products

The increased interest in the role of fiber in nutrition led to the introduction of several high fiber breads in the retail market. Moreoever, it appears to be very acceptable by the consumer (Anonymous, 1977). According to this information, and to the fact that most of the flours and cereal products which are consumer in the United States came from wheat products (USDA, 1964), it is feasible that these products could provide suitable carriers for dietary fiber components, which can be used in the development of high quality baked products, and subsequent increase in the consumption of fiber.

Recently, a number of studies have been conducted to evaluate the effect of different types and levels of fiber on the physical characteristics and the quality of various baked products. Some of the fibrous materials used in these experiments were in their natural form, like wheat bran, while others were different types of pharmaceutical, purified, and modified celluloses. These celluloses and wheat brans have been incorporated successfully in breadmaking (Pomeranz, Shogren, Finney, and Bechtel, 1977), except that the loaf volume decreases with the addition of cellulose or wheat bran by more than seven percent. Cellulose has also been added to cake and biscuit systems to reduce their caloric value while increasing the fiber content (Brys and Zabik, 1976). The incorporation of cellulose produces higher quality cake than biscuits at the same level of addition. Zabik, Shafer, and Kukorowski (1971), and Gorczyca and Zabik (1979) incorporated the same type of cellulose products that had been used by Pomeranze et al. (1977) in a standard white layer cake and sugar-snap cookies to test the feasibility of increasing the dietary fiber content in it. Subjective and objective analyses of these baked products indicate few significant differences among cakes containing any type of the celluloses used at a substitution level of 36 percent of the cake flour. The addition of cellulose coated with 15 percent pectin produced a higher scoring cake than the 30 percent coated cellulose. At the 10 percent level of substitution, high quality cookies were produced with some differences in physical parameters; however, the increase in dietary fiber was feasible.

Wheat bran of different varieties, levels, and combinations were incorporated in various baked products in an attempt to increase the dietary fiber content of the products. The addition of bran and middlings at four and eight percent substitution levels of flour in a white layer cake formula produced cakes that rated as good as the control (Brockmole and Zabik, 1976). Substitution of 70 percent flour with wheat bran in another layer cake system significantly increased batter viscosity, reduced cake volume, and was less acceptable (Springsteen, Zabik, and Shafer, 1977). Cakes with 30 percent bran substitution, however, were acceptable. The bran with smaller particle size produced higher scoring cakes. Shafer and Zabik (1978) tested the effects of different varieties and types of brans on layer cake quality. Thirty percent of the flour was substituted with two varieties each of hard red and soft white wheat bran, commercial wheat bran, corn bran, soy bran, and oat bran. Cakes made with corn bran and all types of wheat bran were acceptable; however, oat and soy bran substitution produced cakes with poor flavor.

The feasibility of producing high fiber sugar-snap cookies was investigated by Vratanina and Zabik (1978). They indicated that substitution of 10 percent red and white wheat bran contributed 7/10 g with 30 percent substitution. Sensory data revealed that bran affected only surface and interior color at 10 and 20 percent substitution levels. Flavor was adversely affected at the 30 percent substitution level. However, in a later study the same researchers concluded that oatmeal cookies, in which 50 percent of the flour was replaced with either red or white wheat bran, were higher in fiber content and were well liked and accepted by a higher percentage of a consumer panel, since the oatmeal flavor of the cookies masked the flavor of bran (Vratanina and Zabic, 1980).

Recent attention was given to some industrial waste by-products, which were high in fiber content, and their possible use to increase fiber consumption. Brewer's spent grain, the main by-product of the brewing industry, is high in fiber because of the barley bran and husk, and also contains appreciable amounts of proteins. It was used in the production of high fiber bread and cookies (Prentice and D'Appolonia, 1977; Prentice et al., 1978). Consumer panels accepted favorably the bread made with brewer's spent grain in flour replacement at five and ten percent levels. Crude fiber and acid-detergent fiber were approximately doubled with 10 percent substitution. Organoleptic evaluations of the cookies showed that 15 percent incorporation of brewer's spent grain led to a three-fold increase in dietary fiber and was in an acceptable range. However, the physical qualities of the product were acceptable with 40 percent substitution.

Data showed that peanut hulls are one of the by-products which could have a potential as a fiber additive (Childs and Abajian, 1976; Collins and Post, 1981). Studies indicate that dried, ground peanut hulls have an acceptable flavor and color, are very high in dietary fiber components, and have physical-chemical characteristics which would produce a desirable effect on human nutrition and health (Childs and Abajian, 1976). Peanut flour, incorporated in some baked products to increase the protein content, showed an increase in the dietary fiber contents of these products and were highly acceptable (Sproul, 1975).

CHAPTER III

RESEARCH PROCEDURES

A review of related literature indicated the need for further studies about the supplementation of baked products with various natural fibrous materials from different sources such as fruits, vegetables, and grains. As a result, this study was developed to determine the effects of types and levels of plant fibers on the sensory and objective qualities of drop cookies. The research design, attribute panel selection and training, instrumentation, data collection, and data analyses will be outlined in this chapter.

Research Design

Experimental type of research which took place in the food research laboratory under controlled environmental conditions was conducted to test the hypotheses, employing type and levels of fiber materials as the independent variables. Samples of different treatments with four types of plant fibers at four different levels were evaluated subjectively and objectively. A 4 x 4 latin square design (Federer, 1955) was applied since the laboratory experimentations were mainly concerned with the comparison of four treatments or varieties. Latin square design controls more of the variation and often results in a small error mean square. Each of the four 4 x 4 standard latin squares was selected for each type of fiber used, then the columns and rows of each square which represent the replicates and the locations in the oven of the different treatments from each fiber used were arranged at random. Also, four replications for each treatment were made since the experimental design requires as many replicates as treatments.

Attribute Panel Selection and Training

Product evaluation took place in a sensory evaluation room adjacent to the preparation area of the food research laboratory. The room was well lighted, ventilated, and equipped with separate carrels.

Sensory evaluation by a trained attribute panel was used to measure and characterize differences in shape, color, flavor, cell distribution, and other qualities of the experimental cookies (Amerine et al., 1965 and Carlin and Harrison, 1978). Eleven panelists were selected for their ability and consistency in recognizing differences between cookie samples in preliminary tasting experiments.

The 11 panel members consisted of three males and eight females. Four panelists were faculty members in the departments of plant pathology; statistics; and food, nutrition and institution administration at Oklahoma State University. The remaining seven were departmental secretaries and graduate students who have previously been involved in sensory evaluation of other baked products.

Training sessions were held prior to taste panel evaluation to acquaint the 11 panel members with the orange drop cookies sensory evaluation card, and with the basic characteristics of the product (Appendix). These sessions also assured accuracy and reliability of the panel members in detecting differences.

Instrumentation

Instruments from previous research by Lee, Rust, and Reber (1969) and Vratanina and Zabic (1978) were examined and an evaluation instrument was developed according to the need and objectives of the study (Appendix). Dimensions in the developed instrument included surface appearance, interior appearance, and eating characteristics of the product. Members of the Food, Nutrition and Institution Administration graduate faculty evaluated and approved the instrument. The difference in each characteristic evaluated was determined by rank order. No ties were allowed. Each judge received four randomized coded samples of cookies with four different levels of substitution during each period of the 16 sensory evaluation sessions. These samples were ranked against each other on a scale of 1 to 4, with 1 being the closest to the basic criteria and 4 the farthest from the criteria descriptions. Rank order was used for the evaluation to allow the comparison of all replications of each experiment, to simplify the work of the panel members, and to eliminate errors caused by different scoring levels used by the different judges (Carlin and Harrison, 1978).

Data Collection

Prentice et al. (1978) and Vratanina and Zabik (1978, 1979) have demonstrated the feasibility of cookies as carriers of dietary fiber. In addition, preliminary experiments showed that cookies were preferred over muffins and yeast bread relative to the complexity of procedures and time element. For these reasons, cookies were chosen as the baked product in the four experiments in this study.

Materials

All-purpose flour was used in all experiments. Asparagus fiber, beet fiber, and high fiber citrus flour were substituted for the flour on a weight basis at zero, three, five, and seven percent in the first, second, and third experiments, respectively. Zero, five, ten, and fifteen percent of high fiber peanut flour replaced the all-purpose flour on a weight basis in the fourth experiment.

The plant high fiber sources were obtained from commercial companies and the United States Department of Agriculture (USDA). Asparagus fiber was prepared and received in a tiny flake-like form from the Larsen Company, Green Bay, Wisconsin. It was used as it is in the flour replacement. Beet fiber was also obtained from the Larsen Company and received in the form of large and small dark colored granules which were ground into tiny particles before use. High fiber citrus flour was prepared and provided by Ben Hill Griffin, Incorporated, Frost Proof, Florida. It is specially processed orange and grapefruit pulp with sesame flour added as an antihygroscopic agent or to prevent the flour from caking or clumping. Defatted white skinned peanut flour was prepared from three white skinned spanish peanut varieties, C-32W, SR-57, which were grown in Georgia, and the Pearl variety that was grown in Texas. All three varieties were extracted with hexane, dried, and ground to a flour in the Engineering and Development Pilot Plant of the Southern Regional Research Center, USDA, Science and Education Administration (SEA), Agricultural Research (AR), New Orleans, Louisiana. These peanut flour samples were also analyzed for microbial content by the Central Analytical Laboratories, Incorporated and were found to be bacteriologically safe. Fiber analysis of these peanut flour varieties and the other high fiber materials used in the experiments are shown in Table II. The high fiber peanut flour (C-32W variety) was used in this study. All other common ingredients were purchased from a local supermarket.

TABLE II

FIBER ANALYSIS OF VARIOUS FIBER SOURCES*

Fiber Source	Neutral Detergent Fiber (NDF) (%)	Acid Detergent Fiber (ADF) (%)	Lignin (%)	Cellulose (%)	Hemi-Cellulose (%)
White skinned peanut flour (C-32W)	10.36	7.93	1.315	5.675	2.43
White skinned peanut flour (SR-57)	11.60	7.80	1.18	6.045	3.80
White skinned peanut flour (Pearl)	10.21	8.20	0.680	6.605	2.01
Citrus flour	20.55	23.49	0.655	21.85	2.94
Beet fiber	49.12	38.02	2.71	34.99	11.1
Asparagus fiber	77.50	54.75	10.32	44.56	22.75

*Fiber analyses were conducted in a chemistry laboratory at Oklahoma State University.

Preliminary Experiment Procedures

The standard formula (Table III) used for cookies was adapted from an orange drop cookie recipe in a cookbook (Betty Crocker's New Picture Cookbook, 1961). Through the preliminary experiments, different levels of substitution were chosen on the basis of certain characteristics of the cookies such as flavor, texture, and desirability.

TABLE III

FORMULA FOR COOKIES

Ingredient	Weight (grams)
Shortening	29.5
Granulated sugar	39.0
Eggs	13.5
Orange juice	30.0
Vanilla	1.5
All-purpose flour	65.3
Baking powder	0.5
Baking soda	0.6
Salt	0.7

Preliminary experiments also indicated some modifications needed to be done to the basic formula. The amount of leavenings were reduced to 0.6 grams of baking soda and 0.5 grams of baking powder. The amount of liquid (orange juice) in the basic formula had to be increased by two grams for each substitution level of three and five percent for the flour from each of the citrus flour, beet fiber, and the asparagus fiber; and increased by five grams for the seven percent substitutions for the flour from each of these fiber sources. Also, there was five grams of increase in the orange juice for the peanut flour substitution level of 15 percent for the flour. These changes were made for optimal dough handling and for obtaining cookies from the different levels of substitution closest in appearance to the standard cookies.

Experimental Proceudres

One cookie formula (Table III) provided 15 control cookies with diameter size of approximately 4.5 cm. For each experiment, four replications were made over a period of four days of the control and of a certain variable with three different substitution levels for the all-purpose flour.

A day prior to the preparation of the cookies for each replicate, four portions of flour plus leavenings and salt for a control and each of three substitution levels, and also three portions of the fiber material needed for each level of substitution were weighed to the nearest 0.01 gram on a Mettler PC 4400 digital top loading balance. All portions were sealed separately in clear polyethylene bags, marked, and placed in an upright institutional refrigerator (Hobart Model H1) until preparation time the following morning. Ingredients for the creamed mass were weighed in the morning of each experimental day. Shortening, granulated sugar, and egg were creamed for about two minutes at medium to high speed in a Kitched Aid mixer, Model K45. The bowl and beater were scraped down and then the orange juice and vanilla were added and blended for another 60 seconds at a slower speed.

Four portions of that creamed mass, each weighing around 112.4 grams, were transferred to four separate glass mixing bowls. Each of the four batches of the dry ingredients, after being brought to room temperature, were then added to a creamed mass portion and mixed until well blended (about 60 hand strokes). Afterward, the mixture in each bowl was portioned into 15 cookies by using a #70 dipper. Each batch of 15 cookies was placed on a coded ungreased 15 x 10 x 1 inch aluminum cookie sheet. The four batches of cookies were then baked at the same time for eight minutes in a preheated, institutional type electric deck oven (General Electric, Model CN50) at 400°F. Cookies were cooled for a few minutes on wire racks before being placed on plates for sensory evaluation.

Four replications of cookies containing one type of high fiber material were completed before another series of cookies were started. In the first experiment, four replications of cookies with 0, 5, 10, and 15 percent of the all-purpose flour substituted with high fiber peanut flour were prepared and evaluated subjectively for a period of four days. The amount of peanut flour needed for each substitution was sifted with the dry ingredients (flour, leavenings, and salt) of each treatment, then was added to the creamed mass. For the 15 percent substitution an extra five grams of liquid (orange juice) was added to the creamed mass and blended well before the addition of the dry ingredients.

The next three series of experiments were done with three other types of high fiber sources: citrus flour, beet fiber, and asparagus fiber. Each of these fiber materials was used individually in replacement of 0, 3, 5, and 7 percent substitutions of all-purpose flour. For each type of fiber, four replications of cookies with each of these percentages of substitutions were prepared and evaluated subjectively for a period of four days. In the second experiment, each of the percentage substitutions with citrus flour was sifted with the dry ingredients before being added to each of the creamed mass. An additional two grams of liquid (orange juice) were added to the creamed mass for each of the 3 and 5 percent substitutions before adding the dry ingredients. Another five grams of liquid were added to the creamed mass of the 7 percent substitution of the same fiber flour. For the third experiment, each amount of the 3 and 5 percent replacements of beet fiber for the flour was placed separately in two grams of extra liquid (orange juice) to be softened somewhat for two or three minutes, then was added to the creamed mass for each to be blended and softened further before adding the dry ingrdients. The same was done for the 7 percent replacement of the beet fiber, except that five extra grams of liquid was used instead of two grams.

In the last and fourth experiment, two more grams of liquid were added and blended into each of the creamed masses for the 3 and 5 percent flour substitutions with the asparagus fiber. Then the percentages of the fiber were added afterwards to be soaked into the creamed mass for about five minutes before adding each amount of the dry ingredients. Also, this was done with the 7 percent substitution of this fiber with the addition of an extra five grams of liquid instead of two grams.

A total of 16 baking periods were covered during these experiments. Sixty cookies divided into four batches were prepared and baked at the same time during each period. The 15 cookies in each batch represented a different substitution level. Cookies with four substitution levels were placed in the oven to be baked in a randomized order based on the treatment. Four coded cookies, each from different substitution levels, were presented on white plates to every member of the trained panel consisting of 11 judges for sensory evaluation. The arrangement of the samples presented to the panelists was done by random variation (Table IV). Distilled water was provided to the judges for rinsing the mouth between samples. The four cookies remaining from each substitution level were sealed after cooling into four marked transparent polyethylene bags and stored in the freezer to be used for objective evaluation.

Randomly chosen cookies of different substitution levels from each experiment were evaluated objectively. Tenderness by shear force (kg/g) was determined by using the Instron Universal Testing Machine (Model 1122). Tenderness was also determined in cm^2/g by measuring the area under the peak using a Li-Cor Area Meter (Model 3100). The exterior appearances for the different substitution levels of cookies from each experiment were recorded by photographic means.

Data Analyses

Data were analyzed using the Statistical Analysis System (SAS) (Barr and Goodnight, 1972). For the sensory evaluation data, Friedman Tests on Rank Analysis and Chi-square tables were used to determine any significant differences between samples at .05, .01, and .001

levels of significance (Conover, 1980). Analysis of Variance (ANOVA) and the Least Significant Difference test (LSD) (Snedecor and Cochran, 1973) were used to determine if any significant differences existed between means of the objective evaluation data.

TABLE IV

EXAMPLE OF ONE DAY RANDOM VARIATIONS FOR SAMPLE PRESENTATION TO JUDGES

Judge	Treatments (% Substitutions)			
1	5*	0	10	15
2	15	10	0	5
3	0	5	15	10
4	0	5	15	10
5	10	5	0	15
6	10	0	5	15
7	0	15	10	5
8	15	5	0	10
9	5	0	10	15
10	15	10	0	5
11	0	5	15	10

*A set of codes was used each experiment day such as α, ∞, ?, and X to represent percent substitution or treatment levels.

CHAPTER IV

RESULTS AND DISCUSSION

Four types of plant fibers were incorporated at four levels into an orange drop cookie formula to increase the fiber content of the cookies while maintaining its nutritional and eating qualities. The cookies were evaluated subjectively by an 11 member trained attribute panel for physical attributes and eating properties. Objective tests performed included determinations of tenderness by shear force (kg/g) and by measurement of the area under the peak (cm^2/g), exterior appearances by means of photography, and the fiber contents of cookies were also calculated. This chapter presents the data analyses of the sensory and objective tests of cookies with plant fiber added and those without plant fiber.

Sensory Evaluation of Cookies

Cookies with four types and four levels of substitutions were subjectively evaluated by ranking for surface appearance, interior appearance, and eating characteristics. To test the sensory evaluation portions of hypotheses 1, 2, 3, and 4 (Chapter I, p. 3), analysis of variance was performed for each characteristic investigated, the Friedman test on rank analysis, and Chi-square tables were used to establish statistical differences among means at various levels of probability.

Peanut Flour

Substitution of the peanut flour at 5, 10, and 15 percent for the all-purpose flour in the formula of orange drop cookies did not affect the surface appearance parameters which include shape, top crust, and exterior color (Table V). There were no significant differences among all levels of substitution with the peanut flour in regard to these parameters. The interior appearance of the cookies, including cell distribution, shape and size of cells, and the interior color, were not significantly affected by increasing levels of peanut flour substitution, except for the interior color (Table V). Data analysis showed no significant differences between all levels of substitution for cell distribution and the shape and size of cells of the cookies. The Friedman rank analysis revealed significant differences ($p<0.001$) for interior color between the 0, 5, 10, and 15 levels of substitution with peanut flour (Table V). The trend of the ranking indicated that eating characteristics were significantly decreased as the level of peanut flour substitution increased. The data analysis showed significant differences ($p<0.001$) in flavor between 5, 10, and 15 percent fiber substitution in cookies, as well as between the control cookies and each of the cookies with the other three different substitution levels. Similar results were also obtained in regard to mouthfeel and eating quality of cookies at all levels. In spite of the rank analysis results, most of the panelists indicated that the cookies with 5, 10, and 15 percent of all-purpose flour substituted with peanut flour were similar in eating quality and appearances to the control cookies except for the greenish color and a little objection to a raw peanutty taste of cookies with the 15 percent of peanut flour.

TABLE V

MEANS AND CHI-SQUARE VALUES FOR SENSORY EVALUATIONS[a] OF ORANGE DROP COOKIES PREPARED WITH DIFFERENT PERCENTAGES OF THE FLOUR SUBSTITUTED WITH HIGH FIBER PEANUT FLOUR

Substitution Level of Fiber (%)	Mean Ranks[b]: Surface Appearance			Interior Appearance			Eating Characteristics		
	Shape	Top Crust	Exterior Color	Distribution of Cells	Shape & Size of Cells	Interior Color	Mouthfeel	Flavor	Eating Quality
0	2.61	2.64	2.57	2.00	1.98	1.34	1.29	1.29	1.27
5	2.66	2.61	2.57	2.34	2.52	2.27	2.43	2.34	2.41
10	2.43	2.25	2.41	2.70	2.66	3.09	3.04	3.09	3.07
15	2.29	2.48	2.45	2.95	2.84	3.32	3.23	3.27	3.25
x^2[c]	2.24	2.49	0.52	13.83	10.96	63.72	60.25	63.95	63.35

[a]Means and Chi-square values of four replications.

[b]The means are of ranking values of 1, 2, 3, and 4 in which 1 is the closest to the basic criteria and 4 is the furthest from the criteria.

[c]Tabulated Chi-square with df=3; $x^2_{.05}=7.815$ $x^2_{.01}=11.34$ $x^2_{.001}=16.27$

Citrus Flour

In the second experiment, high fiber citrus flour was substituted for the all-purpose flour in the orange drop cookie formula at levels of 3, 5, and 7 percent by weight. Data analysis (Table VI) revealed significant differences ($p<0.001$) between the citrus flour levels of substitution in cookies for the shape and top crust parameters of surface appearance. But no significant differences were noted between any of the flour substitution levels of cookies for the exterior color parameter (Table VI). The interior appearance of the cookies which includes the cell distribution, shape and size, and the interior color, were observed to be affected by increased levels of substitution of the all-purpose flour with the citrus flour. There were significant differences ($p<0.001$) in these parameters between the 3, 5, and 7 percent levels of substitution and also between each of these levels and the control. Evaluation of eating characteristics were decreased with the increase in the fiber substitution levels. The data analysis showed significant differences ($p<0.001$) between 3, 5, and 7 percent substitution levels of citrus flour in regard to mouthfeel, flavor, and the eating quality of the cookies, as well as between the control cookies and cookies with each of these substitutions (Table VI). Nevertheless, most of the panel members liked the noticeable citrus flavor accompanying the increase in citrus flour level; however, they objected to the bitter aftertaste, especially in the cookies with seven percent substitution. The panel also described the cookies with highest substitution as being doughy or soggy, more mounded, and smaller in size than those with less substitution or the standard. Most of the

TABLE VI

MEANS AND CHI-SQUARE VALUES FOR SENSORY EVALUATIONS[a] OF ORANGE DROP COOKIES PREPARED WITH DIFFERENT PERCENTAGES OF THE FLOUR SUBSTITUTED WITH HIGH FIBER CITRUS FLOUR

Substitution Level of Fiber (%)	Mean Ranks[b]								
	Surface Appearance			Interior Appearance			Eating Characteristics		
	Shape	Top Crust	Exterior Color	Distribution of Cells	Shape & Size of Cells	Interior Color	Mouthfeel	Flavor	Eating Quality
0	1.98	2.00	2.39	1.77	1.70	1.32	1.54	1.43	1.39
3	2.31	2.22	2.40	2.49	2.64	2.64	2.57	2.33	2.35
5	2.53	2.60	2.42	2.46	2.56	2.72	2.58	2.84	2.77
7	3.18	3.18	2.79	3.27	3.09	3.32	3.29	3.43	3.50
x^2[c]	20.48	21.24	3.09	29.76	26.57	56.37	41.09	56.73	61.55

[a]Means and Chi-square values of four replications.

[b]The means are of ranking values of 1, 2, 3, and 4 in which 1 is the closest to the basic criteria and 4 is the furthest from the criteria.

[c]Tabulated Chi-square with df=3; $x^2_{.05}=7.815$ $x^2_{.01}=11.34$ $x^2_{.001}=16.27$

panelists actually liked the sweet orangy taste of the cookies with lower substitution of citrus flour than the control cookies.

Beet Fiber

The third experiment was completed by incorporating beet fiber into the orange drop cookie formula at 3, 5, and 7 percent levels of substitution for the all-purpose flour based on weight. The shape and top crust of the cookies were affected by the increase in the level of fiber substitution where significant differences ($p<0.001$) were detected in shape between all levels of substitution, and between the control and these levels (Table VII). Friedman rank analysis for top crust appearance revealed significant differences ($p<0.01$) among the cookies with all these substitutions. Definite significant differences ($p<0.001$) were noted for the interior and exterior colors of cookies between the 3, 5, and 7 percent levels of substitution with beet fiber, and between these levels and the control (Table VII). The cell distribution and the shape and size of cells of cookies at 3, 5, and 7 percent substitution with the fiber were decreased with the increase in the fiber substitution level. Significant differences ($p<.001$) among all substitution levels and also between them and the control cookies were noted for the distribution of cells. Also, significant differences ($p<0.05$) between 0, 3, 5, and 7 percent levels of substitution were revealed for the shape and size of cells of the cookies (Table VII). The rank analysis showed significant differences ($p<0.001$) in the eating characteristics of cookies with the different levels of substitution. As the level of beet fiber substitution increased, the mouthfeel, flavor, and eating quality of the cookies decreased. In spite of these results,

TABLE VII

MEANS AND CHI-SQUARE VALUES FOR SENSORY EVALUATIONS[a] OF ORANGE DROP COOKIES PREPARED WITH DIFFERENT PERCENTAGES OF THE FLOUR SUBSTITUTED WITH BEET FIBER

Substitution Level of Fiber (%)	Mean Ranks[b]								
	Surface Appearance			Interior Appearance			Eating Characteristics		
	Shape	Top Crust	Exterior Color	Distribution of Cells	Shape & Size of Cells	Interior Color	Mouthfeel	Flavor	Eating Quality
0	1.84	1.95	1.16	1.89	2.00	1.09	1.57	1.34	1.39
3	2.09	2.41	2.09	2.32	2.48	2.07	2.25	2.27	2.14
5	3.02	2.70	3.09	2.84	2.75	3.14	2.82	2.93	3.00
7	3.04	2.93	3.66	2.95	2.77	3.70	3.36	3.45	3.48
χ^2[c]	30.95	14.10	06.57	19.34	10.23	106.34	46.94	65.81	68.05

[a]Means and Chi-square values of four replications.

[b]The means are of ranking values of 1, 2, 3, and 4 in which 1 is the closest to the basic criteria and 4 is the furthest from the criteria.

[c]Tabulated Chi-square with df=3; $\chi^2_{.05}$=7.815 $\chi^2_{.01}$=7.815 $\chi^2_{.001}$=16.27

the panelists noted that the taste of cookies substituted with beet fiber at the different levels was very acceptable and had more flavor. Some panelists actually liked them better than the control cookies. They also did not object to the specks of fiber which appeared in the cookies. Few panelists mentioned, however, that beet fiber may cause a problem for denture wearers due to "grittiness." The panelists also suggested the addition of ground nuts, poppy seeds, or chocolate chips to the cookies with the beet fiber to mask its presence in the cookies.

Asparagus Fiber

The fiber material which was used in the fourth experiment was asparagus fiber. The fiber was substituted for all-purpose flour in the orange drop cookie formula at 0, 3, 5, and 7 percent levels. The substitutions did affect all the cookie criteria evaluated by the panel members (Table VIII). The sensory evaluations of the shape, top crust, and exterior color of the cookies with the different variations revealed significant differences ($p<0.001$) between all levels of substitution (Table VIII). The interior appearance parameters which includes the cell distribution, shape and size, and the interior color, were also affected by the different levels of fiber substitution, especially the interior color of the cookies. Data analysis for these three parameters showed significant differences ($p<0.001$) between cookies with all levels of substitution. The ranking of the cookie with the different treatments by the judges indicated significant decrease in the eating characteristics. Friedman rank analysis showed significant differences ($p<0.001$) in mouthfeel, flavor, and

TABLE VIII

MEANS AND CHI-SQUARE VALUES FOR SENSORY EVALUATIONS[a] OF ORANGE DROP COOKIES PREPARED WITH DIFFERENT PERCENTAGES OF THE FLOUR SUBSTITUTED WITH ASPARAGUS FIBER

Substitution Level of Fiber (%)	Mean Ranks[b]								
	Surface Appearance			Interior Appearance			Eating Characteristics		
	Shape	Top Crust	Exterior Color	Distribution of Cells	Shape & Size of Cells	Interior Color	Mouthfeel	Flavor	Eating Quality
0	2.07	1.95	1.48	1.93	1.95	1.14	1.39	1.37	1.34
3	2.16	2.07	2.20	2.02	2.18	1.90	1.95	1.98	1.98
5	2.75	2.82	2.86	2.70	2.82	3.18	2.98	3.04	3.02
7	3.02	3.16	3.45	3.39	3.04	3.77	3.68	3.70	3.66
χ^2[c]	16.85	26.92	57.46	36.37	21.05	113.35	83.48	93.14	85.36

[a]Means and Chi-square values of four replications.

[b]The means are of ranking values of 1, 2, 3, and 4 in which 1 is the closest to the basic criteria and 4 is the furthest from the criteria.

[c]Tabulated Chi-square with df=3; $\chi^2_{.05}=7.815$ $\chi^2_{.01}=11.34$ $\chi^2_{.001}=16.27$

the eating quality between cookies with fiber substitution levels of 0, 3, 5, and 7 percent of the flour in the cookie formula (Table VIII). Most of the judges showed no objection, however, to the flavor of the substituted cookies. Some described the texture of the cookies with higher fiber level as moist and chewy or dry and tough. The appearances of the fiber particles in the cookies was not acceptable to many members of the panel.

Objective Evaluation of Cookies

Objective tests were performed on the experimental cookies with all types and levels of fiber substitution. Tests included determinations of tenderness by shear force (kg/g), and by area measurement under the peak (cm^2/g) using the Universal Testing Instrument No. 1122 and the Area Meter No. 3100. Physical appearances and diameters (cm) of the cookies were recorded by photography. Cookies with different types and levels of fiber were chosen randomly from all replications to complete these evaluations. The fiber content of a standard orange drop cookie and each of the experimental cookies were also calculated using available fiber values (Tables I and II). To test the objective evaluation portions of hypotheses 1, 2, 3, and 4 (Chapter I, p. 3), Analysis of Variance (ANOVA) and the Least Significant Difference Test (LSD) were used to determine if there were any significant differences between means at various levels of probability.

Tenderness Evaluation

Tenderness of cookies was measured by the amount of shear force (kg/g) required to break one gram of cookie. Tenderness was also determined by measuring the area under the peak (cm^2/g).

Peanut Flour. Cookies with 0, 5, 10, and 15 percent substitution levels of peanut flour were evaluated for tenderness. Both the force required to shear the cookies, and the measured area under the peak increased as the substitution levels of fiber increased (Table IX). Cookies with 15 percent peanut flour required the highest shear force (5.44 kg/g). Also, the area measurement under the peak for the same level of substitution was largest (1.04 cm^2/g) (Table IX). The LSD values for the peak force showed significant differences ($p<0.01$) between cookies with 15 percent substitution and each of the cookies with 0, 5, and 10 percent substitution levels. There were also significant differences ($p<0.1$) in shear force between the 5 percent level of substitution and the standard. The LSD values for the area under the peak measurements showed significant differences ($p<0.01$) between the 15 percent and each of the standard and 10 percent substitution levels. Also, significant differences ($p<0.05$) between the 15 percent and 5 percent substitution levels of peanut flour was indicated (Table IX). This evaluation indicated a more crisp, less tender cookie as the level of fiber substitution increased, especially in the 15 percent level.

Citrus Flour. Tenderness was measured for orange drop cookies with citrus flour incorporated at 0, 3, 5, and 7 percent substitution levels. The mean values of shear force and of the measured areas under the peak increased with the increase in the fiber substitution

(Table X). The shear force and the area under the peak values were highest for the cookies with 5 percent substitution. The LSD values showed significant differences ($p<0.1$) between the 5 and 3 percent levels and ($p<0.05$) between the 5 percent and the control. There was significant difference ($p<0.1$) between the cookies with 7 percent substitution level and the control (Table X). These results suggest less tender cookies produced with the higher levels of fiber substitution, particularly at the 5 percent level.

TABLE IX

TENDERNESS EVALUATIONS[a] OF ORANGE DROP COOKIES PREPARED WITH DIFFERENT PERCENTAGES OF ALL-PURPOSE FLOUR SUBSTITUTED WITH PEANUT FLOUR

	Tenderness	
Substitution Level (%)	Peak Force (kg/g)	Area Under the Peak (cm^2/g)
0	2.65	0.62
5	3.68	0.77
10	3.54	0.70
15	5.44	1.04
F value[b]	8.20	6.49
$LSD_{.10}$	1.02	0.18
$LSD_{.05}$	1.25	0.22
$LSD_{.01}$	1.76	0.30

[a]Means are based on four replications.

[b]Degrees of freedom (d.f.) for denominator=12; and d.f. for numerator=3.

TABLE X

TENDERNESS EVALUATIONS[a] OF ORANGE DROP COOKIED PREPARED WITH DIFFERENT PERCENTAGES OF ALL-PURPOSE FLOUR SUBSTITUTED WITH CITRUS FLOUR

Substitution Level (%)	Tenderness	
	Peak Force (kg/g)	Area Under the Peak (cm^2/g)
0	2.45	0.59
3	2.89	0.69
5	3.44	0.84
7	3.15	0.75
F value[b]	4.29	3.75
$LSD_{.10}$	0.52	0.14
$LSD_{.05}$	0.63	0.17
$LSD_{.01}$	N.S.[c]	N.S.

[a]Means are based on four replications.

[b]Degrees of freedom (d.f.) for denominator=12; and d.f. for numerator=3.

[c]No significance.

Beet Fiber. The incorporation of beet fiber in the cookie formula at 0, 3, 5, and 7 percent substitution levels of the all-purpose flour did not affect the shear force and the areas under the peak values for the cookies at all levels of substitution, except at the 5 percent level (Table XI). The LSD values indicated significant differences ($p<0.1$) in the peak force between cookies with 5 percent and each of the cookies with 0 and 3 percent substitution levels. There were also significant differences ($p<0.1$) in the measured areas under the peak between the 5 percent and each of the 0, 3, and 7 percent substitution levels (Table XI). The peak force and the area under the peak did not change with increasing the fiber levels at 3 and 7 percent, indicating the production of cookies which are as tender as the control (0 percent fiber).

TABLE XI

TENDERNESS EVALUATIONS[a] OF ORANGE DROP COOKIES PREPARED WITH DIFFERENT PERCENTAGES OF ALL-PURPOSE FLOUR SUBSTITUTED WITH BEET FIBER

Substitution Level (%)	Tenderness: Peak Force (kg/g)	Tenderness: Area Under the Peak (cm^2/g)
0	2.83	0.69
3	2.86	0.68
5	3.44	0.77
7	3.04	0.67
F value[b]	3.33	2.99
$LSD_{.10}$	0.39	0.07
$LSD_{.05}$	N.S.[c]	N.S.
$LSD_{.01}$	N.S.	N.S.

[a]Means are based on four replications.

[b]Degrees of freedom (d.f.) for denominator=12; and d.f. for numerator=3.

[c]No significance.

Asparagus Fiber. Orange drop cookies with asparagus fiber at 0, 3, 5, and 7 percent substitution levels were evaluated for tenderness. The shear forces and areas under the peak values were increased significantly with each increase in the added fiber levels (Table XII). The 7 percent substitution level of fiber had the highest shear force and highest for area under the peak values, while the control cookies had the lowest values for both measurements. The LSD values for shear force indicated significant differences ($p<0.01$) between the 7 percent and each of the 0 percent and the 3 percent substitution levels, and between the 0, 3, and 5 percent levels. There was also significant difference ($p<0.1$) between the cookies with 5 percent and 7 percent substitution levels, and ($p<0.05$) between the 3 and 5 percent substitution levels of fiber (Table XII). The LSD values for the areas under the peak measurements showed significant differences ($p<0.01$) between 7 percent and each of the 0 and 3 percent levels, and ($p<0.05$) between 7 percent and 5 percent. The same level of significance existed between the 3 percent and the control. Significant difference was ($p<0.01$) indicated between the 0 and 5 percent levels of substitution; however, there was no significant difference between the 3 and 5 percent levels of substitution (Table XII). These evaluations showed definite increases in the shear force required to break the cookies, as well as increased areas under the peak with the increase in the fiber levels, which indicated that the higher the fiber levels, the more crisp and less tender the cookies.

Photography

Exterior Appearance. Cookies with different types and levels of fibers were chosen randomly from all replications for black and white photographs to show their exterior appearance and diameter measurements (Figure 1). Variations in appearance were insignificant; however, the cookies tended to be smaller in diameter as the substitution levels increased for the cookies with asparagus fiber, beet fiber, and citrus flour.

TABLE XII

TENDERNESS EVALUATIONS[a] OF ORANGE DROP COOKIES PREPARED WITH DIFFERENT PERCENTAGES OF ALL-PURPOSE FLOUR SUBSTITUTED WITH ASPARAGUS FIBER

Substitution Level (%)	Tenderness	
	Peak Force (kg/g)	Area Under the Peak (cm^2/g)
0	2.51	0.93
3	4.57	1.44
5	5.73	1.72
7	6.69	2.38
F value[b]	26.18	19.58
$LSD_{.10}$	0.88	0.34
$LSD_{.05}$	1.08	0.41
$LSD_{.01}$	1.52	0.58

[a]Means are based on four replications.

[b]Degrees of freedom (d.f.) for denominator=12; and d.f. for numerator=3.

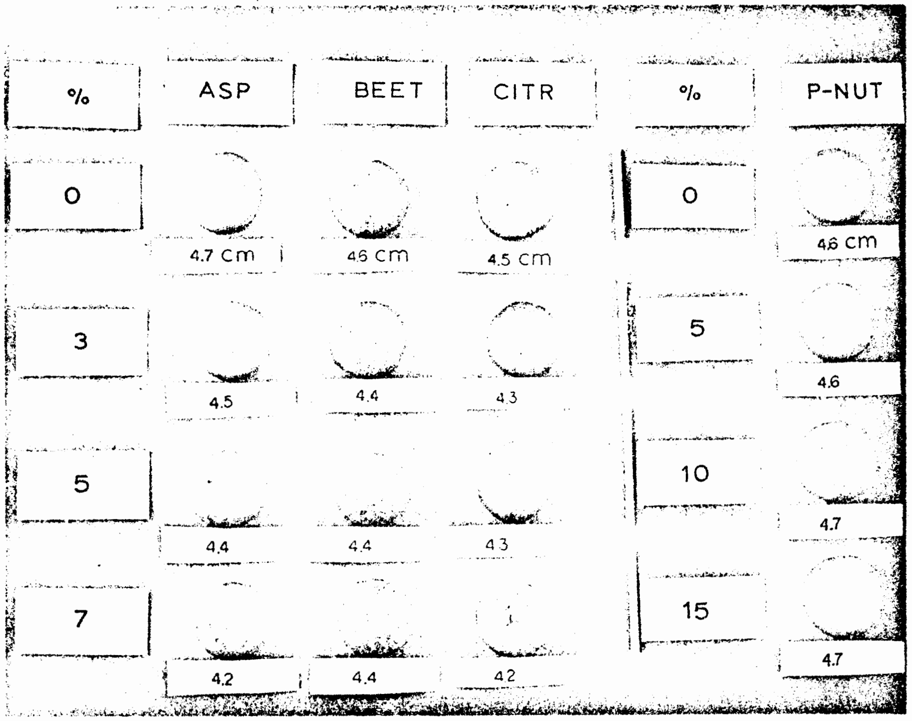

Figure 1. Exterior Appearance of Drop Cookies Prepared With Increasing Levels of Different Plant Fibers Substituted for Flour. The Number Under Each Cookie Indicates the Diameter in Centimeters.

Fiber Content of the Baked Product

The main objective of this study was to increase the fiber content in cookies by substituting various types of plant fibers at different levels. Hence, the levels of dietary fiber in the experimental fiber substituted cookies were calculated (Table XIII). The dietary fiber content in cookies was calculated from the proportion of each fiber substituted at the different levels for the all-purpose flour in the cookie formula, in addition to the proportion of all-purpose flour used for each treatment.

The calculations were based on a dietary fiber content of 3.5 percent in the all-purpose flour (Table I), and on the dietary fiber content of the various fiber sources used in this study (Table II). Substituting 15 percent of the all-purpose flour in the cookie formula with peanut flour increased the amount of dietary fiber in a cookie with an average weight of 9 g to approximately 0.20 g of fiber (Table XIII). The 7 percent substitution of citrus flour also contributed 0.20 g of dietary fiber. Seven percent substitution of beet fiber provided 0.30 g and the 5 percent substitution of the same fiber provided 0.25 g of dietary fiber. The asparagus fiber substitution level of 7 percent contributed almost 0.40 g of dietary fiber and 0.30 g at the 5 percent substitution level. A control cookie had 0.15 g dietary fiber; hence, some of the fiber sources used in the study contributed almost three times the amount of fiber in a control cookie.

TABLE XIII

CALCULATED AMOUNT OF DIETARY FIBER (g) PER COOKIE[a] AT DIFFERENT SUBSTITUTION LEVELS (%) FROM VARIOUS SOURCES OF FIBER

Source of Fiber	Dietary fiber (g) per cookie at different substitutions					
	0	3	5	7	10	15
Peanut Flour	0.152	--	0.167	--	0.181	0.195
Citrus Flour	0.152	0.174	0.190	0.204	--	--
Beet Fiber	0.152	0.211	0.251	0.290	--	--
Asparagus Fiber	0.152	0.248	0.313	0.377	--	--

[a]The cookie formula provided 15 cookies. The average baked weight for each cookie was 9 g.

Testing the Hypotheses

The first hypothesis (H_1) stated that there will be no significant differences in the sensory and objective qualities of cookies when high fiber peanut flour was substituted for all-purpose flour in the basic formula at 0, 5, 10, and 15 percent by weight. Based on the statistical analyses of the subjective and objective evaluations (Tables V and IX), the researcher failed to accept H_1.

The second hypothesis (H_2) stated that there will be no significant differences in the sensory and objective qualities of cookies when high fiber citrus flour was substituted for all-purpose flour in the basic formula at 0, 3, 5, and 7 percent by weight. However, according to the statistical analyses of the subjective and objective evaluations (Tables VI and X), the researcher failed to accept H_2.

The third hypothesis (H_3) stated that there will be no significant differences in the sensory and objective qualities of cookies when beet fiber was substituted for all-purpose flour in the basic formula at 0, 3, 5, and 7 percent by weight. Based on the statistical analyses of the subjective and objective evaluations (Tables VII and XI), H_2 was not accepted.

The fourth hypothesis (H_4) stated that there will be no significant differences in the sensory and objective qualities of cookies when asparagus fiber was substituted for all-purpose flour in the basic formula at 0, 3, 5, and 7 percent by weight. However, according to the statistical analyses of the subjective and objective evaluations (Tables VIII and XII), the researcher failed to accept H_4.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Pertinent literature proposed that a lower intake of dietary fiber is associated with several disorders of the human body, including constipation, diverticular disease, and cancer of the colon, ischemic heart disease, diabetes, and other gastrointestinal tract diseases (Burkitt, 1971; Burkitt et al., 1972, 1974; Painter et al., 1972; Trowell, 1972, 1976; Jenkins et al., 1976). A review of related literature indicated an increased interest in the nature and nutritional function of plant fibers due to the rising awareness of their important role in health and nutrition. Methods have been suggested to incorporate fibrous materials into food products, with special reference to baked products, to increase its fiber contents (Brockmole and Zabik, 1976; Lee et al., 1969; Prentice et al., 1978; Vratanina and Zabik, 1978, 1980).

The purpose of this study was to incorporate various sources of plant fiber at different levels into a cookie formula to increase the fiber content and evaluate the effects on the sensory and objective qualities of the cookies. Four different types of fiber were incorporated individually in an orange drop cookie formula at different levels of substitution of the all-purpose flour in the basic formula. High fiber, white skinned peanut flour was substituted at 0, 5, 10, and 15 percent levels in the cookie formula. High fiber citrus flour, beet and asparagus fibers were substituted at 0, 3, 5, and 7 percent levels. The baked product with each type and level of fiber was evaluated by a trained 11-member attribute panel. Objective determinations for tenderness were also performed. The fiber content of the cookies was calculated and the exterior appearance was recorded by photography.

Summary and Conclusions

The data collected from sensory evaluation were analyzed for differences by the Friedman Test Rank Analysis and Chi-square tables. ANOVA and the LSD test were used to determine differences between means for objective data.

Peanut Flour

The first hypothesis (H_1) stated that there will be no significant differences in the sensory and objective qualities of cookies with different substitution levels of peanut flour. Surface and interior appearance evaluation data showed no significant differences among cookies with different substitution levels of peanut flour, except for the interior color (Table V). There were significant differences in this parameter ($p<0.001$) between the 0, 5, 10, and 15 percent levels. This was mainly due to the greenish color of the experimental cookies, especially at the 15 percent level of peanut flour. The eating characteristics were significantly decreased ($p<0.001$) as the level of peanut flour in the cookies increased, due to the noticeable raw-peanutty taste at the higher substitution levels. Tenderness by shear force (kg/g) and by measurement of the area under the peak (cm^2/g) increased, indicating that the cookies became less tender as the substitution levels of fiber increased (Table IX). Because of these results, the researcher failed to accept H_1.

Citrus Flour

Hypothesis two (H_2) stated that there will be no significant differences in the subjective and objective evaluations of cookies with different substitution levels of high fiber citrus flour. There were significant differences ($p<0.001$) between cookies with 0, 3, 5, and 7 percent substitution levels with citrus flour for most of the parameters evaluated subjectively. The exterior color was the only parameter which did not change from the basic criteria at all levels of substitution (Table VI). The cookies were smaller in size, more mounded, and had a slight bitter aftertaste at the 7 percent substitution level; however, the lower substitutions were described as having a nice citrusy flavor and sweet orangy taste. The cookies were less tender as the citrus flour substitution levels increased, as indicated by shear force (kg/g) and area under the peak (cm^2/g) measurements (Table X). Because of these results, the researcher failed to accept H_2.

Beet Fiber

The third hypothesis (H_3) stated that there will be no significant differences in the subjective and objective evaluations of cookies with 0, 3, 5, and 7 percent substitution levels of beet fiber. There were significant differences ($p<0.001$) between cookies with all levels of beet fiber substitution in regard to shape, cell distribution, interior and exterior color, mouthfeel, flavor, and eating quality of the cookies. Significant differences ($p<0.01$) were indicated for top crust appearance between cookies with all levels. Also, the shape and size of cells were affected ($p<0.05$) as the fiber substitution level increased (Table VII). These results were mainly due to the dark color of the fiber specks in the cookies and its grittiness; otherwise, there was no objection to the flavor and taste of cookies with the different variations. Tenderness by shear force (kg/g) and by area under the peak (cm^2/g) decreased ($p<0.1$) at the 5 percent substitution level of the fiber, but it did not change at the other levels (Table XI). Since there were significant differences in some of the parameters measured, the researcher failed to accept H_3.

Asparagus Fiber

The fourth hypothesis (H_4) stated that there will be no significant differences in sensory and objective evaluations between cookies with different levels of asparagus fiber. The subjective evaluation showed significant differences ($p<0.001$) between cookies with 0, 3, 5, and 7 percent substitution levels of asparagus fiber for surface and interior appearances and for eating characteristics of the cookies (Table VIII). This was mainly due to the appearance and dryness of the fiber particles in the cookies; however, the flavor was not objectionable. Tenderness attribute, as measured by shear force (kg/g), and by area under the peak (cm^2/g) decreased significantly by the increase in the fiber level in the cookies (Table XII). Because of these results, the researcher failed to accept H_4.

The fiber content of the baked product increased with the increase in the different fiber levels; however, cookies with asparagus fiber had the highest increase in fiber content (g/cookie) (Table XIII).

Recommendations and Implications

Incorporation of different types of plant fibers in baked products appeared to be a successful means of increasing the dietary fiber in the diet. Based on the analyses of the objective and subjective data of this study, a recommendation of peanut flour substitution up to the 15 percent level in the cookie formula appeared to be feasible. This was also true for the beet and asparagus fibers up to the 7 percent level; however, this level of substitution is not recommended for the citrus flour because of the bitter aftertaste. These levels of substitution and even higher ones for the peanut flour, beet, and asparagus fibers could be possible and may be more desirable if they would be incorporated into a flavored rather than bland cookie formula such as oatmeal cookies, or with addition of other ingredients such as ground nuts, chocolate chips, or different seeds and spices in a basic cookie formula. The researcher also believes that using roasted peanut flour, milled beet and asparagus fibers, may actually improve the flavor and/or appearance of the cookies. The incorporation of these fiber materials into other foods and baked products such as chips, cereals, pasta, breads, and cakes need to be investigated.

Investigations similar to this research, but with the use of different instruments for the evaluation and using a consumer panel, could provide helpful information or data about the acceptability of the products. Other objective evaluations such as the analysis of the baked products themselves may also be utilized to determine their actual fiber and other nutrient contents. Moisture content determination could also be performed. In general, more research needs to be done to minimize any objectionable features in experimental food products due to the incorporation of various plant fibers.

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APPENDIX

INSTRUCTIONS TO PANEL MEMBERS

I would like you to do the visual and olfactory characteristics of all samples. Then take one sample and complete all other characteristics and continue in this manner. Be sure to use the distilled water provided to rinse your mouth between samples. After tasting each product, please indicate your evaluation by ranking them against each other on a scale of 1 to 4 with 1 being the closest to the criteria descriptions and 4 the furthest from the criteria. Remember that there can be no ties.

You will receive four coded samples of cookies in each session to be judged on the basic characteristics such as:

1. Surface Appearance

   Shape - should be symmetrical, otherwise please indicate.

   Top Crust - slightly mounded, not flat or sunken, porous, may be slightly cracked.

   Color - pale, light gold, even color.

2. Interior Appearance

   Distribution of cells - not too compact, evenly distributed.

   Shape and size of cells - uniform in size, with fairly thin wall.

   Color - cream, pale crumbs (otherwise may be affected by ingredients or treatments used, if specks are present, they should be evenly distributed).

3. Eating Characteristics

   Mouthfeel - slightly moist, tender, not rough or dry texture.

   Flavor - a distinctive characteristic of a product. It should be slightly sweet with a delicate taste.

   Eating Quality - the overall satisfaction in eating each product.

Please indicate other criteria you see more fit for a product, and make any comments you feel would help us in our evaluation of the product. Be sure to complete Name and Date. Thank you.

NOTE: For one half an hour before evaluation sessions, please try to avoid smoking, eating, or drinking coffee because this may affect your taste.

Name________________________________ Date________________

SENSORY EVALUATION OF COOKIES

Please rank order the four coded samples 1-4 (with 1 being the closest to the criteria description and 4 the farthest) based on these characteristics. (Remember there can be NO TIES.)

SAMPLE CODE ____ ____ ____ ____

1. Surface Appearance
   a. Shape: symmetrical ____ ____ ____ ____
   b. Top Crust: slightly mounded ____ ____ ____ ____
   c. Color: even, light gold; bottom, darker rim ____ ____ ____ ____

   Comments:____

2. Interior Appearance
   a. Distribution of cells: evenly distributed and not compact ____ ____ ____ ____
   b. Shape and size of cells: uniform, fine grain. Some large cells but evenly distributed ____ ____ ____ ____
   c. Color: creamy, even crumbs ____ ____ ____ ____

   Comments:____

3. Eating Characteristics
   a. Mouthfeel: tender, fine texture ____ ____ ____ ____
   b. Flavor: delicate taste, slightly sweet ____ ____ ____ ____
   c. Eating Quality: overall, it is pleasing and satisfactory ____ ____ ____ ____

   Comments:____

VITA 2

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