# THE EFFECT OF DIETARY FIBER SIZE AND TYPE ON BREATH HYDROGEN AND BLOOD GLUCOSE

By

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# THE EFFECT OF DIETARY FIBER SIZE AND TYPE ON BREATH HYDROGEN AND BLOOD GLUCOSE

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# CHAPTER I

# THE RESEARCH PROBLEM

## Introduction

> Take thou also unto thee
> wheat, and barley, and beans,
> and lentiles, and millet, and
> fitches, and put them in one
> vessel, and make bread thereof...
> Ezekiel 4:9
> King James Version

Dietary fiber is receiving more and more attention by nutrition researchers, the medical community and the public each day, even though the importance of a high fiber diet was recognized even in 575 B.C. when Ezekiel described the bread recipe quoted above. A generation ago it was usually called "roughage", and was recognized for its value in promoting regularity of bowel function. Epidemiological evidence now relates a high fiber diet to a lower incidence of various diseases including cancer of the colon and rectum, adult onset diabetes, obesity, hiatus hernia, hemorrhoids, appendicitis, varicose veins, deep vein thrombosis, coronary heart disease, gallstones, and diverticulosis (Burkitt, 1973; and Painter, 1969). These diseases are common to Western civilizations where a highly processed, low residue diet is typically consumed. Some

researchers and scientists are referring to these diseases as possible fiber deficiency disorders (Cummings, 1975).

In an attempt to gain the health benefits believed to come from consuming high fiber diets, people have incorporated various types of fiber into commonly eaten foods. The consumption of commercial bran preparations in our society has increased markedly (Bing, 1976). In many packaged wheat bran preparations the particle size of the bran flake has been altered drastically due to processing, packing, and shipping. It is uncertain whether it will exibit the same physiological characteristics in the body as whole brand flakes or whole grain with the bran intact. Alpha cellulose is apparently assumed to exhibit the same fecal bulking characteristics as wheat bran since it is added to many "high fiber" bread products. However, powdered alpha-cellulose, is very different from wheat bran, which is composed of a combination of fibers, protein and starch, of which only 10% is cellulose.

Various types of fibers have differing physiological effects. Some of these effects are improving glucose tolerance, decreasing total tract passage time, increasing fecal weight, and decreasing concentrations of serum cholesterol (Tsai et al., 1983; and Stasse-Wolthuis et al., 1979). Effects are known to vary depending on fiber source (Jarjis et al., 1984). It is uncertain what effect altering the particle size of various fibers have on their physiological role in the body.

Because so little is known about the effects of various fibers in the gastrointestinal tract, this study was conducted to determine the effect of two different types of fiber (wheat bran and beet pulp) at two particle sizes on specific physiological effects.

## Objectives

The objectives of this study are:

1. To determine the effects of two particle sizes of wheat bran and beet pulp on the concentration of hydrogen gas excreted through the lungs.

2. To investigate the passage time to the cecum, as measured by time of increase in breath hydrogen concentrations, of large and small particle sizes of wheat bran and beet pulp.

3. To determine the influence of large and small particle sizes of wheat bran and beet pulp on blood glucose levels.

## Hypotheses

H1. Breath hydrogen concentration will not be related to fiber type or particle size.

H2. Passage rate will not be related to fiber type or particle size.

H3. Blood glocose levels after a test meal will not be related to fiber type or particle size.

## Assumptions

The following assumptions were accepted in this study:

1. The volunteers taking part in this study will follow the diet.

2. Normal daily activities will not effect the results of this study.

## Limitations

The following limitations were accepted in this study:

1. Response to the fiber may have been affected by the different lifestyles and genetic backgrounds.

2. Measurements were obtained for only one nine hour period per treatment per subject.

3. Passage rate of the fibers to the cecum was measured only by breath hydrogen.

## Development of the Experiment

An overview of the measurements taken on the human subjects follows. Two types of dietary fibers (wheat bran and beet pulp) with two distinct particle sizes 1) smaller than 2.8 mm and larger than 2.0 mm, and 2) smaller than 1.0 mm and larger than 0.6 mm, were used to determine passage rate to the large intestine, breath hydrogen concentration, and blood glucose concentrations after a single high fiber meal. After consumption of the test meals breath hydrogen concentrations were measured at specific time intervals using gas chromatography and blood glucose concentrations

were measured using an Ames glucometer.

## Format of Thesis

The described experiment was organized as a manuscript and will be submitted to the American Journal of Clinical Nutrition. Chapter IV was written in accordance with the Information for Authors from that journal.

# CHAPTER II

# REVIEW OF LITERATURE

## Dietary Fiber Components

Dietary fiber is the largest source of polysaccharides in the world. Unlike starch, a polysaccharide which is readily broken down by digestive enzymes, fiber is resistant to the digestive enzymes secreted in the gastrointestinal tract (Trowell et al., 1976). The main components of dietary fiber are cellulose, hemicellulose, pectins, gums, mucilages, and lignin. All these components, except lignin, are polysaccharides produced by plants. They are biologically and chemically described by Van Soest (1978), Eastwood and Passmore (1983), Selvendran (1984), Reiser (1984), Bing (1976), and Heaton (1983).

Cellulose is a polymer of glucose linked by Beta 1-4 bonds, and is the major structural polysaccharide in the cell walls of plants.

Hemicellulose is another structural polysaccharide, and is a branched polymer of various pentose and hexose sugars, mainly xylose, arabinose, mannose, galactose, and uronic acid.

Pectins are non-structural polysaccharides that readily hold water. D-galacturonic acid is the principle component

of this group.

Gums are water soluble non-structural polysaccharides, made up primarily of glucose, galactose, arabinose, and rhamnose.

Mucilages are polysaccharides made up of highly branched arabinoxylans or glucouronic acid, found mainly in seeds and seaweed. They are very viscous and have tremendous water holding properties.

Lignin is the major non-carbohydrate portion of the plant cell wall and a polymer of aromatic alcohols.

## Fiber Analysis

The complex nature of dietary fiber in food materials has made it difficult to develop a method of identifying all of the dietary fiber components in food. Crude fiber analysis used for over 150 years, originally used to measure fiber in animal forages, has been repeatedly abandoned, since it measures only a small and variable fraction of the total dietary fiber. Originally called the Weende method, it involves boiling a fat free sample with sulfuric acid then with sodium hydroxide (Williams and Olmsted, 1934). This system fails to measure most of the hemicellulose or any gums, pectins, or mucilages, major fiber fractions of some human food. This is because portions of the fiber have been solublized in the acid and base solutions. Crude fiber analysis destroys up to 80% of the hemicellulose, while only 20-50% of the cellulose and 10-50% of the lignin remain in

some crude fiber fractions (Van Soest and McQueen, 1973).

Ever since Burkitt (1973) presented epidemiological evidence demonstrating benefical effects of fiber on the etiology of certain diseases common to Western societies, a great deal of effort has been directed toward development of simple routine methods to assay the dietary fiber content of food. Earlier, P.J. Van Soest, when working as an analytical chemist at the USDA station in Beltsville, Maryland, developed a method of analyzing fiber in forages (Van Soest, 1963). This first method, the acid-detergent fiber (ADF) method, separates the cellulose and lignin acid-detergent fiber fraction from the sample by boiling in an acid-detergent and filtering. Further separation of these fiber components is accomplished by adding sulfuric acid to the ADF, removing the cellulose portion and leaving acid-detergent lignin (ADL). The ADL is placed in an ashing oven to remove the lignin and leave only the minerals, thus the cellulose and lignin portions of a forage can be calculated (Van Soest, 1963; Van Soest, 1965). Later it was found that hemicellulose could be extracted and measured by boiling the sample material in a neutral detergent to remove the cell contents and soluble fibers. This is known as the neutral detergent fiber (NDF) method. The NDF contains hemicellulose, cellulose, and lignin. The NDF can then be broken down into the cellulose and lignin portions by the ADF method (Van Soest, 1967). The ADF and NDF methods were designed primarily to measure insoluble fiber components,

again, mainly for animal feed forages, which are high in these components. Most of the water-soluble polysaccharides and other soluble polymers thereby go undetected (Belo and Lumen, 1981).

Human foods, in contrast to animal forages, contain more starch and considerably less fiber. The starch interferes with the NDF/ADF method and results in an overestimation of fiber. Also, the fiber in human foods tend to contain a high proportion of soluble fiber components, which are not detected by the ADF/NDF method (Belo and Lumen, 1981). A method developed by Southgate (1969) takes nearly a week of systematic extractions to complete, but it is more accurate than the ADF/NDF method in that it measures each component of the unavailable carbohydrates in foods. This method provides values for the water-soluble and insoluble polysaccharides in each fiber fraction. The merit of this method is that it identifies constituent polysaccharides of the plant. The procedure is, however, too time consuming and labor intensive to be useful as a routine analysis.

The fiber separation and analysis methods of Southgate and Van Soest are non-physiological. Hellendoorn et al., (1975) and Asp et al., (1983) proposed fiber determination methods using two digestive enzymes, pepsin and pancreatin. These enzymes are part of a process that mimmicks the digestion of foods in the stomach and small intestine in which pepsin digests the protein and pancreatin digests the starch in the fat free sample. Hellendoorn's method, how-

ever, still basically analyzes for only insoluble fiber. The method proposed by Asp, though it accounts for soluble portions, can overestimate dietary fiber if care is not taken to completely hydrolyze all of the starch in the sample. Thus studying the effects of various types of fibers from natural sources still lacks certainty in knowing the precise makeup and level of fibers present.

## Metabolic Effects of Fiber

Fiber has long been recognized for its value in the promotion of regular bowel activity and its effects on the relief of constipation. Studies now indicate that dietary fiber may play a much greater role in good health. Research has shown that a high fiber diet is positively correlated with a lower incidence of various degenerative diseases common to Western societies (Burkitt, 1972; Burkitt et al., 1974: Painter, 1969; and Talbot, 1981).

## Fermentation

Virtually all of the fiber consumed by monogastrics, like humans, enters the cecum chemically unchanged. When fiber reaches the large intestine it is fermented to varying degrees by the bacterial flora present. This fermentation results in the formation of hydrogen, carbon dioxide and methane gas, and short chained volatile fatty acids (Levitt, 1969; and Bond and Levett, 1972). Some of the fatty acids are absorbed and metabolized. A portion of the gases formed

are absorbed into the bloodstream and excreted via the lungs while the remainder are excreted as flatus.

Hydrogen is not found to any appreciable extent in our atmosphere. However, it is produced by bacteria in our large intestine when the bacteria ferment unabsorbed carbohydrate (Levitt, 1969). Measuring the hydrogen in the expired air is a simple yet accurate procedure when using a gas chromatograph (Solomons et al., 1977). Studies on lactose intolerant individuals revealed that the amount of hydrogen produced was directly proportional to the amount of lactose reaching the colon (Levitt and Donaldson, 1970; Bond and Levitt, 1972: Read, 1984: and Solomons et al., 1980).

Dietary fiber is by definition mainly unabsorbable carbohydrate. Therefore, like lactose in the lactose intolerant individual, any unavailable carbohydrate such as fiber, when fermented in the colon should produce hydrogen in expired air (Tadesse and Eastwood, 1975: and Hickey et al., 1972). The time of initial onset of hydrogen production indicates the passage rate of lactose or unabsorbed carbohydrate to the colon (Bond and Levitt, 1976; and Flatz et al., 1984).

Read and associates (1986) confirmed earlier passage rate results by feeding human subjects a high fiber meal marked with a radioactive isotope. Three of the subjects had terminal ileostomies. Breath hydrogen and a gamma camera were used to measure passage rate in the normal subjects. In the ostomites the gamma camera and the actual

recovery of marked ileal contents were used to determine transit time. The researchers found a significant correlation ($r=0.88$, $p<0.01$) between the onset of breath hydrogen and the presence of the marker by use of the gamma camera. In the subjects with ileostomies the gamma camera was accurate in showing when the marked meal would appear in the collection appliance. Thus onset of hydrogen excretion in breath is an accurate indicator of passage of fermentable material to the cecum.

The amount of hydrogen in the expired air of an individual reflects the amount of fermentation taking place (Marthinsen and Fleming, 1982; and Hanson and Winterfeldt, 1985). This fermentation is dependent upon fiber type and level consumed. Both Marthinsen and Hanson found less hydrogen production when testing subjects consuming corn bran and significantly greater amounts when they tested the same subjects consuming pectin or citrus flour (a fiber source with a high pectin content). Hickey et al., (1972) studied subjects consuming commercial wheat bran cereals and commercial cereals composed primarily of the endosperm and germ portions of the wheat. They found significantly greater amounts of hydrogen in the expired air of subjects consuming bran cereals. These breath hydrogen rises occurred much earlier than the slight increases produced by the endosperm and germ cereals, thus indicating a much faster passage rate to the cecum by the bran cereals. Hanson and Winterfeldt (1985) also saw a faster passage to

the cecum with wheat bran consumption compared to citrus flower or the control diet. Meyer, and Calloway (1977) tested the fermentation of wheat bran, raffinose, oat bran, and oat gum in human subjects, and found that breath hydrogen excretion increased over baseline measurements with all of the fiber sources. However, ingestion of raffinose, an undigestable sugar, produced the greatest rise in hydrogen. Wheat bran was followed closely by oat bran and oat gum. Conversely, Hanson and Winterfeldt's research (1985) showed oat bran was more fermentable than wheat bran. The level of dietary fiber consumed also has a significant role in the amount of hydrogen produced.

Fermentation of starch may interfere with fiber fermentation studies. In most people some starch and other digestible carbohydrates are not absorbed before reaching the cecum (Thornton et al., 1986). The amount of starch broken down by enzymes and absorbed in the small intestine is highly individual and variable. Stephen et al., (1983) showed that a rise in breath hydrogen correlated with unabsorbed digestible carbohydrates reaching the cecum. Human subjects were intubated after an overnight fast and fed high starch meals marked with an indigestible dye. Breath samples were taken every 30 minutes and measured for hydrogen concentration, and intestinal contents were aspirated and analyzed for the presence of the marker and undigested starch. The researchers found that between 2 and 20 percent of the dietary starch consumed reached the cecum

undigested and unabsorbed. Thornton et al., (1986) compared the starch absorption capacity of normal healthy subjects to that of persons with symptomatic diverticular disease. In the normal subjects 12.4 percent of the starch in a potato meal was not absorbed before reaching the cecum but in persons with diverticular disease only 3.3 percent was not absorbed. Other data indicating that a large portion of starch reaches the large intestine before being absorbed (Anderson et al., 1981; and Wolever et al., 1986), suggest that 10-20 percent of the starch in white flour or bread is not absorbed before reaching the cecum. These amounts can be further increased by the administration of large doses of highly purified amylase inhibitors (Layer et al., 1986). Thus, when testing a fiber for fermentation and passage rate using the breath hydrogen technique, measures must be taken to not include large amounts of starch or amylase inhibitors (for example from dried beans) in the meal.

The amount of fermentation of a fiber is thought to be indicative of its action. Wheat bran and corn bran increase stool weight, but have little effect on hydrogen excretion (Marthinsen and Fleming, 1982). This indicates that these fibers are poorly fermented by bacteria in the colon but are found in relatively high amounts in fecal material. These particulate types of fibers have been shown to speed intestinal transit time, producing stools that are more frequent, have increased bulk and a greater water content (Eastwood et al., 1986; and Wrick et al., 1983).

Fedail et al., (1984) fed sorghum bran and wheat bran to Sudanese medical students. They found that sorghum bran, like wheat bran, decreased transit time and increased fecal bulk over the control diet. Beyer and Flynn (1978) had similar results by replacing white bread with the whole wheat bread, and substituting starchy fibrous vegetables for pasta and rice products. The mean transit time changed from 48 hours during the low-fiber diet to 12 hours when subjects consumed the high-fiber diet. Stool weight means changed from 51 grams per day to 157 grams per day. Stasse-Wolthuis et al., (1979) increased fecal weight by an average of 115 g per day and decreased mean transit time by 18 hours by using a naturally high-fiber versus low-fiber diet. Fecal material from persons consuming these high-fiber diets were generally softer and bulkier than those from persons eating low-residue diets and therefore, were easier to pass. This effect of particulate types of fiber eases constipation while at the same time reduces the strain on the colon, thus possibly lowering the incidence of hemrrhoids. The decrease in passage time and the fecal bulking characteristics may be responsible for the lower incidence of diseases such as Crohn's disease, ulcerative colitis, diverticular disease, and large bowel cancer. Because passage rate is speeded, carcinogens are not in contact with the gastrointestinal tract for extended periods of time. Particulate fibers increase bulk and thereby, also dilutes carcinogens.

Gastric emptying is delayed when the diet includes

gummy fibers such as psyllium, guar gum and pectin (Holt et al., 1979: and Chang and Li, 1984). This slowing is accomplished by the fiber's formation of viscous gels (Russell and Bass, 1985). The addition of six grams of guar gum to the breakfast meal of non-insulin dependent diabetics significantly slowed gastric emptying Ray et al., (1983). Although these gummy fibers slow gastric emptying, they do not slow total tract transit time. Pectin has been shown to slightly speed total tract transit time (Spiller et al., 1980).

Gummy fibers, also known as gel-formers, have been shown to alter absorption of certain nutrients (Johnson et al., 1984; and Dryden et al., 1985). Madar (1983) significantly lowered plasma glucose levels in diabetic rats by feeding soybean fiber before a glucose load compared to feeding rice fiber. This glucose lowering effect also has been seen in humans. Jenkins (1977) fed both insulin-dependent and non-insulin dependent diabetics 25 grams of guar gum per day. Testing urine for glucose spillage, he found a significant improvement indicating better diabetic control. Parsons (1984) found that feeding bran and apples lowered plasma glucose levels of non-insulin dependant diabetics after a glucose load. Tsai and et al., (1983) improved glucose tolerance response by feeding soy polysaccharides to human subjects. Conversely Schweizer et al., (1983) found that dehulled soybean fiber only marginally improved oral glucose tolerance in human subjects. However,

in these subjects the fecal wet weight was markedly greater and total tract passage rate was significantly faster when consuming this fiber as compared to the control. These studies show that two different dietary fibers coming from a single source, can exert distinctly different metabolic effects. Jarjis et al., (1984) studied the effect of ispaghula and guar gum on glucose tolerance in man. Ispaghula - psyllium husks - are a major component of several bulk laxatives such as Metamucil. Jarjis found that guar gum significantly improved glucose tolerance but ispaghula did not. Tredger et al., (1981) found that adding 20 g of sugar beet pulp to a test meal had no significant effect on lowering blood glucose or insulin curves at any time after the test meal.

The same gel forming fibers that improve glucose tolerance have been shown to alter serum lipid concentrations (Sirtori et al., 1977; and Eastwood et al., 1986). Judd and Truswell (1981) lowered plasma cholesterol concentrations by a mean of eight percent, by feeding 125 grams of rolled oats per day (9 g of dietary fiber) to human subjects. Penagini et al., (1986) found that feeding 10 g of guar gum daily to human subjects decreased serum cholesterol levels by 16%. The cholesterol and glucose lowering properties of the gel-forming fibers is of great importance to man living in Western societies where heart disease and diabetes are found in almost epidemic proportions. Although wheat bran is not a gel-forming

fiber, some research has shown it to improve blood lipid parameters. Moore et al., (1985) fed human subjects 0.15 grams of unprocessed wheat bran per kilogram of body weight. The total concentration of serum cholesterol remained fairly constant, but the high density lipoprotein fraction increased while the low density lipoprotein portion decreased.

## Particle Size

The food industry is responding to the consumer demand to incorporate more fiber into the foods we eat. Unfortunately, in many cases the food industry is altering the fiber source so drastically it is not known whether beneficial qualities remain. One of the most common alteration is the mechanical grinding of a fiber source. This is often done for palatibility and ease of incorporation into a food item. Researchers are now questioning whether altering the particle size of a fiber change its physical characteristics and metabolic effects. Heller et al., (1977) measured the hemicellulose, cellulose, lignin, and cutin in two sizes of wheat bran, corn pericarp, and peanut hulls. Using Van Soests's ADF/NDF method for measuring fiber fractions, the researchers found significant decreases in the hemicellulose content of the finely ground fibers. The differences in analysis between the different particle sizes of the same fiber were up to 20%. The cellulose, lignin, and cutin fractions remained fairly constant. Thus only the hemi-

cellulose portions of these fibers were destroyed by mechanical grinding. Mongeau and Brassard (1982), testing commercial breakfast cereal fibers for bile salt binding and water holding capacity, found that as the particle size decreased the bile salt binding and water holding capacity also decreased linearly. Researchers have investigated if these altered physical characteristics of fiber affect its metabolic roles. Cadden et al., (1983) fed different size of fiber to laboratory rats. When wheat bran and sunflower hulls were evaluated for particle size effects, the researchers found that coarse sunflower hulls and coarse wheat bran were both associated with high fecal volumes and low fecal density. However, the fine sunflower hulls and fine wheat bran were linked to lower fecal volume and higher fecal density. Fine particles of wheat bran and sunflower hulls were digested to a much greater degree than the coarse particles, probably because of increased fermentation by colonic bacteria.

Kirwan and associates (1974) tested particle size effects of wheat bran on patients with either chronic constipation or diverticular disease. In subjects given 20 g of wheat bran daily for four weeks, the coarse bran significantly lowered intraluminal pressure and decreased transit time. The researchers attributed this to the greater water holding capacity of coarse wheat bran. Heller et al., (1980) fed 32 g of coarse or fine wheat bran daily for two months to college students in a more controlled

study than that of Kirwan. Although fine wheat bran speeded passage rate it was not significant, however, coarse wheat bran significantly speeded passage rate. Heller et al. (1980) also found that in humans, as in rats, fecal volume increased and the density decreased with the large size wheat bran. These results support both Kirwan's and Cadden's studies. Thus, coarse fibers generally are more effective in decreasing transit time, increasing fecal bulk, increasing water holding capacity, and increasing bile salt binding.

Table I illustrates some of the current (1980 to present) findings in these areas of fiber research. Fiber source and particle size is compared to various physiological roles: passage rate (either total tract, to the cecum, or gastric emptying), fecal bulking characteristics, and fermentability of the fiber, serum cholesterol and blood glucose responses. These current research studies are revealing about what leading scientists and fiber experts are investigating.

TABLE I

CURRENT FIBER RESEARCH USING HUMAN SUBJECTS

| Author | Fiber Source | Particle Size | Passage Rate | Fecal Bulk | Fermentability | Glucose Tolerance |
|---|---|---|---|---|---|---|
| | | | (total tract) | | | |
| Ehle et al. 1982 | Wheat bran | Coarse | N.A. | Increase | Some | N.A. |
| | Wheat bran | Fine | N.A. | Increase | Some | N.A. |
| | Cellulose | N.A. | N.A. | No change | Little | N.A. |
| | Cabbage | N.A. | N.A. | Sl. increase | Great | N.A. |
| | | | (total tract) | | | |
| Fedail et al. 1984 | Wheat bran | N.A. | Speeded | Increase | N.A. | N.A. |
| | Sorgum bran | N.A. | Speeded | Increase | N.A. | N.A. |
| | | | (to cecum) | | | |
| Hanson and Winterfeldt, 1985 | Wheat bran | N.A. | Speeded | N.A. | Some | N.A. |
| | Corn bran | N.A. | Speeded | N.A. | Little | N.A. |
| | Citrus flour | N.A. | Sl. Speed. | N.A. | Great | N.A. |
| | Oat bran | N.A. | Sl. Speed | N.A. | Great | N.A. |
| | | | (total tract) | | | |
| Heller et al. 1980 | Wheat bran | Coarse | Speeded | Increase | Some | N.A. |
| | Wheat bran | Fine | Sl.Speed | Increase | More | N.A. |
| | | | (to duodenum) | | | |
| Jarjis et al. 1983 | Ispaghula | N.A. | No change | N.A. | N.A. | No change |
| | Guar gum | N.A. | Slowed | N.A. | N.A. | Improved |
| | | | (total tract) | | | |
| Judd and Truswell 1981 | Rolled oats | N.A. | No change | Sl. increase | N.A. | N.A. |
| | | | (total tract) | | | |
| McNamara et al. 1986 | Soyfiber | N.A. | Speeded | No change | Great | N.A. |

Sl.=Slight change
N.A.= Not Apply

TABLE I (CONTINUED)

| Author | Fiber Source | Particle Size | Passage Rate | Fecal Bulk | Fermentability | Glucose Tolerance |
|---|---|---|---|---|---|---|
| Penagini et al. 1986 | Guar gum | N.A. | (total tract) No change | No change | N.A. | N.A. |
| Spiller et al. 1980 | Cellulose | N.A. | (total tract) Speeded | Increase | N.A. | N.A. |
| | Pectin | N.A. | No change | No change | N.A. | |
| Schweizer et al. 1983 | Dehulled-soy beans | N.A. | (total tract) No change | Increase | Great | Improve |
| Tredger et al. 1980 | Beet pulp | N.A. | N.A. | N.A. | N.A. | No change |
| Tsai et al. 1983 | Soy beans | N.A. | (total tract) Sl. speed | Sl. increase | N.A. | Improve |
| Villaume et al. | Wheat bran | N.A. | (total tract) Speeded | N.A. | N.A. | Sl. improve |
| Wrick et al. 1983 | Wheat bran | Coarse | (total tract) Speeded | Increase | N.A. | N.A. |
| | Wheat bran | Fine | Speeded | Increase | N.A. | N.A. |
| | Cellulose | N.A. | Speeded | Increase | N.A. | N.A. |
| | Cabbage fiber | N.A. | No change | No change | N.A. | N.A. |

Sl.=Slight Change
N.A.= Not Apply

# CHAPTER III

# METHODS AND PROCEDURES

## Subjects

Five female subjects were selected from volunteers from the student body and staff at Oklahoma State University to participate in the five week study. The ages of the subjects ranged from 20 to 34 years, the mean age was 26 years. Mean height and weight was 162.8 cm (66 in) and 68.8 kg (151 lb). Two of the subjects were at 100% of ideal body weight. The remaining three ranged from 106 to 155% of ideal body weight. The mean body weight was 116% of ideal body weight. All of the subjects were verbally questioned and indicated they had no known history of gastrointestinal disorders, food allergies, or adverse effects to eating large quantities of fiberous foods. This study was approved by the Oklahoma State University Institutional Review Board. The subjects were given a letter outlining the study and asked to sign a consent form. A copy of the information letter and the consent form are in Appendix A.

## Design

The evening before the test day at approximately 1800 hours once each week for five consecutive weeks the subjects

consumed a standardized, low residue dinner. After a 14 hour fast, at approximately 0800 hours the following day, breath and blood samples were taken. A predetermined randomly selected test meal was consumed within 15 minutes with at least 8 ounces of water. Blood samples were taken at 0815, 0830, 0845, 0900, 0915, 0930, 0945, 1000, and 1030 hours. All blood samples were immediately analyzed for glucose concentrations in the whole blood. Breath samples were collected every 30 minutes for nine hours and analyzed for hydrogen concentration within four hours after collection. At 1200 hours, subjects consumed a standardized low residue lunch. Sampling was completed at approximately 1700 hours and the subjects were allowed to resume their normal eating habits and lifestyles.

## Diet

The standardized low residue dinner eaten the evening before the test day provided approximately 450 kcal. It consisted of chopped beef steak and gravy, seasoned potatoes, peas and corn, and butter cookies. The meal provided approximately 21 g of protein, 25 g of carbohydrate, and 21 g of fat. The subjects were not allowed to consume any other foods or beverages with the exception of water, until the next morning when the test meal was administered.

The test meal consisted of 30 g of test fiber, 20 g of sugar, 20 g of whole fresh egg, and 2 g of cinnamon. The

control meal substituted 30 g of enriched white flour for the test fiber and provided approximately 194 kcal. The two test meals containing wheat bran provided approximately 154 kcal while the remaining test meals using beet pulp as the fiber source provided approximately 136 kcal. To prepare the test meal, ingredients were mixed together and placed in 80 degree centigrade drying oven for 10 hours so that no non-enzymatic browning occurred thus reducing the addition of undigestible carbohydrate-protein complexes to the diet. This recipe produced a granola type mixture.

Four hours after the test meal, at 1200 hours, the subjects consumed a standardized low residue lunch consisting of 56 g of lean precooked ham and two slices of commercial white bread with the crusts removed. Lunch provided approximately 175 kcal. Throughout the test day no other food or beverage was permitted except water.

## Preparation of Wheat Bran and Beet Pulp

Five kilograms of hard red winter wheat bran (Shawnee Mills, Shawnee, OK) and five kilograms of sugar beet pulp (American Crystal Sugar Company, Moorhead, MN) were shaken through U.S.A. standard testing sieves (Fisher Scientific Co., Pittsburg, PA). The sieves were shaken on a sieve shaker (CSC-Meinzer; Model 18480-033, CSC Scientific Co., Fairfax, VA). The shaker vibration was a combination of vertical and lateral gyratory motion. This alleviated any human error such as shaking one sample more vigorously than

another. The test fibers were shaken in 30 g allotments for 10 minutes.

Wheat bran was shaken simultaneously through five sieves, the sizes of the sieves were as follows: 2.8 mm, 2.0 mm, 1.0 mm, 0.6 mm, and 0.25 mm. Only the wheat bran that was smaller than 2.8 mm and larger than 2.0 mm was used in this study. Three hundred grams of the 2.0 - 2.8 mm size wheat bran was ground in a coffee spice mill (Waring, Model CM111-8, Waring Products Division, Dynamics Corporation of America, New Hartford, CT) in 20 g allotments for 45 seconds. The ground wheat bran was then reshaken to obtain particle sizes that were smaller than 1.0 mm and larger than 0.6 mm. This procedure was used in order to obtain two different particle sizes of wheat bran that had originally been the same size.

The beet pulp was shaken through sieve sizes 4.0 mm, 3.35 mm, 2.8 mm, 2.0 mm, 1.0 mm, and 0.6 mm. The original size of the beet pulp was determined by the processing of sucrose. Sugar beets are sliced to allow removal of the sucrose so the largest particle size of the beet pulp received was established by the sugar processing procedure. Like the wheat bran, only the beet pulp that initially rested on the 2.0 mm sieve and passed through the 2.8 mm sieve was used in this study. A portion of this beet pulp was ground and resieved using the procedure mentioned earlier. Again, like the wheat bran, the particle sizes of beet pulp used in this study was between 2.8 mm and 2.0 mm,

or this original size ground to a range of 1.0 mm to 0.6 mm.

## Blood Sampling Techniques

Blood samples were taken by first having the subject wash her hands in warm soapy water. Using a sterile lancet, a finger prick was made to obtain two drops of capillary blood. The first drop of blood was discarded and four seconds later the second drop of blood was placed on the pad of a Dextrostix (Ames Division, Miles Laboratories, Inc., Elkhart, IN), a glucose oxidase reagent strip. The strip then underwent a color change proportional to the amount of glucose in the blood. After 60 seconds the blood was washed off the test strip using distilled water, then blotted with a clean lint free paper towel. The test strip was immediately inserted into the Glucometer (Ames Division, Miles Laboratories, Inc., Elkhart, IN) and read. This reading indicated the level of glucose in mg/dl (milligrams of glucose per 100 milliliters of whole blood).

## Breath Hydrogen Sampling Techniques

Breath samples were collected in three-liter, gas tight, laminated aluminum sample bags. The sample bags were made by heat sealing laminated aluminum (Reynolds Metals Co., Richmond, VA) to form a completely sealed bag except for the sampling tube. Subjects blew into the bags via 1/8 in ID, 1/4 inch OD tygon tubing. Subjects drew in a large breath, exhaled, drew in again and waited 10 seconds before

blowing the entire breath into the sample bag. The tubing was attached to the bags with metal hose fittings and rubber gaskets, this ensured a gas tight seal.

The breath samples obtained were analyzed for hydrogen concentration using a gas chromatograph (Varian, model 920; Varian Associates, Walnut Creek, CA) that was equipped with a thermal conductivity detector set at 112 degrees centigrade. The filament current remained at a constant 132 milliamperes. The 336 cm, 0.16 cm ID column was packed with a 60-80 mesh 5A molecular sieve (Supelco, Bellefonte, PA). Argon (Sooner Supplies, Stillwater, OK) flowing at 18 ml per minute served as the carrier gas.

Breath hydrogen concentrations were compared to a reference gas that contained 100 ppm hydrogen (100 parts hydrogen mixed with 999,900 parts nitrogen). The reference gas was mixed and stored in the same type bag that was used to collect breath samples. The standard was made by first injecting 990 ml of nitrogen and 10 ml of hydrogen (Sooner Supplies, Stillwater, OK) into an evacuated sample bag using gas tight syringes and allowing the gasses to equilibrate. Then in another evacuated sample bag 990 ml of nitrogen and 10 ml of the first nitrogen/hydrogen mixture were combined to form a solution that was 100 ppm hydrogen to nitrogen.

CHAPTER IV

# THE EFFECT OF DIETARY FIBER SIZE AND TYPE ON BREATH HYDROGEN AND BLOOD GLUCOSE

Karen K. Burch and Christa F. Hanson

## Abstract

The effects of two particle sizes of wheat bran and beet pulp on passage rate, fermentation, and blood glucose levels were monitored by measuring hydrogen gas concentration in the expired breath and measuring glucose in whole blood after a 20 g sugar load. Five subjects consumed meals containing either no added fiber or 30 g of coarse wheat bran (CWB), fine wheat bran (FWB), coarse beet pulp (CBP), or fine beet pulp (FBP), replacing white flour. Blood samples were taken at 0, 15, 30, 45, 60, 75, 90, 105, 120, and 180 minutes. Every 30 minutes for 9 hours breath samples were obtained. Mean glucose concentration (mg/dl) over the 2.5 hour test glucose period ranged from 74.7 (CBP) to 80.2 (CWB). Peak glucose was 91 (CBP), 93 (FBP), 95 (FWB), 106 (CWB), and 110 (Basal). Both sizes of beet pulp and the fine wheat bran significantly decreased peak glucose levels. Mean hydrogen concentration over the nine hour test period ranged from 6.0 ppm (CWB and FWB) to 2.5 ppm (CBP). Hours from the test meal to the highest

hydrogen peak were 3.1 (CWB), 3.1 (FBP), 3.6 (FWB), 4.1 (CBP), and 4.4 (Basal). Consumption of fiber increased passage rate over the control. Consumption of CWB produced the highest mean hydrogen value followed by FWB. Consumption of either size of beet pulp produced mean peak hydrogen similar to the control (5.7, 7.1, and 6.5 ppm, respectively). Results suggest that hydrogen gas excretion is not a good indicator of beet pulp fermentation. Coarse particle sizes of beet pulp and wheat bran more effectively reduce blood glucose levels 1 hour after a test meal than small particle sizes of the same fibers.
Key Words: breath hydrogen, passage rate, blood glucose, particle size, wheat bran, beet pulp.

## Introduction

The role of dietary fiber in human nutrition and health has received increasing attention in recent years. Epidemiological evidence has linked a high fiber diet to the prevention of various degenerative diseases common to Western civilization (1-3). The differing physical and chemical properties of various fiber types have made assessment of all of the physiological and metabolic roles fiber influences difficult.

Virtually all of the fiber consumed reaches the cecum chemically unchanged. Here it is fermented to varying degrees by colonic bacteria (4,5) resulting in the formation of hydrogen, methane, and carbon dioxide gases, and volatile

fatty acids (6,7). Some of the fatty acids are absorbed and metabolized while the gases formed are either excreted as flatus or absorbed into the bloodstream and excreted via the lungs (7).

Particulate fibers have been shown to significantly decrease transit time (8-10). These fibers are less fermentable and significantly increase fecal bulk (10-12). However, these effects can be changed by altering the particle size of the fiber (10,13,14). The effect of wheat bran on fecal bulk and passage time can be altered by grinding (14). Corn bran is not well fermented (4) and exibits significant fecal bulking characteristics (12). Conversely, pectin has been found to be almost entirely fermented in the colon and at the same time does not contribute to fecal bulk (15).

The gel-forming or gummy fibers have been shown to delay gastric emptying by the formation of viscous gels (16-18). These fibers do not delay total tract transit time,

Research indicates that guar gum, along with pectin, will significantly decrease blood glucose concentrations after a glucose load (17,19). These gummy type of fibers also are attributed with serum cholesterol lowering properties (20,21).

In this study, to clarify some of the basic physiological effects of different dietary fiber sources and particle size, wheat bran and sugar beet pulp were used to

investigate their effects on 1) the concentration of hydrogen gas excreted, 2) the passage rate to the cecum as measured by time of increase in breath hydrogen concentrations, and 3) glucose tolerance after a 20 g sugar load.

## Methods

Five female subjects were selected from volunteers from the student body and staff at Oklahoma State University to participate in the five week study. The mean age, height, and weight, were 26 years, 162.8 cm, and 68.8 kg respectively. All of the subjects indicated they had no known history of gastrointestinal disorders, food allergies, or adverse effects to eating large quantities of fiberous foods.

The evening before the test day at approximately 1800 hours once a week for five weeks the subjects consumed a standardized low residue dinner (Table II). No other food or beverage with the exception of water was permitted until the next morning when the test meal was consumed. At 0800 hours the following day after a 14 hour fast a breath and blood sample were taken. All breath samples were collected in three-liter, gas-tight, laminated aluminum (Reynolds Metals Co., Richmond, VA) sample bags that had been heat sealed. Tygon tubing, 1/8 in ID, 1/4 in OD, was attached to the sample bags with metal hose fittings and rubber gaskets, thus a gas-tight seal was maintained. Breath samples were

analyzed within four hours of collection using a gas chromatograph (Varian, model 920; Varian Associates, Walnut Creek, CA) equipped with a thermal conductivity detector. The 336 cm, 0.16 cm ID column was packed with 60-80 mesh 5A molecular sieve (Supelco, Bellefonte, PA). Blood samples obtained from finger capillary blood, were analyzed colorimetrically using a Glucometer (Ames Division, Miles Laboratories, Inc., IN).

Following the collection of the breath and blood samples, subjects consumed a predetermined random test meal (Table II). The test meal consisted of 30 g of test fiber, 20 g of sugar, 20 g of whole fresh egg, and 2 g of cinnamon. The control meal substituted 30 g of white flour for the test fiber and provided approximately 194 kcal. The two test meals containing wheat bran contained approximately 154 kcal while the beet pulp meals provided approximately 136 kcal. This recipe produced a granola type mixture.

## Fiber Preparation

Five kilograms of hard red winter wheat bran (Shawnee Mills, Shawnee, OK) and five kilograms of sugar beet pulp (American Crystal Sugar Co., Moorhead, MN) were shaken through U.S.A. standard testing sieves (Fisher Scientific Co., Pittsburg, PA). The sieves were shaken on a sieve shaker (CSC-Meinzer; Model 18480-033, CSC Scientific Co., Fairfax VA). The test fibers were shaken in 30 g allotments for 10 minutes.

Wheat bran was shaken simultaneously through five sieves, the sizes of the sieves were as follows: 2.8 mm, 2.0 mm, 1.0 mm, 0.6 mm, and 0.25 mm. Only the wheat bran that was smaller than 2.8 mm and larger than 2.0 mm was used in this study. Three hundred grams of the study size wheat bran was ground in a Waring mill (Waring, Model CM111-8, Waring Products Division, Dynamics Corp. of America, New Hartford, CT) in 20 g allotments for 45 seconds. The ground wheat bran was then reshaken to obtain particle sizes that were smaller than 1.0 mm and larger than 0.6 mm. This procedure was used in order to obtain two different particle sizes of wheat bran that were orginally the same size fiber particle.

The beet pulp was initially shaken through 4.0 mm, 3.35 mm, 2.8 mm, 2.0 mm, 1.0 mm, and 0.6 mm sieves. Only the beet pulp that rested on the 2.0 mm sieve and passed through the 2.8 mm sieve was used. Part of this beet pulp was ground and resieved using the described procedure. Like the wheat bran, the particle sizes of beet pulp used in this study were between 2.8 mm and 2.0 mm, or this size ground to a range of 1.0 mm to 0.6 mm.

Blood samples were taken at 0, 15, 30, 60, 75, 90, 105, 120, and 180 minutes. Breath samples were collected at time 0 and every 30 minutes for nine hours following consumption of the test meal. At 1200 hours subjects consumed a standardized low residue lunch consisting of 60 g of lean ham and two slices of commercial white bread with the crusts

removed (Table II). Subjects were allowed to consume water as desired but no other food or beverages. For presentation in tables III, IV, V, and VI, means were compared by Duncan's multiple range test with a significance level of ($p<.05$). In addition, treatment effects were compared using four orthogonal contrasts. These contrasts were for the effect of fiber (control versus all other treatments), source of fiber (wheat bran versus beet pulp), particle size of fiber (coarse versus fine), and interaction between fiber source and particle size. Probability levels are listed in colums under appropriate orthogonal contrasts.

## Results

Breath hydrogen concentration for each time period are presented in table III and in figures 1, 3, 5, 6, and 9. Consumption of coarse wheat bran resulted in an increase in breath hydrogen compared to the control (13.6 ppm versus 1.8 ppm) 2.5 hours after the test meal. Coarse wheat bran also resulted in the greatest increase in hydrogen concentration (23.1 ppm). Consumption of fine wheat bran also resulted in an increase in breath hydrogen concentration compared to the control(13.1 ppm versus 1.1 ppm) 3 hours after the test meal. Mean hydrogen concentration was not increased by consumption of either particle size of beet pulp.

Consumption of fiber significantly increased breath hydrogen at 3 to 3.5 hours after the test meal, however much

of the effect was due to wheat bran, which significantly increased hydrogen excretion from 2.5 to 3.5 hours after consumption. A particle size effect was observed at the third hour, with fine particle size producing more hydrogen ($p<.02$) than coarse particle size and again at 5 and 6 hours ($p<.10$, and $p<.09$ respectively). Beginning at hour 6.5, the control diet produced more gas than the fiber sources, with hydrogen excretion at various times for each source being significantly lower than the control (Table III). Although time of onset of gas excretion due to intake of wheat bran is similar for both coarse and fine particle sizes (Table III and Figure 5), the coarse particle size hydrogen excretion decreases within 2.5 hours. After fine wheat bran consumption however, the hydrogen excretion remains elevated an additional 1.5 hours. When compared to the control, fine beet pulp consumption caused slight but not significant increases in hydrogen concentration (Table V, Figure 6). Three hours after the test meal, the fine particle sizes of beet pulp and wheat bran produced greater ($p<.02$) hydrogen concentrations than the coarse particle sizes (9.5 ppm versus 3.6 ppm). Coarse wheat bran consumption resulted in the greatest excretion of hydrogen gas and significantly more than coarse beet fiber at 2 and 3.5 hours, while fine wheat bran consumption produced significantly more hydrogen gas than fine beet pulp at 3.0, 5.5 and 6 hours (Table III). No differences were seen in time of onset of hydrogen gas excretion based on individual

subjects peak values (Table V). However, based on these values, coarse wheat bran consumption resulted in greater ($p<.05$) hydrogen concentration than any of the other test fibers or the control diet. Significant effects were also seen in peak hydrogen concentration due to the addition of fiber to the diet ($p<.06$). Peak hydrogen concentration was greater with wheat bran than with beet pulp consumption ($p<.01$). An interaction between fiber source and fiber size was seen with hydrogen concentration. Coarse wheat bran consumption produced more hydrogen than fine wheat bran consumption but concentration of hydrogen after consuming coarse beet pulp was less than after consuming fine beet pulp.

Based on individual subjects peak values (Table VI), consumption of fiber resulted in a lower mean blood glucose value than the consumption of control diet. After the test meal, significant reduction in blood glucose values due to fiber consumption were observed from .75 to 1.75 hours (Table IV, and Figures 2, 4, 7, 8, and 10).

However, the glucose values obtained from eating the meal containing coarse wheat bran rose to 101 mg/dl, nearly as great as the control meal value of 107 mg/dl at that same time, but the glucose concentration dropped rapidly with coarse wheat bran consumption and resembled the values obtained from consuming the other fiber sources, fine wheat bran, and coarse and fine beet pulp (Table IV and Figures 2, 7, and 10). An effect of particle

size was observed at 1.25, 1.75, and 2 hours after the test meal with coarse particles significantly lowering glucose levels compared to fine particles. Coarse beet pulp most consistently reduced ($p<.05$) blood glucose levels compared to the control meal but only at .5 hours after the test meal was beet pulp more effective than wheat bran in lowering blood glucose ($p<.08$) (Table IV).

## Discussion

The two fiber types used in this study differed in their chemical and physical structure (Table VI) and in their effects on breath hydrogen concentrations and transit times. Heller (14) found that reducing the particle size of a fiber will affect its action in the body. Hanson (4) found that consumption of a commercially packaged, unsized wheat bran resulted in a peak hydrogen concentration of 25.3 ppm 4.7 hours after the fiber meal. In this study the hydrogen concentration peak after consumption of coarse wheat bran was 29.6 ppm 3.1 hours after the meal, while the fine wheat bran hydrogen peak concentration was at 15.5 ppm, 3.6 hours after the test meal. Wrick et al., (9) and Van Soest (22) found that the fine grinding of bran significantly slowed total tract passage rate. In this study we measured passage rate to the large intestine only. Based on the hydrogen measurements, fine wheat bran took slightly longer to reach the cecum, however, this was not significant, and it remained in the cecum and large intestine longer where it

may have been fermented to a greater degree than the coarse wheat bran. This could result in the decreased fecal bulking ability and slower passage time compared to coarse wheat bran observed by other researchers (14).

Approximately 63% of the fiber in wheat bran and 36% of the fiber in beet pulp was recovered in the feces of rats (11) and 20 to 30% of beet fiber was recovered in the feces of pigs (23,24). Thus, beet pulp which is approximately 81% fiber is highly fermentable. However, the amount of hydrogen gas produced by consumption of beet pulp was not significantly different than that of the control and was significantly less at times than that of wheat bran (Table III).

McNamara et al., (25) found that more than 80% of the fiber in a diet containing between 30 and 60 grams of soy fiber disappeared in the large intestine of human subjects, however, these researchers also found breath hydrogen was a poor indicator of the digestibility of the soy fiber but a good indicator of wheat bran digestion (26). Eastwood et al., (27) found that 20 g of potato fiber in the diet, sped total tract passage rate but, like soy and beet fiber, did not raise breath hydrogen levels. In this study we found that consumption of the control diet produced a similiar hydrogen peak value to coarse beet pulp, 9.9 and 8.9 ppm, respectively. The mean hydrogen peak after consumption of the fine beet pulp was 16.0 ppm, which also was not significantly different from the control or the coarse beet

pulp. Therefore measuring hydrogen concentration appears to be a poor indicator of the digestibility of beet pulp.

Consumption of fiber appeared to speed passage rate compared to the control however, this was not significant based on peak hydrogen values. A high-fiber diet the day before the hydrogen breath test raises fasting breath hydrogen concentrations (27).

Although this study controlled the evening meal the day before the study, the mean concentrations of hydrogen appearing before hour 2.0 were not regarded as being indicative of passage rate because of high fasting levels in some subjects. This high fasting level appeared to be due to subject body weight with higher fasting levels found in heavier subjects.

The gel-forming, or more fermentable fibers, have been found to lower blood glucose (17, 19, 21). Fruits and vegetables generally contain more gel-formers than grains. The beet pulp used in this study contained 26% pectin, a gel former which reduced the blood glucose response to the test meal when consumed as coarse pulp. Tredger (28) found that adding 20 g of sugar beet pulp to a test meal had no significant effect on lowering the blood glucose or insulin curves at any time after the test meal, however, that beet pulp was a finely ground material that contained processing contaminents not found in the pulp used in this study.

Coarse beet pulp had a more beneficial effect than fine beet pulp. Wheat bran which contains no pectin was also

effective at lowering blood glucose levels at various times after the test meal (Table IV). All of the fiber sources tended to lower glucose .75 to 1.75 hours after consumption, with the coarse particles of both fibers lowering concentrations the most (Table IV). These results also confirm that vegetable fibers aid in glucose tolerance after a sugar load. Villaume et al., (29) showed that glucose response was somewhat improved after a wheat bran meal was served. The wheat bran used in this study had some endosperm particles still attached to it. The grinding and resieving of the fine wheat bran may have removed some of the absorbable starch, explaining why consumption of coarse wheat bran increased blood glucose slightly initially compared to the other fiber sources also the test meals each had different amounts of digestible nutrients, with the control meal containing 40 kcal more than the wheat bran meals and 50 kcal more than the beet pulp meal. These differences in available nutrients may have had an effect on blood glucose values. Overall, addition of fiber to the diet reduced peak glucose concentration with the greatest reduction seen with coarse beet pulp.

Peak hydrogen values were increased by addition of fiber to the diet, however, the effect of wheat bran differed from that of beet pulp. Coarse wheat bran consumption significantly increased peak hydrogen concentration compared to the control diet and other fiber sources, and mean hydrogen values were greater with wheat

bran that with beet pulp. Mean and peak hydrogen values for coarse beet pulp were lower than the values for the control diet. Thus, measurment of breath hydrogen concentrations do not accurately determine the extent of fermentation of beet pulp in the intestinal tract.

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TABLE II

NUTRIENT CONTENT OF MEALS

| | Standardized Meals | | Test Meals | | |
|---|---|---|---|---|---|
| | Lunch | Dinner | Control | Wheat Bran | Beet Pulp |
| Calories | 225 | 450 | 194 | 154 | 136 |
| Carbo-hydrate | 20g | 25g | 39g | 32g | 22g |
| Protein | 18g | 21g | 5g | 2g | 2g |
| Fat | 8g | 21g | 2g | 2g | 2g |

# TABLE III

## MEAN HYDROGEN CONCENTRATION IN BREATH AT 30 MINUTE INTERVALS

| Time | Treatment | | | | | Orthogonal Comparisons | | | |
|---|---|---|---|---|---|---|---|---|---|
| After Meals | Control | Fine Beet Pulp | Coarse Beet Pulp | Fine Wheat Bran | Coarse Wheat Bran | Probability Level | | | |
| | | | | | | A[c] | F[d] | P[e] | I[f] |
| 0 | 2.3 | 5.3 | 2.2 | 2.6 | 1.7 | - | - | - | - |
| .5 | 4.0 | 6.8 | 3.4 | 5.8 | 4.8 | - | - | - | - |
| 1.0 | 1.6 | 5.2 | 3.2 | 4.0 | 6.0 | - | - | - | - |
| 1.5 | 1.4 | 6.8 | 2.5 | 3.5 | 2.5 | - | - | - | - |
| 2.0 | $3.1^{ab}$ | $9.6^{ab}$ | $2.5^{b}$ | $8.8^{ab}$ | $13.1^{a}$ | - | - | - | .10 |
| 2.5 | $1.8^{b}$ | $4.2^{b}$ | $3.9^{ab}$ | $9.3^{ab}$ | $13.6^{a}$ | - | .06 | - | - |
| 3.0 | $1.1^{b}$ | $5.9^{b}$ | $1.4^{b}$ | $13.1^{a}$ | $5.7^{b}$ | .03 | .02 | .02 | - |
| 3.5 | $1.0^{b}$ | $5.0^{b}$ | $5.4^{b}$ | $12.3^{ab}$ | $23.1^{a}$ | .04 | .01 | - | - |
| 4.0 | 3.4 | 7.1 | 5.7 | 5.6 | 11.5 | - | - | - | - |
| 4.5 | 2.4 | 6.8 | 5.1 | 8.8 | 6.6 | - | - | - | - |
| 5.0 | $3.6^{ab}$ | $3.8^{ab}$ | $1.4^{b}$ | $10.7^{a}$ | $5.0^{ab}$ | - | .04 | .10 | - |
| 5.5 | $6.5^{ab}$ | $2.0^{b}$ | $1.8^{b}$ | $9.4^{a}$ | $5.1^{ab}$ | - | .03 | - | - |
| 6.0 | $4.3^{ab}$ | $1.0^{b}$ | $1.7^{b}$ | $7.3^{a}$ | $2.5^{b}$ | - | .01 | .09 | .03 |
| 6.5 | $5.4^{a}$ | $1.2^{b}$ | $1.3^{b}$ | $2.6^{ab}$ | $5.2^{ab}$ | .06 | .06 | - | - |
| 7.0 | $5.6^{a}$ | $.6^{b}$ | $.6^{b}$ | $1.9^{b}$ | $2.1^{b}$ | .01 | - | - | - |
| 7.5 | 4.4 | .4 | 1.6 | 1.3 | 1.4 | .04 | - | - | - |
| 8.0 | $4.0^{a}$ | $2.5^{ab}$ | $1.6^{ab}$ | $.3^{b}$ | $2.2^{ab}$ | .08 | - | - | - |
| 8.5 | 2.3 | 2.0 | 2.0 | 5.4 | 1.9 | - | - | - | - |
| 9.0 | 1.9 | 2.3 | 1.3 | 2.2 | .5 | - | - | - | - |

Means in a row with different superscript letters differ ($p<.05$)
[1] Underlined means differ from control means ($p<.05$)
[c] Effect of adding fiber
[d] Effect of beet versus wheat fiber
[e] Effect of particlte size
[f] Interaction of fiber source and particle size

# TABLE IV

## MEAN BLOOD GLUCOSE VALUES

| Time | Treatment | | | | | Orthogonal Comparison | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Probability Level | | | |
| After Meals | Control | Fine Beet Pulp | Coarse Beet Pulp | Fine Wheat Bran | Coarse Wheat Bran | A[c] | F[d] | P[e] | I[f] |
| 0 | 80 | 76 | 75 | 77 | 77 | - | - | - | - |
| .25 | 76 | 79 | 74 | 75 | 80 | - | - | - | .05 |
| .50 | 93[ab] | 86[b] | 89[ab] | 90[ab] | 101[a] | - | .08 | - | - |
| .75 | 107[a] | 89[ab] | 80[b] | 85[b] | 101[ab] | .03 | - | - | .07 |
| 1.0 | 105[a] | 84[b] | 78[b] | 88[ab] | 81[b] | .01 | - | - | - |
| 1.25 | 89[a] | 83[ab] | 70[c] | 80[abc] | 74[bc] | .02 | - | .03 | - |
| 1.50 | 89[a] | 78[a] | 71[b] | 73[b] | 73[b] | .01 | - | - | - |
| 1.75 | 80[a] | 80[a] | 66[b] | 77[a] | 71[ab] | .08 | - | .01 | - |
| 2.0 | 80 | 79 | 70 | 75 | 71 | - | - | .10 | - |
| 2.5 | 83 | 78 | 74 | 71 | 73 | - | - | - | - |

Means in a row with different superscript letters differ ($p<.05$)

[1] Underlined means differ from control means ($p<.05$)

[c] Effect of adding fiber

[d] Effect of beet versus wheat fiber

[e] Effect of particlte size

[f] Interaction of fiber source and particle size

TABLE V

BREATH HYDROGEN VAULES

| Fiber Source | Particle Size | Peak Hydrogen Concentration[a] (ppm) | Peak Hydrogen Time (h) | Mean Hydrogen Concentration[b] (ppm) |
|---|---|---|---|---|
| Control | - | 9.9 | 4.4 | 3.2 |
| Beet Pulp | Fine | 16.0[c] | 3.1 | 4.1 |
| Beet Pulp | Coarse | 8.9[c] | 4.1 | 2.6 |
| Wheat Bran | Fine | 15.5[c] | 3.6 | 6.0 |
| Wheat Bran | Coarse | 29.6[d] | 3.1 | 6.0 |

[a]Peak hydrogen values were increased ($p<.06$) by the addition of fiber to the diet.
[b]Mean hydrogen values were greater ($p<.04$) with wheat bran than with beet pulp.
[c,d]Means in a column with different super scripts differ ($p<.05$).

TABLE VI

BLOOD GLUCOSE VALUES

| Fiber Source | Particle Size | Peak Glucose Concentration[a] (mg/dl) | Peak Glucose Time (h) | Mean Glucose Concentration[b] (mg/dl) |
|---|---|---|---|---|
| Control | - | 110 | .80 | 88[c] |
| Beet Pulp | Fine | 93 | .70 | 81[cd] |
| Beet Pulp | Coarse | 91 | .75 | 75[d] |
| Wheat Bran | Fine | 95 | .75 | 79[d] |
| Wheat Bran | Coarse | 106 | .60 | 80[cd] |

[a]Peak glucose concentration was reduced ($p<.06$) by the addition of fiber to the diet.
[b]Mean glucose concentration was reduced ($p<.01$) by the addition of fiber to the diet.
[c,d]Means in a column with different superscripts differ ($p<.05$)

TABLE VI

COMPOSITION OF TEST FIBERS

| Source | Hemicellulose | Cellulose | Lignin | Pectin | Total |
|---|---|---|---|---|---|
| Wheat Bran | 35% | 10% | 3% | - | 48% |
| Beet Pulp | 29% | 17& | 10% | 25% | 81% |

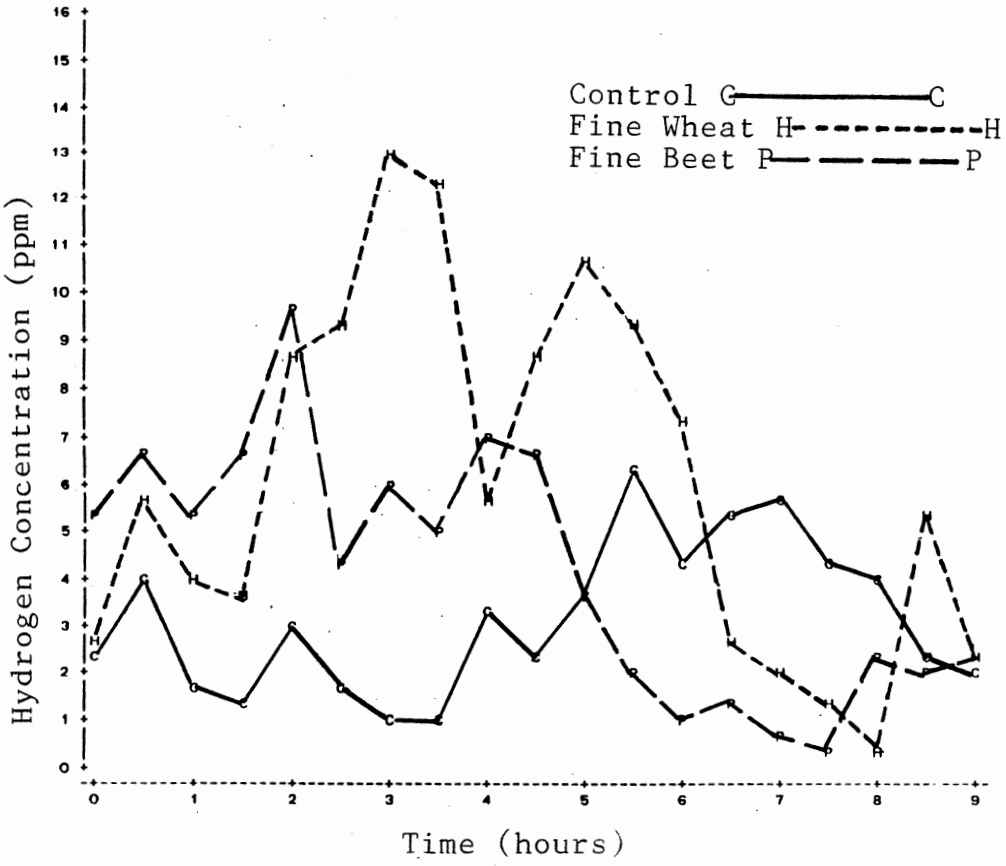


Figure 1. Mean Hydrogen Concentration for Subjects Consuming Fine Particle Sizes of Fiber or Control

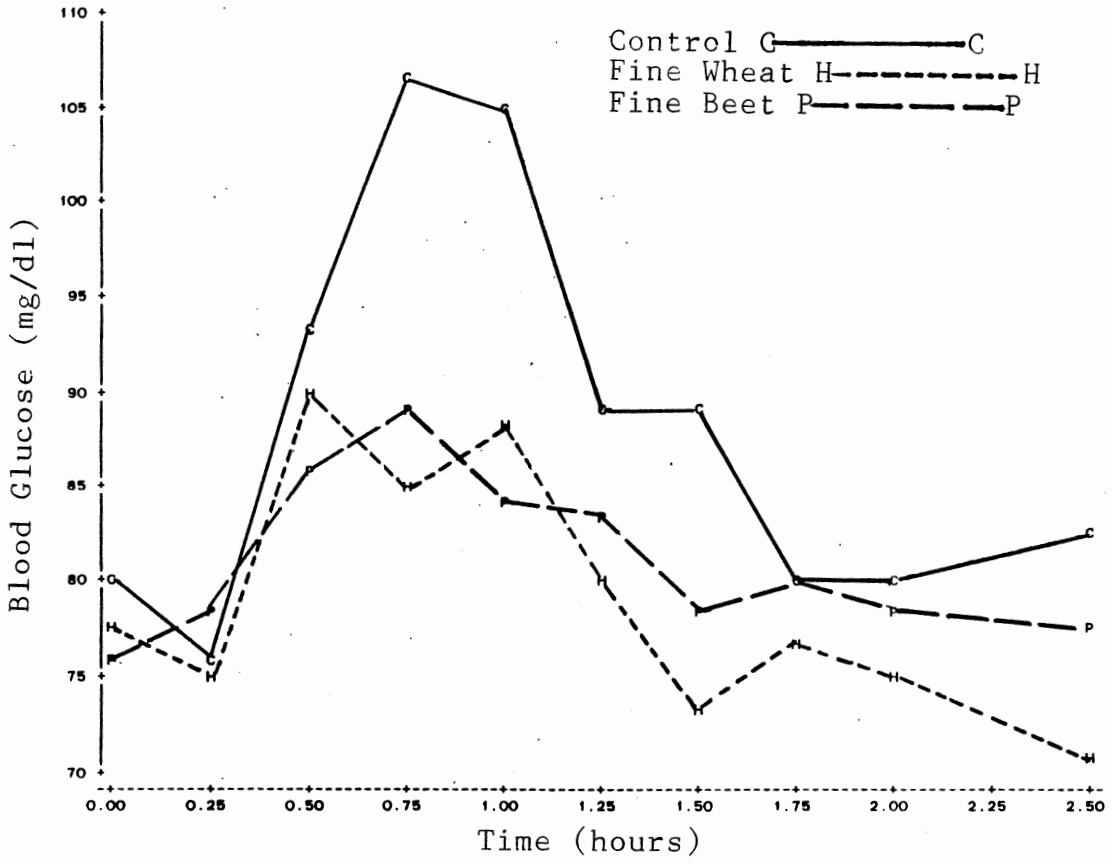


Figure 2. Mean Glucose Levels for Subjects Consuming Fine Particle Sizes of Fiber or Control

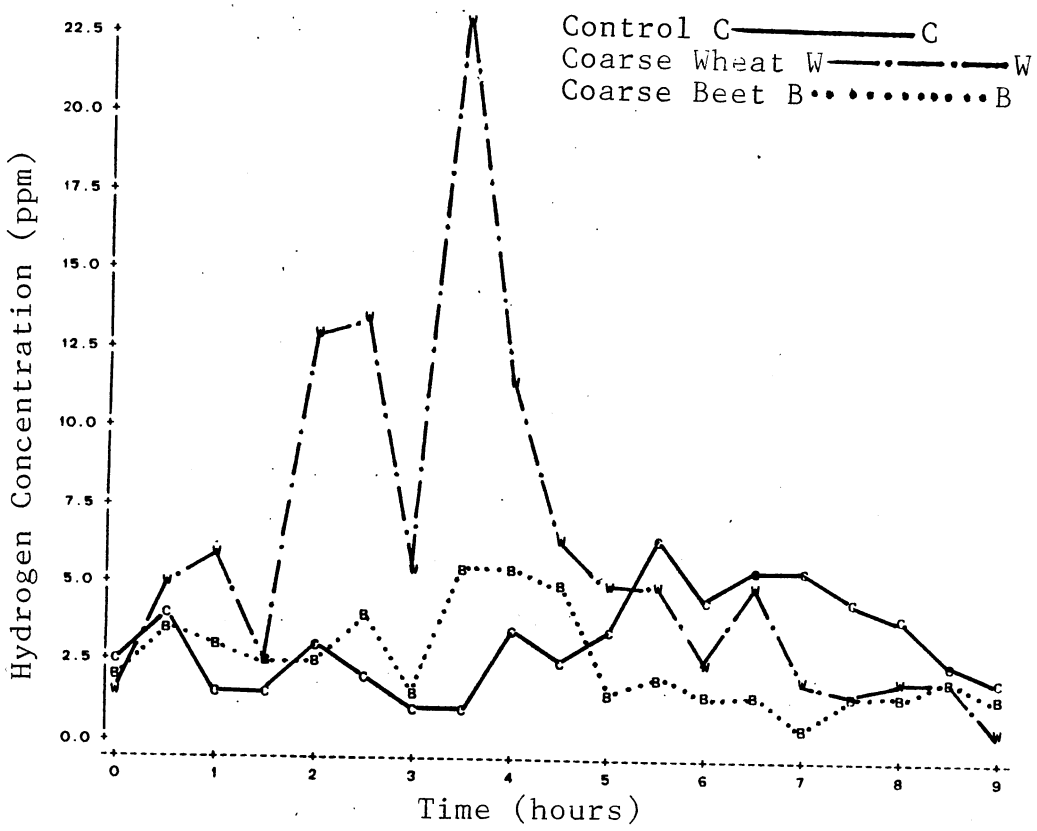


Figure 3. Mean Hydrogen Concentration for Subjects Consuming Coarse Particle Sizes of Fiber or Control

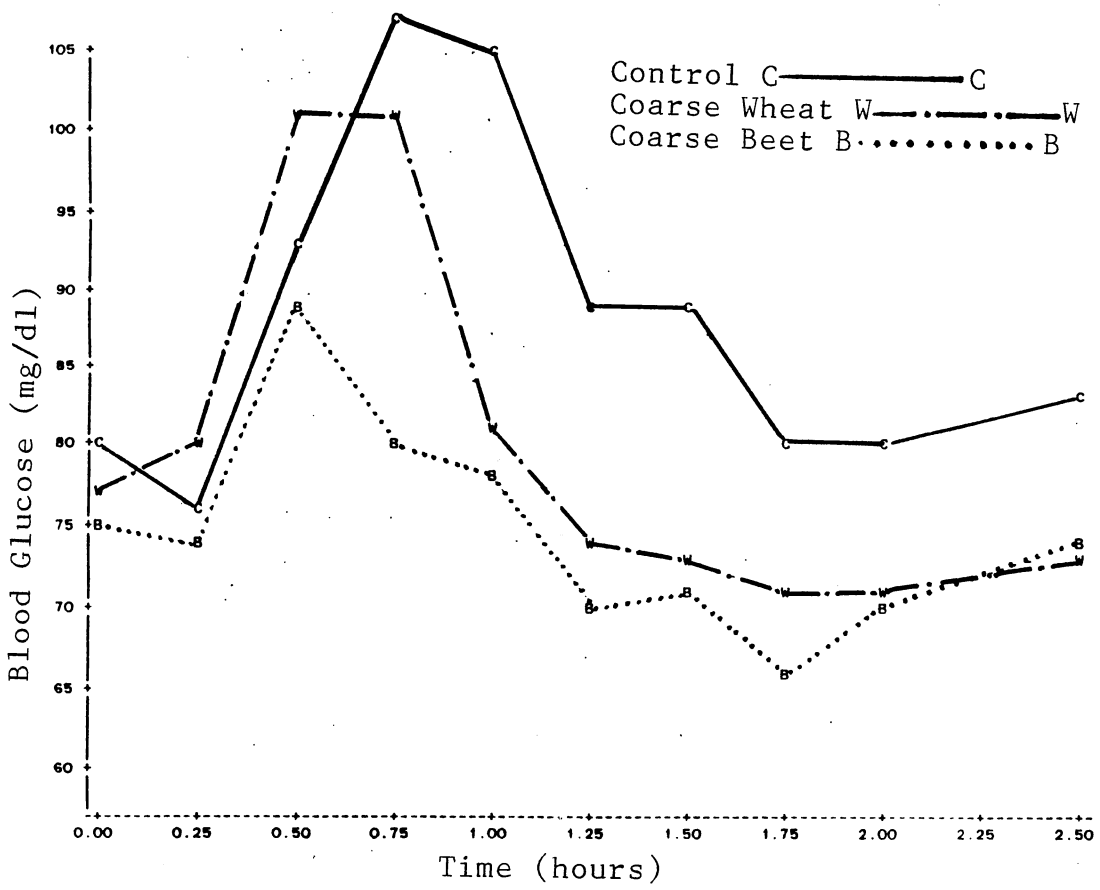


Figure 4. Mean Glucose Levels for Subjects Consuming Coarse Particles Sizes of Fiber or Control

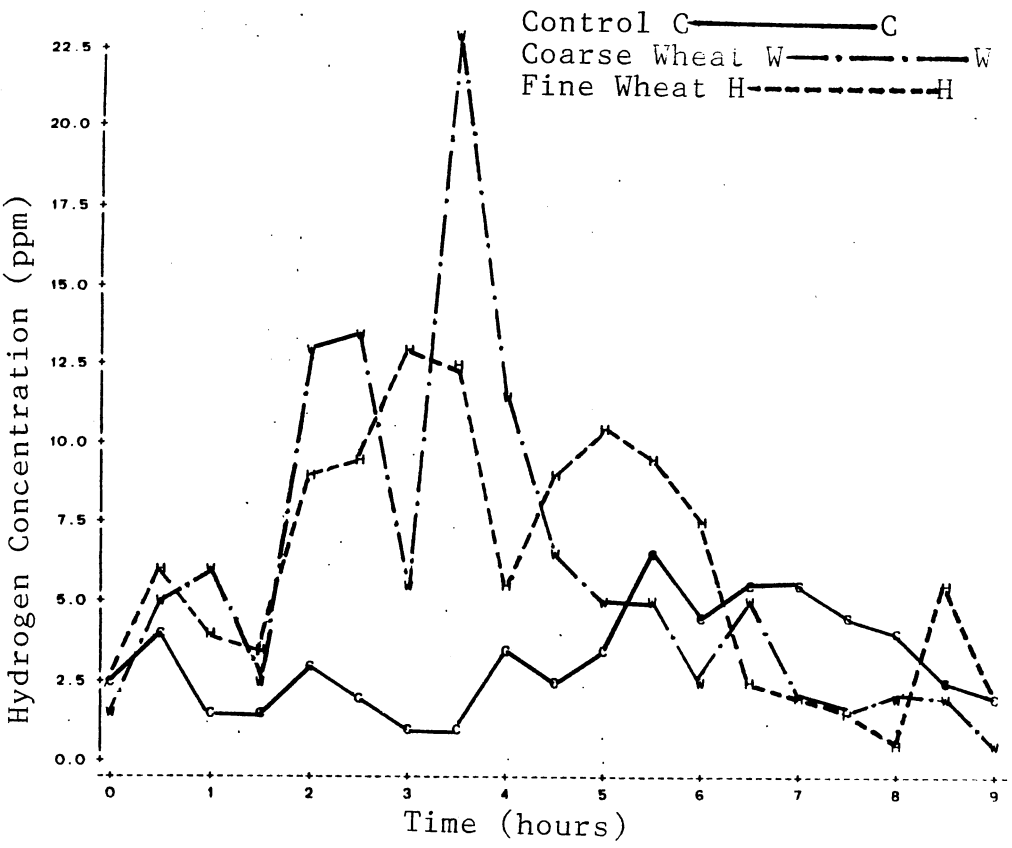


Figure 5. Mean Hydrogen Levels of Coarse or Fine Wheat Bran versus the Control

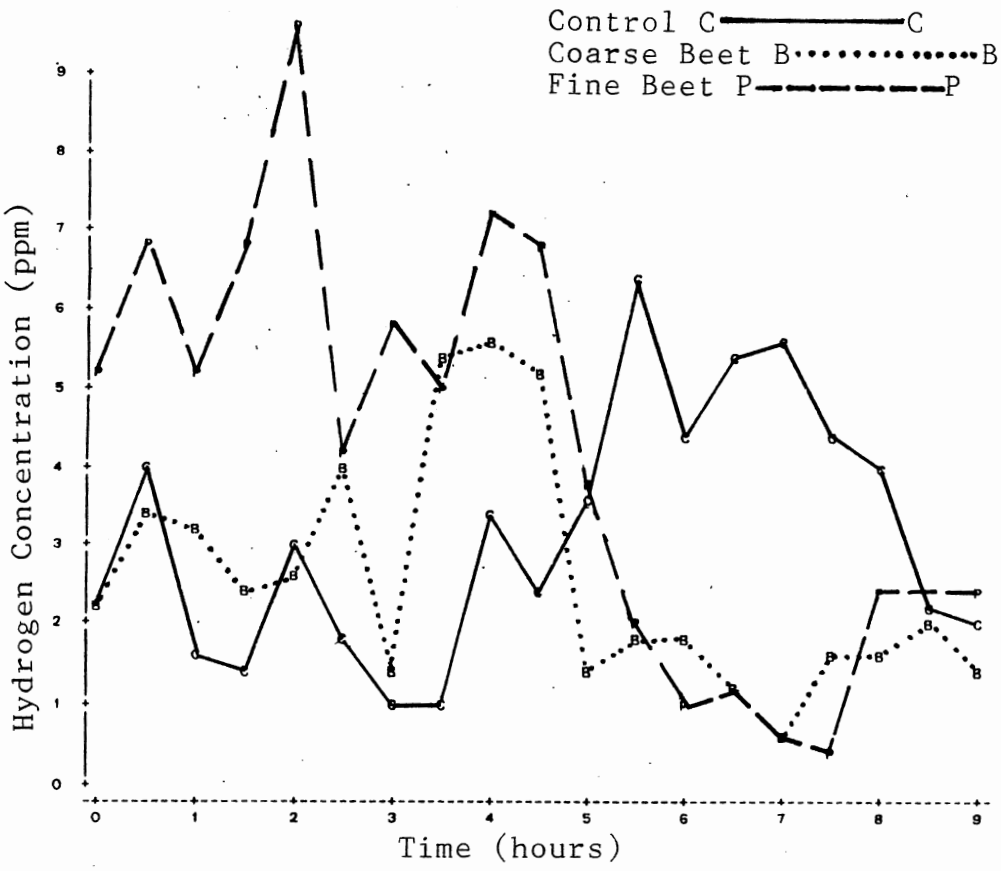


Figure 6. Mean Hydrogen Levels of Coarse or Fine Beet Pulp versus the Control

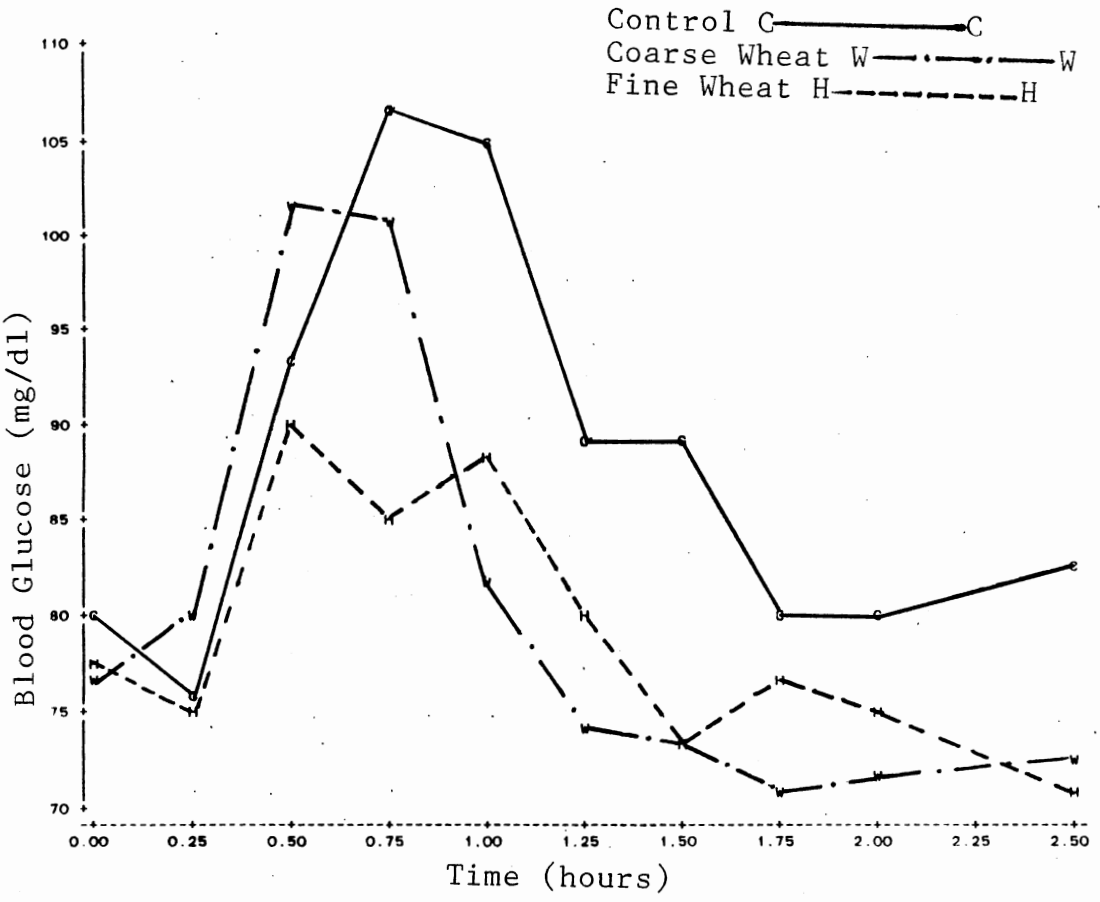


Figure 7. Mean Glucose of Coarse or Fine Wheat Bran versus the Control

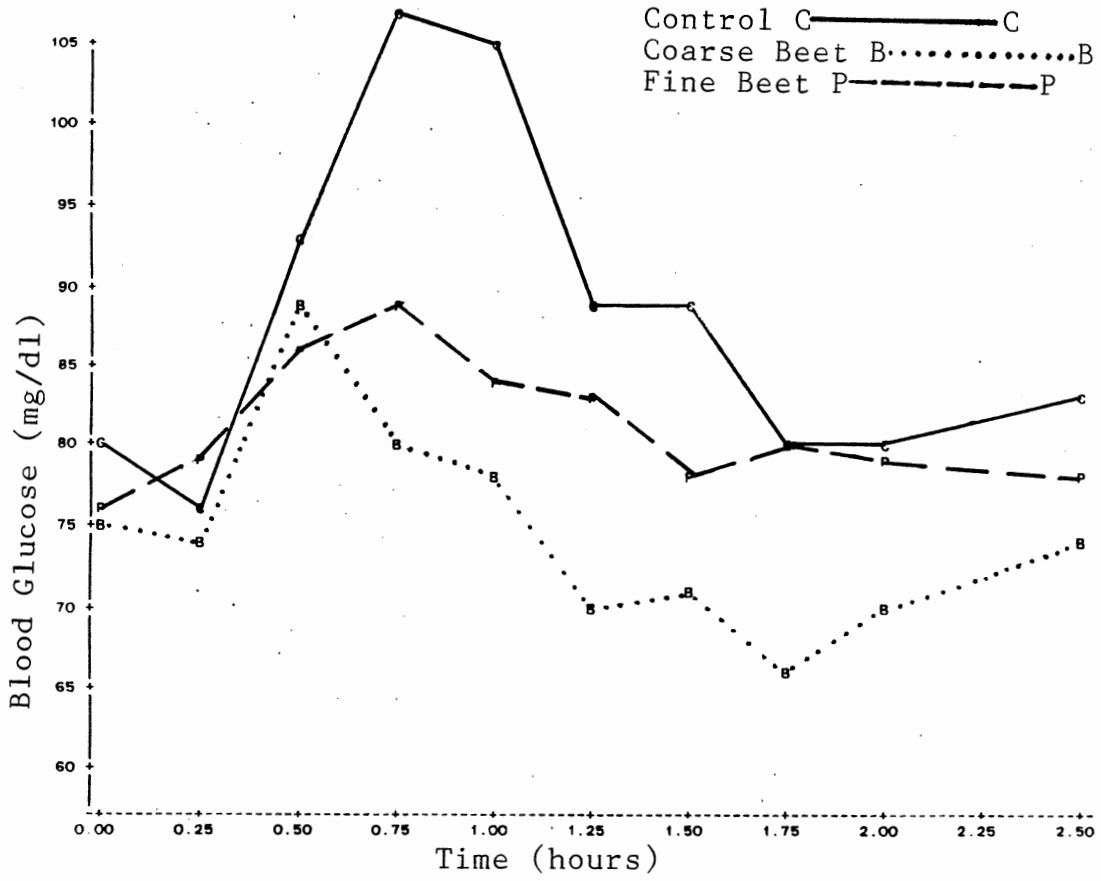


Figure 8. Mean Glucose Levels of Coarse or Fine Beet Pulp versus the control

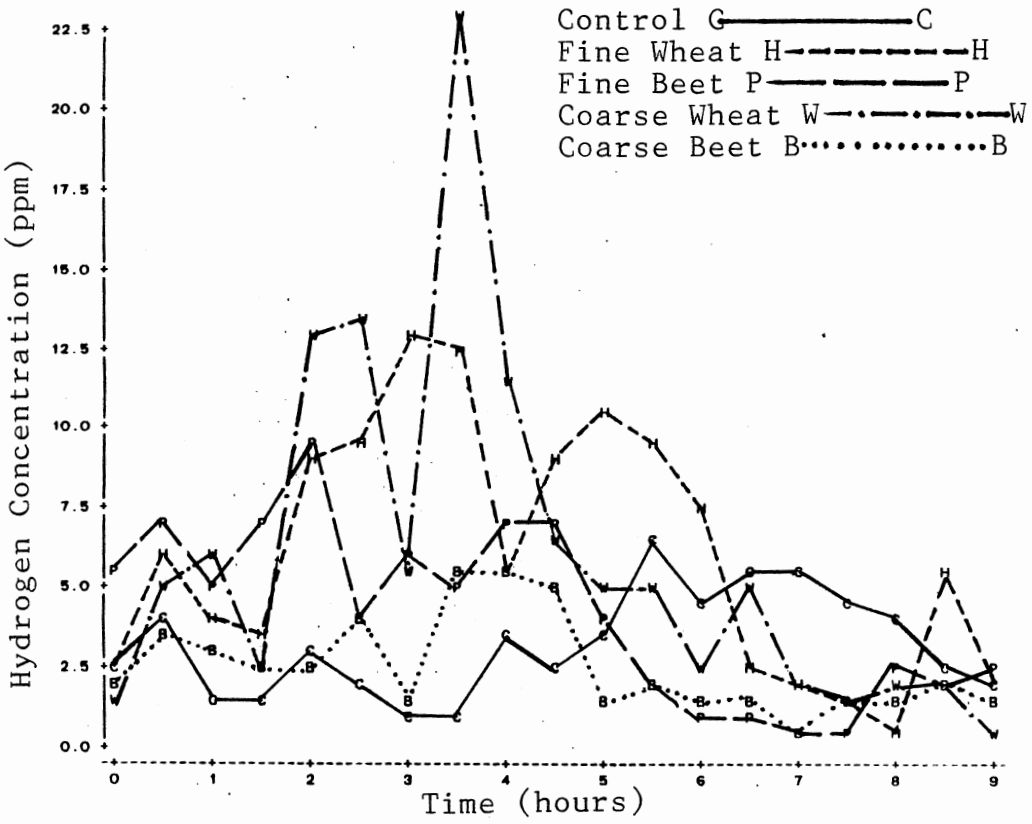


Figure 9. Mean Hydrogen Levels for Test Fibers or the Control

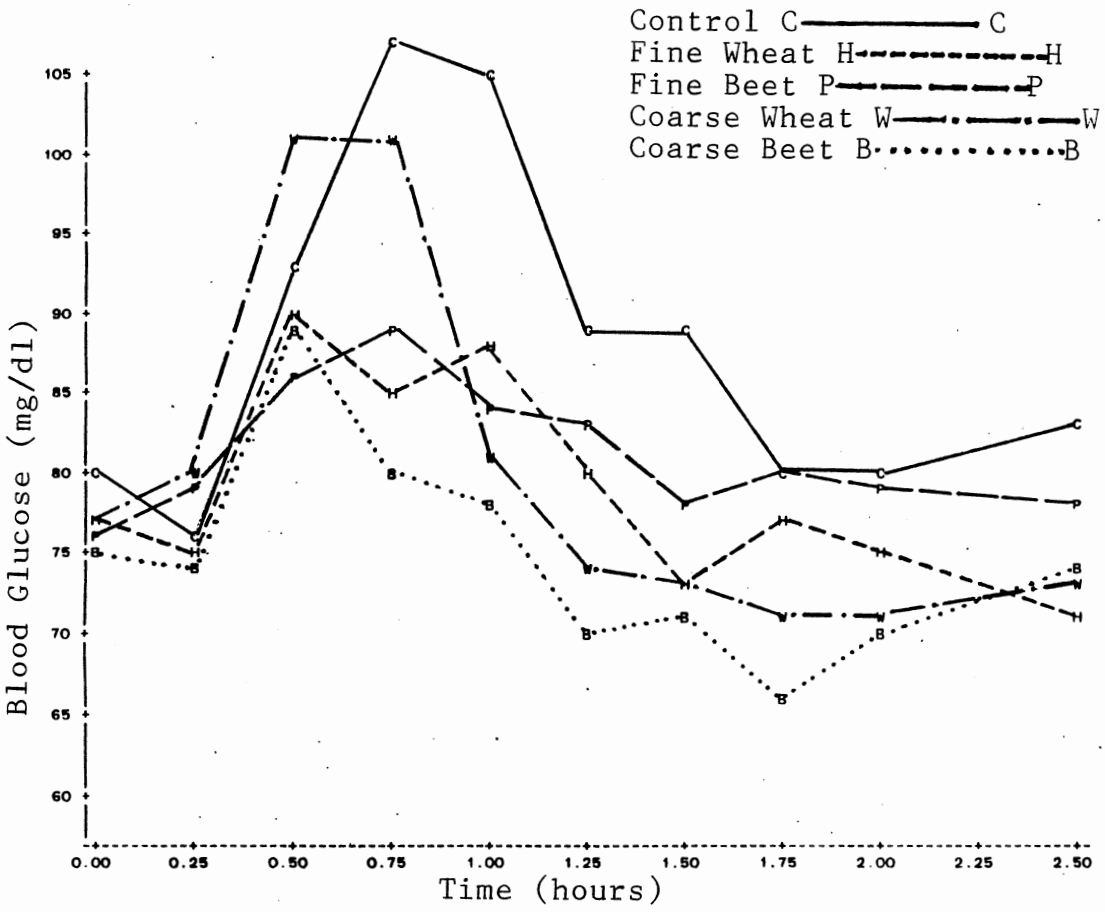


Figure 10. Mean Glucose Levels for Test Fibers or the Control

# CHAPTER V

## RESULTS AND CONCLUSIONS

This thesis addressed several physiological effects of consumption of different particle sizes of the two fiber sources, wheat bran and sugar beet pulp by human subjects. Passage rate to the cecum was indirectly measured by detecting the presence of hydrogen in the expired air of the subjects. Concentration of hydrogen produced by colonic bacteria fermenting fiber in the large intestine was measured. The role that fiber plays in glucose tolerance after a sugar load was also determined. The possible effects of the two different fiber sources and the two particle sizes were stated in the hypothesis found in the introduction of this thesis. Each hypothesis will be discussed and either accepted or rejected individually and further conclusions and recommendations presented.

Hypothesis one stated that breath hydrogen concentration would not be related to fiber type or particle size.

Significant differences were found in breath hydrogen concentrations of the subjects consuming fiber. At several times during the nine hour test period, the hydrogen concentration differed among fiber sources and particle size

(Table III and Figures 1, 3, 5, 6, and 9). At 3, 5.5, and 6 hours after consumption, hydrogen concentration was significantly less with fine beet pulp than with fine wheat bran consumption. At 2 and 3.5 hours after the meal, coarse wheat bran produced more hydrogen than coarse beet pulp. No significant differences were seen between fine and coarse particle sizes of beet pulp. For wheat bran however, differences were seen at hours 3 and 6 when fine bran resulted in excretion of more hydrogen gas than coarse bran ($p<.05$). An overall significant effect of particle size ($p<.02$) is seen at hour 3, and again at hours 5 and 6 ($p<.1$) when fine fiber produced more gas than coarse fiber. Hydrogen concentration after fiber consumption differs from the control level between 2.5 and 3.5 hours for wheat bran and again between 7 and 8 hours. At the earlier time, the wheat bran produced more hydrogen than the control diet and at the later time, the control meal produced more hydrogen than the wheat bran. Beet pulp consumption resulted in hydrogen concentrations different from the control diet from 7 to 7.5 hours, when the control produced more hydrogen gas. For the reasons stated above the first null hypothesis is rejected.

Hypothesis two stated that passage rate would not be related to fiber type or particle size.

Based on peak hydrogen value, no significant differences in passage time were observed. However, consumption of coarse wheat bran produced a rise in breath

hydrogen of 13.6 ppm, 2.5 hours after consumption which peaked one hour later with a concentration of 23.1 ppm. These measurments are both greater ($p<.05$) than the control levels. Hydrogen concentration after consumption of fine wheat bran was significantly different from that of the control 3 hours after consumption. Breath hydrogen rose approximately 2.5 to 3 hours after consumption of wheat bran (Table III, and Figure 5).

Hydrogen concentrations for beet pulp were significantly different from the control at 6.5 and 7 hours, however, at these times, the control diet produced more hydrogen than the test meal (see Table III, and Figure 6). Although no clearly detectable passage of beet pulp was seen, a slight rise in hydrogen was seen at approximately 2.5 hours for fine beet pulp and 3.5 hours for coarse beet pulp. Both sizes of beet pulp produced slightly elevated hydrogen peaks 3.5 to 4 hours after they were eaten (see Table III). At no time during the test period did beet pulp produce a significant increase over the amount of hydrogen produced by the control diet. Speeded passage of both fine and coarse wheat bran based on increased hydrogen, was observed. Because of the reasons stated above the second null hypothesis is rejected.

Hypothesis three stated that blood glucose levels after a test meal would not be related to fiber type or particle size.

Consumption of fiber tended to lower the blood glucose

curve compared to the control (Table IV, and Figures 2, 4, 7, 8, and 10), however, the meal containing coarse beet pulp appeared to have the greatest effect in lowering blood glucose levels, significantly reducing blood glucose from .75 to 1.75 hours after meal consumption ($p<.05$). Blood glucose levels were less for small and large beet pulp and large wheat bran compared to the control at hour 1, and at 1.5 hours only small beet pulp was not different from the control meal. Fiber had a significant overall effect from .75 to 1.75 hours after consumption and large particle size had a greater lowering effect than small particle sizes (Table IV). Glucose levels in the blood tended to return to baseline faster after consumption of large and small wheat bran and large beet pulp as compared to the control. One hour after the consumption of the meal, the highest blood glucose levels were seen in the control diet (105 mg/dl), whereas, at the same time blood glucose ranged from 78 to 88 mg/dl for the fiber meals. Thus both effects of fiber type and of particle size were observed and for these reasons the third null hypothesis is rejected.

Researchers have indicated that reducing the particle size of a fiber will affect its action in the body (Cadden et al., 1983; Heller et al., 1983; Mongeau and Brassard, 1985). The research presented in this thesis shows this to be true. When measuring the blood glucose levels produced after consumption of fine or coarse beet pulp and when measuring hydrogen concentration after consumption of large

and small particle sizes of wheat bran significant differences were observed. The somewhat elevating effect of large particle sizes of wheat bran on blood glucose at .5 and .75 hours after consumption may be partially explained by the composition of the wheat bran used. Freshly milled Oklahoma hard red winter wheat bran was used in this study. Small but visible amounts of flour were still attached to the bran flakes. The fine wheat bran, although never significantly different from large wheat bran, had a more beneficial effect on blood glucose levels. It was mechanically handled during two additional processes compared to the coarse wheat bran. Possibly, during the extra grinding and resieving process some of the flour was dislodged from the bran flakes. Flour, being a digestible carbohydrate composed of glucose units, will contribute to elevating blood glucose levels thus accounting for the higher glocose peak experienced after consumption of the coarse wheat bran. Also while some of this flour was digested and absorbed in the small intestine, because of the speeded passage rate experienced by bran consumption, some of this flour on the wheat bran may have reached the cecum before absorption. Flour would be easily utilized by bacteria, producing a rise in hydrogen. This effect, coupled with the partial fermentation of the wheat bran could account for the high breath hydrogen peak experienced after consumption of the coarse wheat bran. In addition, the test meals each had slightly different amounts of

digestible nutrients due to the composition of the test fibers. Thus the control meal contained 40 more calories than the wheat bran test meal and 58 more calories than the beet pulp meal (Table II). The additional available nutrients may have influenced the glucose response.

Cadden et al., 1983 stated that reducing the size of wheat bran slows passage rate. This effect was not found in this study in measuring transit time to the cecum only. Possibly, grinding the bran to a smaller size renders more of the cellulose and hemicellulose available for fermentation by intestinal flora, thus slowing passage time because less fiber is present in the large intestine to attract water and increase bulk. Coarse wheat bran fermentation produced hydrogen concentrations above 6.6 ppm until 4.5 hours after the test meal whereas fine wheat bran was still being fermented, producing hydrogen concentrations above 6.6 ppm, for an additional one and one half hours, with the fine wheat bran producing more hydrogen ($p<.05$) than large wheat bran at 6 hours after consumption (7.3 versus 2.5 ppm).

The results of this study suggest that passage rate to the large intestine is affected by the presence of fiber and by the source of the fiber. However, passage rate was not significanly ($p<.05$) affected when the particle size of the fiber was altered.

The presence of fiber in the test meal tended to lower blood glucose during the 2.5 hour measurment period,

however, coarse wheat bran consumption resulted in a peak glucose response similiar to the control diet. This study's results demonstrate that breath hydrogen concentrations are apparently poor indicators of the digestibility of sugar beet pulp. At the same time the results show that fine wheat bran produces hydrogen for a longer time and thus apparently is fermented longer than coarse wheat bran.

## Recommendations for Further Research

Many difficulties are encountered when trying to develop a research project comparing various fiber sources. In most instances the different fiber sources have differing fiber compositions that vary in percentage of fiber and digestible nutrient fractions. For example, the wheat bran used in this study was approximately 48% fiber while the sugar beet pulp was approximately 81% fiber, and the beet pulp contained 25% pectin while the wheat bran contained no pectin (Table VI). This study used 30 g of the fiber source. The response of the same physiological functions may differ markedly using the same amount of total fiber, rather than the same amount of fiber source.

In practice, a glucose tolerance test uses a 50 or 100 gram glucose load. This study administered 20 g of sucrose (equal parts glucose and fructose) and variable amounts of starch. Further studies might use a higher dose of glucose enabling the researcher to more clearly compare results to a simple oral glucose tolerance test.

This study looked at short term effects of consumption wheat bran and beet pulp using a one dose test. It is important to closely examine long term effects as well. The sugar beet pulp used in this study is not available for general human consumption nor has it been widely studied. Because it is a vegetable fiber and tended to lower glucose levels after a sugar load, it would be beneficial to learn how it affects fasting glucose levels in a long term study. It would also be interesting to know how long term beet pulp consumption affects serum lipid concentrations since beet pulp appears to have some properties similar to other soluble fiber sources, which lower serum cholesterol.

Subjects with ostomies could be used to study passage rate and fiber changes in the small intestine with fibers that do not produce hydrogen gas. The results of this study suggested that breath hydrogen was a poor indicator of the digestibility of beet pulp , since animal studies (Nyman and Asp, 1982; and Hanson et al., 1987) show that beet pulp is from 64 to 80% fermented in the large intestine.

The recommendations for further research listed thus far have been extensions of the study reported in this thesis. Only non-smoking, normal weight subjects with no known history of gastrointestinal disorders or food allergies should be used. It was found in this study that persons not within ideal body weight range limits had more variation in breath hydrogen values. It was also found that smoking seemed to increase breath hydrogen concentration

readings.

Questions still to be answered about fiber include how much per day is optimum, which are the best types of fiber to consume, fiber nutrient interactions, the metabolic role of fiber fermentation products, and fiber-disease relationships.

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# APPENDIXES

# APPENDIX A

# INFORMATION LETTER AND CONSENT FORM

OSU

*Oklahoma State University*

DEPARTMENT OF FOOD, NUTRITION AND INSTITUTION ADMINISTRATION
COLLEGE OF HOME ECONOMICS

STILLWATER, OKLAHOMA 74078
HOME ECONOMICS WEST 425
(405) 624-5039

Dear Research Participant,

Thank you for agreeing to participate in this experiment. This research will provide important information on how different types and particle sizes of dietary fiber effect passage rate and blood glucose levels.

As a participant in this experiment, you will recieve valuable information about your own blood glucose levels and the passage rates of various types of fibers. You'll also gain the experience of being a research subject, of great value if you are a student.

This study will take five weeks to complete. Ten times each day on the experiment days you will have your finger pricked. Only a total of ten drops of blood will be needed on each of the five testing days. You will also be asked to blow into an airtight bag every 30 minutes for nine hours. It is very important that you consume only the standardized control dinner, the test fiber breakfast, and the standardized control lunch on your testing days. You may drink water at will but no other beverages should be consumed.

I'm very appreciative that you are willing to contribute your time and effort in order that this research may be carried out. Any information you provide will be kept confidential, and at the conclusion of the study all records associating you as an individual with any data will be destroyed.

In the event that you experience any discomfort which might be due to the experiment, please let me know, so that appropriate action can be taken. You may drop out of the study at any time. I hope that this will be an interesting and profitable experience for you. Please feel free to contact me at any time at either my office, 624-5039, or at home 372-8057.

Sincerely,

Karen K. Burch,
Masters Student, FNIA

CENTENNIAL
DECADE
1980 • 1990

OSU

*Oklahoma State University*

DEPARTMENT OF FOOD, NUTRITION AND INSTITUTION ADMINISTRATION
COLLEGE OF HOME ECONOMICS

STILLWATER, OKLAHOMA 74078
HOME ECONOMICS WEST 425
(405) 624-5039

CONSENT TO PARTICIPATE

I have been told about the nutrition research study at Oklahoma State University to find out the effects of fiber on digestion, passage of material in the digestive tract, and blood glucose levels. I understand that being in this study means that I agree to:

1.) Eat the standardized dinner the night before the test and consume nothing but water untill the test meal is consumed.
2.) Eat only the meals provided for me on the testing days and no other food or beverage unless approved by the project director.
3.) Blow into breath collection bags once every 30 minutes for 9 hours, starting at breakfast of the designated day.
4.) Have glucose levels of my blood measured using an Ames Glucometer and Dextrostix, every 15 minutes for 2 hours and every 30 minutes for 1 hour.

I understand that I will be well cared for, can ask questions at any time, and drop out of the study any time I want to. Any unusual findings from tests will be reported to me, and no information about me will be given to other people.

I authorize Oklahoma State university, the Oklahoma Agricultural Experiment Station, Dr. Christa F. Hanson, Karen K. Burch, and whomever they may designate, to carry out the procedures I have agreed to and which have been explained to me.

I assume whatever risk is involved, but my consent to be in this study does not mean I give up any legal rights or release the person in charge from liability due to negligence. I understand that all information about me will be strictly confidential.

I voluntarily agree to be in this study.

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Participant Date

---

Project Director: Christa Hanson Ph.D. Date
409 HEW X-5039
377-3188 Home

---

Coproject Director: Karen Burch Date
407 HEW X-5039
372-8057 Home

CENTENNIAL DECADE
1980 • 1990

# APPENDIX B

## RAW DATA

SUBJECT A

| BREATH HYDROGEN | | | | | BLOOD GLUCOSE | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Week # | | | | | | | | | |
| Fiber | | | | | | | | | |
| #4 Con | #1 LW | #3 SW | #5 LB | #2 SB | #1 LW | #2 SB | #3 SW | #4 CO | #5 LB |
| 1.0 | 0 | 0 | 1.85 | 12.5 | 81 | 76 | 73 | 90 | 70 |
| 1.8 | 2 | 0 | 1 | 2.38 | 77 | 84 | 70 | 82 | 81 |
| 1.8 | 1 | .39 | 1.85 | 8.93 | 123 | 90 | 79 | 111 | 95 |
| 1 | 2 | 9.38 | 0 | 8.93 | 114 | 87 | 66 | 119 | 86 |
| 2.68 | 15.2 | 13.48 | 1 | 5.95 | 80 | 80 | 66 | 138 | 86 |
| 2.23 | 29.1 | 15.23 | 4.17 | 1.98 | 76 | 81 | 68 | 97 | 81 |
| 1.79 | 7.9 | 10.74 | 3.47 | 0 | 73 | 83 | 74 | 98 | 81 |
| 2.23 | 13.2 | 12.7 | 2.89 | 2.98 | 76 | 89 | 72 | 77 | 75 |
| 6.7 | 5.3 | 7.32 | 1.85 | 6.94 | 82 | 84 | 65 | 80 | 81 |
| 2.01 | 0 | 8.79 | 2.78 | 11.9 | 80 | 80 | 70 | 104 | - |
| 2.79 | 0 | 2.34 | 4.05 | 10.12 | | | | | |
| 10.4 | 5.6 | 7.62 | 1.39 | 2.98 | | | | | |
| 5.58 | 3.2 | 9.96 | 2.31 | 2 | | | | | |
| 8.93 | 9.5 | 0 | 3.47 | 5.95 | | | | | |
| 8.93 | 41.0 | 0 | 1 | 0 | | | | | |
| 11.16 | 0 | 0 | 2.31 | 0 | | | | | |
| 9.49 | 0 | .39 | 1.39 | 2.0 | | | | | |
| 21.05 | 0 | 0 | .93 | 0 | | | | | |
| 42.11 | 0 | .39 | 1.39 | 0 | | | | | |

SUBJECT B

| | BREATH HYDROGEN | | | | BLOOD GLUCOSE | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Week# Fiber | | | | | | | | | |
| #2 CON | #4 LW | #1 SW | #3 LB | #5 SB | #1 SW | #2 CON | #3 LB | #4 LW | #5 SB |
| .38 | 1 | 4.79 | 0 | 0 | 84 | 71 | 80 | 85 | 77 |
| 0 | 5.38 | 2.93 | 1 | 1 | 82 | 89 | 77 | 88 | 87 |
| 0 | 0 | 4.69 | 1 | 1 | 117 | 96 | 84 | 108 | 94 |
| 1 | 0 | 2.73 | 0 | 9.22 | 97 | 101 | 84 | 105 | 90 |
| 0 | 0 | 3.52 | 2 | 2.19 | 86 | 97 | 88 | 72 | 89 |
| 0 | 1 | 7.32 | 7.39 | 7.68 | 87 | 81 | 68 | 72 | 84 |
| 0 | 2 | 8.79 | 2.46 | 19.14 | 80 | 76 | 61 | 85 | 91 |
| 1.92 | 13.71 | 6.35 | 7.39 | 6.58 | 86 | 82 | 69 | 82 | 85 |
| 5.77 | 16.13 | 4.88 | 1 | 6.58 | 88 | 80 | 66 | 71 | 79 |
| 1.92 | 7.53 | 9.38 | 2 | 8.22 | 82 | 82 | 80 | 83 | 84 |
| 0 | 1 | 9.96 | 0 | 5.48 | | | | | |
| 1 | 2.69 | 13.48 | 1 | 3.84 | | | | | |
| .38 | 0 | 7.62 | 0 | 2.19 | | | | | |
| 1 | 0 | 2.44 | 0 | - | | | | | |
| 2.31 | 0 | 1 | 1 | 2.19 | | | | | |
| 0 | 1.12 | 1 | 2.96 | 2.19 | | | | | |
| 2.88 | 1 | 1 | 1 | 4.39 | | | | | |
| 0 | 1 | 0 | 0 | 9.21 | | | | | |
| 0 | 0 | 0 | 0 | 10.53 | | | | | |

SUBJECT C

| | BREATH HYDROGEN | | | | BLOOD GLUCOSE | | | | |
|---|---|---|---|---|---|---|---|---|---|
| WEEK# FIBER | | | | | | | | | |
| #5 CON | #2 LW | #4 SW | #1 LB | #3 SB | #1 LB | #2 LW | #3 SB | #4 SW | #5 CO |
| 1 | 3.37 | 4.3 | 5.9 | 7.65 | 74 | 69 | 63 | 71 | 71 |
| 1 | 4.62 | 12.9 | 9.2 | 12.24 | 72 | 76 | 66 | 70 | 65 |
| 2 | 3.37 | 2 | 7.5 | 9.95 | 87 | 80 | 84 | 78 | 76 |
| 0 | .87 | 0 | 9.7 | 7.65 | 65 | 63 | 94 | 71 | 77 |
| 9.32 | 2.88 | 1 | 7.73 | 16.91 | 56 | 67 | 67 | 71 | 74 |
| 0 | .87 | 2 | 7.52 | 4.46 | 61 | 66 | 72 | 65 | 74 |
| 0 | 0 | 10.22 | - | 5.36 | 69 | 67 | 64 | 63 | 81 |
| 0 | 36.85 | 10.75 | 10.95 | 3.85 | 64 | 72 | 70 | 69 | 69 |
| 1 | 13.85 | 3.76 | 21.05 | 9.18 | 72 | 67 | 72 | 74 | 60 |
| 0 | 4.62 | 2 | 14.17 | 8.52 | 58 | 68 | 71 | 73 | 70 |
| 0 | 13.46 | 10.08 | 0 | 2.3 | | | | | |
| 0 | 12.98 | 2.15 | 6.44 | 0 | | | | | |
| 1 | 2.88 | 1 | 1 | 0 | | | | | |
| 2.63 | 5.38 | 0 | 1 | 0 | | | | | |
| 3.07 | 1.92 | 1 | 1 | 0 | | | | | |
| 1.75 | 4.33 | 1.12 | 2 | 0 | | | | | |
| 1.75 | 7.5 | 2.15 | 2 | 0 | | | | | |
| 7.13 | 6.35 | 5.91 | 0 | 0 | | | | | |
| 1.75 | .38 | 4.84 | 0 | 0 | | | | | |

SUBJECT D

| BREATH HYDROGEN | | | | | BLOOD GLUCOSE | | | | |
|---|---|---|---|---|---|---|---|---|---|
| WEEK # | | | | | | | | | |
| FIBER | | | | | | | | | |
| #3 CON | #5 LW | #2 SW | #4 LB | #1 SB | #1 SB | #2 SW | #3 CON | #4 LB | #5 LW |
| 1.75 | 3.95 | 1.89 | 1.75 | 1.17 | 91 | 85 | 82 | 70 | 84 |
| 2.92 | 11.84 | 3.79 | 2.19 | 2.93 | 81 | 82 | 69 | 72 | 95 |
| 1 | 13.82 | 6.31 | 2.74 | 2.34 | 93 | 104 | 104 | 102 | 117 |
| 1.75 | 9.87 | .5 | 1.32 | 1.17 | 100 | 107 | 114 | 88 | 131 |
| 0 | 27.74 | 7.58 | 1 | 2 | 99 | 110 | 103 | 77 | 99 |
| 4.67 | 34.54 | 9.47 | 0 | 1.56 | 95 | 87 | 79 | 56 | 71 |
| 0 | 16.45 | 15.15 | 3.84 | 0 | 86 | 70 | 89 | 68 | 59 |
| 0 | 46.05 | 17.42 | 2.63 | 2.44 | 85 | 83 | 78 | 55 | 57 |
| 3.74 | 19.74 | 13.64 | 3.51 | 10.25 | 83 | 78 | 88 | 69 | 62 |
| 1.87 | 21.05 | 13.26 | 1 | 2.73 | 94 | 72 | 86 | 70 | 71 |
| 1 | 10.42 | 17.42 | 1 | 0 | | | | | |
| 10.51 | 4.39 | 15.91 | 0 | 2.34 | | | | | |
| 7.01 | 6.58 | 9.85 | 4.39 | 0 | | | | | |
| 5.26 | 9.87 | 7.58 | 1 | 0 | | | | | |
| 9.11 | 4.39 | 6.07 | 0 | 0 | | | | | |
| 5.84 | 1.75 | 4.54 | 1 | 0 | | | | | |
| 4.09 | 1.32 | 0 | - | 4.3 | | | | | |
| 5.26 | 1 | 11.36 | 1 | 0 | | | | | |
| 5.84 | 1 | 0 | 2 | 0 | | | | | |

SUBJECT E

| BREATH HYDROGEN | | | | | BLOOD GLUCOSE | | | | |
|---|---|---|---|---|---|---|---|---|---|
| WEEK # | | | | | | | | | |
| FIBER | | | | | | | | | |
| #1 CON | #3 LW | #5(C) SW | #2 LB | #4 SB | #1 CON | #2 LB | #3 LW | #4 SB | #5(C) SW |
| 7.27 | 0 | 1.77 | 1.32 | 5.17 | 84 | 82 | 65 | 71 | 78 |
| 14.51 | 0 | 9.34 | 3.95 | 15.52 | 74 | 66 | 66 | 75 | 73 |
| 3.18 | 11.6 | 6.72 | 2.74 | 3.77 | 80 | 76 | 79 | 70 | 73 |
| 3.18 | 0 | 4.93 | 1.32 | 7.11 | 122 | 81 | 90 | 76 | 83 |
| 3.41 | 19.8 | 18.4 | 1 | 21.12 | 115 | 84 | 89 | 87 | 94 |
| 2 | 2.3 | 12.55 | .66 | 5.39 | 114 | 83 | 86 | 84 | 95 |
| 3.63 | 2.3 | 20.7 | 1 | 4.31 | 103 | 74 | 82 | 66 | 78 |
| 1 | 5.68 | 14.1 | 3.29 | 9.1 | 95 | 69 | 67 | 71 | 75 |
| 0 | 2.27 | 1.15 | 1 | 2.6 | 92 | 63 | 75 | 75 | 71 |
| 6.25 | 0 | 10.34 | 5.73 | 2.7 | 72 | 90 | 61 | 60 | 59 |
| 14.1 | 0 | 13.9 | 1.75 | 1 | | | | | |
| 10.8 | 0 | 7.96 | 0 | 1 | | | | | |
| 7.7 | 0 | 8.15 | 1 | 1 | | | | | |
| 9.6 | 1 | 3.0 | 1 | 1 | | | | | |
| 4.55 | 0 | 1.4 | 0 | 1 | | | | | |
| 3.41 | 0 | 0 | 0 | 0 | | | | | |
| 2 | 1 | 0 | 0 | 1.62 | | | | | |
| 1 | 1 | 9.75 | 8.22 | 1.0 | | | | | |
| 3.41 | 1.36 | 5.62 | 3.29 | 1 | | | | | |

(C) = Computer generated values

VITA 2

Karen Kelly Burch

Candidate for the Degree of

Master of Science

Thesis: THE EFFECT OF DIETARY FIBER SIZE AND TYPE ON BREATH HYDROGEN AND BLOOD GLUCOSE

Major Field: Food, Nutrition and Institution Administration

Biographical:

Personal Data: Born in Yale, Oklahoma, April 20, 1960, the daughter of Charles A. and Dawn M. Burch.

Education: Graduated from Yale High School in May, 1978; received Bachelor of Science in Home Economics from Oklahoma State University in December, 1983; completed requirements for the Master of Science degree at Oklahoma State University in December, 1987.

Professional Experience: Assistant Food and Beverage Director, Howard Johnson's, January, 1984 to August, 1986; Research Assistant, Department of Food, Nutrition and Institution Administration, Oklahoma State University, September, 1986 to June, 1987; Dietetic Internship, Oklahoma Memorial Hospital, July, 1987 to December, 1987.

Organizations: American Dietetic Association; Institute of Food Technologists.