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MICHELLE HUI-MING YU for the MASTER OF SCIENCE
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Lorraine Miller

The effect of cooked wheat bran on the excretion of fecal nutrients, fecal weight, and transit time was investigated in 10 men, aged 20 to 35 years. The study was divided into three 18-day periods. The subjects were divided into two groups; one received the basal diet supplemented with 15 g of AACC Certified Food Grade Wheat Bran (B) during the first period, no bran (NB) in the second, and B in the third. The other group received NB, B and NB in that order. The basal diet supplied 6.6 g neutral detergent fiber (NDF). The subjects' fat intake was constant. All feces were collected; values for each subject were obtained from the second and third 6-day fecal composites of each period. Bran induced significantly higher ($p < 0.01$) fecal loss of energy, nitrogen and ash. In response to B and NB diets, respectively, mean

fecal caloric output was 211±27 and 179±27 kcal/day; mean fecal nitrogen was 2.1±0.3 and 1.9±0.3 g/day; fecal ash was 5.0±0.5 and 4.3±0.5 g/day. Although the mean daily fat excretion was higher on B (5.4±1.7 g) than on NB (4.5±1.3 g), the difference was not statistically significant. Bran caused a consistent increase in fat loss only in one group of subjects. Fecal NDF (determined in the last 6-day composite of each period) was higher ($p < 0.05$) on B (8.3±2.2g/day) than on NB (5.1±2.6 g/day). Fecal wet weight and dry solids, respectively, were higher ($p < 0.05$ and $p < 0.01$) when the subjects received B (172±39 and 43±3 g/day) than when they received NB (143±34 and 36±4). Percentage moisture content of the feces was not altered by bran supplementation. Mean transit time in hours was shorter on B (28.5±4.8) than NB (32.3±8.4); the difference, however, was not statistically significant. Results suggested that cooked wheat bran may cause increase in nutrient loss in feces. The increment, however, may not be important nutritionally.

Effect of Wheat Bran on Fecal Nutrients And Bowel Function in Humans

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Michelle Hui-Ming Yu

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Associate Professor of Foods and Nutrition
in charge of major

Head of Department of Foods and Nutrition

Dean of Graduate School

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EFFECT OF WHEAT BRAN ON FECAL NUTRIENTS AND BOWEL FUNCTION IN HUMANS

INTRODUCTION

The lack of fiber in the Western diet has been suggested recently as an etiologic factor of a variety of diseases (1). Western populations are now encouraged to include more natural fiber in their diets. Among all the fiber-containing foods, wheat bran is an economical one for increasing fiber content in the diet. In the form of breakfast cereal, whole wheat bread and crackers, etc., wheat bran has been well accepted by consumers. Raw wheat bran is also popular.

However, it has been postulated that dietary fiber may have a deleterious effect on nutrient utilization. The study of Southgate and Durnin revealed that a diet high in fruits and vegetables increased the fecal excretion of nitrogen, fat, and energy (2). Poorer nitrogen balances were observed in subjects who were in marginal or negative nitrogen balances when they were supplemented with hemicellulose (3). Supplemental Isogeo (high in hemicellulose) in a controlled study (4), however, induced different responses among individuals in the digestibility of nutrients.

There has been only limited research concerning the effect of wheat bran on the utilization of dietary nutrients. In an uncontrolled diet study, daily supplementation of 38 g of wheat bran increased fecal loss of nitrogen, fat,

and energy (5). Adding various forms of cooked wheat fiber (breakfast cereal, whole wheat bread, and bran muffins) to a controlled diet of six men caused a daily increase of 28 g of fiber intake and also induced fecal loss of fat, nitrogen and calcium (6). It should be pointed out that the addition of these commercial wheat fiber products altered the composition of the diet served.

It is commonly believed that dietary fiber increases fecal weight and, at the same time, decreases the gastrointestinal transit time. Although its effect on stool weight has been proven consistently, the mechanism bringing about this change is still under debate. Some opine that the increased fecal water resulting from the water holding capacity of dietary fiber accounts for most of the increased fecal weight. Yet, some suggest that the cathartic effect of the bacterial digestion products of fiber is the main driving force in increasing fecal weight. As for transit time, contradictory results have been reported. McCance et al. (7) showed that in 6 men wheat bread passed through the gut faster than white bread. The transit time in eight subjects who were fed a diet supplemented with 16 g of raw wheat bran, however, was not altered (8).

In the present study, a moderate amount of wheat bran (15 g) was incorporated into a constant but otherwise normal American diet. The purpose of the study was to investigate the effect of dietary wheat bran on fecal

nutrients and bowel function, i.e., fecal weight and intestinal transit time, and to deduce the possible mechanisms to effect both changes.

REVIEW OF LITERATURE

Components of Plant Cell Walls

The polysaccharides of plant cell walls are usually classified as matrix polysaccharides and fiber polysaccharides (1). Matrix polysaccharides are normally composed of pectic substances and hemicellulose. Fiber polysaccharides are mostly crystalline. They are present as microfibrils, composed mainly of cellulose, which are held together by hydrogen bonds in a cement of largely amorphous matrix polysaccharides, lignin and some proteins. Collectively, cellulose, hemicellulose, and pectin are referred to as the plant structural polysaccharides. Lignin is the main non-carbohydrate structural component of the plant cell wall. The chemistry of these components is discussed below under "Chemistry of Plant Cell Walls."

Besides these plant structural polysaccharides, there are some non-structural components often closely associated with plant cell walls. Among these are: cutins found in the surface layer of many leaves, stems, fruits and seeds; mucilages, which are common constituents of the outer walls of many plants; and inorganic compounds such as silica and calcium salts, iron, and other metals present in the cell wall together with small amounts of protein. The plant cell wall is chemically a dynamic structure. The amount of each

component varies with the type of plant tissue and the age of the plant (10).

Nomenclature of Plant Fiber

Dietary fiber, a widely used term, is currently accepted as denoting the plant polysaccharides and lignin which are resistant to hydrolysis by human digestive enzymes. Some dietary fiber, however, may be partly degraded by human colonic bacteria (11). Under this definition some of the more important constituents of dietary fiber are cellulose, hemicellulose, pectins, lignin, gums, mucilages, and algal polysaccharides. Table I shows the components of dietary fiber and their structural features (12).

Acid detergent fiber, neutral detergent fiber and crude fiber are also used to describe plant cell wall materials (13). These terms relate directly to the methods used for the isolation of the plant fiber materials. Acid detergent fiber refers essentially to the crude lignin and cellulose fraction of plants. Neutral detergent fiber measures essentially lignin, cellulose, and hemicellulose as well as other cell wall components such as cutin, minerals, and protein. The difference between neutral detergent fiber and acid detergent fiber is hemicellulose. Crude fiber value, which was determined in the past, nowadays is considered of little nutritional importance, because it

Table 1. The components of dietary fiber and their structural features

Terminology	Major Groupings	Principal Structural Types
Neutral Detergent Fiber	Hemicellulose	Galacturonans
		Xylans, arabino-glucurono-
		Mannans, gluco-galacto-
		Galactans, arabino-
Acid Detergent Fiber	Cellulose	β-D-Glucose
	Lignins	Aromatic polymers
	Pectin	Galacturonans
	Gums	Great variety including arabino-xylans and gluco- and galacto-mannans
	Mucilages	Sulphated galactans
	Algal Polysaccharides	Gulurono-mannuronans

(Adapted from Southgate, D. A. T. (12))

fails to represent any specific component of dietary fiber. Crude fiber is defined by the Association of Official Analytical Chemists (AOAC) (14) as the residue of a feeding material after treatment with boiling sulphuric acid, sodium hydroxide, water, alcohol and ether. According to Van Soest and McQueen (15), crude fiber represents about 20% of the hemicellulose, 10 to 50% of the lignin and 50 to 80% of the cellulose of the true dietary fiber intake.

Chemistry of Plant Fiber

Cellulose, the most abundant organic compound in nature, is a linear polymer of repeating β-1-4 linked D-glucose units. It was at one time thought that hemicellulose was a cellulose precursor but this has been disproven. Hemicellulose may be separated into two main groups: pentosans, based either on xylose or arabinogalactans; and non-cellulose hexans, mannans or β-glucans (15).

Galacturonans are the main components of pectic substances. There are also some L-rhamnose units in the chain and various proportions of D-galactose and L-arabinose units in side chains (15). Lignin is a very complex, branched polymer that originates from three closely related phenylpropanoid monomers: p-coumaryl, coniferyl, and sinapyl alcohols. They are interconnected in a variety of ways in varying proportions and in random sequences (16).

Gums and mucilages have many structural types but all are very soluble in water. The principal chemical components of gums, mucilages and algar polysaccharides are also outlined in Table I.

Composition of Wheat Bran

Wheat bran is commonly used to increase the dietary fiber content of the diet. The composition of wheat bran is highly variable, depending on the variety of wheat, age of the plant and degree of milling (17, 18). The wide range of difference in proximate composition of wheat bran is illustrated in Table 2.

On a moisture-free basis, wheat bran contains about 70 percent carbohydrate which consists of approximately 12 percent starch, 8 percent sugar, 45 percent hemicellulose and 35 percent cellulose. Wheat bran contains less than 5 percent lignin. Bran hemicellulose, composed mainly of arabinoxylan, is more highly branched than the hemicellulose of wheat flour, straw, or leaves. The chemical composition of cellulose and lignin in wheat bran has not been documented. The sugars are located primarily within the aleurone layer which is separated from the endosperm during the milling process.

Wheat bran also contains numerous vitamins, minerals, proteins and fat. The aleurone layer is the major site of

Table 2. Proximate analysis of wheat bran

Item	Percentage
Moisture	3.7-17.7
Protein (N x 6.25)	11.9-22.9
Fat	3.0- 6.8
Ash	3.8- 9.6
Crude Fiber	6.8-17.5

Data from the Millfeed Manual (17)

these nutrients. Although bran protein is high in the amino acid lysine, the protein is of limited digestibility (18).

Physiochemical Properties of Dietary Fiber

Dietary fiber may affect the physiological function of the gastrointestinal tract because of the physiochemical properties of some of its components.

WATER ADSORPTION. When water is added to some polysaccharides, they swell to form a semi-rigid, jelly-like mass which holds all the liquid present (19). This property is the basis for the therapeutic use of plant gums and mucilages in the treatment of constipation. Eastwood (19) noted that various components of plant fiber have different water-adsorbing capacities. Pectic substances and hemicellulose have a high water absorbing capacity, cellulose has a moderate capacity, and lignin has a low capacity to absorb water. Water-binding capacity also varies among dietary sources of fiber due to the differences in fiber composition. Among 7 different fruits and vegetables (onions, apples, oranges, potatoes, cauliflower, carrots, and lettuce), and wheat bran analyzed by Heller and Hacker (20), wheat bran was by far the best holder of water as measured by an *in vitro* method.

CATION EXCHANGE CAPACITY. Acid polysaccharides with

uronic acid residues can bind metals and act as weak cationic exchangers. McConnell et al. (21) demonstrated this property by testing in vitro the cationic exchange capacity of different fruits and vegetables. The cationic exchange capacity of lettuce, cabbage, carrots, oranges, and turnips was in the range of commercial cation exchange resins. This capacity suggests that the electrolyte content of the stool can be affected by dietary fiber. Eastwood and Mitchell (22) reported that fecal excretion of sodium, potassium and magnesium and, to a lesser extent, calcium was increased in subjects who received 16 g of wheat bran daily in addition to their regular diets. This may be related to the free carboxyl groups in pectin and, to a smaller degree, in hemicellulose.

ORGANIC ADSORPTION. Plant fiber also binds bile acids in vitro. Eastwood and Hamilton (23) demonstrated binding by grain residues left after malting. Lignin is responsible for this adsorption. Conjugated bile acids, i.e., those found in bile and the upper duodenum, are only weakly adsorbed onto this fiber, but unconjugated bile acids, i.e., those found in the colon, are strongly adsorbed.

GEL FILTRATION. When plant polysaccharides form a gel, a gel filtration system possessing molecular exclusion capacity may develop. This system has not been studied for vegetable fibers, but experiments have been done on cellulose and its susceptibility to enzyme hydrolysis (24).

This property may be important regarding the ability of enzymes or bacteria to reach substrates enmeshed in the fiber gel.

Digestibility of Plant Fiber

Although man does not secrete enzymes capable of digesting plant fiber, a significant portion of ingested fiber disappears during passage through the gut. The digestibility[1] of crude fiber was reviewed in 1934 by Mangold (25) who pointed out that almost every animal, including man, has the ability to degrade fiber by virtue of his intestinal microflora. The microorganisms are capable of degrading plant fiber by anaerobic fermentation to form acetic, formic, butyric and propionic acids, water, carbon dioxide and methane. This process provides a significant source of energy to both ruminants and herbivores as they are able to absorb the short chain fatty acids. In man, however, the energy contribution through this process is quite trivial. As calculated by Southgate (26), the maximum metabolizable energy from pentosans ranges from 0.6 to 2.1 percent, and from cellulose from 0.03 to 0.38 percent.

The first major study on the digestibility of plant

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1. Digestibility of nutrient $= \frac{\text{Dietary Nutrient - Fecal Nutrient}}{\text{Dietary Nutrient}} \times 100\%$

fiber in man was carried out by Williams and Olmsted in 1936 (27). In three students they found that on the average 38 percent (range, 2-67 percent) of cellulose, and 56 percent (range, 6-89 percent) of hemicellulose were lost during transit through the gut, and that more hemicellulose disappeared than cellulose, with lignin disappearing the least. Great variations among individual subjects and among results of several researchers have since been reported. More recently, Milton-Thompson and Lewis (28) have shown that 57 percent (range, 15-87 percent) of an 8.5 g per day intake of cellulose was digested during the passage through the gut. Southgate and Durnin (2) found the disappearance of hemicellulose to range from 72 to 98 percent, and for cellulose the range was from 15 to 55 percent. According to Southgate (26), these wide ranges in individual differences are probably a consequence of individual differences in intestinal microflora and in transit time. Different sources of fiber and foods may contribute to this variability in results. It is now thought that lignin is not attacked by bacteria and its presence greatly hinders the digestion of other plant fiber components. Hoppert and Clark (28) have shown that bran cellulose was hardly degraded by man, whereas cellulose of fruits and vegetables was degraded to a greater degree. Food components other than fiber may affect intestinal microflora by altering the culture medium for the bacteria (25).

Site of Bacterial Action

Bacteria in the ileocecal region and in the colon are responsible for breaking down the components of dietary fiber (10). Recently, Holloway et al. (30) showed that the major sites for bacterial action are different for hemicellulose and cellulose. By studying healthy ileostomates and non-ileostomates, Holloway et al. found that 84.5 percent of the ingested cellulose was excreted by the ileostomates from the small bowel as compared to 22.4 percent by the non-ileostomates. This indicates that considerable digestion of cellulose takes place in the large bowel. In contrast, for hemicellulose only 27.5 percent was excreted from the small bowel by the ileostomates and 4 percent from the large bowel by non-ileostomates which suggests that hemicellulose is digested in both the small and large bowels.

Van Soest and Robertson (31) pointed out that the fiber of wheat bran is one of the least digestible of all fibers natural to the human diet. Wheat bran is only 30 percent digestible (31). According to Saunders (18), the digestibility of bran is approximately 40 percent and bran protein about 65 percent. The particle size of wheat bran does not affect the digestibility.

The composition of wheat bran is highly variable. In order to be able to compare results of studies related to

wheat bran from different researchers, the Food Fiber Committee of the American Association of Cereal Chemists (AACC), in response to the request of the National Academy of Science, provided a "Certified Food Grade Wheat Bran" for interested researchers (32). Appendix 1 shows the composition of the main components in the analytical data supplied with the AACC "Certified Food Grade Wheat Bran" (33). This particular type of wheat bran was used in our study. The fineness of this bran is also standardized.

Intake of Dietary Fiber

Hardinge et al. (34) reported in 1958 that the crude fiber content of a non-vegetarian American diet averaged about 9.5 g/day. Recently, Heller and Hacker (35) found that since 1957-1959, ordinary American diets contained approximately 4.9 g/day. The mixed British diet contained about 4.2 g/day (36). True dietary fiber intakes, however, are difficult to estimate since current tables of food composition give only the crude fiber value which represents only 1/5 to 1/6 of the total fiber content (37). From this ratio, Cummings (37) calculated that the British diet contained between 16 to 28 g of dietary fiber per day. However, true dietary fiber intake is still unknown.

The change in the amount and source of dietary fiber in the Western diet and the significant geographical difference in fiber consumption have formed the basis for

current interest in the role of dietary fiber in diseases which have occurred predominantly in Western countries during the past century. From the period 1909-1913 up to the period 1957-1959, the amount of crude fiber obtained from potatoes and cereals decreased drastically (36). On the other hand, fiber from fruits and vegetables increased gradually during the same period of time. Data from a report by Robertson (36) showed little change in total crude fiber intake in the British diet. A survey by Heller and Hacker (35), on the other hand, showed that total daily consumption of crude fiber dropped from 6.8 to 4.9 g per person; this drop coincides with increases in some degenerative diseases.

The high fiber intake by rural Africans noted by Trowell (38) has recently been confirmed by Lubbe (39). Lubbe compared the crude fiber intake in 266 rural and 241 urban Venda males by taking dietary histories, weighing their food and analyzing the food composites. The mean crude fiber intake was 24.8 g/day in rural Africa as against 5.7 g/day in urban Africa.

Fecal Bulk and Intestinal Transit Time

It has long been known that dietary fiber increases fecal bulk and improves bowel habits. The therapeutic value of bran in increasing fecal weight and the rate of laxation was first demonstrated by Cowgil and Anderson (40) who

suggested a minimum fiber intake to prevent constipation. More recently, an epidemiological survey carried out by Burkitt et al. (41) showed that populations consuming high fiber diets usually produce feces with a higher wet weight and defecate more often, whereas the groups eating the highly refined diets of the Western world have lower stool weights. Burkitt et al. (42) also showed an inverse correlation between fecal bulk and transit time. Beyond a fecal weight of 200 g/day, however, an increase in fecal bulk has a minimum effect on transit time.

Dietary fiber increases fecal bulk considerably (5, 43, 44). However, the mechanism that increases fecal bulk is still not fully understood. The major hypothesis is that the physical adsorption of water molecules to fiber components, especially hemicellulose (19), increases fecal bulk. Williams and Olmsted (27), however, found that the increase in stool weight resulting from the various fiber residues correlated with the disappearance of the fiber components during transit and that an increase in volatile fatty acid production paralleled the increment in fecal weight. They thus suggested that the cathartic effect of the products of bacterial decomposition, mainly volatile fatty acids, be considered as an important parameter in increasing fecal weight. This point of view has recently been confirmed by Forsythe et al. (45). In rats fed eight different

fiber sources, a high correlation between fecal wet weight and fecal volatile fatty acids was observed. They hypothesized that gut fermentation of the fibers, particularly hemicellulose, results in an osmotic gradient which may either decrease water reabsorption or promote water secretion from the colon. Another mechanism postulated by Cummings (37) was that fiber in the small intestine may bind bile salts and fatty acids which may then be sequestered until reaching the colon where they would be released by bacterial action and might prove cathartic.

Although the effect of fecal bulk on the intestine is not known exactly, fecal bulk is speculated to stimulate smooth muscle activity, thus increasing peristalsis and movement of the contents through the gut. Using radio-opaque pellets, Hinton et al., as cited by Burkitt and Painter (46), showed that rural Africans had a mean transit time of 34.6 hours. Groups consuming a typical Western diet had a transit time of 67.2 hours. As for those consuming a transitional diet, i.e., intermediate in fiber content, the mean time was 43.6 hours. However, these were not controlled studies. Spiller and Amen (10) pointed out in their review that dietary components other than fiber, i.e., type of fat and level of exogenous cholesterol, may also have influence on intestinal transit.

Controlled studies related to the effect of dietary

fiber on transit time have been carried out by several workers, who obtained somewhat contradictory results. McCance et al. (67) followed radiologically the passage of meals of either white or wheat bread in six human subjects. They observed that the brown bread was evacuated from the stomach and passed through the small intestine faster than the white bread. The residue from the brown bread, which appeared to be greater in the colon, left the colon 24 hours sooner than that from the white bread. However, Eastwood et al. (8) found that daily supplements of 16 g of either wheat bran or cellulose had no effect on transit time. Findlay et al. (47) showed that adding 20 g/day of unprocessed bran decreased significantly the transit times of patients with diverticular disease, whereas the reduction in transit time was not significant in normal subjects. Using radio-opaque pellets, Harvey et al. (48) studied the effect of 30 g bran a day on intestinal transit in normal individuals. They found that transit times were reduced in individuals having slow transit but increased in those with fast transit. Similar results were reported by Payler et al. (49). In 20 individuals who consumed a normal English diet, transit time ranged between one to seven days. After the addition of about 20 g of bran daily, transit time became faster in subjects who had an initial time of three days or more, but became slower in those with an initial

one day transit. Recently, Slavin and Marlett (50) reported wide and inconsistent differences in transit times among subjects who were consuming a diet containing 6.2 g of crude fiber for 24 to 35 days.

Several factors may have contributed to these discrepancies in results, e.g., the dose and physical properties of the wheat bran, and the fecal markers used in different studies. Raw and cooked bran have been reported to affect intestinal transit differently. Wyman et al. (51) gave two different doses of both raw (12 and 20 g/day) and cooked (13.2 and 22 g/day) wheat bran to ten subjects and examined the effect on transit radiologically. Only the higher dose of raw bran resulted in significantly faster transit. Kirwan et al. (52) found that the particle size of wheat bran also influences gastrointestinal transit. Ten grams, twice daily, of coarse bran promoted transit significantly from 93.4 ±13.8 hours to 57.9 ± 8.0 hours. Equal amounts of fine bran, however, did not have significant effects on transit time. Mclean Baird et al. (43) investigated the effect of 10.5 g/day bagasse on transit time by the use of two kinds of fecal markers, carmine and radiopaque pellets. Transit time was significantly reduced when carmine markers were used, but the effect was not significant when radiopaque pellets were used. The authors preferred carmine markers because several measurements can be made in a short study period.

The Effect of Dietary Fiber on Fecal Nutrients

In the early 1940's, Murlin and his coworkers (53, 54) compared the digestibility of protein, carbohydrate and fat in white and whole wheat breads. They showed that protein in whole wheat bread was less digestible than that in white bread. The digestibility of carbohydrate and fat, however, was not significantly different. During the same period of time, similar interest among British workers is noted. Krebs and Mellanby (55) and Macrae et al. (56) examined the digestibility of nitrogen and energy from flours of different extraction rates. As the extraction rate increased, the digestibility of both protein and carbohydrate decreased. Using the values Macrae et al. (56) had obtained, Moran and Pace (57) derived a relationship that every increase in crude fiber of 0.2 percent (over a basal figure of about 0.15 percent) would lead to a decrease in digestibility of about 1.1 percent.

The increase in fecal nitrogen loss was at one time generally attributed to the indigestibility of protein, particularly that in the aleurone layer of wheat bran. The findings of McCance and his assistants (58, 59) had thrown new light in this area. They fed their subjects diets in which 80 percent of the energy was from bread. The bread was made from two types of wheat: high protein Canadian wheat and low protein English wheat, each at 80 percent

and 90 percent extraction rates. Apparent digestibility of protein was shown, as expected, to fall with the increasing extraction rate of the flour. However, quantitative analysis revealed that fecal nitrogen was not altered significantly by a large change in protein intake when the fiber intake was nearly constant. The authors thus concluded that the bread protein was completely digested and absorbed and that the increased fecal nitrogen caused by the bran was of endogenous origin.

In agreement with the above hypothesis, Walker (60) believes that endogenous loss of fat is also influenced by the intake of fiber. He carried out fat balance studies on subjects who received diets of varying fat and fiber content. The increased fecal fat content brought about by increased dietary fiber was independent of dietary fat intake. These results could only be explained on the basis that a very high proportion of the fecal fat was of endogenous origin. According to Phillipson (61), there are three principal sources for endogenous fecal nutrients: secretions that enter the gastrointestinal tract, continual desquamation of the epithelial cells of the mucosa and the microflora in the large intestine.

The study of Southgate and Durnin(2) in 1970 has drawn attention among contemporary researchers away from beneficial clinical aspects of fiber to the detrimental effect

of fiber on the utilization of dietary nutrients. Three diets based on food items commonly consumed in the Western world and differing in unavailable carbohydrate content were utilized. Intake of unavailable carbohydrate was, in g/day, 6.2-9.6, 16.2-28.3 and 31.8, respectively. Greater fecal losses of energy, and in most instances, of nitrogen and fat were demonstrated to occur with increasing intake of unavailable carbohydrates. There is concern that this decrease in nutrient utilization may be hazardous to populations consuming diets of high fiber and marginal nutrient content. Southgate (26) also suggested several mechanisms leading to the increased fecal loss of nutrients: a) there are always qualitative changes in the diet as a whole when its unavailable carbohydrate content is increased; b) the decreased transit time caused by increased fecal bulk allows less time for the processes of digestion and absorption; c) the physiochemical effects resulting from the increased bulk and other properties such as water-binding of the unavailable carbohydrates may reduce the rate of diffusion of the products of digestion towards the absorption of mucosal surface.

Both Greenberg (4) and Jeffreys (62) have shown that a test meal containing wheat bran induced a lower blood glucose level. Greenberg found no inhibition of amylase activity by wheat bran *in vitro*, which excludes the possibility that

wheat fiber may hinder the enzymatic digestion in man. It was thus suggested that the increased fecal energy loss may, in part, be due to impaired absorption alone.

The hypothesis that dietary fiber increases fecal losses of nutrients is supported by several studies. Higher fecal excretion of energy, fat and nitrogen was induced by either a high fiber diet (44) or by a wheat fiber supplementation (5, 6, 63); the increment was not altogether statistically significant. Kies and Fox (3) examined the effect of hemicellulose supplementation on nitrogen balance in men. Increased amounts of hemicellulose had no effect on nitrogen balance of subjects in strong positive nitrogen balance; however, poorer nitrogen balances were noticed among individuals in marginal or negative nitrogen balance.

Walker (64) reconfirmed that the increased fecal nutrients were of endogenous origin. In his experiment with Bantu children, who were already consuming their traditionally high fiber diet, supplements of fat or protein did not induce any increase in fecal fat or nitrogen. Yet a daily supplement of 350 g of orange, which is high in fiber and low in protein and fat, resulted in significant increases in fecal excretion of both fat and nitrogen.

The effect of dietary fiber on calcium absorption was first observed by McCance and Walsham (59) 30 years ago. Recently, Rheinhold and his associates (65,66) showed a

significant increment in the fecal excretion of calcium, zinc, magnesium, and potassium in subjects fed whole wheat bread or a cellulose supplement. The impaired absorption of divalent metals is hypothesized to result from the cation binding ability of the fiber components under conditions existing in the small intestine. Their findings more than any other evidence have cast some doubt on the beneficial value of fiber in our diet.

The possible effect of dietary fiber on vitamin metabolism and absorption in the intestine has also been investigated. Although vegetable material was shown to absorb folic acid and its monoglutamates in vitro (67), no impairment of folic acid absorption occurred in men who were fed fiber-rich products (68). In two metabolic studies performed in our laboratory, high fiber diets, either in the form of whole wheat bread (69) or wheat bran supplementation (70), were associated with increased fecal vitamin B6 and depressed urinary 4-pyridoxic acid loss in the men tested. Bran also lowered plasma B6 in most of the subjects. These results suggest that the availability of vitamin B6 is impaired when a diet is high in fiber content.

The results of Greenberg (4), however, do not entirely support the claims that dietary fiber reduces the digestibility of nutrients. Greenberg doubled the intake of fiber by adding Isogeo (high in hemicellulose) to a control diet

fed to four subjects. Only one subject showed significantly impaired digestibility of energy, fat, nitrogen and minerals. The response of the other three subjects was variable. One subject showed no decrease in the digestibility of any of the nutrients. It was thus suggested that wide individual differences be expected in response to a high fiber diet. Similarly, Flynn et al. (71) found that in response to three diets (control, meatless and high-beef diets) imposed on 10 subjects, there were wide individual differences in bacterial flora and their metabolic activities, and consequently, in substrates and by-products that appear in the feces. The immeasurable individuality of emotional and other stress factors may also have an effect on nutrient utilization.

MATERIAL AND METHODS

This study is a part of an investigation entitled "The Effect of Wheat Bran on the Bioavailability of Vitamin B6." Results of this investigation will be presented elsewhere.

Subjects

Ten healthy college men, aged 20 to 35 years, participated in this study. Their vital statistics are given in Table 3. The subjects were free from any known disease. While participating in the study, they did not take any drugs or nutritional supplements other than the vitamin B6 which was added to the 'No-bran' diet to make the content of this vitamin the same as that of 'Bran' diet. The subjects abstained from drinking alcoholic beverages. They maintained their normal physical activity, but refrained from strenuous exercise. Approval of this study was obtained from the Oregon State University Human Subject Committee on December 5, 1975. Before participating in this study, the subjects signed an informed consent form which was approved by this committee.

The subjects were also tested for metabolic normalcy by the following criteria: (1) normal liver function and blood chemistry as determined by automatic analysis performed by Good Samaritan Hospital Laboratory in Corvallis, Oregon; (2) normal xylose absorption (72) as a measure of

Table 3. Vital statistics of the subjects

Subject	Age	Nationality	Weight		Height
			Beginning	End	
	yrs		kg	kg	cm
1	23	American	61.7	62.1	176.5
2	29	Peruvian	61.7	64.4	160.7
3	29	American	55.8	59.0	167.6
4	35	Peruvian	71.7	73.9	169.5
5	20	American	87.5	87.1	193.7
6	26	American	96.2	93.4	178.4
7	24	American	77.1	76.7	181.0
8	28	American	65.3	68.0	184.2
9	23	American	48.1	51.3	171.4
10	22	American	68.0	68.0	179.4

intestinal absorption; (3) adequate vitamin B6 status as determined by plasma vitamin B6, using Saccharomyces Carlsbergensis as the assay organism.

Experimental Design

In this 58-day controlled diet study, a 4-day adjustment period preceded three 18-day experimental periods. The purpose of the adjustment period was to adapt the subjects to the experimental regime, and to acquaint them with their responsibilities during the experimental periods. The adjustment diet and its nutrient composition are given in Table 4. The subjects were divided into two groups and a switchback design was used. Subjects 1 to 5 (Group I) received Bran diet during the first 18-day period, No-bran diet the second and Bran diet the third. Subjects 6 to 10 (Group II) received No-bran, Bran, and No-bran diets, in that order. These diets and their nutritional composition are given in Table 5.

The basal diet was an ordinary American diet. For the Bran-diet, 5 g of AACC Certified Wheat Bran[2] were incorporated before cooking or baking into the breakfast cereal, muffins for lunch, and ground beef (meat loaf) for dinner. The addition of these 15 g of wheat bran resulted in the

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2. AACC Certified Food Grade Wheat Bran, R07-3691. Obtained from American Association of Cereal Chemist, St. Paul, Minnesota. Appendix I gives its composition.

Table 4. Adjustment diet given to the subjects during the first four days of the study[1,2]

Food	Amount
	g
Breakfast:	
Orange juice, (frozen reconstituted)	125
Cornflakes	30
Half and half	125
Hard cooked egg	54
White bread, enriched	25
Banana	30
Margarine (total for a day)	75
Lunch:	
Milk, whole	250
White bread, enriched	50
Bologna	30
Carrots, raw	100
Oatmeal cookies	39
Raisins	40
Chocolate bar	34
Dinner:	
Milk, whole	250
Casserole:	
Ground beef, raw	75
Macaroni, dry	60
Green pepper, fresh	25
Onion, dehydrated	15
Tomato paste, canned	40
White bread, enriched	50
Peaches, canned	90
syrup	30
Vanilla ice cream	75

1. Subjects maintained their weights by consuming additional "free" foods, which included honey, hard candies, sugar, and carbonated beverages (7-Up). They were also allowed coffee and tea. They recorded the amounts of "free" foods, coffee and tea that they consumed.

2. The nutritional value and percent RDA (in parentheses) of the diet without the "free" foods are: protein 80.5g (144%), calories 2424kcal (84%), fat 93.2g, total carbohydrate 323 g, calcium 1163.7mg (145%), phosphorus 1417.7mg (177%), iron 14.97mg (150%), sodium 1924mg, potassium 3443.1mg, vitamin A 15,668IU (470%), thiamin 1.77mg (126%), riboflavin 2.36mg (148%), niacin 15.68mg

(87%), ascorbic acid 132mg (293%). Calculated from USDA Handbook No. 8 (73) and 1974 RDA (74).

- Vitamin B6 content as determined by assay with Saccharomyces uvarium (75) is 1.59 mg (74%).
- Neutral detergent fiber is 3.63g, as determined by the method of Van Soest and Wine (77).

Table 5. Experimental diets fed to subjects[1,2]

Food	Amount
Basal Diet:	g
Breakfast:	
White bread, enriched	50
Orange juice, frozen reconstituted	250
Grapefruit sections, canned	100
syrup	20
Milk, non-fat dried	22.5
Wheat cereal, dry	30
Cocoa mix	30
Tomato juice, canned	100
(Biscuit)	
Margarine (total for a day)	75
Lunch:	
Cheese, cheddar	30
Carrots, raw	25
Tomato juice, canned	100
Raspberries, frozen	60
White bread, enriched	50
(Biscuit)	
Raisins	50
Milk, non-fat dried	22.5
Dinner:	
Beef, ground, raw	120
Green beans, canned	100
juice	10
Pears, canned	100
syrup	20
Rice, dry	45
White bread, enriched	25
Graham crackers	50
(Biscuit)	
Bran Diet:	
Basal diet plus 5g of AACC wheat bran added before cooking or baking to wheat cereal, muffins, and ground beef. Three muffins were consumed at lunch.	
No-bran Diet:	
0.18mg pyridoxine was added to muffins before baking. Subjects consumed one muffin at each meal.	

1. Subjects maintained their weight by consuming additional

"free" foods, which included: honey, hard candies, sugar and carbonated beverages (7-Up). They were also allowed coffee and tea. They recorded the amounts of free foods, coffee and tea that they consumed.

2. The nutritional value and percent RDA (in parenthesis) of the Basal diet without the "free" food is: protein 81.3g (145%), calories 2622kcal (97%), fat 102.3g, total carbohydrate 359.8g, calcium 1186.3mg (148%), phosphorus 1636mg (205%), iron 18.39mg (184%), sodium 3249.5mg, potassium 3047mg, vitamin A 8314IU (250%), thiamin 1.57mg (112%), riboflavin 1.92mg (120%), niacin 18.02mg (100%) ascorbic acid 197mg (438%). Calculated from USDA Handbook No. 8(73) and 1974 RDA (74).
   - Vitamin B6 content as determined by assay with S. uvarum(75) is 1.719mg (86%).
   - Neutral detergent fiber is 6.6 gram, as determined by Van Soest and Wine (77).
   - Nutrient composition of wheat bran is included in Appendix 1.

addition of the following nutrients to the diet: neutral detergent fiber 7.1 g, protein 2.2 g, fat 0.77 g, and ash 0.77 g. When the No-bran diet was fed, 0.186 mg of pryidoxine was incorporated into the muffins before baking in order to make up for the vitamin B6 contributed by the wheat bran to the Bran diet. To equalize the vitamin B6 content of the three meals on the No-bran diet, one No-bran pyridoxine supplemented muffin was eaten at each meal. A batch of muffins was made daily for each subject from a master mix, which is given in Appendix 2. The experimental diets supplied adequate amounts of all required nutrients. Meals were prepared and served in the metabolic unit in the Department of Foods and Nutrition at Oregon State University.

In addition to the Bran and No-bran diets (Table 5), the subjects consumed honey, sugar, hard candies, and 7-Up[3] ("free foods") in amounts needed to maintain their body weight. Coffee and tea as well as spices and mustard were also allowed. In order to meet the higher calorie requirement of subjects 5 and 10 to maintain their body weight, subject 5 received 25 g of extra margarine from the first day of the first experiment period, and subject 10 received 20 g of extra margarine from the seventh day of the first

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3. 7-Up is distributed by Seven Up Enterprises, St. Louis, MO 63105.

experimental period. The subjects recorded their consumption of "free foods" as well as of coffee and tea. They weighed themselves before breakfast each morning.

Blended food composites of the diets were prepared weekly. The diets were analyzed for nitrogen (76), and vitamin B6 (75) content. A portion of the composites were freeze dried and analyzed for neutral detergent fiber value (77).

Fecal Collections

The subjects were given a fecal marker of FDC Blue No. 1[4] every three days during each of the three 18-day experimental periods. They collected their feces in air-tight plastic bags labelled with their initials, the date, and time of defecation. Fecal weight was measured daily and feces were frozen until they were pooled in 6-day composites.[5] A major portion of the 6-day composites were dried at 90°C in a vacuum oven. The last two 6-day composites of each 18-day period were analyzed for nitrogen, fat, energy, and ash. Neutral detergent fiber analysis was done only on the last 6-day composites of each period.

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4. Contain 50 mg of FDC Brilliant Blue No. 1 plus 200 mg methylcellulose in soft gelatin capsule.

5. Prepared from two 3-day fecal composites. Determination made for the B6 study were made on 3-day composite. Fifty percent of each of two consecutive 3-day composites were combined for the 6-day one.

Urine Collections

Throughout the study, daily 24-hour urine specimens were collected under a layer of toluene and refrigerated. After the volume of the samples was measured the following day, portions of urine were either refrigerated or frozen until analyzed. Completeness of daily 24-hr urine specimen was checked by determining creatinine. For nitrogen determination, 6-day urine composites were made by combining 1% of the daily volume.

Blood Collections

Blood was drawn from the antecubital vein of fasting subjects every three days throughout each experimental period by a registered medical technician. For the vitamin B6 study, plasma vitamin B6 as well as pyridoxal phosphate were determined. Results will be published elsewhere.

Laboratory Analyses

Fecal Moisture

Fecal samples were dried at 90°C in a vacuum oven to a constant weight. Percent weight loss of the samples from the drying process was determined as percent fecal moisture.

Total Nitrogen

Total nitrogen of the diets, urine, and feces were measured by the boric acid modification of the Kjeldahl method by Scales and Harrison (65).

Bomb Calorimetry

Dried fecal samples[6] were measured for energy content using a Parr Bomb Calorimeter[7] (78). To make the pellet, it was necessary to add water to the dried feces.

Fat

Dried fecal samples[6] were measured for fat content by following the procedure of Southgate (79).

Neutral Detergent Fiber

Dietary and fecal fiber[6] were measured by the neutral detergent method of Van Soest and Wine (77).

Ash

Fecal ash was measured by AOAC method for analyzing ash content in animal feeds (80).

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6. Dried fecal samples were sieved to remove raspberry seeds before analysis.

7. Parr Bomb Calorimeter, Moline, Illinois.

Transit Time

The time between the ingestion of fecal marker and first appearance of the dye in the excreted feces was recorded as transit time (81).

Urinary Creatinine

Creatinine in urine was determined on a Technicon Autoanalyzer[8] by an automated modification of the Jaffe reaction (82).

Statistical Analysis

The data were statistically analyzed by analysis of variance (ANOVA) for the switch back design using the System of Statistical Package for the Social Sciences (SPSS). The computer analysis was done by a statistician at Oregon State University. The pertinent data from ANOVA tables are given in Appendix 3 for all the variables analyzed. A Hewlett-Packard Calculator Model 9810A[9] was used for performing correlation analysis.

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8. Technicon Autoanalyzer, Technicon Corporation, Tarrytown, New York.

9. Hewlett-Packard, Loveland, CO 80537.

RESULTS

Since there were no statistically significant differences in the results of fecal wet and dried weights and fecal nutrients between the last two 6-day fecal composites of each period, these values were averaged.

Fecal Weight

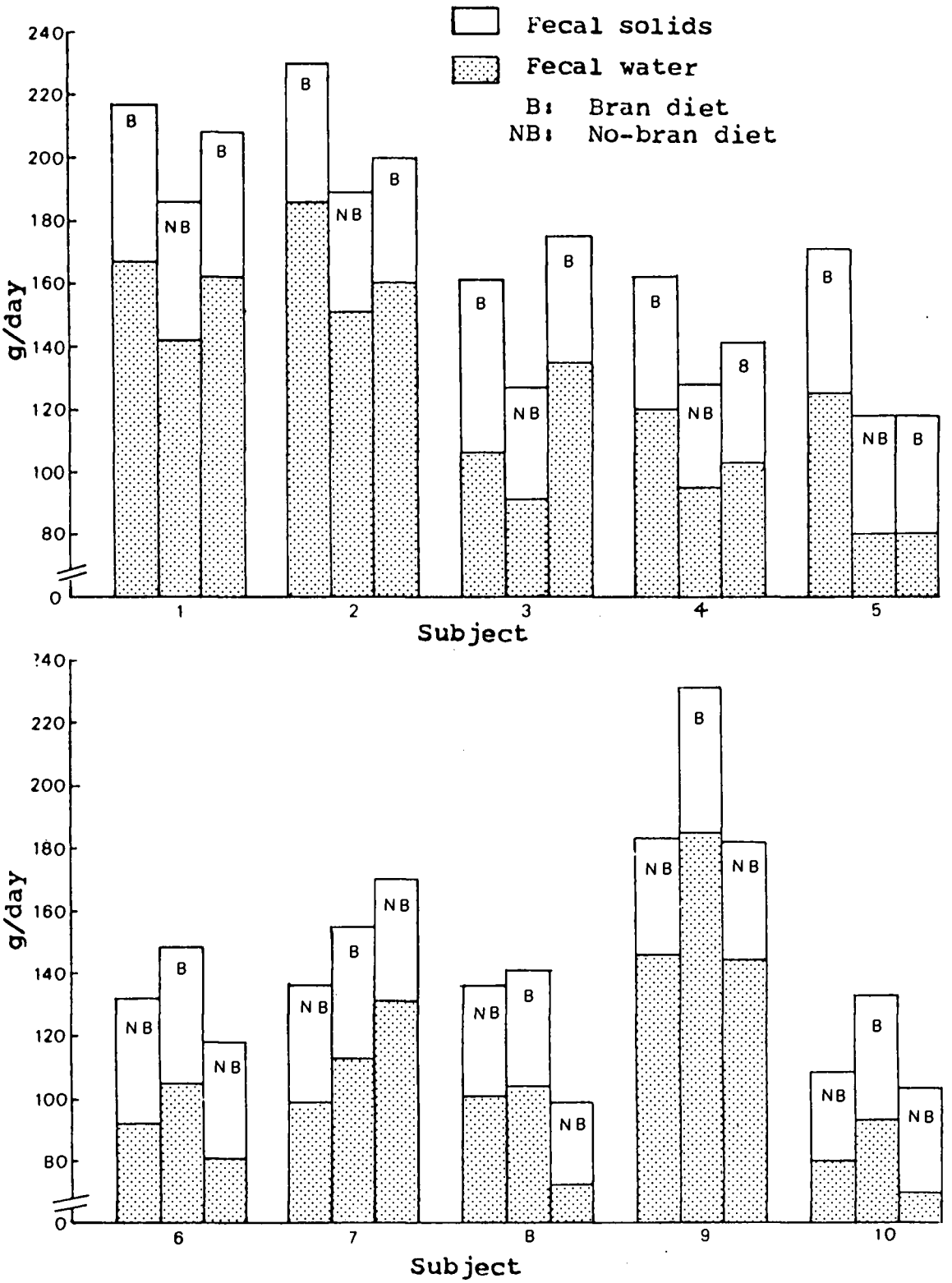
Table 6 presents the effect of 15 g of wheat bran on fecal wet weight, percentage fecal moisture as well as fecal water content and dry solids. Fig. 1 presents the distribution of fecal weight between moisture and dry solids. Great inter-individual variation in stool weight was noticed among the subjects. Fecal wet weight ($p < 0.05$) and fecal dry solids ($p < 0.01$) were significantly increased by wheat bran supplementation. In 18 out of the 20 instances when the subjects were changed either from the Bran to No-bran, or No-bran to Bran diets, the addition of bran induced a higher fecal wet weight and moisture content. Fecal dry weight was enhanced by wheat bran in 19 out of the 20 instances. In response to the Bran and No-bran diets, respectively, the subjects' mean fecal wet weight was, in g/day, 172±39 and 143±34, and mean daily dry weight was 43± 3 g and 36± 4 g. Although bran increased mean fecal water excretion from 105± 29 (No-bran diet) to 130± 34 (Bran diet) g/day, the difference was not statistically

Table 6. Effect of wheat bran on fecal wet weight, percentage moisture, and fecal water and dry weight[a,b,c]

	Group I				Group II		
	Subj.	Pd. I (Bran)	Pd. II (No-Bran)	Pd. III (Bran)	Subj.	Pd. I (No-Bran)	Pd. II (Bran)	Pd. III (No-Bran)
Fecal wet wt. (g/d)	1	217	186	208	6	132	148	118
% moisture		77.1	76.4	78.1		70.2	70.9	69.0
Fecal water (g/d)		167	142	162		92	105	81
Fecal dry wt. (g/d)		50	44	46		40	43	37
Fecal wet wt. (g/d)	2	230	189	200	7	136	155	170
% moisture		80.6	80.1	80.2		73.4	73.3	76.5
Fecal water (g/d)		186	151	160		99	113	131
Fecal dry wt. (g/d)		44	38	40		37	42	39
Fecal wet wt. (g/d)	3	161	127	175	8	136	141	99
% moisture		72.4	72.1	77.1		74.3	73.9	73.7
Fecal water (g/d)		116	91	135		101	104	73
Fecal dry wt. (g/d)		45	36	40		35	37	26
Fecal wet wt. (g/d)	4	162	128	141	9	183	231	182
% moisture		73.5	73.7	72.7		80.0	80.4	79.4
Fecal water (g/d)		120	95	103		146	185	144
Fecal dry wt. (g/d)		42	33	38		37	46	38
Fecal wet wt. (g/d)	5	171	118	118	10	108	133	103
% moisture		73.4	68.2	67.8		73.7	69.6	68.3
Fecal water (g/d)		125	80	80		80	93	70
Fecal dry wt. (g/d)		46	38	38		28	40	33

a. Mean value of last two 6-day composites of each period
b. Fecal moisture = fecal wet weight x % moisture
c. Fecal dry weight = fecal wet weight - fecal moisture

Fig. 1. Effect of wheat bran on fecal weight and water content



significant. Wheat bran supplementation did not consistently alter the percentage water content in the feces. Only subject 1 showed consistent increase in percentage moisture content when bran was added to the diet. A sudden increase in the percentage (3-5%) of fecal moisture content was noticed in subjects 3 and 7 in the last experimental period, and in subject 5 in the first period.

Transit Time

The influence of wheat bran on transit time is given in Table 7. Although the mean transit time was shorter when the subjects received the Bran diet than when they received the No-bran diet (28.5± 4.8 hours vs 32.3± 8.4 hours), the difference was not statistically significant due to inconsistent responses among individuals. In both groups, decreased mean transit time was observed when bran was added to the diet, but only subjects 5 and 6 showed the consistent response of decreased transit time.

Fecal Nutrients

The effect of wheat bran on fecal caloric content, fecal nitrogen, fat and ash for groups I and II are given in Tables 8 and 9, respectively. These results for both groups are also illustrated in Fig. 2. Fecal output of energy ($p < 0.01$), nitrogen ($p < 0.01$), and ash ($p < 0.01$)

Table 7. Effect of wheat bran on transit time, in hours[a]

Group I				Group II			
Subject	Period I (Bran)	Period II (No-Bran)	Period III (Bran)	Subject	Period I (No-Bran)	Period II (Bran)	Period III (No-Bran)
1	24.6± 0.4	24.8± 0.1	24.7± 0.2	6	45.4±13.4[b]	30.2± 31.7	49.5± 9.0
2	34.7±12.6	27.5± 1.7	30.1± 3.9	7	45.0±10.4	28.9± 3.0	25.4± 2.6
3	31.3± 3.3	28.6±10.9	22.0±11.4	8	28.2±18.6	34.4±18.8	24.8± 1.6[b]
4	22.0± 6.6	28.9± 2.4	29.3± 2.5	9	22.2± 5.8	25.0± 0.7	30.4± 3.9[b]
5	27.3± 4.1	33.5±12.3[b]	25.3± 1.2	10	31.1±16.4	38.3± 3.2[c]	39.5± 7.4
Mean ± S.D.	28.0± 7.6	28.4± 6.7	26.3± 5.9	Mean ± S.D.	33.8±15.3	30.6± 9.2	34.4±10.9

a. Mean value ± standard deviation for 4 times during the last 12 days of each period
b. Mean value for 3 times during the last 12 days of the period due to vague separation of the feces
c. Mean value for 2 times during the last 12 days of the period due to vague separation of the feces

Table 8. Effect of wheat bran on fecal energy, nitrogen, fat and ash in group I[a]

	Subj.	Period I (Bran)	Period II (No-bran)	Period III (Bran)
Fecal energy (kcal/d)	1	240	208	217
Fecal nitrogen (g/d)		2.3	2.1	2.1
Fecal fat (g/d)		3.6	3.6	3.4
Fecal ash (g/d)		5.1	4.1	4.4
Fecal energy (kcal/d)	2	214	181	188
Fecal nitrogen (g/d)		2.5	2.1	2.1
Fecal fat (g/d)		4.0	3.9	3.6
Fecal ash (g/d)		5.3	4.5	4.6
Fecal energy (kcal/d)	3	223	174	190
Fecal nitrogen (g/d)		2.2	1.9	2.1
Fecal fat (g/d)		5.4	4.1	4.2
Fecal ash (g/d)		5.6	4.4	4.9
Fecal energy (kcal/d)	4	219	179	202
Fecal nitrogen (g/d)		2.2	1.8	1.8
Fecal fat (g/d)		7.8	7.3	8.0
Fecal ash (g/d)		5.1	4.2	4.7
Fecal energy (kcal/d)	5	230	201	200
Fecal nitrogen (g/d)		2.2	1.8	1.9
Fecal fat (g/d)		6.6	6.7	6.5
Fecal ash (g/d)		5.0	4.4	4.5
Mean ± S.D.				
Fecal energy (kcal/d)		225±10	189±15	199±12
Fecal nitrogen (g/d)		2.3±0.1	1.9±0.2	2.0±0.1
Fecal fat (g/d)		5.5±1.8	5.1±1.7	5.1±2.0
Fecal ash (g/d)		5.2±0.2	4.3±0.2	4.6±0.2

a. Mean value of the last two 6-day composites of each period

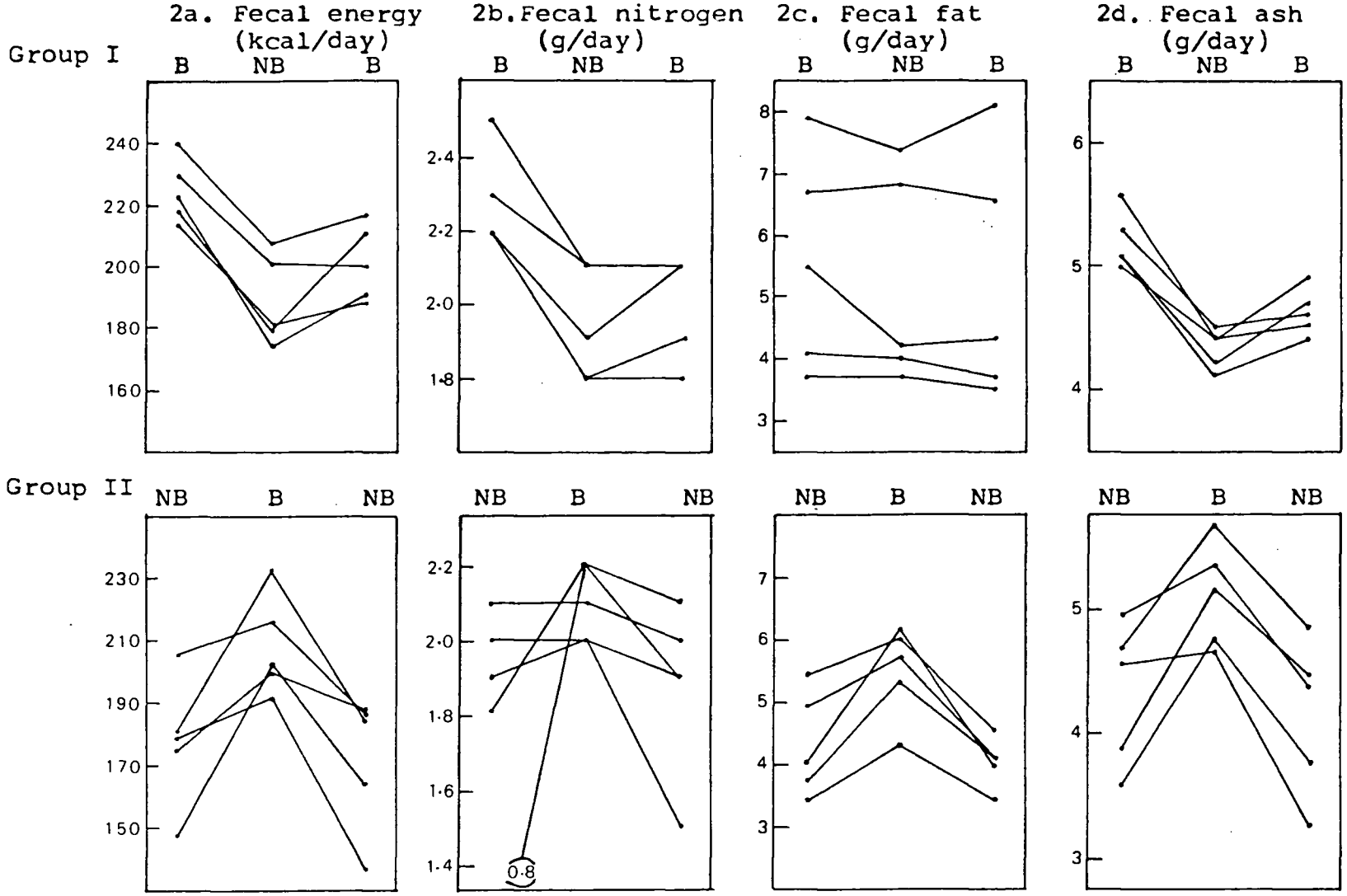
Table 9. Effect of wheat bran on fecal energy, nitrogen, fat and ash in group II[a]

	Subj.	Period I (No-bran)	Period II (Bran)	Period III (No-bran)
Fecal energy (kcal/d)	6	205	216	186
Fecal nitrogen (g/d)		2.1	2.1	2.0
Fecal fat (g/d)		4.9	5.7	4.1
Fecal ash (g/d)		4.9	5.3	4.3
Fecal energy (kcal/d)	7	174	199	187
Fecal nitrogen (g/d)		2.0	2.0	1.9
Fecal fat (g/d)		3.4	4.3	3.4
Fecal ash (g/d)		3.8	5.1	4.4
Fecal energy (kcal/d)	8	178	191	135
Fecal nitrogen (g/d)		1.9	2.0	1.5
Fecal fat (g/d)		5.4	6.0	4.5
Fecal ash (g/d)		4.5	4.6	3.2
Fecal energy (kcal/d)	9	180	231	184
Fecal nitrogen (g/d)		1.8	2.2	2.0
Fecal fat (g/d)		4.0	6.1	3.9
Fecal ash (g/d)		4.6	5.6	4.8
Fecal energy (kcal/d)	10	146	202	162
Fecal nitrogen (g/d)		0.8	2.2	1.9
Fecal fat (g/d)		3.7	5.3	4.1
Fecal ash (g/d)		3.5	4.7	3.7
Mean ± S.D.				
Fecal energy (kcal/d)		177±21	208±16	171±23
Fecal nitrogen (g/d)		1.7±0.5	2.1±0.1	1.9±0.2
Fecal fat (g/d)		4.3±0.8	5.5±0.7	4.0±0.4
Fecal ash (g/d)		4.3±0.6	5.1±0.4	4.1±0.6

a. Mean value of the last two 6-day composites of each period

Fig. 2. Effect of wheat bran on fecal energy, nitrogen, fat and ash in Groups I and II.

Group I received, in order, Bran (B), No-bran (NB) and Bran diets. Group II received, in order, NB, B and NB diets. Values represent means of last two 6-day composites of each period.


2a. Fecal energy (kcal/day)
2b. Fecal nitrogen (g/day)
2c. Fecal fat (g/day)
2d. Fecal ash (g/day)
Group I
B NB B
240
220
200
180
160
2·4
2·2
2·0
1·8
8
7
6
5
4
3
6
5
4
Group II
NB B NB
230
210
190
170
150
2·2
2·0
1·8
1·6
1·4
0·8
7
6
5
4
3
5
4
3

was increased significantly in the subjects when they were fed the bran-supplemented diet. In all of the 20 times when the subjects were changed either from the Bran to the No-bran, or No-bran to Bran diets, including wheat bran in the diet increased fecal excretion of both energy and ash. The excretion of nitrogen was increased in 15 out of the 20 cases. Mean fecal energy values, expressed in kcal/day, were 211± 27 and 179 ± 27 for Bran and No-bran diets, respectively. Fecal nitrogen was increased from 1.9± 0.3 g/day to 2.1± 0.3 g/day by the wheat bran. Bran also increased the ash content of the feces from 4.3± 0.5 g/day to 5.0± 0.5 g/day. In the first group of subjects the increased fecal output of energy, nitrogen and ash induced by bran was greater in the first period than that in the last period (Fig. 2a, 2b, 2d). On the whole, the second group of subjects (Table 9) showed a more distinct effect of bran in enhancing fecal nutrient loss.

Wheat bran increased mean fecal fat output from 4.5± 1.3 g/day to 5.4± 1.7 g/day. This effect, however, was not statistically significant due to the high variability of fecal fat content in the first group of subjects (Fig. 2c). A uniform response was found in the second group of subjects, the excretion of fecal fat was consistently increased by bran supplementation (Table 9).

Urinary Nitrogen and Nitrogen Balance

Both urinary nitrogen and nitrogen balance were not changed by the Bran diet. Tables 10 and 11 give the results of urinary nitrogen and nitrogen balance for Groups I and II, respectively. In general the subjects maintained a positive nitrogen balance throughout the study. The exceptions were subjects 4 and 6, who in the second period of the study suffered from negative nitrogen balance (-4.4 and -1.3 g/day, respectively) due to an increase in urinary nitrogen loss.

Fecal Neutral Detergent Fiber

The influence of bran on fecal neutral detergent fiber content of the three experimental periods is given in Table 12. Bran induced significantly higher ($p<0.05$) fecal excretion of neutral detergent fiber. In response to the Bran and No-bran diets, the subjects' mean fecal neutral detergent fiber was 8.3± 2.2 g/day and 5.1± 2.6 g/day, respectively. If the extraordinarily high value for subject 7 in the third period is excluded from this calculation, the mean fecal neutral detergent fiber for No-bran diet is 4.82 ± 2.36 g/day. Great individual differences in the excretion of neutral detergent fiber were observed. It varied from 2.1 g/day to 9.3 g/day on No-bran diet, and 4.9 g/day to 12.7 g/day on Bran diet. In the feces of subject 1,

Table 10. Effect of wheat bran on nitrogen intake, urinary and fecal nitrogen, and nitrogen balance in group I, in g/day

		Period I (Bran)		Period II (No-bran)		Period III (Bran)	
	Subject	A[a]	B[a]	A	B	A	B
N intake	1	13.9	13.9	13.5	13.5	13.9	13.9
Urinary N		10.8	10.5	10.4	10.2	9.3	10.2
Fecal N		2.2	2.4	2.1	2.1	2.2	2.0
N Balance[b]		0.9	1.0	1.0	1.2	2.4	1.7
N intake	2	13.9	13.9	13.5	13.5	13.9	13.9
Urinary N		8.2	8.8	9.7	10.0	9.8	9.7
Fecal N		2.5	2.5	2.1	2.2	2.2	2.1
N Balance		3.2	2.6	1.7	1.3	1.9	2.1
N intake	3	13.9	13.9	13.5	13.5	13.9	13.9
Urinary N		9.2	8.8	9.7	10.3	10.0	10.3
Fecal N		2.3	2.1	1.8	2.1	1.7	2.5
N Balance		2.4	2.0	2.0	1.1	2.2	1.1
N intake	4	13.9	13.9	13.5	13.5	13.9	13.9
Urinary N		8.8	10.0	10.0	16.2	10.8	10.2
Fecal N		2.3	2.1	1.8	1.7	1.9	1.6
N Balance		2.8	1.8	1.7	-4.4	1.2	2.1
N intake	5	13.9	13.9	13.5	13.5	13.9	13.9
Urinary N		9.0	9.5	6.4	9.8	9.8	10.7
Fecal N		2.1	2.3	1.6	2.0	1.2	2.5
N Balance		2.8	2.1	5.5	1.7	2.9	0.7

a. A = the second 6-day composite of each period. B = the third 6-day composite of each period

b. N Balance = N intake - (Urinary N + Fecal N)

Table 11. Effect of wheat bran on nitrogen intake, urinary and fecal nitrogen, and nitrogen balance in group II, in g/day

		Period I (No-bran)		Period II (Bran)		Period III (No-bran)	
	Subject	A[a]	B[a]	A	B	A	B
N intake	6	13.5	13.5	13.9	13.9	13.5	13.5
Urinary N		10.5	10.1	11.3	13.0	11.9	10.3
Fecal N		2.1	2.2	2.1	2.2	2.2	1.9
N Balance[b]		0.9	1.2	0.5	-1.3	-0.6	1.3
N intake	7	13.5	13.5	13.9	13.9	13.5	13.5
Urinary N		9.0	9.3	10.2	11.3	11.1	11.2
Fecal N		2.1	1.8	2.1	2.0	2.0	1.9
N Balance		2.4	2.4	1.6	0.6	0.4	0.4
N intake	8	13.5	13.5	13.9	13.9	13.5	13.5
Urinary N		8.1	8.4	10.2	9.7	9.3	9.3
Fecal N		1.8	2.0	2.2	1.8	1.8	1.2
N Balance		3.6	2.1	1.5	2.4	2.4	2.0
N intake	9	13.5	13.5	13.9	13.9	13.5	13.5
Urinary N		8.6	8.8	9.9	10.1	10.8	9.7
Fecal N		1.9	1.7	2.3	2.0	2.1	1.8
N Balance		2.0	2.0	1.7	1.8	0.6	2.0
N intake	10	13.5	13.5	13.9	13.9	13.5	13.5
Urinary N		10.5	10.7	10.2	10.7	10.4	9.8
Fecal N		1.2	2.0	2.3	2.0	2.3	1.5
N Balance		1.8	0.8	1.4	1.2	0.8	2.2

a. A = the second 6-day composite of each period, B = the third 6-day composite of each period

b. N Balance = N intake - (Urinary + Fecal N)

Table 12. Effect of wheat bran on fecal neutral detergent fiber, in g/d[a]

Group I				Group II			
Subject	Period I (Bran)	Period II (No- Bran)	Period III (Bran)	Subject	Period I (No- Bran)	Period II (Bran)	Period III (No- Bran)
1	10.6	9.1	12.7	6	3.7	4.9	4.8
2	7.9	4.0	9.6	7	3.7	5.9	9.3
3	8.8	3.7	10.7	8	4.7	5.6	2.1
4	6.7	2.5	6.5	9	9.1	10.2	8.4
5	8.8	4.7	8.0	10	4.6	7.4	2.4
Mean±S.D.	8.6±1.4	4.8±2.5	9.5±2.4	Mean±S.D.	5.2±2.3	6.8±2.1	5.4±3.3

a. Value of the last one 6-day composite of each period

consistently high values of neutral detergent fiber, sometimes higher than intake, were observed. Subjects 3 and 7, in whom there were increases in percentage water content in the feces in the third period (Table 5), also had a sudden increase in fecal neutral detergent fiber during that same period.

Composition of Dry Feces

Table 13 gives the percentages of neutral detergent fiber, ash, fat, and nitrogen in dried feces of the subjects for both the Bran and No-bran diets. There was a great increase in the percentage neutral detergent fiber in dry feces when bran was added to the basal diet. Concentrations of ash, nigrogen and fat in dried feces were not altered by bran supplementation. The increased amount of fecal neutral detergent fiber on the Bran diet represents about 46% of the increased total dry solids.

Subject Weight and Caloric Intake

The addition of 15 g of wheat bran to the diet was well tolerated by the subjects. No subject complained of gastro-intestinal problems during the 58-day study period. They actually preferred the Bran diet to the No-bran diet.

The subjects' body weights and average caloric intakes

Table 13. Percentages of neutral detergent fiber (NDF), ash, fat and nitrogen in dry feces of the subjects fed Bran and No-bran diets

	NDF	Ash	Fat	Nitrogen
Bran	18.6±4.3	12.2±1.4	12.9±3.6	5.0±0.3
No-bran	13.8±5.3	11.9±9.4	13.1±4.2	5.2±0.5

for the three experimental periods are presented in Tables 14 and 15, respectively. Both the subjects' body weights and caloric intakes were not altered by the supplementary wheat bran. On the whole, the subjects managed to maintain their weights through adjusting the consumption of additional calories from refined carbohydrate. The calorie content in the diet was relatively low for the body size of subject 6, and relatively high for subjects 3 and 9. This may have contributed to their respective increase and decreases in body weight, in spite of their effort to consume more or less "free foods". Subject 8 also gained some weight. Our diet may have contained more energy than he required.

Correlations

The results of correlation analysis performed in the present study are given in Table 16. Fecal wet weight, fecal moisture and dry solids were significantly correlated with fecal neutral detergent fiber on both the Bran and the No-bran diets. Fecal dry solids correlated significantly with fecal energy content. Fecal output of energy, nitrogen and ash did not correlate with fecal bulk, with the exception that fecal nitrogen correlated significantly with fecal bulk on the No-bran diet. These fecal nutrients also failed to correlate with fecal neutral detergent fiber. There was no correlation between fecal wet weight and transit time.

Table 14. Range of body weights of the subjects during the three experimental periods, in kg[a]

Group I				Group II			
Subject	Period I (Bran)	Period II (No-bran)	Period III (Bran)	Subject	Period I (No-bran)	Period II (Bran)	Period III (No-bran)
1	62.5-63.6	63.6-63.9	63.6-64.4	6	95.0-97.0	94.8-96.6	93.6-95.2
2	61.9-62.3	62.2-63.3	61.9-63.2	7	78.2-78.9	77.7-79.1	76.6-78.2
3	55.8-58.1	57.6-58.9	58.4-59.4	8	64.2-67.0	66.4-68.1	67.0-69.1
4	71.9-73.6	72.9-74.0	73.0-74.1	9	48.2-48.9	49.1-50.5	50.2-51.1
5	85.5-87.6	85.5-87.3	86.4-87.3	10	66.8-67.8	66.6-68.2	67.3-68.4
Mean±S.D.	68.6±11.7	69.1±11.2	69.5±11.4	Mean±S.D.	71.5±17.4	71.7±16.6	71.7±15.8

a. Range of subjects' weight during each 18-day period

Table 15. Subject calorie intake of the three experimental periods[a], kcal/Kg BW

Group I				Group II			
Subject	Period I (Bran)	Period II (Non-Bran)	Period III (Bran)	Subject	Period I (No-Bran)	Period II (Bran)	Period III (No-Bran)
1	42.0	41.5	41.8	6	29.6	30.9	31.2
2	49.4	42.8	45.1	7	39.9	38.6	36.9
3	50.6	48.2	47.6	8	44.4	44.4	43.7
4	40.2	35.7	36.8	9	56.0	56.5	55.2
5	38.3	37.1	33.3	10	41.7	43.6	42.0
Mean± S.D.	44.1± 5.6	41.0± 5.0	40.9± 5.9	Mean± S.D.	42.3± 9.5	42.8± 9.4	41.8± 9.0

a. Mean value of each 18-day period

Table 16. Results of correlation analysis

Variables	Correlation coefficient	
	Bran	No-bran
Fecal wet weight vs fecal NDF	0.74[a]	0.72[a]
Fecal water vs fecal NDF	0.72[a]	0.68[a]
Fecal dry solids vs fecal NDF	0.72[a]	0.66[a]
Fecal energy vs fecal dry weight	0.88[a]	0.92[a]
Fecal energy vs fecal wet weight	0.60	0.45
Fecal nitrogen vs fecal wet weight	0.58	0.70[a]
Fecal ash vs fecal wet weight	0.43	0.50
Fecal wet weight vs transit time	0.51	0.50
Fecal energy vs fecal NDF	0.63	0.53
Fecal nitrogen vs fecal NDF	0.50	0.43
Fecal ash vs fecal NDF	0.15	0.29

a. $p < 0.05$, significant correlation

DISCUSSION

Since dietary components other than fiber may also affect fecal weight, transit time (10), and fecal nutrients, the value of the present study is that the effect of wheat bran was investigated in subjects who consumed a controlled diet.

Fecal Nutrients

There was a variation in fecal output of nutrients, both within and among the subjects in the present study. The hypothesis was that dietary wheat bran may result in increased fecal nutrient loss. As shown in Fig. 2, the supplementation of 15 g/day of wheat bran significantly increased energy, nitrogen, and ash excretion in the feces. Bran also consistently increased fecal fat loss in one group of subjects. The overall increase in fat loss for both groups, however, was not statistically significant.

The mean increase in fecal loss of energy on the Bran diet was only 32 kcal/day and fecal nitrogen loss just 0.2 g/day. Both bear little nutritional significance. The wheat bran did not alter nitrogen balance (Tables 10 and 11). The subjects' caloric intake on the per kg body weight basis was not altered either. Accordingly, dietary requirements for both energy and nitrogen were not changed

by adding 15 g of wheat bran to the diet in the present study. These findings are similar to the results of the studies by Southgate et al. (5) and Cummings et al. (6). They found that the increased fecal excretion of energy (5) and nitrogen (6), when large amounts of wheat bran were added to the diet, were too trivial to have any nutritional importance. On the other hand, these changes may imply some important effects bran has on the processes of digestion and absorption, or the colonic bacterial function. There was no change in fecal caloric content and nitrogen on the per gram wet feces basis. Therefore, the increased excretion of energy and nitrogen might be a secondary effect of fecal bulk.

Nitrogen balance was not altered by the supplemental bran in the present study. Kies and Fox (3) found that only in subjects with marginal or negative nitrogen balances, increased levels of hemicellulose supplementation further impaired their nitrogen balances. In general, our subjects were in positive nitrogen balances. Although skin loss was not taken into consideration when we calculated nitrogen balance, this loss would not be great enough to produce negative nitrogen balance in our subjects. Also, the error in nitrogen balance tends to favor a positive balance due to overestimation of nitrogen intake and underestimation of nitrogen output from excreta loss (83). We cannot explain

the sudden increase in urinary nitrogen, which caused negative nitrogen balances in subjects 4 and 6 in the second experimental period.

It was noticed that in the first group of subjects (Number 1 to 5), who received the Bran, No-bran, and Bran diets in that order, increases in fecal energy and nitrogen were higher in the first period than in the third period (Fig. 2). We did not analyze samples from the first 6 days of each period. Six days' elapse may not have been sufficient to "wash out" the influence of the preceding diet periods. The order of feeding and individual differences between the two groups of subjects may have something to do with this trend of changes. This may also be evidence of adaptation of the metabolic system of these subjects to the again-ingested wheat bran. This aspect of wheat bran, i.e., its long term effect on fecal nutrient, is worth further investigation. Longer and continuous experimental periods with diets of strictly controlled fiber content would be necessary for this purpose.

Fecal fat loss was not significantly increased by the supplemental bran owing to the lack of response in the first group of subjects. In the study of Walter et al. (84), 39 g/day of wheat bran supplemented as biscuits also failed to significantly increase fecal fat excretion. Both pectin and guar gum (85) enhance fecal fat excretion

significantly. Pectin is a highly charged polygalacturonic acid molecule; guar, a galactomannan, is probably a linear molecule. Both are very different from the hemicellulose of wheat bran, arabinoxylan, which is a highly branched molecule and the principal fiber constituent of wheat bran. Truswell and Kay (86) found that wheat bran has very little effect on blood lipids.

There were, however, consistent increases in fecal fat output in the second group of subjects when they ate the Bran diet (Table 9). The enhanced fat loss in Group II subjects, 1.35 g/day, exceeded the fat content in 15 g of wheat bran, 0.78 g (Appendix I). Since all subjects consumed constant amounts of fat throughout the entire study, it is postulated that part of the increased fat loss due to wheat bran was of endogenous origin. Walker (60) suggested that fecal fat loss induced by dietary fiber is mainly of endogenous origin because dietary fiber increased fecal fat loss to the same degree in subjects receiving different amounts of fat.

Fecal fat output varied considerably among the first group of subjects with and without bran supplementation. The order of introducing bran to the diet may have influenced fecal fat output. Also, an initial 6 days' elapse might not have been long enough to "wash out" the influence of a prior diet in order to show the effect of a

moderate amount of bran on fat utilization. However, it still cannot be ruled out that wheat bran does not enhance fecal fat loss.

Fecal ash content, a reflection of mineral loss in the feces, increased 0.7 g/day with bran supplementation. There is 0.77 g of ash in 15 g of wheat bran (Appendix I). The increase in fecal ash may either result from ash associated with ingested wheat bran, or cation loss induced by the supplemental wheat bran. Rheinhold et al. (65) found increased fecal excretion of calcium, magnesium, zinc and phosphorus in subjects who were fed large amounts of wheat bread. In the first group of subjects of the present study, the trend of fecal ash excretion resembles that of fecal energy and nitrogen (Fig. 2), the increased fecal ash was greater in the first period than in the third period. The long term effect of wheat bran on the availability of dietary minerals should be investigated further.

Fecal Neutral Detergent Fiber

Great individual differences in the amount of fecal neutral detergent fiber were observed on both the Bran (range, 4.9 - 12.7 g/day) and No-bran diets (2.1 - 9.3 g/day) (Tables 10 and 11). These results are compatible with findings in other studies that the digestibility of dietary fiber varies greatly among individuals (26-28) due to the

high variabilities in intestinal microflora and transit time among individuals. Subject 1 consistently excreted a high amount of neutral detergent fiber in his feces, a possible indication of the low capacity of his intestinal microflora to digest dietary fiber. His fecal excretion of neutral detergent fiber was always higher than that provided in the diet. According to Southgate et al. (5), the fecal excretion of lignin was consistently higher than intake in subjects who were fed diets with or without bran supplementation. These authors suggested that "fecal lignin" includes some material of bacterial origin which may account for the high neutral detergent fiber value observed in subject 1. Subjects 3 and 7 in the last period and subject 5 in the first period had a sudden increase in fecal neutral detergent fiber content. Since hemicellulose and, to a lesser extent, cellulose are normally well digested by humans, the sudden increase in fecal output of neutral detergent fiber may be a result of less degradation of hemicellulose and cellulose during the periods in question.

Regression Analysis on Fecal Calorie Value

In an attempt to find out variables contributing to the loss of energy in the feces, a regression analysis correlating fecal energy with fecal fat, nitrogen, and neutral detergent fiber was conducted on both Bran and No-bran

diets. A highly significant regression equation accounting for fecal energy was found for the No-bran diet:

Fecal calorie = -355.92 + 10.42 x fecal fat + 89.04 x fecal N + 26.69 x fecal NDF

($r^2 = 0.911$, $p < 0.05$ for all the variables)

However, on the bran-supplemented diet, fecal energy content cannot be accounted for by the same variables. This might imply that, with the adding of bran to the diet, variables other than fat, nitrogen and neutral detergent fiber are also responsible for the energy value of the stool. According to Southgate and Durnin (2), there were only negligible amounts of free sugars or starch in the feces of subjects who were fed either a high or low fiber diet. Cummings et al. (6) found significantly higher volatile fatty acids in six subjects consuming a diet of high wheat fiber content. These findings may suggest that volatile fatty acids are the missing factor contributory to the loss of energy in subjects receiving the Bran diet.

Fecal Weight

There were considerable variations among our subjects in fecal weight. Bran significantly increased fecal wet and dry weight in each of the subjects (Fig. 1). The increase in fecal moisture content on the Bran diet was not statistically significant, presumably due to the fact that

cooked bran was used in the study. Wyman et al. (51) have shown that raw and cooked bran affect stool weight differently. In their study, both raw and cooked bran had no significant effect on stool wet weight. However, only raw bran significantly increased stool dry weight. It is possible that the water-holding capacity of fiber in the wheat bran can be changed by cooking. In the present study, the percentage of water in the feces was not altered by bran supplementation, a result similar to that of Floch and Fuchs (87), and Mclean Baird et al. (43). Recently, Kelsay et al. (88) also failed to increase percentage fecal water content by including a large amount of fruits and vegetables in the diet.

As was reviewed previously, there are two hypotheses on the mechanism of fecal bulking (increase in wet weight). The first hypothesis is that bulking results from the physical presence of fiber in the feces mainly due to its water-holding capacity. Results from the present study that accommodate this hypothesis were obtained in subject 1 in whom bran produced concomitantly a high fecal neutral detergent fiber and percentage water. Since his fecal neutral detergent fiber value on the Bran diet is higher than that of the other subjects, we are assuming that he has a limited ability to degrade hemicellulose and cellulose in bran. The high percentage of water in his feces can be accounted for by the presence of these two fiber constituents which have

high water holding capacity. Also, in subjects 3, 5 and 7, a simultaneous increase in fecal neutral detergent fiber and percentage water was noticed.

The second hypothesis for fecal bulking is that bulking is brought about by the cathartic effect of the products of bacterial degradation of fiber in the colon, mainly volatile fatty acids. Data supporting this hypothesis in the present study show that in the remaining instances in which subjects had a lower fecal neutral detergent fiber (a greater ability to degrade dietary fiber), bran produced proportional increases in both fecal water and dry weight. Fecal neutral detergent fiber correlated significantly with fecal wet weight, fecal water and dry solids (Table 16). In these cases, fecal bulking is mainly brought about by the cathartic effect of the products of dietary fiber digestion. Cummings et al. (6) found that although total volatile fatty acids excreted in the stool was higher when wheat fiber was supplemented into the diet, the concentration of fecal volatile fatty acids remained unchanged. This finding may explain the proportional increases in fecal moisture and dry solids on bran supplementation in the present study, if the cathartic effect is a result of the production of volatile fatty acids. It is thus suggested that colonic volatile fatty acids may play an important role in fecal bulking.

The increase in fecal dry solids was higher than that

of fecal neutral detergent fiber. Fecal nitrogen, ash, and fat played a part in the increased dry weight. However, only the percentage of neutral detergent fiber in dry feces was increased when bran was added to the diet (Table 13). Fecal energy content correlated significantly with fecal dry solids (Table 16).

Transit Time

In the present study, adding bran to the diet did not significantly alter intestinal transit time. Similar results were found by Eastwood et al. (8). Only two of the subjects (number 5 and 6) consistently showed that bran produces a shorter transit time. Great variation both among and within individuals in transit time was observed (Table 7).

As was reviewed previously, fine bran and cooked bran are less effective in promoting intestinal transit than coarse and raw bran. The particle size of bran (Appendix I) used in this study is similar to that of the fine bran in Kirwan et al.'s study (52). Also, in our study, bran was administered in the cooked form. Wyman et al. (51) could not significantly change transit time by adding 22 g of cooked bran. In another study, 2 ounces (56.7 g) of cooked bran (Kellogg's Bran Buds) was effective in decreasing transit time (89). Fifteen grams of raw wheat bran

served in the cooked form might not have been sufficient to affect gastrointestinal transit in the present study. The reasons for the different effects of raw and cooked bran on transit time are unknown.

Both carmine and FDC Brilliant Blue No. 1 are solid phase dye fecal markers. Mclean Baird et al. (43) preferred to use dye markers since several measurements can be made in a short study period, thus offering more accurate results. They, however, overlooked some drawbacks of dye markers, i.e., the property of the dyes to spread out for several days' passage in the stool (81). In the present study, fecal markers were administered to the subjects every three days. This time period was really too short to distinguish the dye given in one period from that given in the following period as we did have trouble separating the feces (footnotes for Table 7). Lutwak and Burton (81) reported that in order to avoid overlapping of dyes, it was sometimes necessary to have 6-day intervals between two consecutive markers. The poor separation of the marker might have contributed to the variation in transit time in the present study. Expressing our data as means of two 6-day periods reduced errors caused by poor separation of feces.

Our data do not support the hypothesis of Burkitt et al. (41) that an inverse relationship exists between fecal wet weight and transit time. There was no correlation between fecal weight and transit time (Table 16).

The subjects in this study generally had short transit times. Only subject 6 in the last period showed a transit time longer than 2 days (48.5 hrs). Harvey et al. (48) demonstrated that only those with an initial transit of 3 days or more showed significantly decreased transit time after 30 g/day of raw bran supplementation. The short transit time in our subjects may have obscured the effect of bran on gastrointestinal transit. However, significant individual differences in transit time in response to the bran supplementation were still observed among our subjects, who had short transit times.

Dietary Fiber and Obesity

Heaton (90) once suggested the use of a high fiber diet to control obesity, because fiber promotes satiety and decreases the digestibility of nutrients. Our subjects did not show the tendency to be satiated by the supplemented wheat bran (Table 15). The increased energy loss in the feces was also trivial. It seems unlikely that increasing dietary fiber intake, at least through the use of 15 g of wheat bran as in our study, would be valuable in the management of obesity.

Dietary Fiber

The basal diet in the present study contained 6.6 g/day of

neutral detergent fiber. Since neutral detergent fiber does not measure pectin content in the diet, the amount of true dietary fiber intake should be higher than this value. Heller and Hacker (35) found that an ordinary American diet contained about 4.9 g crude fiber/day, which means an approximate intake of 25 to 30 g of true dietary fiber per day if crude fiber represents only 1/5 to 1/6 of true dietary fiber (37). Dietary fiber intake in this study was apparently lower than their value, even with the addition of pectin in the diet. We included many items of canned fruits and vegetables in the diet which may have contributed to the low dietary fiber content.

CONCLUSIONS

The effect of cooked wheat bran on the excretion of fecal nutrients, fecal weight, and transit time was investigated in 10 men, aged 20 to 35 years. The study was divided into three 18-day periods. The subjects were divided into two groups; one received the basal diet supplemented with 15 g of AACC Certified Food Grade Wheat Bran (B) during the first period, no bran (NB) in the second, and B in the third. The other group received NB, B and NB in that order. The basal diet supplied 6.6 g neutral detergent fiber (NDF). The subjects' fat intake was constant. All feces were collected; values for each subject were obtained from the second and third 6-day fecal composites of each period. A 15 g supplement of wheat bran caused a significant increase in fecal excretion of energy, nitrogen and ash. The increased fecal loss of these nutrients, however, was not important nutritionally. Dietary requirements for both energy and nitrogen were not affected by a moderate amount of wheat bran in the diet.

The trend of changes in fecal nutrient output in group I, i.e., the loss of energy, nitrogen and ash when bran was first ingested was higher than when bran was again ingested in the third period, may be evidence of adaptation of the subjects to bran supplementation or the experimental diet.

The long term effect of wheat bran on the utilization of nutrients should be further investigated.

Fecal fat loss was increased only in group II when bran was added to the diet. Wheat bran may not be efficient in affecting the processes of digestion or absorption or both of fat. The increased fecal fat excretion in group II exceeded fat content in 15 g of wheat bran. The fat loss induced by bran supplementation may be in part due to endogenous loss.

Fecal weight was significantly increased by bran supplementation. The effect of wheat bran on transit was not consistent. Our results suggest that both the physical presence of fiber in the stool and the products of bacterial degradation of fiber in the colon affect fecal bulk.

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APPENDIX

Appendix 1. AACC CERTIFIED FOOD GRADE WHEAT BRAN
R07-3691

Assay	Value[a] (as is basis)
Crude Fiber	8.9%
Protein	14.3%
Moisture	10.4%
Fat (Acid Hydrolysis)	5.22%
Ash	5.12%
Aerobic Plate Count	16,000/g
Acid Detergent Fiber	11.9%
Neutral Detergent Fiber	40.2%
Lignin	3.2%
Pectin	3.0%
Water Holding Capacity	9.5 g/g
Cutin	0%
Thiamine (B_1)	0.78 mg/100g
Riboflavin (B_2)	0.39 mg/100g
Niacin	20.9 mg/100g
Pyridoxine (B_6)	0.58 mg/100g
Folic Acid	0.12 mg/100g
Pantothenic Acid	2.48 mg/100g
Vitamin E	2.69 mg/100g
Choline	228 mg/100g
Aluminum	5.0 ppm
Arsenic	<0.1 ppm
Barium	45.07 ppm
Boron	4.5 ppm
Cadmium	2.8 ppm
Calcium	0.12%
Cobalt	39.2 ppm
Copper	15.6 ppm
Iron	122 ppm
Lead	2.3 ppm

Appendix 1 (Cont.)

Assay	Value[a] (as is basis)
Magnesium	0.43%
Manganese	80.0 ppm
Mercury	0.002 ppm
Phosphorous	1.04%
Potassium	1.38%
Selenium	0.1 ppm
Sodium	0.10%
Zinc	54.5 ppm
Damaged Starch	3.74%
Total Starch	17.4%
Total Sugar as Invert	7.04%
Pentosan	22.1%
Phytic Acid	3.36%
β-Sitosterol	123 mg/100g
Campesterol	68.8 mg/100g
Stigmasterol	11.2 mg/100g
Aflatoxin	<10 ppb
Sanitation[b]	0
Pesticides, Phosphorus Containing	<0.005 ppm
Pesticides, Chlorine Containing	<0.02 ppm

Particle Size

ON US#10	1%
#12	2%
#14	5%
#16	11%
#18	13%
#20	9%
#30	33%
#40	17%
#50	8%
#60	1%
#70	Trace
Thru #70	Trace

Appendix 1 (Cont.)

a. Abbreviations: mg - milligrams
ppm - parts per million
ppb - parts per billion

b. Whole insects, insect fragments, whole larvae, larva fragments, rodent hairs, rodent excretion fragments, other contaminants.

Appendix 2. Recipes for Biscuits, Cereal, and Cocoa Mix

Biscuits

Ingredients:

Master Mix — Flour 75 lb, Baking Powder 3 lb 4 oz, Salt 1 lb 6 oz, Non-fat dry milk 11 lb 30 oz, Fat 24 lb 3 oz, Egg (powder) 6 lb, Sugar 15 lb 8 oz.

Bran Biscuits		No-bran Biscuits	
Master mix	85 gm	Master mix	85 g
Bran	5 g	1 ml pyridoxine solution (0.186 mg/ml)	
Water	1/4 cup	Water	3½ Tbsp.

Procedures:

Place mix in small mixing bowl. Add pyridoxine solution (for No-bran biscuit) to top of the mix. Add water. Stir till dough is just moist. Place in greased muffin tin at 425° F for 15 minutes.

Cereal

Bran:		No-bran:	
Wheat hearts[1]	30 g	Wheat hearts	30 g
Salt	1/8 tsp	Salt	1/8 tsp
Water	3/4 c	Water	2/3 C
Bran	5 g		

Procedure: Mix ingredients in cereal bowl and cover. Bake at 350° F for 10 minutes.

Cocoa mix

Non-fat dry milk 30 lb, sugar 13 lb 4 oz, Cocoa 5 lb 8 oz, Salt 8 tsp.

1. General Mills, Minneapolis, Minn.

Appendix 3. Data taken from ANOVA tables

Variable	Unit	Mean Square			F		
		Treatment	Group	Treatment by Group	Treatment	Group	Treatment by Group
Fecal weight	g/6 days	542260.267	105020.833	1471.400	4.349*	.842	.012
% moisture in feces	% of fecal weight	9.680	12.740	6.807	0.198	.261	.139
Fecal water	g/day	4785.507	1096.538	35.420	3.169	.726	.023
Fecal dry wt.	g/day	330.6061	27.486	3.597	19.132**	1.591	.208
Fecal fat	g/6 days	438.751	75.573	175.378	2.135	0.368	.854
Fecal nitrogen	g/6 days	25.233	1.512	.419	11.914**	.714	.198
Fecal energy	g/6 days	549430.929	45439.878	12222.623	22.946**	1.898	.510
Fecal ash	g/day	3.978	0.077	0.112	20.711**	.402	.581
Fecal NDF	g/day	75.272	5.063	12.322	10.543*	.709	1.726
Transit time	hours	138.072	216.969	2.299	1.647	2.588	.027
Urinary nitrogen	g/6 days	.046	.791	5.351	.017	.289	1.955
Nitrogen balance	g/6 days	.716	.468	5.862	.253	.165	2.072
Subject wt.	Kg	10.417	88.614	.027	.017	.146	.000
Calorie intake	Kcal/day	12.150	5.573	1.791	.070	.032	.010
Degrees of Freedom		1	1	1			

*Significant at 0.05 level
**Significant at 0.01 level