Nutrition and Diet Research Progress

Dietary Fiber

Production Challenges, Food Sources and Health Benefits

Marvin E. Clemens
Editor

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DIETARY FIBER

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MARVIN E. CLEMENS
EDITOR

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PREFACE

Dietary fibers are classified into water soluble or insoluble, and most plant foods include in their composition variable amounts of a mixture of soluble and insoluble fibers. This soluble or insoluble nature of fiber is related to its physiological effects. Insoluble fibers are characterized by high porosity, low density and the ability to increase fecal bulk, and act by facilitating intestinal transit, thus reducing the exposure to carcinogens in the colon and therefore acting as protectors against colon cancer. The influence of soluble fiber in the digestive tract includes its ability to retain water and form gels as well as a role as a substrate for fermentation of colon bacteria. This book discusses the production challenges, food sources and health benefits of dietary fiber.

Chapter 1 - Starch is a polysaccharide abundant in nature that undergoes hydrolysis in the small intestine to provide energy in the form of glucose.

Portions of starch resistant to hydrolysis that escape the small intestine and enter the large intestine intact to undergo fermentation is known as resistant starch (RS). Fivetypes of RS, 1-5, have been identified based on the physical inaccessibility, structure, retrogradation, or chemical modification of starch found either naturally or added to food. Thus, RS can be classified as a dietary or functional fiber. The formulation of ingredients containing RS by the food industry, such as high-amylose maize, can increase the fiber content of food without altering physiochemical or sensory attributes. The small molecular size, bland flavor, and white color, make RS an ideal partial replacement for fully-digestible starch in food.

A reduction in caloric availability is observed when RS replaces fully-digestible starch and can attenuate postprandial glucose and insulin concentrations. Additional physiological effects of RS result from the production of short chain fatty acids upon fermentation in the large intestine. RS improves digestive health by acting as a prebiotic, decreasing intestinal pH, and the formation of cancer-causing agents.

In murine models, dietary RS is associated with reductions in total and abdominal adiposity and improvements in lean mass. Increases in intestinal-derived satiety hormones, such as peptide YY and glucagon-like peptide-1, contribute to these findings. Despite mixed results associated with changes in blood glucose and insulin concentrations after long-term RS consumption, adults consuming 15-40 g daily have shown improvements in insulin sensitivity, particularly among those with metabolic syndrome.

RS is a functional fiber that can increase dietary fiber intake and positively impact overall health when consumed in adequate amounts.

Chapter 2 - Dietary fibers are classified into water soluble or insoluble, and most plant foods include in their composition variable amounts of a mixture of soluble and insoluble fibers. This soluble or insoluble nature of fiber is related to its physiological effects. Insoluble fibers are characterized by high porosity, low density and the ability to increase fecal bulk, and act by facilitating intestinal transit, thus reducing the exposure to carcinogens in the colon and therefore acting as protectors against colon cancer. The influence of soluble fiber in the digestive tract includes its ability to retain water and form gels as well as a role as a substrate for fermentation of colon bacteria. However, the viscous soluble polysaccharides can delay digestion and compromise in some degree the absorption of nutrients from the gut.

Dietary fibers have an impact on all aspects of gut physiology and are a vital part of a healthy diet. Diets rich in dietary fiber have a protective effect against diseases such as hemorrhoids and some chronic diseases as well as in decreasing the incidence of various types of cancer, including colorectal, prostate and breast cancer.

The dietary fibers are among the most attractive and studied themes in nutrition and public health in the past decades, and therefore many epidemiological studies have been developed to evaluate the effects of fibers on several aspects of human health.

The current trend is towards diets rich in dietary fiber since these are implicated in the maintenance and/or improvement of health. However, despite the beneficial effects, there is also evidence of some negative effects associated with fiber consumption. For example, fiber can produce phytobenzoates, which can induce a decrease in the absorption and digestion of proteins. On the other hand, some fibers may inhibit the activity of pancreatic enzymes that digest carbohydrates, lipids and proteins. Furthermore, fibers can interfere, although not strongly, with the absorption of some vitamins and minerals like calcium, iron, zinc and copper.

Chapter 3 - The authors aimed to evaluate the effect of the prebiotics Nutriose® FB06 (NUT) and Raftilose® P95 (RAF) upon uptake of ^{14}C-butyrate (^{14}C-BT), and upon its cellular effects, in a rat normal intestinal epithelial cell line (IEC-6 cells). A long exposure (48h) to NUT or RAF (20-100 mg/ml) caused an increase in ^{14}C-BT uptake. This effect involved the sodium-dependent monocarboxylate transporter 1 (SMCT1) but not the proton-coupled monocarboxylate 1 transporter (MCT1), although prebiotics showed no effect on SMCT1 and MCT1 mRNA expression levels. BT (5 mM; 48h) markedly decreased cellular viability and culture growth and increased cell differentiation. Combination of prebiotics with BT did not significantly modify these parameters. In conclusion, the results show that a long exposure to NUT and RAF increases uptake of a low concentration of ^{14}C-BT by intestinal epithelial cells, although the prebiotics do not modify the effects of BT upon cell viability, culture growth and differentiation.

Chapter 4 - *Background:* It is thought that our genomic heritage from late Paleolithic man, 40,000 – 100,000 years ago, influenced not only our phenotype, but also our physiological functions. Our ancestors, for approximately 84,000 generations, survived on a regimen in which plants constituted from 50 to 80% of their diet. Later during the Neolithic agricultural period, our ancestors increased fiber intake even more to amounts that would have exceeded 100g/day. Thereafter, the industrial and agro business eras (200 years ago), and the digital age (2 generations ago) have distanced the nutrition from its primate and Paleolithic ancestors. It is known that fiber, and its sources, whole grain, fruits, and vegetables are also rich in minerals, vitamins, phenolic compounds, phytoestrogens, and related antioxidants. Thus, in conjunction with the discordance between our ancient genetically determined biology and the nutritional, cultural, and activity patterns in contemporary populations that adopted the "western lifestyle", many of the so-called disease of our time have emerged. Consumption of grain products milled from all edible components of grains, have been inversely associated with mortality from a number of chronic diseases.

Objective: To find the determinants of dietary fiber intake and its role in metabolic syndrome (MetS) in a community based intervention.

Design: It was a cross-sectional study of the relationship of ingested fibers with demographic, socieconomic, anthropometric, overall health perception, and specific pathognomonic markers for obesity and MetS and each of its components. The analysis came from baseline data obtained from participants of both sexes, over 35 years of age, enrolled during the 2007-2013 period (n= 605), in the ongoing dynamic cohort, Botucatu longitudinal study "Move for health" and conducted by professionals from the Nutritional and Exercise Metabolism Centre (CeMENutri) of the Botucatu Medical School (SP, Brazil).

Results: Even in the highest quartile, dietary fiber was far below the daily recommended intake, along with its source of fruits, vegetables, and whole grains. The quartile distribution of dietary fiber intake was not influenced by any of the study variables (demographic, socieconomic, anthropometric, overall health perception, or specific pathognomonic markers for obesity and MetS); however, in association-designed studies the authors had found that low dietary fiber intake and its sources represent a risk factor for insulin resistance, high-blood pressure and the presence of MetS. Moreover, in longitudinal studies with lifestyle changing (LISC) interventions, the authors noted a faster resolution of MetS when individuals met the recommended daily dietary fiber intake than only with LISC isolated.

Conclusion: Overall individuals had a high caloric diet and a low intake of all sources of fiber. These results were irrespective to age, gender, literacy and economic reasons, probably cultural, what makes the solution more difficult. However, when these subjects were enrolled in intervention programs with LISC it was found that adding dietary fiber to the diet was an effective booster for faster resolution of MetS. Therefore, the diet adequacy of fiber seems to work by diluting the energy intake that would potentiate the higher energy expenditure of physical exercise in promoting weight (body fat) loss, along with insulin sensitivity, vasodilation, lower inflammation states, etc.

Chapter 5 - The fiber fraction of plant cell walls is one of the major sources of nutrients and energy. Mammals do not produce enzymes that can hydrolyze β1-4 linked polysaccharides (cellulose and hemicellulose) of plant cell walls, and as such fiber cannot be directly used to feed the growing global human population. By symbiosis with rumen microbes, ruminants are capable of converting this non-digestible food resource into high-quality animal products. For dairy cows, fiber is an important feed component, not only as an energy and nutrient source, but also as a regulatory factor for the maintenance of rumen health and feed intake. Compared to other nutrients, fiber, particularly forage-fiber, has much longer ruminal retention time because of slower degradation and greater buoyancy in the rumen. As such feeding fiber with large particle size can increases digesta mass in the rumen that in turn stimulate rumination, increases rumen buffering capacity and reduces the risk of ruminal acidosis and abomasal displacement. On the other hand rumen-fill can also limit feed intake, and the filling effect of fiber in more pronounced in high producing dairy cows. Any reduction in dry matter intake reduces milk and milk protein yield of dairy cows. Therefore, high producing dairy cows can be benifited from feeding fiber sources with rapid rumen-passage rate.

Legumes and corn silage fiber digests and passes from the rumen quickly compared to perennial grasses and can be an excellent source of forage fiber for high producing cows. Fiber-turnover through the rumen is influenced by many factors, these includes intrinsic plant characteristics such as fiber content, particle size, fragility (rate of particle size reduction) and digestibility (rate of fermentation), and extrinsic factors within the rumen environment, such as rumination, absorption of fermentation end products, rumen pH and growth of the microbial population. The fiber fraction generally becomes more lignified, as forage matures, and the degree of fiber lignifications is directly related to the filling effects of the fiber within a forage type. Fiber that is less lignified are more digestible and clears from the rumen faster, allowing more space for the next meal. Selecting forages with high fiber digestibility can increase their feeding value. Alternatively, lignin degrading enzymes can also improve fiber digestibility, however the effect is not consistent. Some fungi specifically degrade lignin in cell walls, and can improve fiber digestibility in low quality fibrous materials such as crop residues. Improving the intake and digestion of fiber in dairy cows will result in a more efficient conversion of this non-digestible food resource into high-quality animal products. The total digestion of fiber is the major determinant of its energy value, however, rate of digestion and physical properties play an important role in maintaining rumen health.

Chapter 6 - Dietary fiber is a common and important ingredient in food product development. Its presence in food is desirable not only due to nutritional benefits but also for their functional and technological properties. In the present work, the rheology of four fiber fractions was evaluated. Two of them were obtained from quince waste which was submitted to different isolation processes: one with an ethanol treatment prior to drying and the other with distilled water washing previous to drying. The other fiber fractions were prepared from fresh peach pulp or peel. Suspensions of the fractions in deionized water were studied through dynamic tests. Weak gels of similar mechanical spectra were obtained when 2% w/w of peach fiber or 10% w/w of quince fiber suspensions were prepared in aqueous medium. Carbohydrate characteristics, particle size distribution and polidispersity influenced the rheological behavior. Mineral content was found to contribute to fiber nutritional value. Special attention should be paid to the process applied for the obtention of dietary fiber concentrates in order to assure their adequate functionality.

Chapter 7 - According to many scientific studies, people who have a diet rich in fiber have a low incidence of gastrointestinal disorders, diabetes mellitus, obesity and cardiovascular disease. An alternative to compensate the deficiency of dietary fiber in foods is to incorporate it as a supplement.

Pectin is a fermentable dietary fiber as it resists digestion and absorption in the human small intestine and experiences a total or partial fermentation in the large intestine. Besides possessing multiple health benefits, pectin has applications in the food industry as a gelling agent, thickener, fat replacement, emulsion stabilizer, among others.

In the industry, pectin is usually extracted by treating the raw material (i.e., apple, citrus) with dilute mineral acid at pH near 2, generating large amounts of effluents in need of treatment. Enzymatic methods of pectin isolation are an environmentally friendly alternative to acidic methods usually used and allow labeling products with ecological connotations tending to promote the consumption of products with these features. On the other hand, the increased consumption of fresh cut and peeled products generates a huge amount of wastes that is usually discarded; its use to obtain pectin can help to reduce pollution and restore biomass and nutrients.

The isolation techniques and characteristics of different fractions of dietary fiber isolated from industrialization wastes (leaves, stems, rhizomes and peels) of *Beta vulgaris* var. *conditiva* were studied in this research. The cell wall material was obtained through drying and grinding of *Beta vulgaris* wastes and its treatment with boiling ethanol rendered the alcohol insoluble residue. To isolate pectin enriched fractions, two different pre-treatments were assayed: one with sodium carbonate and another one with sodium hydroxide. The last one was selected because of the high yields and the product obtained was subjected to enzymatic digestion with cellulase and hemicellulase to obtain previously cited fractions. The highest antioxidant activity was detected in the cell wall material. The highest yield of the pectin enriched fractions was observed for the sodium hydroxide treatment followed by hydrolysis with cellulase. Rheological characterization showed pseudoplastic behavior with yield stress in flow assays. Dynamic assays showed weak gel behavior for all pectin enriched fractions in the presence of $CaCl_2$. Carbohydrate characteristics and polyphenol content influenced the antioxidant activity and rheological behavior.

Isolated fractions exhibited different technological characteristics and may be applied as food additives or ingredients.

Chapter 8 - *Objective:* Ovarian cancer is the third most common gynecological malignancy and the eighth leading cause of cancer-related deaths among women worldwide. The present study aimed to investigate the association between dietary fiber intake and the risk of epithelial ovarian cancer in southern Chinese women.

Methods: A case-control study was undertaken in Guangzhou, Guangdong Province, between 2006 and 2008. Participants were 500 incident ovarian cancer patients and 500 hospital-based controls. Information on habitual foods consumption was obtained by face-to-face interview, from which dietary fiber intakes were estimated using the Chinese food composition tables. Unconditional logistic regression analyses were performed to assess the association between dietary fiber intake and the ovarian cancer risk.

Results: The ovarian cancer patients reported lower intake levels of total dietary fiber and fiber derived from vegetables, fruits and cereals than those of controls. Overall, regular intake of fiber was inversely associated with the ovarian cancer risk, the adjusted odds ratio being 0.09 (95% confidence interval 0.05 to 0.14) for the highest (> 21.9 g) versus the lowest (< 16.5 g) tertile of daily intake, with a significant dose-response relationship ($p < 0.001$). Similar reduction in risk was also apparent for high intake level of vegetable fiber, but to a lesser extent for fruit fiber and cereal fiber.

Conclusion: Habitual intake of dietary fiber was inversely associated with the incidence of epithelial ovarian cancer in southern Chinese women.

Chapter 9 - Recently, the use of alternative fiber sources obtained from agroindustrial sub-products as fruit peels. Meat extenders comprise material that improve water retention (yield) and texture in cooked meat products. The most employed are potato starch and kappa carrageenan. The interaction of these three ingredients in a cooked sausage formulation was studied by means of a mixture design approach. Fiber in orange peel flour increased moisture and water retention, besides decreased oxidative rancidity in cooked sausages. Orange peel flour reduced sausages luminosity and redness, increasing yellowness. Fiber contained in orange peel flour improving texture resulting in softer but more cohesive and resilient sausages. Cooked meat products conditions (temperature and ionic strength) affected the functionality of meat extenders like potato starch and carrageenan. This indicates that orange peel flour as a cheap and viable fiber source can replace more expensive meat extenders, as potato starch or carrageenan.

Chapter 10 - Traditional polysaccharides obtained from plants may suffer from a lack of reproducibility in their rheological properties, purity, supply and cost. Most of the used plant polysaccharides are chemically modified to improve their characteristics. Microbial exopolysaccharides (EPSs) are principally composed of carbohydrate polymers, and they are produced by many microorganisms including bacteria, yeasts and fungi. Microorganisms can synthesize EPSs and excrete them out of cell either as soluble or insoluble polymers. These EPSs are able not only to protect the microorganisms themselves against desiccation, phage attack, antibiotics or toxic compounds, but also can be applied in several biotechnological applications. In food products they increase the dietary fiber content and can be used as viscosifiers, stabilizers, emulsifiers or gelling agents to improve physical and structural properties of water and oil holding capacity, viscosity, texture, sensory characteristics and shelf-life. EPSs are used as additives in various foods, such as dairy products, jams and jellies, wine and beer, fishery and meat products, icings and glazes, frozen foods and bakery products. Over the past few decades, interest in using microbial EPSs in food processing has been increasing because of main reasons such as easy production, better rheological and stability characteristics, cost effectiveness and supply. Dextran, xanthan, pullulan, curdlan, levan, gellan and alginate are the main examples of industrially important microbial exopolysaccharides. They also play crucial role in conferring beneficial physiological effects on human health, such as the ability to lower pressure and to reduce lipid level in blood. Furthermore, these EPSs exhibit antitumor, immunomodulating, antioxidant and antibacterial properties. The utility of various biopolymers are dependent on their monosaccharide composition, type of linkages present, degree of branching and molecular weight. In the present chapter, an attempt was taken to recapitulate the most important polysaccharides isolated from microorganisms as well as the main methods for microbial exopolysaccharide production, purification and structural characterization. In addition, the functional and healthy benefits of EPSs and their applications in food industry were discussed.