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# Dietary fibre as an important constituent of the diet

## Błonnik pokarmowy jako ważny składnik diety

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## Summary

The intake of fibre in the diet of a child or an adult, through various foods (such as wholegrain foods, nuts, fruits and vegetables), plays an important role in reducing the risk and lowering the incidence of numerous diseases. The interest of researchers and consumers in the role of diet in the prevention or treatment of many illnesses, and maintaining the general and oral health, has been growing lately. The aim of our study was to underline the role of dietary fibre through its effects on many aspects of the human body and metabolism. Evidence has been found that dietary fibre from whole foods or supplements may reduce the risk of cardiovascular disease by improving serum lipids and reducing serum total and low-density lipoprotein (LDL) cholesterol concentrations in adults and children. Increased fibre content decreases the glycaemic index of foods, which leads to a significant improvement in glycaemic response. High fibre intake is associated with reduced risk of colorectal and breast cancer. In contemporary children, the reluctance to chew raw, hard plant foods may result in a risk of malocclusion and a lack of tooth wear, which cause the need for orthodontic intervention. Fibre consumption is associated with high nutritional value and antioxidant status of the diet, enhancing the effects on human health.

**Key words:** **dietary fibre • chronic diseases • prevention • public health • oral health**

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## Definition and classification

The term dietary fibre was used in 1953 by Hipsley to indicate the nondigestible constituents which make up the plant cell wall. Since then, the definition has evolved, and now several slightly different versions coexist, defining dietary fibre as non-digestible carbohydrates and lignin that are intrinsic and intact in plants. Functional fibre consists of isolated, non-digestible carbohydrates that have beneficial physiological effects in humans. Total fibre is the sum of dietary fibre and functional fibre. This term includes plant cell wall and storage carbohydrates common in foods as dietary fibre, and includes natural, manufactured and isolated carbohydrates as functional fibre. When inulin occurs naturally in consumable plants (onions, chicory), it is categorized as a dietary fibre; when it is synthetically produced and added to yogurt, it is defined as a functional fibre [19,21].

Dietary fibre is conventionally classified into two categories according to their water solubility: insoluble dietary fibre (IDF) such as cellulose, part of hemicelluloses, and lignin; and soluble dietary fibre (SDF) such as pentosans, pectin, gums, and mucilage. SDF (viscous) can be raised by increasing intake of certain foods: cereal grains, fruits, vegetables, and dried beans, peas, and legumes [46]. Dietary fibre on food labels includes both dietary and functional fibre [44].

## Recommendations for fibre intake

The current recommendations for fibre intake for adults are 25-35 g per day (g/d). The guidelines for consumption in children are based on extrapolated data from studies in adults. According to the Dietary Reference Intakes (DRI), people of all ages should consume 14 g per 1000 kcal, which in general translates for children 1-3 years old into 19 g/d and for children 4-8 years old into 25 g of fibre per day. The American Academy of Pediatrics recommends intake of 0.5 g/kg body weight for children older than 2 years. The American Health Foundation in 1995 developed the rule "age plus five" grams of fibre per day [21,38]. Despite the formulation of recommendations for dietary fibre intake, the average population intake is lower: from 9.4±4.0 g/d in young females to 10.7±3.6 g/d in older females, and 12.0±4.5 g/d in young males to 10.7±4.2 g/d in older males [49].

Possible unfavourable effects (poor growth and nutritional status) of a high fibre diet have been reported in children who are vegans or consume a macrobiotic diet. However, results from a prospective randomized atherosclerosis prevention trial (the Special Turku Coronary Risk Factor Intervention Project; STRIP) by Ruottinen et al. in 2010 showed that fibre intake did not displace energy or disturb growth in children between 13 months and 9 years of age [38]. Fibre intake was associated positively with energy intake and inversely with fat intake. Children with a high fibre intake received more vitamins and minerals than children in other groups.

Data derived from the HELENA-CSS (Healthy Lifestyle in Europe by Nutrition in Adolescence – Cross Sectional Study) and from the cross-sectional study by Kranz et al. in 2005 showed that dietary fibre intake both among American preschoolers and European adolescents was not adequate and well below any recommendations (7.9-9.1 g/1000 kcal, from foods low in dietary fibre, but consumed at high levels). Evidence indicates that children with low fibre intakes are at risk of childhood obesity, chronic constipation and impaired glucose metabolism. Introducing more fibre in children's diets might help improve diet quality: an association between fibre intake and nutrient density was observed (with the exception of calcium and vitamin B-12) [6,21,30]. The increasing prevalence of obesity in children and youth is largely attributed to unfavourable changes in diet, physical activity, and sedentary behaviours. Multiple strategies are needed to change these behaviours in young people. However, little is known about the best approaches [32,37].

## Cardiovascular risk and blood pressure

According to the American Dietetic Association (ADA) and 2005 DGAC Committee review, evidence has been found that dietary fibre from whole foods or supplements may reduce the risk of diabetes (improve glycaemic response), the risk of cardiovascular disease (improve serum lipids, help with weight maintenance, lower blood pressure), and indicators of inflammation [27,31]. Benefits may occur with intakes of 12 to 33 g of fibre per day from whole foods (three servings of nutrient-rich whole grains) or up to 42.5 g of fibre per day from supplements [42,44].

Dietary fibre helps to decrease the risk of cardiovascular diseases by reducing serum total and LDL cholesterol concentrations in adults and children. Vegetarians and semi-vegetarians have lower levels of total and LDL cholesterol than omnivores [40]. Dietary fibre intake usually has no effect on high-density lipoprotein (HDL) cholesterol or triglyceride concentrations. However, inverse associations are possible, and the effect of SDF on HDL cholesterol levels still needs further investigation [34,38]. The cholesterol reduction abilities depend on physical properties of fibre. While IDF does not affect LDL cholesterol [1,43,50], an increase in SDF of 5-10 grams per day is accompanied by an approximately 5% reduction in LDL cholesterol. The beneficial effect of the SDF on LDL cholesterol reduction has also been confirmed in many clinical trials related to β-glucan in oats, pectin, guar gum, and psyllium [29,36]. Taking the findings into account, Adult Treatment Panel III made recommendations that the therapeutic diet should be enriched with foods that provide 5-10 grams of SDF daily (higher intakes of 10-25 g/d can be beneficial) [34,38,46].

John et al. and Solà et al. reported that cereal fibre and high intakes of fruit and vegetables were associated with reduced blood pressure in adults, thus lowering cardiovascular risk [18,43].

## Gastrointestinal health and weight maintenance

Dietary fibre promotes gastrointestinal function by building up important microflora, and acting as a prebiotic (substrate for beneficial microorganisms) [7,9]. According to the ADA position paper [42] high fibre diets provide bulk, are more satiating, and have been linked to lower body weights. Dietary fibres are believed to help regulate appetite, food intake and body weight. The effect depends on dose and chemical structure of fibre (inulin's role in the mechanism affecting the release of gut peptides, or dextrins improving short-term satiety) [14,39]. Under conditions of fixed energy intake, several studies have indicated that an increase in either SDF or IDF consumption increases post-meal satiety and decreases subsequent hunger, but there is no indication of which is more effective [2,25].

Increased fibre content (18g/d) decreases the glycaemic index of foods, which leads to a significant improvement in fasting blood glucose, postprandial plasma glucose and glycosylated haemoglobin. This approach should be encouraged as a lifestyle modification and as an important part of diabetes management [4,34].

Data have shown a significant decrease in the waist circumference (WC) and percentage of body fat in the abdominal region among participants on a whole grain diet as compared to low-fibre foods [20,24]. Total fibre and cereal fibre were inversely associated with subsequent increases in weight and WC. Fruit and vegetable fibre was also inversely associated with WC change, but not with weight change. Studies have demonstrated that high fibre affected the body fat levels more than low-fat diets and that before weight reduction a decrease in total fat mass was observed [28]. Davis et al. in their study of dietary intake on metabolic risk factors in Latino youth concluded that adolescents who increased total dietary fibre intake (3 g/1000 kcal) decreased their visceral adipose tissue (VAT), whereas adolescents on a reduced fibre intake diet increased VAT [10]. Parikh et al. suggested that higher consumption of dietary fibre is associated with a decrease in VAT and changes in some of the biomarkers of inflammation (decrease in C-reactive protein and fibrinogen, and increase in plasma adiponectin) in adolescence regardless of gender or race [31]. Increased visceral adiposity is connected with an increase in production of inflammatory cytokines by adipocytes, though reducing VAT may help to reduce systemic inflammation. Higher intake of dietary fibre has been linked to healthy behaviours (physical activity), higher nutritional value and high antioxidant status of the diet [15].

Recent studies provide additional support for the role of dietary fibre in obesity prevention, by consumption of unrefined, high-fibre carbohydrate-based foods. Traditional weight-control diets are high in dietary fibre and low in dietary fat, making it difficult to separate out these effects. One approach of increasing interest to the food industry for the prevention of weight gain is to provide products with high satiating capacities and low energy densities. According to Roberts and Heynan [35], too often there is an overemphasis on dietary fat. Dietary factors examined for their role in weight gain and obesity include meat, white bread, refined grains and carbohydrates [12,35,42].

## Breast and colorectal cancer

The research by John et al. showed that high dietary intakes of fruit and vegetables are associated with reduced risk of cancer [18]. Many studies on antioxidant bioavailability indicate that food microstructure affects the release of several nutrients, mostly antioxidants. Around 50% of the total dietary antioxidants (mainly polyphenolics) are linked to dietary fibre, being released in the colon [18,41].

The meta analysis by Dong et al. provides evidence of a significant inverse dose response association between dietary fibre intake and breast cancer risk (10 g/d increment in dietary fibre was associated with a 7% risk reduction) [11]. The Aune et al. systematic review and meta-analysis of prospective observational studies showed that high intake of fibre from cereals and wholegrain food is significantly associated with reduced risk of colorectal cancer [3]. The results showed a 10% reduction in risk of colorectal cancer for each 10 g intake of fibre daily. Whole grains are a rich source of many components which also may have protective effects: antioxidants, vitamins (folate), minerals (calcium, magnesium), phytate, phenolic acids, lignans and phytoestrogens. Higher intakes of dietary fibre from plant foods and whole grains are associated with other healthy behaviours: higher intakes of calcium and folate, higher physical activity, better weight maintenance, lower prevalence of smoking, and lower intakes of red meat and alcohol. The biological mechanisms responsible for beneficial effects of fibre include: increased stool bulk, dilution of faecal carcinogens in the colonic lumen, reduced transit time, and production of short fatty acids by bacterial fermentation [47]. Recently the science of nutrigenomics suggested the effects of fibre on the genome and interaction between human and microbiota genomes modifying their gene expression [40].

## Impaired dentition status and tooth wear

General and associated oral health conditions have a direct influence on quality of life. Hung et al. found that subjects who lost five or more teeth had a significant decrease in the consumption of dietary fibre and whole fruits (especially apples, pears and raw carrots) than subjects who had lost no teeth [17]. The results support the temporal association between tooth loss and detrimental changes in dietary intake, which could contribute to the increased risk of development of chronic diseases. A cross-sectional survey performed by Kwok et al. in a group of 76 older vegetarian Chinese women living in an old age home found that the poor dental functional status group was more likely to have chewing difficulties and tolerate a soft diet only. Impaired dentition status was

associated with a lower mean daily fibre intake, but not with intakes of macronutrients and micronutrients [22].

The evidence on oral health–general health relationships can also be observed in the case of tooth wear, which although multifactorial, is strongly associated with diet. Differences in dietary environmental and geographical factors may influence the manifestation of tooth wear. It is known that high fibre foods such as dry food, fresh fruit and vegetables require vigorous mastication and great bite forces. Moreover, the cellulose component present in the wall of vegetable foods and grasses necessitates additional chewing even for foods that do not require heavy bite forces [16].

It is known that mild mechanical wear is a physiological process resulting from tooth-to-tooth contact or interaction between teeth and substances (e.g. food) repeatedly introduced into the mouth. Tooth wear in deciduous teeth progressively reduces cuspal height and permits anterior mandibular shift and undisturbed jaw growth [26]. Data obtained by the study of mediaeval adult populations with a highly abrasive diet indicated that the occlusal surface is worn out and smoothed and is no longer a predilection spot for caries development [48]. There is also a hypothesis that lack of forceful masticatory function and absence of mechanical wear can be a risk of malocclusion in modern man [45].

In contemporary children, the reluctance to chew raw, hard plant foods rich in fibre may result in the lack of tooth wear and the need for orthodontic intervention [26]. Most importantly, it can reduce the intake of substances needed for proper growth.

## Interactions with drugs and microelements

The evidence for the effect of food on drugs has grown recently; it is still difficult to fully assess the impact on bioavailability of drugs and microelements. Several studies have shown food, soluble dietary fibre and espresso coffee to inhibit absorption of levothyroxine sodium, one of the most often prescribed medications in Western populations [5,23]. These findings form the basis for current recommendations to ingest oral levothyroxine 60 min prior to food intake [23].

Dietary fibre has also been associated with decreased absorption of microelements in humans. The main role in inhibitory action of mineral absorption is ascribed to phytic acid (phytate), which is most often found in bran and beans. Its strong binding affinity to minerals such as calcium, zinc, magnesium and especially iron may result in deficiencies of these minerals among those heavily relying on a plant diet [13]. The theory of the human digestive system's adaptation to high phytate intake was not confirmed in a study comparing a group of dedicated vegetarians with a high phytate intake with a control group of subjects with a typical unrestricted Western diet. However, ascorbic acid and some sugars (fructose and high fructose corn syrups) may potentially reduce the malabsorption of microelements caused by phytic acid [8].

## Conclusion

From a public point of view, the recommendation to consume adequate amounts of dietary fibre from a variety of plant foods and wholegrain is very important. Health benefits from consuming dietary fibre must be actively communicated. Nutritional education can provide health benefits for both individuals and communities. For a typical consumer, information about calories, fat and sodium is more important than fibre content. Some people feel confused choosing food products: less than 50% of diabetic patients in the USA correctly identified high fibre food, and less than 30% of Polish students indicated regular consumption of fruit and vegetables as a factor preventing lifestyle diseases.

There has been a noted increase in the interest of consumers, researchers and the food industry in the potential of food products in helping to maintain general health. The role of the diet in the prevention and treatment of many illnesses has become widely accepted. The potential of foods to promote health and improve well-being, and their role in reducing the risk of developing diseases, allow for the usage of terms such as functional or therapeutic foods.

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