Oats and Their Health Benefits

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SHORT COMMUNICATION

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ABSTRACT

Whole grains are one of the body's primary sources of nutrients and bioactive compounds. High intakes of whole grains have been linked to the reduced risk of developing chronic diseases, such as cardiovascular disease, diabetes, metabolic syndromes. Oats, as a recognized healthy food, can directly and indirectly affect human health. The main bioactive components of oats include β-Glucan, phenolics, vitamins, and oat avenanthramides. This article reviews the roles of oats and their bioactive compounds in the prevention of cardiovascular diseases, weight control, diabetes, intestinal diseases, cancer, and inflammation, which are important for further research on the maintenance of a rational for human health, and also provides a rationale for the development of new whole grain products.

Key Words: Whole grain, oats, cardiovascular disease, diabetes, and whole grain phytochemicals

ABBREVIATIONS:

AVNs	avenanthramides
CVD	cardiovascular disease
G6P	glucose-6-phosphatase
PEPCK	phosphoenolpyruvate carboxykinase
PI3K	phosphatidylinositol-3kinase
AKT	protein kinase B
NF-κB	nuclear factor kappa B
DSS	dextran sodium sulfate

INTRODUCTION

Grains are an important food source for humans. More and more scientific evidence suggests that consumption of whole grains occupy an important position in the dietary structure of humans, and their scientific and rational consumption will have a profound impact on human health [1, 2]. Common whole grains include rice, wheat, corn, buckwheat, millet, sorghum, oats, and barley. Not only are they rich in carbohydrates, but they are also a major source of vitamins, proteins, fats, minerals and phenolics [3]. A large body of evidence suggests that high consumption of whole grains are significantly effective in preventing chronic diseases such as obesity, diabetes, cardiovascular disease and intestinal disorders, and are associated with a variety of health benefits [4, 5]. Whole grains are rich in phytochemicals as well as other nutrients and bioactives, and the experimental studies suggest that the synergistic effect of all the compounds and nutrients in whole grains may be more beneficial to human health than the individual compounds alone. The beneficial mechanisms of action of whole grain intake may be through the regulation of intestinal flora, which can lead to disease

prevention and treatment by mediating intestinal microbiota [6, 7].

Oats, an annual herb belonging to the grass family, are generally divided into two categories: naked oats and skin oats. Rich in a variety of bioactive compounds such as oat β-glucan, oat avenanthramides (AVNs), phenolic acids, vitamins, and flavonoids with a variety of biological effects that promote human health, oats have received increasing attention. These bioactive compounds and nutrients of oats may reduce the risk of cardiovascular diseases, diabetes, gastrointestinal diseases and cancer [8]. A large number of experimental and clinical data have shown that the high consumption of oats is associated with a reduced risk of developing a variety of chronic diseases. For example, β-glucan has been identified as an important soluble dietary fiber in oats, and its hypoglycemic, hypolipidemic, anti-obesity and anti-cancer effects have also been recognized. Also notably, AVNs are phenolic alkaloids found only in oats, which have been shown to have antioxidant, anti-inflammatory and anti-proliferative activities [9].

Recent studies have shown that oats can effectively improve intestinal function, regulate intestinal flora, lower blood sugar and blood lipids to prevent chronic diseases. This review will discuss the health benefits of oats, focusing on a variety of physiological effects such as improvement of cardiovascular disease, weight control, anti-diabetes, regulation of intestinal diseases, weight control and anti-cancer effects.

2. HEALTH BENEFITS OF OATS

2.1 The beneficial effects of oats on cardiovascular disease

Cardiovascular disease (CVD) is one of the leading causes of human death worldwide [10]. The 2019 Global Burden of Disease Study found that the rate of cardiovascular disease caused by unhealthy diets is increasing every year [11]. Recent studies have shown that oats, due to their rich levels of dietary fiber, can lower serum cholesterol and thus reduce the risk of cardiovascular disease [12, 13].

The cardioprotective effect of ferulic acid, one of the major phenolic acids of whole grains, has been demonstrated in several studies. The administration of ferulic acid supplementation to Apo-/- mice resulted in a significant increase in metabolite bile acids in the feces of the experimental group supplemented with ferulic acid, in addition to lowering cholesterol in the blood of the test animals. Thus, presumably the modulation of cardiovascular disease by ferulic acid may be related to the excretion of bile acids [14].

In a population-based intervention trial of traditional and roasted oats and barley, Reiners et al. found that 3 weeks of cereal consumption significantly reduced TC and LDL cholesterol levels, and this reduction may be positively correlated with the intake of β-glucan-rich cereals [15]. This supports the clinical data that long-term whole grain cereal intake may reduce cardiovascular risk. In addition, Dioum et al. in a double-blind placebo-controlled clinical study found that after 2-4 weeks of continuous intervention with oat β-glucan and rice, daily intake of 3 g of soluble fiber oat β-glucan beverage reduced LDL cholesterol and had a positive effect on the prevention of cardiovascular disease [16]. Dysbiosis of intestinal flora has also been shown to be associated with the development of cardiovascular disease. In patients with mild hypercholesterolemia, oatmeal supplementation, although not found to reduce inflammatory factor levels, may further improve cardiovascular disease by increasing the abundance of intestinal flora and the proportion of beneficial bacteria, and by increasing serum levels of short-chain fatty acids [17].

2.2 The beneficial effects of oats on diabetes

At present, studies on the antidiabetic bioactive components in oats are mainly focused on β-glucan and phenolics. Guo et al. found that oat β-glucan effectively alleviated lipid metabolism disorders, hepatic steatosis, and insulin resistance induced by streptozotocin/high-fat diet in type 2 diabetic mice, and its mechanism of action may be: (1) reducing blood glucose levels and protecting pancreatic β-cell function in diabetic mice by promoting GLP-1

secretion; (2) enhancing insulin resistance by regulating bile acid metabolism, which in turn ameliorates metabolic disorders in obese mice [18]. One study found that an 8-week dietary intervention with Oat β-glucan resulted in weight loss in rats and modulated oxidative stress, reduced serum inflammatory factors, increased abundance of beneficial bacteria, and influenced the structure of the intestinal flora to treat type 2 diabetes [19]. The combined effects of multiple bioactive compounds in whole grains have stronger health benefits than the effect of each single compounds. Li et al. found that oat β-glucan and phenolics can play a role in preventing hyperlipidemia by synergistically improving lipid metabolism disorders, reducing hepatic oxidative stress, and increasing the abundance of beneficial intestinal flora in hyperlipidemic mice [3]. In addition, experimental studies have also suggested that oat β-glucan and L-arabinose can synergistically improve glucose homeostasis and insulin resistance, and the optimal hypoglycemic ratio of the two was evaluated in animal studies [20]. Yin et al. used a buckwheat-oat-pea mixture as an ingredient in a high-fat rat model after 4 weeks of gavage and found that the oat intervention could lower blood lipids by regulating intestinal microbiota, thereby regulating the dysbiosis of intestinal flora and dyslipidemia caused by a high-fat diet [21]. Ferulic acid, one of the most abundant phenolic acids in oats, has been shown to reduce the risk of diabetes by reducing G6P enzymes and PEPCK, and activating the PI3K-AKT pathway to regulate metabolic disorders [22]. In addition, AVNs, a phenolic alkaloid unique to oats, was also shown in a study to reduce glucose uptake in Caco-2 cells and to inhibit intestinal GLUT2 and SGLT1 activity, thereby lowering blood glucose [23]. Caferoglu et al. found a significant decrease in blood glucose and appetite after consuming barley and whole wheat bread in a healthy population in a double-blind trial, inferring that it may be related to the β-glucan in the cereal covering the gastric mucosa, enhancing the viscosity of the intestine and delaying the absorption of nutrients in the gastrointestinal tract [24].

2.3 Weight control and anti-obesity

Oats, a natural ideal food for weight loss, are often consumed to control weight. Wang et al. studied the effect of oats, buckwheat and corn on the intestinal flora of rats and found that the addition of coarse whole grain had a beneficial effect on the regulation of intestinal flora, indicating that coarse grain plays a role in improving the intestinal environment and weight control [7]. Gao et al. found that 0.8% oat fiber increased the content of short-chain fatty acids, but the degree of increase varied. Analysis of the flora revealed that the proportion of Firmicutes and Bacteroidetes decreased significantly, further reducing intestinal permeability, suggesting that oat fiber alleviated high-fat diet-induced obesity in mice by improving the structure of the intestinal microbiota [25]. In high-fat diet-induced obese mice, the results showed that mixed coarse grain promoted the release of short-chain fatty acids, reversed the overall structural changes of the high-fat-induced intestinal microbiota, enhanced intestinal lora diversity, and significantly increased the number of intestinal bifido bacteria and lactobacilli in rats consuming coarse grain, thus reducing obesity [26].

2.4 The beneficial effects of oats on intestinal diseases

The intestine is the largest digestive and immune organ of the human body, and is often called the "first line of defense for health". Recent studies suggest that oats are effective at improving intestinal function and regulating intestinal microbiota [27]. Bioactive compounds such as phenolics and microbial metabolites in grains can protect intestinal epithelial cells. Polyphenols can increase the abundance of Lactobacillus and Bifidobacterium in the intestine and reduce pathogenic bacteria, reduce secondary bile acids and toxins produced by flora, inhibit the attack of flora on the epithelium, and protect the intestinal barrier function [28]. Ndou et al. reported that dietary supplementation with flaxseed meal and oat hulls could alter the histological characteristics of the small intestine, reduce the absorptive capacity of the porcine intestinal mucosa, promote the biotransformation of bile acids, and

thus alter the intestinal microbial structure and diversity [29]. Another study showed that the addition of 28% oat bran to the diet reduced the mRNA expression of interleukin IL-8 in the cecum and IL-8, NF-κB and TNF-α in the colon, reducing the intestinal inflammatory response and maintaining intestinal immune homeostasis [30]. Dominika Suchecka et al. investigated whether two different molecular weights of oat dextran could alleviate the effects of oxidative stress on intestinal inflammation in rats and found that the intake of higher molecular weight dextran helped to promote the recovery of cells damaged by oxidative stress, reduce the production of ROS, and prevent the development of gastrointestinal diseases [31]. Wang et al. used dextran sodium sulfate (DSS) to construct a rat enteritis model and found that oat antimicrobial peptides could maintain the tight junctions between intestinal mucosal epithelial cells, inhibit the growth and reproduction of other harmful bacteria and adhesion, and thus alleviate the intestinal inflammatory response [32]. In their study, Bai et al. used DSS to establish a mouse model of colitis and then fed mice an oat dextran-rich diet, and found that mice in the dextran-fed group were able to improve intestinal function and cellular function earlier and increase levels of tight junction protein expression [33].

2.5 Anti-cancer

Data from various studies have shown that oat anthranilamide, in addition to phenolic acids and flavonoids, can also be very effective in fighting cancer [34, 35]. Scarpa et al. used Vitexin-2-O-xyloside and AVNs in CaCo-2 and HepG2 cancer cells and showed that a combination of the two could exert better bioactivity and effectively reduce the proliferation of cancer cells by activating the expression levels of caspases 9, 8, and 3 in cancer cells [36]. Furthermore, AVNs also exert in vitro anticancer activity by reducing the expression of mature miR-183, -96, and -182, interfering with normal cell cycle expression, blocking it in G1 phase, and inducing senescence in colorectal cancer cells [37]. Hastings et al. compared the effects of AVN-A, B and C on breast cancer cells and found that out of all three substances, AVN-C could inhibit the proliferation and promote apoptosis in breast cancer cells [38]. In addition, studies have shown that grains have an impact on both intestinal microbiota and host metabolism, regulating intestinal flora, promoting the growth of beneficial flora, improving intestinal function, and preventing colorectal cancer [39]. In addition, another study found that feruloylated oat β-glucan coupling exhibited good anticancer activity against human colorectal cancer HCT-116 cells, prompting the cells to enter an early apoptotic state and showing significant inhibitory effects on colon cancer cells [40].

2.6. Anti-inflammatory

It is well known that inflammation plays a crucial role in the development and progression of chronic diseases, and inflammation above the normal range is considered a key factor in many human diseases. Phenolic compounds in oats exhibit potent anti-inflammatory activity. Several studies have been conducted to investigate the anti-inflammatory activity of oat whole grains and their bioactive compounds in vitro and in vivo. Bai et al. prevented severe colitis in mice by gavage of oat β-glucan, which mediated the inhibition of DSS-induced colitis by promoting the production of short-chain fatty acids, reducing inflammatory factors, and modulating intestinal microbial metabolism [41]. Seita Chudan et al. established a TNBS-induced colitis mouse model and found that the number of Treg cells in the colon increased significantly in mice fed soluble oat flour for 3 weeks, likely because the oat flour changed the intestinal microbiota, butyrate levels and the number of immune cells to alleviate colitis [42]. Aparicio-Garcia et al. conducted a 6-month study on the relationship between the intake of fermented oat beverages and inflammation in patients with celiac disease and evaluated their anti-inflammatory activity using macrophages, showing that fermented oat beverages exerted potent anti-inflammatory activity in vivo and in vitro, and that intestinal flora analysis showed a significant increase in the beneficial bacterial genus as well [43].

3. SUMMARY

The role of whole grains in health is very important. The exact mechanisms of metabolite production by intestinal flora in oats are not clear. The key role of whole grains in the prevention of chronic diseases through modulation of the gut microbiota should be better understood, and the future research should not only define the types of gut microbes that can be modulated through the inclusion of different whole grains in the diet and assess the mechanisms of interaction between the gut microbiota, the bioactive compounds and nutrients in whole grains, but also investigate whether this modulation is related to the dose of the grains. To verify the metabolic pathways of bioactive compounds and their accompanying components in whole grains, we also need to explore their beneficial metabolites, the pathways of action and signaling pathways that ultimately act to further clarify the specific intestinal flora associated with human intestinal health and their mechanisms of action for effective regulation of human intestinal health and chronic diseases. In addition, the development of new functional whole grain products to regulate intestinal microorganisms to prevent the occurrence of metabolic diseases will certainly become a new perspective of whole grain product development and the focus of further research in the research field and food industry. Therefore, people should be encouraged to increase the intake of whole grains, and to achieve the national dietary guidelines recommending a mix of whole and refined grains. Further research can promote the development of new technologies and new products of whole grain foods, making whole grain products more diverse and attractive in order to play a more important role in promoting health.

CONFLICTS OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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