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Potential health benefits of β-glucan from barley and oat

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Abstract

Numerous epidemiological studies indicate that the consumption of whole grains or whole grain products is associated with a reduced risk for chronic diseases. Apart from vitamins and essential fatty acids present in whole grains, particularly dietary fiber contributes to health-promoting effects of whole grain products. Especially, for the "soluble dietary fiber" β-glucan, which is present in barley and oat, positive health-promoting effects regarding diabetes mellitus or cardiovascular diseases are described. These effects are based on the reduction of postprandial glucose values as well as cholesterol-lowering effects. The present article provides an overview of current data regarding physiological mechanisms of barley and oat β-glucan.

Keywords: β-glucan, barley, oat, dietary fiber, diabetes mellitus type 2, cardiovascular diseases

Introduction

The incidence of non-communicable and chronic diseases such as diabetes mellitus type 2 (DMT2), cardiovascular diseases and cancer is constantly increasing worldwide. Thereby, in Germany and Europe, cardiovascular diseases are the most common cause of death accounting for 40% of all deaths followed by cancer which accounts for 25% of all death cases [1]. In the last years, also increasing incidences for DMT2 are observed. At present, nearly 7.2% of the 18- to 79-year-old population suffer from this chronic metabolic disorder [2]. Apart from an effective therapy, preventive strategies are necessary to stop this trend.

Prevention through nutrition rich in dietary fiber

Due to a change of lifestyle-factors, in particular by means of a healthy, well-balanced and dietary fiber-rich nutrition, it is possible to inhibit the development of different chronic diseases or rather to support a therapy [4]. Numerous epidemiologic studies indicate that the consumption of dietary fiber from whole grains or whole grain products is associated with a reduced risk for DMT2, cardiovascular diseases, cancer and obesity [5, 6]. The so-called "soluble dietary fiber", in particular β-glucan, which is predominantly present in cereals such as barley and oat, exhibit diverse health-promoting effects. β-glucan is a high-molecular non-starch polysaccharide consisting of β-(1-4)- and β-(1-3)-linked β-D-glucopyranosyl-subunits in varying proportions. With 3–11%, barley (◆ Figure 1) contains the highest amounts of β-glucan followed

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Processing of barley and oat in Germany

The major part of barley produced in Germany is used for malting or animal feeding. Food products are only made of a minor part of the barley production. Thus, 2,255,845 t malting barley were processed in the fiscal year 2015/2016. 2,176,805 t of barley were used for the production of animal feed and 10,819 t were used for the production of foodstuffs and baking agents as well as coffee substitute. In contrast, the major part of oat was used for the production of food (196,343 t). Animal feed was produced from 31,322 t of oat [3].

Health claims related to β-glucan

Meanwhile, several studies prove the positive health-related effects of β-glucan from barley and oat. These studies provide the basis for already approved health claims related to the reduction of cholesterol levels and glycemic response. To achieve a reduction of the postprandial glycemic response, 4 g β-glucan from barley or oat for each 30 g of available carbohydrates should be consumed per meal according to the current health claim (reviewed in [13, 14]). A reduction of cholesterol levels, which is related to a reduced risk for cardiovascular diseases, is achieved in hypercholesteremic patients with 3 g β-glucan per day [14–17].

by oat (◆ Figure 2), which contains 3–7% (reviewed in [7]). Special barley cultivars (waxy-barley) as e. g. beta®-barley [8] exhibit relatively higher amounts of β-glucan (reviewed in [9]). In barley, β-glucan is located in the subaleurone as well as in cell walls of the endosperm and in oat it is located in the aleurone and subaleurone [10, 11]. Positive health-effects of β-glucan could be determined particularly with regard to cholesterol-lowering effects (reviewed in [12]) as well as to the reduction of postprandial glucose and insulin response (reviewed in [13]).

Fig. 1 : **Spring barley** ***(Hordeum vulgare)***

Health effects of β-glucan

Reduction of cholesterol

Positive health effects of high-molecular β-glucans are, amongst others, based on its pronounced viscosity in aqueous solutions. The consumption increases viscosity of the chyme in the upper gastrointestinal tract [18] which leads to an increased binding of bile acids and their subsequent excretion [19, 20]. Bile acids are synthesized de novo by the cholesterol-7α-hydroxylase which is the key enzyme of bile acid synthesis. Hereby, plasma cholesterol serves as substrate for newly synthesized bile acids which leads to a reduction of blood cholesterol levels [21]. A meta-analysis [12], including 11 studies, could show that the intake of barley products or β-glucan from barley leads to a significant reduction of total cholesterol as well as LDL-cholesterol levels (◆ Table 1). Similar results could be obtained for oat-β-glucans in a meta-analysis of 28 studies [22]. Also Ho et al. confirmed the reduction of LDL-cholesterol as well as non-HDL-cholesterol levels by β-glucan derived from barley and oat in two meta-analyses [23, 24].

Reduction of blood-glucose

The high viscosity of β-glucan is also responsible for the reduction of postprandial blood glucose levels. Hereby, mixing of the chyme with digestive enzymes in the stomach is reduced and the emptying of the stomach is delayed. In-vitro-studies could demonstrate, that β-glucan decelerates starch digestion and absorption of glucose in the intestine. The delayed gastric emptying also increases satiety which leads to a reduced food intake (reviewed in [13]). In total, these effects contribute to a reduction of the glycemic response. Tosh et al. [13] evaluated 34 studies with regard to the influence of barley and oat on postprandial blood glucose concentration and concluded that the intake of 4 g β-glucan from these cereals significantly reduces the glycemic response. Especially for meals containing barley, Hinata et al. [25] demonstrated a reduction of fasting the blood glucose as well as a reduction of HbA1c in patients with DMT2. Similar results could be obtained for oat [26, 27]. However, comparable results were not statistically significant in all studies [28] (◆ Table 2).

Other mechanisms

Furthermore, β-glucan is fermented by intestinal bacteria in the colon leading to the formation of short-chain fatty acids (SCFA) such as acetate, propionate and butyrate [29, 30]. As signal molecules, SCFA are able to modulate the glucose- and cholesterol metabolism via distinct receptors (e. g. Ffr 2/3, free fatty acid receptors) (reviewed in [31]). Via these receptors SCFA can increase the concentration of gastrointestinal hormones such as GLP-1 (glucagon-like-peptide 1) and PYY (peptide YY). PYY induces glucose intake in muscle- and fat tissue and GLP-1 indirectly reduces blood glucose concentration by increasing the concentration of insulin and reducing the glucagon production in the pancreas. *In-vitro*-studies indicated

Reference	Intervention	Number of studies	Number of subjects (I/C)	Effect on total cholesterol [mmol/L] M (95 %-CI)	Effect on LDL-cholesterol [mmol/L] M (95 %-CI)	Effect on HDL-cholesterol [mmol/L] M (95 %-CI)	Effect on triglycerides [mmol/L] M (95 %-CI)
AbuMweis et al. [12]	barley/β-glucan from barley (3–12 g/d)	11	326	-0.30 (-0.39; -0.21)	-0.27 (-0.34; -0.20)	0.00 (-0.01; 0.02)	-0.05 (-0.10; 0.01)
Ho et al. [24]	β-glucan from barley (1.4–12.3 g/d)	14	431/292		-0.25 (-0.30; -0.20)		
Whitehead et al. [22]	oat/β-glucan from oat (3–12.4 g/d)	27	2,518	-0.30 (-0.35; -0.24)			
		27	2,505		-0.25 (-0.30; -0.20)		
		27	1,415			-0.03 (-0.08; 0.01)	
		28	2,314				-0.02 (-0.06; 0.01)
Hou et al. [26]	oat/β-glucan from oat[a]	7	237/216	-0.49 (-0.86; -0.12)			
		5	216/195		-0.29 (-0.48; -0.09)		
		6	229/208			-0.05 (-0.24; 0.14)	
		7	237/216				-0.16 (-0.34; 0.03)
Ho et al. [23]	β-glucan from oat 1.2–12.3 g/d	57	2,419/1 947		-0.19 (-0.23; -0.14)		

Tab. 1: **Overview of selected reviews/meta-analyses regarding the impact of β-glucan-rich barley- and oat-products on parameters of the human lipid metabolism**
C = control; CI = confidence interval; I = intervention; M = mean
[a] quantity not specified

Reference	Intervention	Number of studies	Number of subjects (I/C)	Effect on fasting-blood glucose [mmol/L] M (95 %-CI)	Number of studies	Number of subjects (I/C)	Effect on fasting-insulin [pmol/L]b, [mmol/L][c] M (95 %-CI)
He et al. [27]	oat 20–136 g/d	9	314/287	-0.14 (-0.025; -0.03)	8	256/231	-6.95 (-12.90; -1.00)[b]
	oat-β-glucan 3–10 g/d	16	478/455	-0.13 (-0.21; -0.04)	10	306/291	-6.29 (-11.25; -1.32)[b]
Hou et al. [26]	oat/oat-β-glucan[a]	6	229/208	-0.39 (-0.58; -0.19)	2	36/31	-0.22 (-1.28; 0.84)[c]
Zou et al. [28]	β-glucan from oat or barley 2.8–8.1 g/d	12	302/301	-0.05 (-0.11; 0.02)	6	135/144	0.75 (-1.82; 3.32)[c]

Tab. 2: **Overview of selected reviews/meta-analyses regarding the impact of β-glucan-rich barley- and oat-products on parameters of the human glucose metabolism**
C = control; CI = confidence interval; I = intervention; M = mean
[a] quantity not specified
[b] disclosed as pmol/L
[c] disclosed as mmol/L

that especially propionate modulates the cholesterol metabolism by inhibiting enzyme activities of hepatic 3-hydroxy-3-methyl-glutaryl-CoA-synthase and -reductase. Accordingly, application of propionate led to a reduced cholesterol synthesis in livers of rats (reviewed in [31]). Furthermore, there is evidence that SCFA decrease appetite [32–34]. The regulation of glucose and lipid metabolism is therefore closely related to the regulation of appetite and satiety by SCFA formed in the intestine.

Chemopreventive effects

Besides these effects, SCFA resulting from fermentation of dietary fiber such as β-glucan are able to induce chemopreventive mechanisms in the colon. The term chemoprevention describes the inhibition of carcinogenesis with natural food compounds or synthetic agents. Inhibition of the initiation of cells in the colon into preneoplastic cells is termed primary prevention, whereas the suppression of further transformation to neoplastic cells is termed secondary chemoprevention. Primary effects are predominantly mediated by the reduction of reactive oxygen species to provide protection against DNA damage, whereas secondary effects target to inhibit the growth and further transformation of already initiated cells. Butyrate, which apart from acetate and propionate is the main end product of dietary fiber fermentation in the colon, exhibits several chemopreventive effects in particular. One the one hand, it functions as energy source for healthy epithelial colon cells. On the other hand, butyrate acts as histone deacetylase inhibitor and is able to inhibit the growth of already degenerated cells and to induce apoptosis and differentiation in these cells [35–39]. These chemopreventive properties contribute to the reduction of the risk of colon cancer development.

Fig. 2: **Oat** (***Avena sativa*** **L.**)

Conclusion

The physiological effects of β-glucan are based on an interaction of several mechanisms which are due to gelation characteristics of glucans on the one hand and to fermentative formation of SCFA in the colon on the other hand. Of particular health-relevance are a reduction of the glycemic response as well as a reduction of the plasma cholesterol concentration after consumption of meals containing β-glucan. Furthermore, β-glucan, as soluble dietary fiber, can substantially contribute to intestinal health and to the prevention of colon cancer [40].

Conflict of Interest
The authors declare no conflict of interest.

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