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REVIEW

The Effect of Dietary Oat Consumption and Its Constituents on Fat Storage and Obesity

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Summary

This review is to summarize and analyze the currently available knowledge concerning the action of oat (*Avena sativa* L.) consumption on obesity, as well as possible constituents and extra- and intracellular mediators responsible for its anti-obesity effect. The oat constituents could reduce fat storage via several mediatory mechanisms – brain centers regulating appetite, gastrointestinal functions, gut bacteria, fat synthesis and metabolism and maybe via changes in oxidative processes, steroid hormones receptors and adipose tissue vascularization. Several oat constituents (starch, fiber and beta-glucan) could have anti-obesity properties, whilst one oat constituent (starch or fiber) could affect fat storage via several mechanisms of action.

Key words

Oat • Fibre • Beta-glucan • Obesity • Adipocyte • Gut

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Introduction

Despite visible progress in the development of medicine and well-being, the occurrence of some illnesses is not decreasing, but even increasing now. One of such illnesses is obesity. Worldwide, obesity represent one of the major public health issues associated with increased morbidity and mortality. One third of the world's population is now classified as overweight or obese [1]. The incidence of obesity is growing among domestic animals as well [2].

Hypertrophy of fat containing cells (adipocytes) leads to insufficient oxidation of the adipose cells, their inflammation, fibrosis, deterioration, and disruption in the feedback mechanisms by which the adipose tissue suppresses the hunger center in brain and regulates metabolism, as well as fat accumulation in ectopic tissues (e.g., liver, skeletal muscle, and heart) and in the visceral adipose depots [3,4]. Obesity is strongly linked with chronic diseases such as type 2 diabetes, hypertension, cardiovascular diseases, dyslipidemia, non-alcoholic fatty liver disease, chronic kidney disease, obstructive sleep apnea and hypoventilation syndrome, mood disorders and physical disabilities, and an increased risk of cancer [2,5].

One popular, efficient, inexpensive and natural measure against obesity and related disorders is correct nutrition, which limits income of calories and fat accumulation. The most effective anti-obesity food does not contain too many calories, but biological active molecules suppressing adipogenesis in different ways. Such ability was described in a number of functional food and medicinal plants [6]. One of such plants with preventive and therapeutic influence on obesity and other illnesses can be oat. Its benefits for health have been described in some reviews [7-11]. On the other hand, there is no special reviews summarizing the contemporarily evidence concerning oat influence on fat and its application for treatment of obesity and weight loss yet.

The present publication provides general outlook of evidence concerning general chemical and therapeutic properties of oat. However, its main purpose was to

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review the current available knowledge concerning the action of oat and its particular constituents on fat storage and metabolism, as well as the extra- and intracellular mechanisms of their action.

Methods

Search for literature was performed in agreement with the PRISMA- ScR criteria [12]. Related articles were searched for in Pubmed, Web of Science, and SCOPUS databases from 2000 to 2021. In cases of repeated or conflicting information or references, more recent sources have been preferred. Words used to search were “oat” alone or in combination with “health”, “metabolism”, “fat”, “obesity” and “mechanisms”. Both relevant experimental papers and reviews were evaluated. A total of 4 121 research papers and reviews were inspected, and 1 348 were considered as useful and suitable for analysis.

Provenance and properties

Common oat (*Avena sativa* L.) is a cereal from the family of *Poaceae*. The wide-spread forms of cultivated oat today *Avena sativa* spp. were cultivated from *Avena fatua*. The region of oat’s origin is West Asia and Ancient China. From there, oat spread into Central and Northern Europe. The earliest evidence of oat’s occurrence comes from the Bronze Age. Oat was then a weed growing among barley. From its origins oat has adapted to a wide range of climatic conditions and geographic regions. Its unique macro-, micro-, and phytonutrient composition, high nutritional value, and relatively low agricultural input requirements makes oats unique among cereal crops. Due to its high nutritional value, oat was for many centuries a popular food for people from lower classes as well as horses. Its grain digests well, it has high nutritional value, balanced composition of nutrients and high content of biologically active regulatory molecules [7]. Oat starch offers untypical properties such as small size of granules, well-developed granule surface and high lipid content. Variation in amylose and amylopectin proportion along with the properties associated with the amylopectin molecule makes diversity in composition of oat starch [8]. Oat grains have the highest protein content among all cereals (11-20 %). Lipids take up as much as 5-18 % of the grain’s volume, which is 2 to 4 times as much as in other cereals. They are of high quality – high ratio of unsaturated fatty acids. Starch content (55-60 % of the grain’s content) breaks down during digestion to glucose, but its digestion is slow, therefore oat products are a source of energy long and consistently released into the body and saccharides into the blood stream. Insoluble fiber (ballast materials), which is present primarily in the peels of grain (bran), represents 40 % of the grain’s content, which is almost as much as in rice and two thirds more than in wheat. It is not digested by the enzymes of gastrointestinal track but by the gastrointestinal microbiota. Beta-glucan is an important component of soluble nutritional fiber (2.3 – 8.5 % of the grain’s content). Oats contain the most vitamins from the vitamin B group (the most B1) out of all cereals and high levels of vitamin E. The magnesium content in oat is three times higher than in other cereals, potassium twice as high as in wheat, silicon ten times as high as in wheat. It contains a lot of calcium, iron, phosphorus, phytoestrogens /flavonoids, rutin, phytosterols, tocols, β-glucans, ave-nanthramides and saponins were determined in oat seeds too. The content of these compounds can represent as much as 6 % of the grain mass. Many of these molecules have antioxidant and phytoestrogen properties [7,10-17]. The modern oat cultivars are characterised by increased contents of micronutrients, oils, phenolics, and other biologically active and health-benefiting compounds, but also by reduced resistance to diseases or tolerance to certain abiotic stressors [17,18].

Positive effects on human health

The preventive and therapeutic influence of dietary oat and its various constituents have been well documented. Starch contained in oat is digested slowly and does not trigger rapid increase of the glycemic index after a meal, therefore it is recommended to people suffering from diabetes. Oat is high in fat with a high ratio of unsaturated fatty acids, which have high energy value but do not trigger increase in the levels of “bad” LDL cholesterol in blood and prevent occurrence of cardiovascular diseases. In addition, oat contains β-glucan with the gel-forming properties, which modulates host bile acid and cholesterol metabolism and potentially removes intestinal cholesterol for excretion [9,11,19-21]. It lowers blood pressure. The less digestible fiber also reduces glucose and cholesterol in blood [20], which treats a wide spectrum of gastrointestinal and metabolic diseases and protects the mucus membrane and microbiota of the gastrointestinal tract [6]. Oat intake was associated with reduction in occurrence of gastrointestinal disorders [22]. The soluble fiber β-glucan is an activator of immunity, also reduces cholesterol and glucose in blood and therefore prevents manifestations of cardiovascular diseases and diabetes [9-13,15,20,21,23]. Cardiovascular diseases could be prevented by β-glucan *via* promotion of nitric oxide, a promoter of vascular endothelium dilation [24]. The ability of oat containing diet to reduce the markers of inflammation has been reported too [21]. The oat, in contrast to other cereal grains, does not contain gluten that can cause serious side effects in people with gluten intolerance, or gluten is present in oat only in small amounts. Instead of gluten, the oat produces avenin, a water-insoluble protein similar to gluten but better tolerated by most people with celiac disease because [14,22,25]. Polyphenols and vitamins of oat have antioxidant effects, which means they bind free radicals and are good prevention against tumours. Simultaneously, they inhibit multiplication of tumour cells. The extracts from cereal brans are considered to be used as a source of natural antioxidants for prevention of these diseases [10,26]. Oat antioxidants can strengthen veins and reduce inflammation [13,15]. The anti-inflammatory action of oat could be due to the presence of dietary fiber (β-glucans), copper, iron, selenium, and zinc, polyphenolics (ferulic acid and avenanthramides), and proteins (glutamine) [11,27]. Some polyphenols of oat have a phytoestrogen effect and can reduce the symptoms of menopause [13,15]. Calcium and vitamins help treat osteoporosis [13,15]. Consumption of oat products stimulates physical and mental performance and health. It is even linked to a decrease in general morbidity and mortality in humans [28]. Finally, it contributes to health of teeth, hair, skin and nails [10,11,15,28]. It is necessary to keep in mind that the thermal processing and disruption of the structural integrity of the oat cernel by production of thin/quick/instant oat flakes can result in loss of the health (glycemic) benefits of plant seeds [29,30].

No serious adverse side-effects of oat have been reported. Nevertheless, in rare instances, proteins contained in oat can trigger enterocolitis (allergic inflammation of the intestine) [31] and celiac disease when consumed at excessive doses [22]. Despite that, the European Commission recognised the general safety of oat and included it on the list of components permitted in food with added value [14].

Taken together, the available evidence demonstrates the ability of oat to prevent and to mitigate a wide array of disorders. The effect of this plant could be due to the characteristics and physiological effects of its starch, β-glucan, proteins, polyphenols and microelements. Some physiological, protective and therapeutic effects of oat molecules could have similar mechanisms – its ability to affect gut microbiota, carbohydrate and cholesterol metabolism, to prevent oxidative stress and inflammatory processes and to affect steroid hormone receptors. These changes in turn normalize proliferation and differentiation and promote viability and resistence of cells in various organs to destructive factors and illnesses. Its positive effect on various organs could be mediated by β-glucan stimulatory action on nitric oxide – regulator of organ blood supply as well. On the other hand, administration of dietary β-glucan to patients increased the serum nitric oxide level, but not their flow-mediated vasodilation [24].

Positive effects on weight reduction

Feeding mice oat fiber activated molecules responsible for conversion of white adipose tissue to brown (which is easy to burn) and for fat solution [32]. Feeding mice starch from wholegrain oat, its beta-glucans and their mixture reduced body weight, size of adipose cells, production of molecules responsible for synthesis of lipids and conversely activated production of molecules responsible for solution of fat [33]. People who regularly consume oat products are at decreased risk of obesity [34]. Experiments on humans demonstrated that consumption of oat products suppresses appetite [35], alters cholesterol content in blood and reduces body weight and waist circumference [21,23,28,35]. Consumption of oat component – beta-glucans – reduced waist circumference, but not body weight [23].

These observations indicate that oat and its component (starch and fiber) can prevent obesity by:

- slow release of energy, extending the period of satiety and suppression of appetite [13,35],
- stimulating conversion of white adipose tissue to brown [32],
- suppressing production of molecules responsible for lipid synthesis [33],
- fiber's ability to act as a probiotic, that is stimulating the function of gastrointestinal microbiota, which regulates metabolism and obesity [9,36],
- oat β-glucan can modulate the gut bacterial species that influence host bile acid metabolism and production of short chain fatty acids, factors which

are regulators of host cholesterol homeostasis and resulted fat storage [9,19,27].

- Other mechanisms of oat and its molecules on fat storage might be proposed, but existence of these possible mechanisms are still not properly demonstrated.
- The ability of polyphenols and vitamins contained in oat to prevent oxidative and inflammatory processes in adipose tissue, like in other tissues (see above) might be hypothesized too. Some anti- and prooxidant action of oat and the association of oxidative process with fat storage in animals has been reported [37]. Nevertheless, the available evidence concerning oat influence on markers of inflammation and/or oxidative stress in obese patients were scarce and inconsistent yet [21].
- Function of adipose tissue and prevention of its inflammation and degeneration could be prevented also by its nitric oxide-promoted blood supply. At least, the ability of oat to increase blood nitric oxide level has been reported [24]. This hypothesis requires experimental confirmation.
- It is proposed that increased weight gain and obesity in postmenopausal women and ovarectomized mice can be due to deficit of estrogens, and that oat phytoestrogens could mitigate such deficit and the resulted obesity [37]. Nevertheless, such hypothesis is based on observation of association between estrogen deficit and obesity, but not on direct demonstration of anti-obesity action of estrogen of ovarian or plant origin.

Conclusion

Therefore, the constituents of oat responsible for its anti-obesity activity could be starch, fiber and beta-glucan. In addition, the involvement of oat polyphenols with anti-oxidative and phytoestrogenic properties might be proposed. The oat molecules could affect fat storage via several mechanisms – brain centers regulating appetite, gastrointestinal functions, gut bacteria, fat synthesis and metabolism and maybe *via* changes in oxidative processes, steroid hormones receptors and adipose tissue vascularization. Sometimes, the same oat molecule can affect obesity via several mechanisms. For example, the same oat constituents (beta-carotene, polyphenols, chlorophyll, flavonoids and saponin-based avanacosidase) can express antioxidant, anti-inflammatory and phytoestrogenic properties at once [10,26]. Finally, the functional interrelationships between some of the mechanisms of oat action are not to be excluded. For example, oat fibers and beta-glucan as a prebiotic could promote gut microbiota producing chain fatty acids, which in turn can affect gastrointestinal functions, fat synthesis, inflammatory processes and the feeling of satiety [36,38,39]. Therefore, several oat molecules could have anti-obesity properties, whilst one oat constituent could affect fat storage via several mechanisms of action.

Analysis of the presented scientific data proved the benefits of consumptions of oat products as food with high value as well as means of prevention and treatment of numerous diseases. The efficacy of products from oat and its components (starch and fiber) in metabolism normalization, reduced storing of fat, stimulation of its burning, and weight and obesity reduction is validated. Positive effects manifested at daily dose of 10 – 100 g (in most studies 30 – 60 g) of this cereal or 3 – 4.5 g beta-glucan [23,28]. Therefore, the inclusion of oat products on the menu of healthy people and of persons, who require an improvement in their metabolism and to avoid obesity, is certainly recommend.

Some details of the anti-obesity effects of oat, however, require further elucidation. Genes and biosynthetic pathways defining oat biological active compounds [17] require further elucidation. The anti-obesity action of some oat constituents (polyphenols, vitamins a.o.) requires direct and reliable experimental confirmation. Involvement of some regulatory mechanisms (oxidative and inflammatory processes, vascularization, steroid hormones) in mediating oat effects on fat storage remains to be demonstrated. The comparison of anti-obesity activity of different oat cultivars and oat constituents in the same standardized experiments have not been performed yet. Such studies could enable better understanding of the oat constituents and mechanisms of their action, as well as to identify drug, food additive or food with added value which would be most suitable for prevention and treatment of obesity.

Conflict of Interest

There is no conflict of interest.

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