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Oats in healthy gluten-free and regular diets: A perspective

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ABSTRACT

During the 20th century, the economic position of oats (*Avena sativa* L.) decreased strongly in favour of higher yielding crops including winter wheat and maize. Presently, oat represents only ~1.3% of the total world grain production, and its production system is fragmented. Nonetheless, current interest is growing because of recent knowledge on its potential benefits in food, feed and agriculture. This perspective will serve as a further impetus, with special focus on the recently valued advantages of oats in human food and health.

Five approved European Food Safety Authority (EFSA) health claims apply to oats. Four relate to the oat-specific soluble fibres, the beta-glucans, and concern the maintenance and reduction of blood cholesterol, better blood glucose balance and increased faecal bulk. The fifth claim concerns the high content of unsaturated fatty acids, especially present in the endosperm, which reduces the risks of heart and vascular diseases. Furthermore, oat starch has a low glycemic index, which is favourable for weight control. Oat-specific polyphenols and avenanthramides have antioxidant and anti-inflammatory properties. Thus, oats can contribute significantly to the presently recommended whole-grain diet.

Next to globulins, oats contain a small fraction of prolamin storage proteins, called 'avenins', but at a much lower quantity than gluten proteins in wheat, barley and rye. Oat avenins do not contain any of the known coeliac disease epitopes from gluten of wheat, barley and rye. Long-term food studies confirm the safety of oats for coeliac disease patients and the positive health effects of oat products in a gluten-free diet. These effects are general and independent of oat varieties. In the EU (since 2009), the USA (since 2013) and Canada (since 2015) oat products may be sold as gluten-free provided that any gluten contamination level is below 20 ppm. Oats are, however, generally not gluten-free when produced in a conventional production chain, because of regular contamination with wheat, barley or rye. Therefore, establishing a separate gluten-free oat production chain requires controlling all steps in the chain; the strict conditions will be discussed.

Genomic tools, including a single nucleotide polymorphism (SNP) marker array and a dense genetic map, have recently been developed and will support marker-assisted breeding. In 2015, the Oat Global initiative emerged enabling a world-wide cooperation starting with a data sharing facility on genotypic, metabolic and phenotypic characteristics. Further, the EU project TRAFOON (Traditional Food Networks) facilitated the transfer of knowledge to small- and medium-sized enterprises (SMEs) to stimulate innovations in oat production, processing, products and marketing, among others with regard to gluten-free. Finally, with focus on counter-acting market fragmentation of the global oat market and production chains, interactive innovation strategies between customers (consumers) and companies through co-creation are discussed.

1. Introduction

Oat is more than just a common grain (Clemens & Van Klinken, 2014). It is transforming from a dietary staple for feed and food into a nutritive whole grain source as part of a healthy diet. Several health claims have been officially approved by European Food Safety Authority (EFSA) and USA's Food & Drug Administration (FDA). In cultivation, oat is a low-input crop that positively contributes to soil health especially in crop rotation systems by improving soil structure and reducing crop pests.

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Excavations from 32,600 years ago in Italy revealed the occurrence of thermally pre-treated and grinded oat grains (Lippi, Foggi, Aranguren, Ronchitelli, & Revedin, 2015). The cultivation of oat as a crop started much later than that of wheat and barley. It has been suggested that in the Bronze Age (5000–4000 years ago) common oat (*Avena sativa*) spread as a weed impurity of wheat and barley seeds from the Near East to Central and North Europe. Once arrived, oat turned out to adapt well to the cool and humid climate and long day length. The 'weedy' oat became domesticated in Europe by the early farmers into heterogeneous, robust landraces (Valentine, Cowan, & Marshall, 2011). Oat was appreciated as a perfect feed for working horses in agriculture. For that reason, it was often cultivated on-farm, and fitted well in the economy of small farming communities up to medieval times. Since then, oat became a major crop grown extensively in NW-Europe for feed, food and drinks. Oat was an important brewing cereal in the middle ages in NW-Europe (Meussdoerffer, 2009).

Starting from the early 20th century, horsepower was replaced by diesel engines, and oat beers were replaced by barley and wheat beers. These developments halved the global cultivation of oat. Now, also oat breeding is lagging far behind that of wheat and barley. Oat has become a neglected crop: the attention to the pureness of oat sowing seeds is limited. For example, the U.S. specification for No. 1 oats allowed the presence of up to 2% foreign material. Such a contamination could be wheat and barley (Webster, 2011), which is unacceptable in gluten-free food production.

Oat cultivation in The Netherlands dropped from 160,000 ha in the 1960s to 1200 ha in 2016. Presently, cultivation of oat is mainly for feed production and for (organic) food production. Current commercial yields are ~5.5 ton/ha. An increasing acreage is reported for gluten-free oat production. For the production of oats under gluten-free conditions, only strong-straw and short-straw varieties are being cultivated, to reduce the incidence of lodging, which may cause severe losses in yield (Tumino et al., 2017).

In order to realise oat's potential as a healthy crop in agriculture and as whole grain product in food and feed, and reverse the trend of decreasing production, we propose strategies for innovations in oat products (including specific focus on the gradually growing gluten-free market). A strengths and weaknesses analysis on the current position of oat regarding agronomy, processing, products and business (the successive steps in the production chain) is given in Table 1. These issues will be further elaborated in the paragraphs below.

It is expected that the specific appraisal of oats as versatile whole grain product in food and feed will lead to an increase in global production and application. Its unique food and feed characteristics, complemented with its advantageous agronomic characteristics, should, however, first be better recognized and higher valued globally to make oat an economically competitive crop again.

This perspective aims at answering the questions (1) why oats fit in a healthy gluten-free diet and (2) how (gluten-free) oats products might appeal better to consumers. We discuss the health advantages of oats in the general diet and in the gluten-free diet. We describe the requirements and conditions for gluten-free production of oats. We also address the current position of oats in the global food market, in the global food policy, and in traditional food networks, which is under threat as the global production of oat is mainly as a cheap and underrated source for feed applications.

2. The advantages of oats for health

2.1. Health claims

Oats have several health advantages (Martínez-Villaluenga & Peñas, 2017) and carries approved EFSA (Box 1) and FDA health claims for its positive effects on human health (Mathews, 2011). The health effects especially concern the hypocholesterolemic properties, the cardiovascular benefits through positive effects on the blood glucose level, and the improved management of body weight and blood pressure. In addition, consumption of oats is related to an increase of the faecal bulk. It contributes to a normal stool and maintenance of a balanced microbiome, which is attributed to the high content of soluble fibres, the oat-specific beta-glucans. Oats, therefore, fit perfectly in governmental (health council's) food strategies promoting the consumption of whole grain and cereal fibre, which has scientifically been shown to reduce the risks of chronic diseases and cause-specific mortality (Aune et al., 2016; Benisi-Kohansal, Saneei, Salehi-Marzijarani, Larijani, & Esmaillzadeh, 2016; Chen et al., 2016; Huang, Xu, Lee, Cho, & Qi, 2013; Wu et al., 2015; Zong, Gao, Hu, & Sun, 2016).

2.2. Primary metabolites and minerals

Oats are a good source of various antioxidants such as vitamin E, phytic acid, phenolics and avenanthramides (phenolic amine conjugates belonging to the group of secondary metabolites). Avenanthramides are less known oat-specific compounds (Collins, 2011) with anti-inflammatory properties (Liu, Zubic, Collins, Marko, & Meydani, 2004; Sur, Nigam, Grote, Liebel, & Southall, 2008). Avenanthramides synergistically with vitamin C inhibit LDL-cholesterol oxidation in vitro, they show antihistamine activity and may reduce allergy-related symptoms such as itching, redness and wheals. Formulations of natural colloidal oatmeal should be considered an important component in therapies for atopic dermatitis and other skin conditions, and may allow for reduced application of corticosteroids and calcineurin inhibitors (Cerio et al., 2010). Avenanthramides may also suppress the proliferation of vascular smooth muscle cells, a process known to contribute to atherosclerosis development (Liu et al., 2004).

2.3. Secondary metabolites

The primary metabolites of oat also contribute to nutrition and health. The coeliac-safe oat proteins (15–20% by weight), mainly globulins, are highly digestible and have an amino acid profile that fits very well to the human needs of essential amino acids, even with regard to lysine and threonine (Peterson, 2011). Oat starch (55% w/w) has an amylopectin/amylose ratio of about 3–4, with a complete and relatively slow digestion. In combination with the slow stomach emptying due to the fibre content, this gives a long feeling of satiety. Whole grain oat foods have a low glycemic index, which is advantageous in cases of diabetes and obesity (Mathews, 2011; White, 2011). Oat grains are high in oil content (on average 7%, but in some varieties up to 18% by weight) with large fractions of palmitic acid (C16:0; 20%), oleic acid (C18:1; 35%) and linoleic acid (C18:2; 35%)(e.g., Sterna, Zute, & Brunava, 2016). Alpha linolenic acid (C18:3, omega-3) is notably present in the germ (Lehtinen & Kaukovirta-Norja, 2011). The high oil content can have an adverse effect on the sensory quality as a result of oxidation (also known as rancidity). To prevent this, a kilning process (a short high-temperature treatment) of the oat grains is generally applied before further processing into food products (Londono, Smulders, Visser, Gilissen, & Hamer, 2015).

Welch (2011) gives a comparison of the composition of oats and oatmeal with that of several other cereal grains. Oatmeal has the highest content of several minerals, including phosphorus, iron, zinc and magnesium. The total beta-glucan content of oats is much higher than that of wheat (5 ×), maize (15 ×), brown rice (40 ×) or rye (2 ×), and comparable to that of barley. The solubility of oat beta-glucan is the highest compared to the other grains. Further, oat protein contains the highest levels of lysine, cysteine and methionine. Stewart and McDougall (2014) describe the composition of various compounds in relation to cultivation conditions.