CROPQUEST

Oats: Food and Crop Products

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Oats (Avena sativa)

Oats (Avena sativa), are a hardy cereal grain able to withstand poor soil conditions in which other crops are unable to thrive. Oats, in Ireland, are grown primarily as a minority grain for the horse feed and milling industries (Burke et al., 2001). The high nutritional value of oats is one reason for its popularity and increasing consumption in human nutrition. Most oat mill products are whole grain products containing the entire kernel with all its constituents. Such typical products are rolled oats, steel-cut groats, different types of flakes produced from cut groats, oat flour and oat bran. The main use of milling oats is in hot breakfast cereals. In addition oat products find an important market as an essential component in cold cereal mixes such as muesli and in cereal bars or expanded cereal products.

The fruit of the oat plant, the oat kernel, is a caryopsis enclosed in two hulls, the lemma and the palea; their primary function is to protect the kernel. However, in contrast to barley, the hull and kernel are not fused together. The hulls or husks account on average for 25% of the total grain; they are rich in crude fibre and not suitable for human consumption.The area of oats grown in Ireland has remained relatively unchanged between 2008 and 2013 with between 9,000 and 11,000 ha (~22,000 – 27,000 acres) sown according to data from the central statistics office (CSO, 2015). This represents approximately 9% of the area cultivated with traditional cereal crops. Typical yields for winter oats in Ireland vary from 7 – 8 t ha^{-1}. This is comparable to barley yields with the average yield between 2011 and 2013 being 7.3 t ha^{-1} and 7.2 t ha^{-1} for barley and oats, respectively (CSO, 2015).

In recent years, there has been growing interest from the gluten-free and health food sectors for oats. This is due to the many health benefits that have been attributed to oats and oat products including lowering blood pressure and preventing radical damage to DNA, RNA, proteins, and cellular organelles (Chen et al., 2015). Oats contain contain soluble dietary fiber, unsaturated fatty acids, several vitamins and minerals, abundant antioxidant compounds, and have a well-balanced protein composition (Chen et al., 2015). The primary protein in oats is avenalin, compared with gluten in wheat and barley crops. This makes oats suitable for inclusion in a gluten free diet. However, the crop needs to be kept isolated from wheat and barley (and other gluten containing cereals) so as to avoid cross–contamination of the oats. Oat protein is similar in quality to soy protein, which WHO (2014) research has shown to be equivalent to meat, milk and egg proteins. The protein content of the hull–less oat kernel (groat) ranges from 12 to 24%, the highest among cereal crops (Lasztity, 1999).

Varieties of oat have been bred that naturally lose the husk during the combining and processing of the crop. These oats are known as naked oats (Biel et al., 2009). Naked oats contain a higher propotion of crude protein than conventional oats and are suitable for sale as a health food or to equestrian markets as the lower starch and higher oil contents leads to a better response from performing horses.

Oats also contain an oil content which may reach levels up to 18% but typically range from 3 – 11% (Banas et al., 2007). Oat oil contains high levels of Vitamin E (tocopherols) 729 mg kg^{-1} oil, twice the level present in rice bran oil (Tong et al., 2014). Vitamin E is beneficial to the skin and the cosmaceutical industry has included it in a number of products for anti-aging, anti-irritation and sun care purposes. The leading cosmetics brand, Aveeno, has built its reputation on incorporating oat compounds into skincare products.

Products that can be produced from oats include: Porridge, Flapjacks, protein powder, fat replacer, oat milk, oat oil, yoghurt drinks, beta-glucans, furfural, and animal feed.

Novel Products from Oats

A number of novel products have been developed in recent times with the inclusion of oats or oat compounds for health benefits. A portion of these patented products is presented in Table 1.

Table 1: Recent products developed containing oat and oat derived compounds

Product	Patent Number	Issue Date
Beta-glucan food product	US 20030148015 A1	August 2003
Cancer therapy with Beta-glucans	US 6284886 B1	September 2001
Oat containing dairy beverage	US 20130017300 A1	January 2013
Oat derived sweetener	WO 2012174259 A2	December 2012
	EP 2178394 A1	April 2010
Oat protein lotion and shampoo	US 6506375 B1	January 2003

β-Glucans are polysaccharides of d-glucose monomers linked through β-glycosidic bonds. β-Glucans from cereals help to lower cholesterol and blood glucose levels (Zhu et al., 2016). Of the common cereals (barley, oats, wheat and rye), the largest (seed) amounts of β-glucans are found in barley (3-11%) and oats (3-7%) (Patterson, 2008). Oat groats contain significant amounts of beta-glucan that varies between 2.3 and 8.5 g 100 g^{-1} (Butt et al., 2008). Table 2, adapted from (Zhu et al., 2016) shows the array of products to which beta-glucans can be added. These products include food, feed, pharmaceuticals and cosmetics. Xin-Zhong et al. (2015) reported that the inclusion of 5% oat beta-glucans in a high fat diet resulted in significantly reduced body weight, epididymal and subcutaneous adipose tissue weight compared with high-fat diet fed human flora-associated mice ($p<0.01$).

Table 2: Examples of products to which beta-glucans can be added in a variety of industries.

Area of applications	Products	Functionality
Foods	Prebiotic sausage formulation with β-glucan	Noticeable effect on physical and sensory properties
	Gluten-free bread with β-glucan	Acceptable results of sensory analysis
	Dairy products with β-glucan	Calorie-reduced and cholesterol-lowering
	Yogurts with β-glucan	Faster proteolysis, lower release of large peptides and a higher proportion of free amino acids
	Extruded ready-to-eat snacks	Manipulate the glycemic response
	Beverage containing β-glucan	Control food intake and reduce 24 h energy intake
	Cakes containing β-glucan	Good quality attributes
	Used in food products	As a thickening, water-holding, or oil-binding agent and emulsifying stabilizer
Medicines	Wound dressing material	Larger inner cavity diameter
	Transparent wound dressing sheet	Therapeutic efficacies comparable or superior to a commercial wound dressing
	Curing partial-thickness burns	Decrease post injury pain
	Curing burn-induced remote organ injury	Be effective against burn-induced oxidative tissue damage
	Poly-membranes containing β-glucan	Accelerated wound healing effects
	A bone-substituting material	Easy manipulation and good adaptation to the shape and dimensions of even large bone defects
	Vaccine delivery	Can be exploited for

	platform.	vaccine development
Cosmetics	Film-forming moisturizer	Efficacy for reducing fine-lines and wrinkles
	Skin and dermatological compositions	Moisturization of skin or mucosa and anti-aging and revitalizing effect on the skin
	Cosmetic product	Defer skin aging, impart skin whitening effect and cure skin damage effectively
	Cosmetic product	Treat collagen loss in aging skin
	Cosmetic formulation containing CM β-glucan	With good spread ability and skin smoothing effect
	Emulsion containing CM β-glucan	Improve skin condition
	Cosmetic product containing yeast β-glucan	Enhance ulcer healing and increase epithelia hyperplasia
	Eye drops with mushroom β-glucan	Great moisture retention
Feeds	Animal feed additive	Enhance immunity and as a potential antitumor agent
	Fish feed additive	Increase the number of specific antibody secreting cells and specific Ig levels in serum
Other health products	Materials for health foods	Useful
	Personal care compositions containing β-glucan	Hair care actives
	Novel prebiotics	Health-promoting property
	β-Glucan nanoparticles	Exhibit antifungal activity against Pythium aphanidermatum
	Natraceutical product containing β-glucan	Useful

Oat β-glucan is used as a functional food ingredient, but can also be used to enhance viscoelastic properties of gluten free bread formulations.

In 2010, Quaker Oats developed a method of modifying oats using enzymes in order to derive a potent natural sweetener (Patent number: EP 2178394 A1). As the use of corn based sucrose sugar has come under increasing scrutiny because of its links to causing obesity, there is a large potential market for oat derived sweeteners as a wide range of food product manufactures are actively looking for sucrose replacements that are conventionally added to grain based food products.

Oat products including oat fibres and a water-soluble form of enzyme treated oat flour containing beta-glucan soluble fiber can be used by food processors as a fat replacer. These fat replacers, trademarked brands include Opta, Nutrim and Beta-Trim, can be used in various food products to provide structural integrity, volume, moisture holding capacity, adhesiveness and as a bodying and texturising ingredient. Using oat fibres including beta-glucans reduce the calorific value of the product by 1 – 4 calories per gram (Calorie Control Council, 2015) whilst increasing the beta-glucan content of the product allowing for it to be marketed as a health product.

A number of oat based drinks are available on the market including oat milk and oat-containing dairy beverages. These oat containg dairy beverages usually add the oats to the product for a way to increase the fibre and vitamin content of convience based drinks without affecting the overall taste of the product.

Furfural from Oats

Furfural is a heterocyclic aldehyde, organic compound derived from a variety of agricultural byproducts including oats. The name furfural derives from the latin word furfur meaning bran. Furfural is produced by dehydrating the five-carbon sugars such as xylose and arabinose of a biomass material. These pentose sugars are commonly obtained from the hemicellulose fraction of biomass wastes like cornstalks, corncobs, the husks of peanuts and oat husks. The molecular formula is $C_5H_4O_2$ (Win, 2005). Furfural yield from oat husks have been reported by Shafeeq et al. (2015), to be 10% comparable to corn cobs and rice husks. Furfural yields depend on the pentosan content of the biomass material and the humidity further affects the furfrual yield. Furfural is produced from the cob of the maize plant, the part on which the kernels grow.

As the majority of maize in Ireland is grown for forage purposes oats are the only suitable biomass material with meaningful amounts for furfural production. Hydrogenation of furfural can be done to produce tetrahydrofurfuryl alcohol (THFA). THFA is being employed to be a non-hazardous solvent for various agricultural formulations. It is used to help herbicides in penetrating the leaf structure (Shafeeq et al., 2015). During the production of furfural a number of by-products are also produced, these include Methyl alcohol (0.136 – 0.16 t), Acetone (0.136 – 0.16 t) and acetic acid (0.41 – 0.725 t) (Win, 2005) per tonne of furfural produced. The value of the by-products produced is again dependent on the raw material and can vary.

Oat husks account for approximately 25% of the total weight of oat grains, the husks are rich in crude fibre which is not suitable for human consumption (Ganssmann & Vorweck, 1995).

The average oat hectareage in Ireland from 2011–2013 was 24,000 ha. The average yield for the crop during this three year period was 7.2 t ha^{-1}, yielding 173,600 t of oats (CSO, 2015). Assuming the husk value of 25%, as previously mentioned, 43,400 t of oat husks were removed from the crop during processing of the oats. Using the 10% furfural yields possible from oats husks reported by Shafeeq et al. (2015), 4,340 t of furfural (0.18 t of furfural ha^{-1}) could have potentially been produced annually from the oat crop cultivated in Ireland from 2011–2013.

Emergence of the novel furfural application to manufacture THF, furfuryl alcohol resins and furanics is also expected to have a positive influence on the market growth. Furfuryl alcohol was the largest application segment of the furfural market and accounted for more than 86% of the total market in 2013. Increasing furan resins demand in foundry applications such as sand binders is expected to remain a key driving factor for this segment. Global furfural demand for solvents is expected to grow at an estimated compound annual growth rate of 13.3% from 2014 to 2020. This will raise global demand of furfural from 300,000 t in 2013 to 625,000 t in 2020 (GrandView Research, 2015). With decreasing amounts of corn cobs available in China, the main producer of furfural, and growing demand from regions such as Asia Pacific and Africa, the market value of furfural is expected to remain, during the period to 2020, between $1,200 and $1,500 t^{-1} (GrandView Research, 2015). The global furfural market is expected to reach $1.2 billion by 2020.

Market Outlook

Oats were largely seen as either a horse feed or as a bland cereal product with limited options. Oats will require a re-imaging campaign to highlight and inform members of the public of the extensive product range that can be produced using oats.

Also, the health benefits of oats should be further promoted to enhance the reputation of the cereal crop as a healthy option, including the high fibre and slow release energy aspects of oats as a food product. The fact that oats can be consumed by people suffering from ceoliac disease and for people focusing on a diet containg less gluten is now being exploited, particularly by Glanbia who certify their crop as gluten free (< 10 ppm gluten). Inclusion of oat and oat compounds as functional ingredients in products will increase the market size available to oats.

Demand from health conscious consumers for products containing yeasts and beta-glucans is expected to rise from US$630 million in 2014 to US$1.05 billion in 2021 (Transparency Market Research, 2015). Ireland has an advantage for the production of food ingredients and flavours with a strong industry already established including global market players such as Glanbia and Kerry Foods. A SWOT analysis for the expansion of the production of Oats in Ireland is shown in Figure 1.

Strengths

- Processing facilities already established
- Market with Strumm Foods in USA established
- Suitable for consumption by people suffering from coeliac disease

Weaknesses

- 2 year wait after wheat or barley to ensure gluten free status
- Image as a bland cereal

Opportunities

- Increase production capacity
- Senior nutrition
- 'Free from' foods
- Building consumer awareness
- Production of chemicals from oat by-products

Threats

- Increased production in Canada and Russia
- Trade agreements allowing Canadian imports to EU

Figure 1: SWOT Analysis for the expansion of Oat production in Ireland.

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