Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences

Incorporation of oat β-glucan in pasta and the effect on product quality

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Abstract

Consumers' growing interest in healthy food products has opened up a new market for the food industry. In an attempt to exploit this market there is a constant search for health promoting ingredients which can be incorporated into functional food products. The cereal fibre mixed-linkage (1→3), (1→4)-β-D-glucan has provoked a special interest due to well documented health benefits and approved health claims. This project aimed at developing pasta with high content of oat β-glucan and to evaluate how incorporation of β-glucan affects cooking quality, colour and sensory properties of semolina pasta. A secondary objective was to review the literature regarding prebiotic potential of cereal β-glucans.

Pasta was produced by substituting durum semolina with different levels of β-glucan rich wholegrain oat flour or oat bran concentrate. For each β-glucan source, three tagliatelle samples containing 1%, 2%, or 3% β-glucan were produced. A sample containing both oat flour and oat bran concentrate was also developed. Cooking quality was evaluated by measuring optimal cooking time, cooking loss and water absorption. Stickiness, firmness, elasticity, grain flavour and colour were also evaluated. Generally, addition of β-glucan was found to increase cooking loss, decrease elasticity and to reduce the brightness and yellowness of pasta. The effect was dependent both on the source of β-glucan, and on the level of incorporation. Overall, oat flour had a negative impact on pasta quality, while pasta with oat bran concentrate showed quality characteristics similar to the control.

This study suggests that the use of oat fractions to replace semolina may be possible in order to obtain pasta with high content of β-glucan and potential health benefits. The results also suggest that it is possible to produce acceptable pasta which fulfils the criteria for health claims regarding β-glucan and maintained and/or reduced cholesterol levels. Regarding prebiotic effect of β-glucan enriched products the evidence is still insufficient and more *in vivo* studies are required to determine if β-glucan selectively promotes growth and activity of probiotic bacteria.

Keywords: Oat, β-glucan, pasta, cooking quality, prebiotic, functional food

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1 Introduction

1.1 Background

Consumers' interest in healthy products has increased in recent years and development of foods with health promoting effect has become an interesting topic for the food industry. Cereals and cereal components has been widely studied, and due to health benefits they are often incorporated into functional food product (Havrlentova *et al.*, 2011). The cereal fibre mixed-linkage (1→3),(1→4)-β-D-glucan (hereafter referred to as β-glucan) is interesting for this purpose due to well documented effect on serum cholesterol and blood glucose levels (Cloetens *et al.*, 2012; Daou & Zhang, 2012; Wood, 2007). The fibre has also been suggested to have prebiotic effect (Cloetens *et al.*, 2012), although this has not been very well studied in human subjects.

In 2009, the food company Lantmännen launched a prebiotic platform with products containing fibre from chicory, barley and maize. This platform was later withdrawn from the market, but the interest for prebiotic products remains within the company. Today Lantmännen are interested in the prebiotic potential of oat β-glucan, and how incorporation of this fibre affects the properties of food products. Together with Karolinska Institutet, Lantmännen have initiated a research project, Fibflo, with the aim to investigate the prebiotic potential of oat β-glucan in humans. A range of β-glucan enriched food products will be developed for the study, and if prebiotic effect can be confirmed, the products may also serve as prototypes for commercial purposes.

1.2 Objectives

The objective of this project was to develop pasta with high content of oat β-glucan and potential prebiotic effect as well as to evaluate how level and source of β-glucan affect cooking quality, colour and sensory properties of pasta. Secondary objectives were to determine which health claims that could be used for marketing the produced pasta as functional food products, as well as to review the literature regarding prebiotic effect of cereal β-glucans.

1.3 Delineation

This project will include both practical development and evaluation of products, as well as theoretical studies. The theoretical studies will discuss health benefits associated with cereal β-glucan with focus on prebiotic effect, but will also include theory required to develop and evaluate oat-based β-glucan-rich pasta. The study will be limited to product development and will not include market research, financial aspects or commercialisation. The study will focus on health as an added value and environmental considerations or ethical concern will not be discussed. Due to material and resource limitation nutritional and structure analysis of the finished products will not be included in the report.

2 Theoretical background

2.1 Nutritional composition of oat

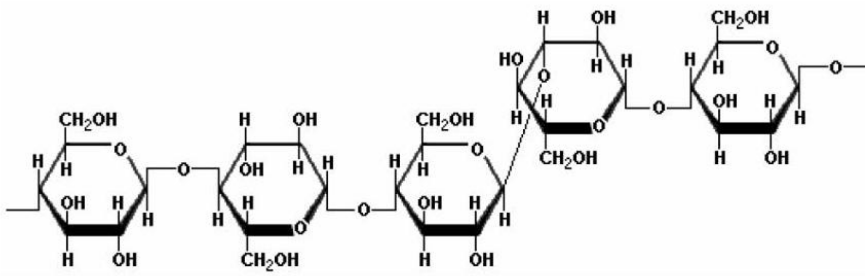
Oat has lately been recognised for its nutritional benefits associated with high content of β-glucan and antioxidants (Peterson *et al.*, 2001; Gray *et al.*, 2000). Oat is rich in dietary fibres, which mainly consists of β-glucan, arabinoxylan and cellulose. Reported data on total fibre content of oat groats spans between 5-12%, where 30-50% is water soluble fibre (Lasztity, 1998). The protein content of groats ranges from 12.4 to 25.5%, and the lipid content, mainly consisting of unsaturated fatty acids, is higher then for other grains (3.1-10.9%). Regarding vitamins, oat is rich in vitamin E and contains a significant amount of folat and biotin, while phosphorus, potassium, magnesium and calcium are the main minerals. The antioxidant content of oat is mainly due to the high level of vitamin E but other phenolic compounds are also present. Except for enhancing the nutritional value of the grain, antioxidants are also important to prevent oxidation of lipids and improve storage stability (for extensive review see Laszitity, 1998).

2.2 Characteristics of oat β-glucan

β-Glucans are dietary fibres consisting of polysaccharides which can be found in cereals, yeast and algae. Among cereals, the highest concentration of β-glucans is found in oat and barley (Havrlentova *et al.*, 2011). In oats, β-glucans are primarily found in the sub-aleurone and endosperm cell walls (Cui and Wang, 2009), however, the level varies widely depending on genetic and environmental factors (Miller *et al.*, 1993). Miller *et al.* (1993) investigated 18 Canadian oat species and found β-glucan content to vary between 1.8-5.5%, while Cho and White (1993) reported values between 4.5-5.5% in oat lines in the United States. Asp and coworkers (1992) reported β-glucan content of 3.5-5.7% for Swedish oat cultivars.

2.2.1 Structure

The linear mixed-linkage polysaccharide (1→3) (1→4)-β-D-glucan found in oat is composed of 70% 4-O- and 30% 3-O-linked β-D-glucopyranosyl units (Webster & Wood, 2011). The glucose units are arranged in cellotriosyl- or cellotetraosyl blocks, where units within a block are connected with (1→4) linkages, and blocks are separated by single (1→3) linkages. In oat β-glucan the cellotriosyl and cellotetraosyl blocks constitute about 90%, while the remaining 10% are blocks longer than four 4-O-linked glucose units (for extensive reviews see Webster & Wood, 2011; Cui & Wang, 2009). The (1→3) linkages are contributing to the water soluble properties of β-glucans, while blocks above 9 units become less soluble and have more cellulose-like properties. The molar ratio of cellotriose to cellotetraose units are relatively low in oat, about 2:1, compared to 3:1 for rye and 4:1for wheat (Webster & Wood, 2011).



Figur 1. Basic structure of cereal β-glucan with β-(1→3) and β-(1→4) bonds. Source: (Havrlentova *et al.*, 2011).

2.2.2 Rheology

The solubility and viscosity of oat β-glucan effect food properties as well as physiological functions of the fibre. With higher molecular weight (MW) and/or concentration of β-glucan the viscosity will increase, and the solution will become more pseudoplastic (Vaikousi *et al.*, 2004). The suggested MW of oat β-glucans, 65-3100 kDa, is somewhat higher than values reported for other cereal β-glucans (Lazaridou & Biliaderis, 2007). The high MW and low ratio of cellotriose to cellotetraose units makes the gel formation somewhat slower and less elastic than for other grains and it results in a lower melting temperature (Webster & Wood, 2011; Lazaridou *et al.*, 2003). The temperature and concentration is also important for gel formation, and gel strength will increase with increasing concentration of β-glucans and with temperatures up till 30ºC. Temperatures above 30 ºC have a negative impact on gel formation (Lazaridou *et al.*, 2003).

2.2.3 β-Glucan in food products

Due to potential health benefits and a growing interest from consumers there have been many attempts to incorporate β-glucan rich fractions from oat and barley into various food products. Incorporation of β-glucans in products such as bread, pasta, breakfast cereals, muffins, dressing and soups has shown to affect various product attributes. Lazaridou and Biliaderis (2007) concluded that water binding capacity, bread making performance, thickening ability, emulsion stability, texture and appearance may be affected by incorporation of β-glucan. The effect on food quality is influenced by concentration, molecular weight and structure of β-glucan. In the same time, processing method and food used for incorporation tend to affect characteristics of β-glucan (Wood, 2007).

2.3 Pasta

Pasta is traditionally manufactured by mixing durum semolina and water. The dough can be extruded in various shapes and are dried through different drying cycles. The interaction of starch gelatinization and protein network in the presence of water much determines the texture as well as cooking qualities of pasta (El-Khayat *et al.*, 2006). The high content of gluten in durum semolina contributes to strong and elastic dough properties, as well as low cooking loss and optimal texture of the final product (Oak *et al.*, 2006; Degidio *et al.*, 1990). The optimal durum semolina should result in pasta with high water absorption, minimum solid loss to the cooking medium, high resistance to break, a clear surface and a light yellow colour (Fuad & Prabhasankar, 2010). The quality of pasta is also related to the texture of the finished product, and firmness, stickiness, bulkiness, adhesiveness and elasticity has been identified as the most important attributes for consumer acceptance (Brennan & Tudorica, 2007).

As the interest for foods providing optimal nutrition is growing, so is the interest in improving the nutritional profile of pasta. Different supplements, including fibre and/or protein rich flours, has been incorporated into pasta and noodles for this purpose; however the texture and cooking qualities of the pasta is often compromised (Mastromatteo *et al.*, 2012; Chillo *et al.*, 2011; Chillo *et al.*, 2009; Brennan & Tudorica, 2007; Tudorica *et al.*, 2002; Marconi *et al.*, 2000).

2.3.1 β-Glucan and pasta cooking quality

Substitution of semolina with barley β-glucan fractions has been suggested to increase cooking loss (Chillo *et al.*, 2011; Brennan & Tudorica, 2007; Cleary & Brennan, 2006). The cooking loss seems to increase with higher levels of β-glucan, while water absorption remains the same (Chillo *et al.*, 2011; Brennan & Tudorica, 2007). However, Cleary and Brennan (2006) observed reduced cooking loss for samples with 5% and 7.5% β-glucan, suggesting that a high amount of fibre might form a polysaccharide network which strengthens the structure and reduces solid loss (Cleary & Brennan, 2006). It was also observed that all samples absorbed more water than the control.

Regarding Optimal Cooking Time (OCT), Chillo *et al.* (2009) concluded that oat pasta had significantly lower (about 5 min) OCT than traditional durum pasta (about 8 min). Pasta with barley β-glucan concentrate was on the contrary suggested to have an increased OCT, where the OCT was highest for the highest level (10%) of β-glucan added (Chillo *et al.*, 2011). An increase in OCT with increasing level of barley β-glucan was also found by Lamacchia *et al*. (2011).

2.3.2 β-Glucan and texture of pasta

Characteristics related to a disrupted gluten matrix, such as decreased pasta firmness and increased stickiness, has been observed for semolina pasta substituted with barley fractions to β-glucan levels above 2.5% (Brennan & Tudorica, 2007). Cleary and Brennan (2006) concluded that incorporation of 2.5% to 10% barley β-glucan had a negative effect on firmness, while adhesiveness was decreased compared to the control sample. In contrast, Chillo *et al*. (2011) did not find any difference in hardness between semolina pasta and pasta with barley β-glucan, however, stickiness was increased in the β-glucan sample.

Chillo *et al*. (2009) found that oat pasta suffered from lack of firmness as well as increased adhesiveness and bulkiness. A sensory evaluation of pasta with 10% oat bran showed similar findings. The oat bran pasta lacked firmness, chewiness and elasticity while stickiness was increased (Bustos *et al.*, 2011). However, acceptable firmness and absence of bulkiness and stickiness has been reported for pasta containing barley flour (Verardo *et al.*, 2011; Marconi *et al.*, 2000).

2.4 Health benefits of β-glucans

The glycaemic index, GI, indicates how consumption of a carbohydrate rich food affects blood glucose levels after a meal. A high GI diet has been related to the risk of developing type 2 diabetes, while low GI diets may reduce hyperglycaemia and cardiovascular risk factors (Parillo & Riccardi, 2004). The beneficial effect of oat β-glucan on glycaemic response is well documented and relates to postponed carbohydrate absorption in the gut (for review see Cloetens *et al.*, 2012). The effect on postprandial glucose and insulin levels seems to be dependent on different properties of β-glucan, such as viscosity and molecular weight, as well as the consumed amount (Granfeldt *et al.*, 2008; Mäkeläinen *et al.*, 2007; Wood, 2007). Pasta with added barley β-glucan concentrate has demonstrated reduced sugar and insulin release compared to semolina pasta during *in vitro* digestion (Chillo *et al.*, 2011; Cleary & Brennan, 2006).

Another well documented effect of cereal β-glucan is the ability to lower total and LDL-cholesterol levels (Wood, 2007; Naumann *et al.*, 2006; Kerckhoffs *et al.*, 2003). Bile is necessary for cholesterol absorption, and the beneficial effect on serum lipids is associated with an increased excretion of bile acid (Lia *et al.*, 1995). Not all studies show a significant effect of β-glucan on blood lipids, and contradicting results may relate to processing method, food used for incorporation, dose or properties of β-glucan (Wood, 2007; Kerckhoffs *et al.*, 2003).

Except for effect on insulin response and serum cholesterol levels, β-glucan consumption may be connected to several other health benefits. It has been suggested that β-glucan increase immunological activity (Havrlentova *et al.*, 2011), prevent and/or reduce obesity, reduce blood pressure, as well as influence the gut microbiota (Cloetens *et al.*, 2012).

2.5 Prebiotics

2.5.1 Definition and effect

Prebiotics are food components that are not fully digested by the consumer, and where a considerable amount can be utilized as substrates by the intestinal micro flora. Prebiotics should also selectively promote growth and/or activity of microbes that are beneficial to the host (Gibson *et al.*, 2004; Gibson & Roberfroid, 1995). Dietary fibres are able to resist absorption in the upper part of the gastrointestinal tract and are available as substrate in colon. However, not all dietary fibres are likely to stimulate growth of health promoting bacteria, such as Lactobacillus and Bifidobacteria, and thus fulfil the prebiotic criteria (Gibson & Roberfroid, 1995).

Stimulation of beneficial bacteria are associated with inhibition of pathogens through competition for nutrients and colonisation sites, increased production of antimicrobial substances as well as production of organic acids resulting in unfavourable conditions for pathogens (Gibson & Rastall, 2006). Probiotic bacteria are also suggested to produce less genotoxic substances, resulting in reduced cancer risk. Except for an increase in Bifidobacteria and Lactobacillus count, prebiotic effect has also been associated with bacteria metabolites such as increased production of the short chain fatty acids (SCFA) acetate, propionate and butyrate (De Vuyst & Leroy, 2011). Except for being converted into energy, propionate is suggested to suppress cholesterol synthesis while butyrate regulates cell growth and differentiation of the colon epithelium (Gibson & Rastall, 2006). Increased level of butyrate has also been suggested to effect several cellular processes and possess anti carcinogenic properties (Gibson & Rastall, 2006).

2.5.2 Prebiotic effect of β-glucans

In vitro

In vitro experiments suggests that neither Lactobacillus nor Bifidobacteria are able to ferment intact cereal β-glucan (Hughes *et al.*, 2008; Crittenden *et al.*, 2002), although reverse findings have been reported (Zhao & Cheung, 2011). In simulations of the colon ecosystem probiotic bacteria have been suggested to utilise oligosaccharides from partial hydrolysed β-glucan (Hughes *et al.*, 2008; Jaskari *et al.*, 1998; Kontula *et al.*, 1998), which is also supported by findings in batch culture (Su *et al.*, 2007). Kedia *et al.* (2009) showed that Bifidobacteria and Lactobacillus count increased during anaerobic fermentation of oat samples in human faecal mixed cultures. β-glucan fermentation by beneficial bacteria in colon may be explained by cross-feeding, where other species hydrolysis β-glucan before utilized as a substrate for probiotic bacteria (Crittenden *et al.*, 2002).

In vivo

Rat studies suggest that β-glucan survive degradation by digestion enzymes and is highly fermented in the lower gastrointestinal tract (Snart *et al.*, 2006; Dongowski *et al.*, 2002; Berggren *et al.*, 1993). In addition, barley β-glucan rich diets are suggested to increase the amount of Lactobacillus species in colon and caecum of rats (Snart *et al.*, 2006; Dongowski *et al.*, 2002).

In human subjects, total faecal bacteria count and Bifidobacteria increased after five weeks consumption of a fermented, ropy, oat based product containing 3.5g oat β-glucan and an unknown amount of microbial β-glucan (Martensson *et al.*, 2005). The study also investigated the effect of a fermented oat-based product containing 3.0g oat β-glucan, without microbial β-glucan, but no significant changes in Bifidobacteria or total bacterial count was detected after consumption of this product. A slight increase in Bifidobacteria was also seen in a randomized double blind trail of 26 individuals consuming 0.75g barley β-glucan per day in form of a cake (Mitsou *et al.*, 2010). However, the increase did not reach significance until grouping the subjects according to age. An increase in Bifidobacteria was then detected for individuals (n=15) 50 years and older. Beneficial bacteria such as Lactobacillus and Bifidobacteria is often lower in older subjects (Woodmansey, 2007), which might explain this result. The study did not show any significant results regarding Lactobacillus or total bacteria count (Mitsou *et al.*, 2010).

Effect on short chain fatty acids

An increase in SCFA has been observed during *in vitro* fermentation of oat bran, β-glucan rich oat flour and long-chain β-glucans (Kaur *et al.*, 2011; Kedia *et al.*, 2009; Kim & White, 2009; Sayar *et al.*, 2007; Kontula *et al.*, 1998). This has also been confirmed in colon and faeces of rats (Dongowski *et al.*, 2002; Berggren *et al.*, 1993). Moreover, a β-glucan rich diet did result in increased levels of SCFA in humans with Ulcerous Colitis (Hallert *et al.*, 2003) as well as in polypectomized patients (Turunen *et al.*, 2011).

Conclusions of the prebiotic effect of β-glucan

Preliminary results indicate prebiotic potential of cereal β-glucan, however, the evidence is still insufficient and more *in vivo* studies are required to determine if β-glucan selectively promotes growth and activity of probiotic bacteria. Fermentation in pure cultures by single bacteria strains does not prove selective fermentation in a complex bacteria ecosystem and is not sufficient as prebiotic evidence (Roberfroid, 2007). In the few human trails on healthy adults, a relatively low dose of β-glucan was used, 0,75 g – 3,5 g/day. In studies of inulin, the most documented prebiotic fibre, 4-20 g/day has been used to demonstrated prebiotic potential (Roberfroid, 2007). A larger daily intake of β-glucan should therefore be evaluated in future trails. Studies investigating the prebiotic effect of β-glucan also tend to use different sources, ranging from oat and barley flours to concentrated β-glucan fractions. It should be highlighted that these raw materials are likely to exhibit somewhat different properties. Another factor that should be kept in mind is that oat and barley also contains arabinoxylan, which has been suggested to possess prebiotic properties (Crittenden *et al.*, 2002). Regarding prebiotic effect of cereal β-glucan, as well as of other potential prebiotics, there is a lack of long term studies to determine the lasting effect on microbial growth and activity.

In addition to stimulating growth of lactic acid bacteria, there is some evidence that consumption of β-glucan results in increased production of SCFA (Turunen *et al.*, 2011; Mitsou *et al.*, 2010; Hallert *et al.*, 2003). However, it is difficult to validate SCFA production as a biomarker of a specific bacteria genera and therefore it is questionable to use as a measurement for prebiotic effect (Roberfroid, 2007).

2.6 β-Glucan and health claims

Due to well documented health benefits, the European Food Safety Authority, EFSA, have approved the use of health claims for foods containing β-glucans. The approved claims relate to maintenance/reduction of blood cholesterol levels and to reduction of blood glucose rise after a meal (EFSA, 2012). Regarding cholesterol levels it is allowed to claim that "β-Glucans contribute to the maintenance of normal blood cholesterol levels", as well as "Oat β-glucan has been shown to lower/reduce blood cholesterol". These claims are valid for food containing 1g oat β-glucan together with a statement that the beneficial effect is obtained at consumption of 3g β-glucan per day. For the second mentioned claim the food must also be labelled with an explanatory text regarding high cholesterol levels as a risk factor in the development of coronary heart disease (EFSA, 2012). Claims regarding β-glucan from oat and barley and normal blood glucose levels are valid for foods containing 4g β-glucan for each 30g of available carbohydrates per portion.

Other claims that may be relevant for oat pasta regards the content of dietary fibre. A claim regarding dietary fibre from oat and increased stool volume has been approved. For this claim the product must contain 6 g dietary fibre per 100g, or 3g per 100 kcal (EFSA, 2012). However, to claim that a food is a source of dietary fibre, the product must only contain 3g dietary fibre per 100g or 1,5g per 100 kcal.

No claims regarding prebiotic effect have been approved at this stage. The rejection of prebiotic claims is due to insufficient characterization of food stuff or due to lack of scientific evidence to support the claim (EFSA, 2012). Prebiotic effect of oat β-glucans have not been assessed by the authority, however, only a limited number of studies have investigated the prebiotic potential in humans.

2.7 Sensory evaluation

Sensory evaluations are often used in research as well in the food industry to evaluate sensory characteristics and human response to food products. Sensory evaluation has been accepted as a scientific method where the five senses; sight, smell, touch, taste and hearing, is used to evoke, measure, analyze and interpret responses to products (Lawless & Heymann, 1999).

Discrimination testing, descriptive testing and affective testing are the main methods used for sensory evaluation. Discrimination tests are used to determine if products differ in any way, while affective tests answers how well products are liked, or which sample that is preferred over another. Affective tests, such as preference tests and acceptance tests, are generally used with untrained consumer panels and with a large number of participants to adjust for the high variability of individual preferences. The 9-point hedonic scale, ranging from like extremely to dislike extremely, is widely used when assessing the degree of liking (table 1) (Lawless & Heymann, 1999). Descriptive tests are the most comprehensive and informative tools, and are useful to characterize specific sensory attributes. Panels for descriptive tests usually consist of 8-12 highly trained assessors which gives consistent and reproducible results. Descriptive tests are often used in pasta quality assessment, where trained panel members evaluate different texture attributes.

Training a sensory panel for texture evaluation is, however, both costly and time consuming, and therefore semi-trained panels, which has been suggested to produce similar results as trained panels (Ruiz-Capillas *et al.*, 2003), may be used.

Often when conducting research and/or product development several different sensory evaluations are needed. The testing sequence often start with a bench-top testing which enables familiarization with product attributes, elimination of defective products and probing of desired sensory changes (Lawless & Heymann, 1999). The next stage might be a test with an employee panel, before investing in more extensive descriptive and/or consumer tests. Sensory evaluations should preferably be performed in a sensory laboratory where participants are separated from each other by individual booths (Lawless & Heymann, 1999). The participants should be given orally and written instructions before the test and samples should be coded with three digit codes and served in a randomized serving order to avoid first and last order effect.

Table 1. The 9-point hedonic scale used to evaluate the degree of liking of a food product.

Number	Description
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like or dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

3 Materials and method

3.1 Raw materials

Durum semolina and wholegrain oat flour was obtained from Lantmännen Cerealia. The oat bran concentrate, OatWell® 32%, was kindly supplied by Swedish Oat Fibre AB. Raw material characteristics, as shown in table 2, were obtained from the suppliers.

Table 2. Raw material characteristics as provided by suppliers

	Durum semolina flour	Oat bran concentrate (OatWell®)	Wholegrain oat flour
Chemical composition;			
Moisture content (%)	15	4 (< 8)	10
Carbohydrates (%)	68	8	56
Total NSP* (%)	1,5	59	10
of which β-glucan (%)	-	32	4.5
Protein (%)	12	22	13
Fat (%)	2	4	7
Physicochemical aspects:			
Particle size	< 450 µm (20% < 85µm)	< 200µm (50% < 90µm)	< 25% > 450 µm
Colour	-	Very light yellow-brown	White-beige
Taste	-	Neutral	Pure oat

*NSP = Non starch polysacharides

3.2 Pasta production

Tagliatelle pasta was produced using the pasta maker Edelweiss TR750. A control sample was prepared using 100% durum semolina. In test samples β-glucan was incorporated at 1%, 2% or 3 % by replacing semolina with different amounts of oat flour or oat bran concentrate in the formulation. The substitution level was calculated from β-glucan content in raw materials. Recipes are shown in table 3. The samples produced with oat flour containing 1 g, 2 g and 3 g β-glucan per 100 g flour mix were denoted OM1, OM2 and OM3. Samples made with oat bran concentrate, OatWell®, containing 1 g, 2 g and 3 g β-glucan per 100 g were denoted OW1, OW2 and OW3. A sample containing both oat flour and oat bran concentrate, with 2% β-glucan, was also produced and denoted Mix2 (table 3). Dough was prepared by mixing 500 g of flour with water until fine consistency and handling properties were achieved. Amount of added moisture needed to be adjusted for each flour mix due to different water absorption levels. The dough was kneaded for 15 min and tagliatelle shaped pasta was extruded and cut. Pasta nests were made by hand and dried for 2*10 minutes at 90°C in an air oven and thereafter for another 3.5 hours at 70°C in a heating cabinet. Each sample was produced in duplicates.

Table 3. Formulations used for preparation of pasta with oat flour and oat bran concentrate.

Pasta sample	Wheat durum semolina (g/100g)	Wholegrain oat flour (g/100g)	Oat bran concentrate (g/100g)	Water (g/100g)
Control	100.0	-	-	40.0
Mix2	89.5	5.0	5.5	43.5
OM1	77.8	22.2	-	45.0
OM2	55.6	44.4	-	52.0
OM3	33.4	66.6	-	62.0
OW1	96.9	-	3.1	42.0
OW2	93.8	-	6.2	45.0
OW3	90.6	-	9.4	48.0

OM is a denotation for oat flour pasta, OW denotes pasta with oat bran concentrate and Mix stands for pasta with both oat flour and oat bran concentrate. The numbers (1, 2 and 3) corresponds to the level (%) of oat β-glucan in the formulation.

3.3 Pasta quality evaluation

3.3.1 Moisture content

Moisture content of the finished pasta was measured with a Satorius moisture analyser. A 2.5 gram sample was dried until constant weight. Each sample was analyzed in triplicates.

3.3.2 Optimal cooking time

Optimal cooking time (OCT) was evaluated according to the approved method 66-50.01 recommended by the American Association of Cereal Chemists (AACC International, 1999). Each pasta sample was boiled in tap water. In 30 seconds intervals a pasta piece was removed from the water and squeezed between two pieces of transparent glass slides. OCT was established as the time, in minutes, when the centre core just disappeared. The test was performed in duplicate.

3.3.3 Water absorption

Water absorption of drained pasta was evaluated as described by Tudorica *et al*. (2002). As suggested by Samaan *et al*. (2006) the boiled pasta was drained for 2 minutes before weighted. Water absorption was calculated as: [[weight of cooked pasta (W1) - weight of raw pasta (W2)] / weight of raw pasta (W2)] * 100. The test was performed in duplicate.

3.3.4 Cooking loss

When boiling pasta some of the material may be lost to the cooking water. Cooking loss was measured as the volume of precipitation left in the cooking water. A 25 g sample was boiled in 300 ml of tap water until OCT, whereupon 100 ml of cooking water was collected in a measuring cylinder. The volume of the precipitate was measured after 24 hours. The test was performed in duplicate.

3.3.5 Colour analysis

The colour of dry, milled pasta was measured with a spectrophotometer (Spectrophotometer CM 600d, Konica Minolta) to determine how the different flour mixtures affected this quality attribute. The spectrophotometer measured each sample four times and gave the mean values for L, a and b. L measures the brightness of the sample, where brighter sample gives higher values, a measures redness when positive and greenness when negative, and b measures yellowness when positive and blueness when negative. Samples (each ~ 50 g) were grounded to a particle size of < 0.5 mm before the measurement. Each sample was measured in duplicates and mean values were calculated.

3.4 Sensory analysis of pasta

Pasta with the highest amount of β-glucan, 3 g/100 g and a control sample were selected for a sensory test to evaluate the maximum effect of oat flour and oat bran concentrate on pasta sensory attributes. A sample containing both oat flour and oat bran concentrate, with 2% β-glucan, was also included in the evaluation. After a bench-top testing firmness, stickiness, elasticity, grain flavour and overall liking were chosen as the most critical attributes. Selected attributes were assessed by a semi trained panel constituted of five employees at Lantmännen R&D. Stickiness was described as the degree of adhesiveness between pasta strands when trying to separate them. Firmness was evaluated by pressing pasta strands between fingers or between front teeth, and elasticity was measured as the ability of pasta to return to its original shape when stretched (Bustos *et al.*, 2011; Andersen, 1993).

All members of the panel were well familiar with pasta products prior to the test. The intensity of the different sensory attributes was evaluated on a 9 cm horizontal scale ranging from low intensity to high intensity. The control sample was pre-positioned in the middle (4.5) of the scale, to allow panellist to compare each sample with control pasta. The panellists were asked to mark the intensity of each sample with a cross on the scale. The formulary ended with a question of the overall liking of the products. Overall liking was assessed on a nine-point hedonic scale ranging from dislike extremely to like extremely (Lawless & Heymann, 1999). For instructions and test formulary see Appendix 1.

One hundred gram of each pasta sample was cooked in one litre of tap water with half a teaspoon of salt until OCT. The samples were served in small white bowls covered with foil to keep the samples warm. The samples were marked with three digits codes and served in a balanced order to avoid first and last order effect. Water and wafers were available to clean the pallet between samples. Participants were introduced to the sensory attributes at a training session. At the training session two pasta samples were served, one sticky and much adhesive (OM3) and one firm and less sticky (control), and after individual evaluation there was time for questions and discussion regarding the predefined attributes. When panellists showed understanding of the attributes the training session was ended and the real evaluation could start. The sensory evaluation was performed in duplicate to ensure reproducibility of panellists.

The results where translated into numerical scores and analysed statistically with analysis of variance (ANOVA, General linear model).

3.5 Statistical analysis

Statistical analyses were performed to study the effect of raw material (oat flour and oat bran concentrate) and level of β-glucan incorporation on cooking quality and colour of pasta. Statistical analysis was also performed to evaluate differences between samples, including the control and Mix2 samples, regarding cooking quality, colour and texture of pasta. Analysis of variance (ANOVA, General linear model) was performed using Minitab 16 Statistical Software (Minitab Inc., State College, PA, USA), and P-values < 0.05 were considered significant.

4 Result and discussion

4.1 Pasta samples

Pasta recipes were developed to obtain formulations with 1%, 2% and 3% β-glucan, using oat flour or oat bran concentrate. The average β-glucan content of raw materials, as given by suppliers (table 2), was used to develop formulations. Raw materials were later sent to an accredited laboratory for analysis regarding β-glucan content. Values from the analysis suggested that the β-glucan content was 3.59% in the oat flour, and 26.6% in the oat bran concentrate. The large difference between values given by the suppliers (table 2) and values obtained at analysis may be due to annual harvest differences of β-glucan content in oats or due to differences in methods used for analysis. If the later obtained values are correct this would mean that β-glucan levels in pasta samples are lower than expected. Due to limited resources the actual β-glucan content of the pasta was not analysed.

After a bench-top evaluation of pasta samples, it was decided that a sample containing both oat bran concentrate and oat flour should be prepared for the Fibflo project. Because oat pasta showed poor quality and oat bran concentrate is a fairly expensive raw material, not produced by Lantmännen, it was important that both ingredients were incorporated into the final product. This way the negative aspect of both ingredients could be minimized. With regards to the design of the Fibflo study, as well as to primarily result from the bench-top evaluation, it was decided that 2% β-glucan was an acceptable level in the mixed product.

4.2 Cooking quality

4.2.1 Moisture content

The moisture content of uncooked pasta containing oat flour or oat bran concentrate was not significantly different (table 4). Neither did the level of β-glucan affect the moisture content (table 5). These results are in line with findings from Chillo *et al.* (2009) examining pasta with barley β-glucan concentrate.

Table 4. Table summarizing the effect of β-glucan source on cooking quality and colour of pasta.

Source of β-glucan	Moisture content of uncooked pasta (g/100g)	Optimal cooking time (min)	Water absorption ((g of water/g raw pasta)*100)	Cooking loss (ml/100ml cooking medium)	Colour L	Colour a	Colour b
Oat bran concentrate	5.50^{a}	5.88^{a}	149.10^{a}	8.50^{b}	83.62^{a}	1.27^{a}	18.00^{a}
Wholegrain oat flour	5.80^{a}	4.21^{b}	141.00^{b}	11.33^{a}	81.70^{b}	1.10^{b}	16.48^{b}

Values in the same column with the same letter are not significantly different. Colour L measures brightness, where brighter sample gives higher values, Colour a measures redness when positive and greenness when negative, Colour b measures yellowness when positive and blueness when negative.

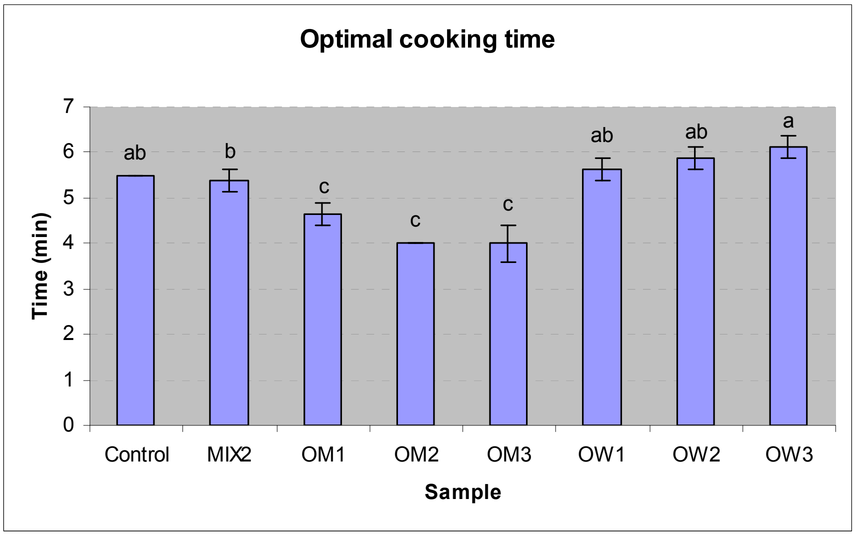
Table 5. Table summarizing the effect of β-glucan level on cooking quality and colour of pasta.

Level of β-glucan	Moisture content of uncooked pasta (g/100g)	Optimal cooking time (min)	Water absorption ((g of water/g raw pasta)*100)	Cooking loss (ml/100ml cooking medium)	Colour L	Colour a	Colour b
1%	5.96^{a}	5.13^{a}	139.40^{b}	7.88^{b}	83.89^{a}	1.02^{b}	17.62^{a}
2%	5.54^{a}	5.06^{a}	147.80^{a}	9.50^{ab}	82.36^{b}	1.20^{ab}	17.26^{ab}
3%	5.44^{a}	4.94^{a}	148.00^{a}	12.38^{a}	81.74^{b}	1.33^{a}	16.85^{b}

Values in the same column with the same letter are not significantly different. Colour L measures brightness, where brighter sample gives higher values, Colour a measures redness when positive and greenness when negative, Colour b measures yellowness when positive and blueness when negative.

4.2.2 Optimal cooking time of pasta samples

The OCT of pasta was significantly affected by the source of β-glucan, OM or OW (table 4), but not by the level added (table 5). The OCT for pasta substituted with oat flour was lower (about 4 min) than that of traditional pasta (5.5 min) and pasta substituted with oat bran concentrate (about 6 min), as shown in figure 2. This result is supported by findings from Chillo *et al*. (2009), and may be explained by a higher water diffusion in oat pasta, resulting in faster water absorption and pasta softening (Cafieri *et al.*, 2008). For pasta samples containing oat bran concentrate there was a trend for increased cooking time with higher substitution level, but without reaching significance (figure 2). This is in line with results for incorporation of barley β-glucan fractions into semolina pasta (Chillo *et al.*, 2011; Lamacchia *et al.*, 2011). β-glucan has been suggested to compete with starch granules for water, resulting in slower hydration and gelatinisation of starch, and increased gelatinisation temperature and OCT (Lamacchia *et al.*, 2011). The difference between samples substituted with oat bran concentrate and oat flour may be explained by differences in protein and fibre content, resulting in diverse chemical structures and mechanical properties. The OCT for the Mix2 sample was similar to that of the control and the OW samples.



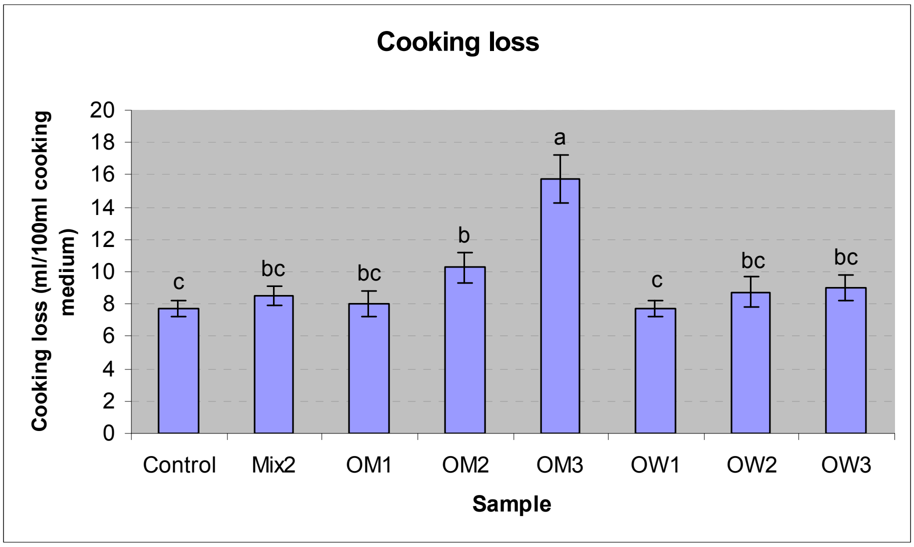
Figur 2. Optimal cooking time for pasta samples. OM is a denotation for wholegrain oat flour pasta, OW is a denotation for pasta with oat bran concentrate and Mix stands for pasta with both oat flour and oat bran concentrate. The numbers (1, 2 and 3) corresponds to the level (%) of oat β-glucan in the formulation.

4.2.3 Cooking loss

Cooking loss differed significantly between pasta with oat flour and oat bran concentrate (table 4), and between pasta samples with different levels of β-glucan (table 5). The cooking loss increased with increased concentration of oat flour, and only the sample with 1% β-glucan from oat flour did not have a significant higher cooking loss than the control (figure 3). As demonstrated in figure 3, none of the OW samples, or the Mix2 sample, differed significantly from the control regarding precipitation in to the cooking medium, and can thus be considered acceptable regarding this aspect. In contrast, other previous studies on pasta with barley β-glucan concentrate showed a significant increase in cooking loss with increasing level of β-glucans (Chillo *et al.*, 2011; Brennan & Tudorica, 2007). A similar trend could be observed for OW samples, but without reaching significance (figure 3). The alternative method used for evaluation of cooking loss in this study may explain these differences. Another reason for the good cooking quality demonstrated by OW samples, compared to barley β-glucan pasta, may relate to the high protein content of the raw material (table 2). The content and quality of protein is crucial for formation of a strong protein matrix which captures starch and reduces cooking loss (Chillo *et al.*, 2011). While β-glucan incorporation is often associated with decreased protein content and increased cooking loss (Cleary & Brennan, 2006), the high protein level of the oat bran concentrate might have counteracted this effect.

The difference in cooking quality between OW and OM is likely to relate to differences in β-glucan concentration of the raw material. To obtain the desired β-glucan level a much higher amount of OM was used in the formulation. This large replacement of semolina has likely contributed to low gluten content resulting in an interrupted protein matrix and high cooking loss.

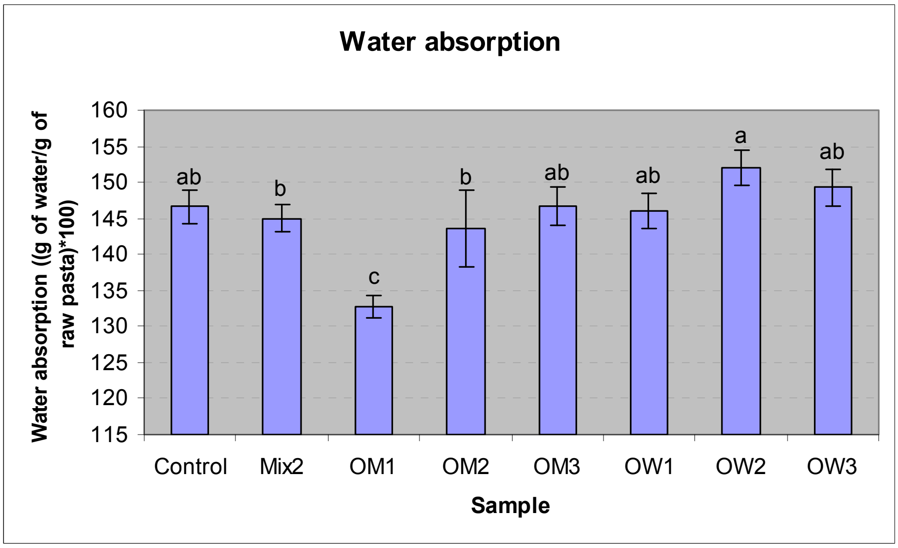
Addition of gluten concentrate, combined with high temperature treatment, has been suggested to promote formation of a coagulated protein network which entraps starch granulates and thus improves the cooking quality (Marconi *et al.*, 2000).



Figur 3. Solids lost to the cooking water for pasta samples. OM is a denotation for wholegrain oat flour pasta, OW denotes pasta with oat bran concentrate and Mix stands for pasta with both oat flour and oat bran concentrate. The numbers (1, 2 and 3) corresponds to the level (%) of oat β-glucan in the formulation.

4.2.4 Water absorption

The result demonstrates a significant difference in water absorption between OW and OM samples (table 4), and between samples containing 1% β-glucan compared to 2% and 3% (table 5). The lower values obtained for oat meal pasta could relate to an interrupted protein-starch matrix, resulting in loss of starch and an inferior ability to withhold water. OM2 and OM3 had higher values for water absorption then OM1 (figure 4), which probably relates to the higher level of β-glucan in these samples and the ability of β-glucan to withhold water. Overall, increased water absorption was associated with higher level of β-glucan substitution, which might be explained by the high water retention of soluble fibre. There was no difference observed for OW or Mix2 samples compared to the control (figure 4), which is in line with results for similar levels of β-glucan substitution in other studies (Chillo *et al.*, 2011; Brennan & Tudorica, 2007). In contrast, Brennan and Cleary (2006) reported increased water absorption with increased level of β-glucan concentrate, however, β-glucan incorporation levels were higher in this study and ranged between 2.5%-10%.



Figur 4. Water absorbed during cooking for pasta samples. OM is a denotation for wholegrain oat flour pasta, OW denotes pasta with oat bran concentrate and Mix stands for pasta with both oat flour and oat bran concentrate. The numbers (1, 2 and 3) corresponds to the level (%) of oat β-glucan in the formulation.

4.3 Colour of pasta

Oat flour pasta and pasta with oat bran concentrate exhibited different colour profiles, as demonstrated in table 4. OM samples were darker and had somewhat lower values for redness and yellowness. A darker colour was also seen with higher β-glucan substitution level, which was also associated with higher values for redness and lower yellowness. These results are not surprising as lower substitution level equals higher amount of durum flour, known for its light yellow colour. The colour of pasta is strongly associated with quality, and a light yellow colour is desirable (Fuad & Prabhasankar, 2010). Samples with oat bran concentrate did in general have brightness and yellowness values closer to the control, and are thus likely to have higher acceptability among consumers. As could be expected when mixing oat flour and oat bran concentrate, Mix2 had brightness and yellowness values in between OW and OM samples (table 6). Compared to the control, Mix2 was somewhat darker and had lower values for yellowness.

Only the sample with 1% β-glucan from oat bran concentrate did not differ significantly regarding any colour coordinate (L, a and b) compared to the control. This can be compared to results from Chillo *et al*. (2011) concluding that substitution with barley concentrate, up to a level of 10% β-glucan, did not affect the colour of pasta. This suggests that barley concentrate might have less severe effect on pasta colour and thus may be better suited for improving the β-glucan content of pasta. However, today darker wholemeal and fibre pasta are common on the market and there is a possibility that darker colour might be associated with a healthier product. What is an acceptable colour is a question for the consumer and should be further evaluated in a consumer acceptability test.

Table 6. Values for colour coordinates L, a and b for uncooked pasta.

	Colour L	Colour a	Colour b
Control	85.22[a]	1.11[ab]	19.67[a]
Mix2	83.17[bc]	1.17[ab]	17.40[bcd]
OM1	83.07[bc]	0.92[b]	16.85[cd]
OM2	81.54[cd]	1.04[b]	16.40[d]
OM3	80.51[d]	1.35[a]	16.20[d]
OW1	84.72[ab]	1.12[ab]	18.39[ab]
OW2	83.18[bc]	1.37[a]	18.12[bc]
OW3	82.97[bc]	1.32[a]	17.50[bcd]

Values in the same column with the same letter are not significantly different. L measures brightness, where brighter sample gives higher values, a measures redness when positive and greenness when negative, b measures yellowness when positive and blueness when negative. OM is a denotation for oat flour pasta, OW denotes pasta with oat bran concentrate and Mix stands for pasta with both oat flour and oat bran concentrate. The numbers (1, 2 and 3) corresponds to the level (%) of oat β-glucan in the formulation.

4.4 Sensory analysis

The mean values from the sensory evaluation of pasta with OM3, OW3, Mix2 and a control are shown in table 7. OM3 had the lowest scores for firmness and elasticity while stickiness and grain flavour was higher than for other samples. OM3 did also have the lowest score for overall acceptability. OW3 had significantly lower elasticity then the control; meanwhile acceptability scores were somewhat higher, but without reaching significance. The Mix2 sample did not differ from the control regarding any sensory parameter, and had the highest value for overall acceptability.

Substitution of pasta with oat flour had a severe effect on sensory attributes, which is in agreement with results obtained by Bustos *et al*. (2011), evaluating oat bran enriched pasta, and Chillo *et al*. (2009), studying oat pasta with addition of structuring agents. The loss of firmness might be related to disruption of the protein-starch matrix and therefore less attractive forces between particles in oat pasta. Lack of elasticity is likely associated with the lower content of semolina, and the larger particle size of oat flour (Peressini *et al.*, 2000). The high MW and low ratio of (1→3): (1→4) linkages in oat β-glucan may also contribute to a less elastic gel formation (Webster & Wood, 2011; Lazaridou *et al.*, 2003). As suggested by Chillo *et al.* (2009), the increased stickiness may be explained by an increased amount of water absorbed by the matrix, dissolving amylose and leading to amylopectin on the pasta surface. Sinesio *et al.* (2008) suggests that incorporation of barley flour up till 20-30% in pasta, levels comparable to oat flour used in OM1, did result in acceptable sensory properties. It would therefore be interesting to carry out a sensory evaluation on samples with lower substitution levels to establish if they receive more acceptable scores.

For OW samples only elasticity had a significantly lower value than the control, which might be related to lower gluten content and the presence of high MW β-glucans. This result is supported by Brennan and Tudorica (2007) for pasta with 2.5% β-glucan from barley concentrate. Brennan and Tudorica (2007) concluded that higher substitution levels resulted in lower firmness and increased stickiness, which is also supported by Cleary and Brennan (2006). Chillo *et al.* (2011) did not notice any effect on firmness, while stickiness was severely affected for all levels of barley β-glucan substitution. Differences in manufacturing procedures as well as in study design may explain these results. While a semi-trained panel was used for texture evaluation in this study, a Texture Analyser was used in studies evaluating barley β-glucan pasta. Perhaps differences may also relate to different properties of oat- and barley β-glucan concentrates, and it would be interesting to conduct a study comparing these two raw materials and their effect on pasta quality.

The sensory evaluation performed in this study should be seen as a pilot trial. Descriptive methods are not developed for untrained panellists, and even if the participants had good knowledge and understanding of the product, they did not have extensive experience of sensory assessments. There was no significant difference in results from the two sessions, which suggest that the panellists did have a good understanding of evaluated attributes. However, it could also relate to a large difference between samples, resulting in a somewhat overly optimistic result. If the project is taken further a panel consisting of 8-12 highly trained assessors should be used to determine the differences between sensory attributes of pasta samples. It would also be interesting to perform a larger consumer test to evaluate which level of β-glucan incorporation is considered acceptable.

Table 7. Sensory evaluation and over-all acceptability of β-glucan enriched pasta.

Sensory observation	Sample			
	Control	OW3	OM3	Mix2
Firmness	4.5^{a}	4.3^{a}	1.3^{b}	3.9^{a}
Stickiness	4.5^{b}	4.4^{b}	7.0^{a}	4.0^{b}
Elasticity	4.5^{a}	3.3^{b}	0.9^{c}	4.2^{ab}
Grain flavour	4.5^{b}	5.5^{ab}	6.3^{a}	5.5^{ab}
Overall acceptability	5.1^{a}	5.4^{a}	1.8^{b}	5.7^{a}

Values in the same row with the same letter are not significantly different. A linear scale ranging from 0-9 was used, and the control sample was prepositioned at 4.5 for comparative purpose. OM is a denotation for whole-grain oat flour pasta, OW denotes pasta with oat bran concentrate and Mix stands for pasta with both oat flour and oat bran concentrate. The numbers (2 and 3) corresponds to the level (%) of oat β-glucan in the formulation.

4.5 Health claims

All pasta samples produced in this study are supposed to contain at least 1% β-glucan and can thus be marketed with health claims regarding β-glucan and maintained and/or reduced cholesterol levels (EFSA, 2012). None of the samples are likely to meet the criteria for statements regarding β-glucan and normal blood glucose levels, which is only valid for foods containing 4 g β-glucan for each 30 g of available carbohydrates per portion (EFSA, 2012). Calculations, based on content of non starch polysaccharides given by the suppliers (table 2), suggest that OM3 and OW3 could be relevant for claims regarding dietary fibre and increased stool volume. However, this statement would only be relevant if the health claim referred to 6 g dietary fibre per 100 g uncooked pasta. It has been argued that the claim referrers to fibre content in 100 g cooked pasta. If this is the case, none of the products will reach the requested level for any statement regarding dietary fibre content.

Due to the high cost of oat bran concentrate, levels above the required amount to reach 1% β-glucan in the final product could be questionable as no additional marketing advantage is likely to be achieved. Regarding oat flour, higher levels than necessary for stating a health claim should be avoided due to severe effect on quality attributes. As long as no health claim regarding β-glucan and prebiotic effect has been approved, it is questionable to launch products containing more than 1% of the health promoting fibre.

4.6 Pasta for the Fibflo project

The Mix2 sample was produced for the Fibflo project. In the Fibflo study, evaluating the prebiotic effect of β-glucan, 22 participants were assigned to a diet high in oat β-glucan. Consumption of one portion of Mix2 pasta contributed to 2 g oat β-glucan. OM and OW samples were evaluated in a bench-top test to decide on a proper formulation for the Mix2 pasta. The Mix2 pasta did in turn pass a bench-top evaluation before it was produced in greater quantities. Thirteen kilos of the Mix2 pasta was produced, by hand, for the study. The recipe was scaled up, so that 1 kg of flour mix could be prepared at once. However, the greater quantity resulted in longer drying cycles and instead of 2*10 min, 2*20 min in the air oven was required to get the nests dry. The increased drying time limited the quantities that could be produced each day. Results from the quality evaluation indicated that the Mix2 sample only differed from the control regarding brightness and yellowness (table 6). Due to high similarity to the control, it is likely that the Mix2 tagliatelle had high acceptability among participants of the Fibflo study.

5 Conclusion

This study suggests that the use of oat fractions to replace durum semolina may be possible in order to obtain pasta with a high content of β-glucan and potential health benefits. Generally, addition of β-glucan was found to increase cooking loss, decrease elasticity and reduce the brightness and yellowness of pasta. This effect was dependent both on the source of β-glucan, and the level of incorporation. Substitution with oat flour had an overall negative effect on pasta quality, meanwhile replacement with oat bran concentrate showed quality characteristics similar to the control. With higher substitution levels the negative impact on cooking loss and colour of pasta was greater. By mixing oat flour, oat bran concentrate and semolina in the right proportions it was possible to produce pasta with 2% β-glucan and quality attributes similar to the control.

All evaluated pasta samples fulfil the criteria for a health claim regarding β-glucan and maintained and/or reduced cholesterol levels. Regarding prebiotic effect of products with β-glucan, the evidence is still insufficient and more *in vivo* studies are required to determine if β-glucan selectively promotes growth and activity of probiotic bacteria. As long as no health claim regarding β-glucan and prebiotic effect has been approved, it is questionable to launch products containing more than 1% of the health promoting fibre. The next stage of this research would be to evaluate the sensory aspects of samples with 1% β-glucan, and to establish consumer acceptability of β-glucan enriched pasta.

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Appendix 1 – Form for sensory evaluation

Sensoriskt test av pasta

Välkommen till detta sensoriska test av pasta! Läs noggrant igenom denna beskrivning innan du påbörjar bedömningen och fråga om någonting är otydligt. Proven ska bedömas var för sig i den ordningen de serveras, från vänster till höger. Skölj gärna munnen med vatten emellan proverna. Du har även tillgång till smörgåsrån som kan vara bra för att neutralisera smaken mellan proven. Om du inte vill svälja det aktuella provet kan du spotta ut det i den vita plastmuggen. Bedöm intensiteten av varje attribut för vart och ett av proven genom att sätta ett kryss på den horisontella linjen. Ett referensen prov är utsatt i mitten av skalan, och du kan utgå ifrån detta i din bedömning av proven. Du kan inte sätta två kryss på samma ställe, utan proven måste skiljas åt. Glöm inte att skriva provets nummer ovanför krysset. Den sista frågan är en fråga om gillande och du ska här markera hur mycket Du tyckte om provet, du ska även markera hur mycket du tyckte om referensprovet. Lämna gärna kommentarer om proverna i slutet av formuläret.

Var god fyll i nedanstående.
Placeringsnummer:
Omgång:

Lämna formuläret till testledaren när du är klar.
Tack för din medverkan!

Förklaring av attribut

Fasthet: Bedöms genom att pressa pastan mellan fingrarna, eller genom att bita i den med framtänderna.

Klistrighet: Bedöms visuellt genom att se hur mycket två pastastrån häftar ihop när man försöker separera dem.

Elasticitet: Bedöms genom att se hur väl pastan återgår till sin ursprungliga form när man sträcker ut den.

Spannmålssmak: Bedöms efter hur tydligt spannmål/havre träder fram i smaken av pastan.

Sensorisk bedömning av pasta

Fasthet

Lite ______________________________ Mycket

Klistrighet

Lite ______________________________ Mycket

Elasticitet

Lite ______________________________ Mycket

Spannmålssmak

Lite ______________________________ Mycket

Hur mycket gillade du produkten?

Extremt lite ______________________________ Extremt mycket

Övriga kommentarer:

____

____

____

____

Tack för din medverkan!

Appendix 2 – Popular science summary

Pasta for a healthy generation

A health promoting fibre has been successfully incorporated into pasta. The fibre contributes to a healthy heart and makes the new pasta a promising product for the health conscious consumer.

With increased demand for healthy food products there is a constant desire to improve the nutritional value of foods. Oats contain a high amount of the healthy fibre β-glucan. By using fibre rich oat bran it is possible to produce high quality pasta rich in β-glucan and with possible heath benefits. β-Glucan is known for its beneficial effect on blood cholesterol levels and glucose metabolism. The soluble fibre has also been suggested to reduce blood pressure, enhance the immune system and to stimulate growth of beneficial bacteria in colon. The new pasta has an improved nutritional value and is a good alternative for the health conscious consumer.

High quality pasta

Due to its content of high quality protein, durum semolina is perfect for producing pasta with desirable eating and cooking properties. To enhance the nutritional value of pasta, semolina was substituted with oat flour or oat bran concentrate, maid from the fibre rich outer layer of oats. Addition of oat flour had a negative effect on pasta, and resulted in dark colour and poor cooking quality. Addition of oat flour also resulted in a soft, sticky, and less elastic pasta that had a palpable taste of oat. Due to a higher concentration of β-glucan in oat bran concentrate a lower quantity was needed to reach desired level of β-glucan in the final products. Despite a somewhat darker colour and loss of elasticity, a sensory panel considered the oat bran pasta, with 3% β-glucan, as good as regular semolina pasta. It was also possible to produce acceptable pasta, with 2% β-glucan, by mixing oat flour, oat bran concentrate and semolina in the right proportions.

Health claims – a marketing advantage

New and stricter regulations regarding health claims have made it more difficult for food companies to market their products as functional foods. Pasta which contains 1% β-glucan will, however, fulfil the criteria for a health claim regarding maintenance/reduction of cholesterol levels. None of the produced pastas contained enough β-glucan to fulfil the claim regarding beneficial effect on blood glucose levels. As the interest for healthy foods are growing, cholesterol lowering pasta is likely to be well received on the market.

Food for beneficial bacteria

Prebiotic foods are foods which contains fibres that can stimulate the growth of beneficial bacteria in colon. The fibre β-glucan has been suggested to possess such properties. However, until this stage there is not enough support for the effect on the human colonic flora. Neither is there enough research on the long term effect of consumption of prebiotic fibres. The prebiotic effect of β-glucan is a hot research topic, and recently Lantmännen, together with researchers at Karolinska Institutet, initiated a study on human subjects. When results are ready, we might get a better understanding of the prebiotic potential of oat fibres.

A long and healthy life demands careful food choices. The desire for a healthier living puts pressure on the food industry. Incorporation of beneficial ingredients often affects the quality of the products, and can thus be difficult. By using oat bran concentrate, the health promoting fibre β-glucan could be successfully incorporated into pasta. The new formulations make it possible to market pasta for a healthy generation.