Development of an Integrated *Pure Oat* Cultivation and Processing Chain for Patients Suffering from Coeliac Disease

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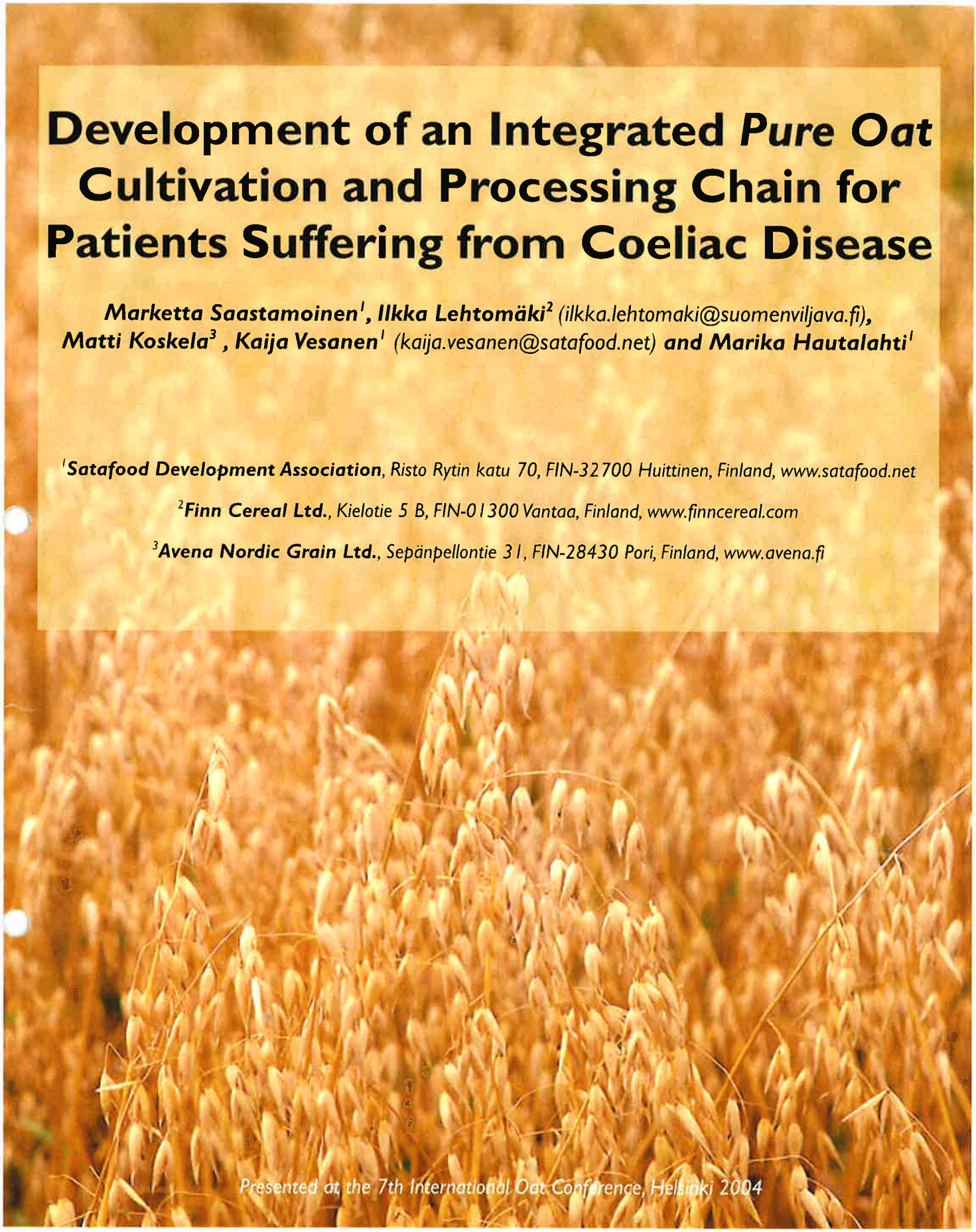

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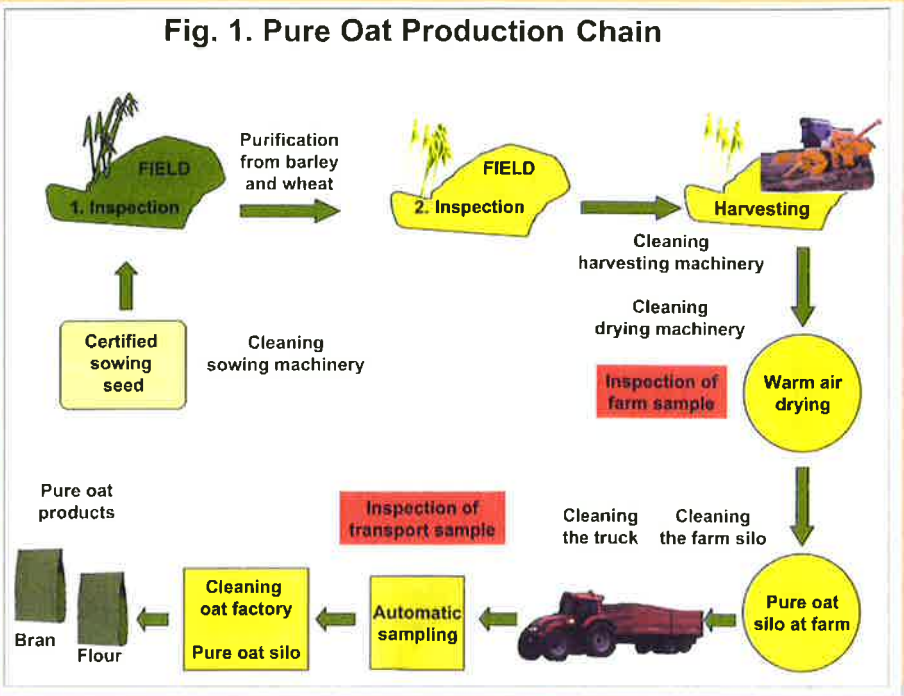
Summary

The protein gluten found in most monocotyledonous cereal crops e.g., wheat, barley and rye causes coeliac disease. Rice, maize and millet do not contain gluten and thus are suitable for consumption by coeliac patients. Many research results also support the suitability of oat (Avena sativa L.) products for consumption by coeliac patients. Oats are an acceptable part of the diet of coeliac patients in Finland, Sweden, Norway and the United Kingdom. Oat products for coeliac patients must be marketed in Finland with the claim: 'contains oats and gluten-free compounds'. A high number of foreign grains often limits the suitability of oats for consumption by coeliac patients.

The objective of the project was to develop an integrated ***pure oat*** cultivation and processing chain, which in practice meant ***pure oats*** containing fewer than 6 seeds of foreign cereal grains per kilogram of oats. The European Guidance and Guarantee Fund, local communities and companies financed the project.

The ***pure oat*** cultivation chain was controlled at every step, from selection of farms, sowing of seed, cultivation, harvesting, transport from fields to farm, drying, storage, and transport of harvested grain from farm to industry.

Fig. 1. Pure Oat Production Chain



The number of foreign seeds was counted in farm samples and samples taken from the vehicle transporting the ***pure oats***. The ***pure oat*** processing chain from receiving, de-hulling and milling all the way to packing was also tightly controlled. All the final gluten contents of both ***pure oat*** samples and products were much below 0.02 g/100 g oat groats.

In the second year 100% and in the first year 42% of the oat fields were approved during field inspections. The project educated farmers in the techniques for growing and handling ***pure oats*** and resulted in development of a quality control system for processing ***pure oat*** products.

Introduction

The protein gluten found in most monocotyledonous cereal crops, e.g. wheat, barley and rye, causes coeliac disease. Rice, maize and millet do not contain gluten and thus are suitable for consumption by coeliac patients. In Finland the major cultivated cereals crops are barley, oats, wheat and rye. In many European countries bread constitutes a staple part of the diet for adults and young people. The diet of coeliac disease patients is weak, due simply to the lack of cereals.

In Finland 20 000 persons have a diagnosed coeliac disease, while the number having non-diagnosted symptoms is probably ten times this amount. Research results support the suitability of oats (Avena sativa L.) for consumption by coeliac disease patients (Janatuinen et al. 1995, Kemppainen 1997). Oats are also a suitable part of the diet for patients suffering from dermatitis hermatiformis caused by gluten proteins (Hardman et al. 1997). As a result oats have been accepted as a staple food for coeliac disease patients in Finland, Sweden, Norway and the United Kingdom. Oat products in Finland must be marketed with the claim: 'contains oats and gluten-free compounds'. The American Dietetic Association is currently advising coeliac patients to use only uncontaminated oats in small amounts per day (Thompson 2003).

The Codex Alimentarius standard defines gluten-free foods as "gluten-free means, that the total nitrogen content of the gluten-containing cereal grains used in the product does not exceed 0.05 g per 100 grammes of these grains on a dry matter basis" (CODEX STAN 118, 1983). A new standard under discussion that would decrease the gluten level to 0.02 / 100 g dry matter. That level has also been proposed in Finland (The Finnish Coeliac Society, personal communication 2004). The use of oats as a food for coeliac disease patients is often limited by the high amount of seeds of foreign cereal crops. The present report describes a cultivation, logistics and production-scheme for pure oat products.

Material and methods

A quality control chain for pure oat production was planned. The maximum number of foreign grains, namely wheat, barley, rye and triticale, was 6 seeds per kilogram oats, corresponding roughly to a foreign protein level of 0.02 g per 100 g dry matter.

Pure oat production was controlled at each step in the cultivation chain: selection of farms and fields, seed material, inspection of oat fields twice per summer, machinery (sowing equipment, harvesters etc.), transport of grain from fields to farms and from farms to food industry, drying the grain, treatment of the grain at food industry.

The oat fields were inspected twice each summer: at the heading of barley and oats and before harvesting. Foreign cereal plants were removed from the fields. The purity of the preliminary samples and the samples of each seed lot received at the oat processing factory was inspected. A special reference material was developed for analysing the gluten content of oat grain. The gluten contents were analysed from the oat groats and the oat products using the ELISA, Gluten Lab-Test (Transia, Lyon), AOAC method (AOAC 991: 19) (AOAC 2000) at the AnalyCen laboratory in Sweden.

The contents of the heavy metals cadmium, lead and arsenic, were analysed in pure oat samples. In the second year the pure oats were also analysed for *Fusarium* toxins, ochratoxin A, zearalenone and pesticides at the Chemistry Laboratory of MTT Agrifood Research Finland. The gluten levels were analysed in normal grain, pure oat grain, NATUREAL® products (http://www.natureal.fi/en/Products/), pure NATUREAL® products and at critical processing points in the milling factory.

Results and discussion

The most significant steps in the pure oat production chain are presented in Fig I. In the first year the accepted pure oat cultivation area was 42% of the total oat area, while in the second year the entire area was found suitable. The main reason for rejection in the first year was excessive contamination with foreign grains due to inferior seed material.

Table 1. Gluten contents of reference oat samples

Reference oat sample	Composition	Gluten content g/100 g	Theoretical prolamin contents[1], g/100 g Oats	Wheat	Barley
Pure oats	Other cereal grains blocked out	0.002	1.0-2.25		
Pure oats	+ 6 barley grains/1 kg	< 0.002	1.0-2.25		0.0014-0.0021
Pure oats	+ 60 barley grains/1 kg	0.003	1.0-2.25		0.014-0.021
Pure oats	+ 60 wheat grains/1 kg	0.016	1.0-2.25	0.010-0.015	
Pure groats	Other cereal grains blocked out	< 0.002	1.4-2.5		
Pure groats	+ 6 barley grains/1 kg	< 0.002	1.4-2.5		0.0014-0.0021
Pure groats	+ 60 barley grains/1 kg	0.002	1.4-2.5		0.014-0.021
Pure groats	+ 60 wheat grains/1 kg	0.010	1.4-2.5	0.011-0.015	

[1] Calculation was made by following values:
Oat grains: protein content 10-14 %, prolamin content 10-15 %
Oat groats: protein content 15-17 %, prolamin content 10-15 %
Barley: 1000 grain weight 40-50 g, protein content 12-14 %, prolamin content 50 %
Wheat: 1000 grain weight 35-45 g, protein content 12-14 %, prolamin content 40 %

The gluten contents of the special reference material containing different amounts of barley or wheat grains are shown in Table 1. The gluten content of pure oats was 0.002 g/100 g dry matter. Six barley grains per kilogram of oats did not appreciably increase the gluten content, while 60 grains increased the gluten content in a slight. The wheat grains resulted in a higher content of gluten than the barley grains. The used ELISA method for gluten content is specific for detection of omega-gliadin.

A pure oat batch was de-hulled and processed to bran and flour at Finn Cereal's production facilities. The gluten levels of both normal and pure oat products are shown in Table 2.

Only one normal oat bran product exceeded the maximum gluten-free level of 0.05 g/100 g dry matter. The quality of all other analysed normal oat products from Finn Cereal were acceptable for coeliac disease patients. The maximum level of foreign grains tolerated in normal oat processing production at Finn Cereal is 1 %. The gluten level of oat starch was very low: < 0.002 g/100 g dry matter. In all oat products processed from pure oats the gluten levels were < 0.002 g/100 g dry matter. It can be seen that the gluten contents of normal Finn Cereal oat products are low, but the purity can be increased and guaranteed by using selected high quality raw material for processing.

Table 2. Gluten contents of pure and normal NATUREAL oat products of Finn Cereal analysed by ELISA method of AOAC (991:19) (2000).

Oat Product	Year 2002 Gluten, g/100 g	Year 2003 Gluten, g/100 g
PURE OAT PRODUCTS:		
Oat bran, native	<0.002	
Oat bran, native	<0.002	
Oat flour 1 (endosperm)	<0.002	
Oat flour 4 (endosperm)	<0.002	
NORMAL OAT PRODUCTS:		
Oat bran, native	0,015	0,005
Oat bran, native	0,014	0,006
Oat bran, native	0,060	
Oat bran, extruded granule	<0.002	
Oat bran, extruded granule	0,008	
Oat bran, extruded granule	0,007	
Oat bran, extruded crushed granules	0,008	
Oat flour (endosperm)	0,008	
Oat flour 1 (endosperm)		0.002
Oat flour 2 (endosperm)		0.002
Oat starch	<0.002	
Oat filter from processing	>0.500	
Bran filter from process	>0.500	

Codex Standard for gluten-free foods is 0.05 g N/100 g d.m. gluten containing grains.
Codex Standard in preparation for gluten-free foods is 0.02 g N/100 g d.m. gluten containing grains.
Detection limit of gluten is 0.002 g/100 g (0.001 g/100 g gliadin)

The cadmium, lead and arsenic levels were analysed from the pure oat groat samples. All cadmium values were low and far from the maximum limiting value of l00 µg/kg accepted for food oats in the EU (Table 3). The lead contents were very low and clearly below the 200 µg/kg limiting value accepted for oats in the EU. The arsenic contents as analysed from the harvest in 2003, were low. No traces of chemical residues were found.

Table 3. Heavy metal contents of pure oat groats in 2002-03.

Year	Cultivar	Samples n	Cadmium, µg/kg mean	max	min	Lead, µg/kg mean	max	min	Arsenic, µg/kg mean	max	min
2002	Aarre	8	36	53	17	19	33	10	-	-	-
	Roope	3	38	41	36	-	-	-	-	-	-
	Veli	12	42	65	26	26	61	14	-	-	-
2003	Aarre	10	37	42	24	9	22	5	18	34	9
	Roope	1	30			4			9		
	Veli	5	39	44	37	10	31	3	12	24	9
Maximum level for food oats in the EU			100 µg/kg			200 µg/kg					

Mycotoxin levels were analysed in the pure oat samples taken from the 2003 harvest (Table 4). Ochratoxin A and zearalenone were not detected in any sample. The highest DON content was 240 µg/kg, which is well below the limiting value for DON 1500 µg/kg proposed by the EU for food oats. The maximum values of T-2 and HT-2 toxin contents were 150 µg/kg and 140 µg/kg, respectively.

Table 4. Mycotoxin contents of pure oat groats in 2003.

Cultivar	Fields n		*Fusarium*- toxins, µg/kg DON	DAS	3-AcDON	F-X	NIV	T-2	HT-2	Ochra-toxin µg/kg	Zeara-lenone µg/kg
Aarre	7	mean	120	<25	<25	<25	<25	21	23	<2	<30
		max	190	<25	<25	<25	<25	150	140	<2	<30
		min	<25					<25	<25		
		s.d.	72					57	52		
Roope	1		24	<25	<25	<25	<25	66	61	<2	<30
Veli	5	mean	104	<25	5	<25	<25	14	11	<2	<30
		max	240	<25	24	<25	<25	47	33	<2	<30
		min	<25		<25			<25	<25		
		s.d.	90		11			21	16		
Maximum value for food oats										5	
Proposed maximum value for food oats in the EU			1500	-	-	-	-	open	open		100

Detection limit of DON, DAS, 3-AcDON, F-X, NIV, T-2 and HT-2 25 µg/kg
Detection limit of ochratoxin A 2 µg/kg
Detection limit of zearalenone 30 µg/kg

Our system for pure oat production was successful and showed that it is possible to produce nutritionally high-value oats for consumption by coeliac disease patients.

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