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ORIGINAL ARTICLE

Nutrient intakes during diets including unkilned and large amounts of oats in celiac disease

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Background/Objectives: We have shown earlier that consumption of moderate amount of oats improve intakes of vitamin B_1, fiber, magnesium and iron in celiac patients using gluten-free diet (GFD). The objective of this study was to clarify the effect of high amount of both kilned and unkilned oats on food and nutrient intakes in celiac patients in remission. Kilning as an industrial heating process is performed to preserve the main properties of oats and to lengthen its useableness. Kilning may, however, change the protein structure of oats and therefore influence on the intake of nutrients.
Subjects/Methods: The study group consisted of 13 men and 18 women with celiac disease in remission. The patients who were earlier using moderate amount of oats as part of their GFD were randomized to consume kilned or unkilned oats. After 6 months, the patients changed the treatment groups. The goal of daily intake of oats was 100 g. Food records and frequency questionnaire were used to follow nutrient intakes.
Results: Type of oats did not affect the amount of oats used. In the group using kilned oats, the intake of vitamin B1 and magnesium and in the group of unkilned oats that of magnesium and zinc increased significantly during the first 6 months ($P \leqslant 0.05$).
Conclusions: Large amounts of oats, both kilned and unkilned in GFD, can increase intakes of nutrients in celiac patients in remission. Oats improve the nutritional value of GFD.
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Keywords: nutrient intakes; celiac disease; oats; unkilned oats

Introduction

Celiac disease (CD) has been defined as a state of increased immunologic responsiveness to ingested wheat gliadin or to similar prolamins of rye and barley in genetically predisposed subjects (Ciclitira *et al.*, 2005). Patients known to suffer from CD have to undergo a life-long gluten-free diet (GFD). Gluten withdrawal from the diet generally leads to recovery of duodenal mucosa (Wahab *et al.*, 2002). Conventional GFD has been shown to be deficient in many nutrients in a proportion of patients (Hakala-Lahtinen *et al.*, 1981; Björkman *et al.*, 1985; Collins *et al.*, 1986; Kemppainen *et al.*, 1995; McFarlane *et al.*, 1995; Kemppainen *et al.*, 1998; Thompson *et al.*, 2005; Kinsey *et al.*, 2008). One reason for this may be that some CD patients observe the gluten-free products unpalatable and therefore reduce their intake of cereal products after commencing a GFD (Størstud *et al.*, 2003a).

Oats have been proven to be generally well tolerated in CD and dermatitis herpetiformis as part of GFD (Janatuinen *et al.*, 1995; Srinivasan *et al.*, 1996; Hardman *et al.*, 1997; Reunala *et al.*, 1998; Hoffenberg *et al.*, 2000; Janatuinen *et al.*, 2000; Janatuinen *et al.*, 2002; Högberg *et al.*, 2004; Størstud

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et al., 2003b). Størsrud *et al*. (2003a) showed that high amount of regular industrially processed oats improved the nutritional value of GFD. Kilning, heat treatment to meet the requirements of convenience of use as well as the flavour and taste of oats with increased time of useableness, is performed to inactive the enzyme lipase (Ganssmann and Vorwerek, 1995). Kilning causes changes in oat proteins occurring in reduction of the solubility of avenin in aqueous ethanol (Kemppainen *et al*., 2008). All these phenomena form the background to analyze the effect of unkilned and high amount of oats on the intake of nutrients in adult patients with CD.

Subjects and methods

Subjects

The study included 33 celiac patients in remission earlier using moderate amounts of regular kilned oats as part of their GFD. They were recruited for the study during the summer–autumn of 1998 in Kuopio University Hospital area and randomized either to consume large amounts of kilned (group A) or unkilned (group B) oats. After 6 months patients changed the treatment groups. They were advised to consume oats 100 g daily. The final study included 13 men and 18 women with two withdrawals, one woman because of abdominal symptoms and another female patient because of pregnancy. Group A using first kilned oats consisted of 6 men and 10 women and the Group B with unkilned oats of 7 men and 8 women. Mean age was 47 (range 16–64) years. CD had been diagnosed 8.6 (range 7–29) years earlier. The patients had used GFD for 8.3 (1–29) years and oats for 5 (0–9) years on an average.

Diet

Both verbal and written instructions regarding the diet were given by a nutritionist. The daily intake of oats was to reach 100 g. Half of the daily oats was given as flour and half baked in bread during 12 months. The bread contained 75% oat and 25% maize flour. Salt, yeast and water were other ingredients. The 100 g of daily oats consisted of minimum 120 g of oat bread and 50 g of oat flour. Oat flour was used for cooking and baking. Bread and oat flour were donated free of charge. Oats and oat products were obtained from Melia OY, Farina Oy and Moilanen bakery (gluten-free bakery). The oats were cleaned and dehulled in a commercial milling company. The sieving, cleaning, dehulling and kilning apparatuses were used only for processing of oats in order to prevent contamination by other cereals. To prevent atmospheric oxidation, oats are given a hydrothermic treatment (kilning) before further processing. The kilned oat groats were milled in a small pilot mill. The flour was packed with small packing machinery used only for processing of naturally gluten-free cereals. The unkilned oat groats were milled into small flour portions according to the consumption eight times during the study and the flour was kept in frozen storage until given to the patients. This was carried out in order to reduce the formation of the rancid taste in these unkilned oat products.

Breads were baked four times during the study. The breads were stored frozen (–18°C) until used. Samples of the flours and breads were taken from each process randomly to be tested for their prolamins by revealing possible contaminating prolamins of wheat, barley and rye. The electrophoretic molecular weight profiles of the prolamins, also of the possible contaminant prolamins, are powerfully exposed after staining with polyclonal anti-gliadin. The molecular weight profile of oat prolamins is around 20–30 000, whereas the wheat, rye and barley prolamins are greater in their molecular weight, about 30–70 000. Western blot of total protein extracted from oat products was performed and treated against polyclonal antigliadin (Sigma, antigliadin, wheat G 9144: Saint Louis, MO, USA). No contaminant prolamins of wheat, barley or rye were found in the oat products used by the patients (Kemppainen *et al*., 2008).

Follow-up investigations

Records and frequency questionnaires of food consumption and symptoms and laboratory investigations were carried out during the 12 months. The patients were asked to evaluate symptoms (abdominal pain, flatulence, abdominal distention and diarrhea) and welfare (bowel movement and health) with questionnaire (Kemppainen *et al*., 2008). Gastroscopy to obtain duodenal biopsies with histopathological analyses and antiendomysial antibody assay of serum were also performed in the beginning, at 6 and 12 months to confirm remission or to detect possible relapses in CD. Description of total, subtotal, partial crypt villous atrophy or normal (Roy-Choudhury *et al*., 1966) with gradings 3, 2, 1 or 0, respectively, were used. Mucosal mononuclear cell infiltration was graded as normal, mild, moderate or severe. The same pathologist (VMK) conducted all the duodenal histopathologic examinations.

Frequency questionnaire was filled at baseline, at 6 and 12 months in order to obtain data on the compliance with GFD and the use of oats. Patients kept four-day food records at baseline, at 1, 3, 6, 7, 9 and 12 months. The intakes of food and nutrients were calculated by the Nutrica computer program (Social Insurance Institution, Turku, Finland), which uses the Food and Nutrient Database of the Social Insurance Institution. The nutrient content data of the gluten-free products, provided by the manufactures, were added into the database before calculations.

Statistical analysis

All statistical analyses were carried out using SPSS statistical program (SPSS Inc., Chicago, IL, USA). The change of the values was calculated. To analyze the consumption of oats the linear mixed-effects model, fitting random effect

subject's interaction was used. The energy intake was studied performing general linear model and repeated measures. The Mann–Whitney *U* test was used to assess the differences between the groups during the first 6 months. Wilcoxon and Friedman tests were applied for the changes during the follow-up within the groups. Bonferreoni correction was used in the analyses (Wilcoxon test). After the Friedman test, the distribution-free multiple comparisons based on the Friedman rank sums between the times points were used to observe which time points differed significantly from each other (Siegel and Gastellan, 1988). The chi-square, Fisher's exact test and Cochran test were used to analyze the differences between the groups in the frequency and proportion of the categorized variables as abnormal laboratory values and abnormal values of nutrient intakes.

Ethical issues

The study was approved by the Ethic Committee of Kuopio University Hospital. All patients received written information concerning the trial, and verbal consent was obtained from each patient before starting the diet. The patients were also informed of the possibility to withdraw from the study at any point of time.

Results

All patients had CD in clinical remission. In the beginning of the study 10 patients had partial villous atrophy and 9 of them had mild mucosal inflammation. Other biopsies were interpreted totally normal. In either group, duodenal villous architecture or mucosal inflammation did not worsen by 6 months but rather improved. At 12 months, only 5 patients had partial villous atrophy and 4 of them mild mucosal inflammation. Other biopsies were normal (Kemppainen *et al*., 1966, 2008). All patients had normal (negative) value of antiendomysial antibody throughout the study (Kemppainen *et al*., 2008). No marked changes occurred in the well-being of the patients, although some had a feeling of abdominal distension (Kemppainen *et al*., 2008). Only one woman with the age of 81 years withdrew from the study because of abdominal symptoms (vomiting). She had used small amounts (20–30 g/vrk) of oats daily during the earlier 9 years. Duodenal biopsies showed mild nonspecific duodenitis. Three patients reported occasional transgression from the diet.

The consumption of oats was both at 6 (96 g/day) and at 12 months (92 g/day) more than its consumption at the baseline (23 g/day) (mixed-effects model, $P=0.001$). The groups did not differ from each other as for the use of oats either at 6 or 12 months. The type of oats, whether kilned or unkilned did not influence the result (mixed-effects model, $P>0.1$).The amounts of other gluten-free cereals decreased during the first 6 months in both groups. The groups did not differ from each other in the use of various other food items either at baseline or during the course of the study (Table 1). At baseline, the groups were similar also for intakes of nutrients (Mann–Whitney *U* test, $P>0.1$).

The intake of energy did not change in the groups during the 12 months (general linear model, $P>0.1$). The intakes of vitamin B_1 and magnesium in group A and those of zinc and magnesium in group B increased during the first 6 months. (Friedman test and distribution-free multiple comparisons based on the Friedman rank sums, $P=0.05$ and Wilcoxon test $P\leqslant 0.05$) (Table 2). The groups did not differ significantly from each other in the intakes of other nutrients during the first half of the follow-up period (Mann–Whitney *U* test, $P>0.1$).

Mean daily intakes of all nutrients in both groups were within recommended dietary allowances without difference between the groups (minimal nutrient intake per day, Finnish recommended dietary allowances) both during the first and the last 6 months (Cochran test, $P<0.05$; chi-square, Fisher's exact test, $P>0.1$).

Table 1 Use of cereals by celiac patients having large amounts of kilned or unkilned oats as part of their gluten-free diet

Variables, mean (± s.d.)	*Group A*				*Group B*				*Difference between groups at 6 months*
	0 Month	*6 Months*	*12 Months*	P-*value*	*0 Month*	*6 Months*	*12 Months*	P-*value*	
All cereals (g)	183 ± 80	182 ± 48	194 ± 97	0.78	251 ± 136	215 ± 117	202 ± 96	0.63	0.80
Oats (g)	24 ± 24	93 ± 28[a]	86 ± 29	0.000	24 ± 18	96 ± 38[a]	98 ± 40	0.000	0.74
Gluten free cereals(g)	157 ± 73	89 ± 41[a]	105 ± 86	0.000	227 ± 136	119 ± 98[a]	107 ± 81	0.000	0.77
Other cereals (g)	3 ± 6	0 ± 0	3 ± 8	0.55	0 ± 1	1 ± 2	1 ± 2	0.86	0.83

Group A started using kilned oats.
Group B started using unkilned oats.
Patients changed the oat brand after 6 months.
P-value, the effect of the amount of oats in the group during the 12 months follow-up (Friedman test).
After the Friedman test, the distribution-free multiple comparisons based on the Friedman rank sums between the time points were used to find which time points differed significantly from each other ($P=0.05$).
[a]From 0 to 6 months.
The difference between the groups at 6 months (Mann–Whitney *U* test).

Table 2 Intakes of nutrients in celiac patients using large amounts of kilned or unkilned oats as part of their gluten-free diet

Variables, mean (± s.d.)	*Group A*				*Group B*				*Difference between groups at 6 months*
	0 Month	*6 Months*	*12 Months*	P-*value*	*0 Month*	*6 Months*	*12 Months*	P-*value*	
Energy (kJ)	8079 ± 2386	8352 ± 2337	8493 ± 2649	0.47	9176 ± 2568	8489 ± 2958	9628 ± 2977	0.28	0.92
Carbohydrates (g)	225 ± 71	231 ± 62	238 ± 81	0.94	266 ± 91	238 ± 83	266 ± 79	0.42	1.00
Protein (g)	76 ± 27	81 ± 22	84 ± 24	0.09	83 ± 29	86 ± 40	88 ± 33	0.16	0.98
Fat (g)	76 ± 27	77 ± 24	84 ± 24	0.78	83 ± 24	76 ± 31	93 ± 33	0.03	0.83
Fiber (g)	15 ± 5	17 ± 3	17 ± 5	0.17	15 ± 7	16 ± 5	17 ± 6	0.17	0.38
Vitamin E (mg)	8 ± 3	7 ± 2	8 ± 3	0.98	8 ± 3	8 ± 2	10 ± 3	0.02	0.45
Vitamin B_1 (mg)	1.1 ± 0.3	1.4 ± 0.4[a]	1.3 ± 0.4	0.02	1.2 ± 0.4	1.3 ± 0.5	1.5 ± 0.5	0.25	0.65
Vitamin B_6 (mg)	2.0 ± 0.8	2.2 ± 0.5	2.4 ± 0.6	0.17	1.9 ± 0.7	2.2 ± 0.7	2.6 ± 0.9	0.09	0.95
Vitamin C (mg)	94 ± 54	94 ± 55	104 ± 115	0.65	76 ± 45	73 ± 41	82 ± 38	0.82	0.40
Folic acid (μg)	231 ± 69	235 ± 79	239 ± 78	0.65	214 ± 99	226 ± 64	251 ± 87	0.63	0.89
Calcium (mg)	1272 ± 513	1313 ± 473	1272 ± 513	0.10	1241 ± 576	1213 ± 692	1281 ± 692	0.45	0.55
Magnesium (mg)	339 ± 79	396 ± 87[a]	410 ± 93	0.003	324 ± 109	382 ± 108	432 ± 115	0.002	0.86
Iron (mg)	12 ± 3	13 ± 3	14 ± 4	0.19	14 ± 6	14 ± 5	16 ± 6	0.28	0.80
Zinc (mg)	13 ± 6	17 ± 9	16 ± 5	0.005	12 ± 3	17 ± 10[a]	17 ± 10	0.002	1.00
Selenium (μg)	75 ± 29	72 ± 20	76 ± 22	0.65	74 ± 23	74 ± 26	83 ± 31	0.55	0.92

Group A started using kilned oats.
Group B started using unkilned oats.
Patients changed the oat brand after 6 months.
P-value, the effect of the amount in oats in the group during the 12 months follow-up (Friedman test).
After the Friedman test, the distribution-free multiple comparisons based on the Friedman rank sums between the time points were used to find which time points differed significantly from each other ($P = 0.05$).
[a]From 0 to 6 months.
The difference between the groups at the 6 months (Mann–Whitney *U* test).

During the time period from 6 to 12 months the change of the type of oats from kilned to unkilned oats in group A or from unkilned to kilned one in group B had no significant influence on the levels of measured values of various nutrients. In consumption of vegetables, we found seasonal variation in group A ($P = 0.08$, Friedman test) and in group B ($P = 0.04$, Friedman test). In other food items seasonal variation was not observed within the groups. Neither were intakes of nutrients affected by seasonal variation.

Discussion

The diet actually consumed by patients with CD has been shown to be deficient in nutrients in some of the patients (McFarlane *et al.*, 1995; Thompson *et al.*, 2005). Björkman *et al.* (1985) found a small decrease in the intakes of energy, protein, fat, carbohydrates and iron in women, when they switched to a GFD. We have also reported (Kemppainen *et al.*, 1995, 1998) that intakes of fiber and vitamin B_1 decreased when patients started to follow GFD. Patients with CD are at risk of having an inadequate intake of calcium, fiber and vitamin D (Kinsey *et al.*, 2008). On the other hand, oats offer a possibility to increase nutrient intake of GFD in celiac patients (Kemppainen, 1997). Oats is generally used after industrial processing, for example, kilning. It is not known whether this can affect the intakes of various nutrients. Kilning itself does not seem to be a prerequisite for the tolerance of oats in CD (Kemppainen *et al.*, 2008).

In our study, celiac patients have tolerated pure oats (Kemppainen *et al.*, 2008). Lundin *et al.* (2003) reported that 1 of 19 patients in remission developed villous atrophy and dermatitis herpetiformis after consuming 50 g of oats per day. In another study, (Arentz-Hansen *et al.*, 2004) three of nine patients who also developed villous atrophy with oats challenge, as well as two other patients who appeared to tolerate oats, were shown to have oat avenin-specific and reactive intestinal T-cell lines. In this study, an old woman withdrew because of vomiting during 1 day. Histopathologically mild nonspecific duodenitis, with no clear reference to a relapse of CD was diagnosed. Besides she had been using oats 20–30 g/day for about 9 years.

Contamination of oats with wheat gliadin or barley hordein has been found during 2003–2008 in Europe, the United States and Canada (Hernando *et al.*, 2008). Now it is known that oats meant to be consumed by celiac patients should be first analyzed by R5 Elisa and further by the western blot and polymerase chain reaction techniques to prove its purity. In our study, electrophoresis of prolamins and western blot were used and no contamination was found (Kemppainen *et al.*, 2008).

In this study, celiac patients increased the ingestion of both kilned and unkilned oats to the median of 100 g per day during 6 months. Groups using unkilned or industrially processed kilned oats did not in general differ from each

other in the intakes of nutrients. However, in group A introducing high amount of kilned oats into the GFD led to increased intake of vitamin B_1. In group B starting with unkilned oats no change was found in this respect. The large amount of oats, whether kilned or unkilned, maintained the intake of nutrients and even showed some tendency to improve it.

Størsrud *et al*. (2003b) have reported earlier that adult celiac patients do tolerate large amounts of regular, for example, industrially processed or kilned oats. In addition, the intake of cereal foods increased (Størstud *et al*., 2003a). In this and in an earlier study, (Kemppainen, 1997) oats in GFD increased intakes of nutrients from cereals, but the consumption of all cereals did not change. In this study, the use of large amount of oats (100 g/day) enhanced the intakes of vitamin B_1, magnesium and zinc and somewhat of vitamin B_6. In our former intervention study (Kemppainen, 1997), oats 50 g/day improved the intakes of vitamin B_1 and fiber. Later follow-up showed that 30 g oats per day increased the intakes of magnesium and iron (Kemppainen, 1997). In those studies, the oat users were compared with a group consuming conventional GFD. In the study of Størsrud *et al*. (2003a), oats of 93 g/day enhanced the mean intakes of iron, fiber, vitamin B_1 and zinc.

Our result of seasonal variation in vegetable consumption is in accordance with earlier studies (Hartman *et al.,* 1990; Kemppainen *et al*., 2009). Seasonal variation in other food items and in intakes of nutrients was not found.

In conclusion, oats in GFD can increase intakes of nutrients from cereals. Adding 100 g oats per day as part of GFD increased intakes of vitamin B_1, magnesium and zinc and possibly vitamin B_6 in adult celiac patients in remission. Kilning of oats as an industrial process does not influence these intakes.

Conflict of interest

The authors declare no conflict of interest.

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