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Effect on appetite control of minor cereal and pseudocereal products

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Recent findings suggest that Western diets based on highly palatable foods are likely to be much less satiating than more traditional diets or those typical of less developed countries. In particular, some alternative crops (for example, buckwheat, oat, barley, spelt, rye, quinoa, amaranth) seem to be of great nutritional interest and to represent important recipes for healthier and typical regional foods. The objective of the present study was to investigate the effect on subsequent food intake and feelings of satiety of alternative oat bread, oat and buckwheat pasta and of quinoa as compared with their wheat counterparts and rice, respectively. Three different experiments (one specific for each alternative crop food) were conducted, all with a within-subjects design. The preloading paradigm strategy was used. Results showed that preload energy level influenced total energy intake (preload plus *ad libitum* test meal intake), larger preloads inducing more eating than smaller preloads. No effect of formulation was observed on energy intake, as the consumption of alternative crop formulations did not decrease the total energy intake as compared with that of the counterparts. Satiating efficiency indices (SEI) for alternative crop foods were higher with respect to traditional cereal foods. In particular, white bread was the least satisfying food (SEI $= 0{\cdot}2$) and the different time of consumption (for lunch or as a snack) did not affect energy intake. In conclusion, oat or buckwheat formulations, and also quinoa, may be exploited for their potential impact on eating behaviour, particularly considering they are good sources of functional substances.

Cereals: Pseudocereals: Satiety: Appetite: Eating behaviour

Some foodstuffs may be more effective than others in reducing hunger and subsequent food intake and this may be due in part to the influence of macronutrients upon hunger and satiety (Blundell *et al.* 1988; Green & Delargy, 1997; Porrini *et al.* 1997; De Graaf *et al.* 1999). A reasonable amount of evidence exists to support that the most satiating foods are high in proteins (Westerterp-Plantega *et al.* 1999) or carbohydrates (Blundell *et al.* 1994; Stubbs *et al.* 2001) or fibres (Delargy *et al.* 1995, 1997) or water (Holt *et al.* 1995) (for example, potato, steak, fish, apples, orange, porridge, brown pasta, baked beans).

In particular, high-fibre foods have been shown to be highly satiating (Blundell & Burley, 1987). In a study by Holt *et al.* (1999) it was demonstrated that hunger returns at a lower rate after a high-fibre, carbohydrate-rich breakfast than after a low-fibre, carbohydrate-rich meal. On the contrary, refined foods have been associated with increased insulin responses and decreased satiety; brown pasta was more satiating than white pasta, wholemeal and grain bread more than white bread, and porridge and all-bran were more satiating than other breakfast cereals (Holt *et al.* 1996). Coarse-wheat breads with intact kernels showed a higher satiety score than did white-wheat breads (Holm & Björck, 1992). Several studies have shown that an increase in the amount of resistant starch in meals promotes a significant reduction in metabolic responses and increases subjective sensations of satiety (Granfeldt *et al.* 1994; Raben *et al.* 1994). Collectively, these findings suggest that Western diets based on highly palatable foods are likely to be much less satiating than more traditional diets or those typical of less developed countries based on relatively unrefined foods (Holt *et al.* 1995, 2001). Moreover, this knowledge has encouraged the food industry to increase the range of available processed carbohydrate foods that have a lower glycaemic response but are more satiating than their counterparts.

At present there is considerable interest in the consumption of alternative crops, such as buckwheat, oat, barley, spelt, rye, quinoa, amaranth, as potential recipes for healthy food production and for special dietary use (diabetes, coeliac disease, phenylketonuria, etc) (Skrabanja *et al.* 2001*a*; Størsrud *et al.* 2003; Di Cagno *et al.* 2004). Several are considered minor cereals, i.e. under-utilised cereals (for example, spelt, rye, einkorn, millet, oat, etc); others are pseudocereals, crops evolutionarily distant from cereals (*Graminaceae*), which produce grains (for example, quinoa, amaranth, buckwheat).

The use of these minor cereals and pseudocereals is of great nutritional interest because of their peculiar composition and the minor components present in these grains (dietary fibre, resistant starch, minerals, vitamins, phenols) (Granfeldt *et al.* 1994; Liljeberg & Björck, 1994; Gutzmán-Maldonado & Paredes-Lopez, 1999; Bonafaccia *et al.* 2000; Zieliński & Kozlowska, 2000; Skrabanja *et al.* 2001*b*; Abdel-Aal & Hucl, 2002; Gabrovská *et al.* 2002; Kim *et al.* 2004).

In particular, food scientists and biochemists are studying the technological and nutritional properties of these minor cereals and pseudocereals as wheat replacements (Coulter & Lorenz, 1990; Ranhotra *et al.* 1995; Hughes *et al.* 1997; Singh & Smith, 1997; Bejosano & Corke, 1999; Valencia *et al.* 1999;

Abbreviations: GF, gluten-free; SEI, satiating efficiency index.

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Ruales *et al.* 2002; Bonafaccia *et al.* 2003; Ogungbenle, 2003; Yilmaz & Dağhoğlu, 2003). For example, oat and buckwheat flours, and also quinoa, have been suggested to be safe for a gluten-free (GF) diet (Størsrud *et al.* 2003; Berti *et al.* 2004*a*; Di Cagno *et al.* 2004).

In the present study, three different experiments were scheduled to investigate the effect of alternative crop formulations and their counterparts on specific and general satiety. Each experiment aimed at comparing a typical Italian food or dish with the same food or dish produced with an alternative crop. In particular, in experiment I, oat and white bread were proposed in order to investigate their potential impact when consumed as preloads immediately before a test meal or as snacks 2 h before a test meal. In experiment II, the effect of different oat, buckwheat and wheat pasta dishes was evaluated when consumed as preloads before a test meal with respect to a test meal alone. In experiment III, the effect of quinoa preloads was compared with rice.

Methods

Subjects

Three different panels were selected for this research, one for each experiment. Fifteen healthy male volunteers (age 22·8 ± 2·2 years; BMI 23·1 ± 3·2 kg/m^2) participated in the bread study (experiment I), fourteen in the pasta study (age 24·0 ± 2·6 years; BMI 23·3 ± 2·7 kg/m^2) (experiment II) and twelve (age 25·4 ± 2·2 years; BMI 23·0 ± 1·9 kg/m^2) in the quinoa study (experiment III). All subjects were recruited from the student population of the University of Milan. They were normal weight for height and were not on any medication or taking any drugs. Furthermore, they declared they were not on a restrictive diet. The study was approved by the Faculty of the Agriculture Ethical Committee.

The recruitment of the volunteers was conducted using data from a questionnaire on subjective eating habits and food preferences (none, normal, high) for ninety-eight foods. The selected subjects had a normal preference for the foods included in the study.

Foods

White bread (regular bread), oat bread (40 % toasted oats), spaghetti (regular spaghetti), oat spaghetti (40 % toasted oats), lasagne (regular fresh pasta; 20 % egg), carboxymethyl cellulose buckwheat lasagne (60 % buckwheat and 40 % precooked rice flour, 30 % egg and 0·5 % carboxymethyl cellulose), buckwheat lasagne (60 % buckwheat and 40 % precooked rice flour, 30 % egg), quinoa (*Chenopodium quinoa*, Willd; Anapqui, Asociacion Nacional de Productores de Quinua) and rice (‘Vialone Nano’; Esselunga, Italy) were tested.

Flours were supplied by Mulino Pagani, Italy. Final products were manufactured in the Food Technology laboratory (Department of Food Science and Microbiology, Faculty of Agriculture, University of Milan).

All pasta dishes were cooked alone in water and then dressed with tomato sauce (GS, Italy).

Quinoa and rice were prepared as ‘risotto’ with aubergine, onion, zucchini and tomato sauce (all the ingredients were put together and cooked adding water).

The chemical composition of the foods determined by means of official chemical analysis (Association of Official Analytical Chemists, 1984) is shown in Table 1. Data on tomato sauce composition refer to the declared nutritional label.

The test meal consisted of a self-selection meal that allowed *ad libitum* consumption of a variety of different foods: baked lasagne, ham, cream cheese, crackers, chips, strawberry yoghurt, apricot jam tart, apple, banana, water. In experiment II, baked lasagne was omitted.

Main procedure

Three different experiments were conducted. A repeated measures design was followed within each experiment. The subjects, who had no knowledge of the aim of the study, were instructed to fast after 22.00 hours the previous evening, consume their standard breakfast before 08.30 hours each test day and to fast until they came to the laboratory. On arrival at 12.45 hours they were seated in a comfortable room.

In all the experiments, a preliminary session (‘specific’ satiety study) was performed in order to evaluate the amount of foods under study necessary to reach ‘specific’ satiety and to decide the large preloads. Subjects were instructed to eat each food served to excess, together with 500 ml water (maximum amount), until they felt ‘comfortably full’ (‘specific’ satiety condition). After this test, the preloading paradigm strategy was used (Kissileff, 1984): each food (preload) was proposed in random order to the subjects at two different energy levels as the first course of a complete *ad libitum* test meal. Large and small

Table 1. Nutrient composition of foods (g/100 g) under study in experiments I, II and III

	Food	Lipid	Protein	Carbohydrate	Fibre	Water	Energy (kJ/100 g)
Experiment I	White bread	2·4	12·0	55·5	3·5	24·7	1222
	Oat bread	3·1	10·3	46·3	5·7	32·6	1063
Experiment II*	Spaghetti	0·8	13·0	20·9	0·0	64·4	599
	Oat spaghetti	1·6	14·9	18·4	0·4	63·6	620
	Lasagne	0·5	6·8	28·9	0·8	61·8	620
	CMC buckwheat lasagne	1·0	5·2	25·1	2·4	64·5	548
	Buckwheat lasagne	1·0	6·6	27·8	1·1	61·9	611
	Tomato sauce	1·7	1·2	5	–	–	167
Experiment III†	Quinoa	3·8	3·4	16·9	4·7	69·8	481
	Rice	2·9	2·4	22·9	0·9	69·6	532

CMC, carboxymethyl cellulose.
* In experiment II we reported separately the nutrient composition of cooked pasta samples and of tomato sauce.
† In experiment III we reported the nutrient composition of cooked and dressed samples.

preloads were selected in order to have two different and distant conditions. In particular, the large preloads approached the 'specific' satiety amount within a range of subjects' acceptability. Water consumption was not limited.

Intake was assessed by weighing foods and drinks before and after consumption. Information about desire to eat, fullness and satiety sensations were obtained from a satiety ratings questionnaire. Three questions ('How satiated do you feel?', 'How full do you feel?' and 'How great is your desire to eat?'), developed in a previous investigation (Porrini *et al.* 1995), provided useful information in discriminating between the different satiety conditions. Three unbroken isosceles triangles were used as scales and the ratings were expressed in cm^2 of area. Satiety, fullness and desire to eat sensation ratings were expressed as the difference between the scores obtained after and before the consumption of the meal. After the consumption of foods, a score of pleasantness was also expressed.

Experiment I

The aim of this experiment was to study the effect of oat breads on subsequent food intake and feelings of satiety, in comparison with white bread, and to understand whether the consumption of bread as a midmorning snack could have a positive impact on energy intake.

The different satiating properties of the two types of breads were explored as described earlier (p 851–852). The preloading paradigm was applied using three rolls of bread as large preloads (224 g corresponding to 2736 kJ (654 kcal) for white bread; 240 g corresponding to 2554 kJ (610 kcal) for oat bread), and to one roll of bread as small preloads (74 g corresponding to 904 kJ (216 kcal) for white bread; 81 g corresponding to 862 kJ (206 kcal) for oat bread).

When bread was consumed as a midmorning snack, subjects came fasted from breakfast to the laboratory at 10.45 hours on two occasions and received the preload together with 500 ml water. Between 11.00 hours and 12.45 hours they left the department, but they were not allowed to eat or drink anything else. The test meal was served at 12.45 hours.

When bread was consumed at lunch, subjects came fasted from breakfast to the laboratory at 12.45 hours.

In both conditions, they were told to eat and drink *ad libitum* and to fill in the questionnaire before and after eating.

Experiment II

The objective of this experiment was to analyse the satiating capacity of different oat, buckwheat and wheat pasta dishes (spaghetti and lasagne), with respect to their wheat counterparts.

The effect of pasta consumption on 'specific' satiety was evaluated only with spaghetti dishes as representative for pasta samples. The preloading paradigm strategy was also used in this experiment: subjects received, in random order, a portion of 500 g (large preload, corresponding to about 400 g cooked pasta and 100 g sauce) and a portion of 250 g (small preload, corresponding to about 200 g cooked pasta and 50 g sauce) of each pasta dish. Desire to eat, fullness and satiety were rated just before and immediately after consumption, and a score of palatability was also ranked.

In addition, a no-load condition (*ad libitum* test meal intake without any preload) was included in this experiment in order to evaluate the impact of the usual consumption of pasta as a first course of a meal on energy intake and satiety.

Experiment III

This experiment was undertaken to test the satiating effect of quinoa as compared with rice.

Subjects received the preloads, each at two different energy levels: the large preloads corresponded to 3852 kJ (920 kcal; 746 g) for quinoa and to 4258 kJ (1017 kcal; 741 g) for rice, while the small preloads corresponded to 1926 kJ (460 kcal; 376 g) for quinoa and to 2127 kJ (508 kcal; 390 g) for rice. They were instructed to eat the whole preload, and then to eat and drink the test meal *ad libitum*. A score of palatability was ranked. In this experiment, nine of the twelve subjects completed the study.

Data analysis

The data from *ad libitum* eating of foods in the 'specific' satiety condition (energy intake, weight intake) were computed by means of one-way ANOVA for repeated measures design using the type of food (formulation) as condition. A one-way ANOVA was also used to evaluate the pleasantness scores registered for the different foods.

In experiment I, energy, weight intake and satiety sensations were analysed by means of three-way ANOVA with bread formulation, preload energy level (small and large) and different time of consumption as factors.

In experiment II, energy, weight intake and satiety sensations were analysed by means of two-way ANOVA with pasta formulation and preload amount as factors. A subsequent comparison between the results obtained and those of the no-load condition was performed (one-way ANOVA).

In experiment III, energy and weight intake and satiety sensations were analysed by means of two-way ANOVA with type of food and preload energy level as factors.

For all the experiments, following a significant main effect in the ANOVA, individual means were compared using the least significant difference multiple range test. The criterion for significance was set at $P < 0{\cdot}05$.

For each food, the satiating efficiency was computed on the average values of the intakes as a function of load sizes for all subjects. The negative slope value of the intake-load function was considered as the satiating efficiency index (SEI; Porrini *et al.* 1995). SEI $< 1{\cdot}0$ are typical of products with low satiating efficiency; this means that the larger the preload the larger would be the amount of increase in the total energy intake (poor compensation). SEI $= 1{\cdot}0$ are typical of products whose consumption produces a perfect compensation of total energy intake. Products with SEI $> 1{\cdot}0$ are satiating; that is, the larger the preload consumed the lower the total energy intake.

Results

Experiment I

Table 2 summarises the energy intake and weight intake of water and breads in the 'specific' satiety condition. No significant difference was observed between white bread and oat bread.

The mean scores of pleasantness are reported in Table 3; all subjects rated the two breads similarly.

Table 2. Energy intake (kJ) and weight intake (g) of water and foods in the 'specific' satiety condition
(Mean values and standard deviations)

		Weight intake		Water intake		Total intake		Energy intake	
	Food	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Experiment I	White bread	317	70	402	59	719	171	3873	240
	Oat bread	336	57	353	98	689	123	3571	145
Experiment II*	Spaghetti	558	64	341	139	796	92	2860	79
	Oat spaghetti	577	147	354	79	931	154	3056	186
Experiment III†	Quinoa	800	181	439	181	1239	289	3852	209
	Rice	801	147	401	156	1202	235	4258	188

* In experiment II we reported the nutrient composition of cooked and tomato-dressed pasta samples.
† In experiment III we reported the nutrient composition of cooked and dressed samples.

Table 3. Palatability scores for foods consumed in experiments I, II and III
(Mean values and standard deviations)

		Palatability	
	Food	Mean	SD
Experiment I	White bread	6·5	1·2
	Oat bread	5·8	0·9
	Spaghetti	4·4	1·7
	Oat spaghetti	5·1	1·7
Experiment II	Lasagne	6·7*	1·2
	CMC buckwheat lasagne	4·5	1·4
	Buckwheat lasagne	4·1	1·4
Experiment III	Quinoa	6·3	0·9
	Rice	6·8	0·6

CMC, carboxymethyl cellulose.
* $P<0·005$.

Table 4 summarises the energy and weight intake of the breads and the test meal under the different conditions.

Both the different time of preload consumption and the bread formulation did not affect weight and energy intake. However, it should be mentioned that oat bread consumption induced a different test meal energy intake depending on the preload energy level (the higher the preload the lower the test meal energy intake) ($P=0·022$) particularly at 12.45 hours. On the contrary, test meal energy intake was not modulated by white bread preloads; thus, the higher the preload energy level the higher the total (preload plus *ad libitum* test meal intake) energy intake ($P=0·016$), independently from the model of consumption (as snack or at 12.45 hours). This was confirmed by the different SEI observed for the two breads (Fig. 1(a)); 0·8 for oat bread and 0·2 for white bread, in both models of preload consumption.

No effect of the preload energy level was evidenced on weight intake.

As regards the variations of satiety sensations before and after the consumption of preloads, we did not observe an effect of bread formulation (data not shown). On the contrary, the preload energy level significantly affected fullness ($P=0·002$), desire to eat ($P=0·009$) and satiety ($P=0·000$); in particular, the large white bread preload induced a significant decrease of desire to eat and a significant increase of satiety and fullness sensations, compared with the small one. Furthermore, a significant effect of the type of preload consumption on the variation of satiety was noted ($P=0·017$), as the satiety rating was significantly higher after the large oat bread consumed at 12.45 hours than after the large oat bread consumed as a snack.

Experiment II

Table 2 summarises the energy intake and weight intake of water and pasta samples in the 'specific' satiety condition. No significant difference was observed among the different pasta samples.

Table 4. Energy intake (kJ) and weight intake (g) in the different conditions of experiment I
(Mean values and standard deviations)

	White bread				Oat bread			
	Large		Small		Large		Small	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Preload energy intake	2736	–	904	–	2554	–	862	–
Preload weight intake	224	–	74	–	240	–	81	–
Preload consumed as a snack								
Test meal energy intake	4107	372	4467	313	3651	250	4769	219
Total energy intake	6845^{b}	372	5372^{a}	313	$6205^{a,b}$	250	$5631^{a,b}$	219
Total weight intake	1239	366	1244	57	1237	366	1304	296
Preload consumed at 12.45 hours								
Test meal energy intake	$3998^{a,b}$	367	$4358^{a,b}$	166	3132^{a}	96	4693^{b}	271
Total energy intake	6732^{b}	367	5263^{a}	166	$5686^{a,b}$	96	$5556^{a,b}$	271
Total weight intake	1094	187	1056	174	1136	213	1131	189

^{a,b}Mean values within a row with unlike superscript letters were significantly different ($P<0·05$).

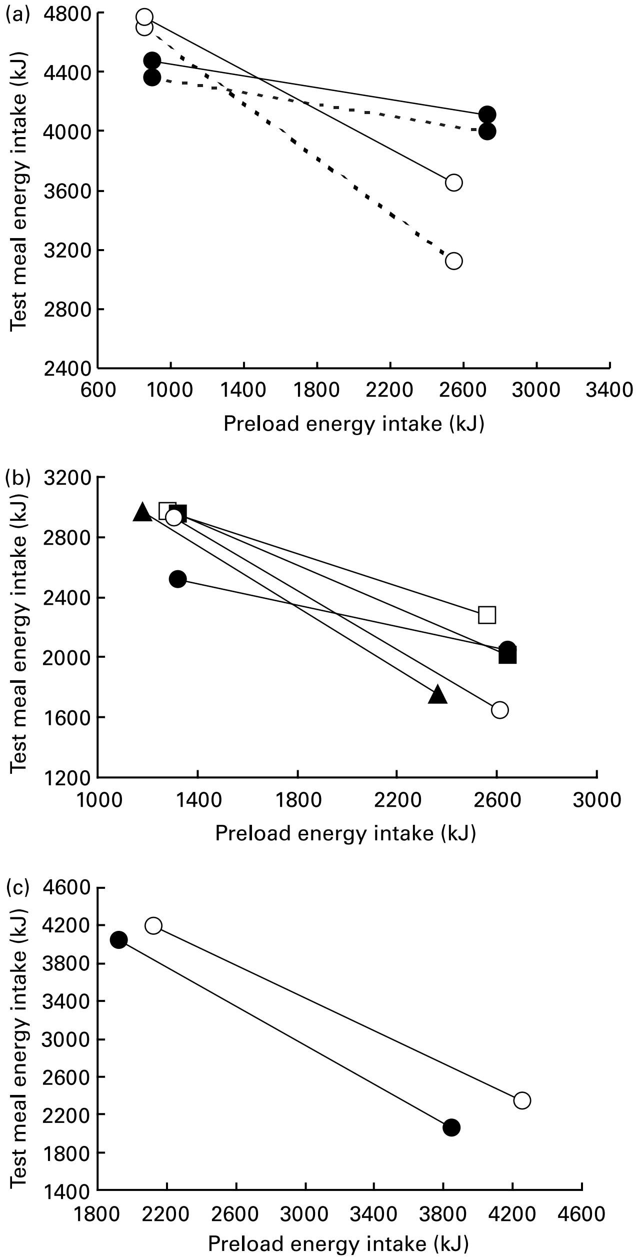

Fig. 1. (a) Intake–preload functions in experiment I for white bread (--●--; satiating efficiency index (SEI) = 0·2), white bread as a snack (–●–; SEI = 0·2), oat bread (--○--; SEI = 0·9) and oat bread as a snack (–○–; SEI = 0·7). (b) Intake–preload functions in experiment II for spaghetti (–□–; SEI = 0·5), carboxymethyl cellulose buckwheat lasagne (–▲–; SEI = 1·0), buckwheat lasagne (–○–; SEI = 1·0), oat spaghetti (–■–; SEI = 0·7) and lasagne (–●–; SEI = 0·4). (c) Intake–preload functions in experiment III for quinoa (–●–; SEI = 1·0) and rice (–○–; SEI = 0·9).

In Table 3 pleasantness scores expressed for each type of pasta are shown. The statistical analysis showed that pasta formulation affected the pleasantness ($P = 0{\cdot}000$); in particular, subjects gave the highest score to lasagne.

Table 5 summarises the energy intake and weight intake of the pasta dishes and the test meal under the different conditions plus that of the no-load condition. Total energy intake with pasta dishes was always comparable with that in the no-load condition, with the exception of the small lasagne that induced significantly lower energy intake.

ANOVA on data obtained from the preloading paradigm did not show any effect of pasta formulation on total (preload plus test meal) energy and weight intake.

The energy level of pasta preloads affected the test meal energy intake ($P = 0{\cdot}000$); in fact, it was always lower after the large ones. As regards the total energy intake, a significant effect of the energy level of preload was observed only for spaghetti and lasagne ($P = 0{\cdot}006$); the least significant difference multiple range test revealed that the large preloads of spaghetti and lasagne caused a significant increase in total energy intake compared with the small ones. Pasta SEI (Fig. 1(b)), calculated considering the two preload energy levels, demonstrated a low satiating efficiency (SEI $\leq 1{\cdot}0$). In particular, the two types of buckwheat lasagne indicated a perfect compensation, whereas the lasagne SEI (0·4) indicated that the larger the preload the larger the amount of test meal intake.

As regards the total weight intake, a significant effect of the energy level of preload was observed ($P = 0{\cdot}000$), as the large oat spaghetti, carboxymethylcellulose buckwheat lasagne, buckwheat lasagne and lasagne preloads determined significantly higher total intake compared with the small ones. Furthermore, the total weight intake was similar to that of small preload conditions, but significantly lower than that after large preloads ($P = 0{\cdot}002$).

A significant effect of preload energy level on fullness ($P = 0{\cdot}000$), desire to eat ($P = 0{\cdot}000$) and satiety ($P = 0{\cdot}000$) was also observed (data not shown).

Experiment III

Table 2 summarises the energy intake and weight intake of water, quinoa and rice in the 'specific' satiety condition. No significant difference was observed between quinoa and rice, and the mean scores of pleasantness (Table 3) were also comparable.

In Table 6 the means of test meal and total intake, expressed as energy content (kJ) and weight (g), are shown. Neither the type of food nor the preload energy level affected the total energy intake. Instead, a significant effect of the preload energy level was evidenced on both the test meal energy intake ($P = 0{\cdot}000$), and the total weight intake ($P = 0{\cdot}042$). In fact, the large preloads induced lower test meal energy consumption.

The load–intake function for the quinoa and rice preloads is reported in Fig. 1(c). The mean SEI calculated for both the foods was 1·0.

No significant effect of preload energy level on fullness, desire to eat ($P = 0{\cdot}000$) and satiety was also observed (data not shown).

Discussion

Experiment I

Oat bran or oat fibre has achieved a very positive consumer image because of the health benefits associated with their consumption; it seems to reduce blood cholesterol, affect glycaemic response, delay gastric emptying and prolong satiety after a meal (Mälkki & Virtanen, 2001). From our data, bread cannot be considered a satiating product; however, oat bread (SEI = 0·7, 0·9) resulted in more satiating than white bread (SEI = 0·2).

The main result of the present study regards the importance of the energy level of bread preloads on eating behaviour. This fact is particularly evident considering the SEI values; despite the fact that the mean total energy intake registered with the consumption of oat bread and white bread is comparable, the SEI indicates a

Table 5. Energy intake (kJ) and weight intake (g) registered after the consumption of tomato-dressed pasta products in experiment II

(Mean values and standard deviations)

	No load		Spaghetti				Oat spaghetti				Lasagne				CMC buckwheat lasagne				Buckwheat lasagne			
			Large		Small		Large		Small		Large		Small		Large		Small		Large		Small	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Preload energy intake	–	–	2562	–	1281	–	2646	–	1323	–	2646	–	1323	–	2361	–	1181	–	2617	–	1310	–
Preload weight intake	–	–	500	–	250	–	500	–	250	–	500	–	250	–	500	–	250	–	500	–	250	–
Test meal energy intake*	4547	246	2273[a]	382	2968§	344	2010[a,b]	277	2952§	307	2047[a,b]	302	2520	296	1754[a,b]	310	2973‖	399	1645[b]	371	2931‖	331
Total energy intake	4547	246	4836[c]	382	4250§	344	4656[c,d]	277	4275	307	4689[c,d]	302	3839†¶	296	4116[e]	310	4153	399	4262[d,e]	371	4237	331
Total weight intake‡	1020	282	1273	380	1171	377	1242	350	1090	325	1256	319	1139	433	1226	426	1072	443	1219	409	1049§	317

CMC, carboxymethyl cellulose.

[a,b,c,d,e] Mean values within a row with unlike superscript letters were significantly different ($P<0·05$ for test meal energy intake; $P<0·01$ for total energy intake). The comparison was among the pasta dishes when the no-load condition was excluded.

* Within the row, all mean values were significantly different from that for the no-load condition ($P<0·001$).

† Within the row, mean value was significantly different from that for the no-load condition ($P<0·05$).

‡ Within the row, all mean values for large preloads were significantly different from that for the no-load condition ($P<0·01$).

§ Within a column, mean value for small preload was significantly different from that for the large preload energy level or weight intake ($P<0·05$). The no-load condition was excluded from this comparison.

‖ Within a column, mean value for small preload was significantly different from that for the large preload energy level ($P<0·001$). The no-load condition was excluded from this comparison.

¶ Within a column, mean value for small preload was significantly different from that for the large preload energy level ($P<0·01$). The no-load condition was excluded from this comparison.

Table 6. Energy intake (kJ) and weight intake (g) in the different conditions of experiment III
(Mean values and standard deviations)

	Quinoa				Rice			
	Large		Small		Large		Small	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Preload energy intake	3852	–	1926	–	4258	–	2127	–
Preload weight intake†	746	–	376	–	741	–	390	–
Test meal energy intake	2060	334	4040*	439	2340	393	4195*	409
Total energy intake	5912	334	5966	439	6598	393	6322	409
Total weight intake	1516	328	1441	338	1543	336	1395	203

* For each food, mean value was significantly different from that for the large preload condition ($P < 0.001$).
† The lower preload weight intakes corresponding to 3852 and 4858 kJ with respect to those reported in Table 2 were due to a loss of water during the cooking procedure.

higher satiating efficiency of the former product. This means that by increasing oat bread consumption we have a decrease in subsequent energy intake, as compared with white bread. The consumption of three white bread rolls instead of one induced an increase in total energy intake of about 1473 kJ; thus, a low satiating effect or appetising effect. Such an observation is supported by data published by Holt *et al.* (1995) which validated a satiety index score (ratio between the 120 min satiety response curve for 996 kJ (238 kcal) portion of test foods and the 120 min satiety response curve for 996 kJ (238 kcal) portion of reference bread) of common foods. The satiety index method was developed to rank the filling powers of equal-energy portions of common foods and to determine which nutrient combinations, sensory and physical factors, and food preparation methods can change the feeling of fullness responses. Comparing the satiety index of white bread with that of grain bread and wholemeal bread, it was found that white bread was the least satisfying. From this point of view, the intake of oat bread (with lower glycaemic index (Foster-Power *et al.* 2002) and higher fibre content with respect to white bread) may be advisable to modulate energy intake. It is suggested that slowly absorbed, low-glycaemic index foods may improve glucose tolerance at the second meal and also affect eating behaviour and satiety (Wolever *et al.* 1988; Liljeberg *et al.* 1999; Roberts, 2000; Lodwing, 2000; Wolever, 2000; Brand-Miller *et al.* 2002).

This may be of particular importance when considering the consumption of bread as a snack rather than for lunch. Meal patterning may influence physiological variables and eating behaviour (Schlundt *et al.* 1992; Porrini *et al.* 1997). There is evidence that snacks have poor satiating efficiency (Marmonier *et al.* 2002) and that the energy consumed from snacks between meals provides further energy to daily intake (Rolls *et al.* 2004). On the contrary, we hypothesised that the consumption of oat bread as a snack could have a positive impact on energy intake at a meal. In the present study, the model of consumption did not affect energy intake and differently from what expected; oat bread exerted the higher satiating effect when consumed for lunch.

Experiment II

Pasta is an important product in the Italian and Mediterranean diet. While the consumption of this product is advisable because of the low glycaemic responses (Granfeldt *et al.* 1994; Barkeling *et al.* 1995; Holt *et al.* 1996; Liljeberg *et al.* 1999), it has been suggested (Porrini *et al.* 1995) that pasta has low efficacy in reducing satiety. Thus, it would be more beneficial to use oat flour or buckwheat flours in order to obtain bulky and less refined foods. In particular, buckwheat (*Fagopyrum esculentum*) is an important source of many substances with high biological value (Bonafaccia *et al.* 2003), resistant starch and dietary fibre content (Skrabanja *et al.* 2001*b*). Moreover, an investigation designed by Skrabanja *et al.* (2001*a*) showed that buckwheat may be potentially used in the design of food with lower glycaemic index.

What emerges from the present investigation is that, from a general point of view, the consumption of pasta just before the test meal does not provide any contribution to the total energy intake when compared with the no-load condition. In fact, the energy introduced was comparable with that observed in the no-load condition. Among pasta dishes, spaghetti and lasagne were the least satiating products, while the formulations containing alternative crops (oat or buckwheat flours) resulted in the increase of the satiating power, as previously suggested.

Though designed with different aims, it seemed interesting to compare the different experiments with volunteers homogeneous in sex, age and eating habits. In particular, a comparison with the results of experiment I suggests that spaghetti and lasagne are more satiating than white bread. Furthermore, a lower energy intake was always registered after the consumption of pasta with respect to bread. This result may be attributed to the fact that to provide a similar energy level, the pasta preload weight was about two-fold higher than bread preload weight, a difference attributable to the lower energy density of pasta meals (Porrini *et al.* 1995; Poppit & Prentice, 1996; Bell *et al.* 1998) due to the higher amount of water intrinsically bound. Furthermore, this result may be interesting, considering that spaghetti has been demonstrated to lower not only glucose and insulin responses, but also the serum triacylglycerol levels after the second meal (Liljeberg & Björck, 2000).

Experiment III

In this last experiment we evaluated the potential exploitation of the alternative crop quinoa, which has been suggested as a recipe for GF foods, as no gliadin-like proteins have been assessed by immunochemical approaches (Berti *et al.* 2004*a*). In addition, comparing *in vivo* metabolic responses to quinoa and other GF foods, we found that quinoa represented a potential alternative for coeliac subjects. In addition, the data we obtained after the consumption of the different products suggested that quinoa induced a lower desire to eat and higher fullness and satiety sensations than the other GF foods (Berti *et al.* 2004*b*). Moreover, as its grains contain lysine-rich proteins, PUFA, micronutrients and vitamins (Chauhan *et al.* 1992; Ranhotra *et al.* 1993; Ruales & Nair, 1993, 1994), mixing cereal grains with quinoa can enhance the nutritional value of the resultant product.

From the present study, the consumption of quinoa and rice as preloads did not produce a satiating effect (SEI of 1·0 and 0·9, respectively). Furthermore, the higher total energy intake registered, with respect to the experiment II, may be explained considering the higher preload amounts consumed.

Interestingly, our subjects expressed a high palatability score for quinoa despite the fact that they were not normally consumers of this grain, indicating that quinoa could be appreciated in our traditional diet.

Conclusion

In general, the present results point out that:

Pasta and bread are not satiating products;

The addition of alternative crops can affect the satiating efficiency of the product;

The availability of large portions of foods may be one of the environmental influences associated with excess energy intake (Porrini *et al.* 1995, 1997; Rolls *et al.* 1998, 2002, 2004). In our experimental conditions, foods consumed in high amounts induced even more eating;

Eating cereal foods (for example, bread) as a snack does not seem to reduce energy intake at the subsequent meal;

Oat or buckwheat formulations and quinoa may represent a viable alternative to traditional cereal products as ingredients for special dietary use, particularly considering that they are good sources of functional substances and are GF foods.

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