Effect on appetite control of minor cereal and pseudocereal products

Cristiana Berti*, Patrizia Riso, Antonella Brusamolino and Marisa Porrini

Department of Food Science and Microbiology, Division of Human Nutrition, University of Milan, Milan, Italy

(Received 17 January 2005 – Revised 10 June 2005 – Accepted 9 July 2005)

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 preloadings 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 = 0.2) 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 (Westeterp-Plantenga 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 foodstuffs 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. 2001a; Storsrud 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; Gutzmann-Maldonado & Paredes-Lopez, 1999; Bonafaccia et al. 2000; Zielinski & Kozlowska, 2000; Skrabanja et al. 2001b; 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;
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/m²) participated in the bread study (experiment I), fourteen in the pasta study (age 24·0 ± 2·6 years; BMI 23·3 ± 2·7 kg/m²) (experiment II) and twelve (age 25·4 ± 2·2 years; BMI 23·0 ± 1·9 kg/m²) 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 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 Paganì, 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

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

* CMC, carboxymethyl cellulose.

† In experiment III we reported the nutrient composition of cooked and dressed samples.
preload amounts 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 cm² 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 objective 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 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<0.05.

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 < 1.0 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 > 1.0 are typical of products whose consumption produces a perfect compensation of total energy intake. Products with SEI > 1.0 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 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 \textit{ad libitum} test meal intake) energy intake \( (P = 0.002) \), 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 2. Energy intake (kJ) and weight intake (g) of water and foods in the ‘specific’ satiety condition

<table>
<thead>
<tr>
<th>Food</th>
<th>Weight intake</th>
<th>Water intake</th>
<th>Total intake</th>
<th>Energy intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td><strong>Experiment I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>317</td>
<td>70</td>
<td>402</td>
<td>59</td>
</tr>
<tr>
<td>Oat bread</td>
<td>336</td>
<td>57</td>
<td>353</td>
<td>98</td>
</tr>
<tr>
<td>Spaghetti</td>
<td>559</td>
<td>64</td>
<td>341</td>
<td>139</td>
</tr>
<tr>
<td>Oat spaghetti</td>
<td>577</td>
<td>147</td>
<td>354</td>
<td>79</td>
</tr>
<tr>
<td><strong>Experiment III</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quinoa</td>
<td>800</td>
<td>181</td>
<td>439</td>
<td>181</td>
</tr>
<tr>
<td>Rice</td>
<td>801</td>
<td>147</td>
<td>401</td>
<td>156</td>
</tr>
</tbody>
</table>

* 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 fried samples.

Table 3. Palatability scores for foods consumed in experiments I, II and III

<table>
<thead>
<tr>
<th>Palatability</th>
<th>Food</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Experiment I</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>6.5</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Oat bread</td>
<td>5.8</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Spaghetti</td>
<td>4.4</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>Oat spaghetti</td>
<td>5.1</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td><strong>Experiment II</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lasagne</td>
<td>6.7*</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>CMC buckwheat lasagne</td>
<td>4.5</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Buckwheat lasagne</td>
<td>4.1</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td><strong>Experiment III</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quinoa</td>
<td>6.3</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>6.8</td>
<td>0.6</td>
<td></td>
</tr>
</tbody>
</table>

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 \textit{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.

### Table 4. Energy intake (kJ) and weight intake (g) in the different conditions of experiment I

<table>
<thead>
<tr>
<th>Food</th>
<th>Weight intake</th>
<th>Water intake</th>
<th>Total intake</th>
<th>Energy intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td><strong>White bread</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preload energy intake</td>
<td>2736</td>
<td>–</td>
<td>904</td>
<td>–</td>
</tr>
<tr>
<td>Preload weight intake</td>
<td>224</td>
<td>–</td>
<td>74</td>
<td>–</td>
</tr>
<tr>
<td>Preload consumed as a snack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test meal energy intake</td>
<td>4107</td>
<td>372</td>
<td>4467</td>
<td>313</td>
</tr>
<tr>
<td>Total energy intake</td>
<td>6845</td>
<td>372</td>
<td>5372</td>
<td>313</td>
</tr>
<tr>
<td>Total weight intake</td>
<td>1239</td>
<td>366</td>
<td>1244</td>
<td>57</td>
</tr>
<tr>
<td><strong>Oat bread</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preload energy intake</td>
<td>3998</td>
<td>367</td>
<td>4358</td>
<td>166</td>
</tr>
<tr>
<td>Preload weight intake</td>
<td>6732</td>
<td>367</td>
<td>5263</td>
<td>166</td>
</tr>
<tr>
<td>Preload consumed at 12.45 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test meal energy intake</td>
<td>1054</td>
<td>187</td>
<td>1056</td>
<td>174</td>
</tr>
</tbody>
</table>

* Mean values within a row with unlike superscript letters were significantly different \( P < 0.05 \).
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 ($P=0.000$); 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 ($P=0.006$); 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 $\leq 1.0$).

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 ($P=0.000$), 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 ($P=0.002$).

A significant effect of preload energy level on fullness ($P=0.000$), desire to eat ($P=0.000$) and satiety ($P=0.000$) 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 ($P=0.000$), and the total weight intake ($P=0.042$). 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 ($P=0.000$) 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 (Mäkki & Virtanen, 2001). From our data, bread cannot be considered a satiating product; however, oat bread (SEI $0.9$) and oat spaghetti (SEI $0.7$) affected the pleasantness ($P=0.000$) and satiety was also observed (data not shown).

In Table 3 pleasantness scores expressed for each type of pasta are shown. The statistical analysis showed that pasta formulation affected the pleasantness ($P=0.000$); 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.
### 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)

<table>
<thead>
<tr>
<th></th>
<th>Spaghetti</th>
<th>Oat spaghetti</th>
<th>Lasagne</th>
<th>CMC buckwheat lasagne</th>
<th>Buckwheat lasagne</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No load</td>
<td>Large</td>
<td>Small</td>
<td>Large</td>
<td>Small</td>
</tr>
<tr>
<td>Mean</td>
<td>2562</td>
<td>2646</td>
<td>2646</td>
<td>2646</td>
<td>2646</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>1281</td>
<td>1323</td>
<td>1323</td>
<td>1323</td>
</tr>
<tr>
<td>Preload energy intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Preload weight intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy intake*</td>
<td>4547</td>
<td>246</td>
<td>2273</td>
<td>a</td>
<td>382</td>
</tr>
<tr>
<td>Mean</td>
<td>2010</td>
<td>277</td>
<td>2952</td>
<td>307</td>
<td>307</td>
</tr>
<tr>
<td>SD</td>
<td>324</td>
<td>344</td>
<td>331</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test meal energy intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy intake‡</td>
<td>1020</td>
<td>282</td>
<td>1273</td>
<td>380</td>
<td>1171</td>
</tr>
<tr>
<td>Mean</td>
<td>1242</td>
<td>350</td>
<td>1090</td>
<td>325</td>
<td>325</td>
</tr>
<tr>
<td>SD</td>
<td>1256</td>
<td>319</td>
<td>1139</td>
<td>433</td>
<td>433</td>
</tr>
<tr>
<td>Total weight intake‡</td>
<td>1020</td>
<td>282</td>
<td>1273</td>
<td>380</td>
<td>1171</td>
</tr>
<tr>
<td>Mean</td>
<td>1242</td>
<td>350</td>
<td>1090</td>
<td>325</td>
<td>325</td>
</tr>
<tr>
<td>SD</td>
<td>1256</td>
<td>319</td>
<td>1139</td>
<td>433</td>
<td>433</td>
</tr>
</tbody>
</table>

CMC, carboxymethyl cellulose.

*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 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.
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 appetite 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 (Wolever et al. 1988; Liljeberg & Bjo¨rck, 2000). 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 (Bonaccacia et al. 2003), resistant starch and dietary fibre content (Skrabanja et al. 2001b). Moreover, an investigation designed by Skrabanja et al. (2001a) 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. 2004a). 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

### Table 6. Energy intake (kJ) and weight intake (g) in the different conditions of experiment III

<table>
<thead>
<tr>
<th></th>
<th>Quinoa</th>
<th>Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
<td>Small</td>
</tr>
<tr>
<td>Preload energy intake</td>
<td>3852</td>
<td>1926</td>
</tr>
<tr>
<td>Preload weight intake†</td>
<td>746</td>
<td>376</td>
</tr>
<tr>
<td>Test meal energy intake</td>
<td>2060</td>
<td>4040*</td>
</tr>
<tr>
<td>Total energy intake</td>
<td>5912</td>
<td>334</td>
</tr>
<tr>
<td>Total weight intake</td>
<td>1516</td>
<td>328</td>
</tr>
</tbody>
</table>

* 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.
induced a lower desire to eat and higher fullness and satiety sensations than the other GF foods (Berti et al. 2004b). Moreover, as its grains contain lysine-rich proteins, PUFAs, micronutrients and vitamins (Chauhan et al. 1992; Ranhotra et al. 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.

Acknowledgements

The present study was partially supported by the National Ministerial Financial Grant COFIN 2000.

References


of buckwheat sprouts as a new vegetable. Food Res Int 37, 319–327.

Kissileff HR (1984) Satiating efficiency and a strategy for conducting food

Liljeberg HGM, Åkerberg AK & Björck IME (1999) Effect of the glycemic
index and content of indigestible cereals of carbohydrate-based
breakfast meals on glucose tolerance at lunch in healthy subjects. Am

Liljeberg HGM & Björck IME (1994) Bioavailability of starch in bread
products. Postprandial glucose and insulin responses in healthy subjects

Liljeberg HGM & Björck IME (2000) Effects of low-glycaemic index spa-
ghetti meal on glucose tolerance and lipaemia at a subsequent meal in


consumed in a nonhungry state have poor satiating efficiency: influence
of snack composition on substrate utilization and hunger. Am J Clin
Nutr 76, 518–528.


Poppit SD & Prentice AM (1996) Energy density and its role in the con-
trol of food intake: evidence of metabolic and community studies. 

and food intake after different preloads. Appetite 25, 17–30.

Porrim M, Santangelo A, Crovetti R, Riso P, Testolin G & Blundell JE
(1997) Weight, protein, fat, and time preloads affect food intake. Phys-
iol Behav 62, 563–570.

Raben A, Tagliabue A, Christensen NJ, Madsen J, Holst JJ & Astrup A
(1994) Resistant starch: the effect on postprandial glycaemia, hormonal

Composition and protein nutritional quality of quinoa. Cereal Chem 70, 303–305.


Roberts S (2000) High-glycemic index foods, hunger, and obesity: is there

Rolls BJ, Castellanos VH, Halford JC, Kilara A, Panyam D, Pelkman CL, 
Smith GP & Thorwart ML (1998) Volume of food consumed affects

intake in normal-weight and overweight men and women. Am J Clin 
Nutr 76, 1207–1213.

Rolls BJ, Roe LS, Kral TVE, Meengs JS & Wall DE (2004) Increasing the
portion size of a packaged snack increases energy intake in men and

tional quality of an infant food from quinoa and its effect on the plasma
level of insulin-like growth factor-1 (IGF-1) in undernourished. Int J 

Ruales J & Nair BM (1993) Content of fat, vitamins and minerals in

Ruales J & Nair BM (1994) Effect of processing on in vitro digestibility of

role of breakfast in the treatment of obesity: a randomized clinical 

meal and oat flour in the extrusion cooking process. J Food Eng 34,
15–32.

Skrabanza V, Elmnstahl Liljeber GM, Kreft I & Björck I (2001a) Nutri-
tional properties of starch in buckwheat products: studies in vitro and

Skrabanza V, Kovac B, Golob T, Elmnstahl GM, Björck I & Kreft I (2001b)
Effect of spelt wheat flour and kernel on bread composition and nutri-

Stonsrud S, Hultén LR & Lenner RA (2003) Beneficial effects of oats in
the gluten-free diet on adults with special reference to nutrient status,

Stubbs RJ, Mazlan N & Whybrow S (2001) Carbohydrates, appetite and
feeding behavior in humans. J Nutr 131, 2775S–2781S.

quinoa (Chenopodium quinoa, Willd): effects on in vitro iron avail-

Satiety related to 24h diet-induced thermogenesis during high protein/
carbohydrate vs high fat diets measured in a respiration chamber. Eur


Wolever TMS, Jenkins DIA, Ocana AM, Rao VA & Collier GR (1988)
Second-meal effect: low-glycemic-index foods eaten at dinner improve

on fatty acid composition and physicochemical properties of meatballs. 

Zielinski H & Kozlowska H (2000) Antioxidant activity and total pheno-
lacs in selected cereal grains and their different morphological fractions.