Short-term appetite-reducing effects of a low-fat dairy product enriched with protein and fibre

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Abstract
The objectives of this work were to investigate short-term appetite-reducing effects of an innovative low-fat yogurt enriched with protein (8 g/serving) and fibre (2.6–2.9 g/serving). Two studies were conducted using randomised cross-over designs. Healthy women consumed a mid-morning snack consisting of either the test or the control yogurt product (Study 1, n = 24: iso-energetic, not iso-weight conditions; Study 2, n = 121: iso-weight, not iso-energetic conditions) under laboratory conditions. Subjective appetite ratings (of hunger, fullness, desire to eat and prospective consumption) were recorded throughout the morning; sensory and hedonic ratings were also collected. In Study 2, two hours after consumption of the dairy snack, subsequent food intake at lunch was also measured. The test product reduced subjective appetite compared to the control (all ratings, P < 0.05). Energy intake at lunch was reduced by 274 kJ after the test compared to the control (P < 0.001). These two studies demonstrated that a low-fat dairy product enriched with protein and fibre can significantly reduce short-term appetite.

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1. Introduction

Maintaining energy balance by controlling appetite is a key strategy to prevent weight gain, which is a major health problem (Wang, Beydoun, Liang, Caballero, & Kumanyika, 2008). Following a healthy, balanced and low-energy dense diet, high in fibre and micronutrients is recommended (World Health Organisation, 2006). In this context, the consumption of low-energy dense products, not only within but also between meals, could be an acceptable strategy to improve the control of appetite (Lluch, Marmonier, Molloy, & Piaia, 2004; Speechly & Buffenstein, 1999), providing that such products are sufficiently satiating and do not result in overeating at subsequent meals. Indeed, from a consumer perspective, the modulation of hunger feelings may help an individual to maintain a weight management strategy (Danone-TNS Sofres, 2008).

High-protein meals and snacks have been shown to induce a greater reduction in appetite than iso-energetic high fat or carbohydrate equivalents (for review, Anderson & Moore, 2004; Halton & Hu, 2004; Soenen & Weusterp-Plantenga, 2008). Similarly, high consumption of viscous vegetable fibres has been shown to decrease appetite in humans (for review, Burton-Free

man, 2000; Howarth, Saltzman, & Roberts, 2001; Slavin & Green, 2007). Because protein and fibre have been demonstrated to be potent modulators of short-term appetite, an innovative low-fat yogurt enriched with these nutrients was developed in order to test its efficiency in reducing appetite. The technological and nutritional challenges were to combine the enrichment of quantities of milk protein with guar gum in a low-energy dense dairy product, which would remain acceptable for commercial use, especially in terms of sensory characteristics including taste and texture.

To test the short-term appetite-reducing effects of this new formulation, two studies were designed to compare the effects of this new product (test product) to a non-enriched marketed low-fat yogurt (control product). In Study 1 we hypothesised that one commercial serving of the test product consumed mid-morning would reduce appetite feelings more over the following 2 h than an iso-energetic control. In Study 2, the iso-energetic control was replaced by a control matched for weight. Furthermore, to test the hypothesis that changes in appetite feelings would be accompanied by changes in subsequent energy intake, food intake was measured at lunch, 2 h after the consumption of the study products.
2. Methods

2.1. Participants

Study 1 was conducted in the United Kingdom (UK) with 24 healthy non-dieting women, with a mean age of 28.7 (SD 9.4) years and a mean BMI of 24.8 (SD 1.8) kg/m². Participants were recruited by 4-Front Research UK Ltd. from the greater Manchester area, using the 4-Front database and advertising leaflets. The suitability of each potential participant was confirmed prior to acceptance onto the study by review of a screening questionnaire. Participants were regular breakfast consumers and had no dislike for the dairy foods or breakfast food items to be served during the experiment. They were excluded from taking part if they had significant health issues likely to affect their well-being and/or appetite. The study was approved by the 4-Front Research UK Ltd. Independent Ethics Committee.

Study 2 was conducted in France with 121 healthy women, with a mean age of 32.1 (SD 6.2) years and a mean BMI of 25.0 (SD 1.4) kg/m². Participants were recruited by 2 study centres (Biotrial in Rennes and Optimed in Grenoble) from their volunteer databases. The selection procedure included a clinical examination, medical history and the completion of a questionnaire on dietary habits and behaviour. In addition to Study 1 criteria, it was ascertained that participants were regular main meal (breakfast, lunch and dinner) eaters, regular dairy product consumers, and usually consumed 300–400 kcal at breakfast, in order to get a homogeneous population in terms of eating habits. Participants were also not dietary restrainers (Three Factor Eating Questionnaire score <9, Stunkard & Messick, 1985). They were excluded from the study if they presented more than 3 kg of weight fluctuations over the previous 6 weeks or used special dietary supplements or treatments of each potential participant was confirmed prior to acceptance onto the study by review of a screening questionnaire. Participants were also not dietary restrainers (Three Factor Eating Questionnaire score <9, Stunkard & Messick, 1985). They were excluded from the study if they presented more than 3 kg of weight fluctuations over the previous 6 weeks or used special dietary supplements or treatments. The study was approved by the CPP “Sud-Est III” Ethical Committee of Nîmes.

Both studies were in accordance with the latest version of the Helsinki Declaration and the ICH for Good Clinical Practice, and all participants gave their written consent after the experimental procedure had been explained to them. All participants were financially compensated.

2.2. Study design

Both studies were single-blinded, controlled trials using a randomised within-subject cross-over design. Study 1 was single-centre and Study 2 was multi-centre. The two products (control and test) were administered in a counterbalanced sequence as a mid-morning snack. 2 h after the beginning of consumption of a fixed breakfast. Each treatment was separated by a one week washout period.

2.3. Test and control products

The nutritional composition of test and control yogurts by tested portion size is shown in Table 1. The test product (Shape 2.3. Test and control products

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Table 1 Portion size and nutritional composition of the study products (control and test) tested in Study 1 and Study 2.

<table>
<thead>
<tr>
<th></th>
<th>Study 1</th>
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<th>Study 2</th>
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<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Test</td>
<td>Control</td>
<td>Test</td>
</tr>
<tr>
<td>Portion size (g)</td>
<td>87</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Energy (kJ)</td>
<td>293</td>
<td>293</td>
<td>356</td>
<td>314</td>
</tr>
<tr>
<td>Energy (kcal)</td>
<td>70</td>
<td>70</td>
<td>85</td>
<td>75</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>13.9</td>
<td>9.4</td>
<td>14.0</td>
<td>10.4</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>2.0</td>
<td>7.8</td>
<td>4.2</td>
<td>7.9</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>0.6</td>
<td>0.1</td>
<td>1.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Total fibre (g)</td>
<td>0.09</td>
<td>2.9</td>
<td>0.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Energy density (kJ/g)</td>
<td>3.35</td>
<td>2.43</td>
<td>2.97</td>
<td>2.59</td>
</tr>
</tbody>
</table>

In Study 2, nutritional and energy intakes were determined by the measurement of food intake from the ad libitum lunch. Nutri-
tional compositions of the offered foods were obtained from the manufacturers labelling.

2.7. Study protocol

Fig. 1 presents the experimental day procedures for both studies.

In Study 1, on the eve of the experimental day, participants were instructed to eat, at home, a similar dinner before each visit. On the experimental day, participants were time-blinded and isolated from their arrival at 07.30 h until departure at 12.30 h. At 08.00 h, participants received a fixed breakfast (761 kJ/182 kcal) to be consumed entirely, consisting of toasted bread (40 g), margarine (10 g), jam (10 g), and a hot drink (250 mL) including milk (10 mL) with optional intense sweeteners. Two hours later, the morning snack (either the test or control yogurt) was served. VAS ratings of appetite were assessed immediately before and after each eating episode and every 30 min after the beginning of breakfast until lunch time.

In Study 2, on the eve of the experimental day, a fixed dinner (2904 kJ/694 kcal) was offered to participants at the study centre and had to be consumed entirely. Dinner consisted of rice with chicken and vegetables (300 g), bread (80 g) and vanilla flavour cream dessert (200 g). On the experimental day, the fixed breakfast (791 kJ/189 kcal), to be consumed entirely, consisted of toasted bread (40 g), butter (8 g) and jam (10 g), and a hot drink (250 mL) with optional intense sweeteners. The morning snack (either the test or control yogurt) and the ad libitum lunch were served two and four hours after the beginning of the breakfast, respectively. Foods offered at lunch consisted of tagliatelli bolognese (600 g), bread (80 g), yogurt (250 g), fruit puree (200 g) and water (1000 mL). The total energy content provided of this meal was 5991 kJ (1432 kcal). Participants were instructed to eat until they were comfortably full, within a maximum of 30 min. Appetite feelings were measured immediately before and after lunch.

In both studies, between breakfast and snack, and between snack and lunch, participants had access to a bottle of mineral water (25 cl). All food items or meals were ready to eat and only had to be heated (when appropriate). The weight of foods consumed at each eating episode and the weight of water drunk (over the morning and during lunch) were measured out of the sight of the participants.

2.8. Statistics

All appetite feelings profiles are presented as mean values and standard errors of the mean (SEM). The appetite feelings profiles were compared by a RM ANCOVA (Repeated Measures Analysis of Covariance) with the baseline as a covariate. The means comparisons between the two products (test or control yogurt) were made (i) over the 2 h preceding snack consumption (with appetite feeling at time 0 as covariate) and (ii) over the 2 h after snack consumption (with appetite feeling at time 0 as covariate). The factors were ‘product, visit, time (i) pre-breakfast to pre-snack or (ii) post-snack to 2 h after’ and product by time interaction’ as fixed factors, ‘subject’ as a random factor and baseline ((i) pre-breakfast or (ii) pre-snack) as a covariate. The carry-over effect was not estimable with our design. Instead, the product by visit interaction was tested. When the product effect was significant, an estimation of differences of least squares means between products is given in millimetres.

Food, water, energy intake and hedonic data are presented as mean values and standard deviation (SD). A two way ANOVA was used to test the mean differences in nutritional data (food and energy intakes at lunch, water intake over the morning and during lunch) between the two products (test or control yogurt). The factors were ‘product, visit and the product by visit interaction’ as fixed factors, and ‘subject’ as a random factor. Comparisons of sensory and hedonic ratings between test and control products were undertaken using paired t-tests (Study 1) and a two way ANOVA (Study 2).

SAS® Enterprise Guide® 4.1, SAS® 9.1, SAS® 8.2 (SAS Institute, Cary, NC, USA) and SPSS® 15.0.1.1 (SPSS Inc. Headquarters, Chicago, Illinois, USA) were employed to test differences in appetite factors, energy intake, and sensory and hedonic data. A significance level of 5% for a two-tailed test was used for all statistical tests.

3. Results

In Study 1, 24 participants completed the experiment. In Study 2, one volunteer dropped out after participating in only one visit (control product). Since our statistical model was a mixed model, the statistical analysis includes 121 and 120 participants in the control and in the test condition, respectively (Brown & Prescott, 2006).

3.1. Subjective appetite

Appetite feelings profiles are presented in Figs. 2 and 3 (Study 1) and Figs. 4 and 5 (Study 2). No significant differences were observed for all appetite indicators over the 2 h before test or control product consumption. Conversely, over the 2 h following product consumption, a significant product effect was observed on appetite score and on all measurements of appetite feelings (Table 2). The consumption of test product significantly reduced mean scores of hunger, desire to eat, prospective consumption and significantly increased fullness and satisfaction resulting in a significantly lower appetite score compared to the control product. Mean difference of the product effect for both studies, estimated by the statistical model (between the test and the control product), is given in Table 2. In Study 1, no time by product interaction and no product
by visit interaction were observed, for any appetite measure. No significant difference between test and control products was observed in VAS thirst profiles (Fig. 3F) or in water intake. In Study 2, no significant time by product interaction was observed, except for hunger ($F(1) = 2.41, P < 0.05$). The product by visit interaction was shown to be significant only for desire to eat ($F(1) = 4.26$) and the appetite score ($F(1) = 4.16$) profiles (both $P < 0.05$); and these interactions were quantitative (i.e. the sign of the treatment effect remained the same between visit 1 and visit 2 but its size increased): the test product reduced desire to eat and appetite score more in visit 2 than in visit 1. A significant difference in product effect ($F(1) = 5.4, P < 0.05$) and an interaction of product effect with time ($F(1) = 3.75, P < 0.01$) was observed on thirst ratings (Fig. 5F). However, there were no significant differences in water intake over the morning.

3.2. Sensory and hedonic ratings

In Study 1, there were no significant differences between test and control products in liking (scores of $3.8 \pm 1.5$ vs $4.1 \pm 1.1$, respectively, ns) and taste pleasantness (scores of $3.7 \pm 1.5$ vs...
4.3 ± 1.0, respectively, ns). Texture of the test product was rated as higher than the control (scores of 3.5 ± 0.7 vs 2.6 ± 0.5, respectively, \( P < 0.001 \)), with the test product rated as “a little too thick” and the control rated as “a little too thin”.

In Study 2, the control was liked significantly more than the test product (scores of 76 ± 18 mm and 58 ± 29 mm, respectively, \( P < 0.001 \)), with higher ratings of participant’s appreciation of taste (76 ± 18 mm and 59 ± 29 mm, \( P < 0.001 \)) and texture (72 ± 22 mm and 54 ± 31 mm, \( P < 0.001 \)).

3.3. Energy and macronutrient intake at lunch

Food, energy and macronutrient intakes at lunch (Study 2) are detailed in Table 3. Significant reductions in the quantity of food (43.3 g), energy (274 kJ/65.5 kcal) and of all macronutrient (in grams) intakes at lunch were observed after the test product consumption compared to the control (\( P < 0.001 \)). There were no significant differences in the energy contribution of each macronutrient. Overall, when combining total morning intakes (i.e. breakfast, snack and lunch), the total quantity of food (837 g) and energy (4766 kJ/1139 kcal) consumed in the test condition

![Fig. 4. Study 2 (n = 121): comparison of appetite score profiles between test (●) and control product (□), from breakfast (T-120) to lunch consumption (T120). Each point represents mean ratings (±SEM) in mm. Appetite score profiles are compared by a Repeated Measure Analysis of Covariance (RMANCOVA) over the 2 h before (with T-120 as covariate) and over the 2 h after snack consumption (with T0 as covariate) to test the product effect at a significance level of 5% (ns, not significant; \* \( P < 0.05 \); \*** \( P < 0.001 \)).

![Fig. 5. Study 2 (n = 121): comparison of appetite feelings profiles between test (●) and control product (□), from breakfast (T-120) to lunch consumption (T120). (A) Hunger profile, (B) desire to eat profile, (C) prospective consumption profile, (D) fullness profile, (E) satisfaction profile and (F) thirst profile. Each point represents mean ratings (±SEM) in mm. Appetite feelings profiles are compared by a Repeated Measure Analysis of Covariance (RMANCOVA) over the 2 h before (with T-120 as covariate) and over the 2 h after snack consumption (with T0 as covariate) to test the product effect at a significance level of 5% (ns, not significant; \* \( P < 0.05 \); \*** \( P < 0.001 \)).

Product effect and mean difference (in mm) of the product effect (test related to control) over the 2 h following study product consumption, for appetite score and appetite feelings, in Study 1 and Study 2.

Table 2

<table>
<thead>
<tr>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product effect</td>
<td>P value</td>
</tr>
<tr>
<td>Appetite score</td>
<td>F(1) = 7.82</td>
</tr>
<tr>
<td>Hunger</td>
<td>F(1) = 4.26</td>
</tr>
<tr>
<td>Desire to eat</td>
<td>F(1) = 7.39</td>
</tr>
<tr>
<td>Prospective consumption</td>
<td>F(1) = 11.51</td>
</tr>
<tr>
<td>Fullness</td>
<td>F(1) = 10.28</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>F(1) = 14.43</td>
</tr>
</tbody>
</table>

Product effect is evaluated by a Repeated Measure Analysis of Covariance (RM ANCOVA), with T0, as covariate. Mean difference (in mm) of the product effect is estimated by the statistical model. A negative result means that appetite rating of control product is higher than test product. A positive result means that appetite rating of control product is lower than test product.

Table 3

Mean (±SD) food, water, energy and nutritional intakes from the ad libitum lunch (Study 2).

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 121)</th>
<th>Test (n = 120)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of food (g)</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Water (g)</td>
<td>242.9</td>
<td>138.0</td>
<td>242.9</td>
</tr>
<tr>
<td>Energy (kJ)</td>
<td>3943.0</td>
<td>905.0</td>
<td>3671.0</td>
</tr>
<tr>
<td>Energy (kcal)</td>
<td>942.3</td>
<td>216.4</td>
<td>877.3</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>116.0</td>
<td>27.2</td>
<td>108.4</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>47.5</td>
<td>12.1</td>
<td>44.0</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>32.0</td>
<td>8.2</td>
<td>29.8</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>49.5</td>
<td>5.0</td>
<td>49.9</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>20.1</td>
<td>1.9</td>
<td>19.9</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>30.4</td>
<td>3.2</td>
<td>30.3</td>
</tr>
</tbody>
</table>

All nutritional data are compared by a two way ANOVA to test the differences between the 2 products (control and test). ns, not significant. * indicates the percentage of energy intake.

was significantly lower than in the control condition (880 g and 5079 kJ/1214 kcal, respectively) with a mean difference estimated by the statistical model of 43 g and 314 kJ (75 kcal) (both P < 0.001). During lunch, participants drank the same quantity of water in both conditions.

4. Discussion

These studies were designed to assess the short-term appetite-reducing effects of the innovative combination of milk protein and guar gum fibre in a low-fat dairy product. In both studies, the test product induced a significant 16% reduction in appetite score, and a significant reduction of subjective appetite (all ratings), compared to non-enriched commercially available controls. Such concordance, despite differences in methodology and design, suggests these findings are robust and reliable. In Study 1, the control and test products were matched for energy and differed slightly in weight (33 g more for test product). This small difference in mass could have explained, at least in part, the differences observed in appetite feelings. However, in Study 2, where test and control products were matched for weight, the test product still significantly reduced subjective appetite ratings compared to the control, despite its slight deficit in energy content (41.9 kJ less in the test product).

Protein or guar gum administered in varying amounts, often high (e.g. for protein, from 12.6 g to 121.2 g; 23–100% energy from protein; for guar gum, from 2.5 g to 12.5 g), have previously been shown to reduce appetite feelings in short-term studies (<24 h), in lean and overweight subjects (for protein: Fischer, Colombani, & Wenk, 2004; Harper, James, Flint, & Astrup, 2007; Johnson & Vickers, 1993; Latner & Schwartz, 1999; Lluch, Boelsma, Vinoy, L’Heureux-Bouron, & Hendriks, 2007; Poppitt, McCormack, & Buffenstein, 1998; Porrini, Crovetti, Testolin, & Silva, 1995; Rolls, Hetherington, & Burley, 1988; Stubbs, Van Wyk, Johnstone, & Harbron, 1996; Vandewater & Vickers, 1996; for guar gum: French & Read, 1994; Hoad et al., 2004; Lavin & Read, 1995), whereas other studies testing the same range of concentrations failed to replicate these findings (for protein: Blom et al., 2006; Porrini et al., 1997; Raben, Agerholm-Larsen, Flint, Holst, & Astrup, 2003; for guar gum: Adam & Westerterp-Plantenga, 2005; Burley, Leeds, & Blundell, 1987). In our studies, we demonstrated the satiating properties of a combination of protein and fibre. Of interest, the effect on reducing appetite was observed after the consumption of a product combining smaller amounts of protein (8 g/serving) and fibre (2.6–2.9 g/serving) than used in previous published studies, while maintaining a high contribution of energy from protein (about 45%) and a low-energy content (70–75 kcal). These types of studies are necessary as experimental nutritional manipulations employed to demonstrate the satiating effects of protein and fibres are not always realistic for single food items or for commercial use. The present studies were not designed to delimitate the specific contribution of any one of these ingredients (protein or fibre), or changes in energy density, volume or sensory characteristics made by adding them, on either appetite or underlying mechanisms.

Nonetheless, the current test product was characterised by a significantly higher in-mouth thickness and texture and higher in-gut viscosity compared to non-enriched control (sensory panel data and rheological measurements of in vitro digestion simulation, data not shown).

Increased thickness and viscosity of foods and beverages are known to positively influence expectations of satiating properties (Bertenshaw, 2008; Brunstrom, Shakeshaft, & Scott-Samuel, 2008), satiation and appetite reduction (Lavin, French, Ruxton, & Read, 2002; Zijlstra, Mars, de Wijk, Westerterp-Plantenga, & de Graaf, 2008). This increase in thickness or viscosity can be associated with decreased palatability (Hoad et al., 2004). In Study 1, conducted in the UK, this difference in texture was detected by the participants, but did not alter liking or taste pleasantness. However, in Study 2, conducted in France, the greater thickness may have contributed to the differences in hedonic ratings indicating that the control was preferred to the test product. This may reflect cultural differences; given that culture is the most potent factor that predicts individual preferences (Rozin, 1998). Additionally, despite its lower palatability, participants were more satisfied after the test product than after the control. If eating a food is followed by beneficial consequences, such as satiety, then the sensory characteristics of the food become more pleasant (Bellisle, 2009). Lastly, the impact of palatability on further food intake is still not clearly established (for review; Sørensen, Møller, Flint, Martens, & Raben, 2003; Yeomans, Blundell, & Leshem, 2004). Altogether, the differences observed in sensory and hedonic ratings may have had limited effects on the study results. However, further
investigation such as testing acceptance of novel foods over repeated exposure would be needed (Weijzen, Zandstra, Alifieri, & de Graaf, 2008). In addition to cognitive and oral factors, other non-measured post-ingestive factors, such as gastric emptying and intestinal absorption rates (Burton-Freeman, 2000; Read, French, & Cunningham, 1994; Wren & Bloom, 2007), hormonal secretion (Blom et al., 2006) and post-prandial circulating amino acids (Veldhorst et al., 2008) may explain the effects of the test dairy product on appetite.

The aim of developing a low-fat yogurt, enriched with milk proteins and guar gum fibre, was to provide a healthy low-energy dense snack which could help in controlling appetite feelings between meals. This in turn could impact subsequent energy intake, a hypothesis which was tested in Study 2. Indeed, the appetite-reducing effects of the test product were accompanied by a significant decrease in lunch energy intake (274 kJ/65.4 kcal). This reduction contributed to an overall 6% reduction in total energy intake (i.e. 314 kJ/75 kcal), when combining breakfast, snack and lunch data. Williams, Noakes, Keogh, Foster, and Clifton (2006) previously showed that a mid-morning, high protein and high fibre bar (compared with a high fat and high sugar bar) significantly reduced energy intake at lunch by 5% ([245 kg]). In our study, food intake was not measured for the rest of the day. This should be further investigated in the short-term setting (e.g. 24–48 h) to check whether the reduction in energy observed at lunch is compensated for over the day (McKiernan, Hollis, & Mattes, 2008).

One limitation of our studies is its generalizability. The tested dairy product was consumed by women as a morning snack, as this corresponds to a real usage (Danone-TNS Sofres, 2008). However, whether these effects are observed if the product was consumed during other times of the day or with a meal is unknown. It would also be useful in the future to explore its appetite-reducing effects in other populations (e.g. men and individuals with more extreme differences in weight status) and at other snack moments such as in the afternoon (Williams et al., 2006). Additionally, designs of future studies should include a no-snack condition to confirm that the consumption of low-energy dense foods between meals could be an effective strategy to improve appetite control and maintain energy balance.

Potentially, a daily reduction of 314 kJ could be clinically significant in terms of energy balance, when considering that for a daily intake of 8.4 MJ, an extra intake of 84 kJ/day above the energy balance has been associated with an annual increase of 1 kg in adipose tissue (Jequier, 2002). However, the effects of small daily changes in energy balance on long-term body weight remain somewhat theoretical. Long-term studies are needed to better evaluate the potential efficiency of the chronic consumption of protein- and fibre-enriched dairy products in daily appetite control and weight management. In the real world food cues are more abundant, eating opportunities more frequent, and food choices less restricted. Given the powerful influence of palatability on ingestion, the beneficial effects of such products on satiety could be undermined by hedonic experience, resulting in overconsumption of other foods. Demonstrating the efficacy of such products in free-living situations, outside the confines of laboratory control, where ‘appetites’ may be more readily stimulated and control overwhelmed, is required.

In conclusion, we demonstrated in both studies that one commercial serving of a low-fat dairy product, enriched with milk protein and guar gum, significantly reduced appetite feelings over the 2 h following its consumption compared to non-enriched control products. Additionally, in Study 2, these changes in appetite feelings were accompanied by a reduction of food intake at a subsequent meal. This significant reduction of short-term appetite should be further investigated to evaluate the potential of this product in longer-term appetite regulation.

**References**


