Short Communication

Snack bar composition and their acute glycaemic and satiety effects

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Background and Objectives: Maintaining blood glucose within homeostatic limits and eating foods that suppress hunger and promote satiety have beneficial impacts for health. This study investigated the glycaemic response and satiety effects of a serving size of a healthier snack bar, branded Nothing Else, that met the required nutrient profiling score criteria for a health claim, in comparison to two top-selling commercial snack bars. **Methods and Study Design:** In an experimental study, 24 participants aged ≥50 years were recruited. On three different days blood glucose concentration was measured twice at baseline and 15, 30, 45, 60, 90 and 120 minutes after consumption of a serving size of each bar. Satiety effects were self-reported hunger, fullness, desire to eat, and amount could eat ratings on visual analogue scales. **Results:** The incremental area under the blood glucose response curve (iAUC) over two hours for the Nothing Else bar was 30% lower than commercial Bar 2 (p<0.001). At 45 minutes after eating, the Nothing Else bar induced the highest fullness rating and lowest hunger rating among the three snack bars. At two hours, fullness induced by the Nothing Else bar was twice that of Bar 2 (p=0.019), but not different to Bar 1 (p=0.212). **Conclusions:** The Nothing Else snack bar developed using the nutrient profiling scheme as a guideline, with its high protein and dietary fibre contents, had a lower glycaemic impact and induced a higher subjective satiety than the two commercial snack bars of equal weight.

Key Words: macronutrient, nutrient profiling, glycaemic response, hunger, satiety

INTRODUCTION

Dietary exposure over a life time contributes greatly to the risk of chronic diseases such as obesity and diabetes.[1] Maintaining blood glucose within homeostatic limits and eating foods that suppress hunger and promote satiety have beneficial impacts for health and prevention of type 2 diabetes mellitus.[2-4] The challenge is that many commercial products, such as snack bars, perceived as healthy by the consumer, do not meet the required nutrient profiling score (NPS) criteria for health claims (<4).[5] Snack foods contribute to more than 20% of the daily energy intake in many Western countries.[6,7] In 2014, the sales value of snack bars in New Zealand was NZ $132 million with muesli bars accounting for NZ $71 million, forecast to retain the same sales value by 2019.[8] However, snacking behaviour in relation to heath properties of snack foods such as glycaemic impact and satiety has not been well studied.[6] There are very few snack products which are made of all natural ingredients in the New Zealand market. Further, there are very few studies available on snack bar macronutrient composition in relation to glycaemia and satiety effects.

Reformulation to improve nutrition profile and front-of-pack food labels is promoted by governments to improve public health nutrition,[9] and there is evidence that government-led food reformulation initiatives improve the quality of food supply, for example to reduce salt intake.[10] However, to date, most actions have involved voluntary industry commitments. There has been a call for high value nutrition products but the focus has been on export and sales rather than improvement in public health.

This study aimed to investigate the glycaemic response and satiety effects over two hours on consumption of an eight ingredient snack bar, branded Nothing Else, in comparison with two top-selling commercial snack bars at each serving size on three different days. Moreover, this study aimed to explore the association between satiety and blood glucose concentration, and the association between macronutrient composition (e.g. protein, fibre, sugar content) and the physiological effects of a snack product.

METHODS

Number of participants and participants

Health claims on reduction in postprandial glycaemic

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Manuscript received 17 March 2016. Initial review completed 19 April 2016. Revision accepted 09 May 2016.
doi: 10.6133/apjcn.072016.04

response requires a test food has a statistically significant decrease (minimum 20%) in incremental area under the blood glucose response curve (iAUC) in comparison to the reference food.[11] The mean coefficient of variations (CVs) for testing glucose from literature are in the range of 20-30%.[12] Therefore, this experimental study with a predicted minimum 20% decrease in iAUC with a CV of 25%, would require 26 subjects to detect a 20% difference in glucose iAUC. This scenario would have 80% power and an alpha of 0.05.

People aged ≥50 years were recruited to the study because older people are more likely to be insulin resistant and benefit from a lower glycaemic load diet. People were not eligible if they had been diagnosed with diabetes mellitus, cardiovascular disease, diseases of the digestive system, or were receiving medication that might affect glucose metabolism. Ethics approval was provided by Auckland University of Technology Ethics Committee (Reference no. 14/342). Participants were provided with written information and the opportunity to ask questions before signing written consent to participate.

Samples and sample preparation

The Nothing Else bar, which met the NPS criteria for a health claim,[5] was developed in partnership with a food manufacturer. The glycaemic index (GI) of the Nothing Else bar was measured with 10 healthy subjects,[13] and was low (52). Two commercial snack bars were selected from New Zealand top-selling brands.[8] From the preliminary sensory study,[14] Bar 1 had the highest overall liking score, Bar 2 had similar ingredients and similar liking score to the Nothing Else bar. The Nothing Else bar was prepared in the kitchen in School of Hospitality, AUT. The two commercial snack bars were purchased from local supermarkets in Auckland.

Each snack bar was provided to participants at the serving size on a plate without packaging to reduce participant bias. The nutritional information and ingredients of three snack bars are shown in Table 1.

Experimental protocol

Blood glucose concentration was measured following the international standard method ISO 26642:2010(E).[13] Participants were asked to attend the laboratory on three mornings after a 10-12 hour overnight fast and standardisation of physical activity and the last meal of the previous day. Capillary blood samples were collected and analysed (HemoCue Glucose 201+, HemoCue AB, Ängelholm, Sweden) from finger pricking twice at baseline, and at 15, 30, 45, 60, 90 and 120 minutes after the start of the ingestion of a snack bar offered in a random order. Participants were asked to remain seated during the course of the tests.

After each blood, sample subjective satiety effects on hunger, fullness, desire to eat, and amount could eat were self-reported on 100 mm visual analogue scales verbally anchored e.g. "not at all full" and "extremely full" at the endpoints.[15,16]

Statistical analysis

Average fasting, postprandial blood glucose concentrations and satiety responses were plotted against time for each test food. Data were presented as mean±SD. The glucose iAUC (mmol.min/L) (i.e. the area above the baseline fasting glucose) was determined geometrically by applying the trapezoid rule.[13] The changes in the satiety response (mm) were calculated. The iAUC and change of satiety scores of the Nothing Else bar were compared separately with those of two commercial bars by repeated measures ANOVA with Bonferroni's correction and post hoc paired t-test to determine if a statistical difference existed at $p<0.05$. Satiety scores were compared with the iAUC to explore the association between satiety and blood glucose concentration using Pearson's linear correlation coefficient. The iAUC values of the three snack bars were compared in relation to the nutrients of each snack bar to explore the association between macronutrient composition and the physiological effects. Statistical analysis was performed using SPSS version 22, 2013 (IBM Corporation, NY, USA).

RESULTS

In 24 healthy subjects (12 men, 12 women; aged 50-71 years, 14 overweight/obese, 6 Asian, 18 European; fasting glucose 4.3-5.9 mmol/L), intra-individual mean fasting blood glucose concentrations were not different by day of testing (mean difference 0.1±0.3 mmol/L, $p=0.565$) (Figure 1). Thirty minutes after consumption, the rise in blood glucose for the Nothing Else bar was less than that for Bars 1 and 2 (6.1±0.7, 6.7±0.9 and 7.1±0.9 mmol/L; respectively). This difference was also seen at 45 minutes. Over two hours, the iAUC for the Nothing Else bar

Table 1. Nutritional information and ingredients of three snack bars

Product	Serving size (g)	Energy (kJ)	Protein (g)	Fat total (g)	Saturated fat (g)	CHO (g)	Sugars (g)	Fibre (g)	NPS
Nothing Else[†]	40	600	4.5	6.8	0.8	17.9	8.1	3.3	-1
Bar 1	35	755	5	11.1	2.4	14.1	8.3	1.9	11
Bar 2	40	652	2.5	5.6	3.5	22.6	15.1	2.2	15

CHO: carbohydrate.

NPS: nutrient profiling score, derived from nutrient profiling model.[5] A food with a NPS > 4 is unable to make health claims.

[†]Derived from food composition tables (FoodWorks version 7, Xyris Pty Ltd., Australia).

Nothing Else bar ingredients[‡]: rolled oats, almonds, dates, egg white, oat bran, honey, sunflower oil, cinnamon.

Bar 1 ingredients: peanuts, almonds, dates, sultanas, milk powder, cocoa powder, vegetable oil, soy lecithin, citric acid, brown sugar, puffed wheat, glucose, sugar, honey, sunflower seeds, glycerol, maltodextrin.

Bar 2 ingredients: sultanas, rolled oats, wheat flour, butter, milk powder, desiccated coconut, preservative, raw sugar, honey, sugar, oat bran, whole egg powder, raising agent, flavour, salt.

[‡]By descending order of ongoing weight.

(89.9±7.7 mmol.min/L) was not different to Bar 1 (87.8±7.1 mmol.min/L), but was 30% lower than that for Bar 2 (122.6±8.7 mmol.min/L, $p<0.001$). The rise of blood glucose over 45 minutes in response to the Nothing Else bar appeared to be slower and lower than that for the other two bars (Figure 1). With five participants, the glycaemic response to Bar 1 did not return to baseline within two hours and stayed elevated for three hours.

Participants recorded that the Nothing Else bar produced the highest fullness rating and the lowest hunger rating among the three snack bars at 30 and 45 minutes after eating. Bar 2 was associated with the higher hunger ratings and lower fullness ratings (Figure 2). At two hours, the increase of fullness induced by the Nothing Else bar was twice that of Bar 2 ($p=0.019$), but not different to Bar 1 ($p=0.212$). At two hours following consumption hunger rating for the Nothing Else bar was not different to baseline but that for Bar 1 and Bar 2 were significantly raised above baseline (6 and 8 mm, $p=0.013$ and 0.004, respectively) and hunger had been elevated above baseline from

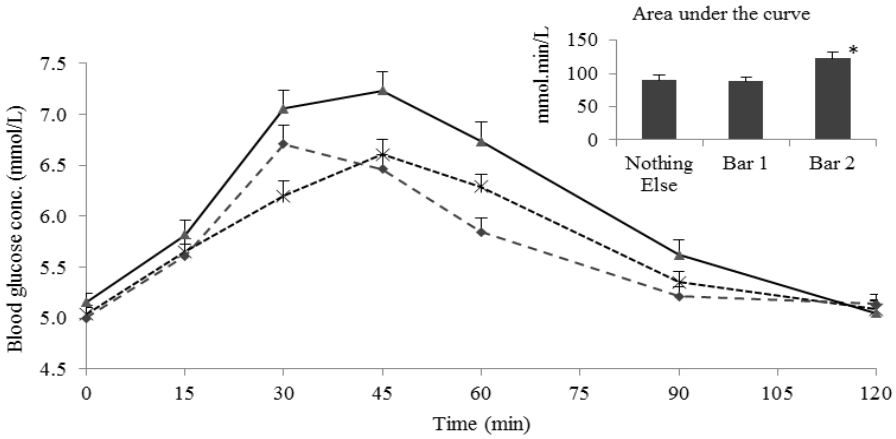

Figure 1. Mean glycaemic responses and incremental areas under the curve elicited by the Nothing Else bar, Bar 1, and Bar 2 in 24 healthy subjects aged ≥ 50 years. Error bars are standard errors. *Different to the Nothing Else bar and Bar 1 ($p<0.001$). Stars - Nothing Else; Diamonds - Bar 1; Triangles - Bar 2.

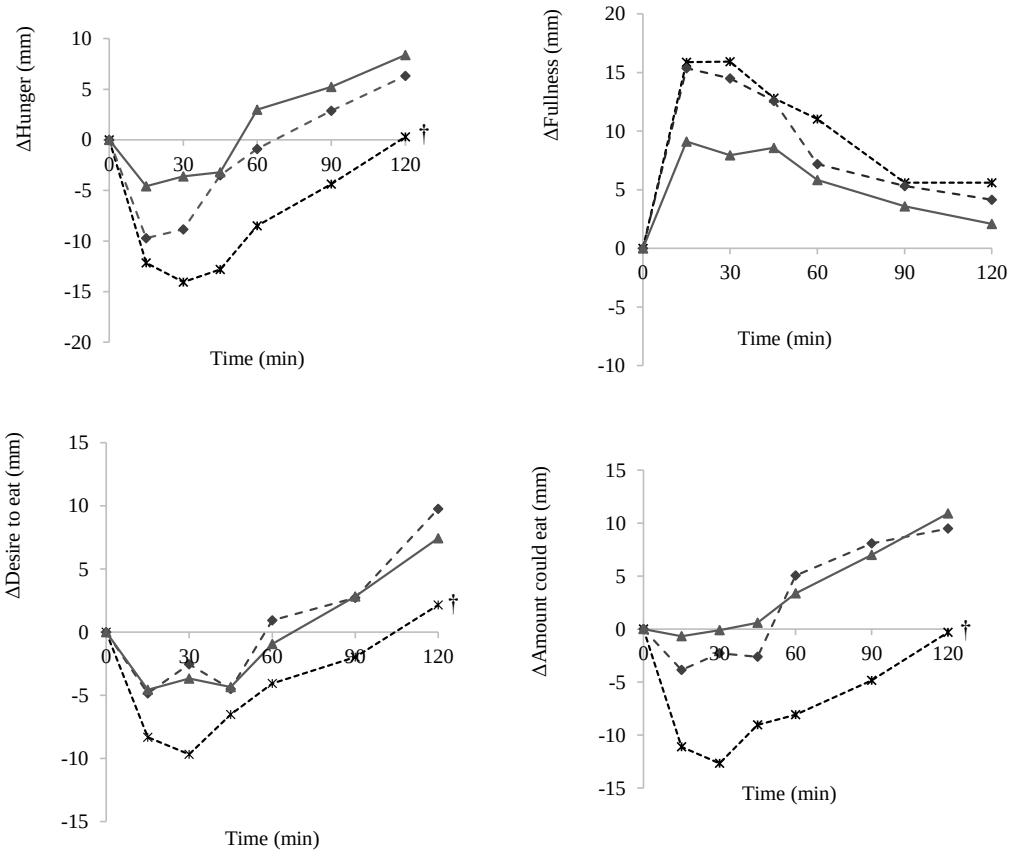

Figure 2. Mean changes (Δ) in self-reported hunger, fullness, desire to eat, and amount could eat ratings obtained on 100 mm visual analogue scales by 24 participants on three test days. †Different to Bar 1 and Bar 2 ($p<0.05$). Stars - Nothing Else; Diamonds - Bar 1; Triangles - Bar 2.

60 minutes (Figure 2). A similar pattern was seen for desire to eat, whereas the perception of amount that could be eaten after consuming the Nothing Else bar was less than the baseline of 0 (-6.6±1.9 mm, 95% CI [-11.2, -1.9]), and also less than that for Bar 1 (2.0±2.1mm, [-3.1, 7.0]) and Bar 2 (3.0±1.7 mm, [-1.0, 7.1]) (Figure 2).

Fullness and hunger ratings were not strongly correlated with the blood glucose concentrations in the present study either at 30 minutes or at 45 minutes where higher blood glucose concentrations were observed (data not shown). When all paired measurements of fullness and blood glucose concentrations over 120 minutes were considered positive correlations were observed for the three bars (Nothing Else bar, Bar 1 and Bar 2; r=0.75, 0.79, 0.77, respectively); and hunger ratings were negatively correlated with blood glucose concentrations (r=-0.85, -0.67, - 0.57, respectively).

Protein, fat and fibre (g/serving) were negatively correlated to iAUC and were positively correlated to fullness. Conversely carbohydrates and sugar were positively correlated to iAUC and negatively correlated to fullness. The correlation between sugar content and iAUC was significant (r=0.997, p=0.048).

DISCUSSION

One 40 g serving of the Nothing Else bar elicited lower glycaemic and higher satiety responses than 35 g and 40 g servings of two commercial snack bars. Furthermore, the Nothing Else bar had the most favourable nutrition profile in relation to fibre, protein and saturated fat. Therefore, the Nothing Else bar could be judged as the most beneficial from the point of view of glycaemic response, satiation and reducing hunger.

To our knowledge, this is the first investigation that has examined the relationships between the nutrition profile, glycaemic response, and satiety for a specific product. It is known that protein is more satiating than carbohydrates or fat.[17-19] Williams et al[20] reported that consumption of a high protein, high fibre snack improved short term glucose profile and reduced subsequent food intake compared with a high fat snack. However, the nutrient profiles of the test snacks were undeclared. The Nothing Else bar was developed by selecting wholesome ingredients that in combination would meet the nutrient profiling score criterion for a health claim,[5] and with structures, e.g. oat bran, that would help to lower glycaemic impact (GI=52, unpublished). To our knowledge the GI values of the two commercial bars have not been tested. The suggested origin for the occurrence of the favourable glycaemic and satiety responses is the nutrient profile and physical structure of the snack bar, which is dependent on the quantity and properties of the ingredients. Each is considered in turn.

Nutrient profile and glycaemic and satiating properties

The physical properties of food affect physiological processes and in turn are correlated with blood glucose response and sensation of satiety.[21] All the snack bars contained at least five grams of fat from various sources. Fat content in a food may delay gastric emptying and affect insulin secretion resulting in a lower glycaemic response,[22,23] however, a high fat content in a food, in particular saturated fat, could contribute to health problems,[24] and certainly makes the food more energy dense. Moreover, although fat reduces the initial rise of blood glucose after eating, it also prolongs elevated blood glucose concentration and a second glucose peak is produced.[25] This was shown in the present study with Bar 1. Despite the similar protein content to that of the Nothing Else bar, Bar 1 induced the highest hunger rating among the three snack bars, which may be explained as fat resulting in a low satiation effect compared to protein and carbohydrates.[4,26] High fat foods may also stimulate excessive consumption, because of the palatability.[27,28]

The higher carbohydrate and sugar contents in Bar 2 were associated with a higher iAUC than that of the other two snack bars. High protein food has higher specific satiety than low protein food.[29,30] Therefore the low protein content in Bar 2 may explain why this bar was rated the lowest for fullness. It is known that, in the short term, whole foods with low energy density increase satiety, decrease the feeling of hunger and reduce energy intake.[4] Even though the correlations between glycaemic response, satiety, and macronutrients such as protein, fat, fibre from the current study were trivial, there was nonetheless a trend seen for the quantity of those nutrients to be associated with the responses.

Effect of ingredients

Of the eight ingredients of the Nothing Else bar, rolled oats and almonds were in the largest proportion, more than 55% by weight. Oats are considered a healthy food with many already known health benefits, such as modulation of glucose metabolism and reduction of hunger.[31] In particular, oat bran reduces postprandial glycaemic and insulinemic responses.[32] Almonds offer healthy fats and give pleasant aroma and texture, and are rich in protein. Both oats and almonds were rich in fibre which were associated with low glycaemic impact and high satiety effect.[33] In addition, in vitro and in vivo animal studies have demonstrated the blood sugar regulation properties of cinnamon.[34] Research has suggested that consumption of cinnamon is associated with lowering glycated hemoglobin (HbA1c) and fasting plasma glucose, low density lipoprotein cholesterol, and triglyceride levels.[34,35]

In contrast to the Nothing Else bar, both the commercial bars have far more ingredients (≥ 15, Table 1). Even though some ingredients in the two commercial bars were same to that of the Nothing Else bar, for example, almonds (7% by weight) in Bar 1, and oats and oat bran (17% by weight) in Bar 2, the proportions of these ingredients were small. Peanuts were in the largest proportion in Bar 1, 42% by weight. The peanuts, almonds and vegetable oil in Bar 1 contributed to the high fat content and high energy density of this bar. Sultanas, sugar and honey in Bar 2 represented the highest sugar content which contributed to the highest glycaemic impact. Moreover, the two commercial bars contain artificial flavour and preservatives, which rationally or irrationally would not meet the growing consumer interest for perceived natural and healthy foods.[36]

Strengths and limitations

Over the past decades, there has been a debate that

whether GI is a likely predictor of satiety and hunger. Studies have shown that low GI foods are associated with an increase of satiety, a delay in the return of appetite, and a reduction of consumption in the short term.[37] The results for the Nothing Else bar support this outcome. However, the GI values of the two commercial bars were unknown and the relationship has not been measured.

The present study showed that the Nothing Else bar had a 30% reduction in postprandial glycaemic response compared with another bar at equal weight which added to the evidence for a health claim for the bar. The present report is one stage of providing an evidence-base that shows the relationships between the nutrient profile, glycaemic response, and satiety for a specific product. Unlike GI which uses a standard amount of carbohydrate, the design of this study was more similar to a natural setting in which snack bars were consumed at a packed serving size.

This was a small study where participants self-identified as healthy individuals without diabetes although more than half were overweight and could be insulin resistant. The study was further limited because insulin resistance was not measured and the time of measurement of the effects was limited to two hours following consumption of a bar unaccompanied by other foods such as milky tea or coffee. Future work is required to investigate the medium to long term glycaemic impact on consumption of the Nothing Else bar, and whether food products of this type are acceptable as part of dietary pattern.

Conclusions

The Nothing Else snack bar, with its high protein and dietary fibre content, had a lower glycaemic impact and induced a higher subjective satiety than two commercial snack products of equal weight in the short term. A wider availability of food with nutrition and verifiable health claims could help consumers to make healthier choices. This was achieved by evidence-based food reformulation to produce a food product which was low in refined starch, high in protein, dietary fibre, and fruits and nuts, and used the nutrient profiling scheme as a guideline.

ACKNOWLEDGEMENTS AND FUNDING DISCLOSURE

The authors thank Peter Tan, the director of AB Foods Ltd., Auckland and Callaghan Innovation for research funding and facilities for the development of the Nothing Else snack bar. We also wish to thank Bruce Donaldson, and the staff in School of Hospitality, AUT for their technical assistance. The Nothing Else brand was created by Dave Brown of AUT.

AUTHOR DISCLOSURES

The authors declare that the development of the Nothing Else snack bar is a project of the AUT food network and may lead to a commercial product that would bring an income associated with the intellectual property related to the branding and formulation that can be attributed to the Auckland University of Technology.

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