Original Article

High protein high fibre snack bars reduce food intake and improve short term glucose and insulin profiles compared with high fat snack bars

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The replacement in the diet of refined carbohydrate and fat with fibre and protein has been shown to promote satiety and improve glucose and insulin profiles. It is less clear whether the macronutrient composition of individual foods such as snacks have any meaningful impact on metabolic parameters and satiety. We examined if the consumption of higher protein higher fibre snack bars would result in reducing outcome measures such as food intake and glucose and insulin patterns compared to a conventional isocaloric high fat high refined carbohydrate snack bar. Twenty three women were randomized in a single blind cross over study with 2 interventions, a high fat high sugar snack bar and a comparatively higher protein, higher fibre snack bar intervention. Snack bars were eaten at mid morning and mid afternoon, and a standard breakfast and ad libitum buffet lunch. The glucose and insulin responses over 9 hours were significantly lower (P = 0.014 and P = 0.012 respectively) during the high protein snack bar intervention. Peak glucose levels were also 16% lower after the morning HP bar (P <0.001). The morning high protein bar reduced the energy intake at the buffet lunch meal by 5% (4657 ± 1025KJ vs 4901 ± 1186KJ, P < 0.05). Altering the macronutrient composition of a snack bar can assist in reducing the energy intake at a subsequent meal and improve short term glucose and insulin profiles.

Keywords: snack foods, satiety, high protein, glucose, insulin response

Introduction

Previous studies have shown that meals with a high protein/carbohydrate ratio (ie lower GL) may contribute to improved post meal and diurnal glucose profiles in subjects with Type 2 diabetes and insulin resistance.[1,2] Although dietary protein is known in controlled experimental studies to result in greater satiation than carbohydrate or fat during meals,[3-6] the effects of protein enriched whole food snacks on subsequent food intake and metabolic profile is less clear and poorly studied. Whole foods comprise a mixture of macronutrients, have varying fibre content and vary in physical form and taste, the totality of which may contribute to their satiating effects. Nine out of 10 Australians regularly consume confectionary including food bars[7] and altering the macronutrient composition of snack bars for health benefits is a priority for food producers and consumers.

The aim of this study was to compare the impact of higher protein higher fibre (HP) snack bars with a commercial high fat high refined carbohydrate (HFC) snack bar on daily glucose and insulin profiles, subjectively assessed appetite control over a day, and objectively assessed appetite control as assessed by food consumed at lunch and at an evening meal. We hypothesised that the consumption of the HP bars would result in reduced diurnal glucose and insulin patterns and provide superior appetite control compared to the HFC bars in overweight younger women.

Materials and Methods

Subjects

Subjects were recruited by public advertisement and selected on the basis of the following criteria: overweight to moderately obese women (BMI 27-34kg/m^2) and aged between 25 - 45 years. Volunteers were not previously diagnosed with type 1 or 2 diabetes, did not have active liver and kidney disease, current gastrointestinal disease or past history of gastrointestinal surgery which may have affected study outcomes. They had no history of hyper-sensitivity to the study foods (casein, whey or wheat) and were not taking any medications which may have affected GI motility or hunger /appetite. All subjects signed an informed written consent to participate in the study which was approved by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Human Nutrition Human Ethics Committee. Twenty nine subjects were selected to participate in the study. Six subjects withdrew before study commencement due to work commitments, unforseen travel or illness. Twenty three women

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Accepted 12 April 2006

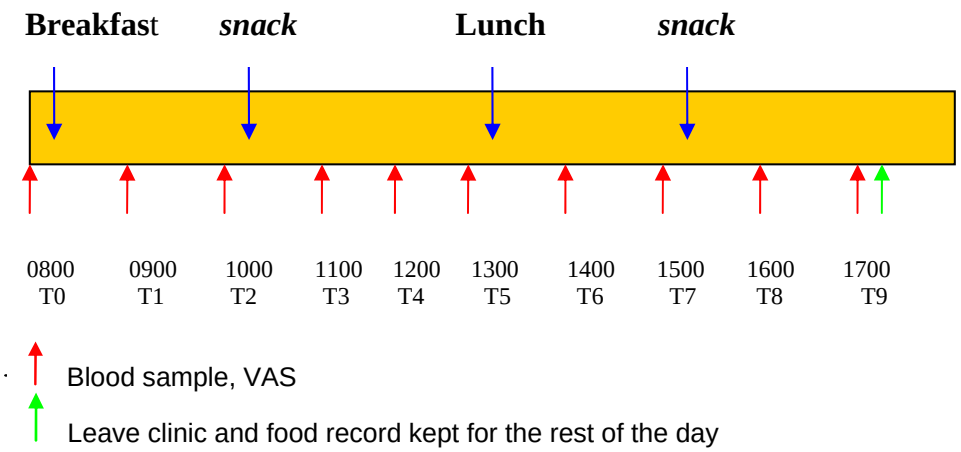

Figure 1. Schematic diagram of study design where T = timepoints.

aged 42 ± 8y (mean ± SD) and BMI 30 ± 4kg/m^2 completed the trial. Women only were chosen in order to narrow the range of energy intake at the buffet lunch and improve the power of the study.

Study design

The design was an acute study, spanning one whole day, performed on 2 occasions with the different snack foods being assessed on separate days. There was a 7 day interval between study days. Volunteers were randomized in a single blind cross over study with 2 treatments as depicted in Figure 1. Blood samples were taken hourly from 8am to 5pm and ad libitum food intake was assessed by the amount of food consumed at a buffet lunch and weighed food records after 5pm. The order of the snack food interventions was fully randomised to avoid effects of habituation to the procedure and the snacks were provided in unlabelled form. Breakfast was consumed after the fasting blood sample was collected (T0). The morning snack (AM) was consumed just after the T2 blood sample. The buffet lunch was commenced after the T5 blood sample and subjects were exposed to the buffet until the T6 blood sample. The afternoon snack (PM) was consumed after the T7 blood sample. Post-prandial glucose and insulin responses to the test bars were assessed by calculating the change in subsequent time points after consumption of bars.

Study meals

The HP bars were commercially produced by Aussie Bodies snack bars (Aussie Bodies 282 Normanby Road Port Melbourne 3207). The nutrient profile of the HP bars and commercial HFC bar are outlined in Table 1. The manufacturer of the HP bars designed the afternoon HP bar (HP-PM) to have a greater protein to carbohydrate ratio than the morning HP bar (HP-AM) to promote satiety later in the day. Because of the study design the effect of the morning HP bar dominated the controlled part of the experiment. The breakfast was standardised in type and quantity and consisted of 2 slices white bread, 1 teaspoon margarine, 20g jam, 1 cup tea/coffee, 30ml fat reduced milk. Lunch was standardised in type and

Table 1. Nutrient composition of snack bars

	HP-AM 50g	HP-PM 50g	HFC 40g
Energy	750kJ (170Cal) 15kJ/g	770kJ (180Cal) 15.4kJ/g	771kJ (181kCal) 17.1kJ/g
Protein	10.1g (21.9%)	18.6g (39.7%)	1.5 (<0.1%)
Fat			
- Total	3.9g (19.4%)	4.9g (24.1%)	7.2g (35.5%)
- Saturated	2.9g	4.6g	4.0g
Carbohydrate			
- Total	25.6g (58.7%)	16.0g (36.2%)	28.4g (64.4%)
- Sugars	17.0g	9.2g	23.1g
Dietary fibre	4.0g	2.6g	<1g

Test bar Ingredients: Protein blend (soy protein isolate, whey protein concentrate, tapioca starch), fructose, apple pieces, glucose syrup, polydextrose, rolled oats, unsalted butter, emulsifier (472c), water, rice starch, flavours, hydrogenated palm oil, salt, preservative (220), antioxidant (306). **Commercial bar Ingredients:** Milk chocolate 40% (sugar, milk solids, cocoa butter, cocoa mass, emulsifier (soy lecithin), flavour), nougat 32% (sugar, wheat glucose syrup, partially hydrogenated vegetable fat, barley malt extract, cocoa powder, milk solids, egg white, salt), caramel 28% (wheat glucose syrup, sugar, milk solids, partially hydrogenated vegetable fat, salt, flavour). Milk chocolate contains a minimum of 22% cocoa solids and 25% milk solids

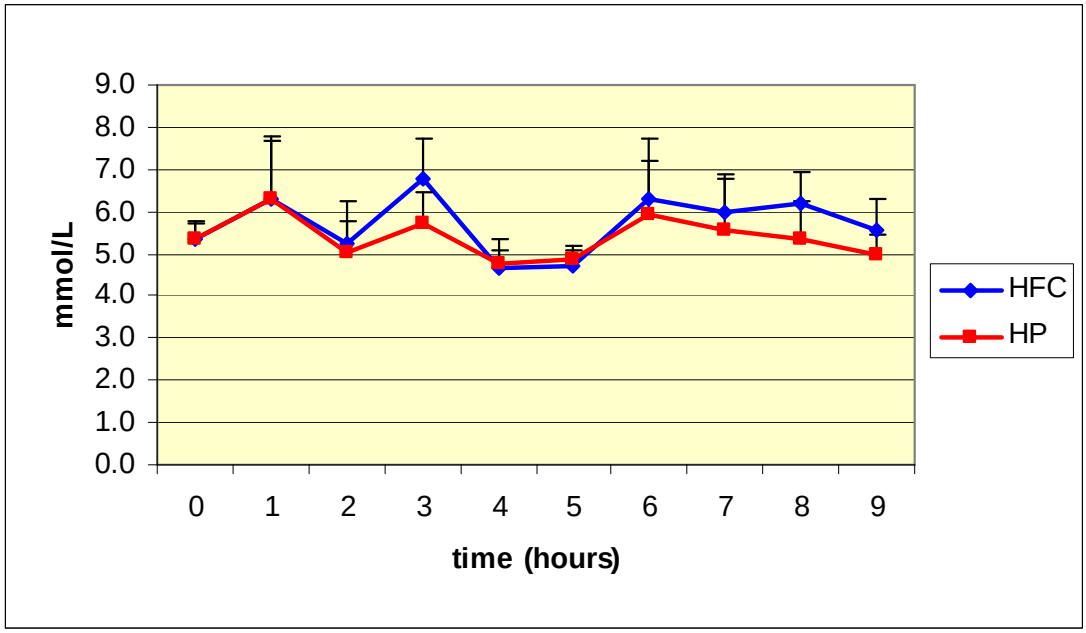

Figure 2. Plasma glucose levels (mean ± SD), *N* = 18, completers. Significant differences at T (timepoint) 3, *P*<0.001; T8, *P*<0.001; and T9, P=0.005.

Table 2. Nutrient intake for *buffet* meal (*N=18)*, completers; paired t tests between groups

	Control		Test	
	Mean	*Std. Dev.*	Mean	*Std. Dev.*
Energy *kJ* Ψ	4901	1186.3	4656	1024.8
Weight *g* Ψ	789	269.9	705	216.4
Protein *%kJ*	16.8	1.7	17.1	1.9
Protein *g*	48.5	12.0	46.8	10.5
Fat *%kJ*	35.1	4.4	35.9	4.4
Fat *g*	46.4	12.2	45.6	12.1
Carbohydrate *%kJ*	44.8	5.1	43.6	5.0
Carbohydrate *g* Ψ	137.2	38.0	125.9	29.9
Saturated fat *%kJ*	15.9	3.7	16.4	3.5
Saturated fat *g*	21.2	6.7	21.0	6.5
Fibre *g*	8.2	2.2	7.9	1.6
Sugars *g* Ω	63.3	25.2	52.9	20.9
Starch *g*	73.2	16.6	72.2	16.2

Ψ = significantly different, *P*<0.05; Ω = significantly different, *P* =0.005

consumed ad libitum. Subjects were provided with a tray of attractive food items, to which they were exposed for 1 hour. The buffet lunch was designed to reflect usual lunch practices. There was variety to optimise choice and foods were available in excess of consumption. Up to 4 subjects were seated at the same table with their separate trays to attempt to mimic normal social conditions. Food intake after 5pm was not controlled. These conditions remained consistent for both the volunteers' study days.

Satiety measures

Objective satiety was assessed by calculating energy content of food intake at the buffet and subsequently over the day. Subjects were instructed how to keep a food record by a dietitian. The food intake for the reminder of the day was analysed using FoodWorks software package (Xyris Software, Highgate Hill, Australia). Subjective assessment of satiety was measured hourly over the day. This was assessed using a visual analogue scale (VAS) from

Table 3. Nutrient intake for the whole day (*N=18)*, completers; paired t tests between groups

	Control		Test	
	Mean	*Std. Dev.*	Mean	*Std. Dev.*
Energy *kJ*	10275	1765.0	9970	1982.2
Weight *g*	1479.0	291.4	1456.0	342.0
Protein *%kJ* $^{\Psi}$	14.8	2.8	19.5	2.5
Protein *g* $^{\Omega}$	89.8	24.3	112.9	20.3
Fat *%kJ* $^{\chi}$	36.1	5.2	31.3	4.5
Fat *g*	101.9	30.7	84.7	23.1
Carbohydrate *%kJ*	45.3	5.2	44.7	4.1
Carbohydrate *g*	287.2	37.4	279.3	66.1
Saturated fat *%kJ*	15.5	2.5	14.5	2.8
Saturated fat *g*	43.6	12.8	39.1	11.5
Fibre *g* *	17.9	4.4	24.2	6.3
Sugars *g* $^{\Psi}$	146.1	23.7	118.3	31.1
Starch *g*	140.2	31.0	159.7	45.0

Ψ = significantly different, $P = 0.000$; Ω = significantly different, $P = 0.003$; χ = significantly different, $P < 0.05$
* = significantly different, $P = 0.001$

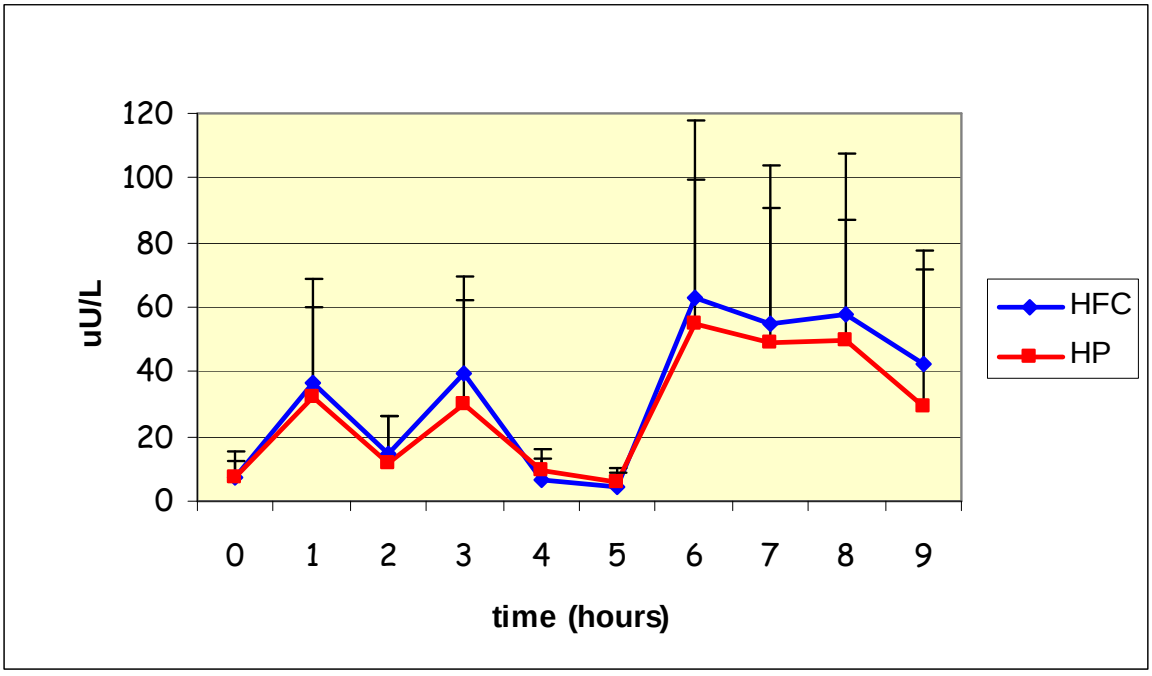

Figure 3. Plasma insulin levels (mean ± SD), $N = 18$, completers. Significant difference at T9, $P = 0.057$.

from 8am to 5pm. The VAS is a validated short questionnaire with a linear scale of 100mm for rating hunger, fullness, satiety, nausea, desire to eat and the amount of food that could be eaten at the next meal.[8] The changes in ratings from baseline were quantified following the method described by Porrini *et al.*,1995[9] and analysis was performed on *N*=23.

Palatability measures

Subjects were provided with a 10 point scale to assess perceived palatability of the snack bars after each snack was consumed where the higher the number the greater the palatability.

Blood analysis

Blood samples for plasma insulin and glucose were collected at baseline before breakfast and then hourly over the day until 5pm. Samples were collected in sodium fluoride/EDTA (1g/L) and stored on ice until processed. The plasma was isolated by centrifuging for 10 minutes at 1500g at 4ºC (Beckman GS-6R Centrifuge CA) and stored at -80ºC. All samples for each individual were

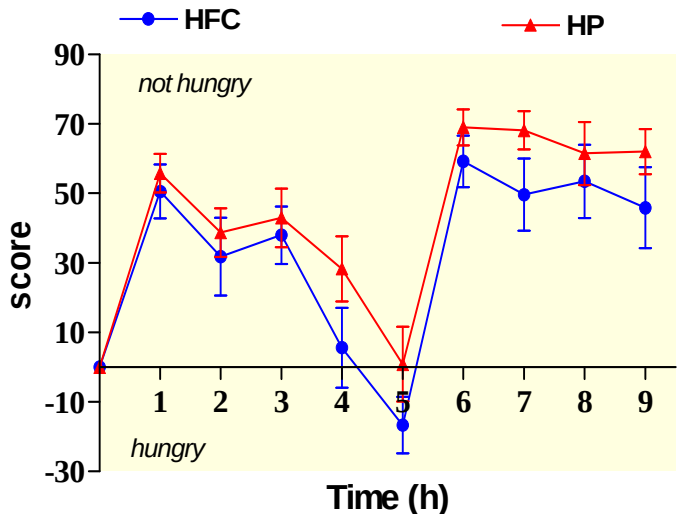

Figure 4. Visual analogue scale (mean ± SD), n=23.

measured in one assay at the end of the study. Plasma glucose was measured on a Hitachi 902 Automatic Analyzer (Roche) and insulin concentration was measured using Mercodia Insulin ELISA kit (ALPCO, American Laboratory Products).

Data analysis

Statistical analysis was completed using SPSS V11.5 for Windows with significance set at $P<0.05$. All the data are presented as means ± SD. Comparisons between macronutrients were calculated using paired t-test. VAS was analysed by using repeated measures general linear model. Glucose and insulin analyses were done using repeated measures ANOVA with bar type (2 levels-control or test) and time (10 levels) as the within subject factors. Palatability ratings were analysed as means ± SD and comparisons between bars calculated using paired t-test.

Results

Of the twenty three women who completed the study, 5 did not consume the entire snack bar on one or both occasions on the same or different days. Therefore, the data was analysed with only those subjects who completely consumed both bars (N=18). Non completion of the HFC bars was due to fullness, or feeling unwell; and the HP snack bars due to fullness or a dislike of the flavour (choc-orange).

Plasma glucose and insulin responses

There was a significant interaction of bar type with glucose response over 9 hours (P = 0.014; Fig. 2) which was lower on the day that the HP bars were consumed. When individual time points between treatments were compared by paired t test, significantly lower glucose values were observed after T3 (P<0.001), T8 (P<0.001), and T9 (P = 0.005), which corresponded to the blood samples following the HP-AM bar (T3) and the HP-PM bar (T8 and T9). Peak glucose levels (T3) were 16% lower after the HP-AM than the HFC.

The 9 hour insulin response was also significantly lower (P = 0.012, Fig. 3) on the day that the HP bars were consumed. When individual time points between treatments were compared by paired t test, lower insulin values were observed at 8 of the 10 time points in the test intervention, though it was only at T9 that this approached statistical significance (P = 0.057).

The change in glucose response to the HP-AM was significantly lower compared to the HFC (P <0.001). The changes in glucose response to the HP-PM were not significantly different from the HFC. The change in insulin response to the HP-AM was significantly lower compared to the HFC (P <0.037). The changes in insulin response to the HP-PM were not significantly different to the HFC.

Nutrient intake

Kilojoule intake of individuals for the buffet lunch was highly correlated between visits (r=0.9, P <0.01). When snack type was considered, subjects consumed 5% fewer kilojoules at the buffet lunch after eating the HP-AM at morning tea (T2) than after the HFC (P <0.05, Table 2). This was due to a significantly greater intake of carbohydrate as sugars after the HFC which on analysis of amounts of foods consumed was due to a greater consumption of yoghurt. Total energy intake over the day, including consumption of snack bars, was 3% lower on the HP bar intervention but this did not reach statistical significance (Table 3). Protein intake in absolute terms was 26% greater over the total day on the HP bar intervention (P = 0.000) but was not different at the lunch buffet. Total carbohydrate intake was 8% lower at the buffet lunch after the HP-AM (P <0.05) but total carbohydrate intake was not significantly different for the day. Total fat intake as a percent energy was 13% lower for the whole day on the HP bar intervention (P <0.05) but not different in terms of foods consumed at the lunch buffet. Fibre intake was 35% higher over the whole day on the HP intervention (P = 0.001) (Table 3).

Subjective appetite rating

The appetite ratings for nausea, hunger (Fig. 4), fullness, satiety, desire to eat and amount of food that could be eaten at the next meal all tended towards greater satiation

on the HP intervention compared with the HFC bars. However, none of these parameters reached statistical significance.

Palatability ratings

Palatability ratings for the control bar versus the HP bar were statistically different for both morning ($P<0.01$) and afternoon ($P<0.01$) periods. The average rating for the control bar when consumed in the morning was 4 (range 1-5) whereas the average rating for the HP-AM was 1 (range -5 to +4). The average rating for the control bar when consumed in the afternoon was 4 (range -2 to +5) whereas the average rating for the HP-PM was -2 (range -5 to +5) which was highly statistically different ($P<0.01$).

Discussion

The main outcome of this study is that differences in the macronutrient composition of a snack bar had an impact on energy intake three hours after consumption and glucose and insulin levels over the whole day. The HP-AM was associated with a 5% reduction in energy intake at the next meal. This was due to a significantly greater intake of carbohydrates as sugars after the HFC and more specifically a greater consumption of yoghurt. It is difficult to determine which attribute caused the reduction in energy intake at the lunch meal given that the control and intervention snack bars varied in several ways. They had a different macronutrient composition, the HP bars weighed slightly more which may have contributed to gastric distension and consequently satiety[10] and there were markedly superior palatability ratings for the control bar. It is therefore possible that there may have been a number of reasons for the results we obtained. However, previous studies have shown that protein exerts a greater inhibitory effect on appetite than either carbohydrate or fat[3,4,11-16] and the protein in the HP bars may have therefore contributed to this reduction in energy intake. However, the reduction in energy intake over the whole day in our study was not significant at 3%. Similarly, Stubbs *et al.* 1996[3] found that while a high protein breakfast led to detectable changes in hunger compared with high fat and high carbohydrate breakfasts this did not correspond to energy intake at lunch or over the rest of the day. Johnstone *et al.,* 2000[17] also found that snack composition did not differentially affect total daily energy intake or hunger. The test and control bars in our study contributed 15% of total energy intakes. Total energy consumed (9970kJ in the HP intervention) would be sufficient for weight maintenance in this group of subjects assuming light-moderate activity.

The palatability ratings of the bars in our study indicated that the HFC bars were more favourably received. There is mixed opinion on whether the palatability of food affects subsequent food intake. Some studies[18-21] suggest subjects were hungrier after a preferred meal while others[22,23] indicate there is no effect on satiety at the next meal. It may be that increased palatability effects satiation (termination of the current meal) but not subsequent satiety.[22]

Subjective perception of hunger, desire to eat and amount of food that could be consumed was measured using the visual analogue scale indicated that subjects were less hungry on the HP intervention however these measures did not reach significance. This is in contrast with Poppitt *et al.,* 1998[5] and Porrini *et al.,* 1995[24], both finding that a protein pre-load resulted in a significant reduction in subjective measures of hunger as well as reduced subsequent energy intake. The lack of statistical significance in our results may have been due, in part, to there not being adequate time for a difference to be observed from when the snack bars were consumed in the morning until lunch time (3 hours later) and in the afternoon until the end of recording (2 hours).

The role of snacks in energy intake and weight reduction is much debated. Some studies indicate that the avoidance of foods consumed as snacks is not associated with weight loss[25,26] and that snacking in some people can assist in regulating excessive energy intake.[27] While other studies show that the inclusion of any snack whether it is high in protein, fat or carbohydrate is detrimental to weight loss as the consumption of energy at subsequent meals is unchanged compared with no snack consumption.[5,28] Marmonier *et al*., 2000[4] showed that a high protein snack delayed the request for the subsequent meal longer than the high fat or high carbohydrate snack. In those individuals who currently consume snacks, the present study lends support to the argument for choosing snacks that have a higher protein and higher fibre content than the conventional high fat high sugar variety that are commonly available. However, we did not include a "no snack" group making it impossible to know if the addition of snack bars in general affected total energy intake.

The present study used protein enriched whole foods in contrast to the majority of studies in this area[3,4] that have used different food components to make a highly controlled macronutrient intake. The snack bars used in this study are whole foods with varying taste, textures, energy densities, weights and appearances. A benefit of such an approach is that foods in the real world are not as rigidly controlled as in the controlled experimental studies and we are therefore obtaining data using a more free living approach. The limitation of such an approach is that causal effects are more difficult to determine. As new food products are developed with higher protein/ carbohydrate ratios and lower GL aimed at the weight conscious consumer, it is important to establish the validity of such products in offering advantages to metabolic, satiation and satiety profiles. This information will inform product development of new foods which may have a meaningful impact on satiety and subsequent weight control.

In conclusion, there is evidence from this study that higher protein higher fibre snack bars have a superior influence on short term metabolic parameters and may assist in appetite control compared with the conventional high fat high refined carbohydrate snack bars. The consumption of high fat high sugar snack bars is very common and it would appear that by altering their macronutrient composition we may see health benefits in people who regularly consume these products.

Acknowledgements

Funding for this study was provided by Aussiebodies 282 Normanby Road, Port Melbourne Australia 3207. We thank

Kathryn Bastiaans, Anne McGuffin, Rosemary McArthur, Mark Manu, Candida Sullivan for their assistance in performing these studies.

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Original Article

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高蛋白高纖維點心棒比高脂點心棒能減少食物攝取並改善短期葡萄糖及胰島素狀況

以富含纖維及蛋白質替代飲食中的精製碳水化合物及脂質，可增加飽足感及改善葡萄糖及胰島素狀況。然而像點心等單項食物中的巨量營養素組成，是否也可益於代謝參數與飽足感則並不清楚。我們評估攝取高蛋白質高纖維點心棒與等熱量的傳統高脂高精製碳水化合物點心棒，是否能降低食物的攝取與葡萄糖及胰島素狀況？此單盲交叉研究共有23名女性參與，研究對象隨機分配到高脂高糖點心棒或高蛋白高纖維點心棒的兩組。點心棒食用的時間是在早午餐間及午晚餐間，早餐為標準早餐，而午餐為不限量的自助午餐。葡萄糖跟胰島素反應在高蛋白點心棒介入九小時後顯著的較低(*P*值分別為0.014及0.012)。而葡萄糖的高峰發生在早上的食用高蛋白（HP）棒之後，也低了16%(*P*<0.001)。早上吃了高蛋白棒之後，可減少午餐大約5%的熱量攝取(4657±1025KJ vs. 4901±1186KJ，*P*<0.05)。改變點心棒的巨量營養素組成有助於減少之後正餐熱量攝取並改善短期葡萄糖及胰島素的狀況。

關鍵字:點心食品、飽足感、高蛋白、葡萄糖、胰島素反應。