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Differences in satiety effects of alginate and whey protein based foods

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Abstract

Satiety is important in regulating food intake and has important public health significance in the control of obesity. Food containing protein and non-starch polysaccharides provides a satiety effect through various mechanisms but a comparison of the satiety effect on each has not previously been investigated. This study compared the satiety effect or reduction of hunger after consumption of (i) a whey protein-based drink versus an alginate-based drink of the same viscosity where only the protein content differed, (ii) two alginate-based drinks differing in alginate type and viscosity, and (iii) a whey protein-based drink versus an alginate-based drink differing in protein content and viscosity. Fasted subjects assessed the effect of a drink on hunger that was one of three variants: a low viscosity whey-protein drink (LVHP); a high viscosity low protein alginate-based drink (HVLP); or a low viscosity low protein alginate-based drink (LVLP) over the 240 minutes postprandial period using a Visual Analogue Scale (VAS). When protein differed and viscosity was the same, results showed subjects felt significantly less hungry after consuming the LVHP drink compared to the LVLP drink, so protein reduced hunger. Subjects reported reduced hunger from the HVLP drink compared to the LVLP drink where viscosity of drinks differed, suggesting viscosity and/or gelation reduced hunger. Subjects reported reduced hunger from the HVLP drink compared to LVHP drink where both protein and viscosity differed, suggesting that viscosity reduced hunger more than the protein effect. Results suggest the physical characteristics such as viscosity and/or gel strength and protein content reduce hunger. Further studies should investigate which of these parameters is more important.

Introduction

Consumption of high protein and high dietary fibre meals has the potential to protect against obesity. The fight to reduce obesity by effective weight management has been linked to food intake regulation and the strategies that reduce energy intake including satiety (Flood-Obbagy & Rolls 2009). Westerterp-Plantenga & Lejeune (2005) also found a positive effect of protein intake on body-weight regulation.

The mechanisms controlling appetite and hunger are complicated, but the study of these mechanisms is important to provide scientific evidence to assist consumers in healthy food choices. Satiety implies there is an inhibition of eating, as a consequence of having eaten (Gerstein et al 2004). This inhibition is due to the many factors including energy density, weight and volume, macronutrient composition, particle size, appearance, satisfaction and palatability of food (Booth et al 1982, Marciani et al 2001, Pereira and Ludwig 2001, Stubbs and Whybrow 2004, Gerstein et al 2004, Mitchell and Brunstrom 2005, Freeland et al 2009 and Yeomans et al 2009). Early researchers (Barkeling et al 1990, Stubbs et al 1996) found protein to be the most satiating macronutrient component of food. More recently, Hall et al (2003) reported a lower energy intake from consumption of whey protein compared to casein consumption and Anderson et al (2004) found subjects who consume whey protein had enhanced satiety relative to other proteins (egg-albumin and soy protein) and carbohydrates. Lang et al. (1998) found no differences between the effect of egg albumin, casein, gelatin, soy, pea, or wheat gluten on appetite. Subsequently, Lang et al. (1999) found a weak effect on satiety but no difference in energy intake after consumption of casein, gelatin, or soy protein based meals. Bowen et al. (2006) found no

difference on appetite and energy intake of a whey or casein preload and Bowen, Noakes and Clifton (2006) found whey, soy, and gluten protein tended to reduce ad libitum food intake equally. Although whey and casein protein influence satiety, casein may provide satiety for longer than whey protein (Borie et al. 1997). Whey protein was found to induce dramatic short increases of plasma amino acids but casein induced a slower prolonged increase (Borie et al. 1997).

Protein when consumed in large amounts is a strong determinant of satiety and food intake (Long et al 2000, Anderson et al. 2004, Anderson and Moore 2004, Westerterp-Plantenga and Lejeune 2005, Veldhorst et al 2009 and Bertenshaw et al 2009). Whey protein in high concentration contributes to viscosity of food and short-term satiety compared to carbohydrates and other proteins (Luhovyy et al 2007, Chung Chun Lam et al 2008 and Burton-Freeman 2008). Anderson et al (2004) introduced the protein source (milk, egg or soy) as a determinant of satiety and these different sources have unique satiety influencing characteristics such as clotting of proteins in milk. Leidy et al (2009) found protein at breakfast had the greatest positive effect on satiety. The different satiety effect or effect on subsequent food intake by various proteins may be due to their physical properties of food in the gut, independent of their nutritional qualities (Anderson et al 2004). Marciani et al (2001) showed fullness from a high viscosity meal was significantly higher than the satiety induced by nutrients alone. Zijlstra et al. (2009) found more viscous dairy products with similar energy density and macronutrient composition, were more satiating than less viscous products.

In addition other factors such as taste influence satiety. Nasser (2001) and Gerstein et al (2004) have reported the influence taste on satiety but many studies compare food where a variety of food with different tastes is compared (Barkeling et al 1990, Kovacs et al 2008).

Insoluble plant cell wall material and water soluble polysaccharides are components of dietary fibre. Both natural food components and gums that are added to food to modify rheological properties or to provide bulk as non-digestible polymers constitute dietary fibre (BeMiller and Whistler 1996). Fibre alters the viscosity of food (Slavin 2008) and may decrease hunger (Chow 2007, Willis 2009). Willis (2009) found the inclusion of resistant starch and corn bran in muffins enhanced short-term satiety when compared with those made with polydextrose. Pelkman et al (2007) and Paxman et al (2008) found consumption of sodium alginate or alginate-pectin plus calcium based food resulted in a reduction of subsequent energy intake.

Australian consumers find breakfast drinks acceptable with 176 nutrients drinks (non-fruit and non-vegetable) available in supermarkets and 7.4% of these are enriched milk-based drinks containing an average energy of 850 kJ (Walker et al 2007). The first stage of this study was a product development stage where test drinks were developed and tested by a consumer panel. The energy, volume, appearance, taste and texture were controlled in this study to ensure they did not influence satiety results. The purpose of this study was to compare the satiety effect of a different breakfast drinks and specifically to test the effect of alginate and the impact of viscosity on hunger. The objective was to compare a low viscosity whey protein-based drink (LVHP) to a low viscosity alginate-based drink (LVLP)

to determine the effect of protein, also to compare a high viscosity alginate-based drink (HVLP) and a low viscosity alginate-based drink (LVLP) to determine the effect of viscosity and to compare the high viscosity alginate-based drink (HVLP) and a low viscosity whey protein based drink (LVHP) where both protein and viscosity were different.

Methods

Subjects

Thirty-three healthy young adults aged between 18 and 24 years with a Body Mass Index (BMI) of 18 to 25 kg/m² were recruited to participate in the study from the Curtin University student population through flyers, posters, recruitment letters, information sessions, and radio and internet announcements (Table 1). Exclusion criteria included medical or health conditions and medication that would affect the purposes of the study. Subjects were not on, or had been on, a weight loss diet in the last six months and were consuming at least three meals per day. Participants were non-smokers and maintained their normal regular exercise habits for the duration of the study. Subjects completed the Three-Factor Eating Questionnaire (Stunkard & Messick 1985) to ensure selected subjects were not under eaters or over eaters. The subject's height and weight were measured according to standard protocols. The study protocol was approved by the Human Research Ethics Committee of Curtin University of Technology and a informed consent form was signed by each subject.

Procedure and experimental design

A breakfast drink product targeted to provide a beneficial effect on bone health (Castaneda 2000) was developed that provides 30 g protein and 600 mg calcium per serve. This product was developed to examine the effect of whey protein on satiety and for another study not described in this manuscript, to examine the effects on the musculoskeletal system and body composition. A protein-free placebo drink was also developed using alginate, known for its viscosity and satiety effect (Pelkman et al 2007, Paxman et al 2008).

The 250 ml calcium rich (602 mg) drink which contained either whey protein (30 g) or alginate (0.25 g) plus maltodextrin was developed with the same energy content (825 ± 12 kJ), colour (CIE L* a* b *), volume and flavour and compared for its satiety properties. Viscosity (cP) of the drink at the time of consumption was controlled at 2 levels, 28.5 ± 7 and 86 ± 7 centipoise by controlling temperature and serving immediately on mixing.

A single-blinded, within subject cross-over design was used to compare the effect of satiety from an alginate-based and whey protein-based drink. At the first sitting half of the subjects consumed HVLP and the other half consumed LVHP. There was wash-out period of one week before the second sitting and subject consumed the alternative drink, either HVLP or LVHP. Three week later subjects consumed either LVLP or LVHP, and after a four day washout subjects consumed the alternative drink, either LVLP or LVHP. Subjects consumed cereal (Kellogg's Rice Bubbles® plus milk) and a test drink as a breakfast meal (Table 2). Subjects consumed both the alginate (HVLP and LVLP) and whey protein drink (LVHP) in either chocolate, strawberry or coffee flavour. The flavour

consumed by each subject remained the same throughout the study. Each subject received 250 ml of the LVHP, HVLP and LVLP drink. The order in which each subject took the LVHP or HVLP and LVLP or LVHP (Table 2) was a stratified random allocation where half the subjects took one formulation and the other half consumed the other at each of the testing occasions.

Sensory evaluation

This research uses sensory evaluation techniques to assist in design of the study and in training of the subjects.

Sensory evaluation and test food consumption were performed in a specially designed air-conditioned sensory evaluation room with individual booths, where noise and odours were limited and drinks were labelled with a random three-digit number.

The satiety subjects rated pleasantness of the drink at the same time as satiety.

‘Pleasantness’ was measured using 100-millimetre line scales (Freeland et al 2009) and subjects were asked to indicate their feelings on the pleasantness of the test drinks. The same scale as that used for satiety i.e. a 100 mm VAS, where a score of zero represented that subjects found the test drink “not pleasant at all” and a score of 100 represented that subjects found the test drink “very pleasant”.

The satiety subjects were trained in the use of Visual Analogue Scale (VAS) to familiarise them with the scales before the actual satiety evaluation. Subjects were instructed to mark the VAS at zero or the lowest level of hunger on the scale, if they were “not hungry at all” immediately after consumption of the meal. Hunger was rated on 100 mm VAS, anchored with descriptors for hunger: “Not hungry at all” and “Hungry as I have ever felt”. Subjects were instructed to rate hunger every 30 minutes, by marking the scale at the point that was most appropriate to their feelings at that time. The distance from the left end of the scale to the subject’s mark was measured in mm. Zero represented that subjects were “Not hungry at all”. A score of one hundred represented that subjects were as “Hungry as I have ever felt”. The area under the curve (AUC) was calculated from immediately after consumption to four hours after consumption. After consumption of the test meal subjects did not consume additional food for four hours. The AUC was calculated by assigning-segments of 30 minutes as 1 unit (w). The VAS score was added and divided by two so that an area for the first segment was calculated, using the area of a trapezium, $\text{area} = \frac{1}{2} (a+b) w$. Segments (0 to 30, 30 to 60, etc. to 210 to 240) were totalled. The sum of these trapezoidal areas was calculated as the total area under the curve.

During the training session, subjects consumed a similar meal to the test meal and discussed their ‘desire to eat more’, ‘fullness’ and ‘hunger’ and came to a consensus on the meaning of the descriptor “Not hungry at all”.

A comparison of hunger and fullness was conducted during training with thirty three subjects. Fullness was also measured using the question “How full do you feel right now?” on a 100 mm VAS. A score of zero represented that subjects were “not full at all” and a score of 100 represented that subjects were “very full”. The relationship between fullness and hunger over one, two and three hours for low proteins was -0.734, -0.611, -0.780 respectively and for high protein was -0.779, -0.740 and -0.704 respectively (Table 3).

The subjects did not assess the test drinks for fullness because although fullness and hunger are related (Table 3) they are not the same and due to the time constraints needed to train of the panel to recognize hunger.

Test drink

Whey protein and sodium alginate were chosen for use in a study where an 825 kJ, high protein drink (LVHP) and two low protein alginate based drinks with different viscosities (LVLP, HVLP) were developed. Three drinks were developed for the study (Table 2). A high protein (Fonterra™, Alacen 894), whey protein-based drink (LVHP) was developed to contain 30 g protein per serve (250 ml) and a low protein (< 3g), sodium alginate-based (FMC Biopolymer, Protanal RF 6650) drink (HVLP) and sodium alginate-based (FMC Biopolymer, Protanal SF120L) drink (LVLP) were developed. The drink was prepared by mixing the powder and water in a shaker. Drinks were provided as breakfast drinks and consumed immediately on mixing with water (21 °C ± 2 °C).

The drink was controlled for energy density, volume, appearance, and macronutrient content (either high or low protein)(Table 2, 4). Commission Internationale d'Eclairage or CIE L* a* b* involves a 3-dimensional representation of colour with L* as the centre axis ranging from white as 100 to black as zero. The red-green axis is a* with positive a* representing red and negative a* representing green. The blue-yellow axis is b* with positive b* representing yellow and negative b* representing blue. The drinks were matched for colour and CIE L*a*b* was measured using a Minolta CM-508i reflectance spectrophotometer and daylight D65 illuminant (Table 4) where the lightness/brightness of colour was measured using CIE L*, redness by a* and yellowness by b*. Viscosity was measured with a Brookfield viscometer using 500 ml of the drink, a constant spindle number (1) (Table 4) and constant r.p.m. Table 4 showed LVLP and LVHP drinks (same flavour) were the same for viscosity and colour and sensory evaluation showed subjects were unable to detect a difference in the test drinks (data not shown). Taste did not differ between drinks of the same flavour.

Data analysis

For the satiety study, the total area under the curve was calculated for each subject from hunger response curves. One-way analysis of variance was used to determine if there were any significant differences between the area under the curve values, pleasantness and time to eat meal. All statistical analyses were performed using SPSS version 14.0 for Windows, (SPSS Inc., Chicago, IL, USA). Levene's Test (SPSS) measured significant difference between hunger at 3 and 4 hours.

Results

During the product development stage three products in three flavours, chocolate, strawberry and coffee were successfully developed. The LVHP, HVLP and LVLP drinks of the same flavour were the same colour (Table 4). In this study macronutrient content and/or viscosity differed - LVLP and LVHP differed in macronutrient content, LVLP and HVLP differed in viscosity and HVLP and LVHP differed in macronutrient content and viscosity.

Satiety-subjects also rated pleasantness of the drink. Sensory evaluation and instrumental analysis showed there was no difference in pleasantness, colour, appearance, flavour and viscosity except where viscosity was deliberately increased in HVLP (Table 4). Subjects rated the pre-determined flavoured drinks' pleasantness on a VAS as 64.90 ± 22.40 for the LVLP and HVLP drink and as 68.99 ± 20.78 for the LVHP (n.s $p = 0.300$). It was observed HVLP changed from a thick liquid after 5 minutes, to form a gel at 30 minutes whereas as the LVLP did not form a gel, so gel strength appeared to be different but was not measured. The time to consume each test drink was not significantly different ($p < 0.05$) and subjects consumed the drink in less than 5 minutes.

Satiety

Subjects who consumed the HVLP meal were less hungry after consumption than those who consumed the LVHP meal, due to the lower feeling of hunger at 3 and 4 hours. The

Rice Bubbles® content was the same for all three meals. The hunger score was significantly lower ($p < 0.05$) at 3 and 4 hours for the LVHP meal than the LVLP meal. Mean area under the curve from immediately after consumption (time 0) to 4 hours after consumption was significantly different ($p < 0.05$) between the two meals 9042 ± 407 for the LVHP meal and 8235 ± 422 for the HVLP meal (Figure 1). Therefore this indicated that subjects were less hungry after consumption of the HVLP drink compared with the LVHP drink and that viscosity affects satiety.

The difference in the hunger induced by the different products LVHP and HVLP support the hypothesis that viscosity affects satiety because if protein was the major influence, the LVHP would provide significantly lower feelings of hunger, even though the HVLP was more viscous. The LVHP meal was compared to LVLP meal where both drinks had the same viscosity. Results showed the mean area under the satiety curve from immediately after consumption (time 0) to 4 hours after consumption was significantly different ($p < 0.05$) between the LVHP and LVLP meals (Figure 1), 9360 ± 407 for the LVHP meal and 11070 ± 422 for LVLP meal. Therefore subject were less hungry after consumption of the LVHP drink compared to LVLP drink indicating that protein affects satiety.

Results showed the mean area under the curve from immediately after consumption (time 0) to 4 hours after consumption was significantly different ($p < 0.05$) between the HVLP and the LVLP (Figure 1), 8235 ± 422 for the HVLP meal and 11070 ± 422 for LVLP

meal. Therefore there appears to be a greater satiety effect from the HVLP drink compared to LVLP drink.

Discussion

All hunger effects could be influenced by viscosity or gel formation or both but the relative contribution of viscosity and gelation is unclear. The comparison of alginate with differing viscosities and high and low gel strength may provide an answer. The relative effect of whey protein, high viscosity alginate and low viscosity alginate when consumed in a breakfast drink were compared. Although there are commercial protein drinks, these were not considered suitable for the trial, due to the added vitamins, minerals and amino acids, which may influence satiety.

During training, satiety subjects who consumed the 250 ml test drink alone reported they did not feel full, however they did not want more than of the test drink but instead indicated a desire to eat food in a solid state rather than liquid. Havermans et al (2009) described the reduced desire to eat a single food as sensory specific satiety. To overcome this problem in the current study, subjects were offered Rice Bubbles® plus milk to consume with the drink – this resulted in renewed acceptance of the drink and was provided without causing any net increase in whey protein or alginate. Satiety subjects also assessed the pleasantness of the drink and selected their preferred flavour during training.

There are multiple mechanisms contributing to satiety and the effect of the viscous alginate drink appears to be greater than the mechanisms responsible for whey protein satiety effects. Although hunger of the subjects was compared it is likely that a reduction in hunger is related to feelings of fullness (Table 3), although more work is needed on this area. The most viscous drink in the study, HVLP provided a large satiety effect. This finding supports the work of Marciani et al (2001) who found fullness was higher with a viscous meal than fullness induced by nutrients. Although rheological properties of HVLP in the stomach were not measured in this study, observation showed the HVLP changed from a thick liquid after 5 minutes, to form a gel at 30 minutes – this suggests thickening in the stomach is a possibility. The gel-forming fibre that hydrates in the stomach leading to gastric distension described by researchers (Hoad et al 2009, Schroeder et al 2009) supports hypothesis that the alginate gels in the stomach. The apparent difference in gelation properties of the different alginates in this study could have been related to different interactions with the other ingredients such as calcium carbonate.

Chow (2007) found an 80 g, 300 kcal nutrition bar with high viscous fibre (guar 5.7 g) promoted satiety. Although Mattes (2007) did not find a fibre effect on satiety in a study of breakfast bars containing alginate (1.1 g) plus guar gum (3.9 g) the bar was lower in weight and energy (55g and 196 kcal) and it is possible a breakfast bar with low water content does not optimise the satiety effect of the alginate and guar gum as gels. In studies where water was not a limiting factor, such as Hoad (2004), gastric emptying was similar for all four meals, but the sense of fullness at the same gastric volume was significantly greater for

all three viscous meals than for the control. Hoad et al (2004) found alginate meals formed lumps in the stomach and the strong-gelling alginate produced the largest volume. In 2001 van Nieuwenhoven et al found the addition of guar gum to a semisolid food did not affect gastrointestinal transit. Kovacs et al (2001) found that a drink containing guar gum reduced hunger and Bergmann et al (1992) found increasing the viscosity of a liquid meal with psyllium increases a person's level of satiety supporting the effect of high water foods in satiety.

The mechanism resulting in a satiety effect from whey protein may be related to a number of independent factors and interactions. Research by Anderson et al (2004) suggests the source of the thickening agent influences the satiety result independent of viscosity. Foods that show multiple characteristics that affect satiety may result in greater benefits to health. For example protein affects the satiety hormones such as ghrelin (Nieuwenhuizen et al 2009) and if the protein concentration is high enough to increase viscosity there may be an added satiety benefit. The viscosity provided by protein is smaller than the viscosity provided by viscofying fibres such as alginate. The LVHP drink required 30 g protein in 250 ml to provide the same viscosity as the LVLP where 2.5 g of alginate in 250 ml was required.

Even though hunger continues to increase with all meals, the significant difference of the hunger score at 3 and 4 hours suggests HVLP provides a more sustained satiety effect compared with LVHP. The sustained lower feeling of hunger following protein

consumption (LVHP) at breakfast compared with the LVLP effect supports Leidy's (2009) suggestion that the timing of protein intake influences sustained satiety.

Proteins have various biological functions, which are related to their structural and physiochemical characteristics, for instance, fibrous proteins and globular proteins have different digestibility (Damodaran 1996) which may affect their satiety response. During digestion absorption of dietary amino acids by the gut varies according to the type of dietary protein consumed (Boirie et al 1997). In addition the viscosity and gelation characteristics of protein and non starch polysaccharides such as alginate and beta-glucan slow glucose absorption (Casiraghi 2006) and due to water holding ability may prolong satiety (Schroeder 2009). The results of this study that place high viscosity alginate as having a greater satiety effect than whey protein is important to developing healthy food products.

The benefit of training the satiety subjects was the ability to allow subjects to select their favorite flavour and assist in the determination amount of food needed for a zero hunger score immediately after consumption. The zero hunger score after consumption certainly contributed to the significant difference in AUC for the test meals (LVHP, LVLP and HVLP).

Another benefit of training was the ability of the satiety subjects to give same satiety effect after LVLP on two separate occasions, more than six days apart. A limitation of training is

that the satiety subjects must undergo regular training (at least every six weeks) and that subjects are not also available for long periods.

Sensory specialists should standardise all the characteristics of the food except the variable under evaluation (Lawless & Heymann 1998) but this is a challenge in clinical studies.

While this study was successful in developing a test drink where subjects were unable to detect a difference in more than one characteristics except the variable being assessed, the drink differed in more than one characteristic. So a limitation is that HVLP and LVHP differed in both macronutrient content and viscosity. Energy was the same between test drink but this was achieved with the addition of maltodextrin and although panelist could not detect a difference in the drinks, this was also a limitation.

The physical, chemical, nutritional and functional properties of individual proteins and types of fibre and changes to these properties during processing will impact on satiety so studies that aim to change only one component of a food, while keeping all other components the same will lead to a better understanding of the mechanisms involved. Our study shows the importance of high viscosity foods in satiety while placing whey protein as more satiating than alginate at the same viscosity. Although gelation was apparent over time in the HVLP drink, subjects were advised to consume the drink immediately i.e. before gelation. Gelation on consumption may be important but this was not measured in this study. Another limitation is the different interaction of the two different alginates with other ingredients in the drink was not measured and may have contributed to gelation and should be considered in future studies.

Conclusion

When included as part of a breakfast meal, the whey protein-based drink (30g protein) resulted in reduced hunger or a higher satiety effect when compared to the low protein (< 2g) alginate-based drink, when the viscosity of both drinks was equal. When the alginate-based drink was made from a product that had high viscosity the result was a lower mean area under the satiety curve and reduced hunger compared to the low viscosity alginate drink and high whey protein-based drink. The results show the relative satiety ranking of the whey protein drink in relation to the alginate drinks with different viscosities and suggest the physical characteristics such as viscosity, affects satiety. The study of other viscous fibre, starch and protein from various sources may assist in the understanding of the mechanisms involved in the satiety effect of food.

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Table 1 Subject characteristics of trained satiety panel showing mean and standard deviations.

Subjects	
n=33	
Age (years)	21.2 ± 1.8
Weight (kg)	61.6 ± 7.5
Height (m)	1.7 ± 0.1
BMI (kg/m ²)	22.7 ± 1.81

Table 2 Nutrient Composition of test drinks (50g powder plus 250 ml water) showing the composition of the test drink and the test meal (test drink with breakfast cereal).

	Wt	Energy	Protein	Alginate	Carbohyd.	Calcium	Fat
	(g)	(kJ)	(g)	(g)	(g)	(mg)	(g)
High protein (LVHP) - Chocolate	252.6	835.9	30.5	0	13.6	605.7	2.6
High protein (LVHP) - Coffee	250.4	796.3	29.9	0	12.9	601.2	2.1
High protein (LVHP) - Strawberry	249.7	796.3	29.9	0	12.9	601.2	2.1
Low protein (LVLP, HVLP) - Chocolate	252.6	845.9	2.5	0.25	42.8	603.1	2.3
Low protein (LVLP, HVLP)- Coffee	250.4	806.3	1.9	0.25	42.1	598.6	1.8
Low protein (LVLP, HVLP) - Strawberry	249.7	806.3	1.9	0.25	42.1	598.6	1.8
Breakfast cereal- Rice Bubbles	30	480	1.9	0	21.8	0	0.1
Milk	25	50	0.8	0	1.2	30	0.35
TEST MEAL							
High Protein (LVHP) + cereal + milk	305.9 ±1.5	1340 ±23	32.8 ± 0.35	0	36.6 ± 0.4	633.5 ± 2.5	2.5 ± 0.4
Low Protein (LVLP, HVLP) + cereal + milk	305.9 ±1.5	1350 ±23	4.8 ± 0.3	0.25	65.8 ± 0.3	630.1 ± 2.5	2.3 ± 0.4

High protein powder had primarily whey protein isolate as a thickener
 Low Protein had sodium alginate as a thickener.
 Chocolate, strawberry or coffee flavour was offered to subjects.

Table 3 Relationship (Pearsons correlation) between VAS satiety rating score over time for the question “How hungry do you feel right now?” and “How full do you feel right now?”

VAS time (minutes)	Low Protein	High Protein
60	-0.734*	-0.779*
120	-0.611*	-0.740*
180	-0.780*	-0.704*

* Correlation is significant at the 0.01 level (2-tailed).

Table 4

Pleasantness (Satiety panel VAS), texture and colour of the test drinks comparing the high protein and low protein drink and the different flavours.

	Pleasantness VAS	Viscosity n= 2 (average) (centipoise at 21° C)	Colour n= 2 (average)		
			L* lightness brightness	a* red	b* yellow
LVHP	64.90 ± 22.40	23.7¹	34.26¹	6.83¹	7.56¹
Chocolate					
LVHP		21.3²	46.80²	5.63²	0.47²
Strawberry					
LVHP Coffee		37.0³	42.04³	3.44³	13.67³
		LVLP	HVLP		
			5 mins		
LV or HVLP	68.99 ± 20.78	27.1¹	88¹	31.48¹	6.90¹
Chocolate					
LV or HVLP		22.8²	86²	48.90²	5.67²
Strawberry					
LV or HVLP		39.0³	93³	43.96³	3.08³
Coffee					

Sample with same number ^{1,2,3} are matched for viscosity, flavour and colour and sensory evaluation showed matched samples were not significantly different. Pleasantness by subjects is on their various preferred flavour.

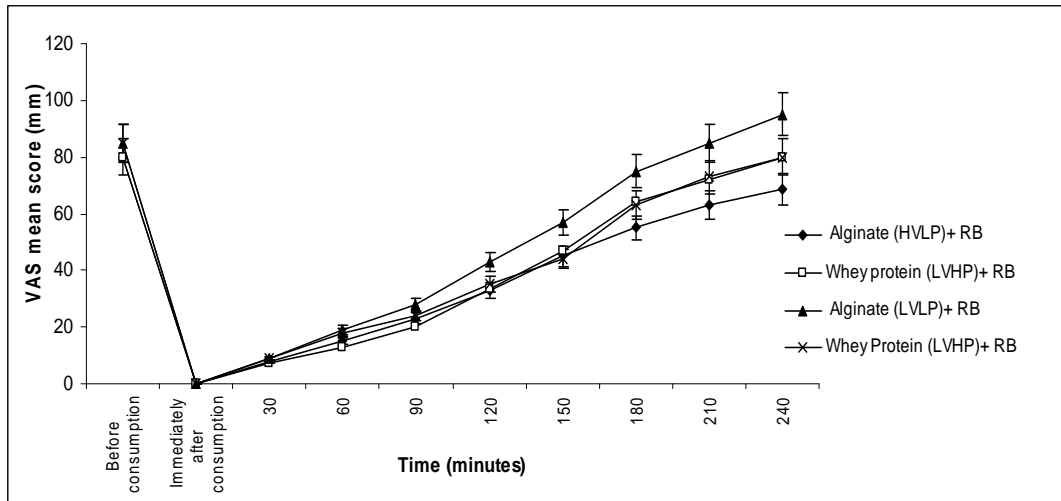


Figure 1 Comparison of 33 subjects mean VAS hunger response curves or satiety rating over time for the question “How hungry do you feel right now?” for HVLP + RB meal , LVLP + RB meal and whey protein drink (LVHP) + RB meal.