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The effect of dairy products consumed with high glycemic carbohydrate on subjective appetite, food intake and post-prandial glycemia in older adults

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Abstract

Objective: To compare the effect of liquid, semi-solid and solid dairy products and a non-dairy beverage when consumed with glycemic carbohydrate on subjective appetite, food intake (FI) and post-prandial glycemia (PPG) in healthy older adults.

Design: Thirty healthy men and women (14 males and 16 females; age: 64.6 ± 2.4 y; BMI: 25.6 ± 2.5 kg/m²) participated in a randomized crossover study. Treatments were one of 250 mL of 2% fat milk and soy beverage, 175 g of 2% Greek yogurt and 30 g of Cheddar cheese consumed as part of an isocaloric (380 kcal) meal with bread and jam. Water alone served as the energy-free control for subjective appetite. At 180 min after consumption, the participants were fed an ad libitum meal to measure FI. Subjective appetite, blood glucose and insulin were measured at baseline and at intervals both before (post-treatment) and after the meal (post-meal).

Results: Cheese and yogurt resulted in lower post-treatment blood glucose than milk and soy beverage when consumed with carbohydrate ($p < 0.0001$) but no differences between any treatments were observed post-meal. Treatments led to similar insulin concentrations. Post-treatment appetite was lower than after the water control for all treatments but suppressed more by cheese and yogurt compared to milk ($p < 0.0001$). There were no differences in FI between treatments.

Conclusions: Cheese and yogurt increase satiety and lower PPG more than milk or a soy beverage when consumed with carbohydrate.

Key words: dairy, satiety, appetite, food intake, glycemia

Introduction

Foods that increase satiety and decrease PPG may be effective for the prevention and management of obesity and T2D (Pasin and Comerford 2015, Onvani et al. 2016). To encourage development and identification of such foods, Health Canada (HC) released two draft guidance documents for food health claims for “satiety” (Health Canada 2012) and “the reduction in post-prandial glycemic response” (Health Canada 2012, Health Canada 2013). These documents acknowledge the potential acute benefits of increasing satiety and decreasing PPG, however do not allow for claims related to long-term benefits such as implications for control of obesity and T2D. The European Food Safety Authority (EFSA) also released their document related to both claims (European Food Safety Authority 2012). Milk proteins are well-known to increase satiety and reduce FI and PPG (Akhavan et al. 2010, Akhavan et al. 2011, Akhavan et al. 2014). More recently, the focus has shifted to milk as a whole entity. Milk consumed in typical serving sizes (e.g. 250-500 mL) decreases appetite, FI and PPG more than other beverages such as juice and colas (Dove et al. 2009, Maersk et al. 2012, Panahi et al. 2013, Panahi et al. 2013, Mehrabani et al. 2016). Similar results have also been seen with liquid and semi-solid yogurts (Tsuchiya et al. 2006, Almiron-Roig et al. 2009, Chapelot and Payen 2010, El Khoury et al. 2014). Therefore, dairy products are candidates for health claims related to appetite and blood glucose control. However, dairy products vary in macronutrient composition and food form which may be expected to result in different effects.

There has only been one report comparing different dairy forms on appetite and PPG. Isocaloric (201 kcal) amounts of yogurt (278 g), Cheddar cheese (49 g) and semi-skimmed milk (410 mL) containing 10.9 g, 12.3 g and 13.9 g of protein, respectively, were compared. Yogurt suppressed hunger the most but there were no differences in FI 90 min later or blood

glucose and insulin measured at 80 min (Dougkas et al. 2012). When skim milk (250 mL, 16.6 g protein) was compared to three yogurts (250 g) containing 23.1 g, 22.2 g and 18.3 g of protein, there were no differences in satiety, FI 120 min later or blood glucose before and after the test meal (El Khoury et al. 2014). However, the effect of dairy consumed at meals with carbohydrate has received little attention even though milk with carbohydrate results in lower blood glucose than carbohydrate alone (Panahi et al. 2013, Sun et al. 2015).

Health claims encouraging consumption of dairy at meals to improve satiety and glycemia may be of specific importance to older adults. Adults post 50 years old have a high prevalence of overweight and obese individuals and are the most at-risk for developing T2D (Kirkman et al. 2012). However, dairy consumption decreases with age (Sebastian et al. 2010, Chollet et al. 2014). In 2004, only 26 and 20% of Canadian men and women aged 51 to 70 years consumed the recommended amount (Statistics Canada 2006). In addition, non-dairy alternatives have been growing in popularity, competing with milk and contributing to the decline in milk consumption (Government of Canada 2013, Mintel 2016). The effects of these beverages in comparison with dairy when consumed with carbohydrate by this population have not been reported.

Therefore, the objective of this study was to compare the effects of 2% milk, 2% Greek yogurt, Cheddar cheese and soy beverage consumed with glycemic carbohydrate on PPG, satiety, as measured by subjective appetite, and FI 180 min later in healthy older men and women. Additionally, a second objective was to determine if a health claim could be made by applying HC's guidance document for comparative satiety claims. We hypothesized that semi-solid and solid dairy products increase satiety, as measured by subjective appetite, and

decrease FI and PPG more than the liquid dairy product and that all dairy products will be more effective than a non-dairy beverage.

Materials and Methods

Subjects

Men and women between the ages of 60-70 years old with a body mass index (BMI) of 18.5-29.9 kg/m² were eligible to participate. Participants were recruited through advertisements posted online, around the city of Toronto and newspapers. Exclusion criteria included smokers, breakfast skippers, lactose intolerance and allergies to study foods, dislike of study foods, trying to lose or gain weight, fasting blood glucose of ≥ 6.0 mmol/L, diabetes or any prescription medication or medical conditions that could interfere with study outcomes. Restrained eaters as identified by a score of ≥ 11 on the Eating Habits Questionnaire were also excluded (Herman and Polivy 1980). Women that had not undergone menopause for at least one year and who were on hormonal treatments were also excluded. The sample size required for detection of treatment effects of 10% reduction on subjective appetite over 120 min and FI at 120 min were 26 and 18, respectively, and for detection of a 20% difference in PPG was estimated to be 12 based on previous short-term satiety, FI and glycemia studies with dairy (Panahi et al. 2013, El Khoury et al. 2014). Participants were financially compensated and the study protocol was approved by the Human Subject Review Committee at the University of Toronto Ethics Review Office.

Study Design

This experiment was a randomized, non-blinded, crossover design. Participants were provided each treatment once per week in random order using a randomized block design generated with a random generator script in SAS version 9.3 (SAS Institute Inc., Cary, NC, USA). Due

to the obvious differences between treatments, neither study coordinators nor participants could be blinded to the treatments. Treatments were 2% M.F. milk (2% milk), soy beverage, Cheddar cheese, 2% Greek yogurt and water (control). Each treatment, except for water, was consumed with bread and jam as part of a breakfast meal. An ad libitum meal was served 180 min following the breakfast meal. Satiety, blood glucose and insulin were measured at baseline and at intervals before and after the ad libitum meal, during which FI was measured.

Treatments

Treatments were: 1) 2% milk (Neilson Dairy; St-Laurent, Canada); 2) soy beverage (vanilla-flavoured) (So Good; Vancouver, Canada); 3) Cheddar cheese (Armstrong; St-Laurent, Canada); 4) 2% Greek yogurt (Danone; Boucherville, Canada) and 5) water (control). To equate the volumes of the liquid treatments, water was provided with yogurt and cheese. Each caloric treatment (i.e. excluding water) was part of an isocaloric (380 kcal) breakfast meal that also included two slices (75 g) of white bread (Wonder Bread, Mississauga, Canada) and strawberry jam (Smuckers; Markham, Canada). White Wonder Bread has a GI of 73 and strawberry jam has a GI of 51 both for 30 g servings when compared to 50 g of glucose (GI = 100) (Foster-Powell et al. 2002). Water was served alone (without bread or jam) as the energy-free control, as recommended by HC for satiety claims (Health Canada 2012). The breakfast meals were isocaloric to fulfill HC's guidelines stating that the test foods should be of equal or lower energy content than the reference foods. This was achieved by modifying the amount of jam served with each treatment. The serving sizes of the treatments were chosen to represent one serving size as listed on the products' Nutrition Facts Table as recommended by the guidelines. The serving size and nutritional composition of each treatment and breakfast food is outlined in Table 1.

All treatments were served chilled and the bread was provided toasted and served with the jam uniformly spread. An additional 100 mL of water was provided to reduce the aftertaste of the breakfast meal which participants were instructed to drink only when they had finished all the other food and beverages.

Protocol

Each participant was scheduled to arrive at the same time (between 8:30 and 10 am) and day of the week to the Department of Nutritional Sciences at the University of Toronto for each of their five study sessions. Participants were required to observe a 12 h overnight fast, except for water, which was permitted until 1 h before the session. They were also instructed to refrain from vigorous exercise and alcohol consumption the day before their sessions and to eat similarly the evenings before.

Upon arrival, participants completed questionnaires, as described previously (Akhavan and Anderson 2007), to ensure no unusual deviations from their diet and lifestyle patterns from the previous day and current morning. If they were deemed unfit to participate (e.g. due to sickness), they were rescheduled. Participants then completed VAS questionnaires to assess their “Food Intake and Activity Level”, “Sleep Habits”, “Stress Factors”, “Feelings of Fatigue”, “Physical Comfort” and “Motivation to Eat” (Panahi et al. 2013, El Khoury et al. 2014). The “Motivation to Eat” VAS consisted of four appetite questions assessing the participants’ “desire to eat” (DTE), “hunger”, “fullness” and “prospective food consumption” (PFC). An average appetite score calculated from these four questions as previously described (Patel et al. 2013).

Participants provided a baseline finger prick capillary blood sample using a single-use lancet (Unistik; Oxfordshire, UK). Plasma blood glucose concentration was measured with a glucometer (Accu-Chek Aviva; Roche Diagnostics Canada, Laval, Canada). A baseline measurement of ≥ 6.0 mmol/L suggested non-compliance with the fasting instructions or high fasting blood glucose and the participant was rescheduled or excluded from the study.

Participants were instructed to consume the breakfast meal within 10 min while eating at a steady pace. After consumption, the palatability of the treatment was measured by a VAS questionnaire assessing the “pleasantness”, “taste”, “texture” and “overall liking”. An average score calculated from these four questions were used to measure palatability. Subjective appetite and blood glucose were measured at 15, 30, 45, 60, 90, 120, 150 and 180 min (post-treatment period) from the time participants began eating the breakfast meal and insulin was measured at 0 (baseline), 30, 60, 90, 120, 150 and 180 min. Blood for insulin analysis was collected via finger prick (as previous described) with Microvette capillary tubes 300 Z (Sarstedt, Numbrecht, Germany). Blood was then immediately centrifuged (20°C, 10000 rpm, 5 min) and the plasma were frozen at -80°C until measurements. Insulin levels were quantified with an insulin enzyme-linked immunoabsorbent (ELISA) kit (Alpco, Salem, USA). Participants were asked to remain seated throughout the session and were permitted to do quiet activities such as read or listen to music.

Satiety was measured over 180 min (3 h) at which time participants were fed an ad libitum test meal. This is consistent with HC’s guidance document for testing the minimum duration of effect for satiety for a health claim. The meal consisted of rice (Uncle Ben’s, Bolton, Canada), beef meatballs (President’s Choice, Brampton, Canada) and tomato sauce (Ragu, Mount Prospect, USA). The meatballs were cut into small and uniform pieces and were mixed

homogeneously with the other ingredients in a bowl. One bowl was a 479.5 g portion which represented 827.5 kcal, 30.8 g fat, 104.8 g carbohydrate and 30.2 g protein. Participants were allowed 20 min to eat and were instructed to eat until they felt “comfortably full”. Halfway through the meal (10 min), their bowl was replaced with a fresh and warm bowl of food.. Subjective appetite, blood glucose and insulin were measured at 210 min (post-meal period). Test meal consumption was calculated by weighing the amount of food consumed and based on the nutritional information provided by the manufacturers. Ad libitum water intake at the test meal was measured by weight (g).

Cumulative energy intake was calculated by adding the caloric content of the fixed breakfast with the calories consumed at the test meal. Caloric compensation, expressed as a percentage, was calculated using the following formula: $\text{Caloric compensation} = [(\text{kcal consumed at the test meal after the water control} - \text{kcal consumed at the meal after the treatment}) / (\text{kcal of the treatment})] \times 100\%$. A caloric compensation of $<100\%$ indicates undercompensation while a score $>100\%$ indicates overcompensation (greater reduction) at the test meal for the energy consumed at breakfast (Panahi et al. 2013).

Statistical Analyses

Statistical analyses were conducted using SAS version 9.3 (SAS Institute Inc., Cary, NC). Two and three-factor repeated-measures analysis of variance (ANOVA; via PROC MIXED procedure) and two-factor repeated-measures analysis of covariance (ANCOVA; via PROC MIXED procedure) were performed to analyze the effects of treatment, time, sex and their interaction on dependent variables over the study period including changes from baseline for subjective appetite scores, blood glucose and insulin concentrations and means for FI, cumulative energy intake, water intake and caloric compensation. Absolute baseline values

were used as covariates for subjective appetite, blood glucose and insulin. No significant interactions were found between treatment and sex for any of the variables, therefore these results were pooled for both men and women. When there was a significant treatment by time interaction, one-factor ANOVA (PROC MIXED procedure) was followed by Tukey's post-hoc test to investigate the effect of treatment on changes from baseline for appetite, blood glucose and insulin at each time of measurement and means for FI, cumulative energy intake, water intake and caloric compensation. Post-treatment changes from baseline were calculated from 15-180 min, post-meal changes at 210 min and cumulative changes from 15-210 min. Since water was only included as an energy-free control to abide by the guidelines stated in HC's guidance document for satiety and not PPG, it was only included in the analysis for subjective appetite and FI. Total areas under the curve (tAUC) for subjective appetite and incremental areas under the curve (iAUC) were calculated for blood glucose and insulin separately for the post-treatment, post-meal and cumulative periods; post-treatment, post-meal and cumulative periods were 0-180 min, 180-210 min, and 0-210 min, respectively, for all variables. Glucose to insulin iAUC ratios were compared among treatments by dividing the blood glucose iAUC by the insulin iAUC for the post-treatment, post-meal and cumulative periods. The glucose to insulin mean changes from baseline ratios at 30 min were also calculated. Glucose to insulin ratio measures the efficacy of insulin action (Vuguin et al. 2001). The lower the ratio is, the higher the efficacy of insulin action. Data are presented as mean $\pm$ SEM. Statistical significance was set at $p < 0.05$.

Data are reported as tAUC for subjective appetite and iAUC for blood glucose as recommended by Health Canada guidance documents and common usage. However, mean changes from baseline may be a more effective evaluation of the data. A treatment that has a high initial peak and then falls and a treatment that has a sustained blood glucose response

may result in the same iAUC but may lead to a different and important observation when expressed as mean changes from baseline.

Results

Participant Characteristics

Thirty healthy men and women (sex: 14 males and 16 females; age 64.6 ± 2.4 years; BMI: 25.6 ± 2.5 kg/m²) completed all five sessions. Dropouts include three female participants and one male participant who were excluded due to high fasting blood glucose. Their results were not included in the analysis.

Palatability of treatments

Treatment had an effect on palatability scores ($p < 0.0001$). Water was the least preferred compared to all other treatments which is likely due to it being served alone with no other food. There were no differences between other treatments.

Food and Water Intake

All treatments resulted in similar FI, cumulative energy intake, water intake and caloric compensation and were similarly undercompensated for at the later meal, averaging 63% (Table 2).

Subjective Appetite

Post-treatment (15-180 min) and cumulative (15-210 min) mean appetite changes from baseline were affected by time ($p < 0.0001$), treatment ($p < 0.0001$) and by a time-by-treatment interaction ($p < 0.0001$). All treatments equally suppressed appetite compared to water between 15-120 min ($p < 0.0001$; Table 3) but at 150 and 180 min milk was no longer different from

water (Fig. 1). Over the entire post-treatment period, all treatments suppressed appetite compared to water but yogurt and cheese led to lower appetite than milk and soy beverage ($p<0.0001$; Table 3). However, tAUCs showed no differences between cheese, milk and soy beverage ($p<0.0001$). There were no differences between treatments and control in the post-treatment period (Table 3). However, tAUCs showed all treatments led to lower appetite compared to water ($p<0.0001$; Table 4).

An examination of the individual appetite scales (data not shown) showed that all treatments led to higher fullness than water and that yogurt led to higher fullness than milk in the post-treatment ($p<0.0001$) and cumulative ($p<0.0001$) periods. Post-meal, water and milk led to higher fullness than yogurt and soy beverage ($p=0.0002$). Yogurt and cheese reduced hunger and DTE compared to water and milk in the post-treatment ($p<0.0001$) and cumulative ($p<0.0001$) periods. Post-meal, hunger was lower after water compared to all treatments except soy beverage ($p=0.0002$) and DTE was lower after water compared to all treatments except milk ($p=0.0005$). Cheese reduced PFC compared to water and milk in the post-treatment ($p<0.0001$) and cumulative ($p<0.0001$) periods. Post-meal, PFC was lower after water compared to yogurt and cheese ($p=0.006$).

Blood Glucose Concentrations

Post-treatment (15-180 min) blood glucose mean changes from baseline were affected by time ($p<0.0001$), treatment ($p<0.0001$) and by a time-by-treatment interaction ($p=0.02$). Blood glucose peaked at 45 min and returned to baseline by 180 min for all treatments (Fig. 2). Blood glucose was higher after soy beverage compared to yogurt from 30-90 min and higher compared to cheese from 60-120 min. Milk was not different from soy beverage and cheese from 30-60 min and not different from yogurt from 90-120 min. Over the entire post-

treatment period, changes from baseline for blood glucose was equally lower for cheese and yogurt compared to soy beverage and milk ($p < 0.0001$; Table 3). However, blood glucose iAUCs showed no differences between cheese and milk ($p < 0.0001$; Table 4). There were no differences between treatments in the post-meal period (210 min) (Table 3) for mean changes or iAUCs.

Insulin Concentrations

Insulin was measured in 12 participants (6 males, 6 females). Post-treatment (15-180 min) mean insulin changes from baseline were only affected by time ($p < 0.0001$). Insulin peaked at 30 and 45 min and returned to baseline by 180 min (Fig 3). There were no differences between any treatments at any time in the post-treatment or post-meal periods (Table 3). Similar results were observed with iAUCs (Table 4).

Blood Glucose to Insulin Ratios

In the post-treatment (0-180 min) period, the glucose/insulin iAUC ratio was highest for soy beverage compared to yogurt with no differences between any other treatments ($p=0.01$; Table 5). There were no differences between any treatments in the post-meal period (180-210 min) (Table 5). Cumulative (0-210 min) results were the same as the post-treatment. When the ratios for mean changes from baseline at 30 min were considered, all treatments led to similar ratios (Table 5).

Discussion

The results support our hypothesis that, when consumed with glycemic carbohydrate, semi-solid and solid dairy products increase satiety and decrease PPG more than liquid forms of dairy products or non-dairy beverages. Yogurt and cheese consumed with glycemic

carbohydrate were more efficacious than milk or soy beverage at reducing appetite and PPG. However, the hypothesis that milk would be more effective than soy beverage was not supported.

This is the first study to report effects of dairy products on PPG, insulin, appetite and FI in older adults when consumed with a source of glycemic carbohydrate. Since there were no differences in insulin between any of the treatments, differences in blood glucose responses are likely due to insulin-independent mechanisms. Yogurt resulted in a low blood glucose peak and sustained blood glucose levels in the post-treatment period, suggesting delayed gastric emptying mediated by an increase in GI hormones due to protein as described in previous studies (Akhavan et al. 2014, Panahi et al. 2014). Additionally, Greek yogurt primarily contains casein which is known to clot and form a gel in the stomach and thereby delaying gastric emptying (Boirie et al. 1997). Although El Khoury et al. (El Khoury et al. 2014) did not detect a difference in blood glucose between Greek yogurts containing 23.1 g, 22.2 g and 18.3 g of protein and skim milk containing 16.6 g of protein, the present results show lower blood glucose after breakfast, consistent with the high protein content of yogurt (17 g) compared with milk (9 g). Evidence for insulin-independent mechanisms also arises from the lower blood glucose to insulin iAUC ratio after the yogurt breakfast compared to the soy beverage breakfast (Table 5). Since soy beverage led to similar ratios as cheese and milk, the higher efficacy of insulin at similar concentrations argues against attributing lower glucose concentrations to insulinotropic properties of milk proteins.

Breakfast meals were isocaloric to remove energy content as a confounder for detecting treatment differences on satiety. Subjective appetite ratings were affected not only by the protein content of the treatments but as well by food form. Although yogurt contained 10 g

more protein than cheese, there were no differences in appetite between them. As previously described, delayed gastric emptying was only observed for yogurt and not cheese therefore a possible explanation in the lack of differences in appetite is the chewing requirements for each food arising from the differences in their food forms. Yogurt, a semi-solid with a gel-like consistency, was eaten with a spoon and required no chewing whereas cheese, a solid, required chewing before swallowing. A recent meta-analysis suggested that increasing chewing time of foods decreases self-reported hunger perhaps due to the stimulation of anorexigenic and the suppression of orexigenic gastrointestinal hormones (Miquel-Kergoat et al. 2015). In addition, cheese contained approximately three-fold the amount of fat, which is known to stimulate release of the satiety hormone, cholecystokinin (Beglinger and Degen 2004).

The semi-solid yogurt suppressed appetite more than milk but not soy beverage even though the latter were both fluids. While this observation may suggest that protein content was not a factor, an explanation for the appetite suppression following soy beverage may be its carrageenan content. Carrageenan is used as a thickening agent and 2.5 g added to milk has been shown to increase satiety (Arshad et al. 2016). However, the amount and type of carrageenan used in this soy beverage was not reported. Furthermore, the sweetness of the soy beverage may have contributed as sweetness increases satiety (Lavin et al. 2002). Cane sugar (sucrose) is the main sweetener used in this brand of soy beverage and has a sweetness factor of 1 whereas lactose has a sweetness factor of 0.22 relative to sucrose (Moskowitz 1970).

A second-meal effect of breakfast treatments was found on appetite but not on post-prandial glycemia. By 180 min, subjective appetite ratings had returned to baseline and were similar to the water control. However, following the ad libitum meal, appetite was lower after water

than all treatments except milk. Since there were no differences in FI, this may be due to a more heightened sense of satiation after eating for the first time after an overnight fast. However post-meal glycemia was not affected, again accounted for by similarities in FI at the meal.

The current study design fulfilled many of the fundamental criteria for satiety claims such as using a healthy adult population, a randomized crossover design, valid outcome measures, the recommended serving sizes of treatments and duration of time (Health Canada 2012).

Comparing the treatments in the context of a meal allowed for isocaloric breakfasts to be tested. If tested alone as usual serving sizes, the treatments could not follow Health Canada's guidelines as being equal to or lower than in energy than the reference food with the exception of the comparison made between the dairy products and soy beverage. However, since it was not a direct comparison of satiety response of the treatments alone but a comparison of their effect consumed with carbohydrate in a usual meal, the present study did not give rise to any satiety comparative claims amongst the treatments. However, compared with the soy beverage and milk, the yogurt and cheese breakfasts provided the greatest satiety and thus suggesting direct comparisons of them alone might allow a claim.

A further limitation of this study was the lack of control treatment for blood glucose as an outcome measure. An additional control of water consumed with bread and jam would have provided additional emphasis to the benefit of dairy on PPG when consumed with a carbohydrate versus consumption of carbohydrate foods (e.g. pastries, breads) alone at breakfast. However, as noted, water alone was necessary to serve as the energy-free control as recommended for a satiety health claim (Health Canada 2012). Nevertheless, when treatment effects are compared using either soy beverage or milk as a control, yogurt and cheese

resulted in lower PPG. The measurement of FI at 180 min, as suggested by HC, appears to be at a duration of time that is too late to be informative of the effect of small treatment effects. Our sample size calculations were based on effects found at 120 min but clearly needed to be larger than 30 participants to detect treatment differences of less than 10% at 180 min compared with that after the water control. Finally, since the study was conducted in healthy individuals, the results cannot be extrapolated to those who are obese, pre-diabetic or diabetic, for whom this type of research can ultimately benefit.

In conclusion, when consumed with glycemic carbohydrate at breakfast, cheese and yogurt increase satiety and lower PPG more than milk or a soy beverage.

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Table 1. Nutritional composition of treatments and breakfast foods

	Treatments ^A				Bread	Jam
	Soy beverage	Cheese	2% Milk	Yogurt		
Portion						
Serving size	250 ml	30 g	250 ml	175 g	75 g	1g
Water (ml)	—	220	—	75	—	—
Jam ^B (g)	19.3	27	23.2	23.2	—	—
Nutrients ^C						
Energy (kcal)	140	120	130	130	190	2.59
Fat (total) (g)	4	10	5	3.5	2	0
Saturated fat (g)	0.6	6	3	2	0.5	—
Trans fat (g)	0	0.3	0.1	0.2	0	—
Cholesterol (mg)	0	25	20	20	0	—
Sodium (mg)	110	240	120	60	300	0.05
Carbohydrate (g)	21	0	12	8	37	0.67
Fibre (g)	0	0	0	0	2	—
Sugars (g)	12	0	12	4	3	0.57
Protein (g)	6	7	9	17	6	0.005
Breakfast Composition ^D						
Energy (kcal)	380	380	380	380	-	-
Protein (g)	12	13	15	23	-	-
Carbohydrate (g)	70.9	55.2	64.5	60.5	-	-

^ATreatments consumed with 75 g bread and varied amount of jam (to achieve an isocaloric breakfast).
^BAmount of jam consumed with each treatment.
^CNutrient content of each product is provided by the manufacturer. Amounts given are per serving size listed of each product.
^DMeal = treatment +bread + jam.

Table 2. Energy intake, cumulative energy intake, water intake and caloric compensation^A

Treatment	Energy intake (kCal)		Water Intake (g)	Caloric Compensation (%) ^D
	Test meal ^B	Cumulative ^C		
Control ^E	867.9±57.2	867.9±57.2	352.3±29.7	—
Soy beverage	792.4±53.1	1172.4±53.1	385.1±27.0	54.0±22.9
Cheese	760.6±54.4	1140.6±54.4	377.5±27.7	82.6±36.5
2% Milk	802.0±49.3	1182.0±49.3	370.0±24.3	54.9±30.5
Yogurt	789.3±61.8	1169.3±61.8	395.2±22.9	60.5±31.9
<i>p</i>	NS	NS	NS	NS

^AAll values are means ± SEMs (*n* = 30). *p* < 0.05 (treatment effect using one-way ANOVA via proc mixed procedure, Tukey's post-hoc).

^BEnergy consumed in an ad libitum meal was measured at 180 min following treatment consumption.

^CEnergy in breakfast meal (treatment + bread + jam) + energy from meal.

^DCaloric compensation = [(kcal consumed at meal after the water control – kcal consumed at the meal after the treatment)/kcal in the treatment] x 100.

^EWater (250 mL).

Table 3. Effect of treatment on post-treatment, post-meal and cumulative mean changes from baseline for subjective appetite, blood glucose and insulin^A

		Control ^B	Soy beverage	Cheese	2% Milk	Yogurt	<i>p</i>
Appetite (mm)	Post-treatment ^C	3.9±0.8 ^a	-22.2±1.7 ^b	-23.8±1.8 ^c	-18.1±1.7 ^b	-25.2±1.9 ^c	<0.0001
	Post-meal ^D	-61.7±4.7	-48.1±4.9	-44.5±5.3	-52.5±5.0	-44.1±4.8	NS
	Cumulative ^E	-2.2±1.4 ^a	-25.5±1.7 ^b	-26.5±1.8 ^c	-22.0±1.8 ^b	-27.9±1.8 ^c	<0.0001
Glucose (mmol/L)	Post-treatment	—	1.6±0.1 ^a	1.2±0.1 ^b	1.4±0.1 ^a	1.1±0.08 ^b	<0.0001
	Post-meal	—	1.7±0.2	1.5±0.2	1.5±0.2	1.6±0.2	NS
	Cumulative	—	1.6±0.1 ^a	1.2±0.09 ^b	1.4±0.09 ^a	1.1±0.08 ^b	<0.0001
Insulin (µU/ml)	Post-treatment	—	31.1±4.2	27.3±3.9	32.3±4.6	34.8±4.4	NS
	Post-meal	—	46.8±8.2	41.3±7.3	49.2±10.3	36.8±7.7	NS
	Cumulative	—	31.2±4.2	27.3±3.9	32.3±4.6	34.8±4.4	NS

^AAll values are means ± SEMs (appetite and glucose: *n* = 30; insulin: *n* = 12). Means within a row with different superscript letters are significantly different, *p* < 0.05 (treatment effect using two-way ANCOVA via proc mixed procedure, Tukey's post hoc).

^BWater (250 mL).

^CPost-treatment values are mean changes from baseline of all observations before the test meal: 15, 30, 45, 60, 90, 120, 150 and 180 min for appetite and glucose and 30, 60, 90, 120, 150 and 180 min for insulin.

^DPost-meal values are mean changes from baseline of all observations after the test meal: 210 min.

^ECumulative values are mean changes from baseline for all observations for the entire session: 15-210 min.

Table 4. Effect of treatment on post-treatment, post-meal and cumulative tAUCs for subjective appetite and iAUCs for blood glucose and insulin^A

		Control ^B	Soy	Cheese	Milk	Yogurt	<i>P</i>
Appetite tAUC (mm min)	Post-treatment ^C	13195.7+466.0 ^c	8678.5+592.1 ^{ab}	7902.8+578.1 ^{ab}	9307.0±584.3 ^b	7652.6+656.1 ^a	<.0001
	Post-meal ^D	1457.3+72.6 ^b	1200.0+78.9 ^a	1080.3+88.7 ^a	1180.5±83.7 ^a	1121.0+78.4 ^a	<.0001
	Cumulative ^E	14703.0±480.9 ^c	9918.6±654.5 ^{ab}	9022.0±632.4 ^{ab}	10494.8±616.2 ^b	8791.2±722.6 ^a	<.0001
Glucose iAUC (mmol min/L)	Post-treatment	—	279.2±29.5 ^a	216.4±26.0 ^{bc}	250.0±24.8 ^{ab}	200.1±21.7 ^c	<.0001
	Post-meal	—	25.9±2.7	23.2±3.1	23.1±2.1	24.5±2.6	NS
	Cumulative	—	302.0±33.3 ^a	231.7±28.3 ^b	266.3±25.5 ^{ab}	220.9±22.3 ^b	<.0001
Insulin iAUC (μU min/mL)	Post-treatment	—	6631.3±874.6	5708.7±918.6	6916.8±987.1	7244.2±801.9	NS
	Post-meal	—	467.5±81.9	412.3±80.0	491.9±103.3	378.7±70.9	NS
	Cumulative	—	6892.8±901.7	6065.5±976.9	7212.9±1017.4	7771.1±938.0	NS

^AAll values are means ± SEMs (appetite and glucose: *n* = 30; insulin: *n* = 12). Means within a row with different superscript letters are significantly different, *p* < 0.05 (treatment using one-way ANOVA via proc mixed, Tukey's post hoc).

^BWater (250 mL).

^CPost-treatment values are AUCs of all observations before the test meal: 0, 15, 30, 45, 60, 75, 90, 120, 150 and 180 min. for appetite and glucose and 0, 30, 60, 90, 120, 150 and 180 min for insulin.

^DPost-meal values are mean changes from baseline of all observations after the test meal: 210 min.

^ECumulative values are AUCs for all observations for the entire session: 0-210 min.

Table 5. Effect of treatment on post-treatment, post-meal and cumulative ratios of blood glucose to insulin iAUC and on ratios of blood glucose to insulin changes from baseline at 30 min^A

		Soy beverage	Cheese	2% Milk	Yogurt	<i>p</i>
Glucose/insulin iAUC ratio (mmol min L-1/μU min mL-1)	Post-treatment ^B	0.06+0.01 ^a	0.05+0.01 ^{ab}	0.05+0.01 ^{ab}	0.04+0.005 ^b	0.01
	Post-meal ^C	0.08+0.02	0.08+0.02	0.07+0.01	0.09+0.02	NS
	Cumulative ^D	0.06+0.01 ^a	0.06+0.01 ^{ab}	0.06+0.01 ^{ab}	0.04+0.004 ^b	0.02
Glucose/insulin changes from baseline ratio (mmol min L-1/μU min mL-1)	30 min	0.1+0.02	0.2+0.04	0.2+0.03	0.1+0.02	NS

^AAll values are means ± SEMs (*n* = 12). Means within a row with different superscript letters are significantly different, *p* < 0.05 (treatment using one-way ANOVA via proc mixed procedure, Tukey's post hoc).

^BPost-treatment values are mean changes from baseline of all observations before the test meal: 0, 15, 30, 45, 60, 90, 120, 150 and 180 min for appetite and glucose and 0, 30, 60, 90, 120, 150 and 180 min for insulin.

^CPost-meal values are mean changes from baseline of all observations after the test meal: 210 min.

^DCumulative values are mean changes from baseline for all observations for the entire session: 0-210 min.

Figure Captions

Figure 1. Effect of treatments on average subjective appetite mean changes from baseline over time. Means with different superscripts are significantly different at each measured time (one-way ANOVA, Tukey-Kramer post-hoc test, $p < 0.05$). All values are mean $\pm$ SEM ($n = 30$).

Figure 2. Effect of treatments on blood glucose mean changes from baseline over time. Means with different superscripts are significantly different at each measured time (one-way ANOVA, Tukey-Kramer post-hoc test, $p < 0.05$). All values are mean $\pm$ SEM ($n = 30$).

Figure 3. Effect of treatments on insulin mean changes from baseline over time. Means with different superscripts are significantly different at each measured time (one-way ANOVA, Tukey-Kramer post-hoc test, $p < 0.05$). All values are mean $\pm$ SEM ($n = 12$).

Figure 1

Figure 2

Figure 3