

Comparison of the effects of a liquid yogurt and chocolate bars on satiety: a multidimensional approach

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In the context of epidemic obesity, satiety is an important target for nutritional interventions. Using a multidimensional approach, we compared the effect on satiety of two food products frequently consumed in France by young adults as a small mid-afternoon meal called the 'goûter'. Participants were eighteen healthy young males (aged 20.8 (SD 1.8) years) of normal body weight (BMI 21.7 (SD 1.7) kg/m²) used to eating four times per d including a 'goûter'. On two occasions, under laboratory conditions, the time-blinded participants consumed a fixed energy lunch (2.8 MJ) and, 240 min later, either a liquid yogurt or chocolate bars matched for energy (1.2 MJ) and weight (366 g). Then, satiety was assessed by: (1) ratings of hunger, appetite, desire to eat and fullness at 20 min intervals (perception), (2) the delay until the subject requested his dinner meal (duration) and (3) energy intake at this meal (consumption). Results showed that satiety was perceived higher after liquid yogurt than chocolate bars over the 60 min preceding the next meal, as evidenced by hunger ($P < 0.005$), appetite, ($P < 0.005$), desire to eat ($P < 0.04$) and fullness ($P < 0.05$) ratings. However, its duration was similar between liquid yogurt and chocolate bars (165 (SE 8) and 174 (SE 7) min respectively) and this difference was not followed by reduced intake at dinner. In conclusion, this approach of satiety revealed that a liquid yogurt induced a lower subjective motivation to eat than chocolate bars during the hour preceding the spontaneous onset of a meal, without affecting subsequent food intake.

Satiety: Energy intake: Appetite: Liquid yogurt: Chocolate bars

Overweight and obesity are the consequences of a positive energy balance and therefore weight reduction requires that energy expenditure is increased and/or energy intake is decreased. In this perspective, increasing satiety, the term that refers to a low motivation to eat, is an important target for nutritional intervention. The effect of foods or ingredients on satiety has stimulated an abundant scientific literature in recent years. Usually, the objective is to identify the optimal diet for sustaining the highest level of satiety over the day, expecting a consistent reduction in intake. The problem is that satiety is multidimensional and consists mainly in a perception, a duration and a consumption dimension⁽¹⁾. Perception is usually assessed by ratings obtained at regular intervals after eating; duration is measured as the delay until the next meal is requested and consumption as the energy intake at the next meal. Most studies on satiety conducted in human subjects using the classic preload paradigm⁽²⁾ actually disregard its duration. This raises concern, since in various species it has been shown that the duration of satiety is the main response to changes in diet composition^(3–5), cost of procurement^(6,7) or hormones such as leptin⁽⁸⁾. Moreover, in humans, the duration is very sensitive to alterations in food composition or metabolic pathways^(9–12). Thus, measuring

the duration of satiety is beginning to be considered as a key outcome⁽¹³⁾. This is all the more important since an effect on satiety perception but none on later energy intake is often reported^(13–19) and leads to difficulties in the interpretation of results.

Among the factors contributing to satiety, macronutrient composition and physical state exert a major influence. Most studies comparing proteins, fats and carbohydrates showed that, for the same energy content, satiety is highest after high-protein meals or preloads⁽²⁰⁾. Thus, for a given eating occasion, high-protein foods appear to be more satiating than high-carbohydrate or high-fat foods, although this remains to be demonstrated with commercially available food items. Comparing the satiety provided by liquid and solid forms of energy sources has led to discrepant results. According to studies, liquids are more^(2,21,22), less^(23–29) or not differently^(28,30,31) satiating than solids. Procedures, test-foods and subjects greatly varied across studies, which may explain these discrepancies. Interestingly, fruit yogurts in liquid (drinkable) or semi-solid (eaten with a spoon) forms were followed by higher satiety ratings than solids⁽¹³⁾.

The aim of the present study was therefore to compare the satiating power of a liquid yogurt and chocolate bars eaten

Abbreviation: VAS, visual analogue scale.

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during the afternoon. These foods were chosen because in France, young adults often consume either of them as a small mid-afternoon meal called the 'goûter' and results may therefore be interesting to recommend a better choice in terms of satiety between these two products. The second objective was to assess if a multidimensional approach may reveal some specific differences in the satiety power of these two commercial items.

Methods

Subjects

Overall, forty-eight young male subjects aged 18–25 years were selected in the area of Grenoble through local advertisement. Overweight or obese individuals, smokers, trained athletes, individuals with food allergies or aversions to the foods provided during the experiment, with any personal or family history of diabetes or other metabolic disease, using medication or who had a change in body weight > 2 kg during the previous 2 months were excluded. Other main exclusion criteria were based on eating behaviour parameters: scores > 9 on the F1-restrained eating score of the Three Factor Eating Questionnaire⁽³²⁾, or eating at irregular hours. Another inclusion criterion was eating a 'goûter' since childhood, at least 5 d per week, bringing > 0.9 MJ. Last, subjects had to be familiar with both test foods. Among the selected subjects, twenty fulfilled all these criteria and were included and randomised, but two subjects were withdrawn because they did not attend both test sessions. Based on previous calculations⁽³³⁾, using a repeated-measures design and a study power of 0.8, a 5 mm difference on mean 4.5 h ratings can be detected with eighteen subjects. Moreover, in our previous studies, differences in intake and in duration of satiety were found with twelve⁽³⁴⁾ and eight⁽⁹⁾ subjects, respectively. Thus, our sample was considered powerful enough for our objectives. Characteristics of the participants are shown in Table 1. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and was approved by the local ethics committee (Comité de Protection des Personnes Sud Est III) and the Health Authorities (Direction Générale de la Santé). Written informed consent was obtained from all subjects. Subjects were told that the present study would evaluate various parameters of eating behaviour in relation to different types of foods.

Table 1. Participants' characteristics
(Mean values and standard deviations for eighteen subjects)

	Mean	SD
Age (years)	20.8	1.8
Body weight (kg)	70.8	8.8
Height (cm)	180.4	6.7
BMI (kg/m ²)	21.7	1.7
Three Factor Eating Questionnaire		
Restrained eating score (F1)	2.7	1.3
Disinhibition score (F2)	4.5	2.6
Hunger score (F3)	5.0	3.5
Frequency of 'goûter' (number/week)*	5.6	1.1
Energy intake at the 'goûter' (MJ)*	1.5	0.5

* 'Goûter' is a French word to describe a small mid-afternoon meal.

Study design

The present study had a randomised cross-over design. Two test sessions took place under laboratory settings, separated by a washout period of at least 6 d.

Foods

In the present study, we chose to use a preload procedure with a fixed energy intake at lunch, because it was closest to the eating habits of our subjects, mostly students who usually ate in a cafeteria serving fixed amounts of foods. We therefore decided to simulate this naturalistic condition by serving a traditional meal of similar energy content and food choices as usually served in these restaurants.

During a pre-experimental session, subjects rated the pleasure provided by each food that would be served during the sessions on three category ratings (negative, neutral, positive).

Lunch consisted of a traditional meal with vegetables (mixed), meat (roast beef), French beans, bread, butter, dairy dessert and apple sauce (685 g, 2800 kJ with 27.6 % protein, 31.6 % fat and 40.8 % carbohydrate).

The 'goûter' consisted of either a strawberry-flavoured liquid yogurt commercialised under the name of Yop[®] (Yoplait Co., Boulogne-Billancourt, France) or a popular chocolate bar (Twix; Mars Inc., McLean, VA, USA). Ratings of palatability scales in the pre-experimental session showed that subjects appreciated both products similarly. To improve the relevance of the experiment to naturalistic conditions, the quantity provided to subjects was based on the usual individual portions of the commercially available chocolate bars, i.e. two bars (58 g; 1190 kJ). Water was ingested with the chocolate bar in order to equate the volume of liquid yogurt to match the energy content in the chocolate bar condition (308 ml). Thus, both products were matched for energy, volume and density (see Table 2). An unpublished study conducted by the manufacturer has shown that consumers do not drink water or soda with this liquid yogurt in naturalistic conditions (Yoplait Co., unpublished results). Thus, no beverage was considered necessary with the liquid yogurt.

Since our dinner test meal was designed to measure energy intake and not food selection, it was not a buffet-type. Moreover, in previous studies^(35–37), we observed that most of the modifications in intake concern the first or the main course of a meal. Therefore, dinner consisted of one main course composed of pasta, meat and tomato sauce and known as Bolognese lasagne (588 kJ/100 g with 13.3 g carbohydrate (38 % energy), 6.2 g fat (40 % energy) and 7.9 g protein (22 % energy)). A semi-solid fruit yogurt was served as dessert in its usual commercial size (125 g). It could be eaten only partially, or another one could be requested. The main course was served on an individual tray in a large portion of 600 g. The portion represented 3525 kJ and was twofold the commercial single portion. Participants were instructed to eat until they felt comfortably full, and the same amount was provided again if more was asked for.

Satiety evaluation

The perceived satiety was assessed using hunger, appetite, desire to eat, and fullness ratings on visual analogue scales (VAS).

Table 2. Composition of the products

	Liquid yogurt	Chocolate bars
Portion		
Product (g)	366	58
Water (ml)	–	308
Energy		
Per portion (MJ)	1.2	1.2
Density (kJ/g)	3.3	3.3
Protein		
Per portion (g)	10.2	2.7
Percentage of energy (%)	16.0	5.0
Fat (g)		
Per portion (g)	4.7	13.7
Percentage of energy (%)	7.3	25.3
Carbohydrate (g)		
Per portion (g)	49.0	37.8
Percentage of energy (%)	76.7	69.7

Each VAS was presented on a separate sheet and consisted of a 100 mm horizontal line, anchored at the left end with 'not at all' and the right end 'extremely'. Phrases were 'Do you feel hungry' for the hunger scale, 'How is your appetite?' for the appetite scale, 'Do you desire to eat something you like very much?' for the desire to eat scale, and 'How full do you feel your stomach is?' for the gastric fullness scale.

Duration was assessed as the delay between the start of the 'goûter' and the request for the dinner meal. As in previous studies^(35–37), participants were encouraged to ask for their dinner when they perceived a hunger signal.

Intake was assessed as the difference between the weight of food served at dinner and leftovers. Energy intake was calculated by multiplying this difference by the energy value of each item as provided by food tables from the CIQUAL (Agence Française de Sécurité Sanitaire des Aliments) or by the manufacturer when necessary.

Study protocol

For the 48 h preceding each session day, subjects were requested to maintain their usual dietary and occupational habits and to avoid any excessive consumption of food. On the previous evening they had their dinner at home, and were required to limit consumption of poorly digestible foods such as high-fibre items (a list was provided). They were asked to have strictly identical dinners (i.e. amount and composition) on both days preceding the test sessions. Food ingestion was forbidden after 20.30 hours and only water was allowed. On the morning of the test sessions, participants consumed their usual breakfast at home. Its composition had also to be strictly identical before each session. Participants arrived at the investigation centre at 11.00 hours. Their dinner on the previous day and breakfast intakes were checked with the investigator by asking participants about the precision of their reports. They were then isolated in single rooms and deprived of time cues by removing watches, phones, and covering windows with black curtains. The standard lunch was served between 12.15 and 13.15 hours according to the eating habits of the subject, at the same time for both sessions. The 'goûter' was served 240 min after the start of lunch. It had to be consumed in less than 15 min. VAS were rated before, immediately after and then every 20 min until dinner was requested. Dinner was served in

each participant's individual room. Participants were informed that they would have to stay at the investigation centre until 22.00 hours to prevent any premature request. After 22.00 hours, they were free to leave the laboratory unit.

Data analysis

All results are presented as mean values with their standard errors except otherwise indicated. Statistical analyses were performed using Systat software (version 10.2; SPSS, Chicago, IL, USA). VAS scores were subjected to a stepwise analysis for serial measurements according to Matthews *et al.*⁽³⁸⁾. Thus, for each rating (hunger, appetite, desire to eat and fullness), three variables of interest were determined: (1) a post-'goûter' profile from the start of the 'goûter' to the time when the earliest dinner was requested across all conditions and participants; (2) a pre-dinner profile starting from 60 min before the dinner request until dinner request; (3) a profile in percentages with each individual intermeal interval transformed in quartiles⁽³⁹⁾. The first variable assessed the time course of the scores during a fixed time period including all participants and conditions. The second variable assessed satiety during the period preceding the meal as it is usually done in studies using duration of satiety^(10,11,40,41). The third variable allowed proceeding to statistics on the complete interval between meals including all subjects. However, the different number of ratings in each quartile across subjects led us to treat the results with caution. A global satiety score was also calculated, adapted from the model of Holt *et al.*⁽⁴²⁾, as the sum of the four ratings representing satiety: fullness score + (100 – hunger score) + (100 – appetite score) + (100 – desire to eat score). The objective was to determine whether the global satiety state when participants asked for their dinner meal was different according to the product consumed for 'goûter'.

For temporal data, ANOVA with repeated measures was conducted with time and conditions (liquid yogurt and chocolate bars) as within-subject factors, and order of the sessions as the between-subject factor. When an interaction between time and conditions was found, the post- and pre-dinner profiles were analysed using paired Student's *t* tests or the Wilcoxon test, depending on the normality of the distribution, corrected for the number of tests according to Bonferroni. The normality of the distribution was tested by a Shapiro–Wilk's test.

The values in each quartile of the intermeal interval in percentages, the delay of the dinner request and energy intake at dinner were compared between conditions using paired Student's *t* tests. Relationships between satiety dimensions were calculated using Pearson correlations for all subjects and all conditions. A *P* value < 0.05 was considered statistically significant.

Results

Duration

Dinner was requested within 165 (SE 8) min after the 'goûter' in the liquid yogurt condition (range 90–216 min) and within 174 (SE 7) min in the chocolate bar condition (range 130–240 min). This duration of satiety was not significantly different between the conditions.

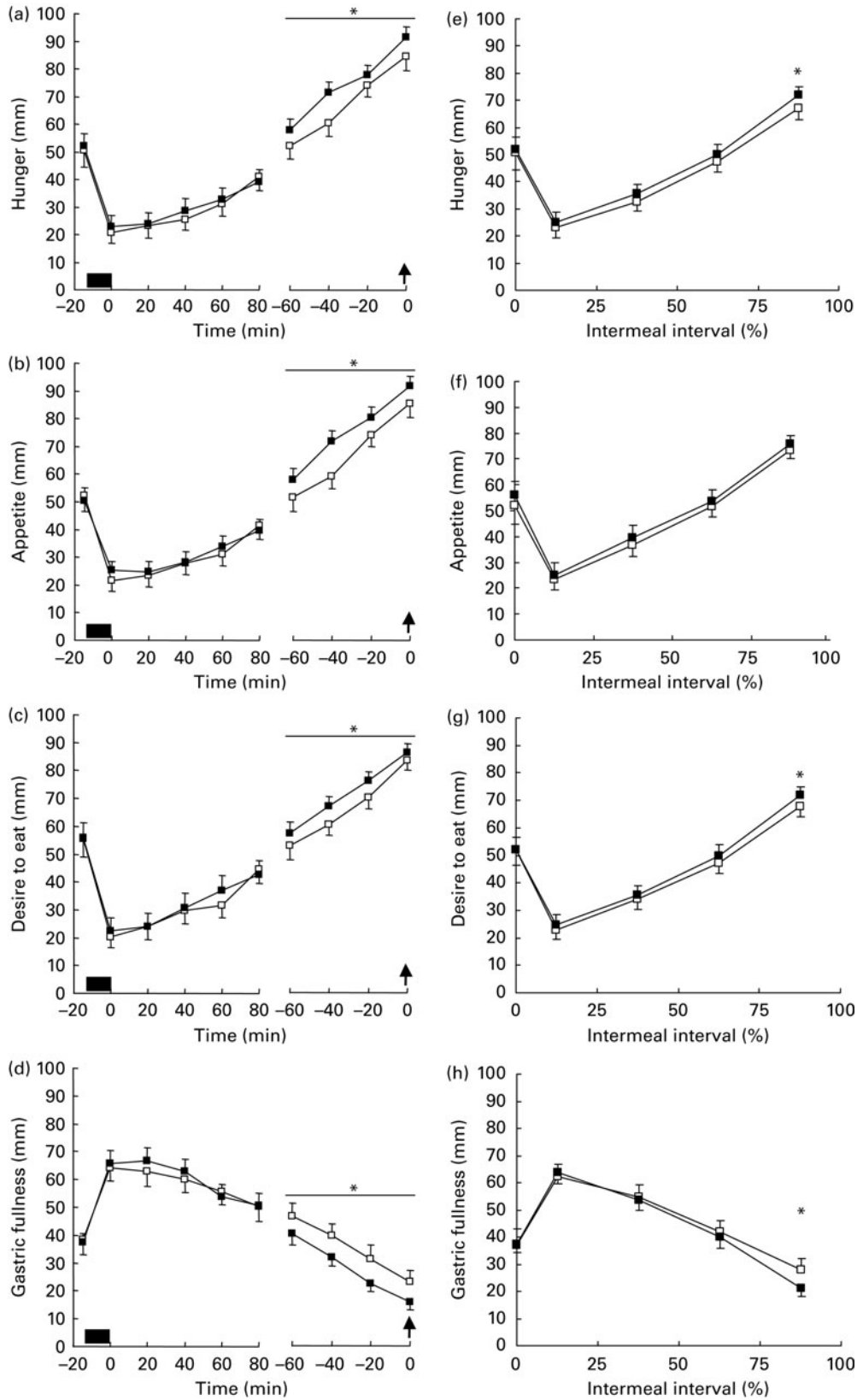


Fig. 1. Perception dimension of satiety. Hunger (a), appetite (b), desire to eat (c) and gastric fullness (d) ratings on the visual analogue scales (VAS) until the first subject asked for his dinner (−20 to 80 min on the x-axis) and during the hour preceding the dinner request (−60 to 0 min on the x-axis) after the liquid yogurt (□) and chocolate bars (■). Hunger (e), appetite (f), desire to eat (g) and gastric fullness (h) ratings on the VAS with intermeal interval in percentages of interval (quartiles). Values are means, with standard errors represented by vertical bars. * Mean value was significantly different from that of the liquid yogurt condition ($P < 0.05$). ■, Goûter intake; ↑, dinner request.

Perception

Hunger, appetite, desire to eat and fullness ratings at the time of the 'goûter' were not different between the conditions. Since the earliest dinner request among subjects and conditions occurred 80 min after the 'goûter' and VAS were rated every 20 min, the post-'goûter' profile was calculated on four time-points. A time effect appeared ($P < 0.001$) but no condition effect nor interaction between time and condition was found for hunger, appetite, desire to eat or fullness ratings.

For the pre-dinner profiles, a time effect and a condition effect for hunger, appetite, desire to eat and fullness ratings appeared ($P < 0.05$), without interaction between time and condition. Thus, compared with the chocolate bar condition, hunger ($P < 0.005$), appetite ($P < 0.005$) and desire to eat ($P < 0.04$) ratings were lower and gastric fullness higher ($P < 0.05$) during the pre-dinner period in the liquid yogurt condition (Fig. 1).

When analysed in quartiles, hunger and desire to eat ratings during the last quartile of the intermeal interval were lower ($P = 0.005$ and $P < 0.05$, respectively) and gastric fullness ratings higher ($P < 0.05$) in the liquid yogurt than in the chocolate bar condition.

Furthermore, dinner was requested with a higher global satiety score in the liquid yogurt than in the chocolate bar condition (17.3 (SE 4.0) v. 12.9 (SE 2.6) mm; $P < 0.05$).

Consumption

Total energy intake at dinner was 4677 (SE 171) and 4761 (SE 226) kJ in the liquid yogurt and chocolate bar conditions, respectively (NS). Intake of lasagne, bread and fruit yogurt was not different according to condition, as was water intake (Fig. 2). Among the thirty-six dinner occasions, two subjects asked at one of their dinners for another portion, and only one finished his portion. In all the other dinners, subjects left at least 50 g in their dish or plate.

Correlations

The difference in the duration of satiety and the difference in appetite ratings at dinner request between conditions were significantly correlated ($r = 0.498$; $P < 0.05$). This was not

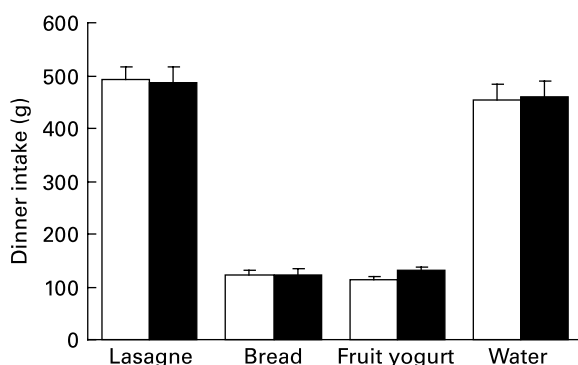


Fig. 2. Consumption dimension of satiety. Amount (g) of lasagne, bread, yogurt and water consumed at the dinner meal in the liquid yogurt (□) and chocolate bar (■) conditions. For energy intake at this meal, see the Results section. Values are means, with standard errors represented by vertical bars.

found with hunger, desire to eat, fullness ratings or satiety index. Thus the longer the duration of satiety, the greater was the difference in appetite rating at dinner request.

Discussion

The present study was an attempt to identify potential differences in satiating power between two food products widely consumed by adolescents and young adults in a small mid-afternoon meal called the 'goûter' in France. One of these foods was a liquid yogurt and the other chocolate bars. To assess satiety, three dimensions were measured: its perception, its duration, and consumption at the next meal. To measure duration, we recreated a spontaneous eating situation according to a time-blinded procedure as described by our^(10,11,34–36,40,41) and other teams^(12,43). Since the satiety power of foods eaten in a non-hungry state is weak^(11,36,40,41), we chose to select subjects usually eating a 'goûter' as done in previous studies^(36,37). Thus, only participants consuming a 'goûter' between lunch and dinner almost everyday from childhood were selected to participate in the sessions.

The first result of the present study is that the duration of post-'goûter' satiety did not differ between the test products, i.e. about 170 min long for both foods. A study conducted in consumers recently revealed (Yoplait Co., unpublished manufacturer's results) that most of them expected a satiety of ≤ 2 h after the consumption of this liquid yogurt or the chocolate bars used in the present study. This suggests that our participants requested their dinner meal according to physiological rather than cognitive factors.

Differences in satiety were found in its perception dimension. These differences were only observed during the hour preceding the dinner request and were significant for all ratings: hunger, appetite, gastric fullness and desire to eat. Each of these ratings is considered to represent a different dimension of satiety although the precise underlying physiological meaning remains unclear. VAS ratings show a good degree of reliability and validity when used in a within-subject design but must be associated with other measures of eating behaviour⁽⁴⁴⁾. Hunger ratings are supposed to represent the energy need, desire to eat ratings a wanting for a specific food, and fullness ratings are taken to reflect the digestive state of the subject. Among these ratings, fullness has shown the highest correlation with intake⁽⁴⁵⁾. An 'appetite' rating was added since in France the meaning of the term does not totally overlap 'hunger' and 'desire to eat'. It was considered interesting to verify whether its variations and relationships with duration of satiety and later intake were similar to the other three scales.

Subjective hunger sensations may represent an homeostatic motivation to eat, whereas ratings of desire to eat as rated in the present study may indicate a motivation for the pleasure produced by food, in other terms, a non-homeostatic or hedonic motivation⁽⁴⁶⁾. Fullness is probably the sensation of stomach distension. Appetite is usually not added to these three classic scales. Here we wanted to test our hypothesis of a distinct meaning. Although its variations were consistent with other ratings, it was the only rating obtained at the time of dinner request that correlated with the duration of satiety. If this is confirmed in the future, it may represent an interesting

subjective tool for studying the time-induced effects on satiety.

Altogether, these ratings provide information on the level of motivation to eat, but it is not known if this may have consequences for eating behaviour in real-life conditions. For this, it would be interesting to test if ratings of satiety modulate the threshold at which subjects initiate eating in the presence of palatable food during their normal intermeal interval. This would be an important demonstration of the clinical relevance of the satiety scores usually published in support of the increased satiety power of certain foods.

A conclusion that can be drawn from the present results is that in the hour preceding the dinner meal, participants experienced a lower level of motivation to eat when the liquid yogurt was consumed in the afternoon than after the chocolate bars. This might represent a benefit for individuals who feel more vulnerable to food when dinnertime comes.

This difference in perceived satiety observed for hunger at the moment of dinner request shows that individuals can request a meal at various levels of perceived hunger. Moreover, the satiety index, a variable constructed from all four ratings and providing an insight into the motivation to eat at meal request, was higher after the liquid yogurt than after the chocolate bars.

However, these differences in satiety ratings at dinner request were not followed by a consistent difference in intake. Importantly, the amount eaten at a meal is rarely modified when the intermeal interval is free^(10,11,17,40,41). Since it has been demonstrated in animals⁽⁴⁷⁾ that the duration between meals and not meal size is the adaptation mechanism of food intake, this is not surprising. When meal times are fixed, meal size becomes an important factor of energy homeostasis. Although the metabolic state at the onset of a meal might be considered a determinant of intake, inconsistency between satiety ratings and intake is frequently reported when a meal is provided at a fixed time^(13–19). This raises the problem of assessing the satiety power of food by the size of the next meal, which is determined by a satiation mechanism. Satiation is mainly driven by sensory and digestive factors and is a conditioned process based on repeated exposures to food. To expect any reduction in intake after a single consumption of a food is therefore not completely appropriate. Last, as stated by some authors⁽⁴⁴⁾, “objective food intake” may not be as objective or as “uncontaminated” an outcome as it ostensibly appears’. This makes the intake dimension of satiety difficult to interpret in short-term studies such as those generally published in this area of research. In the present study, one possible limitation is that subjects had to ask for another one portion of the main course if they finished the first one. This may have reduced the chances to see differences in intake between conditions. Moreover, they may have eaten until their portion was finished and not until they felt comfortably satiated. However, results showed that except one subject in one condition, all either left more than 50 g, and two asked for another portion. This argues for an actual *ad libitum* intake and the validity of our intake results.

Explanations of the observed differences in the perception of pre-dinner satiety between these two products are only hypothetical since no biological parameters were measured. Moreover, our two products differed by several properties. Among those considered, the most likely to explain these

results are the physical form (liquid for the yogurt and solid for the chocolate bars) and the protein content (high for the yogurt and low for the chocolate bars). It has been reported that a food associated with water is either less⁽⁴⁸⁾ or more⁽²⁴⁾ satiating than this food in a liquid form. Among the factors that have been proposed to explain why yogurts have a higher satiety power than drinks are their viscosity⁽²⁹⁾ and the fact that they are consumed with a spoon⁽⁴⁹⁾. However, in a recent study⁽¹³⁾, a liquid yogurt did not differ in satiating power from its semi-solid version eaten with a spoon. Therefore, the satiety power of yogurts is unlikely to be related to its textural properties.

According to many reports, proteins have the most potent satiety power compared with carbohydrate and fat⁽²⁰⁾. The higher protein content of the liquid yogurt compared with chocolate bars (10.1 v. 2.7 g, respectively) may have contributed to the differences in satiety. With a difference of 12.4 g protein, Harper *et al.*⁽¹⁴⁾ also reported higher satiety ratings after chocolate milk than after a sugar-sweetened drink, although with 26 g protein⁽¹⁹⁾, no difference was observed. In these studies, satiety was only followed over 30 and 50 min, so no comparisons can be made with the present results in which differences occurred at least 110 min (170–60 min) after consumption. Since the satiety power of protein is primarily linked to metabolic mechanisms⁽²⁰⁾, it is likely that it may take some time to appear and this argues for the possible involvement of the protein content in the observed effect.

Several nutritional aspects are in favour of the choice of a liquid yogurt rather than chocolate bars for the ‘goûter’, for example, less fat, more protein, more Ca, lower energy density, greater volume. The present results suggest that this nutritional benefit is not associated with a lower satiety power due to its physical form, as previous comparisons between liquid (milkshake) and solid (chocolate bars) meal replacements may have suggested⁽²⁹⁾.

In addition of the limitations cited in the previous paragraphs, it must be added that it was not possible to dissimulate the true aim of the study and this may have influenced results although no element may suggest that this would have favoured the liquid yogurt.

In conclusion, using a multidimensional approach of satiety, we found that a liquid yogurt consumed as a small mid-afternoon meal (the French ‘goûter’) by regular ‘goûter’ eaters, provided the same duration of satiety as chocolate bars matched for energy load, density and volume, but a higher perception of satiety during the hour preceding the next meal when spontaneously requested. However, in the present conditions, this difference was not associated with reduced intake at this meal. A liquid yogurt may represent a good alternative to chocolate bars as a between-meal intake for improving the satiety feeling. Further studies are needed to determine if this effect might contribute to reduce pre-dinner snacking.

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D. C. designed and supervised the study, analysed the data and wrote the manuscript. F. P. supervised the study and reviewed the manuscript.

Conflict of interest: F. P. works for Yoplait France, the company commercialising one of the two tested food products.

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