

Available online at www.sciencedirect.com

ScienceDirect

www.nrjournal.com

Original Research

Food acceptability affects ghrelin and insulin levels in healthy male subjects. A pilot study



Ammar Olabi*, Nahla Hwalla, Hamza Daroub, Omar Obeid, Christelle Cordahi

Nutrition and Food Sciences Department, Faculty of Agricultural and Food Sciences, American University of Beirut, Beirut, Lebanon

ARTICLE INFO

Article history:

Received 2 January 2017

Revised 29 September 2017

Accepted 5 October 2017

Keywords:

Hedonics

Acceptability

Ghrelin

Insulin

Appetite

ABSTRACT

The obesity prevalence worldwide is reaching epidemic proportions, which makes the understanding of the mechanisms that regulate appetite of paramount importance. This study assessed whether the hedonic characteristics of a food item (high acceptability [HA] vs modified low acceptability [LA]) have a significant effect on postprandial ghrelin and insulin levels and appetite scores of isoenergetic meals in normal-weight men. We hypothesize that food acceptability would significantly impact appetite scores and affect the studied postprandial hormones. Eleven healthy men with normal body mass index (19–25 kg/m²) were recruited for a randomized, crossover design. Subjects were randomly assigned to 1 of 2 meals: vanilla custard with acesulfame-K (LA, excessively sweet) or without it (HA). One week later, subjects were crossed over to ingest the other meal. Blood samples were withdrawn before meal (time 0) and after 15, 30, 60, 120, 180, and 240 minutes and were analyzed for ghrelin, insulin, and glucose. Appetite scores were also recorded at the above time points, and acceptability was measured. Ghrelin levels were significantly higher ($P < .05$) for LA meal at 180 and 240 minutes than the HA meal. Insulin levels were significantly higher ($P < .05$) for HA meal at 15 and 30 minutes than the LA meal. Appetite scores varied from baseline levels for both meals but not between meals at different time points. The results suggest that the hedonic properties of a meal could affect food intake and appetite through stimulation or inhibition of appetite hormones, suggesting the need to assess the acceptability of foods in formulating weight-reducing diets.

© 2017 Elsevier Inc. All rights reserved.

1. Introduction

Obesity rates have increased globally in the last 3 decades [1], and projections indicate that half of the population will be obese by 2030 [2]. Although different approaches have been used, in most cases, treatment of obesity has been unsuccessful. Gut hormones such as ghrelin have become appealing novel targets

in the battle against weight gain [3]. Ghrelin is a stomach-derived peptide known to exert orexigenic effects through receptors within the hypothalamus [4]. Because ghrelin plays a role in meal initiation by increasing before meals and decreasing postprandially, introducing dietary measures that affect ghrelin postprandial levels could be of paramount importance in decreasing the desire to eat and affect weight regain.

Abbreviations: LA, low acceptability; HA, high acceptability; HSD, honestly significant difference; AUB, American University of Beirut; REE, resting energy expenditure; VAS, visual analogue scale.

* Corresponding author at: Nutrition and Food Sciences Department, 315 FAFS, American University of Beirut, Riad El Solh 1107 2020, Beirut, Lebanon. Tel.: +961 1 374374x4500; fax: +961 1 744460.

E-mail address: ammal.olabi@aub.edu.lb (A. Olabi).

<https://doi.org/10.1016/j.nutres.2017.10.001>

0271-5317/© 2017 Elsevier Inc. All rights reserved.

Approaches to affect postprandial ghrelin levels included manipulating the macronutrient content of ingested meals [5]. More recently, psychological and behavioral factors were targeted as possible contributing factors to ghrelin fluctuations. Palatable foods rich in fat and sugar were shown to blunt the response to satiety signals and upregulate reward mediators such as dopamine, serotonin, and opiates, leading to overeating [6]. However, a study performed on mice and rats revealed that palatable foods were more efficient in reducing postmeal hunger [7]. The availability of highly palatable food supply has been suggested to be a contributing factor to increasing obesity trends in recent years [8]. This suggestion has evolved from the hypothesis that acceptability of foods may influence or even override satiety responses to food consumption [9].

This study builds on previous approaches to understand the relationship between eating behavior and appetite hormonal response. The hypothesis was that the acceptability of the meal would affect ghrelin, insulin, and appetite scores. Therefore, the objectives were to assess the effect of acceptability on postprandial ghrelin and insulin levels and appetite scores of isoenergetic meals in normal-weight men. The results of this study could help in adopting a new approach in weight

management strategies that increases compliance to diet and reduces risks of long-term failure of weight loss.

2. Methods and materials

2.1. Participants

Eleven healthy men completed the study. Exclusion criteria included smoking; substance abuse; medical or psychological illness; use of medications; previous gastrointestinal surgery; and history of weight fluctuation (>5% in last 3 months before study), dieting, lactose intolerance, food restriction, or eating disorders. This study was approved by the Institutional Research Board of the American University of Beirut (AUB), and a written informed consent was obtained.

2.2. Study design

The study was composed of 4 phases as illustrated in Fig. 1. During phases 1-3, subjects were screened using a screening questionnaire (phase 1), completed a food preference

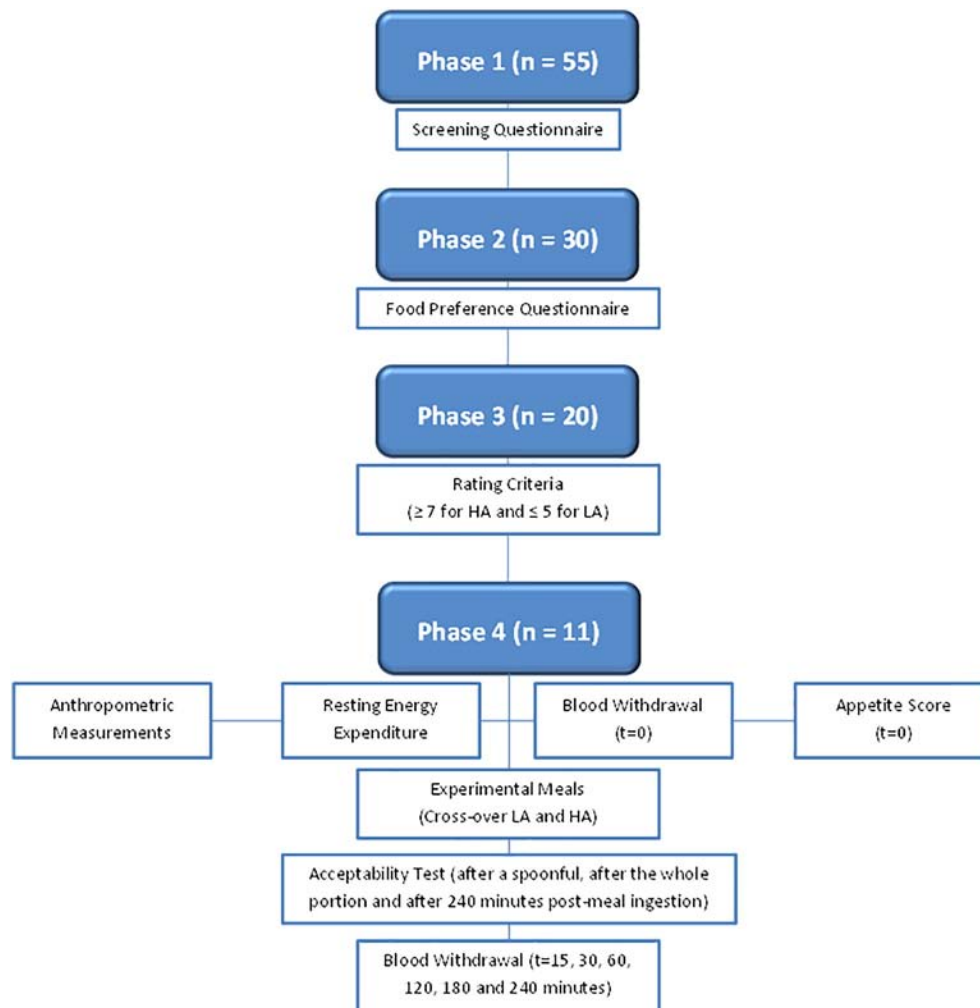


Fig. 1 – Study design illustrating subjects' selection.

questionnaire (phase 2), and underwent several acceptability tests (phase 3). Anthropometric and resting energy expenditure (REE) calculations were conducted (phase 4). Phase 1 subjects were 18- to 50-year-old men with a body mass index of 19–25 kg/m² and were compatible with the exclusion criteria stated above.

Selected subjects based on results of phases 1, 2, and 3 were included in phase 4 during which blood was withdrawn after consumption of 1 of 2 versions of a meal, which was chosen based on subjects' responses on preference and acceptability tests conducted in phases 2 and 3. The 2 versions of the meal had 2 different acceptability levels: low and high acceptability (LA and HA). Subjects were randomly assigned to 1 of the 2 meals. One week later, subjects were crossed over to ingest the other meal.

2.3. Data Collection

2.3.1. Phase 1: screening questionnaire

A preliminary screening questionnaire assessed the subjects' eligibility including information about the physical activity pattern of 55 subjects to accurately calculate their daily energy needs.

2.3.2. Phase 2: food preference questionnaire

Subjects who passed the screening questionnaire (n = 30) completed a comprehensive food preference questionnaire for 141 food items. The questionnaire was a slightly modified version of Issa et al [10,11] in terms of foods included. Foods were rated on the 9-point hedonic scale. Based on subjects' ratings of foods, several common high-acceptability/palatability foods (average score of ≥ 7) were selected to be used as HA meals for phase 3.

2.3.3. Phase 3

2.3.3.1. Custard preparation: sampling acceptability test. Preliminary trials (selected subjects from phase 2; n = 20) using LA and HA versions of several foods indicated that vanilla custard was the best candidate food for modification to yield HA (original recipe) and LA (modified recipe) versions. Vanilla custard, with an average score ≥ 7 in phase 3 (HA food), was

modified by adding 3.5 g of acesulfame-K (Nutrinova, Paris, France) to yield an LA food (average score ≤ 5). The custard formulations are included in Table 1. Custard samples were prepared 1 day before testing and stored overnight in a 5°C cooler. Foods were rated on 9-point hedonic scale, and order of samples was counterbalanced [12]. Subjects (n = 11) who rated custard samples according to desired scores (ie, ≥ 7 for HA and ≤ 5 for LA) were qualified for phase 4.

2.3.3.2. Anthropometric measurements. Subjects were weighed to the nearest 0.1 kg in light clothes and bare feet using a Seca weight scale (Model 877, Hamburg, Germany). Height was measured to nearest 0.5 cm with subject bare foot using a Seca stadiometer (Model 213).

2.3.4. Phase 4

2.3.4.1. Resting energy expenditure. REE was calculated using Harris-Benedict equation [13]. Each subject was given a meal that represented 30% of the subject's REE.

2.3.4.2. Experimental meals. Prior to consuming experimental meals, subjects (n = 11) had a 3-day pre-experiment isoenergetic adaptation [14] and were asked to maintain normal physical activity level. The 2 experimental meals described above (LA and HA custards) were of similar macronutrient composition (42% carbohydrates, 53% fat, and 5% protein for source of energy) and thus provided the same amount of 7.5 kJ (1.8 kcal) per gram. Participants, who were on an overnight 12-hour fasting regimen, were asked to consume their meals entirely within 10–15 minutes and abstained from any other food for 4 hours post-meal ingestion; only 500 mL of water (maximum) was allowed.

2.3.4.3. Metabolic and hormone assays, acceptability test, and appetite scores. On the days of the experimental sessions, subjects made it early in the morning (8:00 AM) to the clinical research unit at AUB's Medical Center. Blood samples were withdrawn immediately before the meal (time 0) and after 15, 30, 60, 120, 180, and 240 minutes.

Appetite scores were also recorded at the above time points using a visual analogue scale (VAS) [15]. Moreover, an acceptability test, using the 9-point hedonic scale, was conducted on 3 instances: after sampling a spoonful, after eating the whole portion, and after 240 minutes post-meal ingestion. The preparation of blood for biochemical analyses was conducted with 5 mL of blood collected per withdrawal instead of 12 mL [16].

Blood analysis for acylated ghrelin and insulin was performed using commercial enzyme-linked immunosorbent assay kits (Millipore Corporation, St Charles, MO, USA) and radioimmunoassay kits (MP Biomedicals, Solon, OH, USA), respectively. Serum glucose levels were determined by means of commercial enzymatic colorimetric tests using a Vitros analyzer (DT60 II System; Johnson & Johnson Clinical Diagnostics, Rochester, NY, USA).

2.4. Statistical analyses

The sample size (n = 11) was determined by a power analysis with a standard deviation of 30 for the population and a minimal detectable difference in means of 40 based on a

Table 1 – Experimental meal formulation

Ingredients	Quantity
Custard ^a	35 g
Full fat milk ^b	350 g
Cooking cream ^c	150 g
Sugar	80 g
Locust bean gum ^d	1 g
Vanilla ^e	15 drops
Yellow color ^e	5 drops
Acesulfame K ^{f,g}	3.5 g

^a Royal, Al Ain, United Arab Emirates.

^b Dairy Day, Kfarchima, Lebanon.

^c Elle et Vire Excellence, Normandy, France.

^d Sigma, St Louis, MO, USA.

^e Foster Clarks Products, San Gwann, Malta.

^f Nutrinova, Paris, France.

^g Used only in the LA recipe.

Table 2 – Participants' baseline characteristics

	Means	Ranges
	(n = 11)	(n = 11)
Age (y)	20.8 ± 0.9	20-23
Height (m)	1.81 ± 0.03	1.75-1.86
Weight (kg)	75.7 ± 7.0	61.6-84.8
BMI (kg/m ²)	22.6 ± 1.7	19.2-24.8
REE (kJ/d)	7669 ± 523	6848-8736
Energy per meal (kJ)	2302 ± 155	2055-2620

Values are expressed as means ± SE and ranges.

previous study of Tannous et al [16], a statistical power of 80%, and a significance level of 5%. A repeated-measures analysis of variance was performed to assess the effect of predictor variables on levels of hormones (ghrelin, insulin) and glucose using the SAS software (version 9.02; SAS Institute, Cary, NC, USA). Each subject served as his own control. Discrete predictor variables were acceptability level (LA and HA) and time elapsed (1-7 blood withdrawals). Response variable was the hormonal level. Main effects and all 2-way interactions were tested. A paired t test was used to determine changes in VAS variables over time and to identify differences in the variables' responses to the 2 meals at every time point. Significant means were separated by Tukey honestly significant difference (HSD) test. Significance was pre-established at $\alpha < .05$.

3. Results

3.1. Participant characteristics

Participants' baseline characteristics are summarized in Table 2. All subjects were shown to have body mass indexes within the normal range.

3.2. Acceptability ratings

Acceptability ratings results are illustrated in Fig. 2. The 2 meals were significantly different ($P < .001$). There was also a significant time effect ($P < .01$). There was a significant decrease in mean acceptability ratings between 0 minute, and 15 and 240 minutes ($P < .05$). Although ratings seemed steady for the HA meal over the 3 time points with a decreasing trend between 0 minute, and 15 and 240 minutes for the LA one, the time × meal interaction was not significant.

3.3. Appetite scores

Appetite scores for different time points are summarized in Table 3. Within the same meal, in comparing different time points with time 0, hunger significantly decreased at 15 and 30 minutes for both meals ($P < .05$) and later significantly increased at 240 minutes for the HA meal but not for the LA meal ($P > .05$). Satiety and fullness results mirrored each other whereby they significantly increased from 15 to 120 minutes for the HA meal and from 15 to 60 minutes for the LA one ($P < .05$), except for fullness at 30 minutes which was not significantly different from baseline. Prospective food consumption significantly decreased at 15, 30, and 60 minutes and 15 and 30 minutes for the HA and LA meals, respectively, because of the ingestion of the food. Given the sweet nature of both meals, the desire for sweet food consumption remained significantly lower than time 0 for both meals and for all time points, except at 240 minutes for the HA meal.

Salty food consumption did not significantly increase until 180 and 240 minutes for the HA and 240 minutes for the LA meals, respectively. There was no noticeable effect on savory food consumption ($P > .05$). The same trend was true for fatty food consumption, despite a trend for slightly higher values with time, except for the HA meal at 240 minutes ($P < .05$). As for differences between meals at the same time points, there were

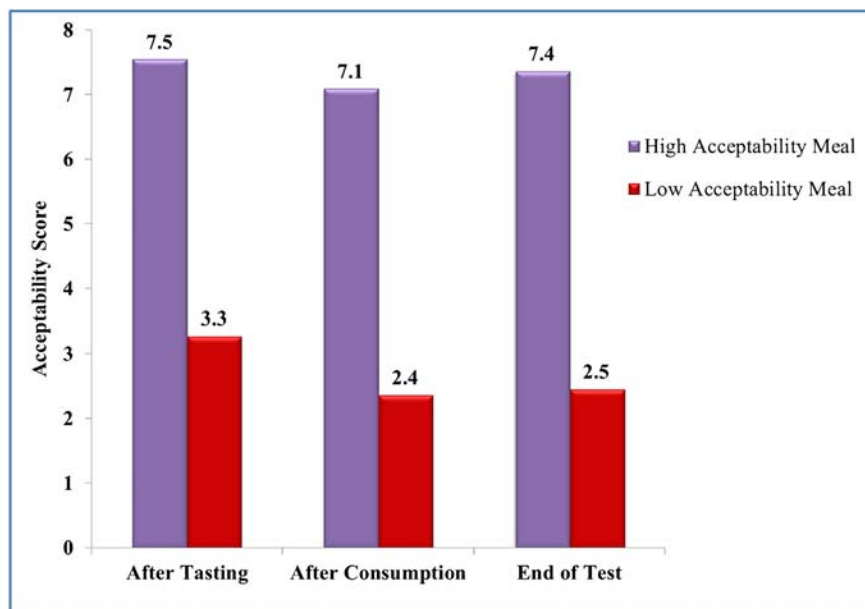


Fig. 2 – Acceptability ratings, on the 9-point hedonic scale, following HA and LA meals in 11 adult normal-weight men. Results are expressed as mean scores.

Table 3 – Appetite scores (hunger; satiety; fullness; and prospective, sweet, salty, savory, and fatty food consumption) for HA and LA meals at different time points

Variable	Meal	0 ^a	15	30	60	120	180	240
Hunger	HA	6.5 ± 1.6	3.1 ± 2.1 ^c	4.2 ± 2.1 ^c	5.3 ± 1.5	6.1 ± 1.6	7.2 ± 0.9	7.6 ± 0.9 ^c
	LA	5.8 ± 2.4	2.9 ± 2.4 ^c	3.6 ± 3.0 ^c	4.2 ± 2.6	5.2 ± 2.0	6.2 ± 2.2	6.7 ± 2.1
Satiety	HA	2.1 ± 1.1	6.4 ± 2.1 ^c	5.4 ± 2.1 ^c	5.0 ± 2.3 ^c	4.5 ± 2.4 ^c	3.6 ± 2.6	2.4 ± 1.9
	LA	2.9 ± 1.7	6.5 ± 2.4 ^c	6.6 ± 2.8 ^c	5.7 ± 2.5 ^c	4.4 ± 2.5	3.5 ± 2.2	3.2 ± 2.1
Fullness	HA	1.8 ± 1.2	5.9 ± 2.8 ^c	5.1 ± 2.8 ^c	4.2 ± 2.5 ^c	3.3 ± 2.3 ^c	2.6 ± 1.9	2.1 ± 1.8
	LA	3.1 ± 2.0	6.2 ± 2.5 ^c	5.5 ± 3.3	5.3 ± 2.8 ^c	3.8 ± 2.4	3.0 ± 2.1	3.1 ± 2.7
Prospective FC	HA	6.7 ± 1.7	3.3 ± 2.0 ^c	4.7 ± 2.0 ^c	5.2 ± 2.3 ^c	6.6 ± 1.6	7.1 ± 1.6	7.6 ± 1.3
	LA	6.5 ± 2.0	4.0 ± 2.8 ^c	3.9 ± 3.0 ^c	5.2 ± 2.4	5.5 ± 2.0	6.6 ± 2.2	6.6 ± 2.3
Sweet FC	HA	6.7 ± 1.7	2.9 ± 1.2 ^c	3.1 ± 1.7 ^c	4.0 ± 2.3 ^c	3.7 ± 2.1 ^c	4.3 ± 2.6 ^{b,c}	4.8 ± 2.1 ^b
	LA	6.5 ± 1.8	2.9 ± 2.9 ^c	2.7 ± 2.7 ^c	3.0 ± 2.7 ^c	3.0 ± 2.5 ^c	2.9 ± 2.1 ^c	3.2 ± 2.8 ^c
Salty FC	HA	5.4 ± 2.2	5.4 ± 2.5	5.3 ± 2.5	5.7 ± 2.1	6.1 ± 1.9	6.9 ± 1.5 ^c	6.9 ± 1.6 ^c
	LA	4.9 ± 2.3	4.6 ± 2.9	4.6 ± 2.9	5.2 ± 3.0	6.7 ± 2.2 ^c	6.5 ± 1.9	7.1 ± 1.4 ^c
Savory FC	HA	5.9 ± 2.5	4.3 ± 2.1	4.8 ± 2.5	5.2 ± 2.6	5.3 ± 2.5	6.3 ± 1.7	6.8 ± 1.8
	LA	5.6 ± 2.8	5.4 ± 2.7	4.8 ± 2.9	5.1 ± 2.7	6.0 ± 2.7	6.1 ± 2.8	6.3 ± 2.9
Fatty FC	HA	3.4 ± 2.5	3.0 ± 2.3	3.2 ± 2.7	3.7 ± 2.5	4.0 ± 2.8	3.9 ± 2.9	5.3 ± 3.4 ^c
	LA	3.3 ± 2.7	3.3 ± 3.0	3.4 ± 3.0	3.6 ± 2.8	3.9 ± 3.0	4.5 ± 3.3	4.8 ± 3.3

Results are expressed as means ± SD.

A paired t test was used to determine changes in VAS variables over time and to identify differences in the variables' responses to the 2 meals at every time point.

Abbreviation: FC, food consumption.

^a Time in minutes.

^b Values, at the same time point, are significantly different at $P < .05$.

^c Significantly different from baseline, within the same meal.

significant differences ($P < .05$) between the LA and HA meals for desire for sweet food consumption at 180 and 240 minutes only, whereby subjects were significantly more willing to consume sweet food after the HA meal than the LA one.

3.4. Metabolic and hormone assays

3.4.1. Ghrelin

Serum ghrelin results are illustrated in Fig. 3. In both meals, ghrelin levels were significantly different from the 0-minute time for all time points except at 180 minutes for the LA meal. The trend for both meals was a significant decrease at 15, 30, and 60 minutes compared with 0 minute, followed by an increase after 90 minutes and until 240 minutes but with a statistically significant increase only at 180 and 240 minutes. Comparing the HA and LA meals, there were significant differences in ghrelin levels between the HA and LA meals at 180 minutes ($P = .0184$) and 240 minutes ($P = .0005$). In both cases, ghrelin values for LA meal were significantly higher. There was a significant time by meal effect ($P < .0001$). There were no replicate or replicate interaction effects ($P > .05$).

3.4.2. Insulin

As illustrated in Fig. 4 and in both meals, insulin levels were significantly higher than the 0-minute time at all the time points between 15 and 60 minutes. Comparing meals, there were significant differences in insulin levels between the HA and LA meals at 15 minutes ($P = .0192$) and 30 minutes ($P = .0008$) where, in both cases, values were significantly higher for HA meal than LA meal. There was a significant time × meal effect ($P = .0315$). There were no replicate or replicate interaction effects ($P > .05$).

3.4.3. Glucose

Glucose results are illustrated in Fig. 5. There was a significant time effect, as expected, but no time by meal effect ($P > .05$). Moreover, there was no meal effect ($P > .05$). The absence of significant time × meal interaction also translated to the absence of significant differences between the 2 meals at the same time points (15, 30, 60 minutes, etc).

4. Discussion

4.1. Acceptability ratings

In this study, the acceptability ratings after a spoonful of consumption of LA and HA meals decreased approximately by 1 point for the LA meal and decreased by only 0.4 point following the HA meal. This outcome is consistent with the hypothesis that acceptability ratings decrease during the course of a meal [17]. In line with this, a previous study had shown that both adulterated and unadulterated versions of a frozen yogurt drink decreased by about 1 point on the 9-point hedonic scale 5 minutes post-meal termination [18].

4.2. Appetite scores

The absence of major differences in appetite scores between the 2 meals was also noted in previous studies in which no effect of pleasantness or palatability of food on satiety and hunger ratings [19], or appetite scores [20,21], was noted, in a similar manner to this work. The acesulfame-K-sweetened LA meal has resulted in less desire to eat sweet food, which has been also shown at the meal/food level [22] and at the 24-hour specific taste diet level [23].

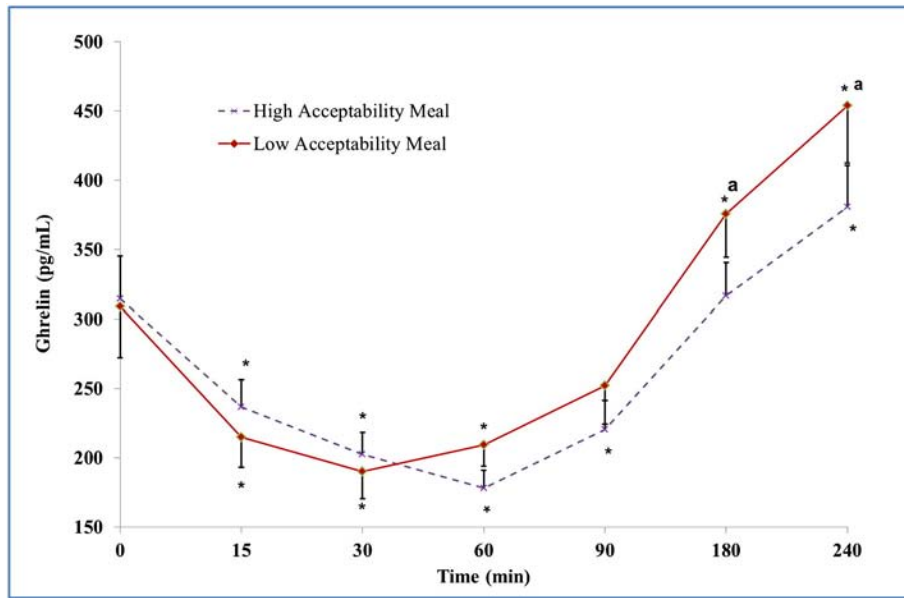


Fig. 3 – Plasma acylated ghrelin responses following HA and LA meals in 11 adult normal-weight men. Results are expressed as means ± SE. Bars above (⊥) or below (⊥) time points are SE. A repeated-measures analysis of variance was performed to assess the effect of predictor variables. Significant means were separated by Tukey HSD test. ^a Values, at the same time point, are significantly different at P < .05. * Significantly different from baseline, within the same meal.

4.3. Metabolic and hormone assays

In this study, serum glucose did not differ between the 2 meals, which confirms having similar meal composition in both meal versions (LA and HA), to avoid any composition-related effect on hormones [14,16] and appetite scores [24,25].

In parallel, ghrelin and insulin levels fluctuated over time; the observed postprandial hormonal trends are physiological and have been extensively reported. Insulin levels increased at 15 and 30 minutes (peak levels) to significantly higher levels following the HA meal and remained higher for the whole experimental period; this was attributed to the stimulation

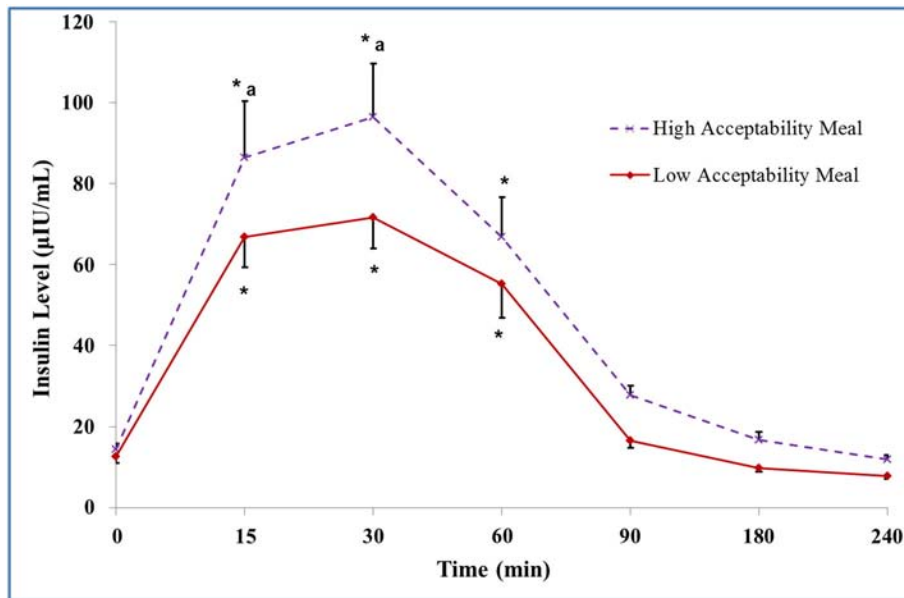


Fig. 4 – Plasma insulin responses following HA and LA meals in 11 adult normal-weight men. Results are expressed as means ± SE. Bars above (⊥) or below (⊥) time points are SE. A repeated-measures analysis of variance was performed to assess the effect of predictor variables. Significant means were separated by Tukey HSD test. ^a Values, at the same time point, are significantly different at P < .05. * Significantly different from baseline, within the same meal.

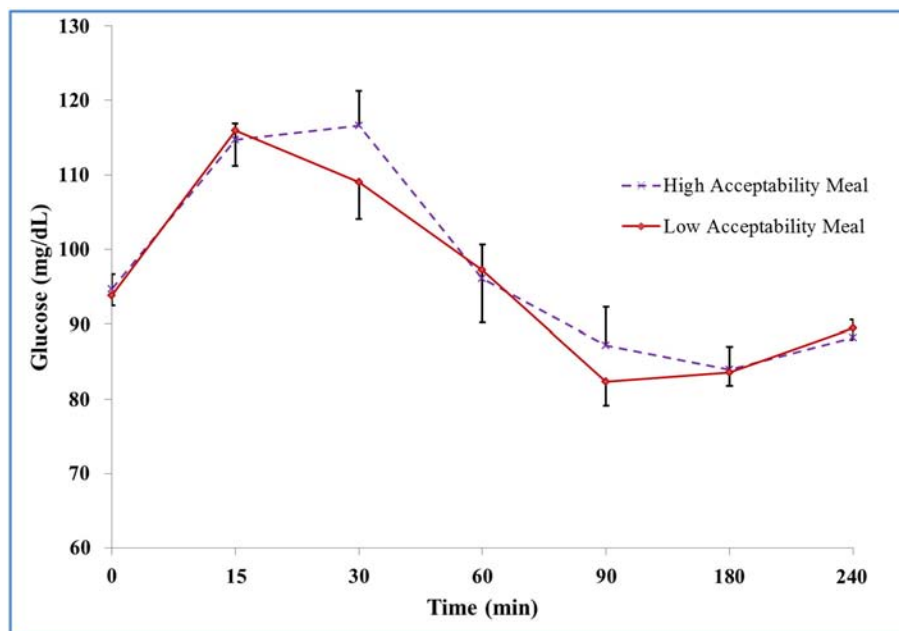


Fig. 5 – Plasma glucose responses following HA and LA meals in 11 adult normal-weight men. Results are expressed as means \pm SE. Bars above (\Uparrow) or below (\Downarrow) time points are SE. A repeated-measures analysis of variance was performed to assess the effect of predictor variables.

of cephalic phase insulin release by palatable and sweet food [26,27]. Conversely, ghrelin levels were lower for the first 30 minutes for the LA meal despite the lack of significant differences. This trend reversed at 60 minutes and afterwards when ghrelin levels increased to a higher extent for the LA meal, suggesting that the acceptability of a meal could be associated with increased satiety and could delay the initiation of the next meal. In fact, ghrelin was found to be involved in hedonic hunger, a state of eating for pleasure in the presence of highly palatable foods even without energy deficit [28]. In a study that explored the role of some substances in hedonic eating, plasma ghrelin levels were (not significantly) higher 5 minutes after exposure to highly palatable food vs the nonpalatable one in satiated healthy subjects [28]. However, unlike what we have found, plasma ghrelin levels followed different patterns in respect to the type of food ingested; they were suppressed after 130 minutes from the consumption of the nonpalatable food and significantly increased after the palatable one [28]. This indicated that highly palatable foods might acutely stimulate ghrelin secretion which was also shown in the first postprandial phase of our study. However, one of the limitations of this study is that food acceptability was not measured but rather inferred for LA foods by using regular staple foods such as bread, milk, and butter, in addition to the lack of consistency and standardization of the 2 versions of meals which differed by up to 20 g of protein. Given the above, it will be interesting to investigate whether an LA food would have the ability to “shut down” the reward pathway, thus possibly triggering an override of the homeostatic pathway, leading to a greater level of hunger later on.

Weight loss diets are generally characterized by the absence of taste-enhancing ingredients such as fat, sugar, salt, and others and have been shown to have lower

compliance and long-term adherence due to several factors, including palatability reasons [29]. Although this may not necessarily apply to foods of relatively LA upon repeated exposure [30], the value of this work highlights the importance of acceptability in satisfying one's desire to eat and hence reducing subsequent meal intake. This is the first work, to our knowledge, where aversive taste affected acceptability ratings and ghrelin response.

As hypothesized, this study showed that (1) food acceptability affects ghrelin and insulin levels in healthy nonobese male subjects and (2) manipulation of the diet based on palatability might assist in curbing obesity, whereby eating a palatable food may satisfy one's desire to eat; however, no major differences in appetite scores between the 2 meals were detected.

The major limitation of the current study is the relatively small sample size; a larger number of subjects would have provided more strength to the results, especially with respect to appetite scores. Moreover, the assessment of the response of acceptability manipulation was studied only in healthy lean men; any sex- or adiposity- (on overweight/obese subjects) related differences are missed. This work paves the way for further research on other appetite hormones such as neuropeptide Y, leptin, and others to confirm the advantage of a highly palatable low-energy diet over a less palatable one in the management of obesity. Future work could benefit from coupling appetite hormones with functional magnetic resonance imaging data, whereby the effect of ghrelin differences on homeostatic and hedonic pathways would be confirmed. Further research studies may also investigate (1) whether obese subjects would have different responses from lean ones; (2) the effect of longer-term intake of LA and HA foods; and (3) the effect of composition of LA and HA foods on hormonal, behavioral, and neural responses.

Acknowledgment

Funding for this study was provided by the AUB through the University Research Board grant. The authors thank Lina Abdouni for her diligent assistance with the literature review; Dareen Shatila and Roy Nassif for technical assistance; and Maya Daaboul, Hala Dandachi, and Rita Feghaly for assistance with subjects' recruitment. The authors declare no conflict of interest.

REFERENCES

- [1] Karageorgi S, Alsmadi O, Behbehani K. A review of adult obesity prevalence, trends, risk factors, and epidemiologic methods in Kuwait. *J Obes* 2013.
- [2] Finkelstein EA, Khavjou OA, Thompson H, Trogon JG, Pan L, Sherry B, et al. Obesity and severe obesity forecasts through 2030. *Am J Prev Med* 2012;42:563–70.
- [3] Troke RC, Tan TM, Bloom SR. The future role of gut hormones in the treatment of obesity. *Ther Adv Chronic Dis* 2014;5:4–14.
- [4] De Vriese C, Delporte C. Ghrelin: a new peptide regulating growth hormone release and food intake. *Int J Biochem Cell Biol* 2008;40:1420–4.
- [5] Foster-Schubert KE, Overduin J, Prudom CE, Liu J, Callahan HS, Gaylinn BD, et al. Acyl and total ghrelin are suppressed strongly by ingested proteins, weakly by lipids, and biphasically by carbohydrates. *J Clin Endocrinol Metab* 2008;93:1971–9.
- [6] Erlanson-Albertsson C. How palatable food disrupts appetite regulation. *Basic Clin Pharmacol Toxicol* 2005;97:61–73.
- [7] Lindqvist A, de la Cour CD, Stegmark A, Håkanson R, Erlanson-Albertsson C. Overeating of palatable food is associated with blunted leptin and ghrelin responses. *Regul Pept* 2005;130:123–32.
- [8] Jequier E. Obesity. Impairment of energy intake or of energy expenditure. *Ann Endocrinol (Paris)* 1994;87–92.
- [9] Le Magnen J. Palatability: concept, terminology, and mechanisms. In: Boakes RA, Popplewell DA, Burton MJ, editors. *Eating habits: food, physiology and learned behaviour*. Wiley; 1987. p. 131–54.
- [10] Issa C, Darmon N, Salameh P, Maillot M, Batal M, Lairon D. A Mediterranean diet pattern with low consumption of liquid sweets and refined cereals is negatively associated with adiposity in adults from rural Lebanon. *Int J Obes* 2011;35:251–8.
- [11] Issa C, Salameh P, Batal M, Vieux F, Lairon D, Darmon N. The nutrient profile of traditional Lebanese composite dishes: comparison with composite dishes consumed in France. *Int J Food Sci Nutr* 2009;60:285–95.
- [12] MacFie HJ, Bratchell N, Greenhoff K, Vallis LV. Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests. *J Sens Stud* 1989;4:129–48.
- [13] Harris JA, Benedict FG. A biometric study of human basal metabolism. *Proc Natl Acad Sci U S A* 1918;4:370–3.
- [14] AlAwar R, Obeid O, Hwalla N, Azar S. Postprandial acylated ghrelin status following fat and protein manipulation of meals in healthy young women. *Clin Sci* 2005;109:405–11.
- [15] Flint A, Raben A, Blundell J, Astrup A. Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. *Int J Obes Relat Metab Disord* 2000;24:38–48.
- [16] Tannous dit El Khoury D, Obeid O, Azar ST, Hwalla N. Variations in postprandial ghrelin status following ingestion of high-carbohydrate, high-fat, and high-protein meals in males. *Ann Nutr Metab* 2006;50:260–9.
- [17] Zhu Y, Hollis JH. Chewing thoroughly reduces eating rate and postprandial food palatability but does not influence meal size in older adults. *Physiol Behav* 2014;123:62–6.
- [18] Bobroff EM, Kissileff HR. Effects of changes in palatability on food intake and the cumulative food intake curve in man. *Appetite* 1986;7:85–96.
- [19] De Graaf C, De Jong LS, Lambers AC. Palatability affects satiation but not satiety. *Physiol Behav* 1999;66:681–8.
- [20] Rogers PJ, Blundell JE. Umami and appetite: effects of monosodium glutamate on hunger and food intake in human subjects. *Physiol Behav* 1990;48:801–4.
- [21] Johnson J, Vickers Z. Factors influencing sensory-specific satiety. *Appetite* 1992;19:15–31.
- [22] Montelius C, Erlandsson D, Vitija E, Stenblom E-L, Egecioglu E, Erlanson-Albertsson C. Body weight loss, reduced urge for palatable food and increased release of GLP-1 through daily supplementation with green-plant membranes for three months in overweight women. *Appetite* 2014;81:295–304.
- [23] Griffioen-Roose S, Hogenkamp PS, Mars M, Finlayson G, de Graaf C. Taste of a 24-h diet and its effect on subsequent food preferences and satiety. *Appetite* 2012;59:1–8.
- [24] Robinson TM, Gray RW, Yeomans MR, French SJ. Test-meal palatability alters the effects of intragastric fat but not carbohydrate preloads on intake and rated appetite in healthy volunteers. *Physiol Behav* 2005;84:193–203.
- [25] Merrill E, Cardello A, Kramer F, Leshner L, Schutz H. The development of a perceived satiety index for military rations. *Food Qual Prefer* 2004;15:859–70.
- [26] Bellisle F, Drewnowski A, Anderson GH, Westerterp-Plantenga M, Martin CK. Sweetness, satiation, and satiety. *J Nutr* 2012;142:1149S–54S.
- [27] Bellisle F, Louis-Sylvestre J, Demozay F, Blazy D, Le Magnen J. Cephalic phase of insulin secretion and food stimulation in humans: a new perspective. *Am J Physiol Endocrinol Metab* 1985;249:E639–45.
- [28] Monteleone P, Piscitelli F, Scognamiglio P, Monteleone AM, Canestrelli B, Di Marzo V, et al. Hedonic eating is associated with increased peripheral levels of ghrelin and the endocannabinoid 2-arachidonoyl-glycerol in healthy humans: a pilot study. *J Clin Endocrinol Metab* 2012;97:E917–24.
- [29] MacLean PS, Wing RR, Davidson T, Epstein L, Goodpaster B, Hall KD, et al. NIH working group report: innovative research to improve maintenance of weight loss. *Obesity* 2015;23:7–15.
- [30] Zandstra E, De Graaf C, Mela D, Van Staveren W. Short-and long-term effects of changes in pleasantness on food intake. *Appetite* 2000;34:253–60.