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Original Research

Comparison of the Effects of Mid-Morning Snacks Prepared with Chia, Amaranth and Quinoa Seeds on Short-Term Satiety and Energy Intake

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Abstract

Objectives: The pseudo-cereals chia, amaranth, and quinoa have received increasing attention due to their advantageous nutritional features in recent years. However, their influence on subjective satiety and consecutive energy intake in humans is mainly unknown. The purpose of this research was to determine whether subjective food consumption and satiety during an open buffet meal were different after consuming test meals prepared with chia, amaranth, or quinoa seeds.
Materials and Methods: Subjects (n=35) were given four mid-morning snacks in a randomized cross-over design. On various test days, participants received plain yogurt (CON), yogurt containing 14 g of chia (CHI), amaranth (AMA), or quinoa (QUI). After subjects were told to report visual analogue scale (VAS) scores on sensory outcomes, they were provided an *ad libitum* meal and their energy intake was recorded.
Results: VAS scores were similar between the test meals. Area under curve data of VAS scores indicated similar hunger, satiety, prospective food consumption and amount of food that could be consumed between the study groups. On the other hand, the area under curve data of desire for sugary snacks was significantly lower in QUI in comparison to CON and CHI. Individuals in all groups had similar energy intake during ad libitum lunch. No difference was determined between chia, amaranth, and quinoa test meals.
Conclusion: Iso-caloric test meals prepared with yogurt and chia, amaranth, or quinoa seeds showed similar effects on *ad libitum* energy intake and subjective appetite sensations.

Keywords: *Amaranth, chia, energy intake, quinoa, satiety response*

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Introduction

The evident increase in obesity presents a major challenge to public health around the world (Chooi et al., 2019). Generally, the underlying cause of obesity is an inactive lifestyle and nutritional transition to energy dense and processed foods consequently leading to excessive adipogenesis (Belfort-DeAguiar and Seo, 2018; Gayathri et al., 2017). The natural treatment of obesity is to lower total energy intake and compose a nutritionally balanced diet (Smethers and Rolls, 2018). However, it is reported that this approach is difficult to achieve in some cases (Montesi et al., 2016). In order to combat this situation, interest in functional and bioactive food components for the suppression of appetite and prolongation of satiety has grown substantially (Torres-Fuentes et al., 2015; Trigueros et al., 2013). Recently, alternative crops, such as chia, quinoa, and amaranth, have taken considerable attention due to their peculiar composition and components (Orona-Tamayo et al., 2018; López et al, 2018).

Specific food components were shown to be more effective in reducing hunger and subsequent energy intake due to their macronutrient composition (Tremblay and Bellisle, 2015). A large body of evidence indicated that the satiating effects of proteins and fibre were higher than other macro-nutrients in healthy subjects (Lonnie et al., 2018; Brennan et al., 2012; Solah et al., 2016). Chia seeds, harvested from *Salvia hispanica L.*, are rich in protein, which is about 19–23% with a non-limiting amino acid profile, and in soluble and insoluble fibres, which are above 30% of total weight (Sandoval-Oliveros and Paredes-López, 2013). Furthermore, this seed is a natural source of α-linolenic acid, vitamins, minerals, and phytochemicals, and the beneficial and protective effects of chia seed consumption on chronic diseases have previously been reported (Valdivia-López and Tecante, 2015). Few studies indicated that these outcomes can be attributable to reductions in post-prandial glycaemia following chia seed consumption and also decreased appetite ratings and reduced short-term energy intakes (Ho et al., 2013; Vuksan et al., 2010; Ayaz et al., 2017). Given the importance of consuming high fibre foods such as chia seed, there is now growing interest in their effects on satiety parameters.

Amaranthus spp., commonly known as amaranth, is a tropical plant that has rich sources of bioactive compounds with antioxidant properties, lysine amino acid (5% of the amino acids), and insoluble fibre, mainly lignin and cellulose (Coelho et al., 2018). Ssepuuya et al. (2018), reported that a vegetable soup prepared with amaranth contributed to over 25% of the required recommended dietary allowance (RDA) of carbohydrate, protein, dietary fibre, vitamin A and iron for adolescents. One study showed that rats ingesting quinoa and amaranth added diets exhibited lower food intake and body weight gain in the amaranth group with improvement in

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glucose concentration as compared to the control group (Mithila and Khanum, 2015). In a different animal model, bread formulations containing whole flour from amaranth, quinoa or chia seed reduced glycaemic index in comparison to white bread (Laparra and Haros, 2018). The innovative data obtained from these studies points out the necessity to confirm to what extent satiety parameters can be regulated with these alternative crops in humans.

Quinoa (*Chenopodium quinoa*) is also a pseudo-cereal containing considerably important nutritional constituents like indispensable amino acids, minerals, and dietary fibre (Mattila et al., 2018). Due to its low glycaemic properties, few studies tested its efficiency on metabolic parameters in clinical groups. One of these studies reported that consuming quinoa for twenty-eight days resulted in decreased body mass index (BMI) and haemoglobin A1c (HbA1c) levels and increased subjective satiation and fullness in pre-diabetic subjects (Abellán Ruiz et al., 2017). Navarro-Perez et al. (2017), showed a reduction in serum triglycerides and prevalence of metabolic syndrome after consuming 50 g quinoa/day for twelve weeks in overweight and obese subjects. On the other hand, a bread containing 20 g of quinoa flour reduced blood glucose but exerted minimal influence on cardiovascular disease parameters (Li et al., 2018). The acute effects of quinoa on energy intake and short-term appetite in humans have not been widely studied.

Several studies have demonstrated that enrichment of common dietary products with high fibre foods or foods with beneficial compounds promotes useful effects on short-term appetite regulation and satiety (Doyon et al., 2015; Pentikäinen et al., 2014). However, the influence of most of the pseudo-cereals on short-term appetite and satiety is largely unknown. More specifically, none of these pseudo-cereals have been compared in a setting where subjective satiety response and energy intake during a subsequent meal were measured. Therefore, the main objective of the present study was to compare three different pseudo-cereals, namely chia, amaranth, and quinoa, added to yogurt as a mid-morning snack on satiety and energy intake during the following meal.

Methods

This study was conducted with thirty-five female subjects recruited from Hacettepe University and the nearby community through poster advertisements and announcements. All volunteers were screened using a questionnaire that included questions about their general health and eating habits. Women between the ages of 18 and 30 who were in good health, not dieting, non-smokers, and not diagnosed with any metabolic or acute disease were agreed to

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participate. They could not be elite athletes, have food allergies or strong sensory issues with certain meals, or be pregnant or breastfeeding. None of the participants were taking drugs that were known to impact appetite or body weight management. Participants were also required to consume breakfast, snacks, and lunch on a regular basis. Before the study, each volunteer signed an informed consent form. Subjects who have a strong aversion to certain foods were also excluded. Participants were excluded if they scored more than 9 on the Beck depression scale due to a depression tendency and had a BMI of less than 18 or more than 25 kg/m^2. The participants' body weight, height, and body compositions were measured in terms of fat percentage (%) and lean body mass (kg) with a Tanita MC-980 (Tanita Corp., Tokyo, Japan). Due to the fact that the menstrual cycle may have an influence on appetite ratings, for all subjects, experiment days were scheduled a week prior to menstruation. This study was granted by the Clinical Researches Ethics Board of Hacettepe University (2018-01-28 KA-17139) on the 19th of January 2018. The principles of the Helsinki Declaration were followed throughout the study period.

This was a crossover study conducted at the Nutrition Laboratory in the Department of Nutrition and Dietetics, Hacettepe University, Ankara, Turkey. The European consensus on postprandial research investigating appetite measures and eating behaviours was used in this study's experimental methodology (Blundell et al., 2010). The experiment was performed over three days, with a 1-2 week washout period between each test day. Subjects arrived at 08.00 h following 12-hour fasting and left at 14.00 h on each test day. Participants had dinner the previous evening, which comprised of a bowl of vegetable soup (200 mL), grilled chicken (90 g), salad (200 g), a bowl of yogurt (200 g), and white bread (50 g) (total 494 kcal), and at 08.30 h, a piece of cheese (30 g), two thin slices of white bread (50 g), and a cup of tea (total 250 kcal) were provided for breakfast. The participants were given 15 minutes to complete the entire breakfast. No further food or drink was permitted until the mid-morning snacks with pseudo-cereals were served. After this, at 10.30 h, subjects received four mid-morning snacks that were closely matched in terms of energy content. Participants were randomly given 200 g plain yogurt with no pseudo-cereal (CON), 115 g yogurt containing 14 g chia (CHI), 130 g yogurt containing 14 g amaranth (AMA), or 125 g yogurt containing 14 g quinoa (QUI) on each test day. To assign participants to the various mid-morning snacks, a randomization system was developed using the website "randomization.com" (Randomization Plans, 2018). Chia, amaranth, and quinoa were purchased from Yayla Agro Corp., Ankara, Turkey. The nutritional value of 100 grams of chia, amaranth, and quinoa was as follows: energy 434, 365, and 317

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kcal, fat 29.3, 7, and 6.8 g, fibre 32.5, 7, and 7.4 g, and protein 22.9, 14, and 14.5 g, respectively. The white versions of chia, amaranth, and quinoa were used in order to match the visual appearance of the test meals (Figure 1). The nutritional compositions of the mid-morning snacks are shown in Table 1.

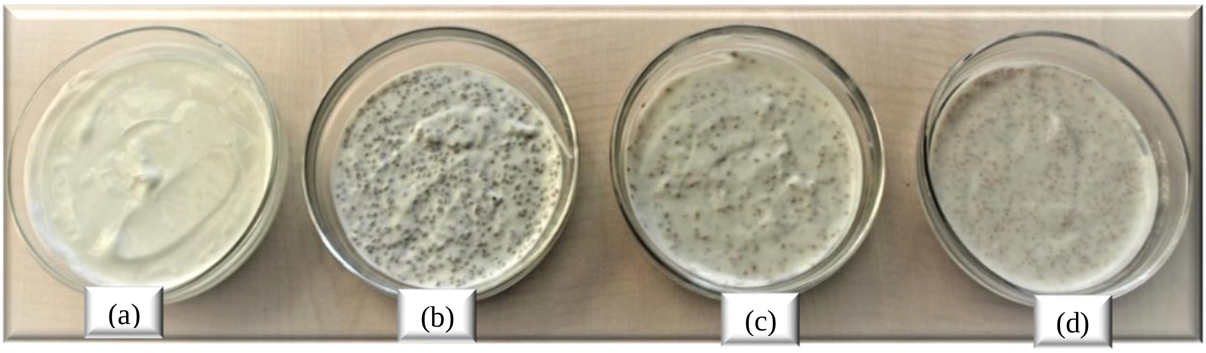

Figure 1. Test meals.

(a) CON, 200 g plain yogurt with no pseudo-cereal; (b) CHI, 115 g yogurt containing 14 g chia seed; (c) QUI, 125 g yogurt containing 14 g quinoa; (d) AMA, 130 g yogurt containing 14 g amaranth.

Table 1. Nutritional composition of mid-morning snacks

Nutrient	Snack			
	CON	CHI	AMA	QUI
Energy (kcal)	146	145	146	146
Protein (g)	8.00	7.81	7.16	7.04
Fat (g)	7.60	8.47	5.92	5.39
Carbohydrate (g)	11.60	11.68	16.64	16.71
Fibre (g)	-	4.55	0.98	1.53
Serving (g)	200	129	144	149

CON, 200 g plain yogurt with no pseudo-cereal; CHI, 115 g yogurt containing 14 g chia seed; AMA, 130 g yogurt containing 14 g amaranth; QUI, 125 g yogurt containing 14 g quinoa.

Ad libitum lunch was provided after 2 hours. Pasta and fruit juice were served for lunch. The pasta was prepared according to the following recipe: 500 g of pasta was boiled with 50 g of sunflower oil in boiling water. The pasta was then combined with 300 g of ready-to-eat Napolitano sauce until it was distributed equally. This recipe had a nutritional value of 287 kcal, 44.8 g carbohydrates, 8.0 g protein, and 8.2 g fat per 100 g. Fruit juices (orange, peach, and mixed) had a nutritional value of 63–90 kcal, with 12.7–20.0 g carbohydrates per 100 mL. The subjects sat at a relatively close distance from the serving table, which was a distinct dining table. The same amounts and kinds of foods were provided on each test day, and the buffet items were identical. On test days, the same portion sizes, serving utensils, and serving bowls

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were used. The participants were told to eat until they were full, and they were free to refill their plates whenever they wanted. Participants were all in the same room throughout the experiment and were allowed to read or use personal computers. Social interaction and physical activity were limited. The participants were not allowed to follow how much food the other participants ate. Energy and macronutrient intakes of participants were calculated by weighing the amount of food and beverage ingested and converting the weights into energy (kcal) and macronutrients according to the manufacturer's labelling. Participants were told that the purpose of the study was to look at their energy intake on different test days, but they were not provided with any details regarding the contents of the mid-morning snacks.

Throughout the study, a visual analogue scale (VAS) was used to evaluate hunger, satiety, prospective food consumption, amount of food they could consume, and desire for sugary foods (Flint et al, 2000). On a 100 mm visual analogue scale, appetite ratings were recorded with statements anchored at each end indicating the extremes of a unipolar question (for hunger: "I am not hungry at all"/"I have never been more hungry"; for satiety: "I am not sated at all"/"I have never been more sated"; for prospective food consumption: "I cannot consume any food at all"/"I have never wanted to consume food that much"; for the desire for a sugary snack: "I do not want to consume a sugary snack at all"/"I have never wanted to consume a sugary snack that much"; for the amount of food: "I can only have a small amount of food"/"I can eat a large amount of food"). The baseline VAS scores were recorded at 08.00 h. before breakfast. The participants were then instructed to have breakfast till 08.30 h. Subjects completed VAS questionnaires every 15 minutes after breakfast until lunch and thereafter for a total of 23 times. They were instructed on how to complete VAS forms before the study period.

The Statistical Package for the Social Sciences (SPSS) version 22 (SPSS Inc., Chicago, IL, USA) was used to analyse data. The primary outcome of this trial was the impact of four different mid-morning snacks on energy intakes during an *ad libitum* lunch. A general linear model and ANOVA were used to analyse the data for the primary outcome. The VAS scores of the subjects were the secondary outcome variables. Data were analysed using a repeated measures ANCOVA with baseline measurement as the covariate for the secondary outcome. Subjects and test days were included in the procedure, in addition to the mid-morning snacks/time interaction. For comparisons among mid-morning snacks, Bonferroni post hoc analysis was used. GraphPad Prism version 6 (GraphPad Software Inc., La Jolla, CA, USA) was used to calculate the area under the curve (AUC) for VAS scores. Baseline values were added as covariates in AUC data. Data is presented as the mean ± standard error of mean unless

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otherwise stated. It was determined that P< 0.05 was statistically significant. Power analysis indicated that at least 24 subjects per condition were required in order to estimate a minimum effect size of 18.35% (for energy intake differences) for comparisons between treatment arms (yielding a power of 0.80 and alpha of 0.05) (Tabachnick and Fidell, 1996).

Results

All of the subjects successfully completed the study, and their data from each test day was analysed. Subjects were 22.06 ± 0.97 years old, with an average BMI of 20.66 ± 1.89 kg/m^2, and had a waist circumference of 71.21 ± 4.96 cm. Body composition data for the subjects were 40.60 ± 11.53 kg lean body mass and 23.79± 4.25 % fat.

VAS-rated hunger, satiety, prospective food consumption, the amount of food that could be consumed, and the desire for sugary foods are shown in Figure 2. Baseline values did not differ between study days (P> 0.05). Despite the significant effect of both breakfast and lunch (P< 0.001), VAS scores were similar during the test days (P> 0.05). There was no interaction between test meals and study time. The interaction between test meals and study time indicated a trend towards significance in average VAS scores of satieties (P=0.058) which resulted in a slightly higher feeling of satiety in CHI (59.43±2.26 mm), AMA (61.39±2.26 mm), and QUI (61.96±2.26 mm) groups in comparison to CON (58.21±2.26 mm). When the AUC data of VAS scores was evaluated, it appeared that consuming CHI, AMA, or QUI test meals did not result in different values in comparison to CON except for the AUC data of desire for sugary snacks (Table 2). Accordingly, the AUC data of desire for sugary snacks was significantly lower in QUI in comparison to CON and CHI (P<0.05). CON, CHI, and AMA had similar AUC data of desire for sugary snacks. There was no further significant difference in the AUC of VAS scores between CHI, AMA, and QUI (P>0.05).

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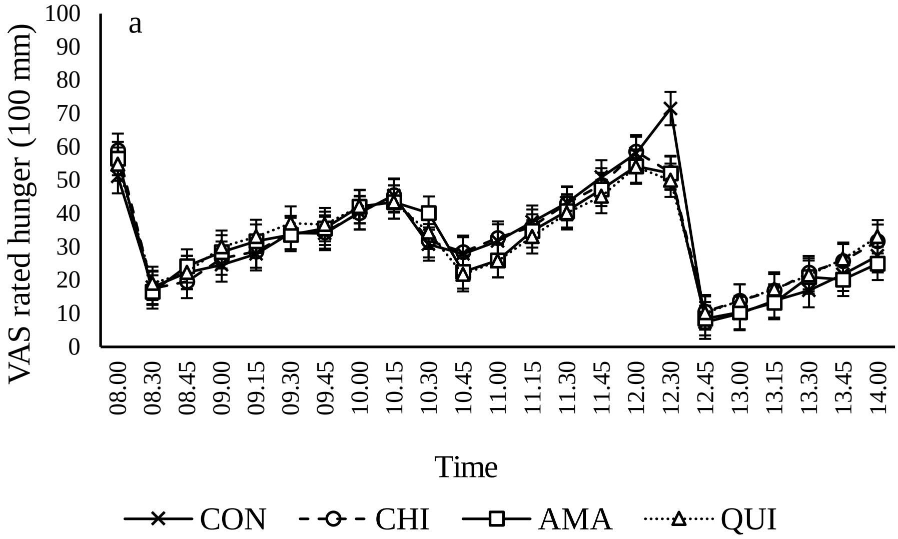

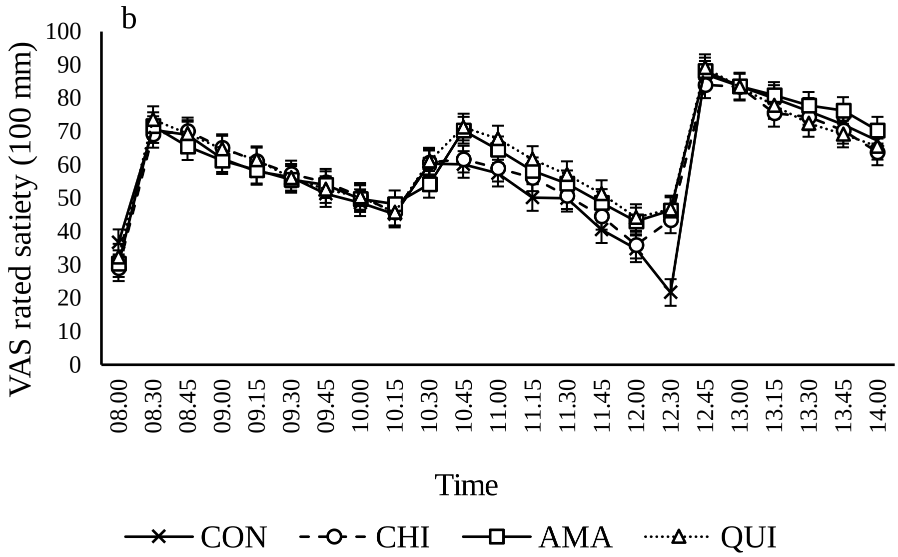

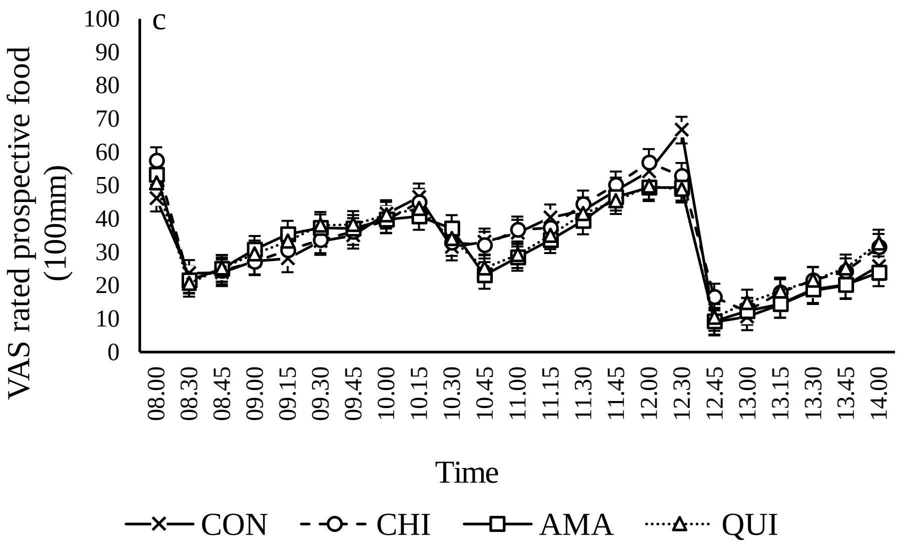

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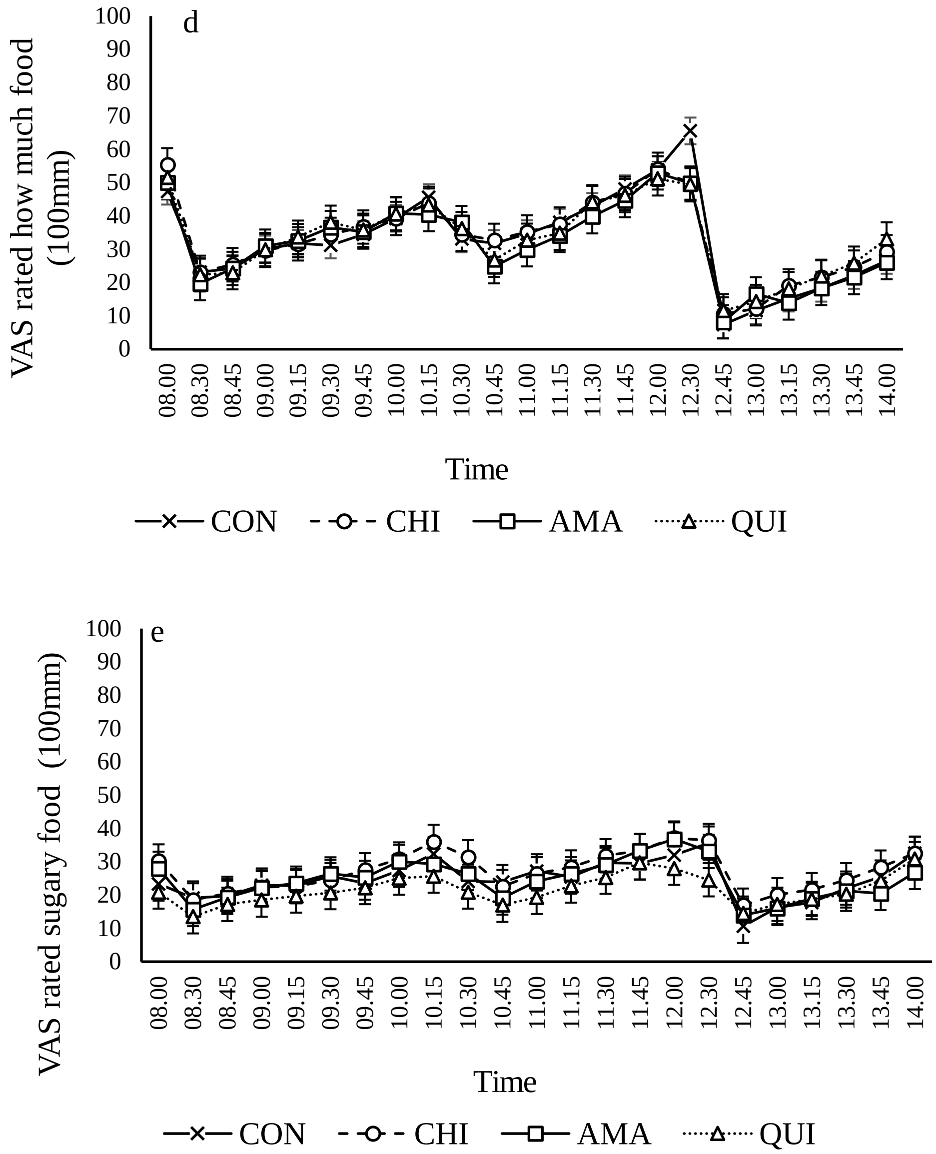

Figure 2. Mean VAS scores (± SEM) during the three test days, n = 35.

(a) VAS-rated hunger, (b) VAS-rated satiety, (c) VAS-rated prospective food consumption, (d) VAS-rated amount of food that could be consumed, (e) VAS-rated desire for a sugary snack. CON, 200 g plain yogurt with no pseudo-cereal; CHI, 115 g yogurt containing 14 g chia seed; AMA, 130 g yogurt containing 14 g amaranth; QUI, 125 g yogurt containing 14 g quinoa. A light breakfast was served at 08.00 h, immediately after recording baseline VAS scores. Lunch was served at 12.00 h. Repeated measures indicated that there were no statistically significant differences between CON, CHI, AMA and QUI groups (P> 0.05).

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Table 2. Area under curve (AUC) data for VAS scores.

VAS question	Snack				
	CON	**CHI**	**AMA**	**QUI**	**p**
Hunger	707.5±69.92	713.5±69.92	687.8±69.92	701.2±69.92	0.991
Satiety	1287.0±71.59	1320.0±71.59	1362.0±71.59	1376.0±71.59	0.809
Prospective consumption	719.2±71.55	718.0±71.55	687.7±71.55	709.6±71.55	0.935
Amount of food	720.2±70.86	729.2±70.86	690.8±70.86	722.0±70.86	0.961
Desire for sugary snack*	541.5±71.11[a]	593.6±71.11[a]	538.5±71.11[a,b]	471.2±71.11[b]	0.013

Mean area under curve data for VAS scores (± SEM) during the three test days (n = 35). CON, 200 g plain yogurt with no pseudo-cereal; CHI, 115 g yogurt containing 14 g chia seed; AMA, 130 g yogurt containing 14 g amaranth; QUI, 125 g yogurt containing 14 g quinoa.
* ANOVA indicated that the QUI group had a significantly different desire for sugary snack VAS scores when compared to CON and CHI *(P< 0.05*).

Figure 3 and Figure 4 show the mean energy intakes and percentage of energy coming from fat, protein, and carbohydrate during *ad libitum* lunch on the test days, respectively. Neither energy intakes nor percentage of energy coming from fat, protein, and carbohydrate during *ad libitum* lunch did show a significant difference between test groups (P> 0.05).

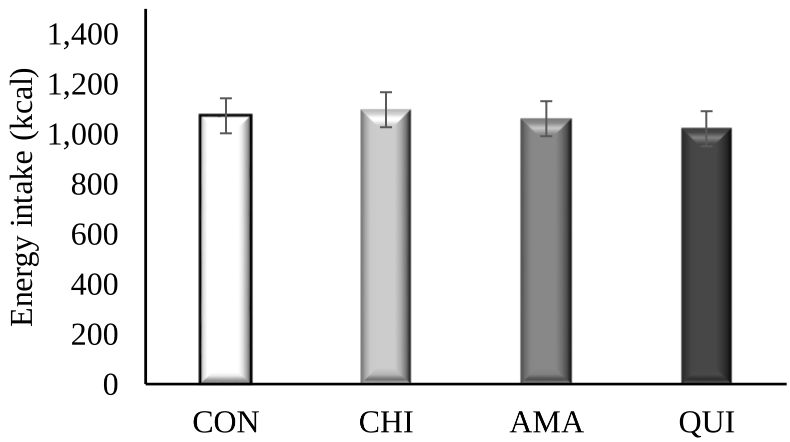

Figure 3. Mean energy intake (± SEM) during the *ad libitum* lunch, n = 35.

CON, 200 g plain yogurt with no pseudo-cereal; CHI, 115 g yogurt containing 14 g chia seed; AMA, 130 g yogurt containing 14 g amaranth; QUI, 125 g yogurt containing 14 g quinoa. ANOVA did not indicate a significant difference between CON, CHI, AMA, and QUI groups (P> 0.05).

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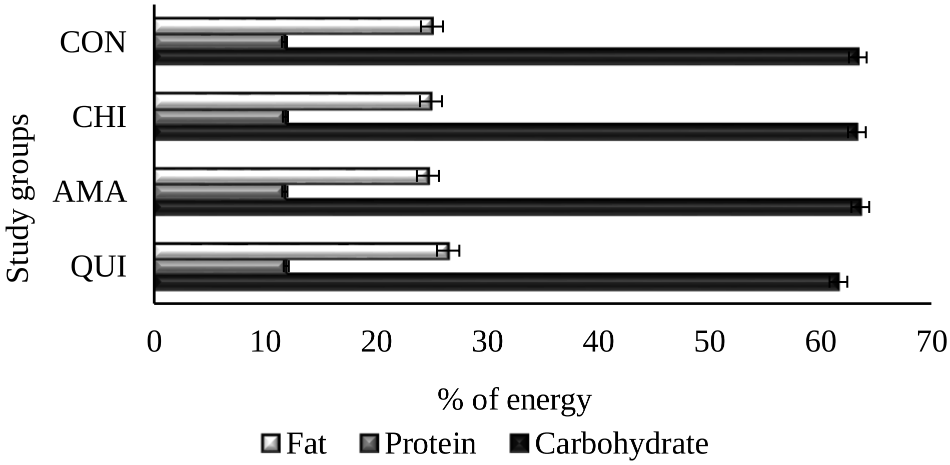

Figure 4. Mean percentage of energy coming from fat, protein and carbohydrate (± SEM) during the *ad libitum* lunch, n = 35.

CON, 200 g plain yogurt with no pseudo-cereal; CHI, 115 g yogurt containing 14 g chia seed; AMA, 130 g yogurt containing 14 g amaranth; QUI, 125 g yogurt containing 14 g quinoa. ANOVA did not indicate a significant difference between CON, CHI, AMA and QUI (P> 0.05).

Discussion and Conclusion

The present study examined whether or not three different test meals prepared with chia, amaranth, or quinoa seeds would exert a significant effect on short-term satiety and food intake. The primary results of this study demonstrated that consuming these test meals as a mid-morning snack did not alter the energy intake during *ad libitum* lunch. In addition, they exerted a similar effect on most of the appetite and satiety-related parameters in the current study. Chia, amaranth, and quinoa seeds, as pseudo-cereals, have attracted considerable attention recently, yet little research has been conducted on their possible effects against overeating. To our knowledge, this is the first study comparing the influence of these pseudo-cereals on short time satiety and subsequent energy intake in normal weight subjects. Overall, the results suggest a slightly modest benefit of consuming pseudo-cereals on appetite control, but this requires further investigation, possibly with different doses and varied test meals.

In the current study, the energy content of the test meals was equalized by adjusting the yogurt quantity in order to prevent any difference due to energy disparity. This resulted in test meals with similar energy and protein content but different serving sizes. Although protein content has a satiating effect, the protein contents of the snacks were similar (Table 1). Therefore, the protein content of the snacks was not considered to be influential. Elucidating the mechanistic factors that generate subjective senses of satiation is important because these senses may contribute to predicting food choice and energy intake (McCrickerd and Forde,

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2016). Previously, it was shown that the volume of food consumed was an important determinant of satiety, independent of its energy content (Rolls et al., 1998). Although the test meals prepared with chia, amaranth, or quinoa had lower volumes than the control meal, this did not affect the resulting area under curve data of VAS scores related to hunger, satiety, prospective food consumption, and amount of food that could be consumed in this study. This finding is consistent with other reports indicating that food volume may not have any or may have only a limited effect on satiety (Vermote et al., 2018; Żurakowski et al., 2006). It is also possible that while this volume difference did not affect individuals' feeling of more fullness with chia, amaranth, or quinoa; it may have affected their energy intake during *ad libitum* lunch. We note that this issue is further complicated by the other properties of test meals.

Research investigating the influence of fats on satiety response has tended to concentrate on fat quality. To date, a few studies have indicated that subjective appetite ratings were not influenced by varied fatty acid compositions (Stevenson et al., 2015; Casas-Agustench et al., 2009) whilst one study reported a greater subjective feeling of fullness after consuming the saturated fatty acid-rich meal in comparison to monounsaturated and polyunsaturated fatty acid-rich meals (Kozimor et al., 2013). In the current study, adding 14 g of chia, amaranth, or quinoa to plain yogurt generated test meals with higher polyunsaturated fatty acids clearly but also altered the amount of total fat. Although the test meals AMA and QUI were composed of lower amounts of fat than the control meal, they still exerted similar VAS scores. However, it should be noted that the VAS score of satiety did not exhibit a significant effect but a trend towards significance, which showed that AMA and QUI consumption resulted in higher satiety scores. According to a relatively long-term study, consumption of high polyunsaturated fatty acid-rich diet for 5 days resulted in lower hunger ratings (Polley et al., 2019). In the future, it would be interesting to incorporate this evidence to examine the impact of polyunsaturated fatty acids originating from pseudo-cereals like chia, amaranth, or quinoa on appetite in both short-term and long-term studies.

It is well-established that dietary fibre can increase satiety through multiple mechanisms such as slowing gastric emptying, delaying digestion and regulating appetite (Salleh et al., 2019). In the current study, one of the most important properties of the test meals prepared with chia, amaranth, and quinoa was their fibre content. Although amounts were different among the test meals, fibre content was the main common ingredient in comparison to the control meal. Therefore, ingestion of test meals with these seeds may have induced a sense of fullness to some degree, but this effect may have disappeared until the following meal. Interestingly,

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despite having the highest amount of fibre content, the test meal prepared with chia seed did not trigger either a superior response in satiety or a reduced energy intake. Similarly, a systematic review found that fibre type or fibre dose were not associated with satiety response or food intake during the acute term (Clark and Slavin, 2013). Indeed, consumption of 7 g or 14 g chia seed also showed alike outcomes on acute term satiety in previous research (Ayaz et al., 2017). Since the European Union approved unprocessed chia seed as a novel food ingredient to be sold as pre-packed chia seed with a recommended daily intake of up to 15 g (European Commission, 2013), test meals were prepared with 14 g of chia, amaranth, or quinoa to match the serving size. Nevertheless, future studies will continue to focus on examining current outcomes with higher doses of amaranth or quinoa.

As all the test meals prepared with pseudo cereals exhibited common outcomes in the present study, this situation can raise the question of participants' awareness of consuming food that is rather experimental. In order to avoid this issue, we used white versions of chia, amaranth, and quinoa. By this way, the test meals looked similar although the final appearance of the test meals still showed a slight difference. In addition, test meal liking was not assessed in the current study. Considerably, liking or disliking food can interact with appetite and satiation, and the amount of food eaten may vary according to these parameters (De Graaf et al., 1999). Despite this, it was estimated that the seeds did not change the taste of yogurt distinctly. Moreover, none of the participants reported an unpleasantness regarding the taste or appearance of test meals in this study. Nonetheless, the pleasantness of the test meals and the interaction between satiety and liking should be evaluated in future studies.

It is previously investigated the effect of test meals containing yogurt and chia seed compared to yogurt, alone (Ayaz et al., 2017). In that study, higher satiety and fullness ratings were found after consuming yogurt with 7 g or 14 g of chia seeds. Furthermore, participants had a lower energy intake at the *ad libitum* lunch served two hours after the test meal. In that study, the macronutrient composition of the test meals was closely matched and reflected the natural content of chia seeds. This could be the main reason for the different outcomes of the two studies but the findings of this study should be interpreted while considering the following limitations. The participants were all females to obtain a homogenous group and were constrained to the laboratory which reduces the generalizability of the results. A further limitation is the inclusion of normal weight individuals. Since nutritional behaviours can be altered in subjects who are overweight or obese due to motivational drives related to food intake (Provencher and Jacob, 2016), the current hypothesis should be tested in different clinical

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groups to clarify these outcomes.

In conclusion, iso-caloric test meals based on yogurt and chia, quinoa or amaranth, were found to have similar effects on *ad libitum* energy intake and subjective appetite sensations among healthy women between the ages of 18 and 30. Moreover, the AUC data of VAS scores indicated a lower desire for sugary snacks with test meal QUI in comparison to CON and CHI. As several biochemical and physical mechanisms underlie these outcomes, future studies will continue to examine the related indicators.

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Declarations of Interest

The authors declare no conflict of interest.

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