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HEALTH SCIENCES

High-saturated fatty meals with orange juice intake have subjective appetite sensations suppressed: Acute, postprandial study

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Abstract: Objective: To elucidate the acute effect of different high-fat meals accompanied by water or orange juice on subjective appetite sensations. Methods: This acute, postprandial study included 39 healthy women (aged 20 to 40 years): 22 participants received a high-monounsaturated fat meal (MUFA) (≈1000 kcal, 56.3% Energy from MUFA) and 17 participants received a high-saturated fat meal (SFA) (≈1000 kcal, 37.6% Energy from SFA). Both interventions were accompanied by 500 ml of water or orange juice. The subjective appetite sensations were evaluated before (fasting) and 1, 2, 3, 4, and 5 hours after the meal intake using the visual analog scale. Results: The subjective area under curve (AUC) appetite sensations and AUC appetite scores were equal after the consumption of high-fat meals from SFA and MUFA. Moreover, the consumption of a high-SFA meal raises the prospective desire to eat something fatty. In addition, the high-SFA meal consumption reduces subjective AUC appetite sensations and AUC appetite scores along the time, compared to a high-MUFA meal, when orange juice consumption followed those meals. Conclusion: Our results demonstrate that high-MUFA meal consumption decreased the desire to intake something fatty, and the high-SFA meal, when followed by orange juice intake, has postprandial appetite sensations suppressed.

Key words: appetite, high-fat meals, lipidis, orange juice, visual analog scale.

INTRODUCTION

The positive energy balance occurs when energy intake exceeds energy expenditure (Loh et al. 2015, Romieu et al. 2017). Over the long term, sustained by positive energy balance leads to obesity and represents a risk factor for other chronic non-communicable diseases (Richard 2015, Bray et al. 2017). In this context, the consumption of energy-dense foods, especially high-fat meals, are associated with positive energy balance and weight gain by influencing satiation and satiety (Blundell & Macdiarmid 1997, Astrup 2005).

However, it is known that not all fats have the same effect on appetite. Studies have shown that monounsaturated fat acid (MUFA) consumption exhibit higher or similar effects on appetite compared to saturated fatty acid (SFA), evaluated by subjective sensations of appetite – Visual Analog Scale (VAS) – a usual, useful and cheap tool to measure the appetite (Flint et al. 2000, 2003). Besides, MUFA intake has enhanced satiety and suppress hunger, via GLP-1 and ghrelin modulation, when compared with SFA consumption (Thomsen et al. 1999, Beysen et al. 2002, Stevenson et al. 2015). In general, the satiety is negatively associated with the degree of saturation, but studies have been inconsistent

(Alfenas & Mates 2003, Strik et al. 2010, Kozimor et al. 2013, Stevenson et al. 2015).

In turn, observational and interventional studies have indicated that the consumption of orange juice does not negatively affect body weight, body composition or other anthropometric measures in adults (Rangel-Huerta et al. 2015, Rampersaud & Valim 2017). To our knowledge, there are no studies evaluating the effect of high-fat meals followed by beverages, especially orange juice, on appetite. The orange juice consumption, despite its sugar content, has shown favorable effects on health, such as, decreased uric acid levels (Büsing et al. 2019) and improves lipid and insulin sensitivity when followed by reduced caloric diet in obese individuals (Ribeiro et al. 2017). Furthermore, we have recently demonstrated that the orange juice intake was able to mitigate the subclinical increase of postprandial inflammation, induced by SFA high-fat meal consumption (Rocha et al. 2017).

Overall, this study aimed to elucidate the acute effect of orange juice on subjective appetite sensations in different high-fat meals.

MATERIALS AND METHODS

Subjects

The local ethical committee of the Universidade Federal de Viçosa (Of. Ref. No. 184/2011 and 542,585/2014) (CAAE: 26469014.0.0000.5153) approved the study, according to the resolution CSN 466/2012. All participants gave written informed consent before enrolment. This work is registered at the Registro Brasileiro de Ensaio Clínicos (ReBec: trials RBR-2h3wjn and RBR-66jx7j).

Participants were recruited through internet, flyers, and advertisements within the local community. Thirty-nine apparently healthy women aged 18 to 40 years were eligible to participate. Exclusion criteria were pregnant, breastfeeding or menopausal women; subjects having inflammatory, hormonal, heart, respiratory, kidney or liver disease, as well as gastrointestinal disease that may alter digestion and nutrient absorption; use of medication that affects metabolism, and body composition; athlete; smoker; subjects having allergy or aversion to food components present in the test meals; under nutritional treatment for weight loss and have maintained unstable weight at last three months.

Study design

The present study comprised two parallel trials (Figure 1). The first study was designed as an acute, randomized, crossover trial with a SFA (37.6% E) high-fat meal test. The second study had the same design but with a MUFA (56.3% E) high-fat meal test. In both studies, the research carrying out the statistical analysis was blinded to the interventions, by labeling the groups with nonidentifying terms, until the entire analysis has been completed.

The test meals were followed randomly by water (500 mL) or orange juice (500 mL) consumption, and consumed within 30 min, after an overnight fast (12 h). Research Randomizer (https://www.random.org/) was adopted to determine the order in which each subject consumed the test meals. The subjects stayed in the laboratory and kept physical activity to a minimum (sitting regime), for the following five postprandial hours, when blood samples and appetite scores were assessed. At the end of each experimental session, all subjects received lunch. To minimize possible interferences two days before the experiment assessment subjects were advised to follow a specified food plan adapted according to individual daily energy requirements. Additionally, all subjects were

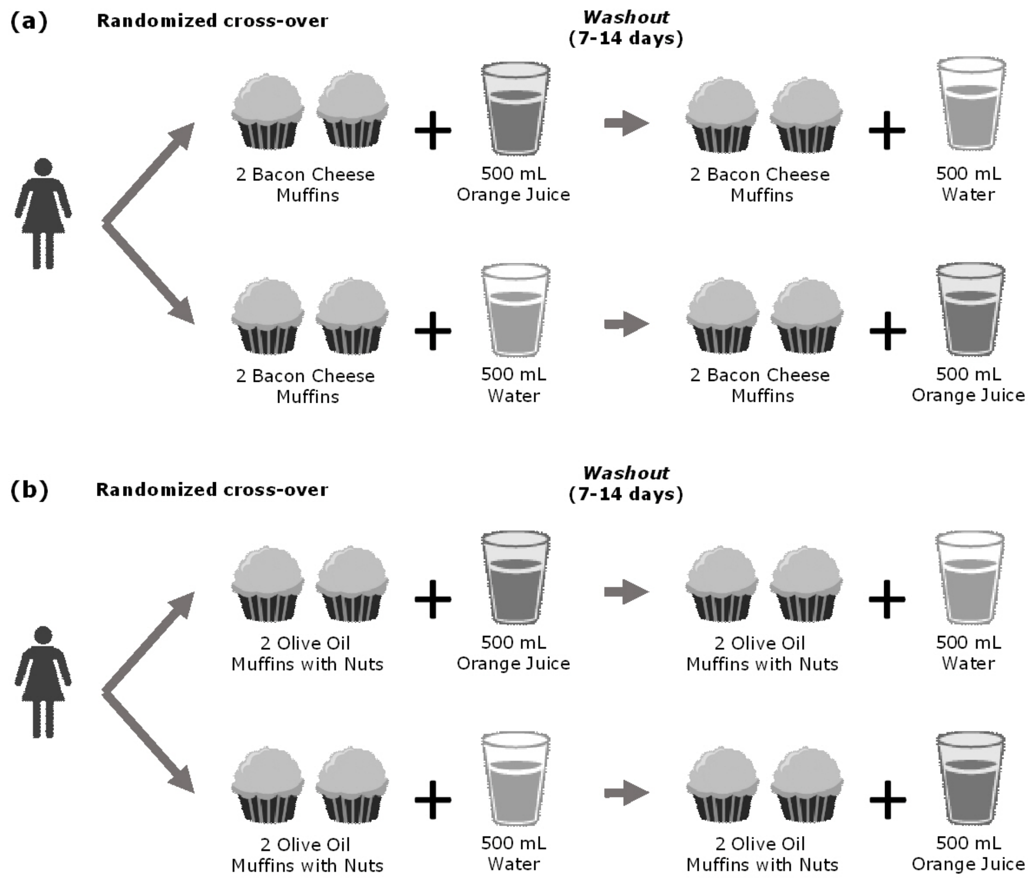

Figure 1. Schematic of study design. (a) Saturated Fat Acid high-fat meal group intervention: ≈1,000 kcal (14.6 Energy (E) % from carbohydrate, 6.2 E % from protein, 79.2 E % from fat – 37.6 E % from SFA); (b) Monounsaturated Fat Acid high-fat meal group intervention: ≈ 1,000 kcal (17.6 E% from carbohydrate, 4.2 E% from protein, 78.2 E% from fat – 56.3 E% from MUFA); Orange Juice: ≈ 230 kcal.

instructed to maintain their regular physical activity and lifestyle throughout the study.

Intervention

The SFA high-fat meal had approximately 1,000 kcal, which was 14.6% energy intake (E) was from carbohydrate, 6.2% E was from protein, 79.2% E was from total fat and 37.6% E was from SFA. The MUFA high-fat meal had also approximately 1,000 kcal, which 17.6% E was from carbohydrate, 4.2% E was from protein, 78.2% E was from total fat and 56.3% E was from MUFA. Each high-fat meal was accompanied with 500 mL of water or 500 mL of orange juice. The orange juice used in the study was industrialized, coming from local commerce and provided approximately 230 kcal, with 57 g of carbohydrates and 88 mg of vitamin C (Figure 1).

Anthropometric and body composition data

Anthropometric (height, body weight, height, and waist circumference) and body composition (body fat) measurements were assessed before each test meal to evaluate any variation. The height (m) was measured using a stadiometer (Seca 206 model, Hamburg, Germany). Body weight (kg) and body fat (%) were obtained by tetrapolar bioimpedance (InBody Composition Analyzer, model Y230), in accordance with the manufacturer's protocol. The body mass index

(BMI) was calculated as the ratio between body weight (kg) and squared height (m). A flexible and inelastic measure tape, subdivided in millimeters was used to measure the waist circumference (midpoint between the last rib and the iliac crest).

Subjective appetite sensations

Subjective feelings of hunger, fullness and prospective desire to eat something now, sweet, salty and fatty were assessed by 100 mm visual analog scales (VAS). The VAS was anchored expressing on each end, words describing extremes (example: *I am not hungry at all/ I have never been more hungry*) (Flint et al. 2000). Subjects were instructed on how to complete the VAS by trained research assistants, in fasting state (0 minutes), and subsequently at 1, 2, 3, 4 and 5 hours after the test meal consumption. During this time, subjects were not allowed to read, watch any TV program or talk about food, appetite, or any subject related. In addition, appetite score was calculated as previously described (Joanna & Craig 2013). Lower appetite score is associated with greater suppression of appetite, and the higher appetite score is associated with greater appetite.

Statistical analysis

Shapiro-Wilk's normality test was used to check for the normal distribution of data. Data were expressed as mean (SEM). The area under the curve (AUC) of subjective appetite sensations scale and appetite score, were calculated from 0 h (fasting) to 5 h, using the trapezoid rule in GraphPad Prism v. 6.01 (GraphPad, La Jolla, CA, USA). Student *t*-test was used to compare the differences in AUC of subjective appetite sensations scale and appetite score between the high-fat meals followed by water or orange juice consumption. Differences in subjective appetite sensations scale and appetite scores, between the high-fat meals followed by water or orange juice consumption, were analyzed by two-way mixed ANOVA, followed by the post hoc Bonferroni's multiple comparisons test, to analyze the statistical effects of the time alone and the interaction of treatment and time (meal x time); and Greenhouse-Geisser correction was applied wherever the sphericity assumption was not met. All analyses were performed using SPSS 23 for Windows (SPSS, Inc., Chicago, IL, USA). The differences were considered statistically significant at $\alpha < 0.05$ for all data analyses. Additionally, sample size calculations indicated that 15 subjects would permit a reasonable and realistic effect size of 10% in studies of appetite using VAS (Flint et al. 2000), with a statistic power of 90% ($\alpha = 0.05$; $\sigma = 12$ mm) (Lesdéma et al. 2016).

RESULTS

Thirty-nine subjects participated in this trial aged 18-39 years (26.3 ± 0.9 years) with a BMI between 18.5-33.0 kg/m² (23.5 ± 0.5 kg/m²), which 17 subjects participated in the SFA high-fat group and 22 subjects in the MUFA high-fat group (Table I).

The postprandial subjective AUC appetite sensations (hunger, fullness, desire to eat something now, desire to eat something sweet and desire to eat something salty) and AUC appetite scores were equal after the consumption of high-fat meals from SFA and MUFA ($p > 0.05$). However, the consumption of a high-SFA meal raises the prospective desire to eat something fatty, compared to a high-MUFA meal ($p < 0.05$) (Table II).

Furthermore, the high-SFA meal consumption reduced subjective AUC appetite sensations (hunger, desire to eat something, desire to eat something salty and fullness) and

Table I. **Summary of characteristics of study participants.**

Characteristics	Test Meals		P-values*
	SFA high-fat (n=17)	MUFA high-fat (n=22)	
Age (years)	25.4 (1.3)	27.0 (1.2)	0.384
Weight (kg)	61.1 (2.0)	60.4 (1.8)	0.802
Height (m)	1.6 (0.0)	1.6 (0.0)	0.862
BMI (kg/m²)	23.7 (0.7)	23.4 (0.8)	0.228
Body fat (%)	28.2 (1.4)	30.1 (1.6)	0.395
SBP (mmHg)	104 (2)	106 (2)	0.482
DBP (mmHg)	65 (2)	66 (2)	0.667

Data are presented AS mean (SEM). BMI: body mass index; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids. *p values from Student *t*-test.

AUC appetite scores, compared to a high-MUFA meal, when orange juice consumption followed those meals (p < 0.05) (Table II).

When we evaluated the interaction on of meal x time of subjects who consumed high-fat meals followed by orange juice, high-SFA meals showed lower appetite score, lower hunger and lower desire to eat something salty at 1h, 2h and 3h postprandial hours, in comparison to the high-MUFA meal (p < 0.05). Also, the high-SFA meal had a lower desire to eat something (from 1h up to 5h postprandial hours) and higher fullness (at 4h), compared to the high-MUFA meal (p < 0.05) (Figure 2).

DISCUSSION

In the present study, we verified that high-fat meals from SFA and MUFA modulate differently subjective appetite sensations. The high-MUFA meal consumption reduced the prospective desire to consume something fatty, in comparison to the high-SFA meal.

Studies are controversial regarding the effect of fats on appetite. Some previous studies had observed higher subjective appetite sensations after high-MUFA meals when compared to high-SFA meals (Lawton et al. 2000, Kozimor et al. 2013). Besides, a current review showed that MUFA consumption increases the satiety hormone glucagon-like peptide-1 (GLP-1), and suppress the appetite hormone ghrelin, in comparison to SFA consumption (Kaviani & Cooper 2017), what could explain at least in part our results. However, other studies have shown that high-MUFA and high-SFA meals present similar postprandial subjective appetite sensations (Alfenas & Mattes 2013, Flint et al. 2003, Strik et al. 2010, Kaviani & Cooper 2017).

The potential effect of orange juice on the modulation of subjective appetite sensations of high-fat meals, to our knowledge, was not evaluated. Therefore, for the first time, we showed that orange juice suppresses postprandial subjective appetite sensations when followed by a high-SFA meal, in comparison to the high-MUFA meal.

Regarding the isolated effected of juice on appetite, Hollis et al (2009) observed that the chronic consumption of the 480 ml from Concord grape juice by overweight subjects had no effects on subjective appetite sensations. However, the group that received a substitute

Table II. Area under curve of subjective appetite sensations after high-fats meals followed by water and orange juice up to 5 hours.

AUC (cm·h)	High-SFA meal + W	High-MUFA meal + W	*P-values* *	High-SFA meal + OJ	High-MUFA meal + OJ	*P-values**
	(n=17)	(n=22)		(n=17)	(n=22)	
Appetite score	16.6 (1.8)	16.8 (1.2)	0.937	13.7 (1.4)	18.5 (1.5)	**0.032**
Hunger	14.2 (2.0)	14.2 (1.4)	0.985	11.2 (1.4)	16.4 (1.8)	**0.040**
Fullness	28.9 (2.5)	28.5 (1.4)	0.876	33.2 (2.0)	26.3 (1.9)	**0.018**
Desire to eat something now	15.7 (2.2)	18.0 (1.3)	0.356	12.5 (1.6)	19.1 (1.7)	**0.010**
Desire to eat something sweet	15.4 (2.3)	18.5 (2.7)	0.420	14.9 (2.4)	20.2 (2.6)	0.152
Desire to eat something salty	12.9 (1.7)	16.1 (1.9)	0.220	12.1 (1.5)	17.6 (1.9)	**0.037**
Desire to eat something fatty	8.2 (1.9)	3.4 (1.0)	**0.039**	5.2 (0.9)	3.5 (0.7)	0.141

Data are presented as mean value (SEM). SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; W = Water; OJ = Orange juice. **p-values* from Student *t*-test.

(polyphenol-free) grape-flavored drink reduced the fullness ratings at 1, 6, and 12 weeks of intervention.

Another study showed that the orange juice consumption followed by a regular meal reduced the energy balance compared to orange juice consumption between meals (≥ two hours after the meal), in healthy young adults (Büsing et al. 2019). Besides, previous studies have demonstrated improved insulin, HOMA-IR, total cholesterol, LDL-C, and hs-CRP concentrations by subjects with calorie- restriction and orange juice (Ribeiro et al. 2017). Despite that, fructose present in fruit juices, as well as in orange juice, has been associated with metabolic effects implicated in the development of the metabolic syndrome, such as insulin resistance and dyslipidemia (Dekker et al. 2010). However, there is no evidence to support the deleterious effect of moderate fructose consumption (≤ 50 g/day) on health (Rizkalla 2010). Moreover, despite the fructose content, the fruit is a healthy matrix, and the orange juice is rich in micronutrients (vitamins, minerals, and bioactive compounds), with potential health effects, including anti-inflammatory properties (Coelho et al. 2013, Rocha et al. 2017). Besides the vascular protective effects of flavonoids, like hesperidin presented in orange juice (Morand et al. 2011), Shukor et al. (2016) observed that *in vitro* the flavonoids stimulate cholecystokinin peptide secretion, which is a hormone related to appetite suppression from the enteroendocrine cells. Moreover, Rondanelli et al. (2013) verified that acute administration of the supplementation of the various flavonoids after eight-week receiving this supplementation increased the subjective satiety compared with a placebo supplement group in overweight adults.

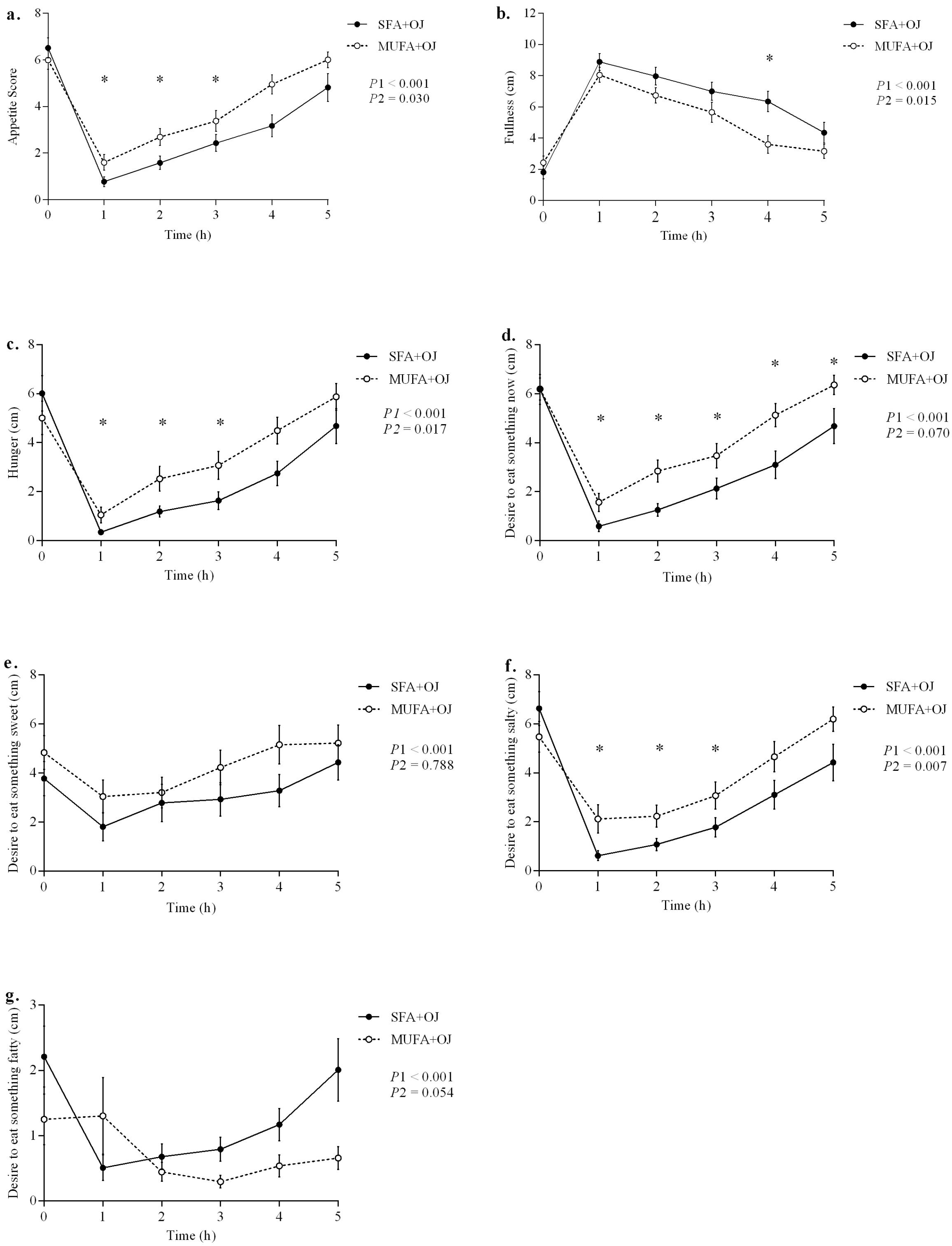

Figure 2. Effect of high-SFA and high-MUFA meals followed by orange juice on a) Appetite Score, b) Fullness (cm), c) Hunger (cm), d) Desire to eat something now (cm), e) Desire to eat something sweet (cm), f) Desire to eat something salty (cm), and g) Desire to eat something fatty (cm) from baseline up to 5 post-prandial hours. SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; OJ: orange juice. Data are presented as mean value ± SEM. P1 = *p*-value of the effect of time based on two-way mixed ANOVA; P2 = *p*-value of the interaction of time vs. diet based on two-way mixed ANOVA; * *p*-values ($p < 0.05$) from Student *t*-test.

Although orange juice has health and satiety benefits, is unclear the reason for the different appetite modulation of orange juice when accompanied by SFA and MUFA.

Besides, studies that have evaluated the intake of fruit and fruit juices in appetite show greater satiating effects when fruits are consumed whole (Haber et al. 1977, FloodObbagy & Rolls 2009). However, a study showed that incorporating consumption of a low energy-dense dietary preload such as grapefruit, grapefruit juice or water, in a restricted caloric diet is a highly effective weight loss strategy. Moreover, the form of the preload did not have differential effects on energy balance, weight loss or body composition (Silver et al. 2011).

Regarding the BMI influence on appetite, studies show that overweight subjects can develop leptin resistance due to the increase the fat accumulation (Chadge & Khaire 2019). The leptin is an adipokine and is related the hunger suppression. Given this, overweight subjects can present hungrier (Klok et al. 2007). However, in our study, a small number of overweight subjects were included together with normal-weight subjects.

To our knowledge, this is the first study that evaluated the acute effect of a high-fat meal accompanied by orange juice on subjective appetite sensations. Besides, our study has a statistic power of 90% and we used a validated tool to measure the subjective appetite sensations.

Finally, our study had some limitations. We included in our analysis subjects with different BMI ranges. However, the number of overweight subjects is low, and we believe not influence the results. In addition, we did not assess food intake after the intervention throughout the day neither evaluate hormones that would help us explain our results. However, the investigation of experimental meals simulating the free-living condition is essential for understanding how the foods influence the appetite in front of the increase from the obesity epidemic.

CONCLUSION

In the present study, we showed that high-fat meals from SFA and MUFA modulate subjective appetite sensations differently. High-MUFA meals reduced the desire to consume something fatty, compared to the high-SFA meal. In addition, a high-SFA meal when followed by orange juice intake, have postprandial appetite sensations suppressed in comparison to the high-MUFA meal. More studies are needed to evaluate the potential related-mechanisms in appetite control by fats and orange juice.

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