Appetite 120 (2018) 92–99

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Acute effects of monosodium glutamate addition to whey protein on appetite, food intake, blood glucose, insulin and gut hormones in healthy young men

G. Harvey Anderson*, Hrvoje Fabek, Rajadurai Akilen, Diptendu Chatterjee, Ruslan Kubant

Department of Nutritional Sciences, Faculty of Medicine, University of Toronto, 150 College Street, Toronto, M5S 3E2, Canada

ARTICLE INFO

Article history:
Received 5 January 2017
Received in revised form
7 June 2017
Accepted 19 August 2017
Available online 24 August 2017

Keywords:
Monosodium glutamate
Protein
Appetite
Food intake
Metabolic control

ABSTRACT

Aims: This study investigated the effects of adding monosodium glutamate (MSG) to carrot soup with or without whey protein, on subjective appetite, food intake (FI) and satiety hormones in healthy young men.

Methods: Two experiments were conducted using a repeated-measures, within-subject, crossover design. In exp-1 healthy young men (n = 28) consumed water alone (500 mL), or carrot soup (500 g) with or without MSG (5 g, 1% w/w) or whey protein enriched (36 g) carrot soup with or without MSG (5 g, 1% w/w). Subjective appetite was measured post-treatment and FI measured at a meal at 120 min. In exp-2 (n = 15) the same treatments except for water were used. In addition to subjective appetite and FI, blood glucose, insulin, glucose like peptide 1 (GLP-1), C-peptide and ghrelin were measured.

Results: Adding MSG to carrot soup or whey protein enriched carrot soup did not affect FI. However, in exp-1 the addition of both MSG and protein increased fullness, and when MSG was added to carrot soup reduced desire to eat. In exp-2, average post-treatment appetite (5–120 min) was lower after carrot soup with MSG and protein than all other treatments ($P < 0.05$). In exp-2, carrot soup with MSG and protein, but not with protein alone, increased post-treatment insulin and C-peptide, and lowered blood glucose in comparison to carrot soup with no additions ($P < 0.05$).

Conclusion: Adding MSG alone, or in combination with whey protein, to carrot soups did not affect FI. However, MSG increased fullness and reduced desire to eat, as well as subjective appetite, and when added to protein decreased blood glucose and increased insulin and C-peptide, offering some support for the hypothesis that MSG in the gut signals protein consumption.

1. Introduction

Glutamic acid is the most abundant amino acid in both free and bound-form in commonly consumed proteins (Brosnan & Brosnan, 2013). Monosodium L-glutamate (MSG) elicits a unique taste, termed umami, and is widely used to enhance the palatability and acceptability of foods (Prescott, 2004). Recently, a study demonstrated that low concentrations of MSG (0.7%) can reduce salt added to foods such as soups by as much as 32.5%, without impacting the pleasantness, saltiness or taste intensity (Jinap et al., 2016). Experimental studies in animals have shown that the free form of glutamate activates tastant receptors found in the mouth and intestine (Depoortere, 2014; Tsurugizawa et al., 2009; Uneyama, Niijima, San Gabriel, & Torii, 2006). Recently, support for activation of these receptors in the human by tastants free of calories has been reported (Van-Avesaat et al., 2015). A combination of tastants, including quinine, rebaudioside A and MSG given by intraduodenal infusion reduced food intake (FI) as well as desire to eat and hunger scores but MSG alone (umami) only reduced desire to eat and hunger and not FI. Because these effects were not associated with increases in GLP-1, CCK or PYY plasma concentrations, it has been suggested that they may instead be related to vagal neuroendocrine signaling (Cunnings, 2015). Others have reported that addition of MSG at concentrations of 0.6%–1%, an amount usually added to foods, increases satiety when added to soup (Masic & Yeomans, 2014a; Miyaki, Imada, Shuzhen-Hao, & Kimura, 2016) or chicken broth (Carter, Monsivais, Perrigue, & Drewnowski, 2011) but effects

* Corresponding author. Department of Nutritional Sciences, Faculty of Medicine, University of Toronto, Toronto, ON, M5S3E2, Canada.
E-mail address: havey.anderson@utoronto.ca (G.H. Anderson).

http://dx.doi.org/10.1016/j.appet.2017.08.020
0195-6663/

Abbrevations

CS	Carrot Soup
CON	Control
PRO	Protein

on FI remain uncertain. MSG additions to a high-protein meal had no effect on appetite or FI (Luscombe-Marsh, Smeets, & Westerterp-Plantenga, 2009), but increased compensation for energy content of protein-rich soup at the next meal (Masic & Yeomans, 2013). Protein compared with carbohydrate suppresses appetite and FI more when compared in isocaloric amounts (Anderson & Moore, 2004; Bertenshaw, Lluch, & Yeomans, 2008; Martens, Lemmens, & Westerterp-Plantenga, 2013) and may in part be due to umami tastants in protein (Cunnings, 2015). However, protein ingestion also markedly increases hormone concentrations associated with both hunger and satiety (Anderson & Moore, 2004; Jahan-mihan, Luhovyy, El-Khoury, & Anderson, 2011; Panahi et al., 2014).

This study tested the hypothesis that MSG added to protein enhances its post-ingestion suppression of satiety and FI in association with enhanced appetite related hormone concentrations in the blood. MSG was added to carrot soup with or without whey protein and subjective appetite, FI, glycemia and FI regulatory hormones were measured in healthy young men.

2. Materials and methods

2.1. Subjects

Fifty-two healthy young men, age 20–30 years with a body mass index (BMI) of 20.0–24.9 kg/m^2 were recruited for this study. Those excluded were breakfast skippers, smokers, dieters or on medications for chronic disorders. Individuals with restrained eating habits identified by scoring ≥11 on the eating habits questionnaire (Panahi et al., 2014; Smith, Mollard, Luhovyy, & Anderson, 2012) were also excluded. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the University of Toronto Health Sciences Review Committee. Written informed consent was obtained from all subjects.

2.2. Experimental design

Two experiments were conducted in this study. Both experiments followed a within subject, randomized, repeated-measures design in which subjects received one treatment per week, one week apart. In exp-1, subjective appetite was measured for 120 min post-treatment and FI was measured from a pizza meal at 120 min. In exp-2, the same outcomes were measured along with selected physiological measures of appetite regulation known to respond to protein and amino acid ingestion. These were the primary outcome measures of exp-2, which included blood glucose, plasma insulin, GLP-1 and active ghrelin (Akhavan et al., 2014; Jahan-mihan et al., 2011; Panahi et al., 2014). C-peptide was also measured as it is marker of early stage insulin synthesis and secretion. Because glutamate receptors have been found on pancreatic cells, it has been suggested that glutamate may stimulate insulin secretion (Molnár, Váradi, McIlhinney, & Ashcroft, 1995; Weaver, Gundersen, & Verdoorn, 1998). Another study showed that although MSG ingestion, averaging 11.2 g, by men prior to exercise did not raise plasma C-peptide it increased plasma insulin concentrations leaving uncertain its effect on insulin synthesis (Mourtzakis & Graham, 2002).

2.3. Treatments

In exp-1 (n = 28), five isovolumetric (500 g) treatments were used: (1) water (control), (2) carrot soup, (3) carrot soup + 5 g MSG (1% w/w), (4) carrot soup + 36 g net protein and (5) carrot soup + 36 g net protein + 5 g MSG (1% w/w). In exp-2 (n = 15), the same treatments were used with the exception of water. Carrot soup alone was the control for the effect of MSG and protein additions on regulatory hormones, the primary dependent measures. The protein soups contained 39.5 g of whey protein isolate (91% protein; BiPro, Davisco Foods International Inc.) to yield the 36 g net protein, which contains 6.48 g bound glutamate. Five grams (1% w/w) MSG providing 4.1 g glutamate (Ajinomoto, Japan) was added to soup with and without protein. Protein and MSG were added in amounts to replace 39.5 g and 5 g, respectively, of carrot soup to achieve a final soup weight of 500 g. Recipe and preparation of the carrot soup (base soup) was as previously reported by (Masic & Yeomans, 2014a). All treatments were followed with 100 mL of water to cleanse the palate. The order of treatments was determined via random number generator for each subject. The nutritional composition of the treatments is given in Table 1. Proximate analysis of carrot soup was conducted by Maxxam Analytics (Mississauga, Ontario, Canada).

2.4. Protocol

Participants attended the Department of Nutritional Sciences laboratory following a 12 h overnight fast, except for water which was permitted until one hour before each session. To minimize within subject variability, each participant was scheduled to arrive at the same time and on the same day of the week for each treatment and maintain the same dietary and exercise patterns the evening before each test. Each participant arrived at the laboratory between 8:00am and 10:00am during weekdays. On arrival, before the beginning of each test, participants completed stress factor and sleeping habits questionnaires (Mollard, Luhovyy, Smith, & Anderson, 2014) to assure compliance with FI and physical activity instructions and Visual Analogue Scales (VAS) assessing their "physical comfort", "feelings of fatigue" and "motivation to eat". VAS for subjective appetite were administered at baseline (0 min) and at 5, 15, 30, 45, 60, 75, 90, 105 and 120 min in both experiments. Average subjective appetite was calculated as the average of the

Table 1
Nutritional composition of carrot soup and protein enriched carrot soup with (+) and without (−) Monosodium Glutamate (MSG).

Nutrient composition	Carrot soup[a]		Protein enriched carrot soup	
	MSG (−)	MSG (+)	MSG (−)	MSG (+)
Fat (g)	10.0	9.9	9.2	9.2
Carbohydrate (g)	43.5	43.1	40.1	40.02
Protein (g)	4.25	8.21	39.9	43.9
Calories (kcal)	281	293.2	401.8	417.6
Free glutamate (g)	0.18 ± 0.14	4.43 ± 0.92	0.18 ± 0.12	4.51 ± 2.26
Total glutamate (g)	1.16	5.41	7.46	11.97

[a] 100 g carrot soup (base soup as prepared) contains; 2 g fat, 8.7 g carbohydrate, 0.85 g protein and 56 kcal. Water was used as a control in experiment 1. Treatment total glutamate is the sum of free glutamate from soup and MSG and protein glutamate (18%) in whey and (23%) carrot protein. Both protein and MSG were added by replacing 39.5 g and 5 g, respectively, of carrot soup to achieve a final soup weight of 500 g.