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Does acute or habitual protein deprivation influence liking for monosodium glutamate?

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HIGHLIGHTS

• Protein is well regulated in the diet and can be detected by the taste system.
• Habitual protein use or acute protein deprivation may alter liking for protein-predictive tastes.
• Acute protein deprivation increases liking for umami, salty and sweet tastes.
• High protein users like high MSG doses most when in acute protein deficit.

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ABSTRACT

The umami flavour generated by monosodium glutamate (MSG) has been proposed as the marker for the presence of protein in foods. As protein is the most closely regulated macronutrient in the diet, the present study addressed whether acute protein deprivation, habitual protein intake or a combination of the two influenced liking for the taste of MSG. 24 low-restraint male participants (mean age: 22; BMI: 23) consumed either their habitual breakfast (baseline), a low protein breakfast (breakfast meal with low protein milk and milkshake) or a high protein breakfast (breakfast meal with high protein milk and milkshake) on three different days, and then evaluated the acceptability of umami (MSG), salty (NaCl) or sweet (Acesulphame K) tastes at low or high concentrations in a soup context at lunchtime. Participants also completed a habitual protein intake questionnaire (39-item protein Food Frequency Questionnaire). Liking for all tastes was higher on the low than on the high protein day, and NaCl and Acesulphame K were liked less on both protein manipulation days when compared to the no added flavour control. Habitual protein intake was not related to liking for MSG stimuli alone but habitual high protein consumers rated a high concentration of MSG as more pleasant than any other taste when in protein deficit. Overall, these findings suggest that liking for high MSG concentrations may be moderated by nutritional need in high protein consumers.

1. Introduction

Protein is an essential macronutrient predominantly consumed in savoury tasting foods [1–3]. It is the most tightly regulated macronutrient in the diet and has been related to the overconsumption of high carbohydrate and high fat containing foods if protein needs have not been met [4]. Animals and humans are able to detect the quality and quantity of protein consumed during a meal and use this information to monitor protein intake [5]. This suggests that the taste system may have evolved to provide information about the nutritional value of food. Umami, the fifth basic taste which can be generated by the flavour enhancer monosodium glutamate (MSG), has been particularly linked to the detection of protein in the diet [2,6–9] and may influence selection of protein-rich foods based on nutritional need state. Therefore, it may be that liking for umami sources such as MSG in foods changes according to the amount of protein generally consumed in the diet (protein status) and may also be sensitive to acute protein deprivation.

Protein accounts for 15% dietary energy intake [10,11] which has remained constant over time and across populations compared to other macronutrients [4,11,12]. This may be related to the body's efficiency in regulating protein feedback [6,13] due to the limited availability of carbohydrate and fat in human evolutionary history [14,15]. Indeed, protein intake has been shown to be prioritized over carbohydrate and fat intake in ad-libitum meals after participants were provided with unbalanced diets [4,14,16–18]. This change in food selection may be influenced by flavour, with increases in consumption of savoury

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foods due to their association with protein. Indeed, the savoury taste elicited by MSG has been found to increase preference for foods with stronger MSG concentrations in both adults [19] and children [20] in protein-deficient states with poor nutritional status compared to well-nourished controls. This indicates that long-term protein deprivation may influence the selection of and liking for MSG. Laska and Hernandez Salazar [21] assessed MSG taste preferences in primates naturally consuming low or high quantities of animal protein. Contrary to the previous findings, they reported that primates consuming more animal protein preferred stronger concentrations of MSG whilst low animal protein consumers enjoyed MSG more overall, particularly when delivered in weaker concentrations. These differences between malnourished humans and primates consuming low amounts of animal protein may be due to learned experiences and familiarity with umami concentrations in foods. As the malnourished humans tested had previously been exposed to animal protein, which is abundant in umami [22], their familiarity, liking and preference for strong concentrations of MSG flavour may have been greater due to previously learned associations between stronger concentrations of umami linked to high protein sources. Indeed, liking for MSG in humans is correlated with liking of high protein foods [2]. However, as primates who consume low amounts of protein subsist on predominantly plant-based diets, their familiarity with and exposure to strong concentrations of umami tastants is less likely and thus they may prefer weaker concentrations of umami, as would naturally be found in their diet. This influence of habitual dietary intake affecting preference for a stimulus which may be predictive of protein has not been previously assessed in humans, and as protein is so tightly regulated, may provide further insight into the influence of general protein intake on hedonic preference.

The influence of protein status may even alter hedonic taste perception in short-term manipulations. Gibson and colleagues [23] found that participants experimentally manipulated to be in acute mild protein deficit (by provision of low protein breakfasts) learned to prefer a dessert flavour that was previously paired with the delivery of more protein when compared to participants in nutritional balance. This mild protein deprivation has also been found to increase ingestion and choice of flavours that have been paired with the post-ingestive consequences of consuming protein in rats [24–26] and protein conditioned flavour preferences have been reported to be eliminated by a protein preload, but not after an equicaloric carbohydrate preload [27]. Such flavour preferences required very few pairings of novel flavoured protein-rich food when in mild protein need [24–26], reflecting the tight regulation of this macronutrient within the diet.

However, although short-term protein deprivation has been shown to influence choice through learning, the effect of an acute deficit on liking for tastes that may naturally be associated with protein has not been assessed. Equally, it is not known whether habitual protein consumption in the diet influences taste preferences for these flavours in humans in the same way as has been reported in animals. It is also not clear whether familiarity with the concentrations generally consumed can account for the differences found in liking. Thus, the current experiment aimed to explore the effects of manipulating protein status (through the presentation of high or low protein breakfasts) and habitual protein intake in the diet (using a protein Food Frequency Questionnaire (FFQ)) on subsequent sensory assessments of a hedonically neutral savoury soup with strong and weak concentrations of MSG (0.6% or 1% (w/w)), sodium chloride (NaCl; 0.3% or 0.4% (w/w)), sweetener (Acesulphame K; 0.005% or 0.01% (w/w)) or an unflavoured control. The additional flavour conditions were included to assess whether the effects of protein were specific to the flavour of MSG alone as opposed to energy need (sweetness [28–30]) or specifically the sodium found in MSG (saltiness). Familiarity ratings as well as baseline flavour assessments were also taken before acute protein manipulations. It was hypothesised that (1) MSG would be optimally preferred when participants were in an acute protein deficit with stronger concentrations of MSG being most preferred (this was manipulated in the test sessions); (2) rated pleasantness of strong concentrations of MSG would be higher in naturally high protein consumers based on protein status derived from habitual protein intake (not manipulated in test sessions) as compared to naturally low protein consumers; (3) this would particularly be evident when these naturally high protein consumers were in acute protein deficit.

2. Method

2.1. Design

Acute effects of protein intake on liking for tastes were tested within-participant using a two way design combining acute protein intake (a baseline, low protein or high protein breakfast) with evaluations of liking for strong or weak concentrations of samples of soup with added savouriness (0.6% or 1% w/w MSG), saltiness (0.3% or 0.4% w/w NaCl), sweetness (0.005% or 0.01% Acesulphame K) or nothing added (control). Additional influences of habitual protein intake were assessed by testing the effects of participant's habitual self-reported protein consumption using a protein FFQ (between-participants) on taste responses. Breakfast conditions were balanced using a Williams square design [31]. Please see Fig. 1 for a schematic of the study design employed.

2.2. Participants

Twenty four healthy weight men from a student population at the University of Sussex took part in the research (mean age: 22; ages from 19 to 31; mean BMI: 23, BMI from 19 to 25 kg/m^2). Participants were recruited based on their responses to an eating habits questionnaire using an online database system. Individuals who smoked, were diabetic, had a diagnosed eating disorder, used medication, or had allergies or intolerances to the foods used were excluded. Those who scored high (ratings above 7) on the Three Factor Eating Questionnaire restraint scale [32] were also excluded due to the potential for confounding factors influencing assessments as high restraint individuals have been found to differ in their perceptions of food [33–35]. Participants who wished to take part were provided an Information Sheet which stated that the study was assessing the effects of 'food on mood'. A cover story was necessary to ensure participants did not respond in line with the experimental manipulations. Written, informed consent was obtained before taking part and participants were paid £10 or were awarded credits in a participant pool scheme upon completion of all sessions.

A-priori power calculations were conducted to establish the number of participants required for a medium effect of protein test day manipulation on changes in pleasantness ratings of strong and weak concentrations of the flavours assessed using G*Power. This indicated that 24 participants would be required to provide 80% power to detect a difference in rated pleasantness for weak and particularly strong concentrations of MSG flavours when in mild protein deficit. All experimental work was conducted in accordance with the standards expressed in the Helsinki Declaration and was approved by the University of Sussex ethics committee.

2.3. Test food

2.3.1. Breakfasts

All nutritional information for the breakfasts can be found in Table 1. Both high and low protein breakfasts consisted of 52 g cereal (Crunchy Nut Cornflakes, Kellogg's, UK). The high protein breakfast also included 170 g skimmed milk (Sainsbury's PLC, UK) and a 300 g high protein breakfast shake made up of 250 g semi-skimmed milk (Sainsbury's PLC, UK) combined with 25 g Greek yoghurt (Total 0%, Fage, UK), 25 g whey protein (MyProtein, UK), 0.1 g vanilla extract (Nielsen-Massey, Netherlands) and 0.04 g Acesulphame K (Beckmann-Kenko, Germany).