ORIGINAL

Association of habitual high-fat intake and desire for protein and sweet food

Hiroshi Tatano[1a], Hisami Yamanaka-Okumura[1a], Bei Zhou[1], Chisaki Adachi[1], Yuka Kawakami[1], Takafumi Katayama[2], Masashi Masuda[1], Eiji Takeda[1], and Yutaka Taketani[1]

[1]*Department of Clinical Nutrition and Food Management, Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima, Japan ;* [2]*Department of Statistics and Computer Science, College of Nursing Art and Science, University of Hyogo, Hyogo, Japan*

Abstract : Reducing dietary calorie density (CD) is useful in body weight management. This study investigates the association between dietary habits and preferences for different CDs. We conducted a randomized crossover study of 232 healthy subjects who consumed packed lunch boxes containing a control, high-meat and low-rice, low-vegetable, medium-fat and low-vegetable, high-fat, and high-fat and low-vegetable meals over six sessions. The subjective levels of sensory properties were assessed over time using a visual analog scale and the area under the curve. Subjects were assessed for dietary habits using a brief-type self-administered diet history questionnaire (BDHQ) and were divided into two groups based on a daily fat energy ratio ≥25% (high fat [HF], n=116) and < 25% (normal, n=116) that was matched for age, body mass index, and sex ratio. Our findings indicate that the desire for sweetness was higher in the HF group than in the normal group, regardless of the meals consumed. Particularly, among the 500-kcal low-CD meals, a high-protein meal provided greater fullness and satisfaction and lower prospective consumption in the HF group than in the normal group. Therefore, our study demonstrates that postprandial appetite sensation is associated with dietary habits of fat intake. J. Med. Invest. 63 : 241-247, August, 2016

Keywords : *calorie density, energy density, dietary habits, food composition, Japanese food*

INTRODUCTION

The World Health Organization has reported that 65% of the world's population lives in countries where obesity and being overweight increases the risk of diseases leads to death. Obesity and being overweight are caused by an energy imbalance, with decreased energy expenditure and increased energy intake as a result of lifestyle (1). Therefore, dietary calorie density (CD) or energy density (ED) may be associated with the regulation of food intake and weight control (2-4).

CD is defined as the amount of energy per unit of weight (e.g., kcal/g), and dietary CD can be decreased by reducing fat intake and incorporating water-rich foods, such as vegetables and fruits into the diet (5). Low-CD foods provide a considerable food weight, making the individual feel full on fewer calories (6-8). For practical exploitation of CD, low-CD foods could be used to provide a satiating diet as these foods contain low levels of fat and high levels of fiber, leading to a higher intake of vitamins and minerals than medium- and high-CD diets.

However, high-CD foods are frequently consumed in daily life because of their lower price and greater palatability that results from their higher fat content (9-12). Fat in foods improves palatability and can be addictive in both animals and humans (9, 13, 14). In relation to the potential effect, dietary habits are associated with weight management and the risk of obesity and chronic disease (15). The guidance provided in the Dietary Reference Intakes for Japanese (16) expresses dietary fat intake as energy ratios, with an upper limit of recommended consumption per day of < 25% energy derived from dietary fats.

Multiple laboratory-based studies have demonstrated a relationship between energy intake and CD (2-4). However, few studies, have examined whether dietary habits influence food preference in free-living individuals with different dietary CDs. To develop an effective dietary pattern for weight management, we need to identify how dietary habits influence food preferences based on sensory properties. Previously, we have reported an association between sensory properties and dietary CD (17, 18). We hypothesized that responses to diets with different CDs would vary among subjects with different dietary fat intake habits and that a higher habitual dietary fat intake would stimulate appetite. The results of this study may provide the basis of an algorithm to derive a suitable diet pattern according to dietary habits.

MATERIALS AND METHODS

Subjects

A total of 300 individuals from Tokushima, Japan, agreed to participate in this study. They had sedentary clerical occupations and routine lifestyles (17, 18). After recruitment, each subject was asked to complete a brief-type self-administered diet history questionnaire (BDHQ). Height and weight were self-reported according to data recorded during annual physical examinations.

BDHQ is a structured questionnaire that inquires the subject's sex, height, weight, date of birth, and dietary habits during the past month. It also includes aspects such as primary cooking methods and the consumption frequency of cereals, soups, beverages, and other food products. The food and beverage items were selected from foods commonly consumed in Japan, mainly among food items used in the National Nutrition Survey of Japan.

Received for publication March 29, 2016 ; accepted May 12, 2016.

Address correspondence and reprint requests to Hisami Yamanaka-Okumura, Ph.D., Assistant Professor, [a]The contributions of the first two authors of the manuscript should be considered equivalent. Department of Clinical Nutrition and Food Management, Institute of Biomedical Sciences, Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima 770-8503, Japan and Fax : +81-88-633-7094.

Dietary habits during the month before the start of the study were assessed using the BDHQ which have been used in large-scale epidemiological studies in Japan (19). Responses to BDHQ and those to an accompanying lifestyle questionnaire were checked twice or more for completeness. The forms were reviewed with the subject to complete any missing answers, when necessary.

We divided the subjects into two groups according to the guidance given in the Dietary Reference Intakes in Japan (16) based on the expressed dietary fat intake as energy ratios : 1) with a dietary fat energy ratio of ≥ 25% and 2) a ratio of < 25%, as assessed by the BDHQ. The two groups were matched for age, BMI, and sex ratio, with a total of 232 subjects, with 116 subjects in each group in this study. The group with a dietary energy ratio of < 25% was designated the normal group and that with a ratio ≥ 25% was designated the high-fat (HF) group.

Study design

An outline of this study design is shown in Fig. 1. A randomized crossover design was used to investigate the post-prandial effects of test meals, with a 1-week interval between testing rounds during the subjects' normal daily life. A packed test meal was systematically provided on a specified day for 6 weeks consecutively, and the details of this study were as previously reported (17, 18). All subjects were provided detailed written and verbal explanations of the general purpose and procedures of the study before their written consent was obtained. 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 Ethics Committee of the Tokushima University Hospital. Subjects were registered by identification numbers to protect their information.

Test meals

Six types of packed lunches, "bento" based on "Washoku" or Japanese food, used as test meals were prepared using the same ingredients each time (17, 18). Without changing the appearance of the test meals, variations were introduced by adding oil, using various cooking methods, or changing the volume/amount of ingredients. The subjects were given 1 L of chilled water to be consumed *ad libitum* throughout the test duration until dinner. However, if requested, additional water beyond the 1 L limit was provided, but no food or other drinks were allowed.

The six test meals were prepared with different cooking methods as follows : 1) the reference meal (Control) : cooked rice 150 g, sautéed beef menu containing 40 g of raw beef, vegetables 240 g, energy 500 kcal and CD 0.8 kcal/g ; 2) high-meat meal (Hmeat) : cooked rice 100 g, sautéed beef menu containing 80 g of raw beef, vegetables 240 g, energy 513 kcal and CD 0.7 kcal/g ; 3) low-vegetable meal (Lveg) : cooked rice 150 g, sautéed beef menu containing 40 g of raw beef, vegetables 80 g, energy 427 kcal and CD 1.0 kcal/g ; 4) medium-fat/low-vegetable meal (MfatLveg) : cooked rice 150 g, sautéed beef menu containing 40 g of raw beef with sauce, vegetables 80 g, energy 520 kcal and CD 1.2 kcal/g ; 5) high-fat meal (Hfat) : cooked rice 150 g, sautéed beef menu containing 40 g of raw beef with sauce and added oil, vegetables 240 g, energy 896 kcal and CD 1.3 kcal/g ; 6) and high-fat/low-vegetable meal (HfatLveg) : cooked rice 150 g, sautéed beefmenu containing 40 g of raw beef with sauce, vegetables 80 g, energy 824 kcal, and CD 1.8 kcal/g.

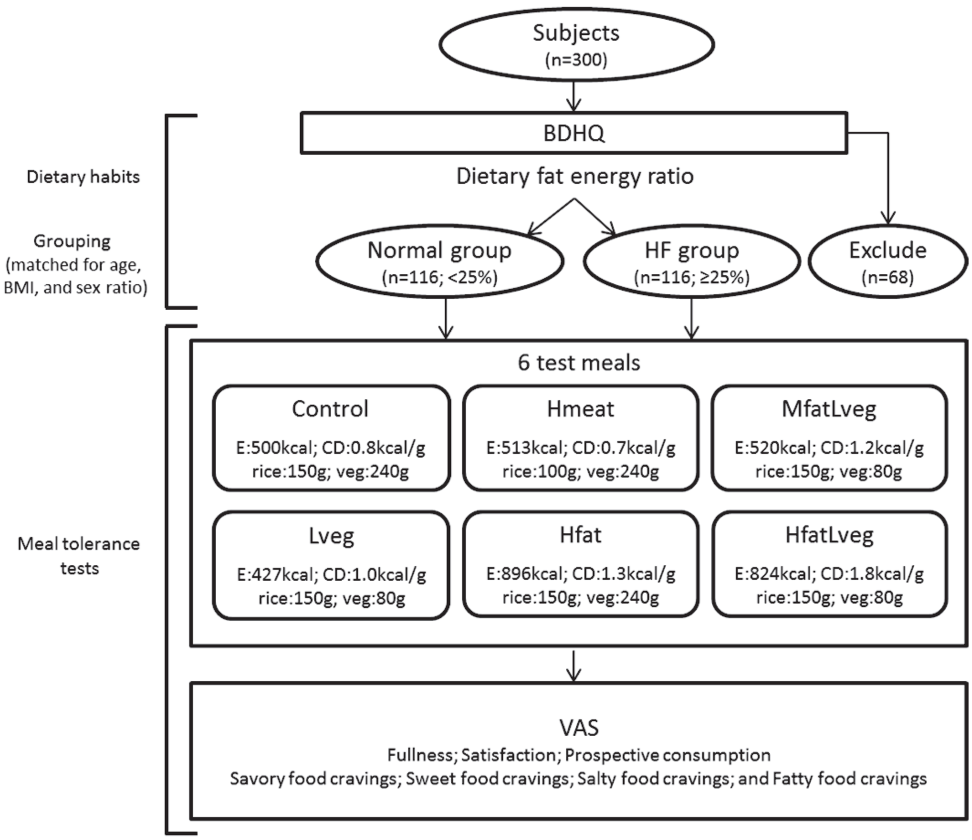

Figure 1. Outline of the study design. BDHQ, brief-type self-administered diet history questionnaire ; Control, control meal ; E, energy ; HF, > 25% of fat energy ratio ; Hfat, high-fat with added oil ; HfatLveg, high-fat/low-vegetable ; Hmeat, high-meat/low-rice ; Lveg, low-vegetable ; MfatLveg, medium-fat/low-vegetable ; normal, < 25% of fat energy ratio ; VAS, visual analogue scale ; and veg, vegetable.

Visual Analogue Scale (VAS)

The subjects were asked to undergo seven VAS assessments over time : before intake, as well as 0.5, 1, 2, 3, 4, and 5 h after the meal. Seven variables were used in the VAS assessment : 1) fullness ; 2) satisfaction ; 3) prospective consumption to assess appetite and palatability (i.e., how much do you think you can eat?) ; 4) savory food cravings ; 5) sweet food cravings ; 6) salty food cravings ; and 7) fatty food cravings. Two contrasting descriptors were noted at each end of the 100-mm VAS line. For example, fullness was rated on the line preceded by the question, "How full are you right now?" and anchored on the left by "not at all" and "very much" on the right. The subjects were instructed to make a mark on each line that corresponded with how they felt at that time.

Data analysis

To examine the effect of dietary habits on variations in appetite sensation, the subjects included in the analysis were divided into two groups according to the fat intake associated with their dietary habits in daily life.

Areas under curves (AUCs) of the VAS ratings for the entire 5-h period for the sensory properties of each of the different meals in each group were calculated. Since VAS is a subjective scale for within-subject comparisons, group differences in AUCs of appetite ratings were analyzed by differences in the ratings between the control meal as a baseline and the modified meals. We also evaluated the absolute values of VAS ratings before the consumption of each test meal.

An unpaired t-test was used to assess the differences between pairs of groups for sensory properties by evaluating the VAS ratings and their AUCs for each meal. In each group, ratings of the sensations for the test meals from 0 to 5 h after the meal, as well as AUCs of sensation ratings for test meals were evaluated by repeated measures ANOVA, followed by a Bonferroni post hoc test.

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS ; version 16.0, 2007 ; SPSS Inc., Chicago, IL, USA). The results were reported as mean±SEM and were considered significant at $P < 0.05$.

RESULTS

Subjects

Subject characteristics are shown in Table 1. They were classified into two groups according to a fat energy rate intake ≥ 25% or < 25% in daily life. Each group consisted of 90 men and 26 women, and they were matched by age and BMI to eliminate these influencing factors.

Comparisons of the different habitual fat energy ratio groups on sensory properties for each test meal

We investigated the appetite sensations (fullness, satisfaction, and prospective consumption) and desired palatability (savory, sweet, salty, and fatty) for different test meals and compared these between the HF and normal groups. AUCs for satisfaction with Hfat were significantly lower in the HF group than in the normal group ($P = 0.011$). This result showed that the postprandial satisfaction of high-fat meals was significantly lower in the HF group than in the normal group (Fig. 2).

AUCs for sweet for all the test meals were significantly higher in the HF group than in the normal group ($P < 0.05$). AUCs for salty with Hfat meal were significantly higher in the HF group than in the normal group ($P = 0.045$). This result showed that desire for sweetness both before and after meals was significantly higher in the HF group than in the normal group, regardless of the meal. In addition, the desire for salty food after intake of the high-fat meals was significantly higher in the HF group than in the normal group. It shows the Fig. 3 as detailed data.

Comparisons of test meals within the HF group

In this study, we investigated what type of combination meal would most satisfy the appetite in people with a high fat intake in daily life. We evaluated the changes in VAS ratings and AUCs for appetite sensations for different test meals in the HF group (Fig. 4A).

When the 500-kcal low-CD meals (Control, Hmeat and MfatLveg), which differed in the amount of rice, vegetables, and meat, were compared, it was found that AUC for fullness and satisfaction was significantly higher for the control and Hmeat than for the MfatLveg meals ($P < 0.05$). In addition, AUC for the prospective consumption was significantly lower for the Hmeat than for the MfatLveg meals ($P = 0.013$). In the high-energy content meals containing different amounts of vegetables (Hfat and HfatLveg), AUCs for fullness and satisfaction were significantly higher for the Hfat than for the HfatLveg ($P < 0.05$) meals. When the low-vegetable content meals (Lveg, MfatLveg, and HfatLveg) were compared, no significant differences were observed. These results indicate that appetite sensation (fullness and satisfaction) was enhanced by high vegetable consumption rather than by adding oil.

Similarly, we evaluated the changes in the VAS ratings and AUCs for the palatability desires for different test meals in the HF group. However, no significant differences in AUCs for the desire for savory, sweet, salty, or fatty foods were identified. These results indicate that the desires for palatability were not different, regardless of the meals.

Comparison of test meals within the normal group

Fig. 4B shows that AUC for fullness was significantly higher for the control and Hfat meals than for the Lveg, MfatLveg, and

Table 1 : Characteristics of participants in a study to examine the effects of lunches with different dietary energy densities on sensory properties across fat energy rate groups of Japanese adult

Variable	Normal group (n=116)	HF group (n=116)
Male gender (n, %)	90 (77.6)	90 (77.6)
Age (years)	44.3±0.8	42.3±0.8
Height (cm)	168.3±0.7	168.5±0.7
Weight (kg)	68.3±1.3	67.9±1.1
BMI (kg/m^2)	23.9±0.3	23.8±0.3
Fat energy rate (%)	21.4±0.3	29.4±0.3

HF, higher than 25% of fat energy rate ; Normal, less than 25% of fat energy rate. Values are presented as the mean± SEM.

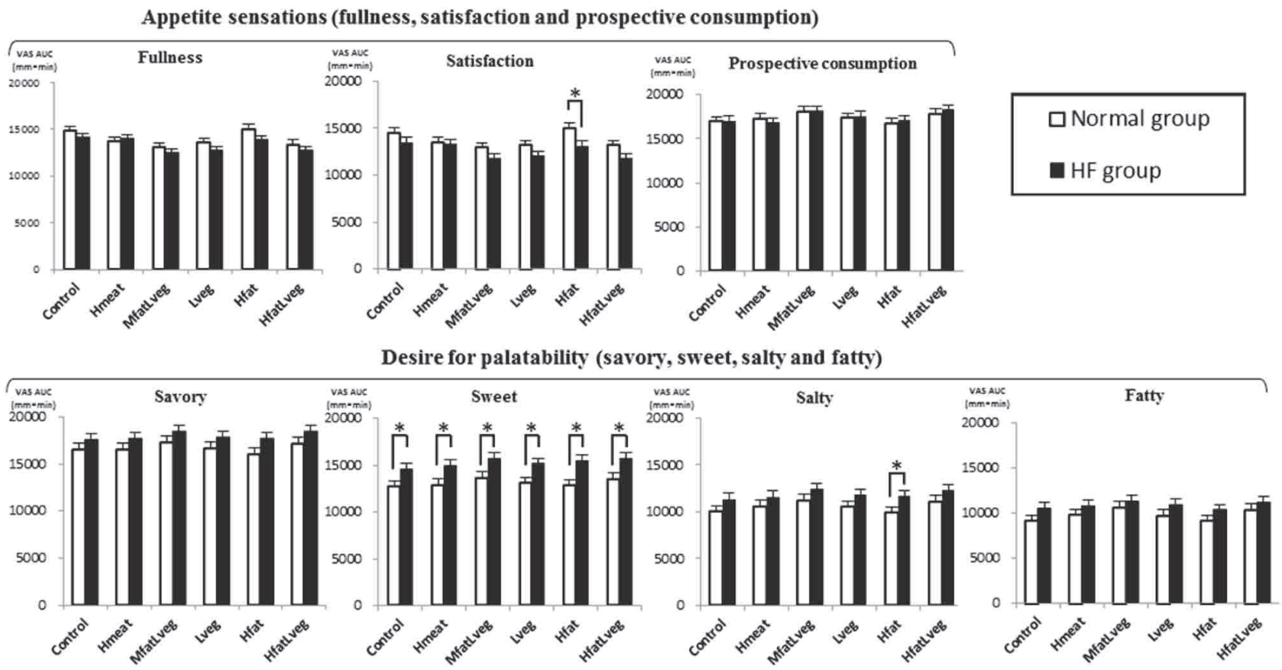

Figure 2. Differences in the mean ± standard error of mean areas under the curve of visual analogue scale ratings for appetite sensations and palatability with different test meals between each group. Control, control meal ; HF, > 25% of fat energy ratio ; Hfat, high-fat with added oil ; HfatLveg, high-fat/low-vegetable ; Hmeat, high-meat/low-rice ; Lveg, low-vegetable ; MfatLveg, medium-fat/low-vegetable ; and normal, < 25% of fat energy ratio. *$P < 0.05$ (unpaired t-test).

VAS ratings	Test meal	Normal group							HF group						
		Time points (h)							Time points (h)						
		0	0.5	1	2	3	4	5	0	0.5	1	2	3	4	5
Fullness (mm)	Control	36.3 ±2.2	60.0 ±2.1*	59.6 ±2.0*	55.6 ±1.9*	50.4 ±1.8*	40.9 ±1.9	35.1 ±2.1	40.2 ±2.0	54.9 ±1.9*	57.5 ±1.9*	52.7 ±1.8*	47.3 ±1.7*	39.0 ±1.8	31.4 ±2.0*
	Hmeat	35.8 ±2.1	55.0 ±2.2*	55.1 ±2.1*	50.9 ±1.9*	46.0 ±2.0*	37.7 ±1.8	32.9 ±1.9	39.7 ±2.0	55.3 ±2.1*	57.3 ±1.9*	52.1 ±1.8*	46.5 ±1.8*	38.4 ±1.8	31.8 ±1.9*
	MfatLveg	33.8 ±1.9	49.3 ±2.1*	52.8 ±2.0*	47.4 ±1.9*	44.7 ±1.9*	36.6 ±1.8	32.6 ±1.8	32.5 ±1.7	46.9 ±1.9*	50.4 ±1.8*	48.1 ±1.8*	42.2 ±1.7*	34.5 ±1.7	28.3 ±1.9
	Lveg	31.2 ±1.8	50.6 ±2.0*	55.0 ±1.9*	51.2 ±1.8*	46.2 ±1.8*	38.4 ±1.7*	32.2 ±1.8	32.4 ±1.5	47.5 ±2.0*	51.1 ±1.8*	47.5 ±1.8*	44.4 ±1.7*	35.4 ±1.7	29.3 ±1.8
	Hfat	36.6 ±2.0	60.5 ±2.2*	59.5 ±2.0*	53.9 ±2.0*	48.8 ±2.0*	43.6 ±2.0	39.5 ±2.1	35.9 ±1.9	54.2 ±2.0*	56.6 ±1.8*	51.4 ±1.7*	47.1 ±1.7*	38.0 ±1.9	32.3 ±1.9
	HfatLveg	32.2 ±1.9	49.0 ±2.1*	52.9 ±1.8*	49.1 ±1.9*	44.8 ±2.0*	39.3 ±2.0*	34.3 ±1.9	30.9 ±1.7	47.2 ±1.9*	51.7 ±1.8*	48.5 ±1.6*	43.8 ±1.7*	35.3 ±1.7	28.2 ±1.7
Satisfaction (mm)	Control	46.7 ±2.2	53.3 ±2.2*	56.0 ±2.0*	52.9 ±2.0	48.7 ±1.9	40.9 ±2.0	37.4 ±2.0*	45.2 ±2.0	50.4 ±1.9	53.1 ±2.0*	48.8 ±1.9	44.3 ±1.8	39.2 ±1.9	33.2 ±2.0*
	Hmeat	42.3 ±2.3	51.4 ±2.2*	52.3 ±2.1*	48.5 ±2.1	45.4 ±2.0	38.2 ±1.8	34.9 ±1.9*	42.3 ±2.0	48.9 ±2.1*	52.8 ±2.1*	49.3 ±2.0*	44.2 ±1.9	37.1 ±1.7*	33.0 ±1.9*
	MfatLveg	37.5 ±1.8	45.7 ±2.0*	48.9 ±1.9*	47.2 ±2.0*	44.6 ±1.9*	37.7 ±1.9	33.9 ±1.9	33.8 ±1.6	40.9 ±1.9*	46.5 ±1.8*	44.3 ±1.8*	39.7 ±1.7*	34.0 ±1.7	29.0 ±1.7
	Lveg	36.1 ±1.8	46.1 ±2.0*	51.2 ±2.0*	49.1 ±1.9*	45.4 ±1.9*	38.5 ±1.9	33.6 ±1.9	35.3 ±1.5	42.4 ±1.8*	47.6 ±1.7*	45.0 ±1.7*	42.2 ±1.7*	34.7 ±1.5	29.1 ±1.6*
	Hfat	46.6 ±2.1	56.5 ±2.1*	58.2 ±2.1*	53.6 ±2.0*	48.5 ±2.0	44.0 ±2.0	41.4 ±2.1	39.8 ±1.9	47.8 ±2.1*	52.2 ±2.1*	47.9 ±1.9*	44.7 ±1.8	37.0 ±1.7	32.8 ±1.8*
	HfatLveg	35.7 ±2.0	45.2 ±2.1*	50.4 ±1.8*	47.5 ±2.0*	44.1 ±2.0*	40.6 ±2.1	35.5 ±2.1	33.9 ±1.8	42.2 ±1.9*	45.9 ±1.9*	43.8 ±1.8*	41.3 ±1.7*	34.4 ±1.7	28.5 ±1.7*
Prospective consumption (mm)	Control	78.5 ±1.8	50.6 ±2.6*	49.0 ±2.3*	52.2 ±2.2*	55.4 ±2.1*	59.4 ±2.1*	67.3 ±2.1*	73.6 ±1.9	53.1 ±2.3*	47.6 ±2.2*	51.4 ±2.1*	55.8 ±1.9*	62.1 ±2.0*	68.9 ±2.0
	Hmeat	75.4 ±1.9	53.1 ±2.6*	48.5 ±2.3*	52.5 ±2.2*	56.8 ±2.1*	62.8 ±2.2*	68.7 ±2.3	74.7 ±1.8	51.5 ±2.4*	48.4 ±2.3*	49.2 ±2.2*	54.5 ±2.1*	61.5 ±2.1*	69.1 ±2.0
	MfatLveg	74.2 ±1.9	54.9 ±2.4*	54.0 ±2.3*	55.6 ±2.2*	59.5 ±2.2*	64.5 ±2.1*	69.5 ±2.0	72.3 ±1.9	53.0 ±2.3*	51.9 ±2.1*	55.2 ±2.0*	60.4 ±1.9*	67.1 ±2.0	72.7 ±1.9
	Lveg	76.7 ±1.9	53.9 ±2.1*	50.1 ±2.1*	52.8 ±2.0*	57.2 ±2.0*	61.6 ±2.2*	67.8 ±2.2*	72.8 ±1.9	52.8 ±2.3*	50.6 ±2.2*	52.2 ±2.2*	57.4 ±2.1*	64.7 ±2.1*	70.5 ±2.0
	Hfat	75.0 ±1.8	52.6 ±2.6*	46.5 ±2.3*	51.2 ±2.2*	56.1 ±2.1*	60.0 ±2.0*	65.0 ±2.1*	73.4 ±1.9	51.1 ±2.3*	48.1 ±2.2*	51.8 ±2.1*	57.0 ±2.1*	62.2 ±2.0*	67.2 ±2.1
	HfatLveg	77.7 ±1.9	54.7 ±2.4*	52.6 ±2.1*	55.2 ±2.2*	58.7 ±2.2*	62.9 ±2.3*	67.6 ±2.2*	75.5 ±1.9	57.0 ±2.2*	52.6 ±2.1*	56.7 ±1.9*	60.5 ±2.0*	64.6 ±2.0*	71.7 ±1.9
Savory (mm)	Control	73.8 ±1.8	52.4 ±2.6*	47.5 ±2.4*	50.1 ±2.4*	54.6 ±2.2*	58.7 ±2.3*	63.8 ±2.5*	72.7 ±1.9	54.8 ±2.4*	52.2 ±2.5*	54.0 ±2.5*	57.1 ±2.3*	62.4 ±2.3*	69.9 ±2.1
	Hmeat	71.2 ±2.0	53.2 ±2.5*	49.3 ±2.4*	49.2 ±2.5*	53.2 ±2.5*	59.6 ±2.4*	65.6 ±2.5	73.6 ±1.7	56.2 ±2.5*	52.4 ±2.5*	54.1 ±2.4*	58.4 ±2.3*	63.0 ±2.3*	68.2 ±2.2
	MfatLveg	67.3 ±2.3	54.5 ±2.5*	52.5 ±2.5*	54.3 ±2.5*	56.2 ±2.5*	61.0 ±2.4	64.7 ±2.3	71.9 ±1.8	58.6 ±2.3*	54.4 ±2.4*	57.7 ±2.3*	60.8 ±2.3*	65.7 ±2.3*	71.7 ±2.0
	Lveg	72.5 ±2.0	53.5 ±2.3*	49.6 ±2.5*	52.3 ±2.4*	54.1 ±2.4*	57.6 ±2.4*	64.1 ±2.4*	70.8 ±1.9	55.2 ±2.3*	53.5 ±2.4*	54.5 ±2.3*	59.5 ±2.2*	63.6 ±2.1*	68.8 ±2.1
	Hfat	69.3 ±2.0	49.5 ±2.4*	46.9 ±2.6*	50.3 ±2.4*	52.1 ±2.4*	56.5 ±2.3*	62.0 ±2.3*	72.8 ±1.8	58.1 ±2.5*	53.5 ±2.5*	54.3 ±2.3*	58.5 ±2.3*	61.8 ±2.3*	67.9 ±2.2
	HfatLveg	71.3 ±2.0	55.5 ±2.5*	51.8 ±2.5*	53.4 ±2.6*	55.3 ±2.6*	59.9 ±2.6*	64.3 ±2.4*	72.7 ±2.0	59.7 ±2.2*	56.5 ±2.4*	58.7 ±2.2*	60.2 ±2.3*	64.4 ±2.3*	70.2 ±2.1
Sweet (mm)	Control	46.4 ±2.2	38.7 ±2.4*	36.7 ±2.2*	39.8 ±2.4*	42.5 ±2.4	46.4 ±2.5	49.9 ±2.7	54.0 ±2.2	43.6 ±2.4*	43.4 ±2.5*	44.5 ±2.4*	48.2 ±2.4	53.6 ±2.4	59.2 ±2.5
	Hmeat	47.9 ±2.2	38.8 ±2.4*	37.8 ±2.3*	38.5 ±2.3*	42.6 ±2.5	47.7 ±2.5	52.4 ±2.7	52.7 ±2.3	46.1 ±2.4*	45.6 ±2.4*	45.7 ±2.3*	50.8 ±2.3	54.3 ±2.4	57.3 ±2.5
	MfatLveg	46.6 ±2.5	40.7 ±2.4*	41.2 ±2.4	43.9 ±2.5	45.8 ±2.6	48.8 ±2.6	52.2 ±2.7	55.1 ±2.1	49.6 ±2.3*	46.9 ±2.4*	49.7 ±2.3	52.9 ±2.4	56.4 ±2.5	60.2 ±2.4
	Lveg	48.0 ±2.3	41.1 ±2.3*	37.7 ±2.3*	41.4 ±2.4	43.6 ±2.5	46.7 ±2.6	51.2 ±2.7	55.8 ±2.2	45.9 ±2.4*	43.7 ±2.2*	47.0 ±2.2*	51.0 ±2.2	55.5 ±2.2	59.3 ±2.4
	Hfat	47.1 ±2.2	39.6 ±2.4*	37.7 ±2.3*	41.1 ±2.2	44.4 ±2.4	45.4 ±2.5	46.8 ±2.6	54.2 ±2.2	47.7 ±2.3*	46.0 ±2.3*	48.5 ±2.3	53.6 ±2.3	54.8 ±2.4	58.3 ±2.4
	HfatLveg	50.1 ±2.3	42.4 ±2.5*	41.0 ±2.4*	42.8 ±2.5*	43.9 ±2.7	48.7 ±2.6	51.5 ±2.8	51.0 ±2.2	48.8 ±2.2	47.2 ±2.4	51.5 ±2.3	52.2 ±2.3	55.2 ±2.3	60.5 ±2.4*
Salty (mm)	Control	42.7 ±2.3	32.1 ±2.3*	30.4 ±2.2*	31.1 ±2.3*	31.9 ±2.3*	35.4 ±2.4*	37.6 ±2.6	51.5 ±2.2	37.5 ±2.3*	35.3 ±2.2*	34.4 ±2.3*	36.3 ±2.4*	38.1 ±2.3*	42.9 ±2.4*
	Hmeat	43.5 ±2.4	34.0 ±2.3*	32.1 ±2.3*	32.2 ±2.3*	33.7 ±2.5*	38.0 ±2.7*	41.7 ±2.9	49.4 ±2.2	36.9 ±2.3*	35.1 ±2.2*	36.5 ±2.2*	37.4 ±2.2*	40.0 ±2.3*	44.0 ±2.4*
	MfatLveg	43.2 ±2.4	35.8 ±2.4*	34.8 ±2.3*	35.6 ±2.5*	37.5 ±2.5	36.8 ±2.6*	41.8 ±2.7	50.0 ±2.2	39.9 ±2.1*	37.3 ±2.2*	38.5 ±2.2*	41.5 ±2.3*	43.0 ±2.4*	47.3 ±2.4
	Lveg	43.0 ±2.4	33.7 ±2.3*	31.8 ±2.2*	33.4 ±2.1*	34.3 ±2.3*	35.7 ±2.4*	40.3 ±2.6	49.1 ±2.2	37.4 ±2.0*	35.7 ±2.0*	36.2 ±2.1*	38.5 ±2.1*	41.5 ±2.2*	45.8 ±2.4
	Hfat	45.2 ±2.2	32.9 ±2.2*	29.6 ±2.1*	30.9 ±2.1*	32.2 ±2.1*	34.0 ±2.2*	36.1 ±2.4*	49.9 ±2.1	38.1 ±2.3*	35.5 ±2.1*	35.7 ±2.2*	38.1 ±2.2*	40.0 ±2.3*	43.9 ±2.4
	HfatLveg	45.6 ±2.4	34.7 ±2.2*	34.3 ±2.3*	34.3 ±2.3*	35.7 ±2.5*	39.0 ±2.7*	40.4 ±2.7	48.4 ±2.2	39.3 ±2.0*	37.9 ±2.1*	38.8 ±2.1*	41.2 ±2.2*	41.8 ±2.4*	46.7 ±2.4
Fatty (mm)	Control	41.2 ±2.3	30.7 ±2.2*	27.5 ±2.2*	28.1 ±2.2*	29.1 ±2.3*	32.0 ±2.4*	34.7 ±2.5*	48.0 ±2.3	35.4 ±2.3*	33.4 ±2.3*	32.2 ±2.3*	33.6 ±2.4*	35.8 ±2.4*	39.9 ±2.5*
	Hmeat	40.7 ±2.3	30.6 ±2.2*	30.0 ±2.2*	29.0 ±2.2*	30.9 ±2.4*	35.2 ±2.5*	39.0 ±2.7	47.9 ±2.3	35.0 ±2.3*	33.2 ±2.2*	33.9 ±2.3*	34.2 ±2.2*	36.7 ±2.4*	41.9 ±2.4*
	MfatLveg	42.1 ±2.5	33.5 ±2.4*	32.8 ±2.3*	33.7 ±2.4*	35.2 ±2.4*	36.2 ±2.6*	40.0 ±2.7	47.7 ±2.3	37.7 ±2.3*	34.4 ±2.2*	34.2 ±2.2*	36.6 ±2.3*	38.7 ±2.4*	44.4 ±2.4
	Lveg	41.4 ±2.4	32.3 ±2.3*	29.3 ±2.2*	30.2 ±2.1*	31.3 ±2.3*	33.0 ±2.3*	38.2 ±2.6	48.3 ±2.2	36.0 ±2.1*	34.0 ±2.0*	33.6 ±2.2*	35.4 ±2.2*	37.6 ±2.3*	42.1 ±2.5
	Hfat	43.0 ±2.2	29.3 ±2.1*	27.0 ±2.1*	28.4 ±2.1*	29.6 ±2.2*	31.4 ±2.2*	33.6 ±2.3*	48.1 ±2.2	35.1 ±2.2*	31.5 ±2.2*	31.7 ±2.2*	33.1 ±2.3*	34.8 ±2.4*	40.1 ±2.5*
	HfatLveg	42.8 ±2.4	31.8 ±2.1*	31.1 ±2.2*	32.3 ±2.2*	33.4 ±2.4*	36.7 ±2.6*	40.0 ±2.7	48.4 ±2.3	36.7 ±2.0*	33.2 ±2.0*	35.1 ±2.1*	36.3 ±2.3*	38.4 ±2.5*	44.0 ±2.6

Figure 3. Changes in visual analog scale ratings of appetite sensations and palatability of test meals in each group†
Control, control meal ; HF, > 25% of fat energy ratio ; Hfat, high-fat with added oil ; HfatLveg, high-fat/low-vegetable ; Hmeat, high-meat/low-rice ; Lveg, low-vegetable ; MfatLveg, medium-fat/low-vegetable ; and normal, < 25% of fat energy ratio. Values are presented as the mean (SEM). *Differences ($P < 0.05$) between the 0 times versus the other time points with each group were assessed using a repeated measures analysis of variance followed by Bonferroni post hoc tests. †Differences ($P < 0.05$) between fat energy ratio groups at each time point were assessed using an unpaired t-test. Significant differences ($P < 0.05$) between the groups are represented by black (significantly high) and gray (significantly low).

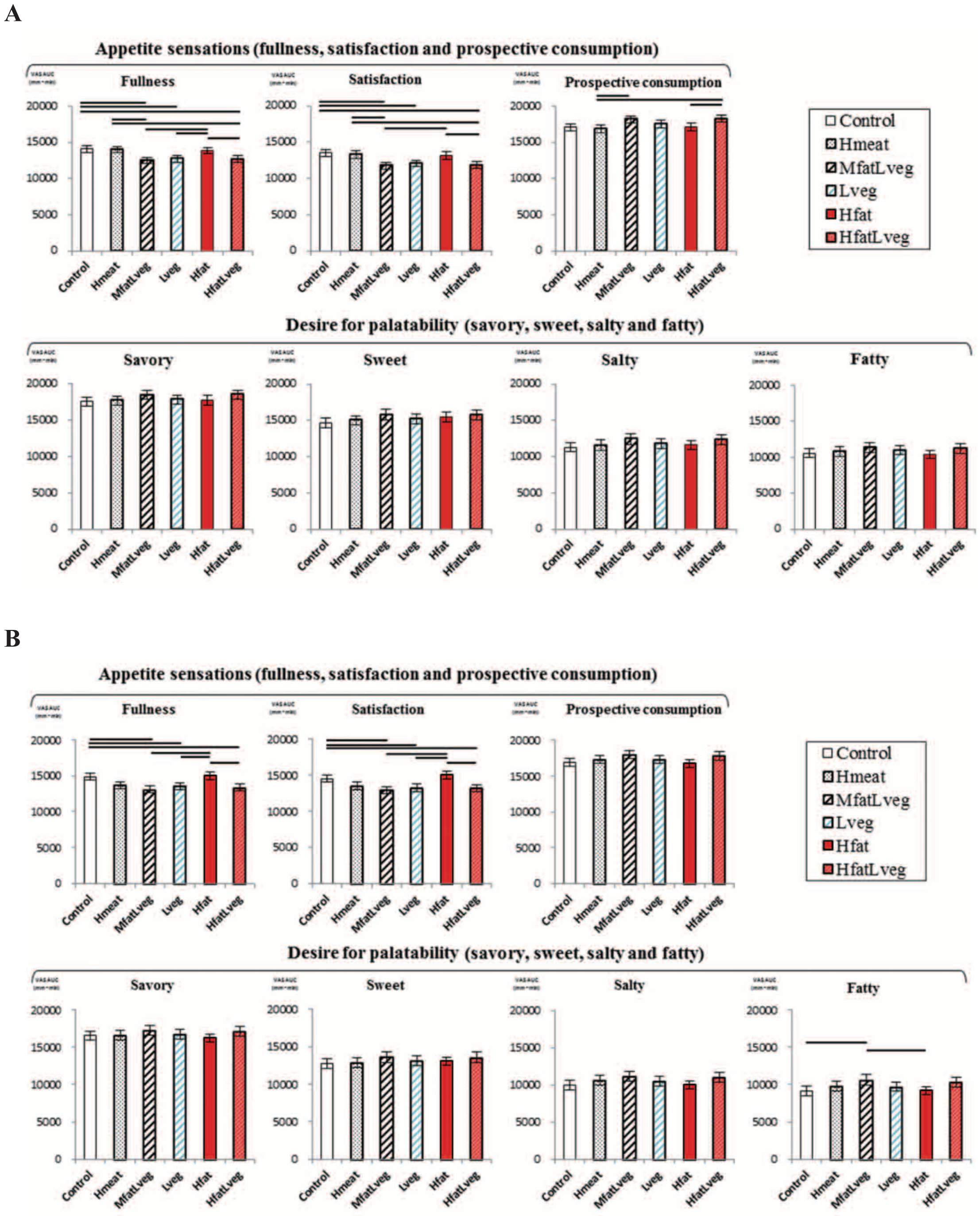

Figure 4. The mean ± standard error of the mean area under the curve (AUC) of visual analogue scale ratings for appetite sensation and palatability of test meals in each group : (A) HF group and (B) normal group. AUC was calculated from before the meal until 5 h after the meal. Differences ($P < 0.05$) in AUC of the ratings were analyzed relative to the control meal using repeated measures analysis of variance followed by Bonferroni post hoc tests. Significant differences between test meals are represented by horizontal lines. Control, control meal ; HF, > 25% of fat energy ratio ; Hfat, high-fat with added oil ; HfatLveg, high-fat/low-vegetable ; Hmeat, high-meat/low-rice ; Lveg, low-vegetable ; MfatLveg, medium-fat/low-vegetable ; and normal, < 25% of fat energy ratio.

HfatLveg ($P < 0.05$) meals. Similarly, AUC for satisfaction was significantly higher for the control and Hfat meals than for the Lveg, MfatLveg, and HfatLveg ($P < 0.05$) meals.

DISCUSSION

In this study, we used VAS ratings to examine the responses of postprandial appetite and palatable sensations of six types of typical Japanese food that varied in CD. We also compared two groups with different dietary fat energy rates which were evaluated by BDHQ.

Our results revealed three main findings : 1) the desire for sweetness was higher in the HF group than in the normal group ; 2) fullness and satisfaction were enhanced by increasing vegetable consumption rather than by adding oil, especially in the normal group ; and 3) a high-protein meal provided greater fullness and satisfaction in the HF group than in the normal group, and lowered prospective consumption.

As part of the body's appetite control system, fullness and satisfaction are important factors to consider when the limiting of energy intake is desired (20, 21). In addition, it is reported that palatable high-CD foods can easily lead to overeating (22). Therefore, a high level of palatability expressed as the desire to eat excessive food can lead to excessive energy consumption. Therefore, it is important to investigate the effect of appetite sensation on eating behavior when considering weight control (23).

It has previously been shown that high-fat meals induced insensitivity to sweetness in obese mice (24). Research on sweet preference in humans reported that obese individuals may not taste sweet stimuli as well as their lean counterparts, but have increased preferences for sweet tastes (25). Therefore, it was suggested that obese individuals require a larger quantity of sweet foods to obtain satisfaction similar to that obtained by thinner individuals.

The results of the present study indicate that the desire for sweetness was greater in the subjects with a dietary habit of high fat intake, regardless of meal type, after adjustment for BMI and age. It is therefore suggested that the desire to increase sugar consumption might be strengthened by a dietary habit of high fat intake. In a previous study, the fat and sugar components of the diet were inversely related when expressed as percentages, but positively related when expressed in grams (26). However, it is unclear whether the observed relationship between fat and sugar reflects physiological or nutritional factors, or eating behavior.

The control (500 kcal) and Hfat (896 kcal) meals had high ratings for fullness and satisfaction, regardless of the subjects' dietary habits. Similarly, Lveg (427 kcal) and HfatLveg (824 kcal) meals had low ratings for fullness and satisfaction. Thus, high-fat meals with a lower amount of vegetables led to lower fullness and satisfaction. This suggests that fullness and satisfaction are promoted by increasing the consumption of vegetables because of the greater food weight of a diet rich in water and fiber (27, 28). In a previous study, a positive correlation was found between dietary CD and fat intake (28). The energy derived from fat and total energy intake have also been shown to be closely associated with each other (29, 30). In contrast, low-CD diets that decrease fat intake can maintain higher levels of fullness and satisfaction, as well as decrease the total energy intake.

In the HF group, the protein, fat, and carbohydrate balance of 25 : 21 : 54 of Hmeat meals led to significantly greater fullness and satisfaction than MfatLveg meals (14 : 30 : 56), whereas there were no significant differences in fullness and satisfaction between the Hmeat and MfatLveg meals in the normal group. Furthermore, prospective consumption (to assess appetite and palatability) was significantly lower for the Hmeat meal than for the MfatLveg and HfatLveg meals in the HF group. Taken together, these findings indicate that meat intake can enhance fullness and satisfaction. One possible explanation is that protein increases satiety to a greater extent than carbohydrates or fat (31, 32). Our study demonstrates that protein has a superior ability to enhance appetite sensations of fullness and satisfaction. Therefore, the intake of high-protein meals in individuals with a dietary habit of high fat intake may facilitate a reduction in energy consumption with an *ad libitum* diet. Taken together, our results indicate that increasing meat intake may play an important role in achieving fullness and satisfaction in people with a high fat intake in daily life.

The strengths of this study include the provision of information about the effects of dietary habits and CD on sensory properties and meal preferences. Our results may provide a basis for practical and flexible dietary guidance according to dietary habits and diet pattern. The consumption of 240 g of vegetables in a 500 kcal lunch is sufficiently satisfying, despite the low energy content, and potentially leads to the prevention of obesity and control of body weight. Thus, appetite might also be influenced by methods of cooking vegetables (33), which should be investigated in the future. The limitations of this study include the limited range of characteristics of the participants (administrative staff) and their dietary habits regarding fat intake. Further research is required to assess a more diverse population sample as the results may differ in a study that includes persons with other dietary habits. As this was a short-term study, further long-term studies are needed with pre- and post-test blood sampling to investigate the effects of test meals on human subjects. Further research into the effects of dietary habits on appetite sensations or preferences would also provide valuable insight. It is also necessary to build algorithms to provide an effective diet pattern suitable for people with different dietary habits. Further evaluation of sensory properties is needed to address these points.

In conclusion, our findings demonstrate that the differences in dietary habits concerning fat intake are related to the appetite sensations after meals, depending on CD. Furthermore, this study suggests that increasing meat consumption in low-CD diets is more effective in suppressing appetite in Japanese people with dietary habits of high fat intake.

ACKNOWLEDGEMENTS

There are no conflicts of interest in this study. This study was supported by Grants-in-Aids for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology, Japan (Research theme number : 26282024), and a scientific research project grant from the Developing Innovation Systems Regional Innovation Strategy Support Program, Japan.

HY-O designed research ; HY-O, BZ, CA and YK conducted the research ; HT and BZ collected the data ; HT and TK extracted the data and performed the analysis ; HT wrote the paper ; HY-O, ET, BZ, MM and YT contributed to updating the review. All authors reviewed and approved the final manuscript.

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