

CHANGES IN BLOOD GLUCOSE CONCENTRATION AND THE DEVELOPMENT OF SENSORY SPECIFIC SATIETY IN YOUNG ADULTS WITH DIFFERENT BODY MASS INDEX

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The aim of the study was to assess the effect of nutritional status of the organism on the sensory specific satiety (SSS) in young adults and to determine the relationship of blood glucose concentration and SSS. The study was carried out on a set of 18 individuals (6 persons in each group with BMI values: <20, 20-25 and >25 kg/m², respectively), which rated the pleasantness of foodstuffs with different sensory properties (milk chocolate, crackers, grapefruit and apples) before and after *ad libitum* consumption of milk chocolate. The SSS was observed in all the tested individuals, irrespective of their BMI value. No statistically significant correlation was found between the change in blood glucose concentration 2 minutes after the consumption of chocolate and the occurrence of SSS. A dependence between these parameters was found 60 min after chocolate consumption.

INTRODUCTION

Sensory specific satiety (SSS) is manifested in the decreasing satisfaction felt along with eating as a result of reaction to the palatability of the currently consumed food, at the simultaneous lack of changes or increased interest in food with different sensory properties [O'Doherty *et al.*, 2000]. The development of this phenomenon and its intensity are dependent on sensory properties of food consumed [Bell *et al.*, 2003; Guinard & Brun, 1998; Rolls *et al.*, 1999; Rolls & Rolls, 1997; Vickers *et al.*, 1998] and the capacity of the organism to detect stimuli generated by food [Rolls & McDermott, 1991; Rolls, 1993, 1999]. The discussed type of satiety may have a negative effect on nutritional status, as it was shown by Rolls & de Waal [1985] when investigating refugees from Ethiopia, who changed the nutritionally balanced, but monotonous diet provided to them, with a sensory more attractive diet, but poorer in nutrients. On the one hand, SSS contributes to the consumption of diverse products within one meal, and as it was suggested by Hetherington [1996] it affects the selection of food at the next consumption, promoting the balancing of the diet in terms of its nutritive value [Rolls *et al.*, 1981]. On the other hand, SSS being essential for the maintenance of energy balance [Hetherington, 1996], when products differing sensory are being offered for a prolonged time may lead to overconsumption and the development of overweight and obesity.

According to the glucostatic theory [Anderson, 1996] the intake of food is closely connected with changes in blood glucose concentration. After-consumption hyperglycemia is accompanied by the sensation of satiety and loss of appetite. In turn, a decrease in glucose level (hypoglycemia) deter-

mines the occurrence of the sensation of hunger.

Thus the aim of this study was to assess the intensity and duration of sensory specific satiety in young adults with normal body weight, underweight and overweight and to determine whether there is a potential relationship between SSS and changes in blood glucose level in the examined individuals.

MATERIALS AND METHODS

The study was realized with the participation of 18 young adults, including 9 women (20.8±2.0 years) and 9 men (21.2±0.8 years), meeting the requirements and conditions of testing given by Hetherington [1996] and Rolls *et al.* [1988]. The examined individuals were divided into three groups characterized by different nutritional status, which were defined on the basis of the BMI value [WHO, 1988]. The first group consisted of underweight individuals with BMI<20 kg/m² (on average 18.5±0.6 kg/m²), the second – individuals with normal body weight, for which BMI ranged from 20 to 25 kg/m² (on average 22.4±0.9 kg/m²), while the third of people with overweight and BMI>25 kg/m² (mean 27.4±2.7 kg/m²). Each group consisted of 3 women and 3 men.

Sensory specific satiety was tested using a modified method presented by Hetherington [1996], based on a specially developed questionnaire. At the beginning of the study the participants were asked not to consume food at least 3 h prior to the initiation of the test and they assessed the degree of their sensation of hunger (satiety) using a 100 mm visual analogue scale, marked on the left end with "very hungry" and on the right end with "very satiated". Next the respondents determined the pleasantness of 5-g samples of foodstuffs with different sensory properties (milk chocolate,

crackers, grapefruit, apples) using a 100 mm visual analogue scale with margin markings: “very unpleasant” and “very pleasant”. Each participant was also provided with mineral water “Zywiec Zdrój” with a low mineral content to rinse their mouth. After evaluation the tested individuals ate milk chocolate „Milka” until satiated. Each member of the panel consumed chocolate *ad libitum* (within max. 15 min), with the weight of consumed chocolate recorded and used to calculate the amount of energy intake. Directly after consumption examined individuals were again asked to rate their hunger (satiety). After 2, 10, 30, 60 and 90 minutes since the completion of the meal the participants again assessed the pleasantness of tested products. Individual series of tests were recorded on separate charts, thus preventing a possible comparing of results and being influenced by them. A measure of SSS were differences in the ratings of pleasantness of a given product before and after consumption of chocolate. Blood was collected from the tested individuals before the initiation of the assessment and 2 and 60 min after the consumption of chocolate and glucose concentration was determined using the enzymatic method [Burrin & Price, 1985].

A one-way analysis of variance, Student’s t-test for paired and unpaired samples and the analysis of correlation and regression were used for the purpose of statistical verification of the results [Stanisz, 1998]. All the calculations were performed using a STATISTICA PL v.7.1 software package.

RESULTS AND DISCUSSION

Table 1 presents changes in ratings of pleasantness of tested products 2 and 60 min after the consumption of milk chocolate. As it results from the presented data, chocolate consumption caused SSS in the examined individuals, with the intensity showing a certain relationship with the body mass index value. The highest decrease of rating of pleasantness of chocolate 2 min after its consumption was recorded in the

group of individuals with BMI exceeding 25 kg/m² (77.6%), while the lowest in the group with BMI < 20 kg/m² (55.0%). In the case of the other tested products after chocolate consumption non-significant changes were observed on their evaluated pleasantness, with an upward trend for these ratings in the group with BMI > 25 kg/m². These results seem to confirm earlier reports by Snoek *et al.* [2004], who when investigating women with normal body weight and overweight showed that the nutritional status of the organism does not have a significant effect on the development of SSS.

As it results from Figure 1, the highest decrease in pleasantness rating of milk chocolate was found 2 min after its consumption to satiety, while the bigger the decrease, the faster the trend to return to the initial level of pleasantness was observed. However, in no case pleasantness reached its level from before consumption. The results obtained confirm reports by other authors [Hetherington *et al.*, 1989; Rolls & Rolls, 1997] that SSS occurs within 2 min after consumption, when there has been little opportunity for digestion and absorption, and it is specific for the sensory aspect of products.

No significant correlation was found between the amount of energy intake with chocolate and the change in the perceived level of its pleasantness 2 min after consumption, which shows that generated satiety was sensory specific and the observed change in pleasantness did not depend on the amount of energy intake. This confirms the results of previous studies [Bell *et al.*, 2003; Galiński & Gawęcki, 2000; Galiński *et al.*, 2004], in which it was shown that the energy value of a meal does not affect the development of SSS. Also the dependence between a change in the sensed pleasantness of a product consumed *ad libitum* and the declared satisfaction of hunger turned out to be statistically non-significant, which is another piece of evidence on the SSS caused by chocolate.

As it results from Table 2, no significant correlation was found between changes in blood glucose concentration in the tested individuals 2 min after the completion of chocolate

TABLE 1. Changes in pleasantness ratings of tested products 2 and 60 minutes after *ad libitum* consumption of milk chocolate (mm).

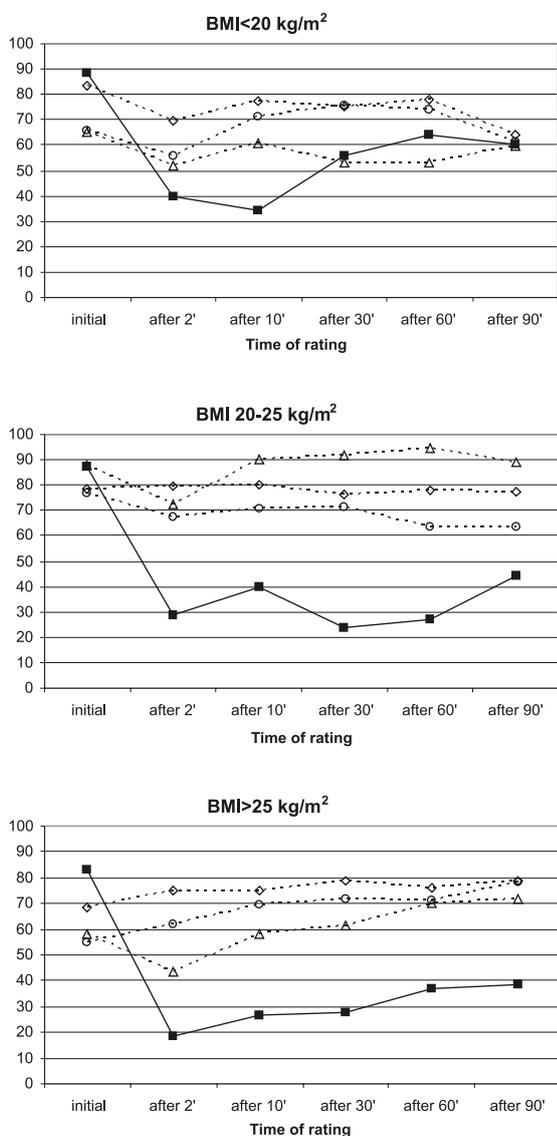
Time of evaluation	BMI (kg/m ²)	Milk chocolate	Crackers	Grapefruit	Apple
2 min after consumption of chocolate	<20	-49 ± 8 ^{***} (-55.0)	-14 ± 7 ^{bc} (-16.4)	-13 ± 8 ^{bc} (-20.0)	-10 ± 17 ^{ac} (-15.0)
	20-25	-59 ± 11 ^{***} (-67.0)	1 ± 12 ^b (1.1)	-16 ± 17 ^b (-17.8)	-9 ± 5 ^b (-11.7)
	>25	-65 ± 13 ^{***} (-77.6)	7 ± 6 ^c (9.5)	-14 ± 9 ^b (-24.7)	7 ± 9 ^c (13.4)
	Significance of differences	ns	ns	ns	ns
60 min after consumption of chocolate	<20	-25 ± 8 ^{a*} (-27.9)	-5 ± 15 ^a (-6.4)	-12 ± 19 ^a (-18.2)	9 ± 11 ^a (13.2)
	20-25	-60 ± 14 ^{a***} (-69.1)	0 ± 14 ^{bc} (0.0)	6 ± 3 ^c (7.2)	-13 ± 7 ^b (-17.2)
	>25	-46 ± 17 ^{a*} (-55.5)	8 ± 7 ^b (11.4)	12 ± 11 ^b (21.3)	16 ± 8 ^b (29.5)
	Significance of differences	ns	ns	ns	ns

Changes in pleasantness rating = rating after 2 (60) minutes after consumption – initial rating; in brackets a percentage change in pleasantness rating of tested products in relation to initial score. Significance of changes in pleasantness rating * - p < 0.05; ** - p < 0.01. Means (mean ± SEM) in the same lines denoted with different letters differ at significance level p < 0.05; ns – differences statistically non-significant

TABLE 2. Energy intake and changes in blood glucose concentration in tested individuals 2 and 60 minutes after consumption of chocolate and their correlation with changes in pleasantness ratings.

Parameter	All tested individuals n=18		Individuals with BMI<20 kg/m ² n=6		Individuals with BMI 20- 25 kg/m ² n=6		Individuals with BMI>25 kg/m ² n=6	
	after 2 min	after 60 min	after 2 min	after 60 min	after 2 min	after 60 min	after 2 min	after 60 min
Energy intake (kcal)	790 ± 77 ^a		822 ± 180 ^a		831 ± 133 ^a		718 ± 112 ^a	
Change in blood glucose concentration* (mg/dL)	19 ± 3	-2 ± 5	15 ± 6	-7 ± 5	22 ± 7	7 ± 9	15 ± 6	0 ± 8
Parameter	Change in pleasantness rating of milk chocolate (Table 1)							
Energy intake	r=0.047 ns	r=-0.410 ns	r=0.908 p<0.05	r=0.354 ns	r=-0.263 ns	r=-0.886 p<0.05	r=-0.636 ns	r=-0.834 p<0.05
Change in blood glucose concentration	r=-0.256 ns	r=0.525 p<0.05	r=-0.250 ns	r=-0.947 p<0.01	r=0.005 ns	r=-0.576 ns	r=-0.452 ns	r=-0.134 ns

Means denoted with identical letters do not differ at significance level p<0.05. * Change in glucose concentration = glucose level 2 (60) minutes after consumption – initial glucose level. ns – Interdependence statistically non-significant.



consumption and the change in the pleasantness rating of FIGURE 1. Dynamics of changes in pleasantness ratings of tested products (■ - milk chocolate, ◇ - crackers, △ - grapefruit, ⊕ - apple) after *ad libitum* consumption of milk chocolate.

chocolate, which shows that sensory specific satiety is not dependent on changes in blood glucose concentration. Sixty minutes after consumption this correlation turned out to be stronger (except for the group with BMI>25 kg/m²), especially in the case of individuals with BMI<20 kg/m².

CONCLUSIONS

1. Consumption to satiety of milk chocolate caused in young adults sensory specific satiety irrespective of their body mass index, with the intensity of SSS being lower in underweight individuals than in those with normal body weight and overweight.
2. The perceived decrease in pleasantness rating of milk chocolate was found to be strongest 2 min after its consumption until sated. The stronger the decrease, the faster the trend to return to the initially perceived pleasantness of the product.
3. The decrease in the pleasantness rating of milk chocolate caused by sensory specific satiety was independent of the amount of consumed chocolate (energy) and changes in subjective perceived satiety.
4. No significant correlation was found between the occurrence of sensory specific satiety and the change in blood glucose concentration 2 and 60 min after the consumption of milk chocolate, with the exception of individuals with BMI<20 kg/m².

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ZMIANA POZIOMU GLUKOZY WE KRWI A ROZWÓJ SYTOŚCI SENSORYCZNEJ SPECYFICZNEJ U LUDZI MŁODYCH O ZRÓŻNICOWANYM WSKAŹNIKU MASY CIAŁA BMI

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Celem pracy była ocena wpływu stanu odżywienia organizmu na występowanie zjawiska sytości sensorycznie specyficznego (SSS) u ludzi młodych oraz określenie związku pomiędzy zmianą poziomu glukozy we krwi a SSS. Badania realizowano z udziałem 18 osób (po 6 osób w grupach o BMI: <20, 20-25 i >25 kg/m²), które określały smakowitość produktów spożywczych o odmiennych właściwościach sensorycznych (czekolada mleczna, krakers, grapejfrut i jabłko) przed i po spożyciu do syta czekolady mlecznej. Stwierdzono występowanie SSS u badanych osób, niezależnie od ich wskaźnika BMI. Nie wykazano istotnego statystycznie związku pomiędzy zmianą poziomu glukozy we krwi po 2 minutach od spożycia czekolady a występowaniem SSS. Zależność pomiędzy tymi parametrami stwierdzano natomiast po 60 minutach od spożycia czekolady.