GLYCAEMIC INDEX OF SELECTED FOODSTUFFS IN HEALTHY PERSONS

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Aims: The aim of this study was to determine glycaemic index (GI) of 10 popular foodstuffs/mixed meals in healthy persons.

Methods: Ten tested foodstuffs and glucose standard were consumed in three replicates in the course of a defined 9-day meal plan: puffed rice squares with chocolate, dark chocolate, white bread, honey and glucose for breakfast (at 7 a.m.) and dinner (at 8 p.m.); pasta with meat, fried fish with mashed potatoes, and buttered apricot dumplings for lunch (at 12 a.m.); wafers, puffed spelt squares with chocolate, and tomato soup for snack (at 4 p.m.). Each portion contained 50 g of carbohydrates and was consumed within 30 minutes. Glucose concentrations were measured by means of the Continuous Glucose Monitoring System (CGMSTM, Medtronic Minimed, Northridge, CA, USA). The results were processed by Solutions Software (Medtronic Minimed, Northridge, CA, USA) and DegifXL4 software, Palacký University, Olomouc, CZ. Twenty healthy persons aged 21.9 ± 1.39 y (mean $\pm$ SE), BMI 23.6 ± 0.63 kg/m² completed the study.

Results: GI of tested foodstuffs ranged from 34.7 % (chocolate) to 105.3 % (puffed rice squares with chocolate). There were more than tenfold differences between minimal and maximal values of the GI for some foodstuffs. Significant interindividual differences were found between GIs of foodstuffs.

Conclusions: In twenty healthy persons the glycaemic indexes of ten popular foodstuffs were determined, to be added to the nutritional labels in order to facilitate the optimum meal planning.

INTRODUCTION

Glycaemic index (GI) is a measure of the hyperglycaemic power of food related to glucose. Since the pioneer papers of Otto¹ and Jenkins² it has become an important part of nutritional labels³ in many countries. However, the GI may be influenced by various factors, so that the determined values cannot be automatically transferred from one centre to another.

At The Faculty of Medicine of Palacký University, Olomouc attempts to determine the GI started in 2004, originally using the traditional methods^{4–6} and recently also a new method based on CGMS and Software Solutions^{7–12} and DegifXL^{13, 14}. Until now, the GI of only 6 foodstuffs had been determined. The aim of the present study was to determine the GI for other 10 popular foodstuffs/mixed meals.

MATERIALS AND METHODS

The study was performed in January and February 2007 as a part of the project DEGIF (IGA NR 7825-3).

Subjects

Twenty-five healthy persons gave their informed consent according to the Declaration of Helsinki approved by the local Ethics Committee and entered the study. There were five dropouts due to intercurrent illness. Twenty persons aged 21.9 ± 1.39 y (mean $\pm$ SE), BMI 23.6 ± 0.63 kg/m², completed the study.

Tested foodstuffs

Ten different foodstuffs/mixed meals with a known content of nutrients (Table 1) were tested. The tested meals were chosen from five different compartments of food: sweets, bakery, rice and spelt products and mixed meals. The choice of foods was also influenced by the amount of carbohydrates in one labeled marketed food package which should yield servings with $50 \text{ g} \pm 5 \%$ of carbohydrates each. The portions were professionally prepared in the expected quality and quantity.

The foodstuffs were divided into 3 groups according to the time of consumption:

1. Foodstuffs for breakfast and dinner, consumed at 7 a. m. and 8 p.m.
2. Foodstuffs for lunch, consumed at 12 a.m.
3. Foodstuffs for snack, consumed at 4 p.m.

Table 1. Content of nutrients and energy in one portion of tested foodstuff

	Content of nutrients and energy			
	CHO [g]	Lipids [g]	Proteins [g]	Energy [kJ]
Meals for breakfast and dinner				
Puffed rice squares Racio with dark chocolate	50	19	7	1649
Dark chocolate	50	62	13	3403
White bread Penam	50	3	8	1133
Lime-blossom honey	50	0	0	808
Glucose solution	50	0	0	850
Meals for lunch				
Tin of Ravioli pasta with meat Heinz, Eidam cheese Promil from Krkonoše	50	32	36	1615
Fried fish Delvita, Mashed potatoes in powder Natura, Fresh butter Madeta	50	34	16	2395
Apricot dumplings Delvita, Fresh butter Madeta	50	27	55	2168
Meals for snack				
Kolonáda Wafers Opavia	50	31	4	2091
Puffed spelt squares Racio with chocolate	50	22	9	1754
Tomato soup Vitana	50	3	6	1077

CHO-carbohydrates

Table 2. Defined meal plan: a total of 32 servings of ten foodstuffs and standard (glucose)

Day	Breakfast 7 a.m.	Lunch 12 a.m.	Snack 4 p.m.	Dinner 8 p.m.
1	-	1 - Ravioli pasta, cheese	2 - Puffed spelt squares	3 - Dark chocolate
2	4 - Glucose	5 - Mashed potatoes, fried fish, butter	6 - Wafers "Kolonáda"	7 - Puffed rice squares
3	8 - White bread	9 - Buttered apricot dumplings	10 - Tomato soup	11 - Lime-blossom honey
4	12 - Dark chocolate	13 - Ravioli pasta, cheese	14 - Puffed spelt squares	15 - Glucose
5	16 - Puffed rice squares	17 - Mashed potatoes, fried fish, butter	18 - Wafers "Kolonáda"	19 - White bread
6	20 - Lime-blossom honey	21 - Buttered apricot dumplings	22 - Tomato soup	23 - Dark chocolate
7	24 - Glucose	25 - Ravioli pasta, cheese	26 - Puffed spelt squares	27 - Puffed rice squares
8	28 - White bread	29 - Mashed potatoes, fried fish, butter	30 - Wafers „Kolonáda“	31 - Lime-blossom honey
9	reserve	32 - Buttered apricot dumplings	-	-

Taking into consideration the content of nutrients and energetic values in each meal a defined meal plan was created (Tab. 2).

Each foodstuff was consumed in three replicates, except for soup, which was consumed two times only.

Energetic values of tested foodstuffs for the whole day were 6000–9000 kJ (Tab. 3).

Study design

1. CGMS sensor^{15–17}, which was inserted subcutaneously into gluteal or lumbar region.

- Each volunteer received personal glucometer Advance (Hypoguard, Woodbridge, UK) and 50 Microdraw strips for calibration of the CGMS.
- Volunteers were trained in handling the CGMS¹⁸. The average of two plasma glucose measurements on a glucometer Advance was taken to calibrate the CGMS every 12 hours.
- In the course of 9 test days, each volunteer entered the exact times of eating, exercise, glucose concentration measured on a glucometer and data on the function of the CGMS into the protocol.
- Every person received 32 servings of tested foods and the 9-day defined meal plan (Table 2).
- Every volunteer was encouraged to drink 400 ml of water or unsweetened tea together with each meal. No drinks were to be taken one hour before the meal start and two hours afterwards. Each meal was to be consumed within 30 minutes¹⁹.
- Any differences in the daily routine were noted in the protocol.
- Having accomplished the meal plan, data were downloaded from the CGMS monitors into the PC to calculate the GIs using the Software Degif XL4 (Ref.²⁰), revised, manually corrected and completed according to protocols. The area under the curve has always been calculated for the period of time between 0 and 120 min.

Table 3. Total daily content of nutrients and energy in meals in the course of 9 test days.

Day	CHO [g]	Lipids [g]	Proteins [g]	Energy [kJ]
1	150	116	59	8060+
2	201	83	28	7150
3	202	33	68	5910
4	200	116	59	8920
5	203	87	36	7460
6	200	91	74	8230
7	198	73	52	7110
8	205	68	29	6630
9	48	27	55	2790++

+ except breakfast (only 3 test meals planned for the day 1)

++ except breakfast, snack and dinner (only 1 test meal planned in the day 9)

CHO-carbohydrates

Table 4. GIs of selected foodstuffs. GI group: low (L), medium (M), high (H).

No.	Foodstuff	Number of tests	GI _{min} (%)	GI _{max} (%)	GI _{mean} (%)	SE	GI group
1	Glucose	50	100.0	100.0	100.0	0.0	H
2	Dark chocolate (CHOC)	34	1.0	79.0	*34.7	5.8	L
3	Puffed rice squares (RICE)	45	32.0	328.0	105.3	17.6	H
4	White bread (BREAD)	50	26.3	144.7	93.3	7.4	H
5	Lime-blossom honey (HONEY)	48	24.3	169.3	76.7	8.4	H
6	Ravioli pasta, cheese (RAV)	48	0.0	110.9	*43.3	6.8	L
7	Mashed potatoes, fried fish, butter (POT)	52	19.9	236.6	94.0	13.7	H
8	Apricot dumplings, butter (DUMP)	41	26.4	221.1	75.0	12.8	H
9	Puffed spelt squares (SPAL)	41	22.8	141.4	*63.7	8.1	M
10	Wafers "Kolonáda" (CAKE)	44	23.2	256.5	77.8	13.2	H
11	Tomato soup (SOUP)	28	0.0	211.3	*38.5	12.1	L
	Total	491					

*p < 0.05 in comparison to glucose

Fig. 1. Boxgraph: Variation of GIs of tested foodstuffs in comparison to glucose (medians and quartiles, ° outliers, * extreme values). For abbreviations of foods see Table 4.

Statistical analysis

MS Excel and the statistical program SPSS v. 14.0 (SPSS Inc., Chicago, IL, USA) were used to analyze the data: An ANOVA was applied to compare the GIs of tested foods; $p < 0.05$ was considered statistically significant.

RESULTS

In comparison to glucose (GI = 100 %), four tested foodstuffs (dark chocolate, Ravioli pasta with cheese, puffed spelt squares, tomato soup) were found to have lower GI ($p < 0.05$). No significant difference in glucose was found for the 6 other foodstuffs (puffed rice squares, white bread, lime-blossom honey, mashed potatoes with fried fish and butter, apricot dumplings with butter, wafers “Kolonáda”).

Taking into consideration the traditional GI derived categories of foods, our results allow us to divide the tested foodstuffs/mix meals as follows:

1. group L: foods with low GI (GI ≤ 55 %): dark chocolate, Ravioli pasta with cheese, tomato soup
2. group M: foods with medium GI (GI = 56–69 %): puffed spelt squares
3. group H: foods with high GI (GI ≥ 70 %): puffed rice squares, white bread, honey, mashed potatoes with fish fingers and butter, buttered apricot dumplings, wafers “Kolonáda”.

See Table 4 and Figure 1 for details.

DISCUSSION

The glycaemic index is an important component of nutritional labels. International tables containing the GIs of

about 750 different foodstuffs have been published³. The GIs of selected tested foodstuffs correspond to values of GI reported before. It is known that the GI of foods has a large inter- and intraindividual variability due to various factors. In this study we found more than tenfold difference between minimal and maximal values of the GI for some foodstuffs. Nevertheless, this finding corresponds with the findings of other authors²¹.

We applied the CGMS to investigate the GIs. The values of GI obtained by this method were not statistically different from values obtained by conventional method²². The CGMS sensor was safe for measuring the plasma glucose in the course of 9 days²³. The function and accuracy of glucose sensors inserted for more than 3 days was also demonstrated²⁴. In our study a total of 640 tests with 11 meals were performed and 491 (77 %) of these were complete and suitable for further evaluation²⁰.

Conventional methods for GI determination involve usually ten healthy persons and tests are performed in the morning hours following overnight fast. In our study 20 healthy persons were tested to increase the precision of the outcomes. In order to increase the capacity of the investigational period not only breakfasts but also lunches, snacks and dinners were used. However, the real benefits of this study design remain to be established. Additionally, it is important to evaluate the glycaemic profiles of individuals in response to a given food e.g. the glycaemic response to a mixed meal²⁵ or to a complex food such as pizza.

CONCLUSIONS

In conclusion it may be said that the determined GIs of ten popular foods can facilitate nutritional labels to enable optimum meal planning^{26, 27}. A low GI was found for three foodstuffs (dark chocolate, Ravioli pasta with cheese, tomato soup), medium in puffed spelt squares and high GI in six foodstuffs (puffed rice squares, white bread, honey, mashed potatoes with fish fingers and butter, buttered apricot dumplings, wafers “Kolonáda”). Further studies focused on other foodstuffs and mixed meals are necessary.

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