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Effect of oatmeal prepared with water or milk on the postprandial glycaemia and glycaemic index in healthy young women

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Abstract

Introduction and Objective. In the past years, oats have received increased attention from scientific researchers. Due to their properties, oats are considered to be a functional food or superfood with many opportunities. The aim of this study is to assess the effect of consuming oatmeal prepared with water or milk on glycaemic response in healthy young women.
Materials and Method. Seventeen healthy women, aged 19–22 years, participated in this study. Each participant consumed two portions of oatmeal prepared with water or milk (2% fat), containing 50 g of available carbohydrates. Glucose solution was provided as a reference food. Glycaemic index (GI) measurements were taken using standard methodology, and calculated according to the ISO 2010 standard.
Results. Fasting glucose levels were normal in all participants (average 81.74 ± 5.83 mg/dL). The incremental area under the glucose response curve (IAUC) after consumption of oatmeal with milk addition, was significantly lower than that after consumption of oatmeal prepared with water. The calculated GI of oatmeal prepared with water was significantly higher than the GI of oatmeal prepared with milk (58.4 vs. 44.5). According to the GI classification, oatmeal prepared with milk can be considered as a low GI product.
Conclusions. The study highlights the potential of oatmeal to play an important role in the prevention and treatment of type 2 diabetes. Oatmeal prepared with milk may be a better choice for people who need to control their glycaemia levels.

Key words

diet, glycaemic index, postprandial glycemia, oatmeal

INTRODUCTION AND OBJECTIVE

Oat (*Avena sativa* L.) is a very common and popular cereal with a unique chemical composition and many potential benefits for health. In terms of global grain production, oats intended for animal feeding and human consumption occupy the sixth position, behind maize, wheat, rice, barley, and sorghum. Major producers and users of oats include EU member states, Russia, Australia, the USA, and Brazil [1, 2]. Oats, primarily considered as animal feed, have been known for thousands of years. Currently, it is one of the most commonly cultivated cereals worldwide, mainly used in breakfast cereals and snack bars. However, due to the continuous development of cereal processing technology, various oat-based foods, such as whole grains, oat groats, flakes (steel-cut, ground), flour, bran, oatmeal, bread, muffins, biscuits, oatcakes, oat-beverages, and oat-based alternative to yogurt, are commercially available to consumers in different countries [3]. New oat products have been introduced to the global market, such as fruit drinks enriched with oat β-glucans, fermented oat-based drinks with added *Lactobacillus plantarum*, and β-glucan formulation [4]. Some research highlights that processed oat products, including biscuits, bars, and instant meals, can contain more than 10 g of sucrose per serving, and more than 200 kcal [4].

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Oats are rich in carbohydrates (51–65%), protein (13–20%), fat (4–10%; 80% of unsaturated fatty acids), dietary fibre (8–30%; 1.8–7% of β-glucan), and phenolics (avenanthramides, p-hydroxybenzoic acid, ferulic acid, vanillic acid). They are also an important source of essential and trace elements, including calcium, magnesium, zinc, phosphorus, potassium, iron, as well as B-group and E vitamins. Their high protein and fat content distinguish them from other cereals. Scientific evidence indicates that oat consumption contributes to improved health by attenuating glycaemic response, reducing glucose and insulin concentrations after meals, lowering total and LDL cholesterol, modulating intestinal microbiota, and helping to maintain normal blood pressure [1–5]. It is therefore not surprising that oats are becoming increasingly popular around the world as an important food in a healthy diet. Studies have shown that regular consumption of at least three servings of whole grain products from various cereals, including oats, can reduce the risk of several chronic diseases (1 serving – 16 g) [5].

The intake of whole grains is recommended in the dietary guidelines and nutritional policies of many countries worldwide as a simple strategy to improve glycaemic control [6]. However, whole grain products may differ in carbohydrate content, their quality, and effect on glycemia and human health [7]. An important tool used to classify carbohydrate-containing foods is the Glycaemic Index (GI). This system allows the catagorization of foods based on their postprandial glycaemic response compared to a standard reference food [8]. Consumption of foods with low GI may be helpful in reducing body weight, and better glycaemic control

among people with diabetes or other metabolic disorders. Diets based on low GI products may also protect against cardiovascular diseases [9]. Therefore, the research on the GI of various whole grain products and various grain-containing meals appears justified.

One of the most common and traditional dishes made from oats is oatmeal/porridge, which is prepared by stewing oats in a heated liquid, such as milk, water, or plant-based beverages, and usually served as a warm breakfast. Nowadays, overnight oatmeal is becoming increasingly popular, and often served accompanied by fresh or dry fruits, nuts, seeds or nut butter. The impact of oatmeal on glycaemic control varies based on several factors, such as preparation methods, type of oat-flakes, serving size, duration of consumption and liquid used for preparation.

The GI tables developed by Foster-Powell et al. and Atkinson et al., as well as several other publications, showed that the glycaemic index of oatmeal prepared with milk is lower than that of oatmeal prepared with water. However, these values originated from studies that used different methodologies and may be difficult to compare objectively [2,10,11].

The current study was conducted in a homogeneous group of young women using a standardized protocol. The trial by Law et al. is worth noting, in which the effect was examined of dairy and non-dairy beverages consumed with a high-glycaemic cereal on postprandial glycemia in young adults. Lower glycaemic response and higher insulin concentrations were observed following the consumption of cereal with dairy beverages, compared with the consumption of cereal with water; however, GI values for the tested products were not calculated [12]. The aim of the current study is to evaluate the effect of oatmeal prepared with water or milk on postprandial glycemia and GI in a healthy adult population, according to standard procedures.

MATERIAL AND METHODS

Study group. Seventeen healthy female participants were enrolled in the study at the University of Life Sciences in Warsaw, Poland. Eligibility criteria included age between 18 – 25 years, normal glucose tolerance, and body mass index (BMI) within 18.5 – 30.0 kg/m^2. Participants had to be in good health, not take any medications or supplements that could affect carbohydrate metabolism, and not suffer from any food allergies or intolerances. Exclusion criteria encompassed pregnancy or breastfeeding, the presence of chronic diseases such as diabetes, cardiovascular disorders, metabolic syndrome, cancer, liver or kidney diseases, celiac disease, or mental illness. Individuals who were underweight (BMI < 18.5 kg/m^2) or obese (BMI > 30 kg/m^2) or who were following restrictive or therapeutic diets were also excluded from the study. The sample size was determined following the ISO guidelines for glycaemic index determination [8].

Recruitment for the study was conducted using a snowball sampling method. Individuals potentially interested in participation received an information leaflet detailing the inclusion and exclusion criteria, which ensured that most of those who presented for screening met all eligibility requirements. Of the 19 individuals who volunteered, 2 were excluded due to low body weight.

All individuals received detailed information on the objectives and procedures of the study and signed written informed consent forms. The qualification for the study was provided by a physician. All study sessions were conducted in September 2020, performed in accordance with the Declaration of Helsinki, and approved by the Rector's Ethics Committee for Research Involving Human Participants at the Warsaw University of Life Sciences SGGW (Resolution No. 52/2019).

Study design. The study was conducted in accordance with the standard GI measurement methodology specified in the International Standard ISO 26642:2010 [8]. Each participant attended seven meetings, including one screening meeting and six meetings for blood glucose measurements after consuming glucose (as a standard), and two tested meals.

Before each of the six days of measurements, participants were asked to fast for at least 12 hours and to refrain from intense physical exercise. Each participant was instructed to follow a standard diet on the days preceding the test sessions, to avoid meals high in simple sugars and fat, and to abstain from alcohol. During the screening session, anthropometric measurements were taken, including height (accuracy 0.1 cm) and weight (accuracy 0.1 kg). BMI was calculated using the standard formula [body weight (kg)/height^2 (m^2)] and then categorized in line with WHO standards [13].

During the remaining, non-consecutive days of the study, participants ingested: (1) a reference food consisting of 50 g of anhydrous glucose dissolved in 250 mL of water; (2) one serving of oatmeal cooked with water; and (3) one serving of oatmeal cooked with milk. Test meals were initiated at 8:00 a.m., and they were consumed within a 12 – 15 minute timeframe. Each meal was administered in duplicate, with a two-day washout interval separating study days [8].

Postprandial glycaemia and GI were determined based on capillary blood glucose measurements using standard Accu-Check glucometers (Roche Diabetes Care Polska) and test strips. A dry enzymatic technique was used to determine glucose levels. Single measurements were taken at the following time intervals: fasting (0 min), 15, 30, 45, 60, 90, and 120 minutes after consumption of reference glucose or a test meal [8].

Tested meals. Oatmeal for the study was prepared using commonly available rolled oat flakes, purchased in a supermarkets. All participants consumed the same amount of oatmeal, prepared in two versions: 1) with the addition of water (OW); 2) with the addition of pasteurized milk with a fat content of 2% and standard lactose content (4.8 g/100 g, according to the manufacturer's declaration) (OM). This type of milk was selected as the most popular among consumers and recommended in healthy eating guidelines. The recipe for preparing the oatmeal was as follows: 365 ml of water was boiled with a pinch of salt; 72.5 g of oat flakes were added to the boiling water and cooked for 1 minute; the oatmeal was left for 15 minutes and then served for consumption. The same method was used to prepare oatmeal with milk: 260 ml of milk and 54.5 g of rolled oats were used. Due to organizational constraints, the order of test meal administration was not randomized.

The amounts of ingredients used to prepare both types of oatmeal (OW and OM) were calculated for a 50 g of available carbohydrate content in each version of the tested meal. The nutritional composition of OW and OM is shown in Table 1.

Table 1. Nutritional value of one serving of tested meals

Nutrients	Oatmeal with water – OW	Oatmeal with milk – OM
Available Carbohydrate (g)	50.0	50.0
Dietary fibre (g)	6.5	4.9
Fat (g)	5.5	9.3
Saturated fatty acids (g)	1.0	4.8
Protein (g)	10.2	16.0
Calories (kcal)	303.1	357.8

Calculations of nutritional value were made for 1 portion of served oatmeal providing 50 g of available carbohydrates using information provided by manufacturer

Calculations of GI. GI values were calculated in accordance with the ISO 2010 standard [8]. The GI of each test meal was defined as the ratio of the incremental area under the blood glucose response curve (IAUC) following oatmeal consumption to the IAUC following ingestion of 50 g of glucose (considered GI = 100). The GI for each oatmeal preparation was obtained by averaging these ratios across all participants. The IAUC was computed for each subject and meal using the trapezoid method; GI was derived from the formula:

$$GI^{*} = \left(\frac{IAUC\ test\ food}{IAUC\ glucose\ standard}\right) \times 100$$

*GI – glycaemic index; IAUC—incremental area under the blood glucose response curve.

Statistical analysis. Data are presented as average values with standard deviations (SD). The normality of variable distributions was verified using the Shapiro–Wilk test. For variables with a normal distribution, the effect of the test meals on blood glucose responses was evaluated using one-way repeated-measures ANOVA; Friedman's test was applied for non-normally distributed variables. Comparisons of the incremental area under the glycaemic curve and the glycaemic index between meals were conducted using ANOVA, followed by Fisher's LSD *post-hoc* test for parametric data, and the Kruskal–Wallis test followed by Dunn's *post hoc* test with Bonferroni correction for non-parametric data. A significance threshold of $p < 0.05$ was adopted, unless otherwise specified. Statistical analyses were carried out with STATISTICA 13.1 software (TIBCO Software Inc., Palo Alto, CA, USA).

RESULTS

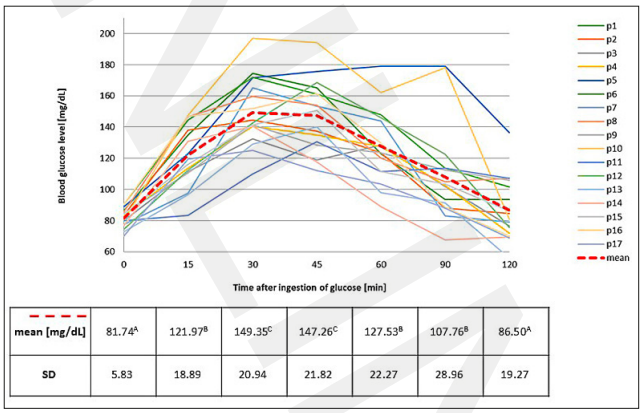
Seventeen young, healthy women participated in the study (average age 20.5 ± 1 year). All subjects presented with normal BMI values and fasting glucose levels within the reference range (70.0–90.5 mg/dL). The mean fasting glucose concentration across participants was 81.74 ± 5.83 mg/dL. A detailed description of the study group is provided in Table 2.

Physiological increases and decreases in blood glucose concentrations after intake of glucose solution were observed in all participants. Figure 1 presents fasting blood glucose concentrations measured at 15, 30, 45, 60, 90, and 120 minutes following glucose intake. Fifteen minutes after consuming the glucose solution, blood glucose levels increased significantly. For 11 participants the highest glucose concentration was recorded after 30 minutes of standard (glucose) ingestion. In five participants the peak was found after 45 minutes, and in one person after 60 and 90 minutes after the glucose intake. In all participants, blood glucose concentrations remained within normal limits (after glucose consumption < 200 mg/dL; after 120 minutes < 140 mg/dL).

Table 2. Characteristics of study participants (n=17)

Characteristics	Mean	SD	Range
Age (years)	20.5	1.0	19–22
Height (cm)	166.2	5.3	160–177
Weight (kg)	59.4	7.7	48–80
BMI (kg/m^2)	21.6	2.5	18.5–26.6
Fasting blood glucose (mg/dL)	81.7	5.8	70.0–90.5

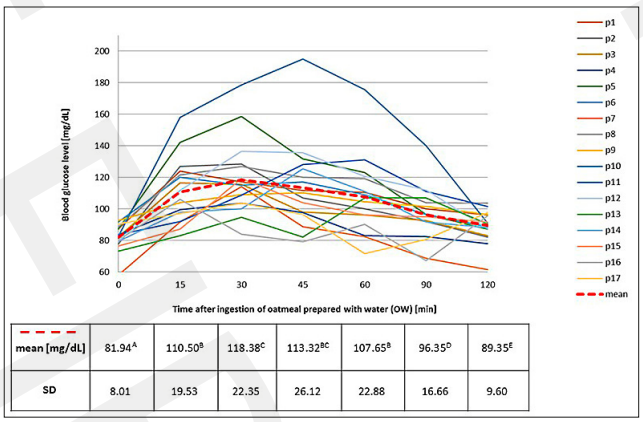
SD – standard deviation; BMI – body mass index



mean [mg/dL]	81.74^{A}	121.97^{B}	149.35^{C}	147.26^{C}	127.53^{B}	107.76^{B}	86.50^{A}
SD	5.83	18.89	20.94	21.82	22.27	28.96	19.27

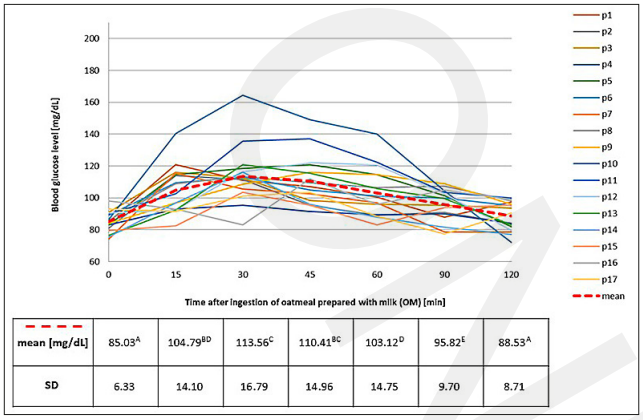
Figure 1. Individual and average glucose concentrations after consumption of glucose solution.
For variables with other letters, the difference is statistically significant between successive measurements – one-way ANOVA with repeated measurements ($p < 0.05$); n=17)

Individual and average glycaemic responses after OW and OM consumption are shown in Figures 2 and 3. Differing from the results after glucose consumption, the highest glycaemic values were recorded 15 minutes after ingestion of OW (in 2 subjects) and after ingestion of OM (in 4 subjects). The average glucose concentration peaked 30 minutes after consumption of OW and OM; however,



mean [mg/dL]	81.94^{A}	110.50^{B}	118.38^{C}	113.32^{BC}	107.65^{B}	96.35^{D}	89.35^{E}
SD	8.01	19.53	22.35	26.12	22.88	16.66	9.60

Figure 2. Individual and average glucose concentrations after consumption of oatmeal prepared with water (OW).
For variables with other letters, the difference is statistically significant between successive measurements – one-way ANOVA with repeated measurements ($p < 0.05$); n=17)



mean [mg/dL]	85.03^{A}	104.79^{BD}	113.56^{C}	110.41^{BC}	103.12^{D}	95.82^{E}	88.53^{A}
SD	6.33	14.10	16.79	14.96	14.75	9.70	8.71

Figure 3. Individual and average glucose concentrations after consumption of oatmeal prepared with milk (OM).
For variables with other letters, the difference is statistically significant between successive measurements – one-way ANOVA with repeated measurements ($p < 0.05$); n=17)

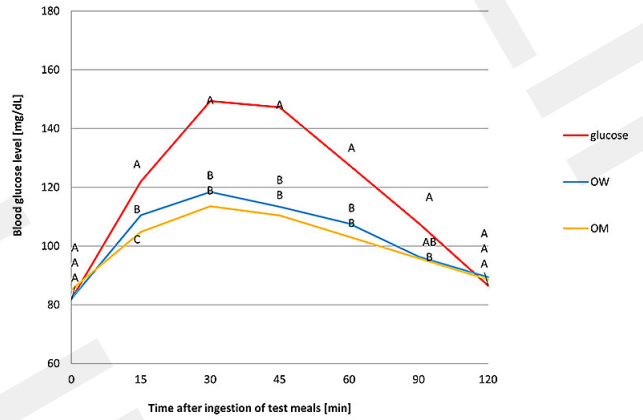


Figure 4. Change in mean blood glucose concentration after glucose, OW and OM ingestion. OW – oatmeal with water; OM – oatmeal with milk. For variables marked with other letters, the difference between blood glucose measurements at corresponding time points is statistically significant (Friedman's test; $p < 0.05$)

glucose levels after consumption of both types of oatmeal were significantly lower than after consumption of the glucose solution (Fig. 4). There was a significant difference between the measurements of glycaemic values ($p \leq 0.05$), with the exception of measurements at 90 and 120 minutes after consumption of oatmeal.

The IAUC after glucose consumption averaged 4,473.8 mg/dL/min, which was significantly higher than after consumption of OW and OM (Tab. 3). The results also indicated that IAUC after OM consumption was significantly lower than after OW consumption. The calculated GI of OW was significantly higher than the GI of OM (58.4 vs. 44.5). According to the GI classification, OM can be considered as a low GI product [10].

Table 3. IAUC values and Glycaemic Index of tested products

	Mean	SD	Median	p
IAUC after glucose (mg/dL x min)	4473.8	1882.0	3683.9	
IAUC after OW (mg/dL x min)	2624.7	1727.5	2471.3	0.002*
IAUC after OM (mg/dL x min)	1948.7	1031.9	1841.4	
GI OW	58.4	25.4	61.3	
GI OM	44.5	22.5	43.3	0.007**

IAUC- incremental area under the glucose response curve after tested meals; SD – standard deviation; GI – Glycaemic Index. *ANOVA analysis with Fisher's LSD test; **Kruskal-Wallis test

DISCUSSION

Oatmeal is a very popular, relatively cheap, and commonly available food. This study aimed to evaluate the effect of oatmeal prepared with either water or milk on postprandial blood glucose concentrations in healthy individuals The results indicate that oatmeal prepared with milk has a GI amounting to 44.5. Foods with a GI below 55 are categorized as low GI. The consumption of low-GI products, which do not cause rapid increases in blood glucose levels, may be advantageous for individuals with carbohydrate metabolism disorders and diabetes. The beneficial effects of oat products and oat β-glucans intake on blood glucose levels among people with or without diabetes have been established by many researchers [14–16]**.** Current data indicate that oats and oat β-glucan improve fasting and postprandial glycaemic parameters, and can complement therapeutic interventions in the management of type 2 diabetes [16]. These results are in alignment with the EFSA statement that 4 g of oat or barley β-glucan per 30 g of available carbohydrates is necessary to achieve a consistent reduction in postprandial glycaemia [17]. However, some researchers have argued that, considering the molecular weight of β-glucan, the minimum effective dose necessary to lower glycaemic response in healthy individuals without diabetes, is considerably lower than the EFSA recommendation [18]. The mechanism underlying this effect is attributed to the ability of β-glucan to increase the viscosity of gastrointestinal content, thereby delaying gastric emptying and slowing the digestion and absorption of carbohydrates in the small intestine [15, 19].

The results obtained in the current study indicate that regular oatmeal prepared with water has medium GI (58.4) – higher than oatmeal cooked with milk. In addition to the soluble fibre described above, other factors may lower the GI of oatmeal prepared with milk, including the protein (especially whey protein, bioactive peptides, branched-chain amino acids [BCAA] and lysine), milk fat, and milk carbohydrates (lactose, oligosaccharides).

Milk proteins can modulate postprandial glycaemia through several complementary mechanisms. Studies indicate that hydrolysates of milk proteins may inhibit carbohydrate-digesting enzymes; for example, they can reduce α-glucosidase activity, which has been shown to attenuate the postprandial glycaemic response [6]. Whey proteins, which are rapidly digested and rich in insulinotropic amino acids, exert both acute and longer-term effects on glucose metabolism. Their ingestion can enhance the insulin response and reduce the incremental area under the glucose curve (IAUC) thereby potentially improving postprandial blood glucose control [20, 21]. Bioactive peptides derived from milk proteins appear to influence glucose tolerance by stimulating the secretion of insulin and modulate incretin responses (e.g., GLP-1 and GIP) [21]. The addition of protein or a protein–fat combination to a carbohydrate-rich meal leads to a marked increase in postprandial concentrations of key glucose-regulating hormones. This was confirmed in a study in which high-protein and high-protein/high-fat meals resulted in a sustained increase in the GLP-1 level, compared with low-protein/low-fat meals [22].

Branched-chain amino acids (BCAAs: leucine, isoleucine and valine) and lysine also play an important role in the regulation of glucose metabolism and insulin secretion. Their effects on pancreatic β-cell function are the subject

of intensive research, particularly in the context of type 1 and type 2 diabetes and insulin resistance [23]. BCAAs can acutely stimulate insulin secretion and thereby contribute to lowering blood glucose levels; this insulinotropic effect has been documented after ingestion of BCAAs in various forms, including dairy products and dietary supplements [24]. There is ongoing debate about the long-term metabolic consequences of chronic exposure to elevated BCAA levels. Some studies suggest that high doses, often from supplements, may impair insulin sensitivity and potentially increase the risk of type 2 diabetes [24]. Lysine also affects insulin signalling pathways. Lysine has been reported to enhance insulin receptor tyrosine kinase (IRTK) and phosphatidylinositol-3-OH-kinase (PI3K) activities in human monocytes exposed to high glucose concentrations, which are crucial components of the insulin signalling cascade, resulting in improvements in blood glucose levels among patients with type 2 diabetes [25]. These data indicate that amino acids commonly present in milk, may have both beneficial and potentially adverse effects on glucose homeostasis, depending on dose, food matrix and individual metabolic status [2, 25].

The fatty acid profile of milk fat includes chains from 4 – 24 carbons, of which roughly two-thirds are saturated fatty acids, such as stearic and palmitic acid. The fat present in milk may affect the GI of oatmeal. However, it appears that it is not the fat content itself that matters, but rather its type and food matrix. Studies report that 14% of milk fatty acids belong to a group of milk-specific fatty acids, and their biological activity is receiving growing scientific attention [21]. Milk fat may also influence glycaemic control by acting on insulin signaling pathways. Animal studies suggest that dairy fat can enhance the activation of insulin-related signalling cascades in peripheral tissues, thereby augmenting insulin action. It may also contribute to delayed gastric emptying, which further reduces postprandial glycaemia [21].

Lactose in milk likewise affects postprandial glycaemia by being hydrolyzed to glucose and galactose. While glucose directly increases blood glucose concentrations, galactose has been shown to stimulate postprandial secretion of incretin hormones, such as GLP-1 and GIP which, in turn, enhance insulin release [21]. GLP-1 additionally slows down gastric emptying, further modulating the rate at which glucose enters the bloodstream [21]. Consequently, the overall effect of lactose on glycaemia reflects a balance between its relatively slow digestion and absorption, and the incretin-mediated enhancement of insulin secretion, giving rise to the characteristic glycaemic response observed after consumption of milk and dairy products.

The current study is in line with the results reported by other researchers in which the GI value of oatmeal ranged from 48 – 76. However, it should be emphasized that comparing the results of different studies is very difficult, if not impossible, because individual studies differ in the type of oat flakes, cooking methods and duration, or additives used to prepare the oatmeal [11, 19, 26, 27]. This study highlights the potential role of oatmeal in the prevention and management of type 2 diabetes [28]. Its content of soluble fibre (oat β-glucans), which forms a gel-like substance in the gastrointestinal tract, contributes to improved postprandial glycaemic control. In addition, oat β-glucan is known to reduce low-density lipoprotein (LDL) cholesterol levels. Therefore, oat products could also be beneficial for people with high serum cholesterol levels [29].

Limitations of the study. The presented study has several limitations. Only 17 participants took part in the study, which exceeds the number required by international ISO standards for testing the glycaemic index. The sample consisted exclusively of young women (aged 19–22), which ensured the high homogeneity of the group, but limited the possibility of generalizing the results to other populations. The diet on the day preceding each test session was not fully standardized, which may have affected the glycaemic response. Due to the large number of measurements each day requiring blood sampling, it was not possible to perform duplicate measurements for each control point. The test meals differed in the amount of oatmeal used and, consequently, in their fat, protein, fibre, and β-glucan content, which may have contributed to the observed differences in glycaemic responses. Relatively large standard deviations in postprandial glycaemic responses indicate significant inter-individual variability, which may have been caused by various factors, including different habitual physical activity levels. However, it should be emphasized that within the framework of this research protocol, the baseline results of each participant served as a reference point for her that participant. Additionally, the observed differences in GI between meals may reflect not only the addition of milk itself, but also the resulting changes in the overall macronutrient composition of the test meals.

CONCLUSIONS

The comparison of oatmeal prepared with rolled oat flakes and water or milk revealed the positive effect of milk addition on postprandial glycaemia and GI of tested meals. The study, conducted in accordance with international ISO standards, confirmed that the intake of oatmeal with milk results in a significantly lower postprandial glycaemia than oatmeal with water. These results suggest that oatmeal with milk may be a more suitable option for individuals requiring glycaemic control. However, to confirm the obtained results, further studies on larger and more diverse populations are needed, especially regarding the effect of oatmeal consumption on postprandial blood glucose levels.

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