

Nutritional Value and Consumer Acceptance of New Cereal Bars Offered to Children

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The main aim of this study was to determine consumer preferences by school-aged children and selected quality indicators of new, highly nutritive grain bars designed as a snack during school break. Consumer acceptance was evaluated by the scaling method using a five-point mimic hedonic scale. Triacylglycerols (TAG) and fatty acids (FA) composition was assayed in fats extracted from the designed bars (fresh and stored) by gas chromatography. Contents of oxidation and hydrolysis products were determined using peroxide value (PV), anisidine value (AnV), and acidic value (AV). The antioxidant activity of the ethanolic extract from bars was measured by scavenging 1,1-diphenyl-2-picrylhydrazyl (DPPH) radicals and Folin-Ciocalteu methods. The overall liking of bars was high (4.05 pts on average in the 5-point scale). The majority of children (71%) scored the designed bars as tasty and very tasty. The designed products contained 22.3% of fat with about 44 g/100 g FA of valuable fatty acids, e.g., short-chain saturated fatty acids (SCSFA), monounsaturated fatty acids (MUFA) and odd and branched chain fatty acids (OBCFA), recommended for young organisms. The content of CN52, CN54, CN50 and CN46 triacylglycerols (TAGs) (about 49 g/100 g TAG) was due to both milk and cocoa fat. Storage of bars did not influence their content of oxidation and hydrolysis products, resulting from a substantial content of total phenolics (TPC) (53.64 mg GAE/100 mL of extract) and DPPH scavenging activity at the level of 24%. The designed bars may be an interesting confectionery product for children and an alternative to snacks currently available in school shops.

INTRODUCTION

Childhood obesity has become a serious public health problem in recent decades and is associated with severe health disorders and risk of illness [de Onis *et al.*, 2010]. Already in 1997, the World Health Organization (WHO) has announced obesity as one of the most severe hazards to the health of children and adults [WHO Report, 1997]. The epidemiological and statistical data indicated that obesity among children had increased dramatically over the last two decades. In 2002, in the United States the problem of obesity affected as many as 30% of the surveyed children and adolescents [Hedley *et al.*, 2004]. Haslam and James estimated that in 2005 *ca.* 10% of the global population under the age of 18 years has suffered from overweight or obesity [Haslam & James, 2005]. In 2010, 43 millions of children were estimated to be overweight and obese; whereas 92 millions were at risk of overweight. This growing trend is expected to reach 9.1% in 2020 [de Onis *et al.*, 2010].

According to estimates from the WHO's Childhood Obesity Surveillance Initiative (COSI), in the EU around 1 in 3 children aged 6–9 years were overweight or obese in 2010 [WHO Report, 2010]. A school-based survey conducted in 2010 among 10–12 year old children in seven Euro-

pean countries revealed that 25.8% of boys and 21.8% of girls were overweight (including obese) [Brug *et al.*, 2012].

Increases in obesity levels have been observed even in very young preschool children, which is very alarming [Lakshman *et al.*, 2012]. A current survey in the USA has reported that among children who became obese between the ages of 5 and 14 years, nearly half had been overweight and 75% had been above the 70th percentile for body mass index at the baseline [Cunningham *et al.*, 2014].

Also in Poland the problem of obesity among children and adolescents under 18 years of age has escalated within the last 10–15 years. Cyclic surveys conducted by the Institute of Mother and Child in Warsaw have demonstrated that the problem of obesity affects 18.3% whereas the problem of overweight – 3.4% of children aged 11–12- years [WHO Report from 2009/2010]. The incidence of obesity in Polish children varies depending on their age and region of residence [Sikorska-Wisniewska, 2007]. The degree of overweight and obesity among 7–9 year old children in different regions of Poland was shown to vary. The highest incidence of overweight and obesity was found in the Masovian province and the lowest in the Subcarpathian province [Wolnicka *et al.*, 2012]. The latest research demonstrated that the average incidence of obesity among Polish children accounts for 17% [UNICEF Report, 2013].

Among many dietary factors which facilitate the development of overweight and obesity in children, significant

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is the intake of highly-processed foods, with poor nutritional value but providing a high energy value, *e.g.* fast foods, chips, carbonated beverages, and sweets [Elliott *et al.*, 2004]. While staying at school, adolescents willingly buy food products offered by school shops which, however, do not cover the daily demand for nutrients. According to Wojtyła-Buciora *et al.* [2013], the school children consumed definitely too frequently sweets and sweet beverages – 74%, and salty snacks – 48% purchased at school shops. These products suppress the sensation of hunger, but have a high energy value from carbohydrates and saturated fats.

From the nutritional point of view, most cookies and confectionery products available on the market are not recommended for children. However, children constitute a significant group of confectionery products consumers owing to sensory attractiveness of these products and to heavy exposure to sweets advertising. For these reasons, children often consume excessive amounts of advertised confectionery products like, *e.g.*, snack bars that are characterized by both a high energy value and a significant content of monosaccharides as well as low contents of dietary fiber and protein [Elliott, 2008]. These products are also substantial sources of fat which is associated with the presence of saturated fatty acids (SFA) and *trans* fatty acids (TFA). These compounds are responsible for an increasing level of plasma cholesterol, mainly LDL-cholesterol which is implicated in increasing the risk of development of cardiovascular diseases and type II diabetes [Mozaffarian *et al.*, 2009].

Considering nutritional demands of children and development of appropriate eating habits, children need to be provided “snacks” that apart from taste values would also be sources of: high-quality protein, dietary fiber, easily-digestible fat and other valuable components. Whole grains and berries are recommended for young organisms as an important part of diet, because of their high nutritional value and health benefits [Holmer *et al.*, 2012]. Oat is appropriate for bars enrichment due to considerable content of dietary fiber, especially its soluble fraction, with a predominating contribution of β -glucans having special physiological effects. β -Glucans are implicated in reducing the risk of colon cancer and glucose absorption in the digestive system. In addition, they play an important role in the prevention and treatment of gastrointestinal diseases and reduce blood level of cholesterol. They are also known for their immunomodulating properties [Wood, 2007]. Amaranth is a valuable ingredient in food production due to its unique protein composition with regard to quality and quantity. Processed products of amaranth, including seeds, flour, flakes and popped (expanded) seeds, are characterized by a high content of protein (especially high content of lysine being indispensable for developing organisms). Protein contained in amaranth seeds is characterized by high bioavailability [Mlakar *et al.*, 2009]. In turn, chokeberry fruits are the richest source of polyphenolic compounds – natural antioxidants, which strengthen and seal blood vessels, prevent atherosclerotic lesions, as well as reduce blood pressure and the risk of cardiovascular diseases incidence. In addition, they exhibit anti-inflammatory, antiviral and antimycotic actions [Ferrazzano *et al.*, 2011]. Milk fat is highly recommended for young organisms because

TABLE 1. Formulation of bars (g/100 g of product).

Ingredient	Type of bar	
	TS	RS
<i>Bar base</i>		
Oat flakes (g)	7.3	7.3
Popped amaranth seeds (g)	3.8	3.8
Apple juice (ml)	10.0	10.0
Butter (g)	6.4	6.4
Wheat flour (g)	9.0	15.1
Cane sugar (g)	6.1	0
Dehydrated chokeberry fruits (g)	3.4	3.4
Vanilla sugar (g)	2.0	2.0
Eggs (g)	6.4	6.4
Baking powder (g)	0.2	0.2
<i>Filling</i>		
Milk 3.2% fat (mL)	6.4	6.4
Butter (g)	13.9	13.9
Defatted powdered milk (g)	8.5	11.9
Sugar (g)	3.4	0
<i>Assembly</i>		
Dark chocolate (g)	8.5	8.5
Milk 3.2% fat (ml)	4.3	4.3
Waffer cake (g)	0.4	0.4

TS = bar with typical saccharose content; RS = bar with reduced saccharose content

of its fatty acids (FAs) profile, especially nutritionally valuable short chain saturated fatty acids (SCSFA) and other bioactive compounds (proteins, peptides and oligosaccharides) [Mills *et al.*, 2011].

The main aim of this study was to determine consumer preferences by school-aged children and selected quality indicators of new, highly nutritive grain bars designed as snack during a school break.

MATERIALS AND METHODS

Preparation of grain bars

The experimental material included snack bars characterized by an increased nutritional value and produced in two variants: with typical (TS) and with reduced (RS) content of saccharose. The increased nutritional value of designed bars resulted from the presence of highly nutritive ingredients, *e.g.* oat flakes, popped amaranth seeds, dehydrated chokeberries and butter. Detailed formulation of both variants of bars was presented in Table 1. The ingredients used for bars production were obtained from the local market.

Ingredients of snack bar base (eggs, butter, apple juice) were mixed with a mixer (type HR 7677/A, Phillips, Austria), poured into premixed dry ingredients and kneaded by hand. The resultant mixture was put into a baking tray as a flat square cake, baked at 200°C for 20 min in a convection oven with forced air circulation (Electrolux AR 85, Italy), and cooled at room temperature. All ingredients of the filing

were mixed for 15 min into a smooth mixture. Glaze was prepared by slowly mixing the melted dark chocolate with milk at a temperature of about 40°C to obtain a uniform, smooth and shiny mass.

The bars were formed as follows: the cooled cereal cake was transferred onto a wafer cake coated with the milk filling, and pressed. The top layer of the cereal cake was poured with chocolate glazing and left to harden. Afterwards, the cake was cut into snack bars 3.5 cm in length and 2 cm in width. Products packed in bags made of polyethylene foil were stored for 4 months at a temp. of 10°C.

Evaluation of consumer acceptance by children

The acceptability of bars was evaluated by potential consumers of the product – 162 children aged 7–12 years, from two schools located in the Mazowieckie Province. All participants were required to have parental consent. Testing was done during morning lessons in the classroom. All children were given a short training to familiarize them with testing procedure. The testing was conducted with the scaling method. Using a five-point mimic hedonic scale, the children expressed the degree of liking of the product by ticking the facial expression corresponding to their preferences. The degree of scale development was consistent with perception capabilities of children aged 7–12 years [Baryłko-Pikielna & Matuszewska, 2014]. The samples were coded and served to the children at random to avoid any bias. Hedonic ratings of each bar were converted into a numeric score ranging from 1 – very untasty to 5 – very tasty. The results were obtained by calculation of overall mean and the acceptance index was determined as acceptance percentage considering 100% the score 5.

Fat content determination

From the designed snack bars (fresh and stored), fat was extracted with the Weibull-Stoldt method [Polish Standard PN-71/A-88021:1971P], which is a modification of the Soxhlet's method. The weighted portion of a snack bar was disintegrated, then hot water was added and the mixture was treated with hydrochloric acid to hydrolyze proteins and carbohydrates contained in the product. Once fat was separated from the hydrolysate, it was extracted with hexane, which was evaporated afterwards.

Triacylglycerols (TAGs) composition analysis

The separation of TAGs was conducted with gas chromatography technique according to Stolyhwo & Rutkowska [2013] using an HP-Agilent 6890 apparatus, equipped in a capillary column (30 m x 0.25 mm) with medium-polar stationary phase. A sample of fat (0.15% in iso-octane) was injected with the “cool on column” method. During analysis, the column's temperature was controlled according to the earlier fixed program: initial temperature 77°C for 3 min, increase by 20°C/min to 240°C, and another increase by 3°C/min to 345°C. The total time of analysis reached 70 min. Peaks were identified using a milk fat standard BCR 519 (Belgium). The quantitative analysis of TAGs in the analyzed sample of fat extracted from snack bars was conducted with the method of internal standardization, using correction factors (Response Factors).

Fatty acid (FA) composition analysis

Methyl esters of fatty acids (FAME) were prepared according to AOAC Official Method 963.22 [AOAC-IUPAC, 2000]. The analysis of FAME profile of fat substance extracted from snack bar was conducted with gas chromatography (GC) technique acc. to the Polish Standard [PN-EN ISO 5508:2000], using an HP-Agilent 6890N apparatus. Use was made of a column with highly polar stationary phase Rtx 2330 (length 100 m, 0.25 mm ID, 0.2 µm Th.) (Restek Corp. USA). FAs were identified with the use of Supelco 37 standard No:47885-U (Sigma Aldrich). Detailed description of this method is described by Rutkowska *et al.* [2012].

Calculation of nutritional value

The nutritional value of the designed snack bars was calculated based on literature data: “Food Composition and Nutritional Value Tables” [Kunachowicz *et al.*, 2005] and “DIETETYK” software (2001). To compare the nutritional value of the designed bars with commercial products, analyses were also conducted for the assortment of snack bars available at retail shops in schools of the surveyed children.

Determination of fat oxidation and hydrolysis products content

The fat fraction was analyzed in terms of health safety by determining contents of primary and secondary products of lipids oxidation. All analyses were conducted in triplicate. Determination of peroxides content was conducted according to ISO 3960:2012 standard method by assaying the peroxide value (PV) with the titration method. Results were expressed as meq O₂/kg of fat. The content of secondary products of oxidation was determined with the spectrophotometric technique at 350 nm acc. to ISO 6885:2008 standard method by assaying the anisidine value (AnV). Contents of free fatty acids (FFAs) were determined with the ISO 660:2010 standard method by assaying the acidic value (AV) to determine the content of products of the hydrolytic degradation of fat. Results were expressed as mg KOH/g of fat.

Preparation of ethanolic extracts of bars

Bars were powdered in a mortar. Then, 5 g of powder were mixed with 50 mL of ethanol/water (80/20, v/v) and the mixture was shaken at room temperature for 1 h, and left overnight. The extract was separated by filtering through a filter paper (POCH, S.A., Gliwice, Poland), and the procedure was repeated twice with 50 mL of the solvent. The extract obtained was used for determinations of total phenolics content and DPPH (1,1-diphenyl-2-picrylhydrazyl radicals) scavenging activity.

Determination of total phenolics content (TPC)

Total phenolics content was determined spectrophotometrically by using Folin-Ciocalteu reagent [Singleton & Rossi, 1965]. Gallic acid was used as a standard and results were expressed as gallic acid equivalents (GAE) (mg GAE/100 g of extract). The 0.1 mL ethanolic extract of bar was diluted with 7.9 mL of pure water. Folin-Ciocalteu's reagent (0.5 mL) and sodium carbonate solution (1.5 mL; concentration 20 g/100 mL) were added, and the reaction mixture was mixed

thoroughly. The mixture was allowed to stand for 120 min with intermittent shaking, and absorbance was measured at 725 nm (Specord 40, Analytik Jena AG, Jena, Germany).

Antioxidant activity determination

Radical scavenging effect of the ethanolic extract of bars on 1,1-diphenyl-2-picrylhydrazyl radicals (DPPH) was determined according to the modified method of Sanchez–Moreno *et al.* [1998] with the modification consisting in the use of an ethanolic solution of DPPH (Sigma-Aldrich, 0.025 g/1000 mL 96% ethanol). An aliquot (1.0 mL) of the DPPH solution was diluted in 2.9 mL of methanol, and 0.1 mL of the ethanolic extract of bars was added. The mixture was shaken vigorously and left to stand for 10 min in the dark, then the absorbance was measured at 515 nm (Specord 40, Analytik Jena AG, Jena, Germany) against the blank (mixture without extract). The antioxidative activity of the extracts was expressed as the percentage of quenched DPPH radical after incubation with the analyzed sample against a blank sample. The percentage of quenched DPPH radical was calculated from the following formula:

$$\text{DPPH}^* = (A_{\text{DPPH}} - A_t) / A_{\text{DPPH}} \times 100 (\%)$$

where: A_{DPPH} – absorbance of blank sample, A_t – absorbance of the analyzed sample.

Statistical analysis

All chemical analyses were conducted in triplicate. Results (mean±SD) were subjected to the analysis of variance (ANOVA) at a significance level of $P \leq 0.05$ using STASTIS-TICA 9.1PL software (StatSoft, Inc. (2010)).

RESULTS

Consumer evaluation by children

The sensory evaluation demonstrated that the designed product received high scores by school-aged children. However, a slightly higher average score (4.21 pts.) was given to the TS variant, whereas the average score for the RS variant reached 3.89 pts. (Figure 1).

The study showed a significant effect of age on snack bar evaluation depending on saccharose content. The highest acceptability of the TS snack bar was noted in the group of children aged 8 years, whereas the designed RS snack bar content received the highest scores by children at the age of 9 years (Figure 1).

In the case of both variants of the designed snack bars, the majority of children evaluated them as “very tasty” and “tasty” (53.6% and 21.8% in the case of TS bars, and 42.3% and 23.0% respectively in the case of RS bars) (Figure 2).

Fat content and fat composition

The mean fat content in the designed snack bars was $22.3 \pm 1.1\%$. Gas chromatography enabled separations of 16 triacylglycerols (TAGs) and cholesterol in extracted fats from bars: CN 24 to CN 54 (Table 2) in which the CN52, CN54, CN50, CN46 were predominating.

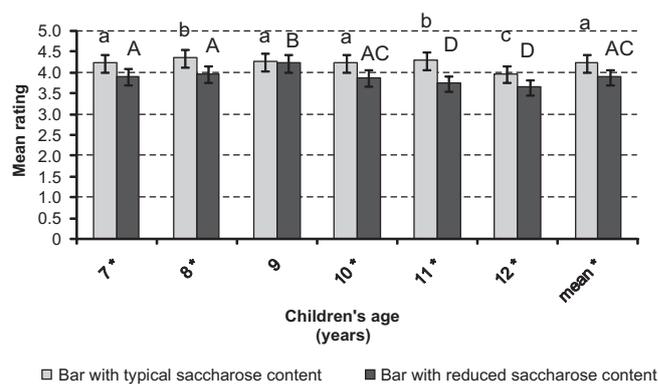


FIGURE 1. Mean rates of designed bars according to children's age. A, a – significant ($p \leq 0.05$) differences according to saccharose content; * – significant ($p \leq 0.05$) differences according to children's age.



FIGURE 2. Distribution of individual preferences of two types of bars.

Results of FA profile analysis of fats extracted from experimental bars are presented in Table 3. The assayed FAs were classified into the following groups: saturated fatty acids (SFA) that were divided into short-chain saturated FA (SCSFA) and long-chain saturated FA (LCSFA) due to their different nutritional properties, monounsaturated FA (MUFA), polyunsaturated FA (PUFA) and odd- and branched chain FA (OBCFA). Quantitatively predominating groups were LCSFA and MUFA (50.55 g/100 g FA and 25.33 g/100 g FA on average, respectively). Noteworthy is also a significant content of SCSFA (14.03 g/100 g FA on average). Fats extracted from bars contained also FAs belonging to odd and branched chain fatty acids (OBCFA) (4.62 g/100 g FA on average) group. In fat extracted from bars, there were also assayed: isomer 9-*cis* 11-*trans* C18:2 (CLA – conjugated linoleic acid) (0.31 g/100 g FA) and isomer 11-*trans* C18:1 (VA – vaccenic acid) (0.98 g/100 g FA).

Comparison of the nutritional value of experimental bars and snack bars available in school shops

Table 4 presents the nutritional value of two variants of the designed snack bars and of commercial products offered in school shops ($n = 13$). The commercial products had energy value between 400 and 552 kcal/100 g of product, whereas the designed products were characterized by the following energy value: 410 kcal/100 g of product for TS and 390 kcal/100 g of product for RS. Considering simple sugars, their content was lower by *ca.* 40% in both variants

TABLE 2. Composition of triacylglycerols in fat extracted from designed bars (mean±SD).

TAG	Mean TAG content (g/100 g)		
	Fresh ^a	Stored	<i>p</i> ≤0.05
CN24	0.14±0.05	0.17±0.02	*
CN26	0.30±0.08	0.34±0.14	
Cholesterol	0.31±0.03	0.33±0.07	
CN28	0.59±0.11	0.69±0.15	
CN30	0.93±0.09	0.90±0.12	
CN32	1.92±0.35	1.89±0.18	
CN34	4.74±0.21	4.46±0.20	*
CN36	8.82±0.41	8.32±0.37	*
CN38	9.62±0.19	9.25±0.21	*
CN40	7.27±0.07	6.91±0.15	
CN42	5.32±0.11	4.97±0.18	
CN44	5.07±0.21	4.98±0.19	
CN46	5.75±0.17	5.22±0.27	
CN48	7.22±0.28	6.85±0.26	
CN50	12.23±0.35	12.16±0.28	
CN52	17.80±0.29	18.56±0.35	
CN54	12.85±0.14	13.25±0.26	

^a Values are expressed as mean±SD of results obtained for bar with typical (TS) and reduced (RS) saccharose content. Values with asterisk significantly differ (*p*≤0.05). TAG = triacylglycerol; CN = carbon number.

of the designed bars than in the commercial products. In most cases, the commercial products did not contain dietary fiber.

Content of fat oxidation and hydrolysis products

Results of the hydrolytic and oxidative changes in bars during storage are presented in Table 5. The AV informing about the content of FFAs reached *ca.* 7.27 mg KOH/g fat on average and did not change over the storage period. The PV indicating the content of primary products of oxidation was low and did not exceed 2 mg meqO /kg fat and remained unchanged during storage. The content of secondary oxidation products, indicated by the AnV, increased negligibly during storage (7.51 for fresh products and 7.82 for stored products).

Total phenolics content and antioxidant activity

Total phenolics content in designed bars was on average 53.64 mg GAE/ 100 mL of extract (Table 5) and did not differ significantly among bar types. Also DPPH·scavenging activity of the ethanolic extract from designed bars was almost equal for each type of bar (about 24%). The time of storage did not affect phenolics content nor DPPH of bars (Table 5).

DISCUSSION

A rapid increase has been observed in the incidence of overweight and obesity in children and adolescents. It may be presumed that the majority of obese adults were overweight or obese in their early youth [Wojtyła-Buciora *et al.*, 2013]. According to a recent survey conducted by the UNICEF in 2013, in Poland the average incidence of obesity in children

TABLE 3. Fatty acids profile of fat extracted from designed bars (g/100 g FA).

FA	Bar		
	Fresh ^a	Stored	<i>p</i> ≤0.05
C4:0	4.21±0.20	4.59±0.17	*
C6:0	2.18±0.10	2.43±0.16	*
<i>iso</i> C8:0	0.03±0.00	0.00±0.00	
C8:0	1.21±0.07	1.41±0.17	*
C10:0	2.48±0.06	2.91±0.21	
C11:0	0.30±0.02	0.27±0.11	
C12:0	3.38±0.27	3.25±0.15	
<i>iso</i> C12:0	0.08±0.01	0.07±0.02	
C13:0	0.08±0.00	0.07±0.01	
<i>anteiso</i> C13:0	0.11±0.03	0.10±0.01	
C14:0	9.35±0.21	8.82±0.31	
<i>iso</i> C14:0	0.22±0.01	0.20±0.03	
<i>anteiso</i> C15:0	0.40±0.03	0.36±0.08	
<i>iso</i> C15:0	0.91±0.04	0.82±0.11	
C15:0	0.95±0.03	0.88±0.12	
C15:1	0.23±0.05	0.21±0.07	
C16:0	30.45±1.46	30.07±1.80	
<i>iso</i> C16:0	0.15±0.02	0.14±0.05	
C16:1 n-10	0.24±0.07	0.24±0.03	
C16:1 n-7	1.26±0.19	1.19±0.08	
<i>anteiso</i> C17:0	0.35±0.05	0.32±0.07	
<i>iso</i> C17:0	0.10±0.01	0.10±0.02	
C17:0	0.47±0.08	0.46±0.13	
C17:1	0.26±0.03	0.25±0.09	
C18:0	10.54±0.29	11.53±0.15	
C18:1 11t	1.40±0.18	1.43±0.14	
VA	0.78±0.11	1.18±0.07	
C18:1 9c	21.13±0.56	20.51±0.37	
C18:1 11c	0.70±0.14	0.44±0.11	
C18:1 13c	0.15±0.07	0.00±0.00	
C18:2 9c 12c	4.44±0.31	4.37±0.25	
GLA	0.31±0.03	0.21±0.09	
C18:3 9c 12c 15c	0.50±0.02	0.47±0.12	
C20:0	0.07±0.01	0.08±0.01	
C18:2 9c 11t	0.29±0.05	0.32±0.03	
C21:0	0.06±0.00	0.09±0.02	
C22:0	0.08±0.01	0.09±0.01	
C20:3 n-3	0.02±0.00	0.00±0.00	*
C20:3 n-6	0.03±0.00	0.00±0.00	*
C23:0	0.02±0.01	0.03±0.00	
SCSFA	13.46±0.91	14.59±0.29	
LCSFA	50.50±2.39	50.59±2.51	
MUFA	25.66±1.71	24.99±0.99	
PUFA	5.59±0.56	5.38±0.41	
OBCFA	4.79±0.31	4.45±0.27	

^a Values are expressed as mean±SD of results obtained for bar with typical (TS) and reduced (RS) saccharose content. Values with asterisk significantly differ (*p*≤0.05). FA = fatty acid; VA = vaccenic acid; GLA = gamma linolenic acid, SCSFA = short-chained saturated fatty acids, LCSFA = long-chain saturated fatty acids; MUFA = monounsaturated fatty acids, PUFA = polyunsaturated fatty acids, OBCFA = odd- and branched-chain fatty acids.

TABLE 4. Nutritional value of designed bars in comparison to commercial products (per 100 g of product).

Sample code	Nutritional value (100 g)				
	Energy (kcal)	Protein (g)	Fat (g)	Monosaccharides (g)	Fiber (g)
TS	410	6.25	17.8	38	28
RS	390	8.00	18.1	33.5	32.5
C-1	400	5.6	7.0	70.4	4.25
C-2	428	4.2	14.8	68.7	2.9
C-3	485	8.6	23.0	60.2	nd
C-4	452	3.7	17.0	70.3	nd
C-5	548	9.8	33.4	50.4	nd
C-6	497	4.4	24.2	64.6	nd
C-7	533	5.2	29.2	61.5	nd
C-8	552	8.0	34	54	nd
C-9	535	5.4	30.5	58.5	nd
C-10	543	8.5	32.5	54.2	nd
C-11	538	6.0	31.6	57.7	nd
C-12	414	6.5	12.8	68.3	nd
C-13	485	4.4	23.5	63.0	nd

C-1 – C-13 = commercial products; TS = bar with typical saccharose content; RS = bar with reduced saccharose content; nd = no data available.

TABLE 5. Quality indicators of designed bars (mean±SD).

Parameter	Bar	
	Fresh ^a	Stored
DPPH (%)	23.89±0.002	23.90±0.004
TPC (mg GAE/100 mL extract)	52.77±0.351	54.50±1.646
PV (meqO/kg fat)	1.992±0.011	1.991±0.008
AnV	7.517±0.275	7.823±0.298
AV (mg KOH/g of fat)	7.258±0.007	7.287±0.002

^a Values are expressed as mean±SD of results obtained for bar with typical (TS) and reduced (RS) saccharose content. DPPH = 1,1-diphenyl-2-picrylhydrazyl radical; TPC – total phenolic content; GAE = gallic acid equivalent; PV = peroxide value; AnV = anisidine value; AV = acidic value.

reaches 17% [UNICEF Report, 2013]. In the case of children, therapy of obesity does not involve pharmacological intervention and its treatment should be based on changes in eating habits [Elliott *et al.*, 2004].

Likewise in other countries, also in Poland the main place where the children may purchase food products while staying at school is the school shops. In Poland, the main products bought by children in school shops include: crisps, chocolate bars and sweets [Wojtyła-Buciora *et al.*, 2013]. Surveys conducted among school children and adolescents aged 7–15 years demonstrated poorer eating patterns with age that resulted from children becoming independent and from the possibility of making self-reliant purchase decisions by pupils. The period of mid-late childhood (7–11 years) is when children are most prone to excessive weight gain [Hughes *et al.*, 2011].

The global strategy for diet, physical activity and health by the WHO recommends the food industry to develop

and provide affordable, healthy choices to consumers. Although children have a reasonable understanding of healthy eating, they are less effective in putting this knowledge into practice in order to sustain a healthy eating pattern [Bower & Sandall, 2002]. To help children make better food choices, healthier snack options should be easily available [Holmer *et al.*, 2012]. Nowadays there is a trend to produce natural, nutritious snacks according with the tendency to reduce consumption of sugary sweets [Estevez *et al.*, 1995]. However nutritive value of snacks for children has been scarcely emphasized.

This research is an attempt of developing “snack” type a food product as a highly-nutritive snack during children’s stay at school that could replace fast-foods available in school shops. Bars designed in this study contained substantial amounts of cereal ingredients with a high content of dietary fiber, β-glucans (oat) and exogenous amino acids (*e.g.* lysine – amaranth), and characterized by a beneficial composition of the lipid fraction. Considering these ingredients, the designed bars could be appropriate for growing organisms.

The assayed fat content in designed bars was 22% and was similar to fat content determined in products containing oat and cranberry manufactured in Nordic countries (Denmark and Sweden) [Holmer *et al.*, 2012] while lower in comparison with various bars designed by Estevez *et al.* [1995], containing different proportions of oat and popped amaranth seed. When comparing the nutritional value of the designed snack bars with commercial products analyzed by Paszczyk *et al.* [2007], the designed bars are characterized by a considerably lower fat content.

The calculated nutritional value in terms of caloric value was similar to that of products containing oat and cranberry manufactured in Nordic countries [Holmer *et al.*, 2012]. Compared to the analyzed commercial products (Table 4), the nutritional value of the designed bars was distinguished by a higher content of fiber and proteins. The designed bars contained significantly less simple sugars than the commercial products, especially the RS bars, the caloric value of which was significantly lower than that of the commercial products. The package of the designed bars with reduced saccharose content could contain a nutritional claim about reduced caloric value, because accordingly to EU Regulation no. 1924/2006 their caloric value is lower by 30%.

The chromatographic analysis of TAGs composition in fat extracted from the designed bars reflects bars formulation, particularly the presence of milk fat and chocolate (dark) with a high content of cocoa fat (Table 2) [Lipp & Anklam, 1998]. It is confirmed by quantitative predominance of TAGs: CN52, CN54, CN50, and CN46, in which the main acyls originate from stearic acid C18:0, palmitic acid C16:0 and oleic acid C18:1, as well as by considerable contents of CN 36 and CN34 TAGs – which corresponds with a significant content of FAs belonging to SCSFA group: C8:0 – C14:0, in the analyzed products. The high contribution of milk fat is confirmed mainly by the presence of CN24 – CN28 TAGs, the total content of which reached 1.12 g/100 g TAG on average. In these TAGs, acyls originated from short- and medium-chain FAs. Such a unique structure of TAGs makes that fat is easily digested by a human body, as SCSFAs in the *sn*-3 TAG position

are easily available to pancreatic lipase. The synthesis of fats containing acylglycerols with appropriate FAs at stereospecific positions *sn*-1 and *sn*-3 may lead to the production of lipids capable of preventing hyperlipidemia or obesity [Hanczakowska & Szewczyk, 2011].

The GC analysis of FAs profile revealed that the designed bars, owing to milk fat contribution in their formulation, contained significant quantities of SCSFAs (14.03 g/100 g FA on average). These acids are known for their very beneficial properties to young organisms [Canani *et al.*, 2011]. They are utilized in the body as an energetic fuel for muscles, heart, liver and kidneys. Their considerable part constitutes a source of energy necessary for metabolic processes, whereas the remaining part is processed into heat further used for *e.g.* maintaining body temperature at a stable level. Because these acids are metabolized without the presence of carnitine, they are not accumulated as storage material and are not risk factors of obesity [Stołyhwo & Rutkowska, 2013]. In addition, they are very valuable to the development of young organisms as by diffusing to cells of the stomach they activate grelin – a hormone which accelerates the growth and development of young organisms both in the prenatal period and after birth [Hanczakowska & Szewczyk, 2011]. SCSFAs exhibit strong antimycotic and antibacterial effects. Butyric acid, occurring in the designed bars at the level of 4.40 g/100 g FA, is a potential inhibitor of cells differentiation and apoptosis in many lines of cancer cells. It may inhibit DNA synthesis in cancer cell nuclei and, thereby, prevent their development [Adamska & Rutkowska, 2014].

Other valuable fatty acids in the lipid fraction of the designed snack bars included CLA, OBCFA, and VA, and their total content reached 5.91 g/100 g FA. Typical commercial products do not contain these acids [Żbikowska *et al.*, 2015].

The designed bars (fresh and stored) were also assayed for the content of primary and secondary oxidation products, as well as for antioxidant activity and content of phenolic compounds. Worthy of emphasizing are very low levels of lipid oxidation in both fresh bars and these stored for 4 months. The content of FFAs (measured as AV) was high and reached over 7 mg KOH/g fat, which resulted from the use of chokeberry fruits in bars formulation that contain significant quantities of organic acids which may, in turn, effect result of determination [Kulling & Rawel, 2008]. The content of primary oxidation products (PV) was low (even after 4-month storage it did not exceed 2 meq O/kg fat) and was 10 times lower than the recommended value for cereals (20 meq O/kg fat) [Estevez *et al.*, 1995]. The content of secondary oxidation products (AnV) increased negligibly during storage (from 7.51 to 7.82), and even though it did not exceed the permissible value AnV = 8 stipulated for confectionery products [Aidos *et al.*, 2002]. It also needs to be emphasized that the designed product did not contain any preserving agents. Oxidative stability of the products and their high quality after storage resulted only from the presence of natural bioactive substances with antioxidant properties, including polyphenols from chokeberry – mainly anthocyanins.

The content of polyphenolic compounds in the designed bars ranged from 52.77 to 54.50 mg GAE/100 mL and was higher than in the amaranth and quinoa breads (13.8 and 30.7 mg

GAE/100 g, respectively) [Alvarez-Jubete *et al.*, 2010]. The high phenolics content may be related to high DPPH• scavenging activity of the designed bars. Free radical scavenging is one of the most important function of antioxidants, since free radicals induce oxidation of lipids, proteins and DNA. This resulted in disturbance and functional loss of biological membranes and enzymes, as well as production of toxic compounds [Niki, 2011]. The antioxidant activity of ethanolic extracts from the designed bars measured as % of quenched DPPH radical (about 24%) was higher in comparison with crackers made with refined and wholegrain buckwheat and wheat flours (0.95, 1.63 and 16.2 %, respectively) [Sedej *et al.*, 2011].

Sensory evaluation is used in bakery and confectionery companies to assess product quality and to predict consumers' preferences, which is of utmost importance for bakery products, as it determines product development and marketing strategies [Rutkowska & Żbikowska, 2010]. For product reformulation or improvement, consumer surveys may be needed to confirm that the change in the product is not detrimental to its acceptability [Popper & Kroll, 2011].

Significant differences ($P \leq 0.05$) in hedonic acceptability between types of bars with different contents of sugar were noted (Figure 3) with higher children's preferences for TS bars. However, the acceptability depended on age of the children. Out of the 6 age groups surveyed, this dependency was not observed only in the 9-year-olds, who scored both variants of bars very similarly (Figure 2). Our results confirmed observations of Hausner *et al.* [2012] that sweetness is considered to be the most important dimension determining children's food preferences. Nordic elementary school children suggested improving the snack bars by making them sweeter [Holmer *et al.*, 2012].

Regardless of the significant differences in the assessments, the overall liking of both types of designed bars was high (4.21 for TS bars and 3.89 for RS bars), similar as in the study conducted among Danish and Swedish children, where the most acceptable type of bar was "oat and cranberry" [Holmer *et al.*, 2012] and slightly lower than cereal bar designed by Estevez *et al.* [1995].

In children's consumer hedonic evaluation of the product, distribution of individual preferences is also important. More than half of the children scored TS bars as "very tasty" (53%), whereas RS bars were rated as "very tasty" by approximately 44% of children (Figure 2). Both variants of bars were evaluated as "tasty" by respectively 22 and 23% of the children, while only 12% of the children on average scored their preferences as "very untasty" and "untasty".

Our results are encouraging as they indicate that the quality of diet for children may be improved by providing children with healthy snack products at school shops.

CONCLUSION

Taking into account the improved nutritional value, safety (very low content of products of lipid oxidation and hydrolysis), and high acceptability among school children, the designed bars may be an interesting confectionery product for children providing an alternative to snacks currently available in school shops.

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