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THE USE OF CARROT AND APPLE POMACE IN THE PRODUCTION OF HEALTHY SNACK BARS

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ABSTRACT

In recent years, the increasing popularity of healthy eating brought about a significant increase in the consumption of fruit and vegetables in the form of juices, purees and cocktails. In the process of their production, the byproduct is pomace, which is treated by the food processing industry as waste. Assuming that pomace accounts for only 20% of the raw material used, annually up to 630 000 tonnes of pomace are obtained globally. However, numerous studies have demonstrated that fruit pomace is a valuable source of many nutritious substances. The objective of the study was to develop a compression-based production technology of apple pomace-based bars, and to assess their quality. Based on the analysis of the structure of produced bars, it can be concluded that their hardness and resistance to cutting does not differ significantly from that of commercial bars made with alternative technology and from different ingredients.

Introduction

Growing awareness of the foods consumed and their effects on human health has resulted in a noticeable decline in the consumption of animal (saturated) fats in favour of those of plant origin. Vegetable oils are particularly valued for their rich content of unsaturated fatty acids and are associated with regulating the abnormal lipid profile (Pawłowska et al., 2018; Ugur and Nergiz-Unal, 2017; Schwingshackl and Hoffmann, 2014, Kozlowicz, 2023).

A significant increase in consumption of vegetable products is also observed in the case of fruit and vegetable juices, smoothies and all kinds of cocktails. Both the production of oils, as well as smoothies or cocktails, is directly connected with generating huge amounts of pomace as byproduct. Assuming that pomace constitutes 20% of raw material, each season 630 000 tonnes of this waste is obtained (Kawecka and Galus, 2021; Assayed, 2010; Sadowska et al., 2022). Repurposing these by products is a significant problem in food processing since they are a highly perishable raw material, containing large amounts of water (up to 73%), which also makes it susceptible to the growth of undesirable microflora. Because biowaste is food waste, the collection of which has a disastrous impact on the environment, human health and wildlife (Obidziński et al., 2019).

At the same time, pomace is a relatively cheap raw material suitable for further processing. The tonnes of pomace produced each season are only used to enrich fodder and in renewable energy production (due to nitrogen and carbon content and trace amounts of heavy metals) (Jewell and Cummings, 1984; Burczyk et al., 2011; Wolski et al., 2017; Kaniewski et al., 2020, Lamidi, 2023). The most common method of managing various forms of plant waste or their combinations (mixtures) is their granulation or briquetting into a solid fuel (pellet, briquette) or in the case of dusty agricultural and food waste – non-pressurized agglomeration (Obidziński et al., 2016). However, pomace can be reused in the production of substances for the chemical industry, in cosmetics and even in pharmaceuticals (Burczyk et al., 2011; Nadulski et al., 2013; Radzymińska et al., 2017; Cohn and Cohn, 2012).

Numerous studies prove that both fruit and oil pomace are a highly valuable source of many important nutrients (Kawecka and Galus, 2021; Burits and Bucar, 2000, Stropek, 2020). The use of pomace in food processing could contribute to an increase in dietary fibre intake and open new ways of its use (Carcea, 2020; Wolski and Najda, 2005). For example, flax and nigella pomace are sources of polyunsaturated fatty acids. On the other hand, pomace obtained from fruits and vegetables is a source of such components as fibre (cellulose, pectin, hemicelluloses), mineral compounds, vitamins, colouring and flavours. The studies carried out so far show that apple pomace, compared to other analysed raw materials, has the most beneficial effect on our health, due to the significant content of pectins and the ability to bind heavy metal ions (Kawecka and Galus, 2021; Radzymińska et al., 2017). Pomace also contains significant amounts of different proteins, carbohydrates and fats, as well as waxes, aldehydes, alcohols and acids. The content of these substances depends on the type and degree of processing of the raw material and the technological process applied, including the equipment used in the process.

The nutritional value of food products, even of sweets (snack bars), can be increased with pomace-based food additives (also dried or pickled). The objective of the study was to develop a method of utilisation of fruit and vegetable pomace as a substitute for sweet snack production and to characterise the textural properties and chemical composition of the resulting snack.

Materials and Methods

Pomace is a perishable resource with a high water content and its chemical composition may vary depending on fruit quality, pressing methods and fruit storage. The pomace used as a foundation for preliminary studies produced after pressing apple (Golden Delicious) and carrot (Nerec) juice. The amount of pomace obtained depended on the technical and technological process used to obtain the research material and the varietal characteristics of the fruit. In this study, the total weight of the mixture was 1000 g, which produced 50 bars, at approximately 20 g each. The chemical composition of apple pomace used for this study is presented in Table 1. Other ingredients used in the production of bars included wheat bran, millet flakes, prunes, hazelnuts, almonds, honey and salt in various proportions.

Table 1.
Selected chemical components of pomace in dry matter (Tarko et al., 2012)

Parameter	Apple pomace	Carrot pomace
Moisture content (%)	80.0	80.8
Total sugars (%)	1.20	0.68
Fibre (%)	6.70	0.40
Pectins (%)	0.66	0.27

The research methodology included not only producing bars of acceptable composition, but also comparing them to commercially available bars.

Composition of the produced bars

Table 2 shows the composition of the produced bars.

The first stage of the research consisted of developing a suitable recipe for the mixture. The proposed recipe composition presented in Table 2 was preceded by preliminary studies aimed at maximizing the use of apple pomace and, at the same time, obtaining a stable bar form. For the recipe thus prepared, the chemical composition of the bars obtained was evaluated.

Table 2.
Composition of the produced bars

Recipe 1	Share (%)	Recipe 2	Share (%)
Wheat bran	30	Wheat bran	15
Apple pomace	30	Millet flakes	15
Carrot pomace	10	Apple pomace	30
Fragmented dried plums	10	Carrot pomace	10
		Fragmented dried plums	10
Other	20	Other	20

Bar production technology

The apple pomace used in the production of bars (approximately 300 g) was obtained from fragmenting and pressing whole apples. The pomace was then enriched with additional ingredients, such as hazelnuts, almonds, dried plums and honey. Hazelnuts and almonds (10%), which were ground in a 1.5 mm slotted grinder and dried plums were fragmented in a vertical cutter (COUPE R2A). The mixture was thoroughly mixed in an 8 liter planetary mixer at 125 rpm for 10 minutes. The moisture content of the resulting mixture was 30.08% for recipe 1 and 28.23% for recipe 2.

The production stages comprised:

1. Mixing the ingredients of the bar.
2. Grinding.
3. Extrusion (bar formation).
4. Portioning (cutting).
5. Heat treatment of the bars.
6. Vacuum packing.

The process of extruding the bars was carried out using a multi-functional device (Mesko EM11-E) with a diameter of 70 mm and 6mm holes in the cutting sieve, using a 4-arm knife, which allowed for additional grinding of the extrudate. The grinding section was fitted with a funnel-shaped end-piece, 125mm long, with an inlet diameter of 28 mm and an outlet diameter of 15 mm. The resulting bar was cut into lengths of 100 mm and subjected to thermal treatment at 130°C in a laboratory oven with convective air exchange for the assumed processing time, i.e. 10, 20, 30, 40, and 50 min. After cooling, the bars were vacuum packed.

Methodology for the assessment of the chemical composition of bars

The assessment of raw material and sample moisture content, as well as basic chemical composition, was carried out according to the AOAC procedure (AOAC 2000). The moisture content analysis of the samples was carried out by drying at 105°C. The moisture content was measured in triplicate and the average value was taken for calculation.

Methodology for measuring the internal temperature of the bar

The temperature of the bars during heat treatment was measured using an Extech SD200 temperature recorder with K-type thermocouples. The thermocouples were placed along the longitudinal axis of the sample (in the geometrical centre of the sample). Measurements were taken 3 times in 5-minute intervals (until the end of the process).

Assessment of the textural parameters

Methodology for measuring bar hardness

Hardness of the product was analyzed using a Stable Micro Systems TA.XT Plus texture analyzer. Measurements were taken using a compression test on a TA.XT Plus with a 500 N head. The bars were compressed to 50% of their original height at the head speed of 1 $mm \cdot s^{-1}$. The hardness was determined as the maximum value of the force recorded during the test and was read from the force-displacement diagram. Measurements were taken at ambient temperature (20±1°C). The measurement test consisted of preparing a cylindrical sample of 15mm in width, length and height. The tests were carried out in 5 repetitions. The placement of the sample is shown in Figure 1.

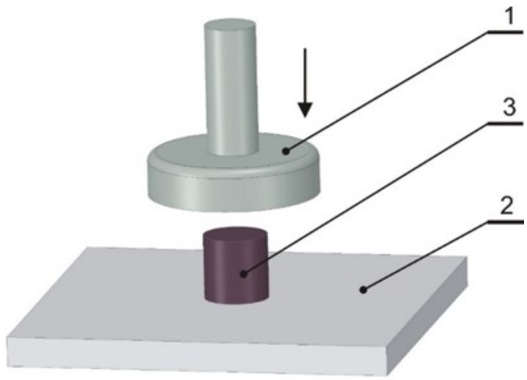

Figure 1. Placement of the sample during hardness analysis: 1 – compression head, 2 – base, 3 – sample (own elaboration).

Methodology for measuring bar cutting force

The texture analysis, i.e., the cutting test, was also carried out on a Stable Micro Systems TA.XT.Plus texture analyzer with a 500 N measuring head. The test consisted of preparing an identical cylindrical shape sample of 15mm in width, length and height each time and cutting it using a knife with an edge angle of 2.5°, at 1 mm·s^{-1}. The cutting force was determined as the maximum value of the force recorded during the test and was read from the force-displacement diagram. The work was determined as the area under the force-time diagram. Measurements were taken at ambient temperature (20±1°C). The tests were carried out in 5 repetitions. The method of sample placement is presented in Figure 2.

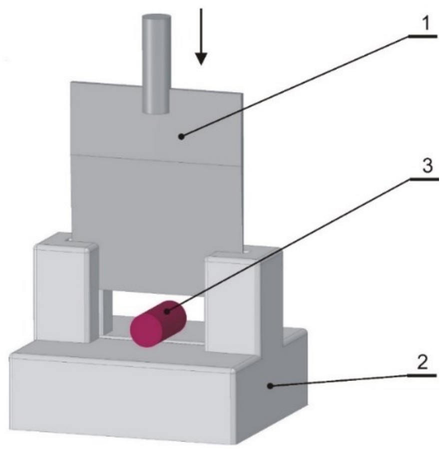

Figure 2. Placement of the sample during measurement of the cutting force: 1 –base, 2 –cutting blade, 3 –sample (own elaboration)

Statistical analysis of the results

Statistical analysis was performed with Statistica 12 software (StatSoft, Inc., Tulsa, OK, USA) using two-way analysis of variance. The significance of differences between mean values was determined using Tukey's test at $p < 0.05$. Test results are presented in tables and as graphical charts, including values of mean standard deviations.

Trends resulting from changes in the amount of additives for each raw material were determined using first-degree multiple regression for confidence intervals of 0.95.

Results and discussion

Considering their prebiotic value for the intestinal microflora, whole grain and plant-based products are extremely important in terms of nutritional value. Various types of commercially available cereal bars with nuts, almonds or dried fruit are produced by adding a binding agent, most often a starch syrup. Whole or half nuts, pieces of dried fruit, rice flakes, barley malt extract, sunflower oil, soy lecithin and palm oil are also added (as a control trial). Thus, the bars obtained contain approximately 14% fat, approximately 6% fiber and more than 60% carbohydrates. They can be a part of a balanced diet, as a convenient and nutritious snack (Carcea, 2020; Wolski and Najda, 2005). However, due to their nutritional value and the high content of simple sugars, such bars are not highly recommended.

Compared to commercial cereal bars, the proposed pomace-based bars definitely differ in chemical composition. For example, they offer a higher fibre content (by 10.7%), less carbohydrates by reducing the binding agent (by 22%) and lower amounts of fat (by 6.85%). What is more, pomace can be used to produce gluten (as well as gluten-free) products (Kawecka and Galus, 2021; AOAC, 2000; Carcea et al., 2019; Harris et al., 2019).

It should be noted that the chemical composition may vary depending on the substances forming the bar, however, when the fruit and vegetable pomace is the base, it significantly increases the group of valuable nutrients in the final product (bar).

The bars obtained according to the procedure are shown on the Figure 3.

Figure 3. Example of obtained bars (own elaboration)

Table 3.
Nutritional properties of the tested bars.

Recipes	Protein (%)	Fat (%)	Ash (%)	Sodium (%)	Salt (%)	Carbohydrates (%)	Fibre (%)
Rec. 1	10.00	7.15	4.56	6,14 ± 0.74	1.56 ± 0.19	40.0	16.6
Rec. 2	8.96	7.32	3.46	5.29 ± 0.63	1.35 ± 0.16	41.6	10.8

In addition, the proposed technology allows for a permanent blending of all ingredients, and heat treatment allows for the inactivation of microorganisms and bacteria that may be present in the obtained pomace. The final moisture content of the obtained products ranged from 16 to 26%, depending on the heat treatment time. The moisture content of the bars without the heat treatment was 34.7% for recipe 1 and 32.7% for recipe 2, respectively (Table 4).

Table *4.*
Moisture content of bars in relation to heat treatment

Heat treatment time	Moisture content (%)	
	Recipe 1	Recipe 2
Control (without treatment)	34.70	32.70
10 min	26.79	26.21
20 min	23.59	23.82
30 min	16.37	18.36
40 min	17.35	16.45
50 min	18.78	9.95

Figure 4 shows the changes of temperature inside the bar during heat treatment. As observed, after only 10 minutes (in both recipes) the temperature inside the bar reached approximately 60°C. Further heat treatment caused a systematic increase in temperature and after 50 min. of heat treatment, the temperature of 90°C was reached for recipe 1, while for recipe 2 this temperature was reached after 40 min of heat treatment.

According to the methodological assumptions, the texture of the obtained bars was evaluated and compared against commercially available muesli-type bars. The results obtained indicate that it is possible to achieving acceptable results for hardness and resistance to cutting as in commercially available bars obtained in a different way.

The cutting force for commercial muesli-type bars was 30.12 N and is similar to the cutting force for bars produced from pomace, which after 30 minutes of the heat treatment was 31.95 N for recipe 1 and 25.66 N for recipe 2. The cutting force for bars produced from apple pomace increased with the heat treatment time. The highest value was reached after 50 minutes of heat treatment (42.20 N for recipe 1 and 45.80 N for recipe 2). The control sample, on the other hand, had the lowest value - 9.13 N for recipe 1 and 6.81 N for recipe 2, which was influenced by the lack of heat treatment (Figure 5).

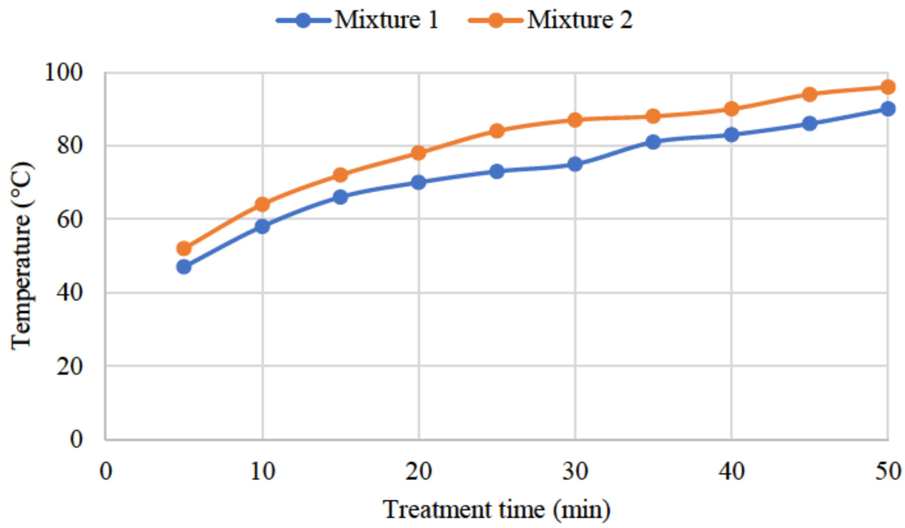

Figure 4. Temperature changes inside the bars during heat treatment

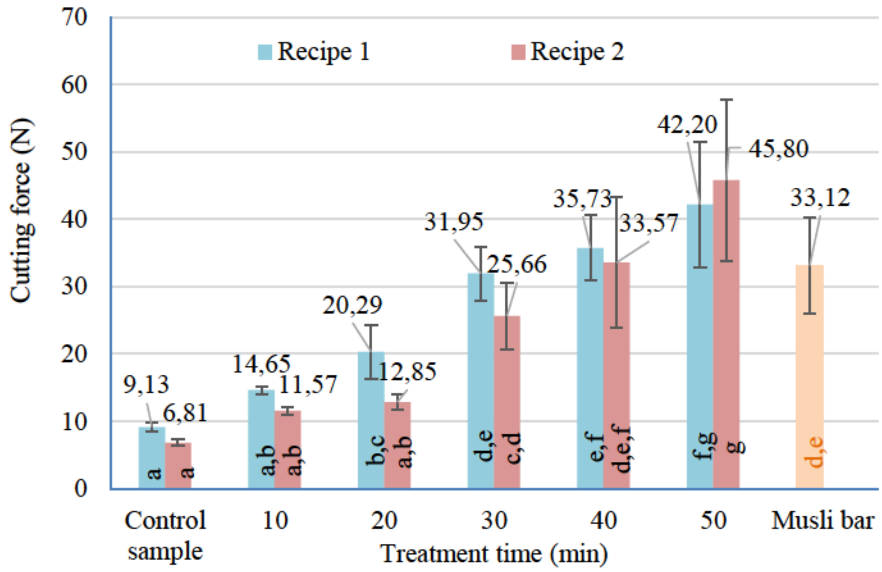

Figure 5. Average values of the bar cutting force with standard deviation. The letters of the alphabet denote homogeneous groups according to the Tukey procedure, with the significance level α=0.05

Marciniak et al. (2012) noticed that the texture affects the functionality of products, eating habits and consumer preferences in many ways. It covers many rheological properties of food, enabling the assessment of changes occurring during production, as well as its storage. On the other hand Sobczak et al. (2020) investigating the texture of compressed tablets made from organic waste obtained the highest cutting force value of around 11 N for agglomerates without heat treatment. In this study, the cutting force value was around 6 and 9 N depending on the recipe. The results obtained are smaller due to the different degree of compaction and composition. The increase in temperature caused by the frictional force due to compression caused the honey powder to change into a viscous liquid which strengthened the dough structure. In the presented study, heat treatment in an oven was applied, which also caused a significant increase in the cutting force. A similar relationship was obtained when measuring the hardness of the products discussed.

Please note that the differences between the results concerning cutting force and hardness obtained in own research could be due to the use of different raw materials, different recipes and different manufacturing process.

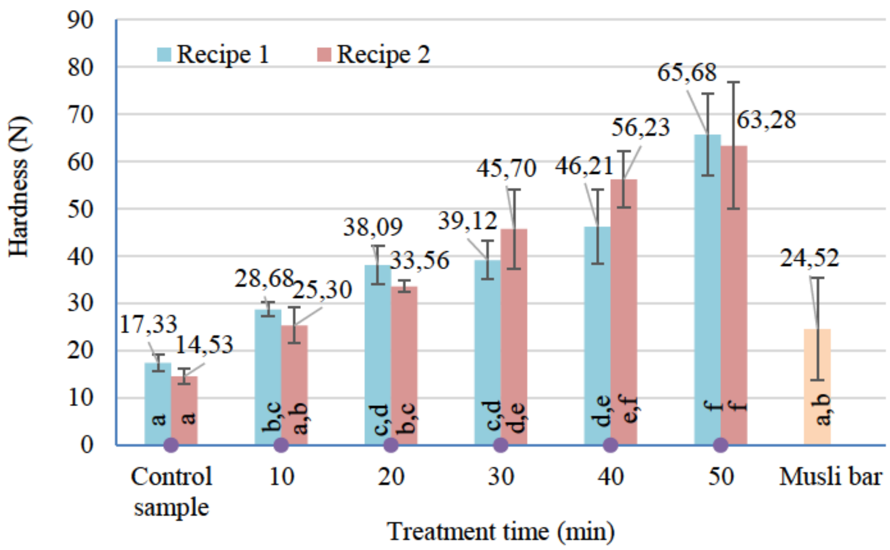

Figure 6. Average values of bar hardness with standard deviation. The letters of the alphabet denote homogeneous groups according to the Tukey procedure, with a significance level α=0.05

The hardness of the muesli-type bars was 24.52 N and the value was similar for the bars made with apple pomace after 10 minutes of the heat treatment. The hardness was 28.68 N for recipe 1 and 25.30 N for recipe 2, respectively. The hardness of the bars increased with the heat treatment time. The highest result was obtained after 50 minutes of heat treatment (65.68 N for recipe 1 and 63.28 N for recipe 2). The lowest hardness of the bars without heat treatment was 17.33 N for recipe 1 and 14.53N for recipe 2 (Figure 6).

Table 5 presents the regression equations showing the course of changes in the cutting force, hardness and cutting work for individual samples. A high regression coefficient indicates a high degree of fit of the equations.

Table 5.
Linear model of cutting, hardness and work of cutting

Name	Recipe	Linear model	R^2
Cutting force (N)	1	$F_1 = 0.686 \cdot \tau + 8.502$	0.98
	2	$F_2 = 0.782 \cdot \tau + 3.154$	0.94
Work of cutting (mJ)	1	$W_1 = 5.9261 \cdot \tau + 125.46$	0.99
	2	$W_2 = 6.374 \cdot \tau + 74.937$	0.96
Hardness (N)	1	$H_1 = 0.844 \cdot \tau + 18.089$	0.93
	2	$H_2 = 0.996 \cdot \tau + 14.86$	0.99

τ - processing time (min)

Conclusions

The following conclusions were drawn from the research:

1. Duration of heat treatment changes the mechanical properties of the bars produced. Increasing the time from 10 to 50 minutes resulted in a 2.8-fold increase in cutting force for recipe 1 and a 4-fold increase in cutting force for recipe 2. Similarly, in the case of hardness, there was a 2.2-fold increase in hardness for recipe 1 and a 2.3-fold increase in hardness for recipe 2.
2. When comparing cutting force values, the bars with the most similar textural characteristics to commercial muesli bars were those after a 40-minute heat treatment for recipe 2 and a 30-minute treatment for recipe 1. However, with regard to hardness, the bars with the most similar textural characteristics were those after a 10-minute heat treatment.
3. It is possible to produce acceptable muesli-type bars with reduced carbohydrate content and increased fibre content from natural ingredients without the addition of a binding agent, such as starch syrup, when aggregating technology.
4. The study showed that the addition of 40% fruit and vegetable pomace allowed for the production of solid bars with similar textural and storage parameters, which can be the starting point for commercial production.

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ZASTOSOWANIE WYTŁOKÓW Z MARCHWI I JABŁEK DO PRODUKCJI ZDROWYCH BATONÓW

Streszczenie. W ostatnich latach, na fali popularności zdrowego odżywiania, znacznie wzrosło spożycie owoców, warzyw, soków, przecierów i wszelkiego rodzaju koktajli (smoothies). Ich produkcja jest bezpośrednio związana z powstawaniem wytłoków. Zakładając, że wytłoki powstałe podczas produkcji soków stanowią jedynie 20% wykorzystywanego surowca, przemysł przetwórczy produkuje aż 630 000 ton wytłoków rocznie. Ponowne wykorzystanie tego surowca stanowi poważny problem dla producentów. Liczne badania dowodzą jednak, że wytłoki owocowe są cennym źródłem wielu substancji odżywczych. Celem pracy było opracowanie technologii produkcji batonów na bazie wytłoków jabłkowych wytwarzanych metodą prasowania oraz ocena ich jakości. Wyniki analizy struktury batonów pozwalają stwierdzić, że pod względem twardości i odporności na krojenie parametry tego produktu nie odbiegają istotnie od parametrów komercyjnych batonów wytworzonych inną technologią i z innych składników.

Słowa kluczowe: wytłoki z owoców i warzyw; agregacja; tekstura; baton