agriculture

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Functional Properties of Fruit Fibers Preparations and Their Application in Wheat Bakery Products (Kaiser Rolls)

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Abstract: In recent years, there has been an increase in consumer interest in functional foods enriched with health-promoting ingredients, which include dietary fiber. Therefore, the present study investigated the functional properties of fruit fiber preparations, i.e., cocoa, chokeberry, and apple fiber preparations, then designed wheat bakery products, kaiser rolls, with these fibers and evaluated the designed products. The fiber preparations selected for the study were evaluated for water binding properties (WHC), solubility (WSI), total polyphenol content, and antioxidant activity using a spectrophotometric method. In the designed bakery products, the weight losses occurring during baking were determined, specific mass, and hardness were evaluated, and sensory evaluation was carried out using a descriptive method. The tested fiber preparations showed varying water solubility, ranging from approximately 17% for cocoa fiber to approximately 30% for chokeberry one. The highest values, both in polyphenol content and antioxidant properties, were characteristic for chokeberry fiber, at 7.0 mg GAE/1 g and 10.1 Trolox/100 g, respectively, while the lowest values were for apple fiber (1.6 mg GAE/1 g, 3.6 Trolox/100 g). Baked products, kaiser rolls, with the proportion of the tested preparations at a lower addition level (3% flour replacement) had more favorable sensory characteristics than those containing a higher proportion of fiber (6% flour replacement). Considering all the tested fiber preparations, the rolls with the addition of chokeberry fiber preparation were the most favorable in terms of sensory characteristics. As the proportion of apple and cocoa fiber preparations in the rolls increased, the hardness and intensity of the bitter taste also increased. The designed bakery products could be a valuable addition to the assortment of semi-confectionery breads (yeast doughs), where the unfavorable bitter taste could be masked by the addition of, e.g., dried fruits (cranberries, raisins), nuts, sunflower seeds, or fruit filling.

Keywords: cocoa fiber preparation; apple fiber preparation; chokeberry fiber preparation; antyokxidant properties; polyphenol content; food design; kaiser rolls; high fiber content

Citation: Sadowska, A.; Świderski, F.; Siol, M.; Niedziółka, D.; Najman, K. Functional Properties of Fruit Fibers Preparations and Their Application in Wheat Bakery Products (Kaiser Rolls). *Agriculture* **2022**, *12*, 1715. https://doi.org/10.3390/agriculture12101715

Academic Editor: Justyna Cybulska

Received: 30 August 2022
Accepted: 14 October 2022
Published: 18 October 2022

1. Introduction

In recent years, the production and consumption of highly processed foods, poor in fiber, which is a valuable food component that affects metabolism and physiological processes in the human body, has increased significantly [1]. Health benefits associated with consuming dietary fiber include preventing constipation, improving intestinal peristalsis, preventing colon cancer [2]. In addition, fruit fibers can be a good source of antioxidants in the diet [3]. Usually, fruit fibers are obtained from pomace (post-production waste in the fruit industry), which is a valuable source of nutrients and bioactive components, such as vitamin C, minerals, pectin, saccharides, as well as aromatic and color compounds [4]. The most commonly produced fruit fibers are preparations obtained from chokeberries, apples, cranberries and cocoa fibers. Chokeberry pomace, the residue of juice production, is rich in bioactive secondary plant metabolites, compounds with the character of polyphenols [5].

They are characterized by a high content of anthocyanins, flavones, phenolic acids, and tannins [6]. Apple pomace, formed during the processing of fruit into beverages, cider, juices, or wine, is rich in pectin, which exhibits health-promoting properties, including inhibiting the absorption of toxic lead compounds from food and participating in the regulation of blood cholesterol levels [7,8]. Roasted cocoa husk, a waste product from the chocolate industry, is used to obtain a fiber preparation with high antioxidant properties [9]. Cocoa fiber contains theobromine, the main alkaloid found in cocoa, which exhibits stimulating properties, improves concentration, and reduces feelings of exhaustion [10]. This fiber prevents food from drying out quickly due to its high binding properties for both water and fat [9,11]. The use of fruit fibers in food technology contribute primarily to increasing the amount of dietary fiber in the diet, but also to enriching the diet with bioactive compounds [12].

There is a lot of research in the literature [13–15] on the use of fiber preparations in food design. Most often, these studies concern the use of fiber obtained from cereals, and to a lesser extent, fruit fibers. The available data most often concern the use of fibers in the development of cereal products, such as pasta, cakes, or bread, and to a lesser extent, the type of kaiser rolls, which are the subject of current study. The literature review shows [16–19] that there is a great interest among scientists in the use of waste products from the food industry as valuable food components rich in dietary fiber and bioactive ingredients. In recent years, fruit and vegetable pomace, processed as low aw fiber preparations, obtained by drying and grinding, has been enjoying great popularity. There are various forms of fiber preparations on the market. Preparations are available in the form of granules, seeds, hulls, shells or grains, as well as in bulk form in the form of powder [20,21].

Taking the above into account, the present study investigated the functional properties of fruit fiber preparations in the form of powder, i.e., cocoa, chokeberry, and apple fibers preparations, and examined the possibility of developing bakery products, specifically kaiser rolls, very popular among consumers, enriched with these preparations at two levels of additive, i.e., 3% and 6%.

2. Materials and Methods

2.1. Materials

The material for the study consisted of fruit fiber preparations, i.e., chokeberry fiber, apple fiber, and cocoa fiber preparations purchased from the local market (Table 1).

Table 1. Energy value (kcal/100 g) and nutrient and salt content (g/100 g) of the tested fiber preparations (according to the manufacturer).

Type of Fiber Preparation	Energy Value	Fat (Including Saturated Fatty Acids)	Carbohydrates (Including Sugars)	Fiber	Protein	Salt
Chokeberry	251	4.25 (0.0)	16.9 (7.0)	57.8	7.2	<0.01
Apple	293	3.7 (0.7)	29 (<1)	60.0	7.0	<0.1
Cocoa	269	6.0 (1.7)	0.7 (<0.2)	72.0	17.0	<0.1

The formulation of rolls with the addition of the above-mentioned preparations was based on the exchange of flour in the amount of 3% and 6% for individual fiber preparations (Table 2).

Table 2. Composition of recipe (%) of wheat dough in the form of rolls enriched with studied fiber preparations.

Formulation Ingredient	Basic Recipe	3% Addition of a Fiber Preparation	6% Addition of Fiber Preparation
Wheat flour type 450	60	57	54
Water	25	25	25
Instant yeast	1	1	1
Sugar	1	1	1
Salt	1	1	1
Eggs	8	8	8
Butter, 82% fat content	5	5	5
Fiber preparation	-	3	6

2.2. Methods

2.2.1. Water Activity (aw)

The aw value was measured using a manual AquaLab Water Activity Meter (Decagon Devices, Inc., Pullman, WA, USA).

2.2.2. The Water Holding Capacity (WHC)

The water holding capacity (WHC) was determined according to the procedure described by Sudha et al. (2007) [22]. Hence, 1 g of powder sample was measured into test tubes and 50 mL of distilled water was added to each. They were then centrifuged at 10,000× g rpm (MPW-380 R, MPW Med. Instruments, Warsaw, Poland) for 15 min and the excess water was discarded. The powder with absorbed water was weighed again. WHC was expressed as g water/1 g of powder.

2.2.3. The Water Solubility Index (WSI)

Water solubility index (WSI) was measured by the method described by Anderson et al. (1996) [23]. After mixing 2.5 g of powder with 30 mL of distilled water, the sample was incubated at 37 °C ± 1 for 30 min and then centrifuged for 20 min at 10,000× g rpm (centrifuge MPW-380 R, Poland). The supernatant was collected in a pre-weighed weighing vessel and dried at 103 ± 2 °C to constant weight. WSI was expressed as g water/100 g of powder.

2.2.4. Total Polyphenolic Compounds

The total polyphenol content was determined by the spectophotometric method described by Singelton and Rossi (1965) [24]. The principle of this method is based on the color reaction between Folin-Ciocalteu reagent and polyphenolic compounds in an alkaline medium. The intensity of the resulting color was measured spectophotometrically, at a wavelength of 720 nm. The content of polyphenolic compounds was expressed as GAE (Gallic Acid Equivalent), i.e., the amount of mg of gallic acid per 1 g of dry weight of powder.

2.2.5. Antioxidant Properties

The antioxidant activity of the powders was determined using ABTS$^{+\cdot}$ (diammonium salt of 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) cationorods according to the method of Re et al. (1999) [25]. The principle of the method is to measure the ability to deactivate synthetic ABTS-+ cation radicals by antioxidant compounds contained in the tested material. These compounds, as a result of the reaction, cause a decrease in the color intensity of the radical solution, which was determined spectophotometrically at a wavelength of λ = 734 nm. The antioxidant activity was expressed as mmol TEAC (Trolox Equivalent Antioxidant Capacity) per 100 g dry weight of the tested powder.

2.2.6. Weigh Loss

Weight loss during the baking of rolls with the addition of the studied fiber preparations was determined by taking into account the difference in weights of the products before and after baking and cooling.

2.2.7. Volume and Specific Mass Measurements

The volume of the yeast rolls was measured using the measurement of the volume of millet groats seeds displaced by the product. Based on the weight and volume of the rolls, their specific mass (*SM*) was calculated using the formula:

$$SM = \frac{m}{v}$$

where:

- SM is specific mass ($\frac{g}{cm^3}$)
- m is sample weight (g)
- v is sample volume (cm^3)

2.2.8. Instrumental Texture Measurement

The hardness of the crumb of the rolls with the fiber preparations tested was evaluated using a TA.XT2 texture analyzer (Stable Micro Systems, Godalming, UK). A compression test was performed using a 25 mm diameter stylus for its penetration to a depth of 9 mm. For the measurement, bun crumb samples measuring 2 cm × 4 cm × 4 cm were prepared and placed parallel to the mandrel. The measurement was repeated four times.

2.2.9. Sensory Evaluation

A simple descriptive method was used to determine the sensory characteristics of the fruit fibers as well as the rolls prepared with them, such as external appearance, smell, texture, and taste. Analysis was performed by six trained assessors fulfilling the requirements of ISO standard 8586:2012 [26]. Individual rolls samples of the same size were placed in plastic containers and covered with lids. The samples were differently coded for each assessor and presented in individual random order. Still mineral water was used as neutralizer between samples. Evaluation was performed in the sensory laboratory fulfilling all requirements of ISO standard 8589:-2010 [27].

2.2.10. Kaiser Rolls Basic Chemical Composition

Determination of the basic composition of kaiser rolls was made on the basis of calculations, taking into account the nutritional value declaration of each component found on the product packaging.

2.2.11. Statistical Analysis

Statistical analysis of the obtained results was carried out using Statistica 13.0 software (Tibco Software Inc., Palo Alto, CA, USA). One-way analysis of variance (ANOVA) and Duncan's post hoc test were used, with an assumed significance level of $p < 0.05$.

3. Results and Discussion

3.1. Functional Properties of the Studied Fiber Preparations

Figure 1 shows the appearance of the fiber preparations tested. All preparations were characterized by a uniform consistency, without lumps in the form of loose powder. The color of the fibers varied depending on the fruits from which they were obtained. The darkest was the chokeberry fiber preparation, with a purple-brown hue, the lighter was the cocoa preparation, with a dark brown hue, and the lightest was the apple preparation, with a light brown color. The fibers showed a fruity taste and smell, characteristic of the type of fruit used, with no foreign aftertaste or aroma.

(**a**) (**b**) (**c**)

Figure 1. Appearance of the fiber preparations tested (**a**) chokeberry fiber; (**b**) apple fiber; (**c**) cocoa fiber.

The tested preparations had a low water activity of approximately 0.30 (Table 3), which should give them adequate microbiological stability during long storage [28]. The type of fruit fiber had a significant effect on water binding properties (WHC). The highest WHC values were characterized by cocoa fiber preparation with 3.29 g water/1 g, followed by apple fiber with 2.02 g/1 g, and chokeberry fiber with 2.55 g water/1 g (Table 2). The lower WHC values in chokeberry and apple fibers may have been due to the lower fiber content in the formulation with a higher proportion of the water-soluble fraction, compared to the cocoa fiber. The varying water binding capacity of fiber preparations of different origins depends on their fractional composition, with greater binding capacity attributed to the polysaccharide fraction than to the lignin fraction. Lignin, due to its hydrophobic capacity, binds much less water than hydrophilic polysaccharides, which have a higher capacity to bind and retain water [29]. The ability to bind water molecules also depends on the distribution and type of hydrophilic groups in a given product as well as the fiber length. According to literature data, micronization or ultra-fine grinding is a new technique used to obtain very fine powder, also in fiber preparations, with a particle size of 1–100 µm and good surface properties. The powder obtained in the micronization process is characterized by high solubility, dispersibility, and water resistance sorption, which improves the quality of food products containing its additive. Moreover, micronization significantly increases the efficiency of the extraction of bioactive compounds [30–32]. According to McConnell et al. (1974) [29], during the micronization of fiber preparation particles, the water binding capacity decreases as a result of a reduction in fiber length and development of the overall fiber surface area. In addition, in some preparations, during the micronization process, the size of the pores inside the fiber fibers is increased, resulting in a greater water holding capacity of the resulting preparations [33]. Water binding capacity also depends on the soluble factor content of the fruit, mainly pectin [34].

Table 3. Physicochemical properties of the studied fiber preparations.

Type of Fiber	Water Activity	WHC ($g\ H_2O/1\ g$)	WSI (%)
Chokeberry	0.29 ± 0.002 [b]	2.55 ± 0.04 [a]	30.1 ± 0.20 [c]
Apple	0.30 ± 0.001 [b]	2.02 ± 0.08 [a]	27.4 ± 0.42 [b]
Cocoa	0.30 ± 0.001 [a]	3.29 ± 0.01 [b]	16.7 ± 0.21 [a]

[a–c]: values marked by different letters differ significantly ($p < 0.05$).

The fiber preparations tested were characterized by moderate solubility in water, achieving a WSI of less than 31% in all preparations tested regardless of their type (Table 3). The chokeberry fiber had the significantly highest ($p < 0.05$) solubility, while the cocoa fiber had the lowest. An important element affecting the solubility of fiber preparations is the proportion of soluble components, that is, mainly pectins, neutral hemicelluloses (high and low branching), gums (including β-glucans), plant mucilages, and polysaccharides in relation to the content of insoluble substances, mainly cellulose, hemicellulose extracted from acidic solutions, lignins, accompanying components (cutin, suberin, silica) [34]. Based on the current study, it can be concluded that the fiber preparations have more insoluble substances in their composition, hence obtaining lower WSI. And considering the type of fibers tested, solubility in water depended on the amount of fiber in the preparation, the higher the content, the lower the solubility. The low values of the solubility index of the fiber preparations suggest that they are suitable for use in products where the palpability of the particles of the preparation is desirable, such as additives to dishes with a heterogeneous texture (soups, sauces, cakes, pastries, fruit and vegetable fillings), as well as a base for milkshakes, yogurts, fruit mousses, and sorbets. Comparing the results of chokeberry fiber preparation to chokeberry powders, it was noted that they have approximately three times lower WHC values and almost twice lower solubility [35].

The type of fruit fiber used had a significant effect on polyphenol content and antioxidant properties (Table 4). The highest results were obtained for chokeberry fiber, lower values were characteristic of cocoa fiber, and the lowest results were noted for the apple preparation. According to numerous literature data [36–38], the antioxidant properties of fruits and vegetables depend on the content of bioactive substances, mainly polyphenols, including anthocyanins, and vitamin C. According to the cited data, chokeberry fiber showed the highest content of total polyphenols and at the same time had the highest antioxidant properties. According to a study by Kulling and Rawel (2008) [39], chokeberry fruits have significantly higher antioxidant capacity compared to other fruits. In addition, the proportion of anthocyanins in the polyphenolic fraction in these fruits is very high, at approximately 33% [40]. In comparison, the share of anthocyanins in the total content of polyphenols in apples and cocoa is approximately 19–20% [41]. Comparing the obtained results of the chokeberry fiber preparation to chokeberry powders, it was noted that they are characterized by a significantly lower content of polyphenols (chokeberry fruit: approximately 2480 mg GAE/100 g d.m.; the tested preparation: approximately 7.0 mg GAE/1 g d.m.) and more than five times lower antioxidant capacity (approximately 59 mmol Trolox/100 g d.m. in the fruit powder vs. approximately 10.1 mmol Trolox/100 g d.m. in the fiber preparation) [35]. In summary, it can be said that the content of bioactive compounds showing antioxidant activity depends on the type of raw material used, from which the fiber is obtained. Another factor is the method of obtaining the preparations, i.e., the drying time and the degree of grinding, as well as the storage conditions of the finished preparations [41].

Table 4. Content of total polyphenols (mg GAE/1 g d.m.) and antioxidant properties (mmol Trolox/100 g d.m.) in the studied fiber preparations.

Type of Fiber	Total Polyphenols	Antioxidant Activity
Chokeberry	7.0 ± 0.03^{a}	10.11 ± 0.02^{a}
Apple	1.6 ± 0.01^{c}	3.63 ± 0.02^{c}
Cocoa	6.3 ± 0.04^{b}	7.62 ± 0.01^{b}

$^{a–c}$: values marked by different letters differ significantly ($p < 0.05$).

3.2. Use of the Fruit Fiber Preparations in Wheat Bakery Production on the Example on Kaiser Rolls

In the study, the addition of fiber preparations was used in such an amount that the final products obtained were characterized by a dietary fiber content at a level that allowed the use of the nutritional claim "source of fibre" or "high fibre" per 100 g of product [42]. When kneading dough with the addition of apple and cocoa fibers, a firmer texture and lower volume during dough rising were noted compared to control samples without the addition of fiber preparations. This may be related to the higher water-binding properties of the fiber preparations compared to flour, the lower gluten content of the rolls with fiber preparations added, as well as the interaction between the various dough ingredients [43]. Other trends were noted for the dough with the addition of the chokeberry fiber preparation. During both kneading and rising, the dough was similar in texture to the control dough. This may be due in part to the lower proportion of fiber (58%) in the chokeberry preparation than in the apple and cocoa preparations (60% and 72%), as well as differences in the presence of individual fractions. Taking into account the water binding capacity and solubility degree of the tested fiber preparations, it can be concluded that the lowest WHC values and the highest WSI values obtained for chokeberry fiber may have influenced the obtaining of a softer and less compact dough texture, while in the other fiber preparations obtaining the opposite relationship perhaps resulted in a more compact and dough-like structure.

Evaluation of Designed Kaiser Rolls

The results shown in Table 5 indicate that the water activity values of all types of rolls were similar to each other. Pathogenic microorganisms do not develop at $a_w < 0.62$. With a_w at 0.3, the product is most stable in terms of lipid oxidation, non-enzymatic browning, enzymatic activity and microbial growth. As a_w increases, the likelihood of food spoilage increases [44]. In the present study, all designed buns were characterized by similar high a_w. Taking the above into account, it can be concluded that bread belongs to perishable foods, in which there is a possibility of the development of microorganisms (bacteria, yeasts, molds) during storage [45].

Table 5. Water activity, weight loss, specific mass and hardness of control and fiber-fortified rolls.

Type of Rolls		Water Activity	Weight Loss (%)	Specific Mass (g/cm^3)	Hardness (N)
Control		0.96 ± 0.003	14.25 ± 0.2 ^{d}	0.30 ± 0.03 ^{a}	17.38 ± 1.82 ^{a}
Apple fiber	3%	0.95 ± 0.001	15.06 ± 0.7 ^{e}	0.37 ± 0.02 ^{b}	53.36 ± 8.41 ^{c}
	6%	0.97 ± 0.002	13.46 ± 0.5 ^{c}	0.52 ± 0.04 ^{c}	65.70 ± 3.64 ^{d}
Cocoa fiber	3%	0.96 ± 0.002	11.70 ± 0.5 ^{b}	0.33 ± 0.06 ^{ab}	36.25 ± 8.76 ^{b}
	6%	0.97 ± 0.001	11.35 ± 0.5 ^{ab}	0.47 ± 0.05 ^{c}	66.23 ± 7.27 ^{d}
Chokeberry fiber	3%	0.97 ± 0.001	10.81 ± 0.8 ^{a}	0.32 ± 0.03 ^{ab}	14.91 ± 3.10 ^{a}
	6%	0.96 ± 0.001	11.73 ± 0.6 ^{b}	0.30 ± 0.02 ^{ab}	20.81 ± 4.34 ^{a}

$^{a–e}$: values marked by different letters differ significantly ($p < 0.05$).

The designed rolls differed in weight losses during the baking process, and in most cases these differences were statistically significant (Table 5). The highest ($p < 0.05$) weight losses were characterized by the control rolls and those with 3% apple fiber preparation (losses of approximately 14% and 15%, respectively). In a study conducted by Tańska and Rotkiewicz (2011) [46], similar results were obtained for baked products with a 10% addition of apple pomace (losses were approximately 15%). In addition, this study found that the addition of pomace did not significantly affect baking losses. Significantly ($p < 0.05$) the lowest weight losses occurred in rolls with 3% and 6% chokeberry and cocoa preparations (approximately 11–12%). Significantly higher losses were found for buns with 10% apple preparation. Hyang-Sik et al. (2014) [47] in their study of bread enrichment with chokeberry fiber preparation at 1%, 3%, 5%, and 10% levels noted that there were significantly lower weight losses as the amount of fiber preparation added increased. In the case of the present study, no such trends were noted. Rolls with the addition of chokeberry fiber preparation at 3% and 6% had similar losses. This may be due to the use of different main components for the preparation of dough and for the baked rolls designed in this study. The addition of fiber to the bread caused significant changes in its specific mass. The rolls with the highest ($p < 0.05$) specific mass were those with the highest content of apple and cocoa fiber preparation (approximately 0.52 and approximately 0.47 g/cm^3, respectively) (Table 5). In other cases, the differences were not significant. Only in the case of the control rolls with a specific mass of approximately 0.30 g/cm^3 and with 3% apple fiber (at 0.37 g/cm^3) was the difference statistically significant compared to the control rolls. It is worth noting that the specific mass of rolls with chokeberry preparation at two levels of addition was not significantly different from that of control rolls.

The designed rolls showed varying hardness depending on the type of fiber added, as well as the level of addition (Table 5). Considering the hardness results obtained, rolls with apple and cocoa fiber at two levels were characterized by significantly ($p < 0.05$) higher hardness compared to control buns and buns with chokeberry preparation, regardless of the amount of addition. The highest hardness was characterized by buns with 6% addition of apple preparation (65.70 N) and cocoa preparation (66.23 N) (followed by buns with 3% addition of apple preparation (53.36 N) and cocoa preparation at the same level of addition (approximately 36.25 N). Sujka et al. (2018) and Amir et al. [48,49] in their studies observed that the addition of fiber significantly increased the hardness of the bread crumb. Fiber in bread can limit the expansion of gas cells. This causes the bread to be more compact and harder, which was also noted in the present study. A different tendency was noted for bread with the addition of chokeberry preparation. Rolls with this fiber preparation, regardless of the level of addition (hardness at 14.91 N and 20.81 N for 3% and 6% addition, respectively), were the least hard and most similar to control rolls (17.39 N). Obtaining the above correlations may have been due to the highest solubility of chokeberry fiber and the lowest water-binding properties, which may have contributed to a less compact and more aerated dough with the lowest specific mass.

On the basis of the sensory evaluation of the designed rolls, it was found that they differed taking into account both texture characteristics, as well as color, taste and aroma (Table 6). The control rolls were defined as typical kaiser rolls. They had a cereal and yeasty aroma. The color of the crust was slightly brown and toasted, the lightest among the buns evaluated. The crumb, on the other hand, was creamy in color with visible even pores. The texture was springy and aerated. The product exhibited a neutral, mildly yeasty and sweet flavor. Rolls with 3% and 6% apple fiber preparation addition showed a cereal, yeasty aroma with a slightly sour note. Products at both levels of fiber preparation addition had a slightly sour and bitter taste, more intensely noticeable in the product with a higher percentage of fiber. The color of the crust was toasted brown, while the crumb was light brown. The cross-section showed irregular pores. After baking, buns with a lower percentage of apple fiber were characterized by a rather aerated, springy texture, more compact compared to control buns. Rolls with a higher proportion of apple fiber were characterized by a moist, more compact, and less springy texture compared to control rolls and those with a lower proportion of the fiber preparation. This could be due to the higher specific mass, lower aeration, and, most importantly, the higher degree of water retention and binding in the buns due to the addition of the fiber preparation, which was reflected in the higher perceived moisture content in these buns compared to the control sample. Similar trends were observed in their study by Baca et al. (2011) [50], where the moisture content of the bread increased as the fiber addition increased. On the other hand, in a study by Wojciechowicz and Gil (2009) [43], products enriched with apple fiber received the lowest odor rating. Designed rolls with 3% and 6% cocoa fiber preparation were characterized by an intense dark brown color of the crust. For buns with a higher addition, the color was darker. Both types of buns had irregular pores in cross-section. The texture, like that of the rolls with apple fiber, was compact; the dough with 3% added fiber preparation was quite aerated and moist, while that with 6% addition showed a more compact texture. A bitter, cocoa flavor was perceptible in the rolls, more intense in products with a higher proportion of the fiber preparation. Rolls with both cocoa and apple fiber preparation were rated worse in terms of taste and aroma characteristics, external appearance and texture compared to rolls with chokeberry fiber preparation. Similar results were obtained by Wojciechowicz and Gil (2009) [43]. In the study conducted, the lowest ratings for crust and crumb color and taste were given to products with cocoa fiber, and the lowest rating for aroma was given to wheat bread enriched with apple fiber preparation, the highest sensory rating was given to bread with oat fiber. Rolls with 3% and 6% added chokeberry fiber preparation were most similar to the control sample in terms of texture characteristics, as confirmed by the instrumental texture measurement carried out. The rolls had a springy, aerated, fluffy texture. They were characterized by a taste with a cereal, yeasty, mildly fruity–berry aroma. The taste was mildly bitter. The color of the crust as well as the crumb in the case of 3% addition was dark brown with a purple tint, more intense in the case of rolls with a higher proportion of fiber. In a study by Petković et al. (2020) [51], it was shown that rolls with the addition of chokeberry fiber were characterized by a pleasant taste and aroma. An increase in the intensity of color, flavor, and aroma was observed with an increase in the level of addition of chokeberry fiber preparation, which is confirmed in the present study.

Table 6. Sensory features of the designed rolls.

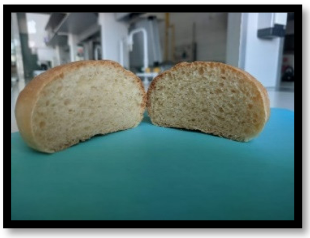
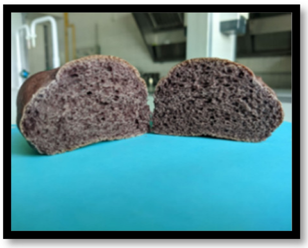
Type of Samples		External Appearance		Smell and Taste	Texture
Control			crust color: slightly brown, toasted, creamy crumb, even pores	cereal (flour), mildly yeasty, mildly sweet	springy, fluffy, aerated
Apple fiber	3%		crust color: gray-brown toasted, crumb light brown, irregular pores	cereal (flour), yeasty, slightly sour slightly bitter	quite springy, aerated, compact, moist, after 5 h of storage crumbly texture
Apple fiber	6%		crust color: brown, toasted, crumb brown, irregular pores	cereal (floury), yeasty, sour, bitter	compact, moist, not very springy, very brittle texture after 5 h of storage
Cocoa fiber	3%		crust color: dark brown, toasted, crumb dark brown, irregular pores	cereal (flour), yeast, bitter, cocoa	quite springy, aerated, compact, moist, after 5 h of storage crumbly texture

Table 6. *Cont.*

Type of Samples		External Appearance		Smell and Taste	Texture
	6%		crust color: very dark brown, almost black, toasted, crumb: intense brown, irregular pores	cereal (flour), yeasty, bitter, intense cocoa	compact, moist, not very springy; very brittle texture after 5 h of storage
Chokeberry fiber	3%		crust color: dark brown with a purple tinge, toasted, crumb: brown with a purple tinge, irregular pores	cereal (floury), yeasty, mildly fruity—berry, mildly bitter	springy, aerated, fluffy, moist, very similar to the control sample
	6%		crust color: dark brown with a purple tinge, toasted, crumb intensely brown with a purple tinge, irregular pores	cereal (floury), yeasty, mildly fruity—berry, mildly bitter	springy, aerated, fluffy, moist, similar to the control sample

Taking into account the results obtained, a reduction in energy value and carbohydrate content can be observed in all types of rolls with the addition of fiber preparations, except for rolls with 3% addition of apple preparation in the case of energy value (Table 7). The rolls did not differ significantly in the content of fat (content at the level of approximately 7%), saturated fatty acids, approximately 4%, sugars approximately 2.5–3%, proteins, approximately 9.5–10% and salt, approximately 1%. The use of fruit fiber preparations to enrich the rolls had a beneficial effect on their nutritional value. Designed products with fruit fibers preparations can be labeled with the nutritional claim "source of fibre" [42], since each type of roll contains at least 3 g of fiber per 100 g (Table 7). In addition, in the case of rolls with a 6% addition of cocoa fiber preparation, the nutritional claim "high fibre" can be applied [42], since this product contains more than 6 g of fiber in 100 g. Each of the designed rolls can be labeled with the nutrition claim "source of protein" [42], as more than 12% of the rolls' energy value comes from protein. It is worth noting that, in addition to increasing the amount of fiber, the addition of fruit fiber preparations to wheat rolls carries with it an enrichment in bioactive components with high antioxidant potential, such as theobromine from cocoa, polyphenols from chokeberries, and organic acids from apples [10,43,51].

Table 7. Energy value (kcal/100 g) and nutrient and salt content of control and fruit-flavored rolls (g/100 g).

Type of Rolls		Energy Value	Fat (Including Saturated Fatty Acids)	Carbohydrates (Including Sugars)	Fiber	Protein	Salt
Control		308.00	7.15 (3.98)	50.34 (2.62)	1.72	9.93	1.20
Apple fiber	3%	309.63	7.31 (4.04)	49.46 (2.61)	3.77	9.88	1.21
	6%	300.56	7.22 (3.96)	46.88 (2.51)	5.66	9.48	1.11
Cocoa fiber	3%	298.26	7.14 (3.93)	46.81 (2.49)	4.05	9.88	1.10
	6%	292.19	7.21 (3.93)	43.93 (2.49)	6.34	9.93	1.11
Chokeberry fiber	3%	289.11	7.00 (3.83)	46.83 (2.69)	3.53	9.44	1.10
	6%	283.80	7.18 (3.83)	45.53 (2.88)	5.45	9.38	1.12

4. Conclusions

The present study confirmed that the type of fruit fiber significantly affects its functional properties. The studied fiber preparations are poorly soluble in water, and their solubility depends on the level of fiber in the preparation and the ratio between the water-soluble and non-water-soluble fraction. Obtaining relatively low WSI values suggests that the studied preparations can find application as components of solid or semi-solid products, they are not recommended for enrichment of products with liquid consistency, where the presence of suspended particles or precipitate in the liquid is not desirable. The studied fiber preparations can be an excellent dietary supplement not only in the ingredients included in the fiber fractions, but also in bioactive compounds derived from fruits, which show free radical leveling properties. The polyphenol content and antioxidant activity of the tested preparations depended on the type of fruit from which they were prepared. The highest values, both polyphenol content and antioxidant properties, were characteristic of chokeberry fiber, while the lowest values were characteristic of apple fiber. The studied fiber preparations may find application in the development of yeast rolls at a nutritionally significant level of addition, allowing them to be labeled with the nutrition claim "source of fibre". Breads with the proportion of fiber tested at 3% had more favorable sensory characteristics than those with 6% addition. As the share of apple and cocoa fibers in the rolls increased, the taste and texture deteriorated (an increase in hardness was noted). Such a relationship was not found for chokeberry fiber. The most favorable taste was characteristic for rolls with the addition of chokeberry fiber preparation, while rolls containing the addition of apple and cocoa preparations showed too bitter taste. During a possible continuation of the research, it would be possible to consider designing confectionery breads with the addition of the studied fiber preparations and other flavor components (dried fruits, nuts, or fruit filling), which could influence the masking of the unfavorable bitter taste, thus increasing their palatability.

Author Contributions: Conceptualization, A.S. and D.N.; methodology, A.S. and K.N.; formal analysis, A.S., K.N. and D.N.; investigation, F.Ś.; resources, A.S.; data curation, A.S. and M.S.; writing—original draft preparation, A.S., D.N. and M.S.; writing—review and editing, F.Ś.; visualization, K.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research was prepared as part of the statutory activity of the Department of Functional and Ecological Food, Warsaw University of Life Sciences.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Kapczuk, P.; Komorniak, N.; Rogulska, K.; Bosiacki, M.; Chlubek, D. Żywność wysokoprzetworzona i jej wpływ na zdrowie dzieci i osób dorosłych. *Postępy Biochem.* **2020**, *66*, 23–29. [CrossRef]
2. Li Olive, Y.; Komarek, A.R. Dietaryfiber basics: Health, nutrition, analysis and applications. *Food Qual. Saf.* **2017**, *1*, 47–59. [CrossRef]
3. Witczak, T.; Stępień, A.; Gumul, D.; Witczak, M.; Fiutak, G.; Zięba, T. The influence of the extrusion process on the nutritional composition, physical properties and storage stability of black chokeberry pomaces. *Food Chem.* **2021**, *334*, 127548. [CrossRef] [PubMed]
4. Tarko, T.; Duda-Chodak, A.; Bebak, A. Aktywność biologiczna wybranych wytłoków owocowych oraz warzywnych. *Żywn. Nauk. Tech. Jak.* **2012**, *4*, 55–65.
5. Schmid, V.; Steck, J.; Mayer–Miebach, E.; Behsnilian, D.; Briviba, K.; Bunzel, M.; Karbstein, H.P.; Azad Emin, M. Impact of defined thermomechanical treatment on the structure and content of dietary fiber and the stability and bioaccessibility of polyphenols of chokeberry (*Aronia melanocarpa*) pomace. *Food Res. Int.* **2020**, *134*, 109232. [CrossRef] [PubMed]
6. Białek, M.; Rutkowska, J.; Hallmann, E. Aronia czarnoowocowa (*Aronia Melanocarpa*) jako potencjalny składnik żywności funkcjonalnej. *Żywn. Nauk. Tech. Jak.* **2012**, *6*, 21–30.
7. Wichrowska, D.; Żary-Sikorska, E. Właściwości prozdrowotne jabłkowych wytłoków poprasowych. *Inżynieria Apar. Chem.* **2015**, *54*, 286–287.
8. Znamirowska, A.; Kalicka, D.; Buniowska, M.; Rożek, P. Wpływ dodatku suszu z wytłoków jabłkowych na właściwości fizykochemiczne i sensoryczne jogurtów. *Żywn. Nauk. Tech. Jak.* **2018**, *25*, 71–80. [CrossRef]
9. Miastkowski, K.; Bakoniuk, J.R.; Czaplicka, M.; Obidziński, S. Charakterystyka wiązania wody przez błonnik kakaowy. *Postępy Tech. Przetw. Spoż.* **2015**, *1*, 15–19.
10. Matysek-Nawrocka, M.; Cyrankiewicz, P. Substancje biologicznie aktywne pozyskiwane z herbaty, kawy i kakao oraz ich zastosowanie w kosmetykach. *Postępy Fitoterapii.* **2016**, *17*, 139–144.
11. Martínez-Cervera, S.; Salvador, A.; Muguerza, B.; Moulay, L.; Fiszman, S.M. Cocoa fibre and its application as fat replacer in chocolate muffins. *LWT Food Sci. Technol.* **2011**, *44*, 729–736. [CrossRef]
12. Masiarz, E.; Kowalska, H.; Bednarska, M. Wykorzystanie wytłoków roślinnych jako źródła błonnika pokarmowego i innych bio-składników w kreowaniu właściwości prozdrowotnych, sensorycznych i technologicznych pieczywa. *Postępy Tech. Przetw. Spoż.* **2019**, *1*, 103–107.
13. Dhingra, D.; Michael, M.; Rajput, H.; Patil, R.T. Dietary fibre in foods: A review. *J. Food Sci. Technol.* **2012**, *49*, 255–266. [CrossRef]
14. Foschia, M.; Peressini, D.; Sensidoni, A.; Brennan, C.S. Review the effects of dietary fibre addition on the quality of common cereal products. *J. Cereal Sci.* **2013**, *58*, 216–227. [CrossRef]
15. Yang, Y.; Ma, S.; Wang, X.; Zheng, X. Modification and Application of Dietary Fiber in Foods. *J. Chem.* **2017**, *10*, 1–8. [CrossRef]
16. Antonic, B.; Jancikova, S.; Dordevic, D.; Tremlova, B. Apple pomace as food fortification ingredient: Asystematic review and meta-analysis. *J. Food Sci.* **2020**, *85*, 2977–2985. [CrossRef]
17. Hussain, S.; Jõudu, I.; Bhat, R. Dietary Fiber from Underutilized Plant Resources—A Positive Approach for Valorization of Fruit and Vegetable Wastes. *Sustainability* **2020**, *12*, 5401. [CrossRef]
18. Xu, J.; Li, Y.; Zhao, Y.; Wang, D.; Wang, W. Influence of antioxidant dietary fiber on dough properties and bread qualities: A review. *J. Function. Foods* **2021**, *80*, 104434. [CrossRef]
19. Jiang, G.; Feng, X.; Wu, Z.; Li, S.; Bai, X.; Zhao, C.; Ameer, K. Development of wheat bread added with insoluble dietary fiber from ginseng residue and effects on physiochemical properties, in vitro adsorption capacities and starch digestibility. *LWT Food Sci. Technol.* **2021**, *149*, 111855. [CrossRef]
20. Ajila, C.M.; Leelavathi, K.U.J.S.; Rao, U.P. Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. *J. Cereal Sci.* **2008**, *48*, 319–326. [CrossRef]
21. Bender, A.B.B.; Speroni, C.S.; Moro, K.I.B.; Morisso, F.D.P.; dos Santos, D.R.; da Silva, L.P.; Penna, N.G. Effects of micronization on dietary fiber composition, physicochemical properties, phenolic compounds, and antioxidant capacity of grape pomace and its dietary fiber concentrate. *Food Sci. Technol.* **2020**, *117*, 108652. [CrossRef]
22. Sudha, M.L.; Baskaran, V.; Leelavathi, K. Apple pomace as a source of dietary fiber and polyphenols and its effect on the rheological characteristics and cake making. *Food Chem.* **2007**, *104*, 686–692. [CrossRef]
23. Anderson, R.A.; Conway, H.F.; Pfeifer, V.F.; Griffin, E.L. Gelatinization of corn grits by roll- and extrusion-cooking. *Cereal Sci. Today* **1969**, *14*, 372–376. [CrossRef]
24. Singleton, V.; Rossi, J. Colorimetry of total phenolics with phosphomolybdic- phosphotungstic acid reagents. *Am. J. Enol. Vitic.* **1965**, *16*, 144–158.
25. Re, R.; Pellegrini, N.; Proteggente, A.; Pannala, A.; Yang, M.; Rice-Evans, C. Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radic. Boil. Med.* **1999**, *26*, 1231–1237. [CrossRef]
26. *EN ISO 8586:2012*; Sensory Analysis. General Guidelines for the Selection, Training and Monitoring of Selected Assessors and Expert Sensory Assessors. ISO: Geneva, Switzerland, 2012.
27. *EN ISO 8589:2010*; Sensory Analysis. General Guidance for the Design of Test Rooms. ISO: Geneva, Switzerland, 2010.
28. Obidziński, S. Charakterystyka aktywności wody i parametrów geometrycznych odpadów melisy w aspekcie ich wykorzystania jako dodatku do pasz. *Acta Agrophysica* **2013**, *20*, 113–124.

29. McConnell, A.; Eastwood, M.; Mitchel, W. Physical characteristics of vegetable foodstuffs that could influence bowel function. *J. Sci. Food Agric.* **1974**, *25*, 1457–1464. [CrossRef]
30. Xue, X.; Wang, J.; Li, S.; Zhang, X.; Dong, J.; Gui, L.; Chang, Q. Effect of micronised oat bran by ultrafine grinding on dietary fibre, texture and rheological characteristic of soft cheese. *Int. J. Food Sci. Technol.* **2020**, *55*, 578–588. [CrossRef]
31. Gao, W.; Chen, F.; Wang, X.; Meng, Q. Recent advances in processing food powders by using superfine grinding techniques: A review. Compr. Rev. *Food Sci. Food Saf.* **2020**, *19*, 2222–2255. [CrossRef]
32. Dziki, D.; Gawlik-Dziki, U.; Tarasiuk, W.; Różyło, R. Fiber Preparation from Micronized Oat By-Products: Antioxidant Properties and Interactions betweenBioactive Compounds. *Molecules* **2022**, *27*, 2621. [CrossRef]
33. Nelson, A. Properties of high-fiber ingredients. *Cereal Foods World* **2001**, *3*, 92–100.
34. Rzedzicki, Z.; Sykut-Domańska, E.; Strychalski, P. Charakterystyka składu chemicznego wybranych sortymentów pieczywa chrupkiego. *Bromat. Chem. Toksykol.* **2008**, *3*, 610–615.
35. Sadowska, A.; Swiderski, F.; Rakowska, R.; Hallmann, E. Comparison of quality and microstructure of chokeberry powders prepared by different drying methods, including innovative fluidised bed jet milling and drying. *Food Sci. Biotechnol.* **2019**, *28*, 1073–1081. [CrossRef]
36. Sadowska, A.; Świderski, F.; Hallmann, E.; Świąder, K. Assessment of chokeberry powders quality obtained using an innovative fluidized-bed jet milling and drying method with pre-drying compared with convection drying. *Foods* **2021**, *10*, 292. [CrossRef]
37. Hallmann, E.; Kazimierczak, R.; Marszałek, K.; Drela, N.; Kiernozek, E.; Toomik, P.; Matt, D.; Luik, A.; Rembiałkowska, E. The nutritive value of organic and conventional white cabbage (*Brassica oleracea* L. Var. *capitata*) and anti-apoptotic activity in gastric adenocarcinoma cells of sauerkraut juice produced therof. *J. Agric. Food Chem.* **2017**, *65*, 8171–8183. [CrossRef]
38. Sadowska, A.; Świderski, F.; Hallmann, E. Bioactive, physicochemical and sensory properties as well as microstructure of organic strawberry powders obtained by various drying methods. *Appl. Sci.* **2020**, *10*, 4706. [CrossRef]
39. Kulling, S.E.; Rawel, H.M. Chokeberry (*Aronia melanocarpa*)—A review on the characteristic components and potential health effects. *Planta Med.* **2008**, *74*, 1625–1634. [CrossRef]
40. Rugină, D.; Sconţa, Z.; Leopold, L.; Pintea, A.; Bunea, A.; Socaciu, C. Antioxidant activities of chokeberry extracts and the cytotoxic action of their anthocyanin fraction on hela human cervical tumor cells. *J. Med. Food.* **2012**, *15*, 700–706. [CrossRef]
41. Szajdek, A.; Borowska, J. Właściwości przeciwutleniające żywności pochodzenia roślinnego. *Żywn. Nauk. Tech. Jak.* **2004**, *4*, 5–28.
42. Regulation (EC) No. 1924/2006 of the European Parliament and of the Council of 20 December 2006 on Nutrition and Health Claims Made on Foods. Available online: http://data.europa.eu/eli/reg/2006/1924/oj (accessed on 25 August 2022).
43. Wojciechowicz, A.; Gil, Z. Jakość pieczywa pszennego z udziałem błonnika pokarmowego różnego pochodzenia. *Żywn. Nauk. Tech. Jak.* **2009**, *6*, 102–111.
44. Sandulachi, E. Water acrivity concept and its role in food preservation. *Meridian Eng.* **2012**, *4*, 40–48.
45. Mathlouthi, M. Water content, water activity, water structure and the stability of foodstuffs. *Food Control* **2001**, *12*, 409–417. [CrossRef]
46. Tańska, M.; Rotkiewicz, D. Wykorzystanie wytłoków jabłkowych w produkcji pieczywa. *Bromat. Chem. Toksykol.* **2011**, *3*, 847–853.
47. Yoon, H.S.; Kim, J.W.; Kim, S.H.; Kim, Y.G.; Eom, H.J. Quality Characteristics of Bread added with Aronia Powder (Aronia melanocarpa). *J. Korean Soc. Food Sci. Nutr.* **2014**, *43*, 273–280. [CrossRef]
48. Sujka, K.; Ceglińska, A.; Romankiewicz, D.; Kacprzyk, E. Wpływ dodatku błonnika na zmianę wilgotności i tekstury pieczywa pszennego w czasie przechowywania. *Acta Agrophysica* **2018**, *25*, 73–84. [CrossRef]
49. Amir, I.Z.; Hanida, H.S.; Syafiq, A. Development and physical analysis of high fiber bread incorporated with cocoa (*Theobroma cacao* sp.) pod husk powder. *Int. Food Res. J.* **2013**, *20*, 1301–1305.
50. Baca, E.; Kapka, A.; Karaś, M.; Zielińska, D. Wpływ dodatku błonnika jabłkowego do mąki pszennej na właściwości funkcjonalne ciasta i jakość chleba. *Prob. Hig. Epidem.* **2011**, *92*, 868–871.
51. Petković, M.; Filipović, V.; Filipović, J.; Durović, I.; Miletić, N.; Radovanović, J. Chemical, antioxidative and sensory characteristics of wheat bread partially substituted with black chokeberry (*Aronia melanocarpa* L.) powder. *J. Food Process. Preserv.* **2020**, *45*, 1. [CrossRef]