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Sensory Profile, Consumers' Perception and Liking of Wheat–Rye Bread Fortified with Dietary Fibre

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Abstract: Evidence of global dietary fibre (DF) deficits provides impetus for research to develop new food products and reformulate commonly consumed foods to enable the transition to more healthy diets. The main aim of the study was to evaluate the sensory properties and consumers' perception, liking, and willingness to buy wheat–rye bread fortified with DF. The study combined expert sensory profiling with consumers evaluation of DF fortified bread in blind and informed conditions. A sensory-trained panel evaluated six samples of bread with flour replaced by 0%, 4%, 8%, 12%, 16%, and 20% with oat DF using 29 pre-identified attributes. A consumer panel (n = 300) evaluated bread samples in blind condition for liking and perception of healthiness, naturalness, and attractiveness and willingness to buy (WTB). Consumers were also asked to indicate the maximum price they were willing to pay for a standard bread of 700 g. In the informed condition, consumers evaluated the 0%, 8%, 12% oat DF samples labelled with either nutritional or health related claims using the same attributes as in blind condition including visual liking. The results of profiling revealed that replacement of flour with oat DF influenced intensity of several attributes related to different modalities. Results of the consumer studies showed that replacement of flour up to 20% with oat DF did not adversely affect consumers' acceptance and willingness to buy wheat–rye breads. The mean values for bread samples labelled with information related to positive health outcomes of DF consumption were not significantly different from those with nutritional claims only. Combining sensory profiling with consumers acceptance studies gives valuable insights for consumer led new product development. The fortification of staple foods like bread with dietary fibre seems like a promising avenue, but other sources of fibre should also be considered in bread fortification to enhance health-related properties and prevent food waste.

Keywords: sensory characteristic; hedonic consumer test; bread fortification; willingness to buy; dietary fibre

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Citation: Żakowska-Biemans, S.; Kostyra, E. Sensory Profile, Consumers' Perception and Liking of Wheat–Rye Bread Fortified with Dietary Fibre. *Appl. Sci.* **2023**, *13*, 694. https://doi.org/10.3390/app13020694

Academic Editor: Maria Kanellaki

Received: 16 December 2022
Revised: 23 December 2022
Accepted: 30 December 2022
Published: 4 January 2023

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1. Introduction

Bread products are consumed daily by the majority of the population in different countries and cultures, and for years the food industry has focused on increasing the nutritional value of these products. The importance of dietary fibre (DF) in the human diet is widely recognized and there were many attempts related to enrichment of food products with fibre [1–5].

Cereal products are the basic source of DF in the diet of Poles [6]. Laskowski et al. [7] indicated that cereals and cereal products contributed 30.4% of total dietary energy supply in the Polish diet, providing a significant percentage of six nutrients, i.e., 64.1% of manganese, 51% of carbohydrates, 48.5% of dietary fibre, 34.1% of iron, 33.6% of folate, and 31.3% of copper.

Reformulation to fortify products with dietary fibre presents an opportunity to counter the health risks without making people radically change their diets. One of the common

ways to increase fibre intake and enhance the potential health benefits is through its incorporation in staple foods such as bread, but there is a challenge to optimise the potential health benefits derived from DF while retaining the consumer acceptability of the food [8–10].

Enhancing the nutritional value of bread with DF is challenging as new sources of fibre become available, and consumers are shifting towards a healthier diet [11–15]. One of the dietary fibres gaining more interest due to its potential health benefits is oat fibre [3,16]. The health effects of oats rely mainly on the total dietary fibre and β-glucan content, e.g., β-glucan can help lower blood cholesterol, glucose, and insulin concentrations [17,18]. This soluble oat fibre is able to attenuate blood postprandial glycaemic and insulinemic responses, to lower blood total cholesterol and low-density lipoprotein (LDL) cholesterol, and to improve high-density lipoprotein (HDL) cholesterol and blood lipid profiles as well as to maintain body weight. Thus, oat β-glucan intake is considered beneficial in the prevention, treatment, and control of diabetes and cardiovascular diseases [19].

In breadmaking applications, a careful selection of DFs with suitable physicochemical properties preventing permanent disruption of the protein matrix is a prerequisite to obtain sensorially accepted breads in highly substituted flour systems [8].

Several studies investigated the influence of DF addition on the quality of cereal-based products such as pasta, bread, muffin and extruded snacks [4,20,21]. Regardless of the improvement in the nutritional value and the associated health benefits, the acceptability of these products is often reported as low [1]. The low acceptability scores of higher fibre-containing products were influenced by the appearance, the texture, as well as the flavour of the products. The adverse effects of fibre on the quality of the baked products have been well documented, and baked products rich in fibre can have properties such as reduced loaf volume, hard crumb, bitter flavour and dark colour [1,9,22,23]. Ortiz de Erive et al. [23] reported that the negative effects of adding soluble oat fibre can effectively be counteracted by optimizing the water content in bread formulas.

Enrichment of white bread with dietary fibre is of great interest for the bakery industry due to the increasing demand of healthier food products. It is underlined in literature that β–glucan fibre is considered as a promising biologically active natural polysaccharide due to its properties related to prevention and control of obesity, cardiovascular diseases, diabetes, and cancer [24]. It can be used in various food products e.g., bread, breakfast cereals, beverages and even in infant foods [25,26].

A deeper understanding of the effect of β-glucan fibre addition on changes in sensory characteristics of wheat–rye bread, taking into account the acceptability and perception of such products by consumers is particularly important from a technological and also cognitive point of view.

Consumers' quality perception of bread is mainly determined by sensory and health attributes. Another issue is the provision of information on the benefits associated with dietary fibre enrichment to increase consumer willingness to accept such products. Consumers' quality perception of bread is predominantly determined by sensory and health attributes [12,27].

However, consumers might only consider consuming functional foods if they are perceived as healthier than their conventional alternatives [28]. Bornkessel et al. [29] found that the higher the health motivation, the higher the consumers' ingredient awareness. Thus, in order to consider consuming a food product enriched with a certain functional ingredient, consumers need to be aware of its potential health benefits. For this reason, knowledge about functional ingredients is likely to significantly affect consumers' perception of cereal products fortified with DF. A low level of nutritional knowledge, particularly of that related to fibre and antioxidants, could lead to a low interest in functional foods fortified with these ingredients, as consumers are not aware of the potential health benefit [30,31].

Although fibre information is used increasingly on various food packaging in Poland, and more particularly for cereal foods, no study on the effect of nutrition or health-related information on dietary fibre combined with hedonic or sensory responses to food fortified with DF has been reported in the literature. These issues provided the rationale for the

present study, which sought to investigate the sensory properties of wheat–rye bread and the perception of such products labelled with health or nutrition-related information on DF.

The main purpose of this study was threefold: (1) to identify sensory characteristics of wheat–rye bread fortified with DF, (2) to evaluate consumer perception and hedonic liking of DF fortified bread and their willingness to buy such products, and (3) to determine if the provision of information on dietary fibre or its health-related properties influences consumers' perception and willingness to buy wheat–rye bread.

2. Materials and Methods

The research was conducted within a project "Bioproducts"—innovative technologies of pro-health bakery products and pasta with reduced caloric value—co-financed by the European Regional Development Fund under the Innovative Economy Operational Programme 2007–2013. The main focus of the project was to develop innovative products in partnership with the industrial partners that could directly test the prototype and provide feedback to improve the overall quality and liking of the innovative products.

The experimental wheat–rye (85:15) breads were produced by a commercial project partner according to the recipe developed within the project and registered at the Patent Office of the Republic of Poland in 2019 [32]. After milling, the flour was supplemented with β–glucan from oat fibre at 4%, 8%, 12% 16% and 20% of the flour wet mass. A control bread with no added fibre (0%) was included as a control sample.

2.1. Sensory Profiling

The sensory profiling of five experimental breads and one control was performed by a trained panel (n = 10) using the quantitative descriptive analysis [33]. Selection of the final list of attributes was based on a consensus. Finally, 29 attributes were used in profiling of bread samples. The following descriptors related to the appearance (colour of the crust, colour of the crumb, regularity of crumb colour, cell size, regularity of cell, dough height), odour (bread, flour, acid, cereal, yeast, sweet, sharp, baked), texture (density, elasticity, crispiness, moisture, adhesivity, roughness), taste (sweet, salty, bitter, sour) and flavour (bread, baked, flour, cereal, yeast) were applied (see Supplementary Materials).

The assessors evaluated the intensity of attributes in two sessions using a 10 cm linear unstructured scale ranging from "none" to "very strong" for odour, flavour, and taste descriptors (example of the scale in Figure 1).

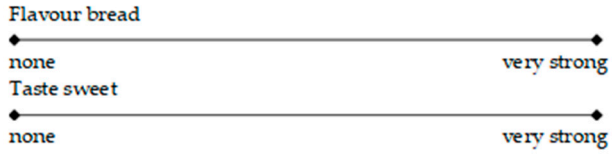


Figure 1. The example of scale used for sensory profiling of bread.

In case of visual descriptors such as colour of the crumb and crust the scale was described from "pale" to "dark". Regularity of the crumb colour was evaluated on a scale ranging from "irregular colour" to "regular colour", whereas regularity of cells was assessed on scale anchored from "low regularity" to high regularity". The scale for cell size descriptors was ranged from "small" to "large". The texture attributes were evaluated on a scale from "low" to "high", e.g., density—"low density-fluffy" to "high density", crispiness—"low crispiness" to "high crispiness".

2.2. Samples Preparation and Presentation

Breads were sliced into 50 g portions that included both the crust and the crumb. Samples were presented in transparent plastic containers (200 mL) that were coded with 3-digit numbers and covered with lids. Individual samples were presented to the assessors and also consumers at room temperature (21 ± 2 °C). Still mineral water was used as a taste neutraliser between the evaluation sessions.

The order of sample presentation was balanced to account for first-order and carry-over effects. All assessments were performed in the sensory laboratory equipped with individual booths with white light. The laboratory met general requirements of ISO standard 8589 [34]. The profiling sessions were conducted during the morning and early afternoon hours, with two sessions per day. Consumer tests were carried out within two weeks with two session per day.

2.3. Consumer Study

Consumers sensory evaluation of bread was performed in two evaluation condition: blind and informed. In blind condition participants had to assess liking of appearance, odour, taste/flavour, texture, and overall liking of each bread sample with 4%, 8%, 12%, 16%, 20% of flour replaced with oat fibre using a 9-point hedonic scale ranging from "I dislike extremely" to "I like extremely" (1—dislike extremely, 2—dislike very much, 3—dislike, 4—dislike slightly, 5—neither like nor dislike, 6—like slightly, 7—like, 8—like very much and 9—like extremely). Control sample without DF was also included in the profiling.

Both crust and crumb were analysed together for the taste/flavour and texture attributes, whereas appearance attributes were assessed on the crumb only.

Additionally, participants were asked to evaluate healthiness, naturalness and attractiveness of each sample using a 7-point scale ranging from 1—"low healthiness", "low naturalness", low attractiveness" to 7—"high healthiness", "high naturalness", high attractiveness", and declare if they are willing to buy such bread indicating maximum price they would pay for a standard package of 700 g.

To determine the impact of information on consumers' perception and liking of DF fortified bread, they were presented with samples 8%, 12% of flour replaced with oat fibre and a control sample. The samples were labelled with two types of information either with the nutritional information "source of dietary fibre" or the health-related information "dietary fibre helps to maintain appropriate body mass" (Table 1).

Table 1. Information included on the label of bread samples.

Sample 1 (No information on % of DF) Wheat–rye bread with dietary fibre Source of dietary fibre	Sample 2 (8% DF) Wheat–rye bread with dietary fibre Source of dietary fibre	Sample 3 (12% DF) Wheat–rye bread with dietary fibre Source of dietary fibre
Sample 4 (No information on % of DF) Wheat–rye bread with dietary fibre Dietary fibre helps to maintain appropriate body mass	Sample 5 (8% DF) Wheat–rye bread with dietary fibre Dietary fibre helps to maintain appropriate body mass	Sample 6 (12% DF) Wheat–rye bread with dietary fibre Dietary fibre helps to maintain appropriate body mass

2.4. Participants

A panel of 300 consumers was recruited by a professional market research agency following European Society for Opinion and Marketing Research code using quota sampling procedure. The detailed characteristics of the sample is provided in Table 2. The inclusion criteria used were declared frequency of bread consumption and primary responsibility for food shopping. All the participants were buyers and consumers of wheat and rye breads (at least once per week).

There were 34% male and 66% female respondents. 26.3% of the respondents were aged below 30 years old, while 17.1% were aged from 35 to 40 years. Respondents above 40 years old comprised 55.7% of the total sample. The majority of them had secondary or higher education, and 31.4% had completed a vocational and/or lower education. Respondents' financial status was relatively good, since 23% declared to be able to "afford all we need and make saving" and 10% agreed that "we have enough to satisfy all our needs, while 67% stated that they "have enough money, to satisfy their basic needs". Most of the consumers assessed their health as "good" or "very good" and only a tiny minority claimed to have bad health.

Table 2. Socio-demographic profile of respondents (n = 300).

Characteristics		N	%
Gender	Women		66.0
	Men		34.0
Age	21–30 years		26.3
	31–40 years		17.7
	41–50 years		15.7
	51–60 years		28.3
	61–65 years		12.0
Education	Primary school		4.7
	Lower secondary school		26.7
	Secondary		37.7
	University graduate		28.8
Occupation	Employed		54.7
	Part time job		9.0
	Still studying		7.0
	Household		7.7
	Unemployed		2.3
	Other		2.3
Subjective health assessment	Very good		32.7
	Good		39.7
	Neither good nor bad		22.3
	Bad		4.7
	Very bad		0.7

2.5. Statistical Analysis

An analysis of variance (ANOVA) procedure was conducted on the trained panel data to determine if significant differences existed among samples tested for all attributes evaluated. Principal component analysis was used to assess the similarities and differences in the sensory profiling characteristics of the tested bread samples (ANALSENS software 7.5). The data from the consumer study were analysed with one way ANOVA and post hoc Tukey's test to compare means using IBM SPSS Statistics for Windows, Version 28.0. (Armonk, NY, USA: IBM Corp).

3. Results

3.1. The Results of Sensory Expert Panel Evaluation

The results of sensory profiling revealed significant differences in terms of most of the attributes included in the study except for toasted odour, acid odour, roughness, and bread flavour (Table 3). In general, the intensity of visual attributes increased with the addition of DF (apart from dough height). Similar relationships were noted for odour attributes such as bread, cereal, yeast, and sharp. It was found that flour odour was the lowest in the samples with the addition of 16% and 20% DF. Density, crispness, moisture, and adhesivity were significantly lower in the samples with the addition of 0%, 4%, and 8% fibre in comparison to the bread samples with a higher DF content (12%, 16%, and 20%). Baked and flour flavour were clearly more pronounced in the samples of 0%, 4%, and 8% of DF compared to the remaining samples. The sample with a 20% addition of DF revealed the highest intensity of cereal flavour. On the other hand, the perception of a bitter taste was most noticeable in the sample without DF. Yeast flavour was significantly higher in samples 8%, 12%, 16%, and 20% of DF in comparison to the control bread. Sweet taste was the highest in the sample of 20% DF, and salty taste was the highest in the samples of 12% DF and 20% DF.

According to the sensory space of PCA (Figure 2), the six samples were divided into two main categories with different sensory profiles based on their dominating sensory attributes. It was found that 86.12% of the variability was related to the first principal component (PC1, horizontal axis); whereas the second principal component (PC2, vertical axis) attributed for 5.62% of the variability. Differences in the sensation of texture descriptors

were loaded mainly along PC1. The results of the quantitative descriptive analysis showed the main modifications induced by DF fortification. The bread with DF significantly differed in visual appearance, odour, flavour/taste intensity, and texture impression from non-DF-fortified bread. Control bread and samples with lower levels of DF, –4% and 8%, revealed very similar sensory characteristics. A completely different profile represented bread with higher concentrations of DF (12%, 16%, and 20%). Texture attributes like density, adhesiveness, moisture, crispness as well as cereal odour and flavour, and visual attributes (regularity of cell, cell size, and colour of the crumb) were particularly affected by the increased level of DF.

Table 3. Sensory profile of wheat–rye bread fortified with dietary fibre.

Attributes	Dietary Fibre Content (%)					
	0%	4%	8%	12%	16%	20%
Colour of the crust	3.1 ^{c}	4.7 ^{b}	5.9 ^{a}	3.6 ^{c}	5.8 ^{a}	5.5 ^{ab}
Colour of the crumb	2.0 ^{d}	2.2 ^{d}	3.1 ^{c}	5.0 ^{b}	7.2 ^{a}	7.5 ^{a}
Regularity of crumb colour	8.5 ^{a}	8.6 ^{a}	7.2 ^{b}	7.6 ^{b}	7.1 ^{ab}	8.0 ^{ab}
Cell size	3.2 ^{bc}	3.3 ^{bc}	3.0 ^{c}	4.5 ^{a}	4.4 ^{a}	4.1 ^{ab}
Regularity of cell	5.1 ^{bc}	6.3 ^{ab}	4.6 ^{c}	7.6 ^{a}	6.6 ^{a}	6.5 ^{a}
Dough height	6.5 ^{a}	7.1 ^{a}	4.9 ^{b}	4.4 ^{b}	4.1 ^{b}	3.1 ^{c}
Odour bread	4.3 ^{ab}	3.9 ^{b}	5.1 ^{ab}	5.4 ^{a}	5.3 ^{a}	5.5 ^{a}
Odour flour	5.2 ^{a}	5.0 ^{a}	4.8 ^{a}	4.5 ^{a}	3.1 ^{b}	2.7 ^{b}
Odour acid	4.1 ^{a}	3.7 ^{a}	4.6 ^{a}	4.4 ^{a}	3.9 ^{a}	4.3 ^{a}
Odour cereal	1.4 ^{d}	1.5 ^{cd}	2.5 ^{c}	4.3 ^{b}	4.9 ^{b}	6.3 ^{a}
Odour yeast	2.8 ^{c}	3.6 ^{bc}	4.0 ^{abc}	4.9 ^{a}	4.4 ^{ab}	4.1 ^{abc}
Odour sweet	2.9 ^{bc}	4.4 ^{a}	3.7 ^{ab}	3.1 ^{bc}	2.8 ^{bc}	2.8 ^{c}
Odour sharp	2.3 ^{bc}	1.9 ^{c}	3.5 ^{ab}	3.3 ^{ab}	4.2 ^{a}	4.6 ^{a}
Odour toasted	5.0 ^{a}	3.8 ^{a}	4.0 ^{a}	3.6 ^{a}	4.0 ^{a}	4.8 ^{a}
Density	4.2 ^{b}	3.9 ^{b}	3.3 ^{b}	6.6 ^{a}	6.7 ^{a}	6.8 ^{a}
Crispiness	2.1 ^{c}	3.2 ^{c}	3.0 ^{c}	4.6 ^{b}	5.5 ^{ab}	6.6 ^{a}
Elasticity	5.2 ^{d}	6.6 ^{abc}	6.0 ^{cd}	6.2 ^{bc}	7.5 ^{a}	7.0 ^{ab}
Moisture	3.8 ^{d}	4.3 ^{d}	4.4 ^{d}	6.1 ^{c}	7.0 ^{b}	8.1 ^{a}
Adhesivity	2.7 ^{c}	2.8 ^{c}	3.9 ^{b}	5.6 ^{a}	6.6 ^{a}	6.5 ^{a}
Roughness	1.8 ^{a}	1.8 ^{a}	1.5 ^{a}	2.2 ^{a}	2.2 ^{a}	1.7 ^{a}
Flavour bread	4.0 ^{a}	4.2 ^{a}	4.6 ^{a}	4.0 ^{a}	4.5 ^{a}	4.9 ^{a}
Flavour baked	5.3 ^{a}	4.0 ^{ab}	4.3 ^{ab}	2.3 ^{c}	2.6 ^{c}	3.2 ^{bc}
Flavour flour	4.4 ^{ab}	4.4 ^{ab}	4.6 ^{a}	3.5 ^{b}	2.3 ^{c}	1.8 ^{c}
Taste sour	1.7 ^{b}	2.1 ^{ab}	2.8 ^{ab}	3.1 ^{a}	3.3 ^{a}	3.0 ^{ab}
Flavour cereal	1.6 ^{de}	1.5 ^{e}	2.6 ^{d}	3.7 ^{c}	4.8 ^{b}	6.2 ^{a}
Flavour yeast	1.8 ^{b}	2.4 ^{ab}	3.3 ^{a}	3.4 ^{a}	3.4 ^{a}	3.2 ^{a}
Taste sweet	4.1 ^{b}	4.6 ^{ab}	4.4 ^{ab}	4.7 ^{ab}	4.7 ^{ab}	5.3 ^{a}
Taste bitter	4.2 ^{a}	2.6 ^{b}	2.4 ^{bc}	1.4 ^{d}	1.1 ^{d}	1.7 ^{cd}
Taste salty	3.2 ^{b}	3.9 ^{ab}	4.0 ^{ab}	4.7 ^{a}	4.2 ^{ab}	4.4 ^{a}

The superscript letter indicates if significant differences exist between the mean values in rows for each attribute ($p \leq 0.05$).

3.2. Consumer Liking and Perception of DF Fortified Wheat–Rye Bread

The results of the consumer panel evaluation show that samples without DF and containing 4% of DF were assessed in a very similar way regardless of the attributes concerned, and the mean scores are slightly above the mean point of the scale (Table 4). The liking scores for all attributes increased with DF concentration. The replacement of flour with more than 8% oat DF caused significant differences between the samples in terms of most liking attributes except for texture. There was no difference in texture liking between samples with 8%, 12%, 16%, and 20% of DF. Similar levels of liking as regards appearance, odour, taste/flavour, texture, and overall liking were observed in terms of samples fortified with 16 and 20% DF. The samples fortified with 12% of DF significantly differed from those

fortified with 20% of DF in liking of appearance, odour, taste, and overall liking, but were similar to samples with 8% and 16% of DF concentration.

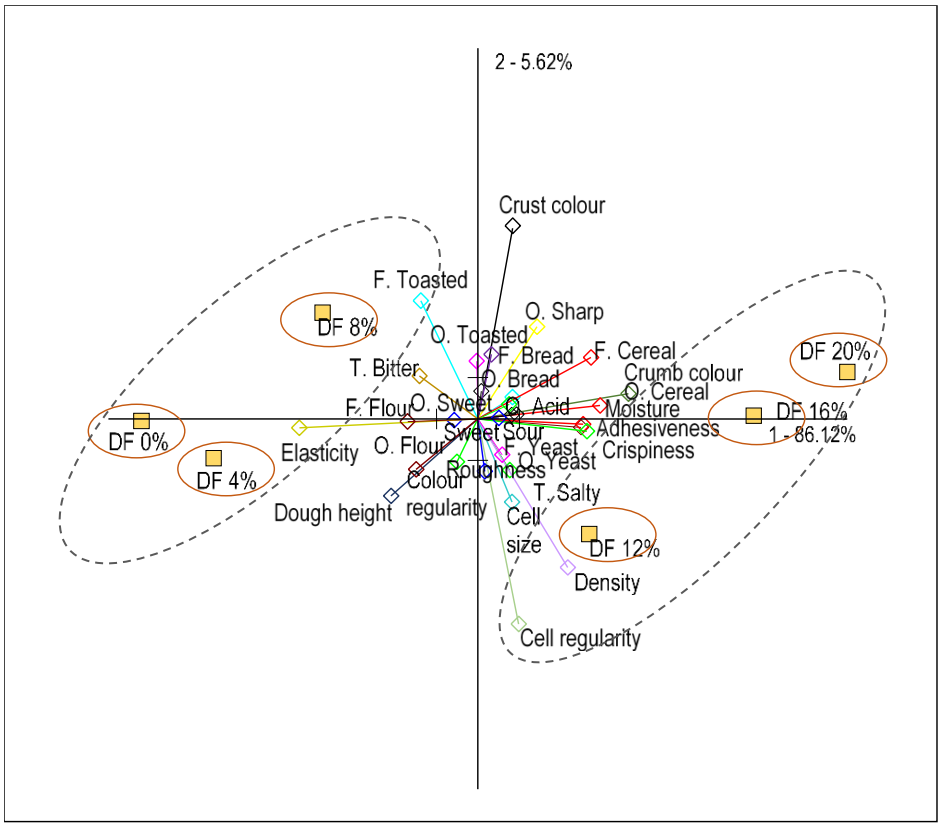


Figure 2. Sensory profile of the DF fortified wheat–rye breads.

Table 4. Consumer liking of DF fortified bread.

Attributes	Bread Samples					
	0% DF	4% DF	8% DF	12% DF	16% DF	20% DF
Appearance	4.48 ^{d}	4.57 ^{d}	5.10 ^{c}	5.28 ^{bc}	5.51 ^{ab}	5.70 ^{a}
Odour	4.51 ^{d}	4.57 ^{d}	4.97 ^{c}	5.19 ^{bc}	5.36 ^{ab}	5.58 ^{a}
Taste/Flavour	4.53 ^{d}	4.55 ^{d}	4.96 ^{c}	5.25 ^{bc}	5.44 ^{ab}	5.64 ^{a}
Oral texture	4.69 ^{c}	4.73 ^{bc}	5.05 ^{ab}	5.17 ^{a}	5.18 ^{a}	5.19 ^{a}
Overall liking	4.46 ^{d}	4.60 ^{d}	5.03 ^{c}	5.35 ^{bc}	5.50 ^{ab}	5.70 ^{a}

The superscript letter indicates if significant differences exist between the mean values in rows ($p \leq 0.05$).

It was revealed that consumers' perception of the healthiness, naturalness, and attractiveness of DF-fortified bread increased in relation to DF concentrations in bread, following a similar pattern as in the case of consumers' liking (Table 5). The samples without DF and those fortified with 4% of DF were scored the lowest. They did not differ significantly in terms of all the attributes concerned, including willingness to buy and the maximum price consumers were willing to pay. The samples with 8–20% concentrations of DF did not differ in perceived attractiveness, but their healthiness and naturalness were significantly different. Samples with 16% and 20% of DF concentration did not differ in evaluation of all quality attributes except for healthiness. Consumers indicated that they would pay the highest price for bread fortified with 20% DF, but the differences between the samples with 12% and 16% of DF concentration were not significant. A similar relationship was observed in the case of willingness to buy DF-fortified bread. The highest scores for willingness to buy were recorded for breads fortified with 12%, 16%, and 20% of DF. There was no statisti-

cal difference in terms of willingness to buy between samples with a 12–20% concentration of DF.

Table 5. Consumer perception of quality attributes and their willingness to buy DF fortified bread.

Attributes	Bread Samples					
	0% DF	4% DF	8% DF	12% DF	16% DF	20% DF
Healthiness	3.35 ^{d}	3.5 ^{d}	4.11 ^{c}	4.34 ^{bc}	4.59 ^{ab}	4.75 ^{a}
Naturalness	3.59 ^{c}	3.65 ^{c}	4.18 ^{b}	4.42 ^{ab}	4.53 ^{a}	4.63 ^{a}
Attractiveness	3.60 ^{b}	3.66 ^{b}	4.17 ^{a}	4.26 ^{a}	4.32 ^{a}	4.36 ^{a}
Willingness to buy	3.25 ^{c}	3.41 ^{c}	3.89 ^{b}	4.09 ^{ab}	4.16 ^{ab}	4.28 ^{a}
Maximum price	2.40 ^{d}	2.62 ^{c}	2.88 ^{b}	3.04 ^{ab}	3.06 ^{ab}	3.15 ^{a}

The superscript letter indicates if significant differences exist between the mean values in rows ($p \leq 0.05$).

3.3. Impact of Nutrition and Health Realted Information on Consmers' Percepton and Willigness to Buy Bread Fortifed with DF

The information included on the label did not significantly influence the perception of DF-fortified bread (Table 6). The sample without DF was scored the lowest in terms of all attributes, whereas the highest mean scores were obtained for the samples fortified with 12% DF that confirm the tendencies observed in the blind condition. Respondents also indicated the lowest willingness to buy bread without DF added, which was also reflected in the maximum price they wanted to pay for a standard package of 700 g. The samples labelled with information on ingredient "source of dietary fibre" were scored lower than samples labelled with information on the function of fibre, "dietary fibre helps to maintain an appropriate body mass", but the mean values did not differ regarding the type of information provided.

Table 6. Impact of information on consumers' perception and willingness to buy DF-fortified bread.

Attributes	Information					
	Source Of Dietary Fibre			Dietary Fibre Helps to Maintain an Appropriate Body Mass		
	0% DF	8% DF	12% DF	0% DF	8% DF	12% DF
Visual liking	4.79 ^{c}	5.04 ^{abc}	5.27 ^{bc}	4.86 ^{c}	5.25 ^{abc}	5.48 ^{a}
Healthiness	3.86 ^{c}	4.15 ^{abc}	4.31 ^{a}	4.05 ^{ab}	4.26 ^{abc}	4.49 ^{a}
Naturalness	3.89 ^{c}	4.12 ^{abc}	4.37 ^{a}	4.00 ^{c}	4.34 ^{abc}	4.42 ^{a}
Attractiveness	3.86 ^{c}	4.11 ^{abc}	4.21 ^{a}	3.98 ^{c}	4.25 ^{a}	4.33 ^{a}
Willingness to buy	3.75 ^{b}	3.96 ^{ab}	4.13 ^{a}	3.76 ^{b}	4.08 ^{a}	4.25 ^{a}
Maximum Price	2.74 ^{a}	2.92 ^{a}	2.99 ^{a}	2.77 ^{a}	2.93 ^{a}	3.05 ^{a}

The superscript letter indicates if significant differences exist between the mean values in rows ($p \leq 0.05$).

4. Discussion

An increased demand for healthy breads has led to considerable efforts to develop breads that combine health benefits with acceptable sensory properties. The fortification of white bread, which is the most consumed type of bread in Poland, with dietary fibre is of great interest to the bakery industry due to the increasing demand for healthier food products. Producers are particularly interested in bread products that are fortified with higher levels of DF to meet the requirements of legal regulations on health and nutrition claims. Although the addition of DF to bread has the potential to improve the nutritional benefits, its incorporation, particularly at the level to be able to communicate the health benefit using nutritional and health-related claims legally approved at the European Union level, is challenging, as fortification impacts the sensory properties.

This study presents original findings from sensory profiling of DF-fortified wheat–rye bread combined with a consumer study on perception, sensory acceptance, and willingness to buy such products.

The results of sensory profiling confirmed the changes in appearance, texture and taste of baked products with the addition of fibre reported in other studies [1,4,35,36]. Martin et al. [4] found that DF fortification leads to a darker crumb that contains many particles and exhibits small cells, which gave the crumb a denser appearance (reduction of loaf volume). Almeida et al. [20] revealed that acceptance of crust colour, crust appearance, aroma and taste were not affected by the addition of different dietary fibres in bread that is also confirmed in consumer study.

Many studies confirmed that DF fortification leads to alteration of texture attributes in bread [23,36–39]. The addition of fibre results in a significant reduction in the volume of wheat bread, which could be due to the lower protein content [40]. Higher concentration of DF in wheat–rye breads resulted in higher density texture, higher adhesiveness and moisture of wheat–rye bread that was also reflected in other studies [4,8,36,40]. Moistness is an attribute with great influence on other bread characteristics and is associated with freshness [36,41]. Consumers are less inclined to buy bread with the moisture content below what they consider to be right [41]. As a result, higher moistness in DF fortified bread was not perceived as a negative attribute and did not decrease its acceptance.

Fortification with DF also resulted in more intense cereal and yeast flavour and less intense bitter taste as revealed by sensory profiling. According to Martin et al. [4] addition of DF leads to substantial increases in the intensities of flavour attributes like coffee, cereal, and malt flavours, and bitter taste, to the detriment of more conventional attributes (brioche and raw dough flavours, fresh and milky notes). Increased bitterness in bread fortified with DF was also reported by Kołodziejczyk et al. [42]. However, it was not confirmed in our study.

Results of the consumer panel evaluation showed that fortification of wheat–rye bread up to 20% of fibre did not affect adversely consumers' acceptance and willingness to buy such breads. Martin et al. [4] suggest that deterioration of sensory properties might be less substantial when the DF enrichment is realized in superior quality breads, such as baguettes obtained using a traditional French bread-making process. The results of the joint analysis (trained panel and consumers) on traditional Galician breads demonstrated that the loaves with a predominance of large cells, and an alveolation with non-uniform distribution were the ones that showed the greatest acceptance [36]. Therefore, the potentially negative impact of the DF enrichment on the sensory properties of wheat–rye bread revealed in sensory profiling could be compensated by the positive image of the wheat–rye bread that is the most commonly consumed by Poles [43].

The provision of information on DF content or positive outcomes of DF on the human body did not differentiate the perception of samples with identical DF concentrations or those that were not fortified with DF. The samples with higher concentrations of DF received higher scores regardless of the information included on the label. Another issue is the familiarity of consumers with DF since health-related claims referring to such compounds or substances are considered more understandable and trustworthy, which leads consumers to believe more in the healthiness of such products, which in turn may influence their perception and purchase intention [44].

Despite the deficiencies identified, the new functional prototypes breads showed satisfactory sensory performance. The changes in the sensory properties identified in the profiling did not adversely affect the consumers' perception and liking of DF-fortified bread. Our results also have some practical implications for consumer-led product development since they provide information about the hedonic expectation and perception of credence attributes like the healthiness and naturalness of wheat–rye bread fortified with DF that supports the development of well-targeted strategies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13020694/s1, Table S1: Descriptors and scale used in sensory profiling.

Author Contributions: Conceptualization, S.Ż.-B.; methodology, S.Ż.-B. and E.K.; formal analysis, S.Ż.-B. and E.K.; investigation, S.Ż.-B.; writing—original draft preparation, S.Ż.-B. and E.K.; writing—review and editing, S.Ż.-B. and E.K.; visualization, S.Ż.-B. and E.K.; supervision, S.Ż.-B.; project administration, S.Ż.-B.; funding acquisition, S.Ż.-B. All authors have read and agreed to the published version of the manuscript.

Funding: This research was realized within the Project no POIG.01.03.01-14-041/12 "Bioproducts", innovative technologies of pro-health bakery products and pasta with reduced caloric value, co-financed by the European Regional Development Fund under the Innovative Economy Operational Programme 2007–2013.

Institutional Review Board Statement: Referring to this research (the project) the ethical approval was not required, however the study was conducted according to the guidelines laid down in the Declaration of Helsinki and following the ESOMAR code (European Society for Opinion and Marketing Research).

Informed Consent Statement: Informed consent was obtained from all of the subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: The financing of the work by The System of Financial Support for Scientists and Research Teams of Warsaw University of Life Sciences (WULS) is gratefully acknowledged.

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

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