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Energy bars enhanced with fish hydrolysate and their effects on consumers' sensory perception

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Abstract

This study examines the effect of adding fish hydrolysate to energy bars, on consumer acceptability. Among the five types of fish hydrolysate energy bars prepared with different amounts of hydrolysate (0%, 1%, 3%, 5% and 10%), consumer preferences indicated a positive sensory evaluation only for the products with 0% and 1%. The sample containing 0% hydrolyzed fish had the highest value of the "general acceptability" parameter, while the sample containing 10% hydrolysate presented the lowest value. The 0% hydrolyzed (standard) sample received the highest overall acceptability score (8.29, $p > 0.05$) from male panelists (28.09% of participants). In the case of panelists residing in the city (56.18% of participants), the highest value for general acceptability was obtained by bars with 0% hydrolyzed. Village participants (43.82% of the participants) attributed the highest degree of general acceptability to the sample with 1% hydrolyzed. They rated the hardness, appearance and color of the samples differently, indicating a great variability between them ($p < 0.05$). According to age, the bars with 3% hydrolyzed scored highest for "color" (7.89), the samples with 10% hydrolysate had the highest scores for "hardness" (7.47) and "stickiness" (7.38), and the samples with 1% hydrolyzed were the most valued for "texture" (7.96) and "stickiness" (7.38). Unfortunately, energy bars with higher protein content (3%, 5% and 10% hydrolyzed) were rejected by consumers due to the "unpleasant smell of fish" and the "very pronounced" taste given by the presence of hydrolysate, requiring an improvement of the technological process.

Key words: sensory characteristics, fish hydrolysate, energy bars, high protein content, functional foods, blue withing, consumer acceptability

1. Introduction

Since the demand for safe and healthy foods has increased globally due to their associated health claims, eating a balanced diet is a good way to prevent or treat conditions like diabetes, obesity, heart disease, and malnutrition, which are mostly caused by dietary choices [1]. However, the demand for easy and immediate nutrient-dense meal replacement has been growing for the past two decades with growing concerns about health and fitness [2].

As they are typically high in calories and nutrients and come in a convenient, portable, and ready-to-eat package, nutrition bars can be classified as meal replacements and/or supplements. These bars can be categorized based on their nutritional value as food bars, protein bars, energy bars, or sports bars [3]. Though, the high levels of sugar and artificial sweeteners in commercial energy bars generally inhibit their protein content, making the products nutritionally unbalanced. [4].

Fish is a nutritious type of food that is high in micronutrients, high-quality animal proteins, and polyunsaturated fatty acids (PUFAs), particularly docosahexaenoic acid (DHA) and

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(ω)-3 eicosapentaenoic (EPA) acid. In tropical nations, fish are more accessible and less expensive than other sources of animal proteins because aquaculture is one of the industries with the fastest rates of growth in the food production industry [5]. Fish products are a more affordable and favored source of animal protein and are thought to be a good source of numerous important micronutrients and macronutrients [6].

Currently, fish protein hydrolysates are considered the most important source of protein and bioactive peptides. Protein hydrolysates are byproducts of proteins being broken down by enzymes into smaller peptides. Protein hydrolysates are typically tiny peptide fragments with 2 -20 amino acids. Native proteins are hydrolyzed by enzymes to produce these protein hydrolysates [7].

Fish proteins exhibit distinct functional properties that make them ideal for lipid binding, water retention, strong gel formation, stable foam formation, and the creation of stable lipid emulsions [6]. Yet, some consumer groups tend to unexpectedly reject this great source of protein due to its strong, unpleasant fishy taste and odor. Fish protein isolate (FPI) production may therefore be one of the more promising ways to increase public acceptance of eating fish, being a stable fish preparation intended for human consumption, with a higher protein content than the fish they are derived from [1].

This manuscript summarizes the effects of fish (*Micromesistius poutassou)* hydrolysate protein enriched energy bars on the sensory acceptability of various categories of consumers.

2. Material and methods

2.1 Raw materials

The ingredients used in the manufacturing process of the fish hydrolysate energy bars were purchased from different feedstocks: pitted dates, coconut powder, almonds, coconut oil and hemp seeds were purchased from Sanovita, Romania. Whey protein was purchased from SFD Nutrition, Poland. Cocoa powder (Dr. Oetker, Germany), dark chocolate (Nestle, Romania) and salt (Ilida, Romania) were purchased from local supermarket.

2.2. Provenience of fish hydrolysate

Bio-Marine Ingredients Ireland Ltd. supplied the fish hydrolysate known as "ProAtlantic SG". This is a high-quality hydrolyzed Fish Protein Isolate (FPI) made from wild-caught Blue Whiting *(Micromesistius poutassou)* in the North Atlantic Ocean.

2.3. Production of energy bars

Energy bars samples, containing 0% (control), 1%, 3%, 5% and 10% fish protein hydrolysate were prepared using the ingredients presented in Table 1.

Ingredients	0% FH	1% FH	3% FH	5% FH	10% FH
Pitted dates, g	555	555	555	555	555
Coconut powder, g	240	240	240	240	240
Almonds, g	210	210	210	210	210
Cocoa powder, g	90	90	90	90	90
Dark chocolate, g	100	100	100	100	100
Coconut oil, g	135	135	135	135	135
Hemp seeds, g	66	66	66	66	66
Whey protein, g	160	160	160	160	160
Salt, g	3	3	3	3	3
Fish hydrolysate, g	-	15.60	46.80	78.10	156.00
Water, mL	150	150	150	150	150

Table 1. The ingredients used to produce the fish hydrolysate energy bars

*** FH** – fish hydrolysate protein

The pitted dates were softened in water for 20 to 30 minutes before all the ingredients (apart from water and cocoa nibs) were combined in a food processor (Biovita, Romania) to make the energy bars. As a taste and odor corrector, 10% whey protein concentrate was added to

each sample. The cocoa nibs were added after the dough had thickened and became sticky. Water was added to create a homogenous mixture after the final composition had been thoroughly mixed. After lining a baking tray with baking paper, the composition was put in the refrigerator for at least half an hour. Before being subjected to sensory analysis, the sticks were cut into appropriate squares and kept between 4 and 8 ^{o}C.

2.4. Sensory analysis protocol

Following the 9-point hedonic test scale method described by Stone et al. [1], 89 panelists (25 men and 64 women) with an average age of 42.50 ± 15.09 years (minimum 19 years, maximum 72 years) took part in the sensory analysis of the examined samples within three hours of baking, in daylight and at room temperature (21°C). The panelists were grouped by several criteria, particularly gender (71.01% females and 28.09% males), age (62.92% between 18 to 30 years old, 17.98% 31 - 50 years old, and 19.10 older than 50 years old), education level (92.13 % with academic education degree and 7.87 with upper secondary school) and residence (43.82% village residents and 56.18% city residents) in order to get a clear sensory assessment.

The study was authorized by the Ethics Committee of Technical University of Cluj Napoca, Romania (nr. 593/08.04.2024) and adhered to the moral principles of the 2013 revision of the 1975 Declaration of Helsinki. Prior to the sensory investigation, the participants were informed of the study's aim and purpose and gave their written consent. They were also instructed to familiarize themselves with the descriptive lexicon of snack bars. In three evaluation sessions spaced 30 minutes apart, panelists were given randomly selected samples of each energy bar, coded, and presented for tasting. To prevent the carryover effect, the panelists rinsed their mouths with room-temperature water in between sessions. Panelists were seated in different testing booths to assess the products. The products' appearance, color, texture, smell, taste, hardness, stickiness, and general acceptability were all rated on a nine-point hedonic scale, with 1 denoting a strong dislike and 9 denoting a strong like. The overall score for each attribute was determined by averaging the individual scores. The mean ± standard deviation was used to express the final results.

2.5. Statistical analysis

Results were expressed as the mean ± standard deviation (SD). Statistical analyses were conducted using IBM SPSS Statistics 24 and the one-way analysis of variance (ANOVA) with Tukey HSD post-hoc test was used to evaluate the difference between the mean values, where the significance was defined as $p < 0.05$.

3. Results and Discussion

3.2. Appearance of energy bars

The visual appearance of the fish hydrolysate high protein energy bars is displayed in Figure 1.

As seen in Figure 1, the energy bar samples containing fish hydrolysate displayed a homogeneous and uniform surface structure, free of cracks in areas that lacked uniformity, a pleasing, distinctive color, and an appealing appearance. Additionally, the five hydrolyzed bar samples in the section (at the bottom of the figure) were notable for their appealing color and consistent texture, with the dark chocolate pieces in the composition helping to create an appealing appearance for panelists.

3.2. Fish hydrolysate composition

Tables 2-4 present the bio-chemical composition of fish hydrolysate, as provided by the manufacturer. Given the high protein and mineral content, nutritional value and complex amino-acid profile of the fish hydrolysate obtained from Micromesistius poutassou, it was utilized to improve the functional and nutritional qualities of foods, particularly for developing high protein energy bars.

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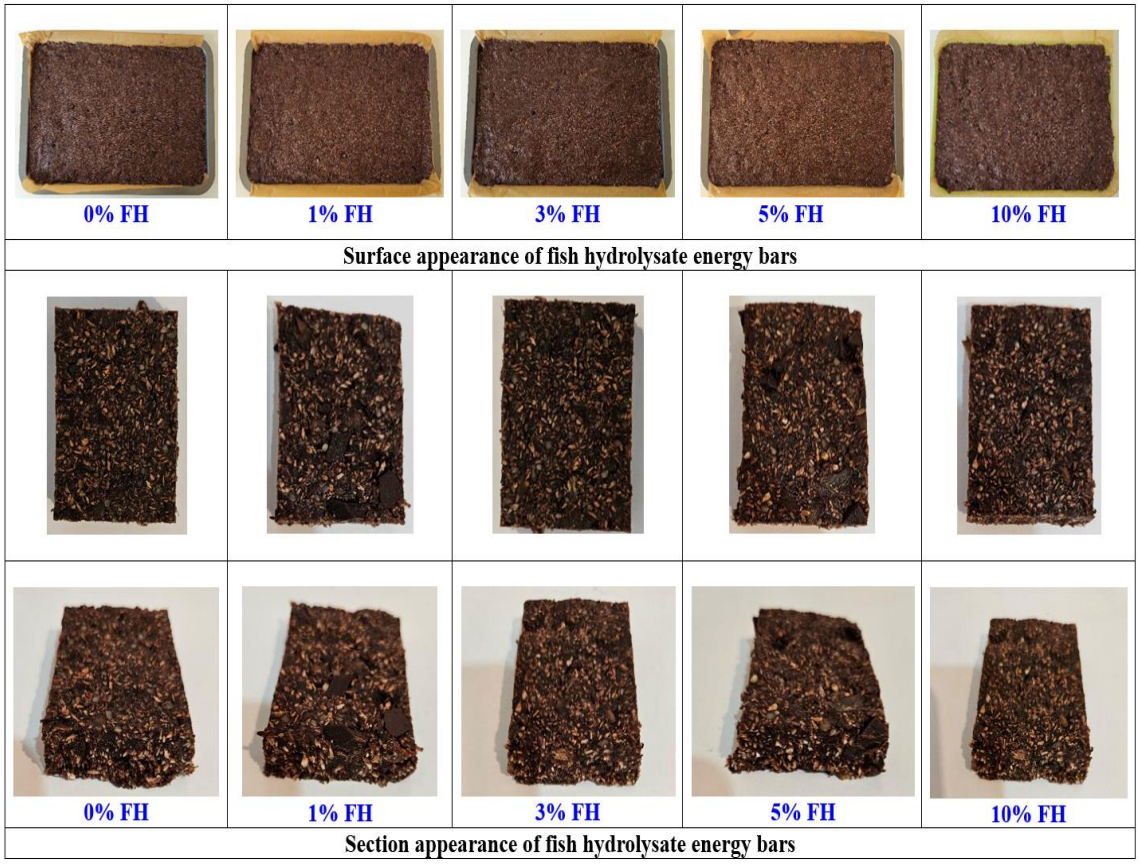

Figure 1. Visual representation of fish hydrolysate energy bars, where 0% FH – control, 1% FH – bars with 1% fish hydrolysate, 3% FH - bars with 3% fish hydrolysate, 5% FH - bars with 5% fish hydrolysate, 10% FH – bars with 10% fish hydrolysate.

Table 2. Proximal analysis of fish hydrolysate derived from *Micromesistius poutassou*

Typical analysis	
Protein (dry basis), %	92-95
Protein (as is), %	88-91
Moisture, %	< 6
Fat, %	< 0.5
Minerals, %	8-10
pH	> 6.5
Heavy metals	
Arsenic (Inorganic)	< 0.5
Cadmium	< 0.5
Lead	< 0.3
Mercury	< 0.5
Microbial Analysis	
Total plate count	< 100.000 cfu/g
Coagulase + Staphylococci	< 100cfu/g
Enterobactericeae	< 10 cfu/g
B-Glucuronidase + Escherichia coli	< 10 cfu/g
Listeria	*Not detected*
Salmonella	*Not detected*

Table 3. Nutritional content of fish hydrolysate

Nutritional analysis	
Calories, kcal/100g	367
Calories from fat, kcal/100g	< 2
Total fat, g/100g	< 0.5
Dietary fibre, g/100g	3
Sugars, g/100g	< 0.5
Added sugars, g/100g	-
Protein, %	89-91
Vitamin content	
Vitamin B12, ug/100g	44.60
Vitamin B2, mg/100g	3.70
Vitamin B9, ug/100g	53.10
Vitamin A, mg/100g	0.73
Minerals	
Calcium, mg/100g	88.20
Sodium, g/100g	2.18
Potassium, mg/100g	2304.00
Magnesium, mg/100g	276.00
Iron, mg/100g	0.97
Zinc, mg/100g	0.54

Table 4. Amino-acid composition

Glutamic acid, g/100g	13.30
Aspartic acid, g/100g	8.70
Lysine, g/100g	7.80
Glycine, g/100g	6.70
Arginine, g/100g	6.20
Alanine, g/100g	6.10
Leucine, g/100g	5.40
Serine, g/100g	4.50
Proline, g/100g	3.60
Threonine, g/100g	3.50
Valine, g/100g	3.50
Isoleucine, g/100g	3.20
Phenylalanine, g/100g	2.80
Tyrosine, g/100g	2.40
Methionine, g/100g	1.90
Histidine, g/100g	1.70
Cysteine, g/100g	0.70
Tryptophane, g/100g	0.50

3.3 Sensory analysis results

3.3.1. General results

To express the general results, the mean values of each sensory parameter were calculated for the total number of 89 participants. The results are presented in Figure 2.

The sensory analysis of the sensory parameters revealed that, despite the high nutritional and functional qualities of fish hydrolysate, products with higher hydrolysate concentrations were rejected because of the significantly altered sensory characteristics that matched the panelists' preexisting tastes for this kind of snack bar. Remarkably, the control sample (0% FH) had the highest appreciation rate in the general sensory analysis results, scoring 8.25 ± 0.99 out of 9.00 for "general acceptability." The high values (11.90% – 93.42%) of relative standard deviation (RSD %) indicate a very high variability between the individual scores given by the panelists, for each individual sensory parameter.

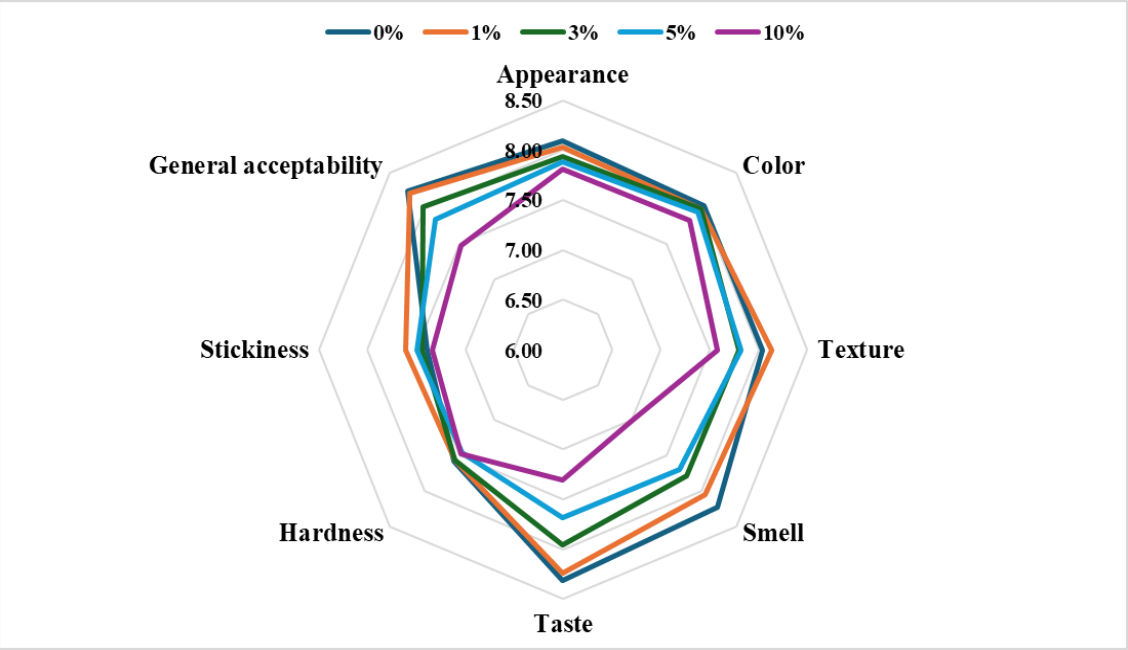

Figure 2. General sensory analysis results, where 0%, 1%, 3%, 5% and 10% represent the amount of hydrolysate used to produce the samples

In samples containing 3 percent, 5 percent, and 10 percent fish hydrolysate protein, the general acceptability scores ranged from 7.48 ± 1.41 (10% FH) to 8.25 ± 0.99 (0% FH), indicating a high degree of rejection because of the "unpleasant smell of fish" and "pronounced taste" caused by the hydrolysate. Both "texture" (8.04 ± 1.27) and "stickiness" (7.39 ± 1.32) were highest for the sample containing 0% hydrolysate. The samples with 5% and 10% hydrolyzed had the lowest values for the parameters "taste" and "smell," which have a significant impact on the consumer's overall perception and were the ones with the highest degree of rejection from panelists.

3.3.2 Results according to gender

According to gender, the samples were evaluated by 28.09% male and 71.91% female participants. Sensory analysis results for male participants are displayed in Figure 3, while the results in case of females are summed up in Figure 4.

The highest data variability was obtained in case of “appearance”, where scores ranged from 7.95 ± 1.05ab (10% FH) to 8.12 ± 0.78a (control). Male participants positively evaluated control sample (0% FH) in case of “appearance” (8.12 ± 0.78), “color” (8.04 ± 0.84), “texture” (0.28 ± 0.84), “smell” (8.36 ± 0.81) and “taste” (8.36 ± 0.91) and “general acceptability”, with a score of 8.29 ± 0.79 out of 9.00.

Bars with 1% and 5% fish hydrolysate, obtained the highest marks in terms of “appearance” (8.12 ± 0.93 out of 9.00), “stickiness” (7.76 ± 1.23) and “hardness” (7.68 ± 1.11) while the lowest marks for “general acceptability”, “smell” and “taste” were attributed to samples with 5% and 10% fish hydrolysate.

Compared to males, females presented a greater tendency to appreciate samples with higher amount of protein, namely 1% fish hydrolysate. As displayed in Figure 3, “general acceptability” results varied between 7.49 ± 1.43 (10% FH) and 8.29 ± 1.01 (1% FH).

"Color" (8.06 ± 1.22), "texture" (8.13 ± 1.29), "hardness" (7.64 ± 1.55), and "stickiness" (7.55 ± 1.53) were the individual parameters with the highest scores for 1% FH energy bar. Similarly, the control sample received the highest ratings for "appearance" (8.08 ± 1.28), "smell" (8.19 ± 1.33), and "taste" (8.30 ± 1.12). In contrast, the samples containing higher amounts of fish hydrolysate, particularly 10% FH, received the lowest ratings, with scores ranging from 6.87 ± 1.84 for "smell" to 7.77 ± 1.37 for "color."

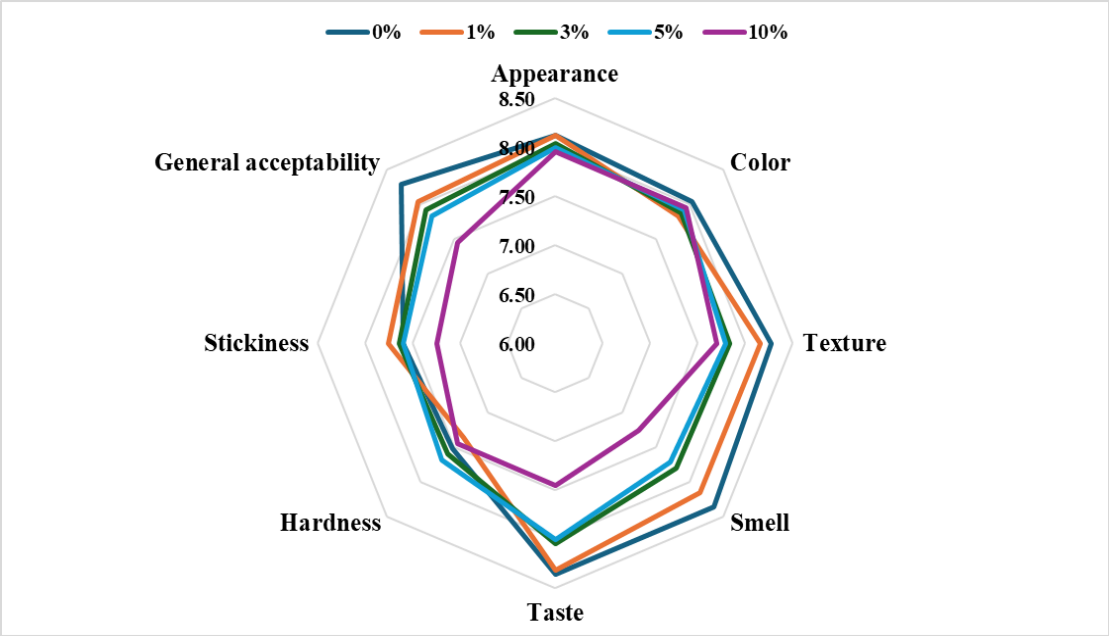

Figure 3. Sensory analysis results for male participants, where 0%, 1%, 3%, 5% and 10% represent the % of fish hydrolysate used for samples production

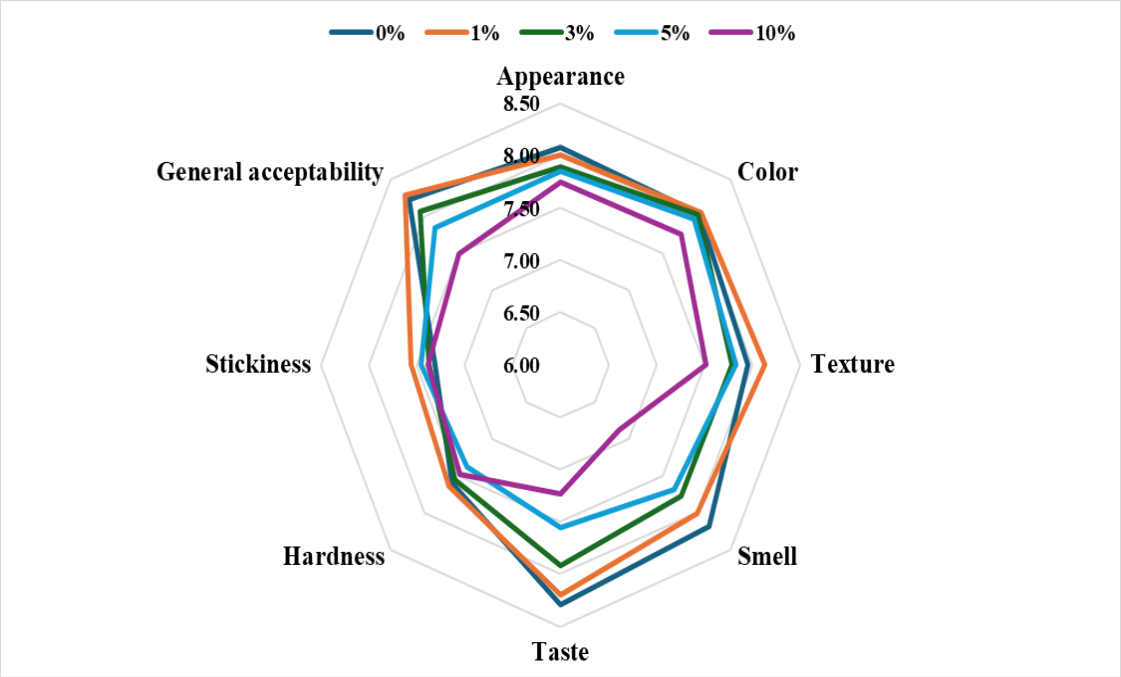

Figure 4. Sensory analysis results for female participants, where 0%, 1%, 3%, 5% and 10% represent the % of fish hydrolysate used for samples production

3.3.3. Results according to residence

The greatest data variability was seen among city residents in terms of color characteristics (Figure 5).

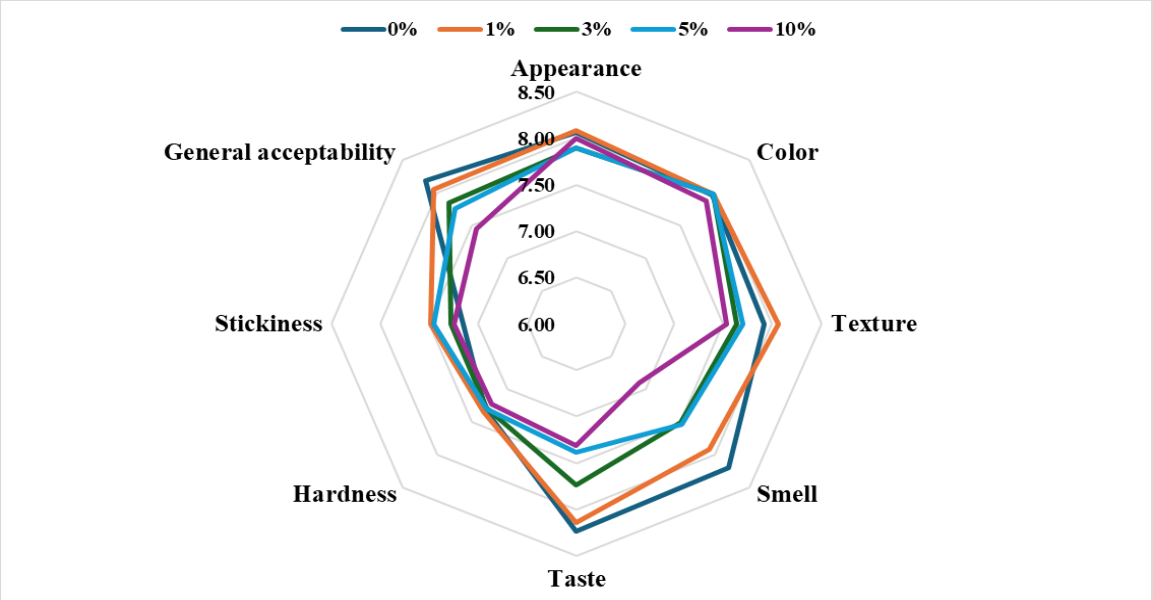

Figure 5. Sensory analysis results for city residents, where 0%, 1%, 3%, 5% and 10% represent the % of fish hydrolysate used for samples production

It was found that 10% FH had the lowest score (7.88 ± 1.18^{ab} out of 9.00), while 0% FH presented the highest score (9.96 ± 1.26^{ab}), which also displayed the highest "general acceptability" score (8.18 ± 1.06). "Taste" and "smell" are regarded as the most significant sensory qualities [1], for which, control sample (0% FH) received the highest ratings from city residents (8.20 ± 1.20 and 8.24 ± 1.12 points out of 9.00). As for "color", 1% FH, 3% FH and 5% FH were likewise marked with 7.98 ± 1.13 out of 9.00. Diverse results were obtained for "appearance", texture", "hardness" and stickiness", with variations between 7.90 ± 1.15 and 8.08 ± 1.18 (appearance), 7.53 ± 1.39 and 8.06 ± 1.30 (texture), 7.22 ± 1.39 and 7.34 ± 1.64 (hardness) and from 7.15 ± 1.87 to 7.49 ± 1.51 in case of stickiness, 1% FH presenting the highest scores.

Compared to city residents, village residents displayed a greater sensory variability for "appearance", "color" and "hardness" (Figure 6).

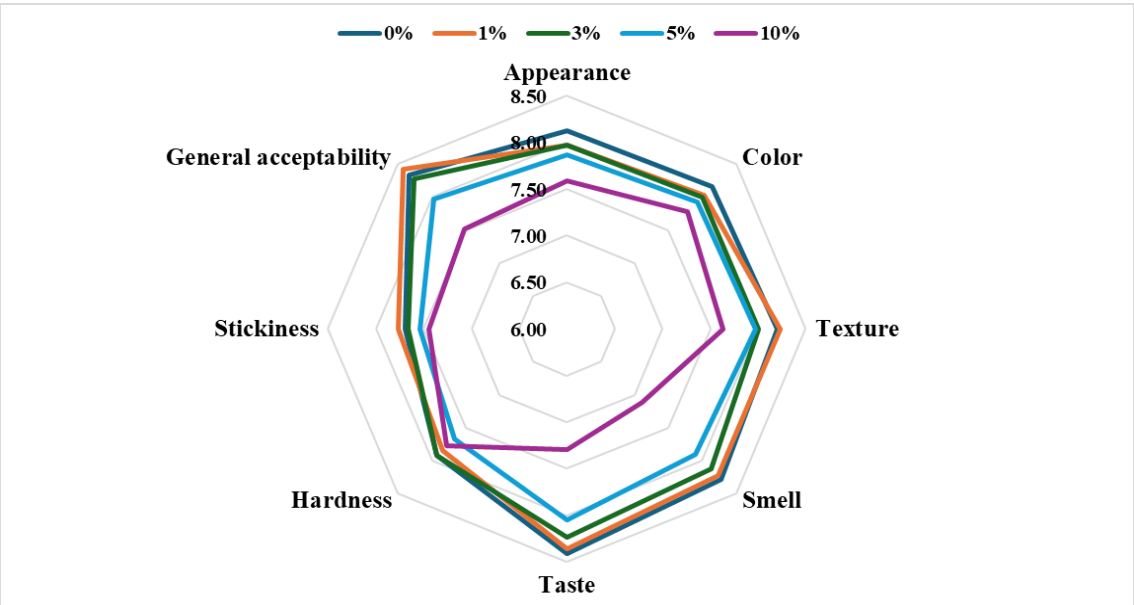

Figure 6. Sensory analysis results for village residents, where 0%, 1%, 3%, 5% and 10% represent the % of fish hydrolysate used for samples production

For hardness, the greatest disparity between village and city dwellers was observed (7.92 ± 1.20a and 7.29 ± 1.46b in case of 1% FH). Bars with 1% FH had the highest sensory score for "general acceptability," with 8.42 ± 0.71 points, while 10%FH had the lowest, at 7.52 ± 1.37 out of 9.00 points (11.96% lower). The highest scores for control were obtained by parameters such as "appearance," "color," "smell," "taste," and "hardness," which ranged from 8.13 ± 1.24 to 7.92 ± 1.26.

Compared to city dwellers, village dwellers received the highest ratings across all sensory parameters. The largest variations were observed in samples containing higher concentrations of fish hydrolysate (3, 5, and 10% respectively). Villagers displayed overall acceptability scores that were higher, ranging from 3 to 6% for 3% FH, 5% FH and 10% FH.

3.3.4 Results according to age

Age-related differences in sensory results were seen among panelists between the ages of 18 and 30 (Figure 7) and the other categories of analysts, while panelists aged between 31 and 50 years old (Figure 8) respectively over 50 years old (Figure 9) evaluated the energy bars with comparable scores. The greatest significant variations ($p < 0.05$) among the three categories of panelists grouped by age were found in case of "stickiness" (for panelists aged 18-30), "color", "texture" and "hardness" (for 31-50), respectively "color" and "texture" (in case of > 50).

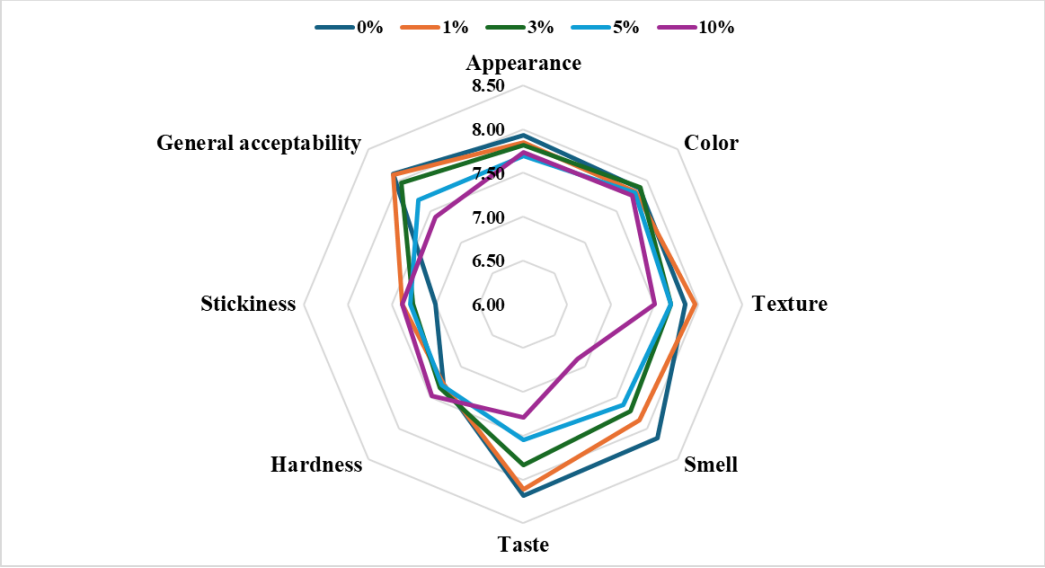

Figure 7. Sensory analysis results according to age (18-30), where 0%, 1%, 3%, 5% and 10% represent the % of fish hydrolysate used for samples production

Panelists aged between 18 and 30 years of age showed the highest appreciation for control bars, compared to bars with higher amounts of fish hydrolysate.

The parameters that received the highest scores were "general acceptability," "taste," "smell," and "appearance" (8.10 ± 1.08). On the other hand, samples containing 1%, 3%, and 10% fish hydrolysate scored highest for individual parameters like "texture," "stickiness," "color," and "hardness".

As displayed in Figure 8 (referring to panelists aged 31-50), based on general acceptability, control bars received the highest score (8.44 ± 0.89) out of the 5 tested samples. Similarly, "color" (8.13 ± 1.09), "appearance" (8.19 ± 1.05), "texture" (8.25 ± 1.06), "taste" (8.38 ± 0.96), and "hardness" (8.00 ± 1.26) were rated with the most points for reference sample.

However, there was also a high appreciation for 1% FH in terms of "texture" (8.25 ± 1.18), "smell" (8.19 ± 1.52), "hardness" (8.00 ± 1.26) and "stickiness" (7.94 ± 1.44), while samples with 3%, 5% and 10% fish hydrolysate received the lowest sensory scores.

The figure below (Figure 9) points out the results obtained in the case of panelists who are over 50.

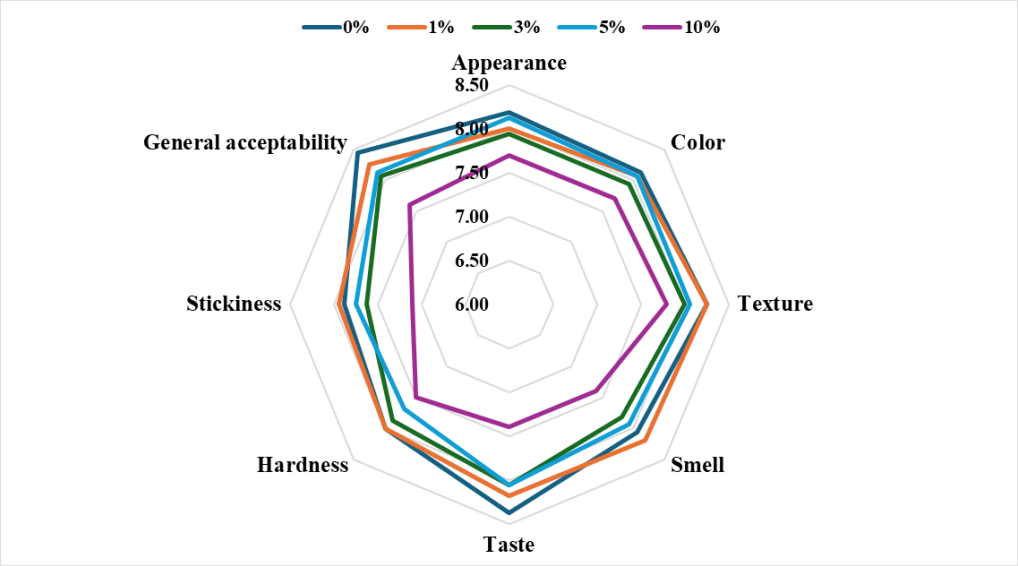

Figure 8. Sensory analysis results according to age (31-50), where 0%, 1%, 3%, 5% and 10% represent the % of fish hydrolysate used for samples production

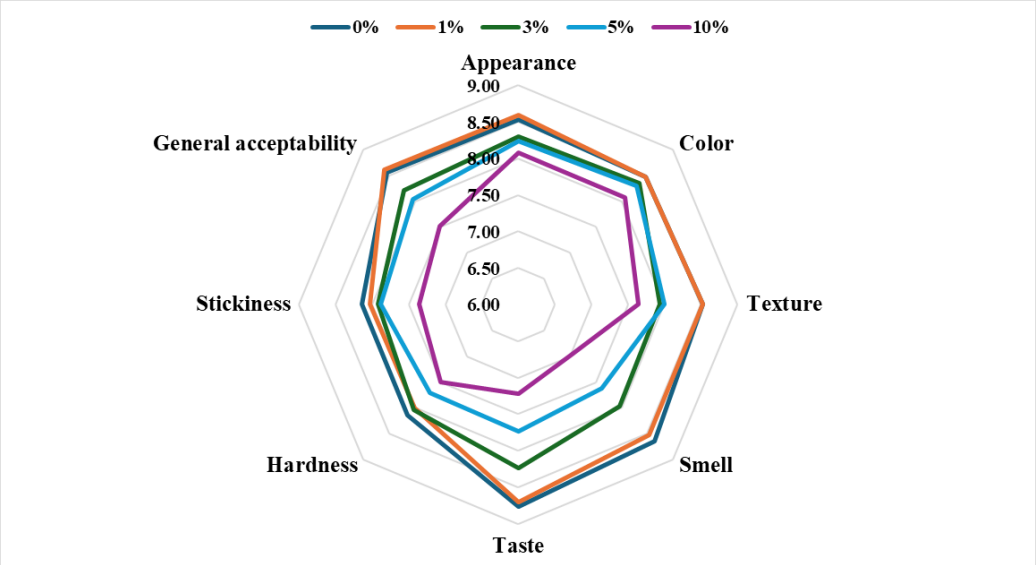

Figure 9. Sensory analysis results according to age (over 50), where 0%, 1%, 3%, 5% and 10% represent the % of fish hydrolysate used for samples production

As anticipated, the least appreciated sample was 10% FH (7.51 ± 1.29), while among panelists over 50, 1% FH had the highest "general acceptability" score (8.60 ± 0.57). The highest ratings for "appearance," "color," and "texture" were given to 1% FH, whereas the highest ratings for "smell," "taste," "hardness," and "stickiness" were given to the control (0% FH).

3.3.5. Results according to education attainment

The sensory results filtered by educational attainment are shown in the final panelist clustering. Because average values could not be obtained, the data for samples containing 10% hydrolyzed fish were not statistically validated in the case of analysts with a medium level of education (upper secondary education/post-high school) (Figure 10). The relative standard deviations (RSD %) in this instance, which range from 4.27% to 36.12 %, show the highest degree of data variability, indicating a greater level of appreciation for samples that contain more protein.

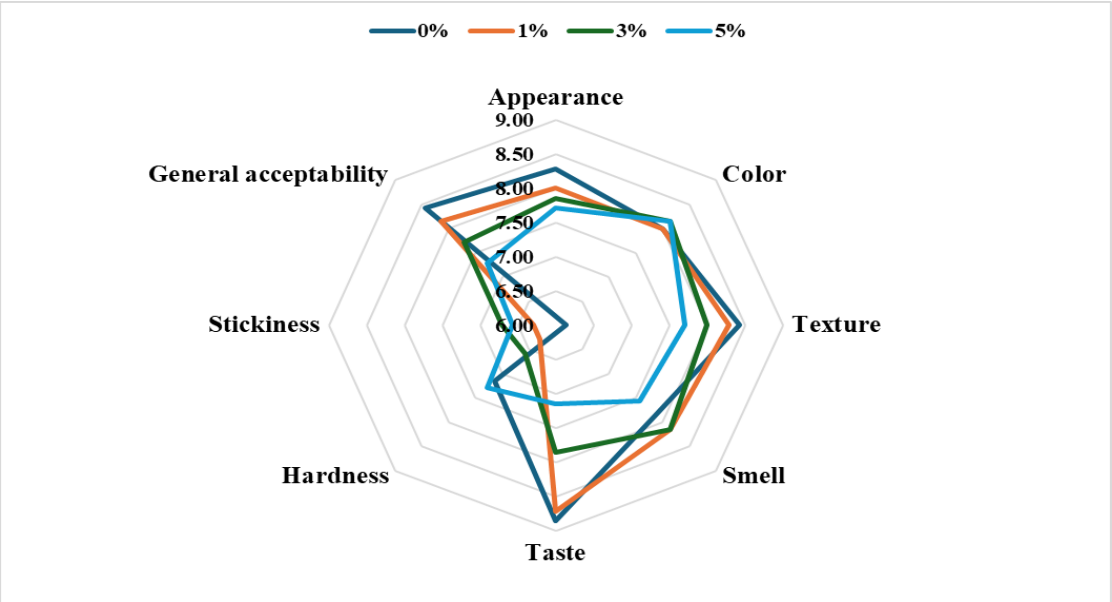

Figure 10. Sensory analysis results according to education attainment (upper secondary education) where 0%, 1%, 3%, 5% and 10% represent the % of fish hydrolysate used for samples production

Of all the results (Figure 10), the most significant differences were found for "smell" ($p < 0.01$). Although control (8.43/9.00) had the highest overall acceptability score, parameters such as "smell" received the highest scores for 1% FH, "color," and "stickiness" for 3% FH, and "hardness" for 5% FH.

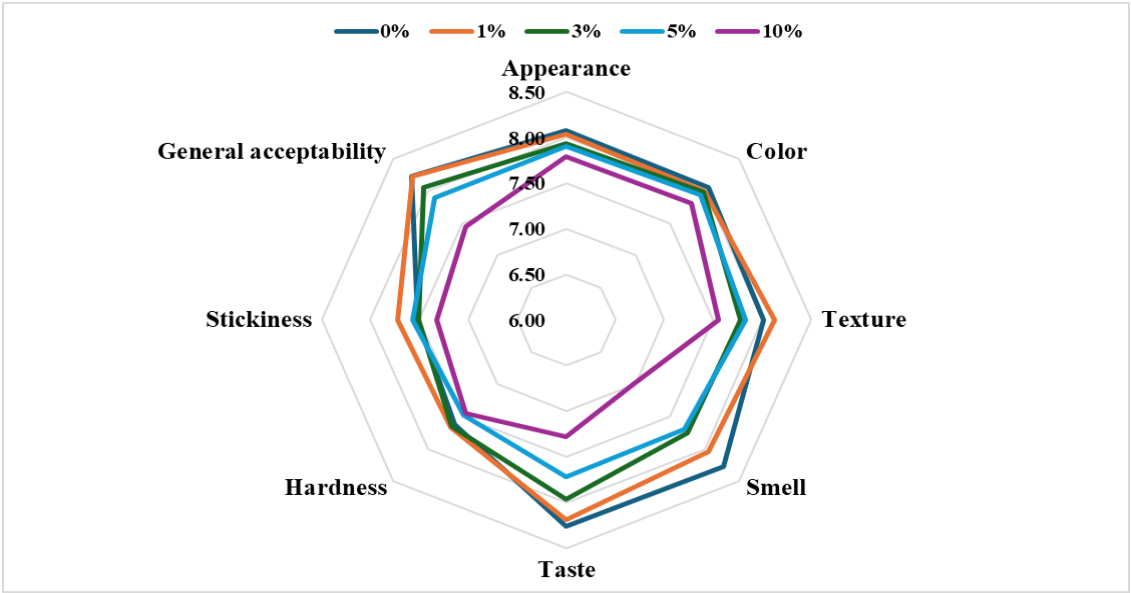

Figure 11. Sensory analysis results according to education attainment (academic education degree) where 0%, 1%, 3%, 5% and 10% represent the % of fish hydrolysate used for samples production

The samples with 3%, 5%, and 10% FH were rejected by panelists with higher education levels (Figure 11), with the highest "general acceptability" score (8.23 ± 1.02) being achieved by reference. While "texture," "hardness," and "stickiness" received the best evaluations in terms of 1% FH, "appearance" (8.07 ± 1.17), "color" (8.05 ± 1.16), "smell" (8.27 ± 1.19), and "taste" (8.27 ± 1.09) received the highest scores for 0% FH.

4. Conclusion

The potentiation of taste and smell provided by the presence of fish hydrolysate affected the sensory analysis results in all panelist groups, particularly for samples where it was present in higher concentrations. The samples containing 5 and 10% hydrolysate were strongly rejected because, despite efforts to modify the energy bars' flavor and aroma by adding whey protein concentrate, the bitter and fishy taste caused by the hydrolysate could not be entirely eliminated. This finding, however, was expected, and the results' diversity and variability were largely influenced by the panelists' sensory perceptions based on their age, gender, level of education, and place of residence.

The high values of relative standard deviations indicate a very high variability between the individual scores given by the panelists for each sensory attribute of the samples. In the case of the individual parameters analyzed for each sample, the highest scores were obtained by the samples with 0%, 1%, 3%, 5% hydrolysate (in the case of participants aged between 18-30 years). People with secondary education level had a greater tendency to appreciate products with 5% hydrolyzed in terms of color and hardness. Following the processing of the sensory analysis results of the fish hydrolysate bars in concentrations of 0%, 1%, 3%, 5% and 10%, a high appreciation from consumers was found, only for the samples with 0% (reference) and 1% hydrolyzed.

Unfortunately, bars with a higher protein value (3%, 5% and 10% hydrolyzed) were rejected by consumers due to the "unpleasant smell of fish" and the "very pronounced" taste given by the presence of hydrolysate. For this reason, it is necessary to improve the technological process of obtaining protein bars based on fish hydrolysate, in order to adjust their taste and smell – sensory characteristics with a strong impact on consumer perception, for producing foods with high nutritional value and benefits for different categories of people.

Author Contributions

Conceptualization, A.M.U. and A.M.C.; methodology, A.M.C. and A.M.U.; software, L.M.C.; validation, S.G., A.P. and C.N., formal analysis, L.M.C.; investigation, A.M.U.; resources, A.M.U., S.G.; data curation, A.M.U.; writing-original draft preparation, A.M.U., A.M.C.; writing-review and editing, A.M.U., A.P. and C.N.; visualization, A.P., C.N. and A.M.C.; supervision, A.M.C.; project administration, L.M.C.; All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statements

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of Technical University of Cluj Napoca, Romania (nr. 593/08.04.2024).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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