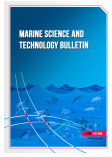
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RESEARCH ARTICLE

Impact of silverberry (*Elaeagnus angustifolia*) seed powder as a functional additive on chemical, microbiological and sensory properties of trout meatballs

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ABSTRACT

This study aimed to determine the effects of silverberry (*Elaeagnus angustifolia*) powder, used as a functional additive, on the quality characteristics of trout (*Oncorhynchus mykiss*) meatballs. In the formulation, silverberry seed powder was exclusively used instead of wheat breadcrumbs, which are commonly employed as binders and texture enhancers in traditional meatball production. Silverberry is known for its antioxidant and antimicrobial properties due to its high content of phenolic compounds, flavonoids, and dietary fiber, making it a promising natural additive for food applications. Within the scope of the research, trout meatballs were prepared with varying levels of silverberry powder (0%, 10%, 15% and 20%), and the samples were subjected to chemical (pH, TVB-N, TBARS), microbiological (total mesophilic aerobic bacteria (TMAB), psychrotrophic bacteria (TPB), and yeast-mold counts (TYM)), and sensory analyses. The results revealed that silverberry powder enhanced the oxidative stability of the meatballs, inhibited microbial growth, and positively influenced several quality parameters. Moreover, sensory evaluation indicated that the inclusion of silverberry seed powder at certain levels did not adversely affect consumer acceptance. These findings demonstrate that silverberry powder can be effectively used as a natural additive in fish-based products, offering both functional and technological benefits. Additionally, its use contributes to sustainable food production by valorizing a plant-based by-product.

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Introduction

In recent years, growing consumer interest in healthy, natural, and functional foods has positioned plant-based alternatives to synthetic additives at the forefront of the food industry. Natural ingredients particularly those exhibiting antioxidant and antimicrobial properties are increasingly incorporated into various food formulations to enhance product quality and prolong shelf life. Within this context, the integration of functional food components contributes not only to the development of products that promote public health but also to the advancement of sustainable food production. (Elal Muş, 2023; Sarıcan et al., 2024; Dhiman et al., 2025).

Fish and fish products play an important role in healthy nutrition due to their high biological value protein content, richness in omega-3 fatty acids, and essential amino acids. However, due to their high water activity and polyunsaturated fatty acid content, these products are highly susceptible to oxidative spoilage and microbial contamination. This shortens the shelf life of the products and negatively impacts their sensory quality (Qiu et al., 2019; Noreen et al., 2025; Turlybek et al., 2025).

The rising prevalence of health conditions such as celiac disease and gluten intolerance has led to an increasing demand for gluten-free food products. For individuals with celiac disease, adherence to a lifelong gluten-free diet is essential, as products containing wheat, rye, and barley must be strictly avoided. This has necessitated the reformulation of traditionally wheat-based products using alternative ingredients. The incorporation of gluten-free binders particularly in widely consumed items such as meatballs offers safe and accessible options for both celiac patients and those with gluten sensitivity. In this context, the development of protein-rich products like fish meatballs with gluten-free formulations presents significant potential in terms of nutritional value and functional properties (Yıldırım, 2020).

Silverberry (*Elaeagnus angustifolia*) is a plant widely used in traditional medicine and possesses antioxidant and antimicrobial properties. Its fruit seeds, in particular, have the potential to be used as a functional additive in the food industry due to their high content of phenolic compounds, flavonoids, and dietary fiber. However, silverberry seeds are generally considered waste during fruit processing and are underutilized. This presents an opportunity that should be evaluated from both environmental sustainability and economic value perspectives (Teymuroğlu, 2022; Emami et al., 2024).

This study investigated the potential use of silverberry powder as a functional additive in the production of trout meatballs. One of the novel aspects of the study was the use of silverberry powder alone, replacing traditionally used wheat breadcrumbs. This not only developed a gluten-free product formulation but also enabled the utilization of a waste material as a high-value-added food ingredient. Within the scope of the study, the physicochemical, microbiological, and sensory properties of trout meatballs supplemented with different amounts of silverberry powder (0%, 10%, 15%, and 20%) were analyzed, demonstrating in detail the effects of this natural additive on product quality.

Material and Methods

Materials

The material for this study consisted of 10 kg rainbow trout (*Oncorhynchus mykiss*) fillets, cultivated at the Inland Fish Research and Application Unit of the Faculty of Fisheries at Atatürk University. The fish had an average weight of 225±15 g and an average length of 26.5±1.3 cm (n = 45). The ingredients used in meatball preparation were procured from a local market in Erzurum. The silverberry seed powder used in this study was purchased from local herb markets in Erzurum. The chemical composition of the powder is based on the manufacturer's declaration. Accordingly, the powder is rich in carbohydrates and sugars but relatively low in protein and fat. The reported values are approximately moisture 10–12%, protein 0.7%, fat 0.2%, fiber 2.9%, and sugars 14–15%.

Methods

Fresh rainbow trout fillets were minced twice using a Bosch meat grinder (2000 W, Germany) equipped with a 3 mm plate to obtain a homogeneous texture. The minced fillets were then thoroughly blended with the ingredients listed in Table 1 to prepare fish meatballs, following the procedure described by Keser & İzci (2020).

Formulations were prepared in four groups (K, A, B, and C). Approximately 2.5 kg of fish meat was used for each group. Garlic (1.08%), sunflower oil (0.86%), cumin (0.43%), allspice (0.43%), black pepper (0.43%), red pepper (0.43%), and salt (1.72%) were added in fixed proportions across all groups. After cooking, the samples were placed in sterile polystyrene trays, sealed in polyethylene zip-lock bags, and stored at 4°C under refrigerated conditions. In experimental groups (A, B, C), silverberry powder was substituted for breadcrumbs at concentrations of 10%, 15%, and 20%, respectively. To

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maintain a total formulation of 100%, the minced fish ratio was proportionally reduced. After cooking, samples were placed in sterile polystyrene trays, sealed in polyethylene zip-lock bags, and stored at 4°C under refrigerated conditions.

Table 1. Formulation of meatball

Additive (%)	K	A	B	C
Minced fish	86.02	84.62	79.62	74.62
Breadcrumb	8.60	-	-	-
Silverberry powder	-	10	15	20
Garlic	1.08	1.08	1.08	1.08
Sunflower oil	0.86	0.86	0.86	0.86
Cumin	0.43	0.43	0.43	0.43
Allspice	0.43	0.43	0.43	0.43
black pepper	0.43	0.43	0.43	0.43
red pepper	0.43	0.43	0.43	0.43
Salt	1.72	1.72	1.72	1.72
Total	100.00	100.00	100.00	100.00

Chemical Analyzes

Meatball samples (5 g/50 ml) diluted with pure water were broken down in a homogenizer for 1 minute and then measured with a digital pH meter (Gökalp et al., 2001).

TBARS analysis of meatballs was performed according to the Lemon (1975) method and the absorbance values of the samples were read at a wavelength of 532 nm and the amount of mg/g malonaldehyde in the meatballs was calculated according to the formula (Eq. 1).

$$TBARS = \frac{\frac{Absorbance}{\frac{K \times 2}{1000}} \times 6.8}{sample\ weight(g)} \times 1000 \quad (1)$$

TVB-N analysis (mg/100 g) was performed according to the method of Malle & Tao (1987) and calculated with the following formula (Eq. 2):

$$TVB - N\left(\frac{mg}{100g}\right) = n \times 16.8\ mg\ nitrogen \quad (2)$$

Microbiological Analyzes

A 10 g meatball sample was homogenized in a stomacher with 90 ml of sterile saline solution and inoculated onto the appropriate culture media using the surface spreading method. Plate Count Agar (PCA) was used for total mesophilic aerobic bacteria (TMAB) and psychrotrophic bacteria (TPB), and Potato Dextrose Agar (PDA) for yeast-mold (TYM) counts. The samples were incubated at 37°C for 2 days (TMAB), 10°C for 7 days (TPB), and 25°C for 5 days (TYM). Colony counts were recorded at the end of incubation to determine microbial loads (Halkman, 2005).

Sensory Analyzes

The sensory attributes of the meatball samples, cooked in a preheated oven at 180°C for 5 minutes, were evaluated by a panel of ten assessors consisting of faculty members and graduate students from the Faculty of Fisheries, Atatürk University (Erzurum, Türkiye). Panelists rated the samples for color, taste, appearance, odor, and texture using a nine-point hedonic scale 1 (poor) to 9 (fairly good). The evaluations were conducted under controlled laboratory conditions with standardized lighting and temperature, and samples were presented in randomized order to minimize bias (Çoban, 2024).

Statistical Analyzes

Statistical analysis of the data was performed using the SPSS program using a completely randomized experimental design using analysis of variance (ANOVA). Each measurement was repeated twice, and the means of sources of variation showing significant differences were analyzed using the Duncan multiple comparison test ($p<0.05$).

Results and Discussion

Microbial Quality

Table 1 presents the microbiological analysis results of trout meatballs. The incorporation of silverberry powder resulted in lower total mesophilic aerobic bacteria (TMAB) counts compared to the control group. At the end of the 15-day storage period, the control samples reached 7.14±0.12 log CFU/g, whereas samples A, B, and C exhibited values of 6.62±0.22, 6.15±0.25, and 6.14±0.19 log CFU/g, respectively. According to the International Commission on Microbiological Specifications for Foods (ICMSF, 1986), although no specific criteria are defined for processed fish products, the acceptable upper limit for aerobic microorganism counts in fresh, chilled, and frozen fish is 7 log CFU/g. The control group exceeded this threshold on day 15, while all silverberry powder-supplemented groups remained below the limit throughout the storage period. Similarly, Yi et al. (2011) reported that the total viable count (TVC) of *Collichthys* fish ball samples was 3.5 log CFU/g, and significantly lower TVC values were observed in tea

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polyphenol-treated groups compared to the control ($p<0.05$). In another study, Guan et al. (2019) found that total microbial counts increased over time in both control and grape seed-treated hairtail fish balls, indicating that microbial growth during storage is inevitable, but can be mitigated by natural additives.

Trout balls prepared with silverberry seed powder had lower total psychrotrophic bacterial counts compared to the control group. This indicates the microbial growth-suppressing potential of silverberry seed powder. A similar microbiological protective effect was observed in a study conducted on fish nuggets containing green banana flour (GBF) and HERP. Specifically, in the F1 formulation (GBF+0.4% HERP), psychrotrophic bacterial counts remained at 4.39 log CFU/g at the end of day 15, a value significantly lower than in the control groups (de Santana et al., 2024).

The present study investigated the impact of silverberry seed powder on yeast and mold (TYM) growth in trout patties during refrigerated storage. Although TYM values increased in all groups over time, the rise was notably less pronounced in samples containing silverberry powder compared to the control. Particularly on days 6 and 9, the C group (20% silverberry powder) exhibited significantly lower TYM counts ($p<0.05$). When mean values were considered, the C group showed the lowest microbial load, with 2.57±0.73 log CFU/g. These findings suggest that silverberry powder possesses antifungal properties and contributes to enhanced microbiological stability of the product. Supporting this, da Silva et al. (2021) evaluated the use of innovative gluten-free coatings made from tapioca and coconut flours in fish nuggets. Initial mold and yeast counts ranged from 3.61 to 3.80 log CFU/g, with no significant differences among treatments. However, during storage, a significant increase in microbial counts was observed in nuggets coated with coconut flour ($p<0.05$), while the control and tapioca-coated samples maintained stable levels. These results collectively highlight the potential of natural ingredients in controlling fungal growth and improving shelf-life in fish-based products.

Table 1. Microbiological results of trout meatballs (log cfu/g)

Analyses	Storage Time (day)	K	A	B	C	Mean (X±Sx)
TMAB	0	2.78±0.31	2.07±0.09	2.03±0.04	2.01±0.01	2.22±0.36^{a}
	3	3.48±0.22	2.63±0.40	2.67±0.26	2.36±0.25	2.78±0.50^{b}
	6	4.15±0.17	3.29±0.21	3.40±0.21	3.19±0.23	3.50±0.43^{c}
	9	5.14±0.13	4.50±0.30	4.37±0.42	3.95±0.06	4.49±0.49^{d}
	12	6.66±0.14	5.39±0.22	5.22±0.14	5.17±0.20	5.60±0.67^{e}
	15	7.14±0.12	6.62±0.22	6.15±0.25	6.14±0.19	6.51±0.46^{f}
	Mean (X±Sx)	4.90±1.67^{C}	4.08±1.67^{B}	3.98±1.50^{AB}	3.80±1.54^{A}	
TPAB	0	2.67±0.05	2.12±0.16	2.05±0.07	2.02±0.02	2.22±0.29^{a}
	3	3.48±0.09	2.58±0.43	2.45±0.41	2.28±0.32	2.70±0.56^{b}
	6	4.16±0.06	3.44±0.32	3.34±0.46	3.22±0.36	3.54±0.46^{c}
	9	5.26±0.14	4.49±0.56	4.42±0.60	4.34±0.32	4.63±0.51^{d}
	12	6.77±0.15	5.36±0.43	5.22±0.31	5.07±0.21	5.60±0.76^{e}
	15	7.30±0.17	6.60±0.39	6.27±0.08	6.12±0.06	6.58±0.51^{f}
	Mean (X±Sx)	4.94±1.75^{B}	4.10±1.66^{A}	3.96±1.59^{A}	3.85±1.55^{A}	
TYM	0	2.00±0.00	2.00±0.00	2.00±0.00	2.00±0.00	2.00±0.00^{a}
	3	2.00±0.00	2.00±0.00	2.00±0.00	2.00±0.00	2.00±0.00^{a}
	6	2.25±0.10	2.17±0.16	2.13±0.08	2.08±0.04	2.16±0.10^{b}
	9	2.98±0.05	2.74±0.10	2.67±0.17	2.43±0.16	2.70±0.23^{c}
	12	3.38±0.20	3.12±0.14	3.01±0.09	2.96±0.09	3.11±0.20^{d}
	15	4.51±0.38	3.95±0.23	3.86±0.12	3.95±0.09	4.06±0.33^{e}
	Mean (X±Sx)	2.85±0.94^{D}	2.85±0.94^{C}	2.61±0.70^{B}	2.57±0.73^{A}	

Note: Superscript letters (a–f) indicate significant differences between storage days ($p<0.05$). Capital letters (A–D) indicate significant differences between treatment groups on the same day ($p<0.05$). Mean values (X±Sx) represent the overall average across storage periods, with statistical comparisons performed between treatments. K: Control; A: 10% Silverberry powder; B: 15% Silverberry powder; C: 20% Silverberry powder.

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Chemical Quality

A progressive increase in TVB-N values was observed in trout patties during the storage period. On day 15, the control group reached a TVB-N level of 27.66 mg/100 g, whereas the increase was more restrained in the silverberry powder–supplemented groups. Among these, Group C (20% silverberry powder) exhibited the lowest TVB-N value, measured at 19.19 mg/100 g. A level of 30–35 mg/100 g TVB-N in muscle is generally considered to be the acceptable limit for cold-water fish stored under chilled conditions, indicating that all groups remained within acceptable quality limits (Al-Harbi & Al-Asous, 2022). These findings suggest that silverberry powder may contribute to delaying protein degradation and enhancing the chemical stability of the product throughout storage (Figure 1a). In the study conducted by Sinha et al. (2023), TVB-N values were assessed in fish patties and found to be higher in the control group compared to those prepared with oat flour supplementation.

According to the results of the variance analysis, both the sample groups and the storage time had statistically significant effects on the TBARS values of the product ($p<0.05$). However, the interaction between sample and storage time was not significant, indicating that the effect of the additive remained consistent regardless of the time factor. Significant reductions in TBARS values were observed in trout patties prepared with the addition of silverberry powder compared to the control group. Although TBARS values increased in all groups throughout the storage period, this increase was more limited in Group C, with a final value of 6.50 µmol MDA/kg measured on day 15 (Figure 1b). The acceptable limit of TBARS in fish has been reported as 8 mg MDA/kg by Ulusoy et al. (2024). These results support the antioxidant capacity of silverberry powder in retarding lipid oxidation and highlight its potential to extend the shelf life of the product. Similarly, in a study conducted by Ali et al. (2019) on tilapia fish burgers, the effects of mashed pumpkin and mashed potato added at different levels were evaluated in terms of lipid oxidation. The results showed that TBA values significantly decreased as the additive level increased, with the lowest value (0.185 mg MDA/kg) observed at the 25% supplementation level. The findings of both studies demonstrate that natural plant-based additives are effective in preserving chemical quality and extending shelf life by limiting oxidative degradation in fish products.

According to the pH results in Figure 1(c), fluctuations in pH values were observed in all groups throughout the storage period. The interaction between sample and storage period, as well as between sample and storage period, was also found to be significant ($p<0.05$). In a study conducted by Oğuzhan Yıldız & Arslan (2022) on catfish patties enriched with flax and chia seeds, fluctuations in pH values were observed across all groups during storage, and statistically significant differences were detected between the groups ($p<0.05$). These findings are in agreement with the results of our study.

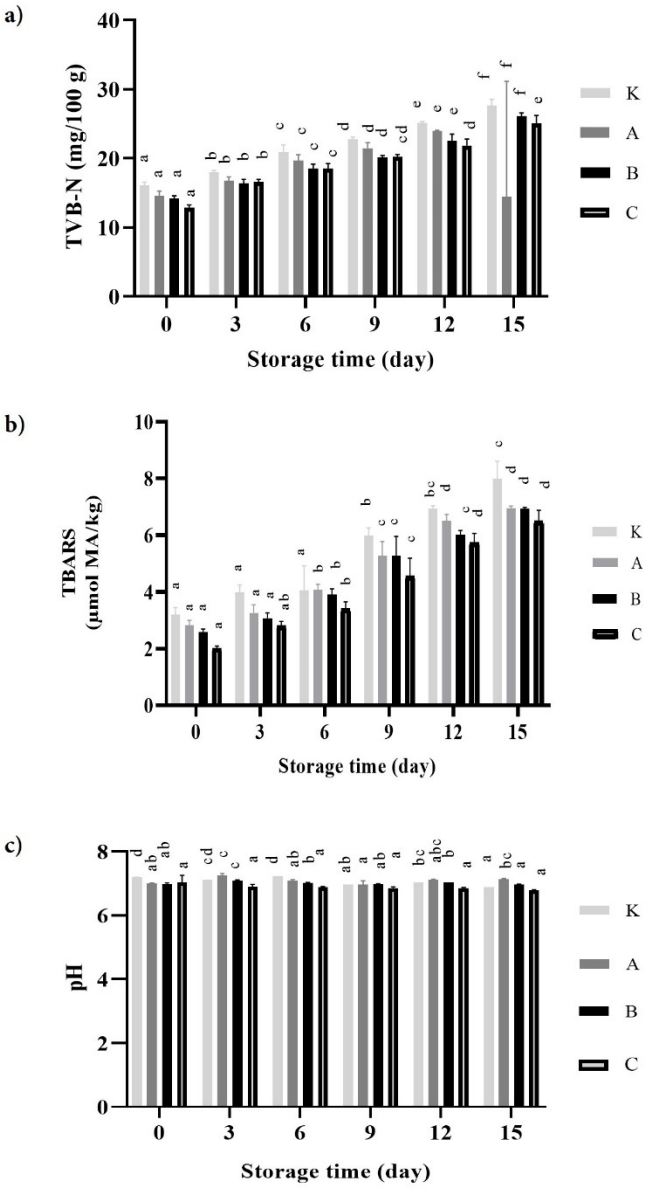


Figure 1. a) TVB-N, **b)** TBARS, **c)** pH results of rainbow trout meatballs. K: Control, A: 10% Silverberry powder, B: 15% Silverberry powder, C: 20% Silverberry powder.

Sensory Quality

Figure 2 presents the sensory evaluation results of the trout meatball samples throughout the storage period. Among the groups, meatballs prepared with 15% silverberry powder (Group B) received the highest scores in terms of sensory attributes such as color, texture, flavor, and overall

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acceptability. Statistical analysis revealed that Group B scores for flavor and overall acceptability were significantly higher ($p<0.05$) than those of the control and Group C, indicating that moderate incorporation enhanced consumer preference. The improvement observed at the 15% level may be attributed to the balanced presence of silverberry powder, which provided natural sweetness and phenolic compounds without negatively affecting texture. At higher incorporation levels (20%), the increased presence of phenolics likely contributed to oxidative stability but may have introduced astringent or bitter notes, explaining the lower sensory scores. This highlights the importance of optimizing the level of incorporation to achieve both functional and sensory benefits. These findings are consistent with previous studies. Romero et al. (2018) reported that the type of flour used in fish balls significantly affected sensory properties, while Cavenaghi-Altemio & Fonseca (2024) demonstrated that corn and cassava flours improved sensory acceptability in gluten-free fish fingers. Kızıloğlu & Yıldız (2024) reported that the incorporation of Jerusalem artichoke fiber into fish fingers positively influenced sensory attributes, leading to higher scores for freshness perception and overall acceptability compared to the control group. Taken together,

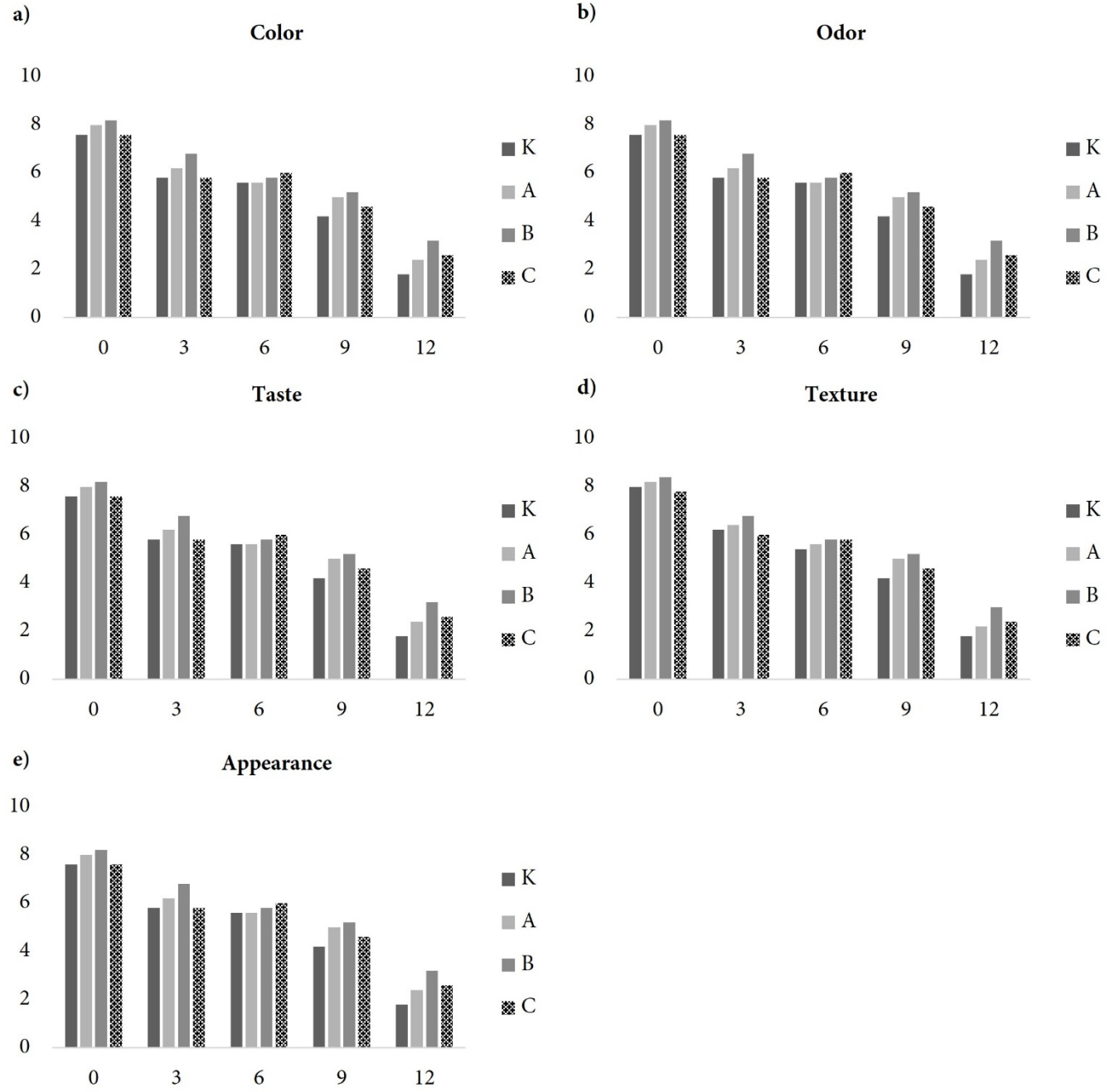


Figure 2. Sensory evaluation results of rainbow trout meatballs. K: Control, A: 10% Silverberry powder, B: 15% Silverberry powder, C: 20% Silverberry powder.

these findings emphasize the role of additive characteristics in shaping consumer perception and align with our results, which demonstrate that silverberry powder supplementation influenced sensory attributes of trout meatballs, particularly enhancing overall acceptability at the 15% incorporation level.

Conclusion

The incorporation of silverberry (*Elaeagnus angustifolia*) seed powder as a functional additive in rainbow trout meatballs demonstrated significant improvements in chemical, microbiological, and sensory quality parameters. The enriched samples exhibited lower microbial counts during storage, indicating enhanced shelf-life and microbial stability. In addition, oxidative degradation was mitigated, as reflected by reduced TBARS values, while sensory evaluations revealed higher acceptability in terms of taste, color, odor, texture, and overall appearance. These findings highlight the potential of silverberry seed powder as a natural preservative and functional ingredient in fish-based products, contributing to both product safety and consumer appeal. Moreover, this study provides an original contribution to the literature by presenting, for the first time, a formulation of rainbow trout balls prepared with gluten-free flour. The results demonstrate that gluten-free binders can positively influence the physicochemical and sensory properties of fish-based products. Considering the increasing consumer demand for gluten-free foods, this research offers a novel perspective for functional food development and sustainable production. Future investigations may focus on exploring different types of gluten-free flours and natural binders to further enhance product diversity and evaluate industrial-scale applicability.

Compliance With Ethical Standards

Authors' Contributions

POY: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing
GA: Investigation, Supervision
All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

Funding

Not applicable.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

AI Disclosure

Artificial intelligence-assisted technology was not used in the preparation of this work, except for minor grammar and spelling checks.

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