Sustainable innovation in plant-based protein: Development and optimization of champignon mushroom-TVP meatloaf as a nutritious meat alternative

Efrina Efrina [1*], *Dhimas* Armando Pangestu[1], *Muhammad* Lutfi Maqdum[1], *Syahrul* Mustofa[1], *Alvina* Fadila Maulida[2]

[1]Seni Kuliner dan Pengelolaan Jasa Makanan, Fakultas Teknik, Universitas Negeri Jakarta, Jl. Rawamangun Muka No 11, Jakarta Timur, 13220, Indonesia
[2] Pendidikan Tata Boga, Fakultas Teknik, Universitas Negeri Jakarta, Jl. Rawamangun Muka No 11, Jakarta Timur, 13220, Indonesia

Abstract. This study developed a champignon mushroom–based meatloaf as a plant-based meat substitute using textured vegetable protein (TVP) to improve texture and sensory quality. Three formulations containing 8%, 11%, and 14% TVP were prepared and evaluated through descriptive sensory analysis conducted by 10 trained panelists and hedonic preference testing involving 100 untrained and semi-trained consumers. The sensory attributes assessed included color, aroma, flavor, and texture. Results from descriptive analysis indicated that the 8% TVP formulation most closely resembled conventional meatloaf, particularly in terms of softness and natural mushroom flavor, while higher TVP levels produced firmer and more elastic textures. Hedonic testing showed that consumer preferences varied according to texture, with some respondents favoring the denser structure of higher TVP formulations. Based on the combined results of both sensory evaluations, the 8% TVP formulation was selected for nutritional analysis. Proximate analysis revealed that the mushroom-based meatloaf contained lower fat (5.30 g/100 g) and energy (140 kcal/100 g) compared to the meat-based control (9.17 g fat and 190 kcal/100 g), while providing moderate protein content (8.65 g/100 g) and higher moisture levels. These findings demonstrate that champignon mushrooms combined with TVP can produce a nutritionally adequate, lower-fat, and lower-calorie plant-based meat alternative with favorable sensory characteristics.

1 Introduction

The demand for plant-based food products continues to rise as consumers become more aware of the health and environmental impacts of excessive meat consumption. High intake of red meat has been linked to an increased risk of chronic diseases such as heart disease, type 2 diabetes, and cancer [1]. Additionally, meat production significantly contributes to greenhouse gas emissions, deforestation, and excessive water usage [2]. In this context, there is an urgent need to develop more sustainable and environmentally friendly plant-based food alternatives [3].

One potential solution is the use of mushrooms as a meat substitute. Mushrooms are rich in protein, fiber, vitamins, and minerals, while also possessing a texture and umami flavor similar to meat [4]. Champignon mushrooms (*Agaricus bisporus*), for instance, are among the most commonly used meat alternatives due to their high nutritional value and low environmental impact [5]. The development of mushroom-based products has been shown to reduce fat and sodium intake without compromising taste satisfaction [6].

Research has demonstrated that incorporating mushrooms into meat-based products can improve nutritional quality while maintaining desirable sensory characteristics. Partial substitution of meat with mushrooms has been associated with reduced fat and energy content, as well as enhanced umami flavor, without negatively affecting consumer acceptance. The natural flavor compounds in mushrooms contribute to improved palatability, making mushroom–meat blends appealing to consumers while supporting healthier and more sustainable food choices [7,8].

Beyond health and sensory benefits, mushroom-blended meat products are also more environmentally sustainable and align with the trend toward healthier and more eco-friendly food choices. Edible mushrooms have been found to serve as sustainable meat substitutes with a smaller land, water, and carbon footprint compared to traditional livestock production, making them attractive for environmentally conscious consumers seeking lower-impact protein sources [9]. This research is highly relevant amidst a growing consumer preference for food products that are not only delicious but also nutritious and sustainable.

The urgency of this study lies in addressing both health and environmental challenges through the development of innovative food products. Increasing the consumption of healthier and more sustainable food products is necessary to reduce the negative impact of meat production and consumption. The novelty of this study is the combination of champignon mushrooms with textured vegetable protein (TVP) in meatloaf

* Corresponding author: efrina@unj.ac.id

formulation, which is expected to enhance the texture, flavor, and nutritional value of meatloaf without compromising the traditional meat flavor experience [10,11].

With numerous studies demonstrating positive consumer acceptance of mushroom-blended meat products, this research is expected to make a significant contribution to the development of mushroom-based food products that are not only healthier and more environmentally friendly but also delicious and satisfying in terms of taste and texture.

2 Materials and Methods

2.1 Materials and Formulation

The study was conducted in the food processing laboratory of Universitas Negeri Jakarta (UNJ). The main ingredients used in this research were fresh champignon mushrooms as a meat substitute and breadcrumbs. To improve the texture profile of the meatloaf, textured vegetable protein (TVP) was incorporated at different concentrations (8%, 11%, and 14%) to determine the most preferred formulation. Additional ingredients, including salt, pepper, and tomato paste, were used to enhance the color and flavor of the product. The equipment utilized in this study included an oven, baking molds, knives, and a food processor. The formulations of the meatloaf samples are presented in Table 1.

Three mushroom-based meatloaf formulations were prepared: Sample A contained 8% TVP, Sample B contained 11% TVP, and Sample C contained 14% TVP. These formulations were evaluated to examine the effects of different TVP concentrations on the sensory and nutritional characteristics of the product.

Table 1. Formulations of champignon mushroom–based meatloaf with different TVP levels

Ingredients	**Treatment** *)		
	Sample A	**Sample B**	**Sample C**
Champignon mushroom	56%	56%	56%
textured vegetable protein	8%	11%	14%
Bread crumbs	8%	8%	8%
eggs	11%	11%	11%
onion	6%	6%	6%
Tomato Paste	3%	3%	3%
celery	1%	1%	1%
flavoring	2%	2%	2%
Black pepper	1%	1%	1%
salt	2%	2%	2%
Tomato Paste for spreading on top of meatloaf	3%	3%	3%

2.2 Meatloaf Preparation Process

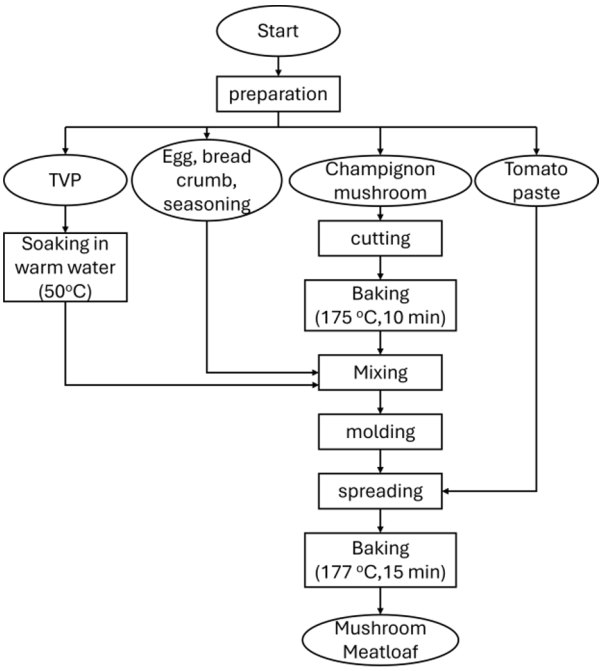

Figure 1. Flow Chart of Mushroom Meatloaf Production

The preparation process began with soaking the textured vegetable protein (TVP) in warm water for several minutes to rehydrate it. Fresh champignon mushrooms were then chopped using a food processor and pre-baked at 175 °C for 10 minutes to reduce moisture content. After pre-baking, the mushrooms were mixed with the rehydrated TVP, eggs, breadcrumbs, and other ingredients using a spatula until a uniform mixture was obtained. The mixture was subsequently molded into a meatloaf pan, and tomato paste was spread evenly on the surface to enhance color and flavor. The final product was baked at 175 °C for 15 minutes until fully cooked.

2.3 Sensory Evaluation

Sensory evaluation plays a crucial role in the development of food products, as it provides systematic information about the sensory characteristics and consumer acceptance of a product. In this study, sensory evaluation was conducted to assess both the sensory attributes and the level of consumer preference for champignon mushroom–based meatloaf formulated with different concentrations of textured vegetable protein (TVP). Two complementary sensory methods were applied: descriptive sensory analysis to characterize the intensity of specific sensory attributes, and hedonic preference testing to measure overall consumer acceptance.

2.3.1 Descriptive Sensory Analysis

Descriptive sensory analysis was performed by 10 trained panellists with professional experience in the culinary field. The sensory attributes evaluated included color, aroma, flavor, and texture. A 5-point intensity

scale was used to rate each attribute, and the data were analyzed using Quantitative Descriptive Analysis (QDA) to describe the sensory profiles of the formulations. The descriptive sensory questionnaire is presented in Table 2.

Table 2. Questionnaires For Hedonic Quality Testing

Sensory Atributes	Descriptive Scale	
Colour	Colour inside	
	Colour outside	
Aroma	Mushroom aroma	Strong Mushroom Aroma
		Mushroom Aroma
		Slight Mushroom Aroma
		Very slight mushroom aroma
		No mushroom aroma
	TVP Aroma	Strong TVP Aroma
		TVP Aroma
		Slight TVP Aroma
		Very slight TVP aroma
		No TVP aroma
Flavour	Mushroom Flavour	Strong Mushroom flavour
		Mushroom flavour
		Slight Mushroom flavour
		Very slight mushroom flavor
		No mushroom flavor
	TVP Flavour	Strong TVP flavour
		TVP flavour
		Slight TVP flavour
		Very slight TVP flavor
		No TVP flavor
Texture		Very Dense
		Dense
		Slightly Dense
		Slightly dense
		Not dense

2.3.2 Hedonic Preference Testing

Hedonic preference testing is a sensory evaluation method used to measure the degree of liking or preference that consumers have for a food product based on their individual perceptions. According to [4], hedonic tests are designed to assess consumer acceptance using a structured scale—most commonly a 9-point or 5-point hedonic scale—where respondents indicate their level of liking, ranging from “dislike extremely” to “like extremely.”. This method is particularly useful in product development and reformulation to determine which formulation is most preferred by target consumers. In this study, hedonic preference testing was used to evaluate three formulations of mushroom-based meatloaf, each containing different concentrations of textured vegetable protein (TVP): 8%, 11%, and 14%. The samples were coded to ensure unbiased responses, with only the researcher aware of which code corresponded to each formulation. Panellists were asked to evaluate the samples based on four sensory attributes: colour, aroma, texture, and taste.

The hedonic preference test involved 100 participants. A five-point hedonic scale was used, where a score of 5 indicated “strongly like” and a score of 1 indicated “strongly dislike.” The data were analyzed using analysis of variance (ANOVA) to identify significant differences in consumer acceptance among the formulations. This approach provided insight into consumer preferences and supported the selection of the most acceptable formulation in terms of sensory appeal. The appearance of the champignon mushroom–based meatloaf samples is shown in Figure 2.

(a) (b) (c)

Figure 2. The Pictures Of Champignon Mushroom-Based Meatloaf Containing 8 % TVP (a), 11% TVP (b), and 14 % TVP (c)

2.4 Proximate Analysis

2.4.1 Sample Preparation

Two types of meatloaf samples were prepared for laboratory analysis: a conventional meat-based meatloaf (control) and the most preferred mushroom-based meatloaf formulation selected from the hedonic preference test, containing 8% textured vegetable protein (TVP). Each sample was prepared in standardized 100 g portions and vacuum-packed prior to submission. All samples were in good condition, with normal sensory characteristics (odor, taste, and color), and were delivered to the regional food laboratory (LABKESDA Jakarta Raya) under controlled temperature to maintain quality before testing.

2.4.2 Analytical Procedures

Proximate analysis was conducted at LABKESDA Jakarta Raya in accordance with procedures outlined by the Indonesian National Standard (SNI 01-2891-1992) and PP.16.22-PROKS/17025/LABKESDA protocols. Due to limited laboratory access, each parameter was measured once; therefore, the results are presented without standard deviation. The parameters analyzed included total protein, total fat, total carbohydrate, moisture content, ash content, and energy value. The energy content of the samples was calculated using the Atwater general factors based on the proximate composition results, where protein and carbohydrate were multiplied by 4 kcal/g and fat by 9 kcal/g.

3 Result and Discussion

This study resulted in the development of a champignon mushroom–based meatloaf as a meat substitute, formulated with different concentrations of textured vegetable protein (TVP). The products were evaluated to assess their sensory characteristics, including color, aroma, flavor, and texture. Product development was conducted through several experimental stages, in which TVP was incorporated into the mushroom meatloaf at concentrations of 8%, 11%, and 14%.

3.1 Descriptive Sensory Analysis

Based on the descriptive sensory analysis conducted by 10 trained panelists (Figure 3), the formulation containing 8% TVP exhibited a texture most similar to that of conventional meat-based meatloaf. Formulations with 11% and 14% TVP were perceived as denser and more elastic in texture, while still maintaining acceptable sensory characteristics.

The external color of all samples, enhanced by the application of tomato paste, showed an appealing reddish-brown appearance resembling roasted meat. Internally, meatloaf formulations containing 8% and 11% TVP appeared light brown, whereas the 14% TVP formulation displayed a darker interior, which may be attributed to a more pronounced Maillard reaction during baking.

The intensity of mushroom aroma and umami flavor was most prominent in the 8% TVP formulation. In contrast, the 11% and 14% TVP samples exhibited a stronger “meaty” flavor profile, although the mushroom characteristics remained perceptible. Regarding texture, the 8% TVP meatloaf was described as softer and closer to traditional meat-based meatloaf, while the higher TVP formulations were perceived as firmer and more elastic. Among the tested samples, the 11% TVP formulation provided the most balanced combination of texture and flavor attributes.

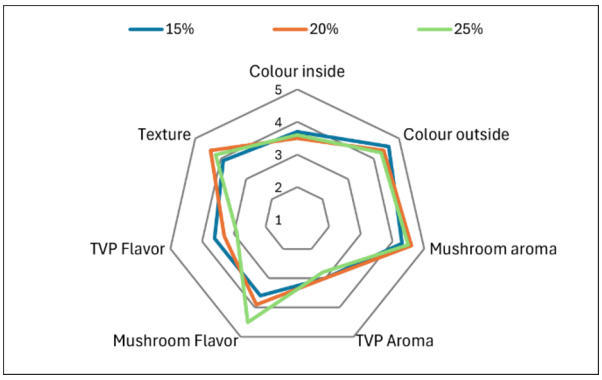

Figure 3 Result of Hedonic Test

The findings of this study demonstrate that champignon mushrooms can serve as an effective meat substitute in vegetarian meatloaf products. These results support previous research indicating that mushrooms possess meat-like texture and umami flavor characteristics [4,5]. The incorporation of textured vegetable protein (TVP) further enhanced the textural properties of the product, resulting in improved chewiness and density. This is consistent with previous finding showing that TVP is an effective ingredient for replicating meat-like texture in plant-based products [11].

Moreover, champignon mushrooms contributed significantly to flavor development. Their natural umami flavor enhanced the overall palatability of the meatloaf. This observation is in agreement with reports indicating that mushrooms are rich in umami compounds and are highly suitable for use in meat analogues [12]. In the present study, the 8% TVP formulation was characterized by a softer texture and a more natural mushroom flavor, closely resembling traditional meat-based meatloaf. This finding aligns with studies showing that combining plant-based ingredients with moderate levels of textured proteins can improve sensory acceptability [10].

Formulations containing 11% and 14% TVP exhibited firmer textures and more pronounced meat-like flavor characteristics, which may appeal to consumers who prefer a denser bite. However, for meatloaf products where a softer and moister texture is desired, the 8% TVP formulation was found to be the most suitable.

Overall, the combination of champignon mushrooms and TVP provided a favorable balance in terms of flavor, texture, and sensory quality. The resulting product not only offers a healthier profile—characterized by lower fat and energy content—but also represents a more sustainable alternative for consumers seeking to reduce meat consumption. These results are consistent with previous studies emphasizing that shifting from meat-based to plant-based products can significantly reduce environmental impacts [2].

3.2 Hedonic Test

Building upon the qualitative findings obtained from expert panellists, this study further examined the

sensory acceptability of mushroom-based meatloaf formulated with varying concentrations of textured vegetable protein (TVP) using both untrained and semi-trained consumer panels. The objective was to assess overall acceptability and to identify which formulation best met the sensory and structural expectations of different consumer groups.

The hedonic evaluation conducted with untrained panellists revealed statistically significant differences in four key sensory attributes: aroma ($\rho = 0.0176$), thickness ($\rho = 0.0313$), mushroom flavor ($\rho = 0.0053$), and overall acceptability ($\rho = 0.0007$). The 8% TVP formulation received the highest scores for mushroom aroma and umami flavor, likely due to the lower proportion of soy protein, which allowed the natural characteristics of champignon mushrooms to dominate. In contrast, the 14% TVP formulation was noted for its firmer and denser texture, contributing to its higher overall acceptability. These findings are consistent with previous studies highlighting the flavor-enhancing and meat-like textural properties of mushrooms[4,5] as well as the structural advantages of TVP in simulating animal-based protein [11].

Dunn's post-hoc analysis further supported these results by showing that the 8% TVP formulation differed significantly from the higher TVP concentrations in terms of aroma and mushroom flavor. Meanwhile, thickness and overall acceptability scores favored the 14% TVP variant, likely due to its more cohesive and chewy texture, which was perceived as more meat-like by general consumers.

Interestingly, the semi-trained panel, composed of culinary students with formal sensory training, reported a significant difference only for the thickness attribute ($\rho = 0.0372$), suggesting a more consistent and objective approach to sensory evaluation. Post-hoc analysis indicated that the 14% TVP sample was significantly thicker than the 8% and 11% formulations, while no substantial differences were observed in flavor, aroma, or overall acceptability. This behavior aligns with the notion that trained individuals are more calibrated in detecting structural changes and may overlook subtle flavor differences unless they are pronounced [10,12].

The divergence in responses between untrained and semi-trained panellists underscores the importance of demographic and experiential diversity in product testing. While untrained consumers are more influenced by hedonic attributes such as aroma and flavor, semi-trained individuals tend to prioritize structural consistency. These contrasting preferences should inform formulation strategies, particularly for products targeting both culinary professionals and general consumers.

These findings also reaffirm the versatility of champignon mushrooms and TVP in developing plant-based meat analogues that address both sensory quality and environmental responsibility. Champignon mushrooms provide a favorable umami profile primarily due to their high glutamate content and serve as a low-fat, low-calorie base for meat alternatives [6,12]. The incorporation of TVP further enhances texture while maintaining nutritional balance, meeting modern consumer demands for healthier plant-based products.

From a sustainability perspective, replacing animal protein with plant-based formulations such as mushroom–TVP blends can significantly reduce greenhouse gas emissions and resource consumption [2]. Thus, beyond sensory appeal, the development of mushroom-based meatloaf represents a viable approach to health-conscious and environmentally sustainable food innovation.

Overall, the sensory evaluation demonstrated that champignon mushroom–based meatloaf formulations with different levels of textured vegetable protein (TVP) exhibited distinct sensory profiles in terms of aroma, flavor, texture, and overall acceptability. The descriptive sensory analysis indicated that the 8% TVP formulation most closely resembled conventional meat-based meatloaf, particularly in terms of softness and natural mushroom flavor, while higher TVP concentrations produced firmer and more elastic textures. The hedonic preference test further revealed that consumer acceptance varied according to sensory expectations, with the 14% TVP formulation preferred for its denser, meat-like texture and the 8% TVP formulation favored for its pronounced mushroom aroma and umami flavor. Based on the combined results of both descriptive sensory analysis and hedonic preference testing, the 8% TVP formulation was selected as the optimal formulation for further nutritional evaluation. These findings confirm that both mushroom content and TVP concentration play important roles in shaping the sensory characteristics of plant-based meatloaf and that formulation adjustments can be made to meet diverse consumer preferences while maintaining desirable sensory quality.

3.3 Nutritional Composition Analysis

In addition to sensory evaluation, the proximate composition of two meatloaf products was analyzed: a self-prepared conventional meat-based meatloaf (control) and the selected champignon mushroom–based meatloaf formulated with 8% textured vegetable protein (TVP). The analysis compared protein, fat, carbohydrate, moisture, ash, and energy content to evaluate the nutritional differences between the two formulations and to assess the potential of the mushroom-based product as a healthier alternative.

Table 3. Nutritional Composistion between Meat-Based and Mushroom-Based Meatloaf

Parameter	Meat-Based Meatloaf (Control)	Mushroom-Based Meatloaf (8% TVP)
Total Protein (g/100g)	23.65	8.65
Total Fat (g/100g)	9.17	5.3
Total Carbohydrate (g/100g)	3.09	15.11
Moisture Content (g/100g)	62.28	68.8
Ash Content (g/100g)	1.81	2.14
Energy (kcal/100g)	190	140

The champignon mushroom–based meatloaf formulated with 8% TVP contained 8.65 g of protein per 100 g, contributing approximately 15% of the recommended daily intake (AKG, *Angka Kecukupan Gizi*, the Indonesian Recommended Dietary Allowance). In comparison, the self-prepared conventional meat-based meatloaf provided a higher protein content of 23.65 g per 100 g, equivalent to about 40% of AKG. This difference is mainly attributed to the naturally higher protein content of meat. Despite the lower protein level, the mushroom-based formulation remains a valuable source of plant-based protein, particularly for individuals seeking to reduce animal protein consumption.

Regarding fat content, the mushroom-based meatloaf contained 5.30 g/100 g (7% AKG), which is lower than the 9.17 g/100 g (13% AKG) observed in the meat-based control. This indicates that the mushroom formulation offers a leaner nutritional profile, making it potentially more suitable for individuals managing fat intake or concerned about cardiovascular health. Conversely, the carbohydrate content of the mushroom-based meatloaf was higher (15.11 g/100 g) than that of the meat-based product (3.09 g/100 g), likely due to the inclusion of breadcrumbs and other plant-derived ingredients. Although higher in carbohydrates, this level remains within a reasonable range and may contribute to improved satiety.

The moisture content of the mushroom-based meatloaf (68.80%) was higher than that of the meat-based version (62.28%), which supports the sensory findings indicating a softer and moister texture for the plant-based formulation. Ash content was also slightly higher in the mushroom-based product (2.14 g/100 g) compared to the control (1.81 g/100 g), suggesting greater mineral retention from mushroom and plant-based ingredients. In terms of energy, the mushroom-based meatloaf provided 140 kcal/100 g, while the meat-based meatloaf contained 190 kcal/100 g, positioning the former as a lower-calorie alternative that may appeal to calorie-conscious consumers.

Overall, although the plant-based meatloaf contained less protein than the conventional meat-based product, it offered several nutritional advantages, including lower fat and energy content, higher moisture levels, and a balanced macronutrient profile. These characteristics support its potential application in health-oriented and vegetarian diets. The findings also align with previous studies highlighting the nutritional benefits of mushrooms and soy-based proteins as meat substitutes [6,10,12].

Altogether, the laboratory results confirm that champignon mushroom–based meatloaf with 8% TVP is a nutritionally adequate and healthier plant-based alternative, consistent with the growing consumer demand for sustainable, nutritious, and environmentally friendly food products.

4 Conclusions

The present study demonstrates that champignon mushrooms, when combined with textured vegetable protein (TVP), can be effectively used to formulate a vegetarian meatloaf with favorable sensory and nutritional characteristics. Descriptive sensory analysis indicated that the formulation containing 8% TVP most closely resembled conventional meat-based meatloaf, particularly in terms of softness, natural mushroom flavor, and overall sensory balance. Hedonic preference testing further revealed that while the 14% TVP formulation was preferred by some consumers for its firmer, meat-like texture, the 8% TVP formulation was consistently favored for its pronounced mushroom aroma and umami flavor. Based on the combined results of both sensory methods, the 8% TVP formulation was selected as the optimal formulation for further nutritional evaluation.

Nutritional analysis supported the suitability of the mushroom-based meatloaf as a healthier alternative to conventional meat-based products. The 8% TVP formulation contained lower levels of fat (5.30 g/100 g) and energy (140 kcal/100 g) compared to the meat-based control (9.17 g fat and 190 kcal/100 g), while still providing a moderate amount of protein (8.65 g/100 g). In addition, the higher moisture content of the mushroom-based meatloaf contributed to its softer texture, which was positively reflected in the sensory evaluation. These findings highlight the potential of champignon mushrooms and TVP as nutritious, low-fat, and lower-calorie ingredients that align with current dietary trends toward plant-based food consumption.

Future research is recommended to explore intermediate TVP concentrations to further optimize the balance between flavor intensity and textural firmness. Studies involving broader consumer groups, including vegetarians, health-conscious individuals, and older adults, are also encouraged to capture more diverse preference patterns. In addition, evaluations of microbiological safety, water activity, and shelf-life stability are essential for commercial application. Nutritional fortification using additional plant-based protein sources may further enhance the functional value of the product. Finally, environmental impact assessments, such as life cycle analysis, would strengthen sustainability claims and support the positioning of mushroom-based meatloaf as an environmentally responsible food alternative.

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References

1. Godfray HCJ, Aveyard P, Garnett T, Hall JW, Key TJ, Lorimer J, et al. Meat consumption, health, and the environment. Science 361, 6399 (2018). https://doi.org/10.1126/science.aam5324.
2. Poore J, Nemecek T. Reducing food's environmental impacts through producers and

consumers. Science 360, 6392 (2018). https://doi.org/10.1126/science.aaq0216.
3. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet 393, 447–92 (2019). https://doi.org/10.1016/S0140-6736(18)31788-4.
4. Feeney MJ, Dwyer J, Hasler-Lewis CM, Milner JA, Noakes M, Rowe S, et al. Mushrooms and Health Summit Proceedings. J Nutr 144,1128S-1136S (2014). https://doi.org/10.3945/jn.114.190728.
5. Roncero-Ramos I, Delgado-Andrade C. The beneficial role of edible mushrooms in human health. Curr Opin Food Sci 14,122–8 (2017). https://doi.org/10.1016/J.COFS.2017.04.002.
6. Wong KM, Decker EA, Autio WR, Toong K, DiStefano G, Kinchla AJ. Utilizing Mushrooms to Reduce Overall Sodium in Taco Filling Using Physical and Sensory Evaluation. J Food Sci 82, 2379–86 (2017) https://doi.org/10.1111/1750-3841.13838.
7. Pérez-Montes A, Rangel-Vargas E, Lorenzo JM, Romero L, Santos EM. Edible mushrooms as a novel trend in the development of healthier meat products. Curr Opin Food Sci 37, 118–24 (2021). https://doi.org/10.1016/j.cofs.2020.10.004.
8. Singh U, Tiwari P, Kelkar S, Kaul D, Tiwari A, Kapri M, et al. Edible mushrooms: A sustainable novel ingredient for meat analogs. EFood 4 (2023). https://doi.org/10.1002/efd2.122.
9. Pashaei KHA, Irankhah K, Namkhah Z, Sobhani SR. Edible mushrooms as an alternative to animal proteins for having a more sustainable diet: a review. J Health Popul Nutr 43, 205 (2024). https://doi.org/10.1186/s41043-024-00701-5.
10. Kumar P, Chatli MK, Mehta N, Singh P, Malav OP, Verma AK. Meat analogues: Health promising sustainable meat substitutes. Crit Rev Food Sci Nutr 57, 923–32 (2017). https://doi.org/10.1080/10408398.2014.939739.
11. Bhat ZF, Fayaz H. Prospectus of cultured meat—advancing meat alternatives. J Food Sci Technol 48, 125–40 (2011). https://doi.org/10.1007/s13197-010-0198-7.
12. Kalač P. A review of chemical composition and nutritional value of wild-growing and cultivated mushrooms. J Sci Food Agric 93, 209–18 (2013). https://doi.org/10.1002/jsfa.5960.