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Quality parameters of beef patties replaced with oyster mushroom

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ABSTRACT

Due to oyster mushrooms' meaty texture, fiber content and natural umami taste, it can enhance the sensory properties of meat patties, making them closer in taste and texture to traditional meat products. Meat patties were prepared using a 2n-type experimental design, with mushroom and beef meat fat content as the two factors. Low levels were set at 20% mushroom and 10% fat beef, while high levels were 50% mushroom and 20% fat beef. The control sample was beef with 20% fat. After cooking, patties were analyzed for cooking loss, CIELAB* color measurement, texture analysis, and sensory evaluation. Results indicate that increasing mushroom content enhances water retention and juiciness, softens the texture and makes it crumblier, also altering the color. Although fat content had no significant effect across the range tested, partial meat replacement was successful and made a good base for future research.

KEYWORDS

oyster mushroom, meat replacement, functional properties, physical measurements, sensory evaluation

INTRODUCTION

Intense socio-economic changes, rising incomes in developed countries and accelerating urbanization have significantly increased consumer demand for frozen and ready-to-eat meals.

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As a result of changes in consumer lifestyles, consumption of ground beef-based products such as meatballs, burgers, and stuffed products has risen over the past 20 years (Utrera et al., 2013; Mazumder et al., 2023). Mushrooms serve as meat alternatives in human nutrition because they provide a relatively high amount of macronutrients such as protein and fiber, essential micronutrients including amino acids, vitamins, and minerals, while being low in fat, sodium and calories (Ketnawa and Rawdkuen, 2023; Chirinang and Intarapichet, 2009) and bio functional properties (Bermúdez et al., 2023). The unique texture and functional compounds of mushrooms will make them a vital ingredient in future foods, for example as alternatives to meat or other plant-based products, in response to the growing demand for healthier and more sustainable foods (Oh et al., 2024). They are currently being studied as meat alternatives in the production of protein-based foods, for example nuggets or sausages and products that resemble meat texture, called Textured Vegetable Protein (Ketnawa and Rawdkuen, 2023). Mushrooms are mostly added to meat-based foods in freshly minced, dried and/or powdered, extracted or fermented form (Boylu et al., 2024).

Classified under Basidiomycota, Pleurotus mushroom which is also widely known as oyster mushroom, are notable for their rich nutrient content and versatility in culinary applications (Boylu et al., 2023). Consuming protein from high quality sources is essential for proper nutrition (Kenesei et al., 2025). Oyster mushroom, due to its rich protein levels and essential amino acids, can be considered a valuable plant-based protein option for vegan nutrition (Boylu et al., 2023). A wide variety of proteins are present in them, although not many of these proteins have been precisely identified. A total of 18 amino acids have been recorded in oyster mushrooms (Chirinang and Intarapichet, 2009), including all nine essential amino acids, with leucine, aspartic acid, phenylalanine, and lysine present in the highest amounts (Boylu et al., 2024). However, the plant-based protein's bioavailability is usually lower, as they contain antinutritive compounds such as tannins, lectins, and protease inhibitors in addition to the lower accessibility due to the partial digestibility of the cell walls in the human gastrointestinal tract (Kenesei et al., 2025). The protein content of mushrooms varies according to the subspecies, physical and chemical properties of the growing medium, substrate composition, hat size and harvest date (Deepalakshmi and Mirunalini, 2014).

To prevent cooking losses and deformation in meat products, combinations of starch and animal or vegetable proteins are typically applied. Research has consistently shown that these additives enhance physicochemical characteristics and organoleptic qualities such as cooking yield, emulsion stability, and general consumer acceptance (Romero et al., 2019). Oyster mushrooms possess an umami taste and fibrous texture similar to meat, making them more suitable to use for meat products (Boylu et al., 2024). Powdered mushrooms incorporated into meat emulsions improved nutrient content, helped in emulsion formation, and increased the strength of the emulsion. The addition of mushroom flour significantly influenced the texture of the meat patties (Cerón-Guevara et al., 2019; Santhapur et al., 2024). The addition of oyster mushrooms showed lower values for firmness, rubberiness and chewiness than the control. The observed reduction resulted from protease enzymes naturally present in the mushrooms. The alkaline proteases in oyster mushroom can improve meat tenderness, while endogenous enzymes such as lipoxygenase can promote protein oxidation and protein matrix formation (Qing et al., 2021). A reduction in the diameter of meat patties is often observed after cooking beef patties (Pan and Singh, 2001). Due to the fiber content of mushrooms, many technofunctional attributes of products, including their ability to retain water and fat, can be improved (Botella-Martínez et al., 2023).

When assessing meat, consumers place the greatest importance on its color as an indicator of quality and acceptability (Romero et al., 2019). The color of meat patties always indicates high quality, attracts attention and encourages consumption (Tokarczyk et al., 2023). The brown color of the roast meat is determined by several pigments. The main one is the heme pigment, a denatured globin compound. In addition to the heme pigments, other compounds derived from oxidation and polymerization of lipids, sugars and proteins contribute to the final color (Romero et al., 2019). Mushroom addition increased the b^* values (yellowness) and decreased the L^* values (lightness) of the samples. Except for the oyster mushroom sample, all showed a decrease in a^* value (redness). This may be explained by the distinct coloration of mushrooms compared to meat, affecting the beef paste's color directly (Qing et al., 2021). Also, mushrooms are highly susceptible to discoloration and browning as a result of processing treatments, microbial contamination, and enzymatic reactions (Boylu et al., 2023).

Simulating the desirable sensory and nutritional characteristics of animal-based products like meat, eggs, or dairy using only one alternative protein source often presents a challenge (Santhapur et al., 2024). Focusing on sensory properties research is key to the innovation of new mushroom products in the global market (Oh et al., 2024). The acceptability of products supplemented with mushrooms is highly dependent on the consumer's familiarity with the taste of the mushrooms (Cerón-Guevara et al., 2019). Mushroom contributes to the hydrolysis and oxidation of beef paste, which leads to the production of flavorful amino acids with the disappearance of some free amino acids. The characteristic meaty taste known as umami in mushrooms originates from free amino acids (Oh et al., 2024).

OBJECTIVES

This study focuses on the development of a burger patty with reduced meat and fat content using oyster mushrooms as a partial replacement for minced beef. The research aims to investigate the effects of different meat–mushroom–fat ratios on the physical and sensory properties of the product. Oyster mushrooms were incorporated due to their favorable composition, including essential amino acids, dietary fiber, vitamins, and minerals, as well as their ability to provide a meat-like texture and enhance umami flavor. This approach responds to current consumer demand for healthier and more sustainable meat alternatives and may contribute to mitigating health concerns related to excessive meat and fat intake.

MATERIALS AND METHODS

Materials

Ground beef with 20% fat content and lean beef chuck (purchased from a local wholesale market) was used for the experiment. The meat was stored at 2 °C until utilization. Fresh oyster mushrooms (Sylvan HK 35 grown on straw substrate) were obtained from Korona Gomba (Lot 0173/7/A/1, Demjén, 3395, Hungary). The exact nutritional content of oyster mushrooms differs by the cultivated type, the range of their total protein content is 23.48–33.16 g, total fat content is 0.91–2.6 g, total carbohydrate is 45.25–63.22 g and total dietary fiber content is 42.87–52.31 g in 100 g dry matter (Tiupova et al., 2025). The measured moisture content of the used oyster mushroom is 89.78 ± 0.77%. Prior to their utilization, the oyster mushrooms were refrigerated at 4 °C.

Based on preliminary trials it was found that raw beef patties fall apart if the mushroom content is too high, so the aim for a maximum mushroom content was set to 50% and a minimum was set to 20%. Since fat content reduction was also an objective, part of the minced meat was replaced with a fat and connective tissue free beef meat to achieve a lower fat content sample. This way beef meat with a fat content of 10% in addition to 20% was also achieved (Fig. 1). As adjusting the total fat level would have decreased the overall meat ratio, the experiment was conducted with a fixed fat percentage in the meat component. As a supplementary note, the overall fat % of each patty formulation is presented in Table 1. Based on the 2^n experimental design, the quantities required for the recipes were calculated. For the control sample, regular minced beef with 20% fat content was used for the patties.

Preparation of the patties

The oyster mushroom leaves were picked, cleaned, and the fatless beef meat was cut into small cubes for easier handling. Then the ingredients were measured according to the recipe (Table 1).

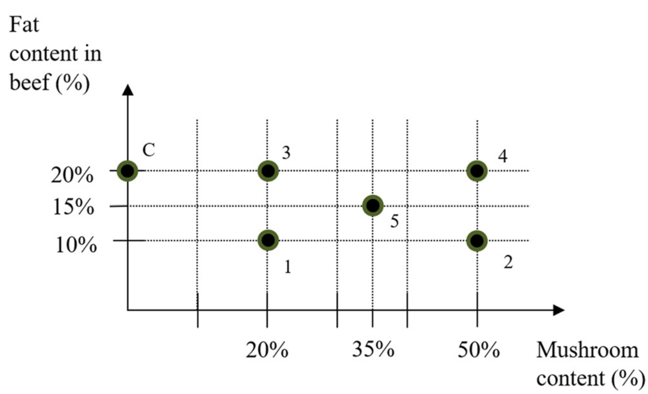

Fig. 1. Visualization of the 2^n-experimental design of beef-oyster mushroom patties. Numbers 1–5 indicate the low, high and center mushroom and fat content samples and C indicate the control

Table 1. Ingredients of the beef-oyster mushroom patties based on the 2^n-experimental design shown in Fig. 1

Quantity (g/100 g patty)				Fat content (%)	
	Beef with 20% fat	Fatless beef meat	Oyster mushroom	Meat	Total
1	40	40	20	10	8
2	25	25	50	10	5
3	80	0	20	20	16
4	50	0	50	20	10
5 (Median)	48.75	16.25	35	15	9.75
C (Control)	100	0	0	20	20

Robot Coupe R502 (ROBOT COUPE SNC, France) cutter was used for the mixing, to achieve a consistent, but heterogeneous mixture, the device was used for a total of 20 pulses, each 1 s long. From the mixtures of each recipe, 13 beef patties were made of exactly 100 g using a metal ring as a mold. The patties then were placed on an ovenproof metal tray, covered carefully with foil and were put in a refrigerator at 4 °C. After 16 h, the cooled patties were placed in a LAINOX VE051P oven (LAINOX Ali Group S.r.l. a Socio Unico, Italy), which was preheated to 180 °C, then the patties were cooked for 20 min without flipping them. Finally, after the cooking, approximately 0.15 g of salt was sprinkled on each of the meat patties to support the sensory testing. To determine the physical properties of the heat-treated patties, after taking them out of the oven they were let to cool down to room temperature.

Measuring cooking loss

After cooking, from all sample types (samples 1–5, C) all 13 patties were reweighed one by one using a digital scale with an accuracy of two decimal places to ensure precise measurements. By comparing the initial weight of the raw patties with their weight after cooking, the percentage of cooking loss was determined (Fig. 2). The equation to calculate the cooking loss was the following:

$$Cooking\ loss\ (\%) = \left(\frac{Raw\ patty\ weight\ (g) - Cooked\ patty\ weight\ (g)}{Raw\ patty\ weight\ (g)}\right) * 100$$

Measuring color parameters

The change of color of the patties was measured after cooking with a CR-400 Chroma Meter (Konica Minolta, Tokyo, Japan). Prior to taking measurements, the device was calibrated using the provided white reference standard to ensure reliable and consistent results. For each mushroom and fat combination of patties (samples 1–5, C), three pieces were randomly selected to represent the whole batch. Measurements were conducted in triplicate on both the outer surface (also referred as upside) and the cross section (also referred as inside) of each patty, resulting in six measurements per piece. To avoid inaccurate readings, the sensor was carefully positioned on areas of the patties free from surface juices or visible moisture build-up, as these could distort the results. The results were recorded in CIELAB* color system. Due to the color differences

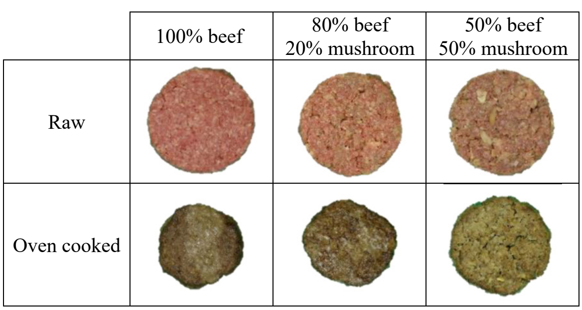

Fig. 2. Prepared raw and cooked beef-oyster mushroom patties, made of beef with 20% fat

between the surface and cross section of the heat-treated patties, the data from upside and the insides were analyzed separately. Given the color values, the value of the color difference between two samples visible to the human eye, denoted by ΔE^* (Table 2), was calculated with the equation below:

$$\Delta E^*_{a\,b} = \sqrt{\left((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\right)}$$

Measuring texture

To determine the texture of the meat patties, a TA.XTplus Texture Analyzer (Stable Micro System, Surrey, UK) was used. On the device a cylindrical 5 mm diameter probe was installed, and the following settings were applied in the device's own software to perform the measurement: Test speed before and during the measurement 2.00 mm s^{-1}, Distance for start 20 mm and Trigger Force 0.049 N. For the measurement, two patties per mushroom and fat combination (samples 1–5, C) were randomly selected and 4 parallel measurements were performed on each of them. The recorded data was analyzed by the instrument's own software, saving the data in Microsoft Excel for further calculations. From the measured curves, two pieces of data were used: the peak of the curve (maximum force [N]), which gives the hardness of the sample, and the area between axis 'x' and the curve (work [N^*mm]), which gives the work required by the probe to pierce the sample.

Sensory evaluation

A total of 47 non-professional panelists were asked to analyze the patty samples. The meat patties were randomly numbered so that they would not know which number represents which mushroom–fat combination. The judging was done by profile analysis, with the panelists scoring the characteristics of the samples based on the six attributes indicated on the judging sheet, with a score ranging from 0 to 10. Hedonic scale was used for smell (0 bad – 10 good), taste (0 bad – 10 good) and overall liking (0 don't like it – 10 really like it). For color (0 greyish – 10 brownish), texture (0 crumbly – 10 firm) and juiciness (0 dry – 10 juicy) the end of the scale represented two opposite extremes of each sensory attribute.

Statistical analysis

To analyze the 2^n-experimental design, the Camo Unscrambler 9.2 software, for ANOVA the IBM SPSS Statistics for Windows v.29 (IBM Corp., Armonk, NY, USA) and for the editing of

Table 2. Perceived color difference based on Lukács (1982)

Value of ΔE^*	Perceived color difference
0–0.5	Not noticeable
0.5–1.5	Slightly noticeable
1.5–3.0	Noticeable
3.0–6.0	Visible
6.0–12.0	Large

tables and figures Microsoft® Excel® for Microsoft 365 MSO Version 2503 (Microsoft Corp., Redmond, WA, USA) software were used.

RESULTS AND DISCUSSION

Based on the 2^n-experimental design, the measured physical properties and the sensory evaluation a model was fitted on each measured attribute, these results are shown in Table 3. To analyze the relationship between the instrumentally measured and sensory data, the fitted surfaces based on the model values were compared (Figs 4–6). The effect of the sample's fat content was not proved, while the effect of oyster mushroom content was confirmed for some measured attributes.

Cooking loss

It can be observed overall that the samples lost weight after cooking, but the samples with 50% mushroom content (samples 2 and 4) lost less weight. A significant difference in weight ($P < 0.05$) from the control sample was observed only in these cases (Fig. 3). This difference can be explained by the techno-functional properties of the dietary fiber content in the mushroom. It has water binding, oil retention and gelling abilities as described by Botella-Martínez et al. (2023), thus reducing cooking loss.

Other than reducing cooking loss, the incorporation of mushrooms had a noticeable effect on the juiciness of the patties which is shown in Fig. 4. Sensory evaluation results clearly indicated that the juiciness increased as the mushroom content was raised, furthermore at 50% mushroom content (samples 2 and 4) the higher fat ratio did not make a difference. The improvement in juiciness can be explained by the basically high moisture content of mushrooms, as well as the ability of mushroom-derived fibers and proteins to retain water throughout the cooking process. These molecules trap moisture within the matrix of the patty, reducing the extent of cooking loss that typically occurs during heat treatment.

Color parameters

Based on the results of the objective colorimetry, the lightness value on the outside of the cooked meat patties changed. For patties containing oyster mushrooms, L^* values were higher compared to the control except for sample 5 (35% mushroom – 15% fat in meat). A significant effect ($P < 0.05$) was limited to the samples with the greatest mushroom addition, namely sample 2 (50% mushroom – 10% fat in meat) and sample 4 (50% mushroom – 20% fat in meat). The higher L^* value measure opposes the conclusions drawn by Qing et al. (2021) and Boylu et al. (2024), who experienced decreased L^* value with mushroom addition. Red coloring (a^*) of the patties after cooking was reduced with the addition of mushrooms, as observed by Qing et al. (2021) and Boylu et al. (2024). However, only the samples with the highest mushroom content sample 2 (50% mushroom – 10% fat in meat) and sample 4 (50% mushroom – 20% fat in meat) differed significantly ($P < 0.05$). Boylu et al. (2023) also found that oyster mushroom by itself had decreased L^* and a^* values after oven cooking. Botella-Martínez et al. (2023) noted that the modification in color parameters of fresh mushroom when added to foods is unavoidable.

Table 3. 2^n-experimental design's statistical results of the instrumentally measured data and sensory evaluation

	Model *P*-value	Mushroom% (A) *P*-value	Meat fat% (B) *P*-value	AB *P*-value	Mushroom% B-coefficient	Meat fat% B-coefficient	AB B-coefficient	Intercept B-coefficient	Model correlation (*R2*)
Color	0.4739	0.1903	0.5877	0.8427	−0.0553	−0.0596	0.0709	6.514	0.7215
Smell	0.8130	0.6040	0.7613	0.5248	−0.0117	0.0202	0.145	5.376	0.4922
Texture	0.1295	0.0387†	0.6619	0.6025	−0.0518	−0.0213	0.0851	5.171	0.9016
Juiciness	0.2431	0.1023	0.5733	0.3144	0.0603	0.0489	−0.312	6.128	0.8414
Taste	0.2513	0.1274	0.2850	0.3992	−0.0280	0.0521	−0.131	5.202	0.8372
Overall liking	0.3976	0.2785	0.2785	0.4726	−0.0206	0.0617	−0.128	5.314	0.7621
Cooking loss	0.2619	0.1026	0.8176	0.3426	−0.188	−0.0611	0.91	27.567	0.8318
L_Outside	0.6347	0.2641	0.8261	0.9241	0.1630	−0.0853	−0.123	46.876	0.6272
a*_Outside	0.2809	0.0989††	0.7164	0.5312	−0.0463	0.0234	−0.138	4.707	0.8221
b*_Outside	0.0145††	0.0040†	0.2840	0.2973	0.0901	0.0437	−0.141	7.733	0.9787
ΔE*_Outside	0.2548	0.0813††	0.6599	0.9762	0.175	−0.0985	−0.0219	3.077	0.8354
L_Inside	0.8702	0.6302	0.5777	0.8977	0.0466	0.1630	−0.122	51.845	0.4331
a*_Inside	0.1437	0.0482†	0.5066	0.4144	−0.0540	−0.0377	−0.158	6.309	0.8937
b*_Inside	0.8785	0.8472	0.495	0.9245	0.0047	0.0523	−0.0232	10.99	0.4232
ΔE*_Inside	0.9471	0.8231	0.8138	0.6764	−0.0175	−0.0554	0.331	2.903	0.3181
Hardness	0.1244	0.0352†	0.8488	0.8743	−0.0961	0.0164	0.0452	3.738	0.9044

†The effect of the factor on the measured value is statistically significant at the 95% confidence level.
††The effect of the factor on the measured value is statistically significant at the 90% confidence level.

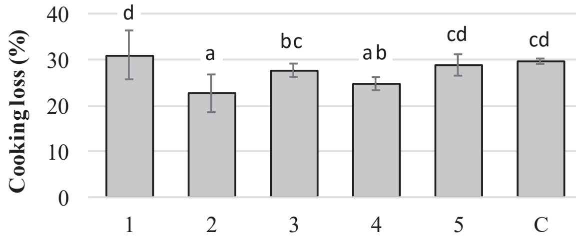

Fig. 3. Cooking loss of the different beef–oyster mushroom patties, where letters a–d represent significantly ($P < 0.05$) different groups

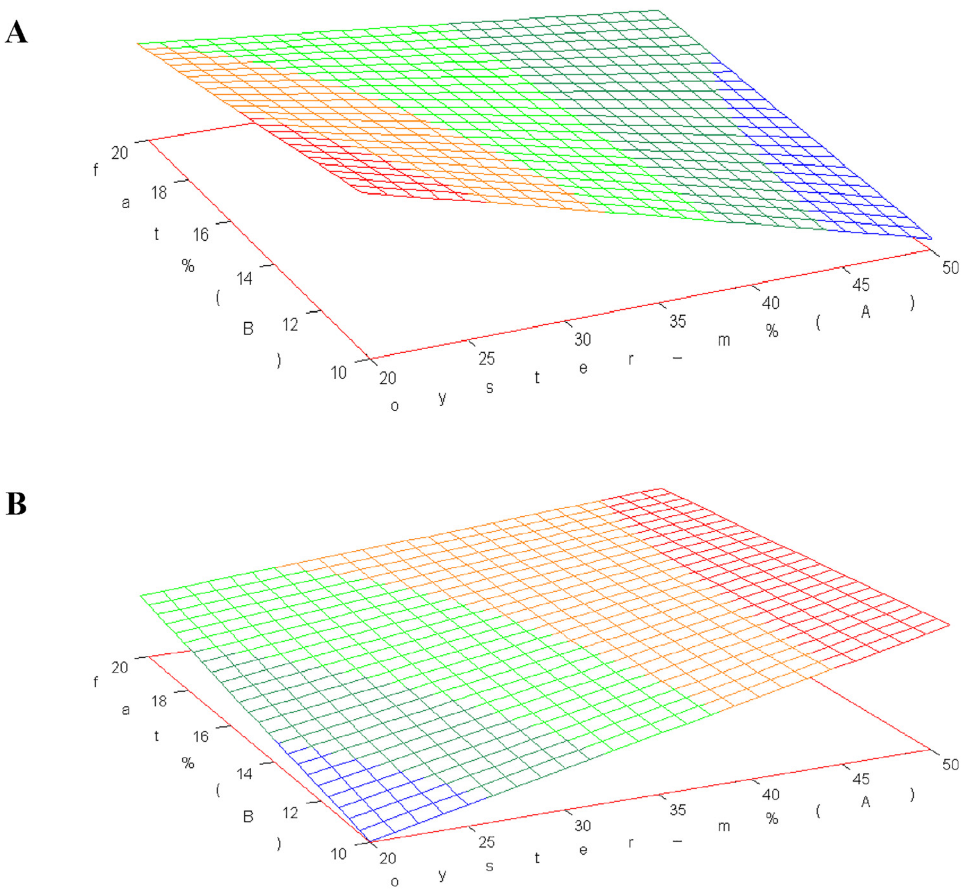

Fig. 4. Statistical output visualization of measured cooking loss (A) and sensory evaluation of 'juiciness' (B) in function of beef meat fat content (10–20%) and mushroom content (20–50%) based on the results of Table 2

From the CIELab* color parameters ΔE* values were calculated (Table 4) between the control sample and mushroom replaced samples and the corresponding perceived color differences between the samples were found. As with the color values, higher mushroom content patties sample 2 (50% mushroom – 10% fat in meat) and sample 4 (50% mushroom – 20% fat in meat) differ the most from the control sample, and from large to visible differences for all samples. Although the measured color values for each sample did not differ significantly compared to the control sample, there are noticeable differences based on ΔE*.

When analyzing the cross section of the patty, significant difference ($P < 0.05$) in L* is only seen for sample 5 (35% mushroom – 15 fat in meat), the other samples did not differ significantly. No significant difference ($P < 0.05$) was observed in the red coloration (a*) of the patties compared to the control, except in sample 4 (50% mushroom – 20% fat in meat) with elevated mushroom and fat levels. The other samples had no significant difference ($P < 0.05$). Following with the b* value, it is observed that the mushroom content had no effect on the blue-yellow color of the meat patties and none of the recipes differed significantly from each other.

From the Lab* color values ΔE* values were calculated (Table 5) between the control sample and mushroom replaced samples and the corresponding perceived color differences between the samples were determined. The slight differences in the measured L*, a* and b* values are also reflected in the ΔE*. The individual meat patty samples can be distinguished by their insides but the large color difference between them is no longer observed.

Table 4. Calculated ΔE* values and perceived color differences of outside between each sample

Sample	1	2	3	4	5	K
1		6.19	1.18	5.24	2.60	2.05
2	Large		6.38	1.24	7.76	7.37
3	Slightly noticeable	Large		5.37	1.84	1.13
4	Visible	Slightly noticeable	Visible		6.63	6.31
5	Noticeable	Large	Noticeable	Large		0.87
C	Noticeable	Large	Slightly noticeable	Large	Slightly noticeable	

Table 5. Calculated ΔE* values and perceived color differences of the cross section between each sample

Sample	1	2	3	4	5	K
1		2.11	2.08	3.69	1.35	2.90
2	Noticeable		1.32	1.59	3.23	1.39
3	Noticeable	Slightly noticeable		2.34	3.40	1.36
4	Visible	Noticeable	Noticeable		4.74	1.83
5	Slightly noticeable	Visible	Visible	Visible		4.19
C	Noticeable	Slightly noticeable	Slightly noticeable	Noticeable	Visible	

Texture

In all samples, the inclusion of mushrooms resulted in lower hardness of the meat patties relative to the control. The hardness of the samples were grouped into two categories that differed significantly ($P < 0.05$) from the control. A 'H1', which includes the 35 and 50% oyster mushroom content samples (sample 2, 4 and 5) and 'H2', which includes samples with 20% mushroom content (samples 1 and 3). Within the H1 and H2 groups, no significant differences were found. The work of the probe is calculated from the hardness of the sample multiplied by its thickness. Thus, the work required to pierce patties of approximately the same thickness (only the deformation due to cooking causes difference) is similar to the hardness diagram. The samples can also be divided into two statistically distinct groups compared to the control, with group 'W1' having 35 and 50% mushroom content and group 'W2' containing 20%. There is no significant difference within the W1 and W2 groups. Souppez et al. (2025) found that plant-based burgers have decreased hardness compared to regular beef patties. Low-beef burgers showed reduced hardness relative to high-beef and handmade patties. Our findings from texture measurements show that control beef patties are the hardest and the addition of mushrooms to

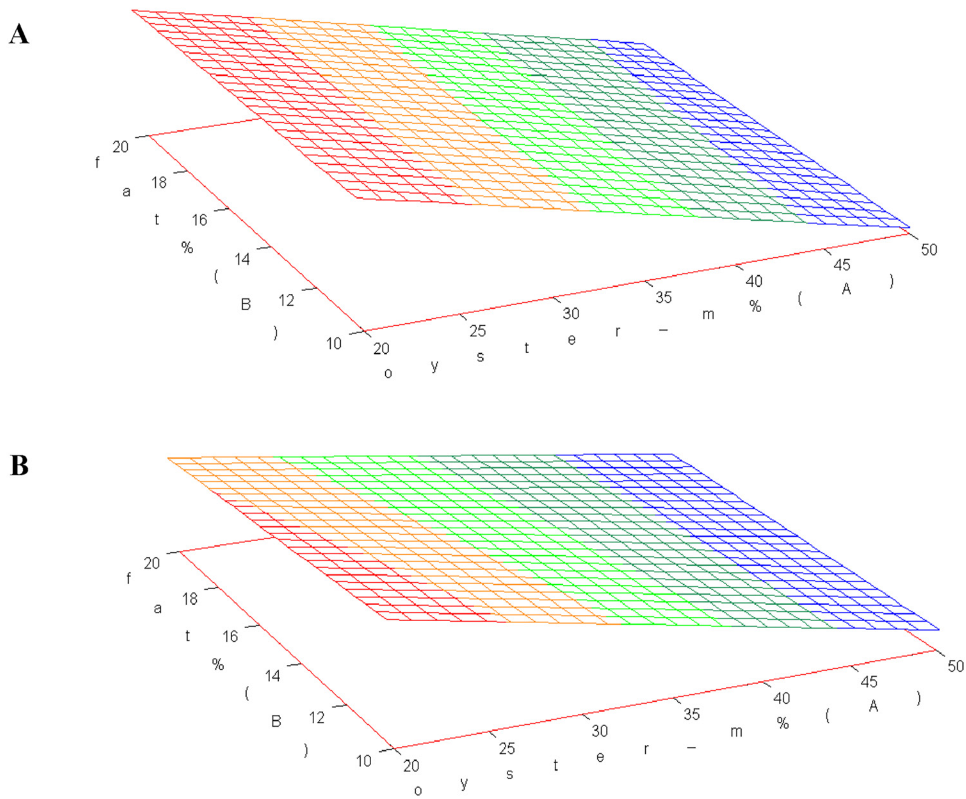

Fig. 5. Statistical output visualization of instrumentally measured hardness (A) and sensory evaluation of 'texture' (B) in function of beef meat fat content (10–20%) and mushroom content (20–50%) based on the results of Table 2

the patties results in a decrease of hardness, which is also supported by the literature of Cerón-Guevara et al. (2019), Qing et al. (2021) and Santhapur et al. (2024).

Patty formulation with mushroom addition noticeably alters its texture, making it more crumbly, Fig. 5 is used for representation. This effect was statistically significant ($P = 0.05$) and can be attributed solely to the increased mushroom content, as no difference was found between the same mushroom level and different fat percentage. The sensory evaluation findings also support that oyster mushroom has a texture altering effect and it can be perceived by panelists. However, the samples which contained more fat were differentiated more easily. The likely cause is that mushrooms lack the binding capacity of meat proteins and introduce more moisture and fiber, which disrupts the structural matrix of the patty. Since mushrooms do not form a strong gel-like network during cooking, higher levels reduce cohesiveness. To maintain a stable patty structure, the mushroom content must therefore be kept below a certain threshold unless additional binding agents are used.

Taste results from sensory evaluation (Fig. 6) revealed that patties with higher fat content were generally rated more favorably in terms of taste, while an increase in mushroom content

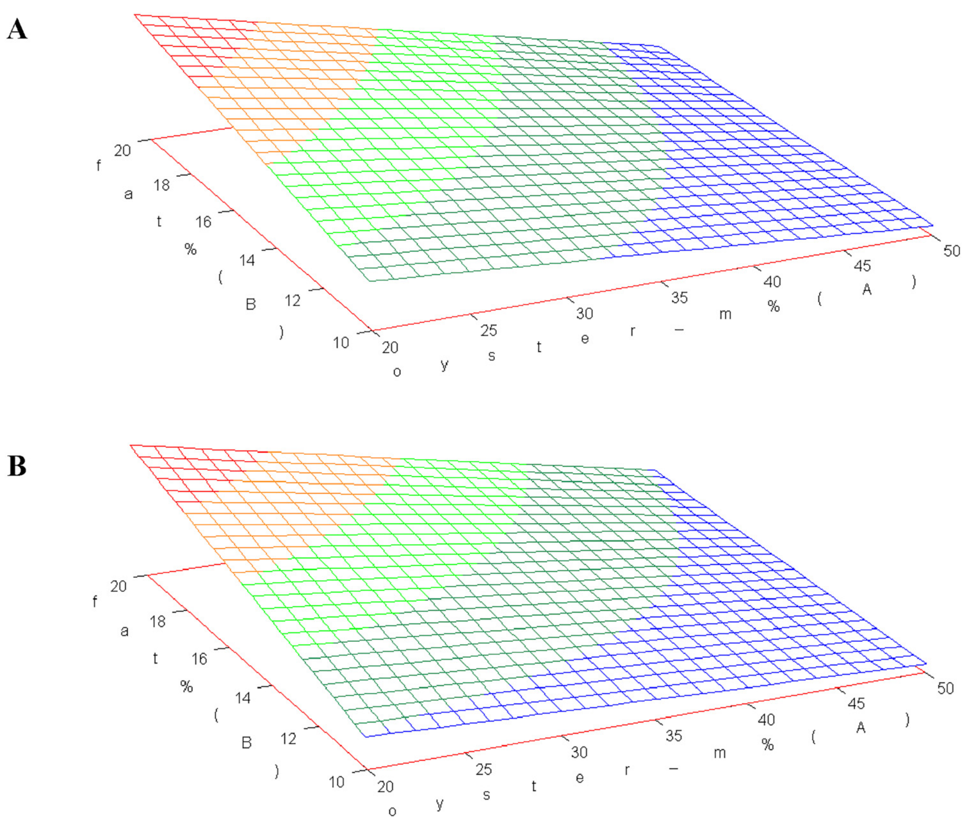

Fig. 6. Statistical output visualization of sensory evaluation of ‘taste’ (A) and sensory evaluation of ‘overall liking’ (B) in function of beef meat fat content (10–20%) and mushroom content (20–50%) based on the results of Table 2

tends to negatively affect the flavor. This effect can be explained by the ability of fat to solubilize the flavor compounds of mushroom. However, a high proportion of oyster mushrooms may result in an overpowering taste, even for individuals who typically like mushrooms. When higher mushroom content was combined with higher fat content, panelists perceived the products more positively, suggesting that fat can moderate the intensity of mushroom flavor and enhance overall palatability. The overall liking scores strongly mirrored the taste scores, indicating that taste plays a critical role in shaping consumer acceptance.

CONCLUSION

The partial replacement of meat with oyster mushroom influenced key quality attributes of beef patties, particularly at the 50% replacement level. These samples demonstrated reduced cooking loss and textural hardness, alongside improved juiciness and taste. The observed effects are attributed to the moisture-binding capacity and matrix-disrupting properties of mushroom-derived fibers and enzymes. Sensory data aligned with instrumental measurements, indicating perceptible changes without compromising product acceptability. The limited statistically significant differences relative to the control sample highlight the successful replacement of meat, supporting oyster mushrooms with the ability to improve taste and improving juiciness by reducing cooking loss, to be an effective functional ingredient for further meat analogue development.

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