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OYSTER MUSHROOM (*PLEUROTUS OSTREATUS*) AS A NATURAL SALT SUBSTITUTE IN FERMENTED SAUSAGES (SUCUK): EFFECTS ON TEXTURE AND QUALITY

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I. INTRODUCTION

Sodium chloride is widely used in the production of meat products due to its essential functions in enhancing flavor, texture, and shelf-life. However, salt consumption exceeding recommended levels worldwide, particularly the sodium intake from processed meat products, has been associated with various health risks. The World Health Organization's recommendation to limit daily sodium intake to 2 grams per person has necessitated the development of salt reduction strategies in meat products [1]. Nevertheless, due to its critical roles in microbiological safety, sensory properties, and structural integrity, reducing salt content may adversely affect overall product quality. In this context, various technological and formulation-based strategies have been explored to achieve sodium reduction without compromising product quality [2]. The use of mushrooms as a salt substitute offers several advantages, primarily because mushrooms are a natural ingredient with a highly beneficial nutritional profile—rich in protein and dietary fiber, yet low in fat and sodium. Additionally, their cultivation is economically viable and environmentally sustainable, aligning well with current trends in food production and consumption [3]. However, mushrooms have not yet been explored as a salt replacer in sucuk-type fermented sausages. Therefore, in this study, oyster mushroom (*Pleurotus ostreatus*) powder (MP) was utilized as a natural salt substitute, owing to their umami-rich composition, and potential to improve the textural properties of fermented sausages.

II. MATERIALS AND METHODS

Fresh boneless beef and beef backfat were sourced from a local processor in İzmir, Turkey. Oyster mushroom (*Pleurotus ostreatus*) powder (62.5% total carbohydrates, 25% dietary fiber, 25% protein, 12.5% sugar) was supplied by Kurucum Gıda (Isparta, Turkey). Four sucuk formulations were prepared: a control group (C) with 2% salt, and three test groups with 25% (M25), 50% (M50), and 75% (M75) of the salt substituted by MP. Per kg of meat mixture, the following ingredients were added: 20% beef backfat, 4 g sucrose, 2.5 g ascorbic acid, 1.5 g sodium nitrite mix (90% salt, 10% nitrite), 27.5 g mixed spices, 10 g garlic, and 0.5 g freeze-dried starter culture (*Staphylococcus xylosus* and *Pediococcus acidilactici*). Beef and fat were minced through a 3 mm plate, mixed with other ingredients, and homogenized. The mixture was stuffed into 36 mm casings using a hydraulic filler (Alpina–SG–Schweiz). The ripening process was as follows: at 21 °C and 88% RH until pH dropped to 5.4; then 6 h at 20 ± 1 °C and 80% RH; followed by 23–24 °C and 80% RH until pH reached 5.0; and finally at 15 ± 1 °C and 70% RH for the remaining period. Moisture and ash contents were analyzed by AOAC [4]. pH was measured with a portable meter (WTW pH 330i/SET, Germany); titratable acidity was expressed as % lactic acid. Water activity (aw) was determined at 25 °C using a Testo AG 400 device. Salt content was analyzed using the Ludorf and Meyer method [5]. Texture was evaluated on 20 mm slices using a TA-XT2 texture analyzer (Stable Micro Systems, UK) with a 36 mm aluminum probe under 75% compression at 1.0 mm/s with a 3 s pause between cycles. Ethical approval was obtained from Ege University. The fermented sausage production was replicated twice, and all analyses were conducted in triplicate (n=3) for each formulation group. Data were analyzed using ANOVA and Duncan's test (SPSS 23).

III. RESULTS AND DISCUSSION

The physicochemical and textural properties of fermented sausages were given in Table 1. The moisture content of the samples increased as the mushroom ratio increased, reaching its highest level in the M75 ($P < 0.05$). This may be attributed to the high water-holding capacity of mushrooms. Ash and salt contents significantly decreased with mushroom substitution ($P < 0.05$). Notably, the salt content dropped to 2.47% in M75 ($P < 0.05$), indicating a successful salt reduction. The pH value increased with the substitution level ($P < 0.05$), with M50 and M75 groups showing similar ($P > 0.05$), and the highest pH values. Total acidity showed a marked decrease in the M50 and M75 groups ($P < 0.05$). Water activity remained generally similar across the groups; however, a slight increase was observed in the M75 ($P < 0.05$).

The hardness values significantly decreased with mushroom substitution up to the 50% level. However, a noticeable increase was observed in M75 ($P < 0.05$). This trend suggests that the structural contribution of MP is dependent on the level of substitution. No significant differences were found among the groups in terms of springiness ($P > 0.05$). On the other hand, a significant reduction in cohesiveness was observed in M75, implying that higher levels of MP may weaken the internal structural integrity of the product ($P < 0.05$). Gumminess values decreased as the MP level increased, with the lowest value recorded in M50 ($P < 0.05$). This reduction may reflect a lower resistance to

mastication in samples with higher mushroom content. The highest chewiness was observed in M25, while the M50 group exhibited the lowest value ($P < 0.05$). These findings suggest that low levels of mushroom incorporation may enhance chewiness, whereas higher levels may compromise the structural properties contributing to this parameter. Although the lowest chewiness value was observed in the M50 group and the highest in the M25 group, these results may be attributed to the interactions between the meat matrix and the functional properties of MP. A significant decrease in resilience was noted in M75 ($P < 0.05$), indicating a diminished ability of the product to recover its shape following deformation at higher levels of mushroom substitution.

Table 1. Physicochemical and textural properties of fermented sausages

Parameter	Treatments*			
	C	M25	M50	M75
Physicochemical Properties				
Moisture (%)	27.47±2.15^{b}	27.54±0.37^{b}	29.16±1.39^{ab}	30.39±0.74^{a}
Ash (%)	2.50±0.10^{a}	2.01±0.05^{b}	1.58±0.26^{c}	1.25±0.04^{c}
Salt (%)	3.78±0.08^{a}	3.63±0.21^{a}	3.83±0.09^{a}	2.47±0.20^{b}
pH	5.22±0.01^{c}	5.27±0.01^{b}	5.33±0.01^{a}	5.34±0.00^{a}
Total acidity (%)	3.37±0.21^{a}	2.38±0.14^{a}	1.69±0.02^{b}	1.60±0.08^{b}
aw	0.89±0.00^{ab}	0.89±0.00^{b}	0.89±0.01^{ab}	0.90±0.01^{a}
Textural Properties				
Hardness (N)	145.98±1.29^{a}	144.19±2.03^{a}	72.98±1.39^{c}	122.01±0.28^{b}
Springiness (mm)	0.23±0.03	0.29±0.08	0.29±0.05	0.29±0.02
Cohesiveness	0.41±0.02^{a}	0.39±0.01^{a}	0.41±0.03^{a}	0.30±0.01^{b}
Gumminess (N)	52.39±1.78^{a}	45.99±0.28^{b}	29.88±1.42^{d}	38.82±0.72^{c}
Chewiness (N.mm)	10.02±2.02^{bc}	19.39±1.23^{a}	7.73±0.96^{c}	11.44±0.50^{b}
Resilience	0.13±0.01^{a}	0.12±0.01^{a}	0.13±0.02^{a}	0.09±0.07^{b}

*C: Fermented sausages with 2% salt (control); M25: 25% of the salt substituted with MP; M50: 50% of the salt substituted with MP; M75: 75% of the salt substituted with MP. $^{a-c}$: Different superscript letters within the same row indicate significant differences between means ($P < 0.05$).

M50 received the highest scores in almost all parameters, indicating that replacing 50% of the salt with MP positively affected the sensory qualities (Table 2). The control group showed lower scores in all attributes except off-flavor, particularly in flavor and overall acceptability. While M25 and M75 also performed better than the control, M75 showed a slight decline in some parameters, such as flavor.

Table 2. Sensory properties of fermented sausages

Parameter	Treatments*			
	C	M25	M50	M75
Appearance	6.79 ± 2.12	7.50 ± 0.95	6.64 ± 1.23	7.29 ± 1.03
Texture	6.43 ± 1.83	6.57 ± 1.45	6.71 ± 1.53	6.43 ± 1.64
Flavor	5.00 ± 2.39^{b}	7.64 ± 1.35^{a}	7.36 ± 1.17^{a}	6.57 ± 1.95^{a}
Off-flavor	6.57 ± 2.14	7.07 ± 1.98	7.64 ± 1.95	7.21 ± 1.78
Saltiness	5.71 ± 3.12^{b}	7.21 ± 1.33^{ab}	7.50 ± 1.12^{a}	6.64 ± 2.16^{ab}
Overall acceptability	5.50 ± 2.50^{b}	7.29 ± 0.85^{a}	6.93 ± 0.88^{a}	6.64 ± 1.72^{ab}

*C: Fermented sausages with 2% salt (control); M25: 25% of the salt substituted with MP; M50: 50% of the salt substituted with MP; M75: 75% of the salt substituted with MP. $^{a-c}$: Different superscript letters within the same row indicate significant differences between means ($P < 0.05$).

IV. CONCLUSION

Partial replacement of salt with oyster MP significantly influenced the physicochemical, textural, and sensory properties of fermented sausages. Substitution at 50% yielded the most balanced results, enhancing moisture content and sensory attributes while maintaining favorable textural characteristics. Higher substitution levels further improved moisture but negatively impacted structural integrity and flavor. These findings suggest that using mushroom powder as a partial salt replacer, particularly at 50%, can be an effective strategy to reduce sodium content without compromising product quality.

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