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Review

The Consumer Is Always Right: Research Needs on Sensory Perception of Mushroom-Enriched Meat Products

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Abstract: Currently, consumers demand healthier and more sustainable foods, but it must be considered that sensory characteristics directly drive acceptability and preference. The objective of this review was to analyze the functions of mushrooms and the sensory terminology used for the sensory characterization of mushrooms and mushroom-enriched meat products. Efforts have been made to reduce animal fat, salt, synthetic additives, and meat, in which mushrooms stand out because they can replace these components. Various species have been explored, mostly with positive effects on physicochemical, nutritional, technological, and sensory characteristics. However, in the sensory aspect, the results are limited to the measurement of acceptability using a hedonic scale. Studies of the sensory properties of mushrooms relate terms beyond umami. For instance, terms such as fermented, yeasty, musty, earthy, crunchy, hard, sweet, mushroom, nutty, moist, and salty, among others, have been associated with various mushroom species. This terminology needs to be explored in mushroom-enriched meat products. However, little has been explored regarding consumer opinions for the generation of sensory terms to characterize mushrooms or mushroom-enriched meat products, which may be relevant for the purposes of reformulating healthier and more sustainable meat products. In this sense, future studies should explore diverse mushroom species, the amount and form of use, processing conditions, and functions. Therefore, better decisions can be made about which species to use, considering factors that allow for maximizing the benefits of mushrooms. This purpose can be achieved if the background of consumers who evaluate the products through their opinions is explored, which is a direct response to the industrial scaling of mushrooms as new ingredients in meat products.

Keywords: edible mushroom; processed meat; sensory attributes; sensory acceptability

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1. Introduction

The growing consumer demand for healthier and more sustainable food products has prompted significant reformulations in the food industry. Meat products, in particular, have come under scrutiny due to their associated health risks and environmental concerns. In response, incorporating plant-based ingredients has become a key strategy to improve processed meats' nutritional and functional properties. Among these ingredients, mushrooms are notable for their multifunctional capabilities; they can replace fat, salt, synthetic additives, and even meat [1].

While many studies have shown the physicochemical, nutritional, and technological benefits of using mushrooms in meat products, their sensory impact remains a crucial factor influencing consumer acceptance [2]. Sensory attributes are essential in determining consumer preferences and significantly affect market success [3]. Most research on mushrooms in meat products has focused primarily on instrumental and chemical analyses, with limited investigation into their specific sensory profiles. Although some studies have examined the umami characteristics of mushrooms, the broader spectrum of their sensory effects in meat matrices has not been thoroughly explored.

Moreover, traditional sensory evaluation methods often overlook the subtleties of consumer perception, which individual backgrounds, cultural differences, and familiarity with the product can shape [4,5]. Consequently, understanding how consumers perceive and describe meat products that contain mushrooms is vital for optimizing their formulation and market positioning.

This paper emphasizes the importance of consumer perspectives in the sensory characterization of meat products that include mushrooms. It seeks to identify key sensory attributes that drive consumer acceptance and explore alternative methods, such as free comment analysis, to enhance traditional sensory evaluations. By incorporating consumer insights into sensory research, we can make more informed decisions regarding the selection, processing, and application of mushrooms in meat product formulations. Therefore, this review aims to synthesize current findings on mushroom incorporation into meat products with a special emphasis on consumer sensory evaluation and terminology.

2. Article Search

The articles were collected from the Scopus and Web of Science databases between 19 November 2024 and 5 March 2025. The keywords used were "Mushroom AND Meat product", "Mushroom AND Sensory evaluation", and "Mushroom AND Sensory evaluation AND Meat product". Due to the specificity of the search, the year of publication was not considered a selection criterion.

3. The Need to Reformulate Meat Products

The nutritional contribution of meat products to the diet is unquestionable. They are a source of high biological value proteins, essential amino acids, lipids, and minerals such as iron, with the advantage of being highly appreciated for their unique sensory characteristics related to flavor, odor, aroma, appearance, texture, and juiciness [6,7]. These characteristics are due to incorporating key ingredients in the formulation of meat products, such as meat, animal fat, salt, and additives with important technological functions (stabilizers, flavor enhancers, etc.). In addition, an important element is the stability of meat products during storage; for this, the role of preservatives and antioxidants is essential. However, excessive or frequent consumption of meat products has been strongly associated with cancer and other diseases related to metabolic syndrome [8,9]. In turn, sustainability is an increasingly adopted concept by industries and consumers; for these reasons, there is a need to reformulate meat products towards less harmful and sustainable alternatives.

Animal fat has sensory and technological functions in meat products, improving palatability, forming emulsions with water and proteins, and improving product yield. However, its lipid profile contains saturated fatty acids and cholesterol, which decrease the nutritional quality of meat products. Therefore, over the years, various alternatives have been proposed to partially or totally replace animal fat in meat products, including vegetable or marine oils directly added or in the form of emulsions, gels, and microcapsules, in addition to fibers and mushrooms [7,10]. These alternatives differ in their preparation methods and physicochemical conditions. Some try to imitate the physical structure of

animal fat, as is the case with gels, and others have simpler processes for obtaining them, as is the case with vegetable flours as sources of fiber. In all cases, the goal is to improve the nutritional profile and to have minimal impact on the meat product's final texture and sensory characteristics. Another characteristic that differentiates fat substitutes is the cost of production and the availability of the raw material in the processing context.

The function of sodium chloride, or salt, is to impart flavor, improve texture, retain components such as water and fat during cooking, and retard microbial growth in meat products [11]. For these reasons, its use is indispensable. However, some meat products may contain high doses of salt, contributing to an excess of sodium intake in the diet, which is associated with the risk of hypertension and cardiovascular diseases. Alternatives for reducing sodium in meat products include potassium, calcium, and magnesium chloride salts, which, due to their metallic and bitter flavors, require the use of flavor maskers and enhancers; other salt reduction options are salt with reduced particle size, salt with different morphologies, and mushrooms [7,12]. Sodium reduction often results in technological defects in meat products, mainly related to texture. Thus, using technologies such as ultrasound is an option to counteract the defects [12]. With sodium chloride reduction, a product with reduced sodium levels is expected without compromising meat products' texture, juiciness, flavor, and microbiological quality.

Additives play important roles in the stability and shelf life of meat products. Among the most commonly used are stabilizers, preservatives, and antioxidants. However, these are often of synthetic origin, negatively affecting the image of meat products. Some examples of additives are phosphates, sodium nitrites and nitrates, and butylhydroxytoluene (BHT), for which academic efforts have been made to replace them with botanical alternatives, including mushrooms [1]. As a result, the meat product is intended to present a "clean label" image.

Mushrooms play a pivotal role among the substitutes for traditional ingredients and additives in meat products. They are multifunctional, including their ability to replace meat, as reported in some studies [13,14]. The following section describes their properties, species, and effects on meat products.

4. The Multifunctionality of Mushrooms in Meat Products

Mushrooms are an important source of proteins, carbohydrates, fibers, essential amino acids, bioactive compounds (phenolic compounds, terpenes, flavonoids, carotenes, among others), vitamins, and minerals [1]. They also have attractive sensory properties, such as umami flavor and firm and meaty texture [15], so there is a growing interest in incorporating them into the formulation of meat products. Table 1 shows the mushroom species used in the formulation of meat products, their functions, form of use, and main effects.

Table 1. Mushrooms as ingredients in meat products.

Mushroom Species	Meat Product	Function	Form of Use	Main Effects	Reference
Lentinula edodes and *Agaricus bisporus*	Buffalo meatballs	Fat substitute	Ground	*L. edodes* increased cooking yield and redness; *A. bisporus* improved texture and juiciness.	[16]
Flammulina velutipes, *Hypsizygus tessellatus*, *Lentinula edodes*, *Pleurotus ostreatus*, *Agaricus bisporus*, and *Pleurotus eryngii*	Buffalo meatballs	Fat substitute	Ground	*L. edodes* promoted best notes of flavor, texture, and juiciness.	[17]
Auricularia polytricha	Chicken meat emulsion	Fat substitute	Ground	Decreased fat, increased moisture and redness, and improved technofunctional properties (emulsion stability and water-holding capacity).	[18]
Agaricus bisporus	Burgers	Fat substitute	Ground	Decreased fat and lipid oxidation and increased sensory acceptability. Sensory terms related were juicy, tender, and flavorsome (tasty).	[19]
Lentinula edodes	Burgers	Salt substitute	Dehydrated	Tended to decrease instrumental hardness and chewiness. Increased amino acids (proline, phenylalanine, glutamic, and aspartic acids).	[20]
Lentinula edodes	Burgers	Salt substitute	Dehydrated and water-homogenized	Improved saltiness and acceptance of color, aroma, texture, flavor, and overall perception. Slightly changed pH, yield, shrinkage, shear force, and color.	[21]
Agaricus brasiliensis	Pork patties	Antioxidant	Powder diluted in solvents	Reduced pH, lipid oxidation, and microbial growth during 9 days of refrigerated storage.	[22]
Pleurotus ostreatus	Pork patties	Antioxidant	Powder diluted in solvents	Improved pH, water retention capacity, texture, and color stability. Decreased lipid and protein oxidation.	[23]
Lentinus edodes (current name: *Lentinula edodes*)	Chicken patties	Antioxidant	Powder extracts in the marination process	Increased pH, redness, yellowness, and water-holding capacity. Decreased lipid oxidation and moderately increased protein oxidation are associated with improved texture and flavor. Improved taste, saltiness, and umami.	[24]
Agaricus blazei	Pork sausages	Antioxidant	Powder	Decreased lipid oxidation up to 35 days of storage at 4 °C.	[25]
Pleurotus ostreatus	Emulsion-type sausages	Phosphate substitute	Powder	Improved emulsion stability and physicochemical properties. Reduced lipid oxidation and aerobic bacterial growth. At 2%, water retention capacity and apparent viscosity increased, while reducing cooking losses. There were texture changes.	[26]

Table 1. *Cont.*

Mushroom Species	Meat Product	Function	Form of Use	Main Effects	Reference
Flammulina velutipes	Emulsion-type sausages	Phosphate substitute	Powder	Decreased hardness, springiness, gumminess, chewiness, fat exudation, and lipid oxidation. Increased pH.	[27]
Flammulina velutipes	Ground hams	Nitrite substitute	Ground and treated by atmospheric non-thermal plasma	The lipid oxidation and curing properties of hams containing plasma-treated mushrooms were similar to those containing 0.007% sodium nitrite and 0.3% sodium phosphate.	[28]
Auricularia polytricha	Hybrid patties (chicken, beef, mutton, or buffalo meat)	Meat substitute	Ground	The beef and mushroom mixture obtained high water retention capacity, gel strength, chewiness, and cohesiveness. The texture characteristics (less compact and dense structure) increased the sensory acceptability of the product.	[14]
Agaricus bisporus	Emulsion-type sausages	Meat substitute	Fresh and ground	Increased moisture, cooking losses, ester and ketone contents, and polyunsaturated fatty acids. Decreased protein content, pH, lightness, redness, yellowness, texture properties, sensory acceptability, and lipid and protein oxidation. At 10% substitution, it was comparable to the control sausage.	[13]
Pleurotus ostreatus	Salami	Meat substitute	Dried	Decreased fat, protein, color parameters (L*, a*, b*), and lipid and protein oxidation. Increased undesirable textural changes were observed, but no negative effects on color, flavor, and overall acceptability.	[29]
Flammulina velutipes	Goat meat nuggets	Meat substitute	Dried	Improved emulsion stability, fiber, ash, phenolics, water-holding capacity, and oxidative stability. No negative effects on color and hedonic responses at 4% *Flammulina velutipes*.	[30]
Agaricus bisporus and *Pleurotus ostreatus*	Liver pâté	Fat, salt, and phosphate substitute	Dried	Increased moisture, dietary fiber, protein, and hardness. At 7.5%, the mushroom, odor, and taste were acceptable.	[31]
Agaricus bisporus and *Pleurotus ostreatus*	Frankfurter sausages	Fat, salt, and phosphate substitute	Dried	Increased moisture and dietary fiber and maintained the amino acid profile. *A. bisporus* sausages were darker, while *P. ostreatus* sausages were softer and less cohesive. The inclusion of the mushroom was sensorially acceptable.	[32]
Agaricus bisporus	Burgers	Antioxidant, fat, and salt substitute	Ground	Mushrooms act better as partial fat substitutes, considering instrumental and sensory responses.	[33]

4.1. Fat Substitute

As fat substitutes, *Lentinula edodes* and *Agaricus bisporus* were incorporated at 10% in the formulation of buffalo meatballs. The mushrooms were ground in a cutter at three different times (5, 10, or 20 min), observing that as the grinding time increased, *Lentinula edodes* increased the cooking yield and the red color (a*), while *Agaricus bisporus* favored the sensorial notes of texture and juiciness [16]. In a similar study, Ramle et al. [17] used *Flammulina velutipes*, *Hypsizygus tessellatus*, *Lentinula edodes*, *Pleurotus ostreatus*, *Agaricus bisporus*, and *Pleurotus eryngii* to replace the total fat content (10% of the formulation) in buffalo meatballs. Mushrooms increased moisture, protein, and water-holding capacity, and also decreased fat content, yellowness, and lightness, but the best notes of flavor, texture, and juiciness were obtained with *Lentinula edodes*. Ground *Auricularia polytricha* incorporated at 15% by total replacement of chicken skin in chicken meat emulsion resulted in lower fat content, increased moisture and red intensity, and improved emulsion stability and water-holding capacity [18]. Beef burgers containing 15% ground *Agaricus bisporus* and 5% pork fat resulted in the lowest fat and lipid oxidation, with high sensory acceptability scores and were sensorially characterized as juicy, tender, and flavorsome (or tasty) [19].

4.2. Salt Substitute

Studies have reported that, as salt substitutes, mushrooms are used in a dehydrated state. França et al. [20] dehydrated *Lentinula edodes* by-products to obtain an "umami ingredient" used as a partial substitute for salt in burgers. At 70% salt reduction, the burgers obtained lower instrumental hardness and chewiness values than the control. The umami ingredient increased the content of proline and phenylalanine amino acids, and the most abundant amino acids were glutamic and aspartic acids. Mattar et al. [21] also used dehydrated and water-homogenized *Lentinula edodes* at concentrations of 5, 12.5, and 20% (*w*/*w*) to replace up to 75% of salt in beef burgers. Homogenization at 20% and 50% salt substitution improved saltiness perception and acceptance of color, aroma, texture, flavor, and overall perception. However, slight physicochemical changes were observed in pH, yield, shrinkage, shear force, and color.

4.3. Antioxidant

Antioxidant extracts can be obtained from mushrooms. Vargas-Sánchez et al. [22] prepared *Agaricus brasiliensis* powder extracts using ethanol and water (1:1) as the solvent and ultrasound technology. The extract was concentrated at 60 °C and then freeze-dried for use in pork patties at concentrations of 0.5 and 1.0%. The phenolic compounds present in the extract had antioxidant activity evaluated with Fe^{3+} reduction, free-radical (DPPH), and radical–cation scavenging activity (ABTS) methods. In addition, the extract showed antibacterial activity against Gram-positive bacteria. The extract reduced pH, lipid oxidation, and microbial growth during 9 days of refrigerated storage in raw and cooked pork patties. Similar extracts were used by Torres-Martínez et al. [23]. *Pleurotus ostreatus* powder was mixed with water, ethanol, and the mixture of these solvents, assisted by ultrasound, concentrated at 60 °C, and freeze-dried. The extracts were added to pork patties, where it was observed that at 2% and 5% *Pleurotus ostreatus* extract concentrations, there were improvements in pH, water retention capacity, texture, and color stability compared to burgers without antioxidants and BHT. At these concentrations, lipid and protein oxidation were decreased in raw and cooked burgers. Another way mushrooms are used is in marinating meat products. Chicken patties marinated in aqueous solutions of 0–14% *Lentinus edodes* powder resulted in increased pH, redness, yellowness, and water-holding capacity. Furthermore, marinating with mushrooms modified water distribution, decreased lipid oxidation, and moderately increased protein oxidation, which was associated with improved texture and

flavor. Marinating with 10% *Lentinus edodes* was associated with higher taste, saltiness, and umami values [24]. Dried mushrooms may also exhibit antioxidant activity when directly added to meat products. *Agaricus blazei* powder was added at concentrations of 1% to 4% to pork sausages. At the highest mushroom concentration, sausages exhibited the lowest lipid oxidation up to 35 days of storage at 4 °C [25].

4.4. Phosphate and Nitrite Substitute

Mushrooms are ingredients that potentially replace phosphates and sodium nitrite in meat products. In emulsion-type sausages, *Pleurotus ostreatus* powder was added at two concentrations (1% and 2%) and compared with sausages without phosphate and with 0.2% sodium triphosphate. *Pleurotus ostreatus* improved emulsion stability and physicochemical properties and reduced lipid oxidation and aerobic bacterial growth. *Pleurotus ostreatus* at 2% concentration had the highest water retention capacity and apparent viscosity, as well as reduced cooking losses. Texture changes were associated with the formation of emulsion structures entrapped by filament-like components, a product of polysaccharides, or the interaction between proteins and polysaccharides [26]. Similarly, Choe et al. [27] replaced sodium pyrophosphate with *Flammulina velutipes* powder at concentrations up to 2% in emulsion-type sausages. Mushrooms caused a decrease in instrumental hardness, springiness, gumminess, and chewiness of sausages; in turn, they increased pH and inhibited fat exudation and lipid oxidation at concentrations higher than 1%. There were no negative effects on color and sensory acceptability. However, Jo et al. [28] concluded that *Flammulina velutipes* is not efficient as a phosphate substitute in ground hams but is effective as a sodium nitrite substitute. In that study, mushrooms were ground and homogenized to be treated by a curing method called atmospheric non-thermal plasma, generating 4.87 g/kg of nitrite. The lipid oxidation analyzed by TBARS and the curing properties of hams containing plasma-treated mushrooms were similar to hams containing 0.007% sodium nitrite and 0.3% sodium phosphate, as expressed by nitrosyl-hemochrome content and color. However, the proportion of jelly and melted fat exuded from the ground ham was statistically lower in hams containing synthetic additives.

4.5. Meat Substitute

Another functionality of mushrooms is their ability to replace meat. Abdul Wahab [14] used ground *Auricularia polytricha* to replace meat in four types of hybrid patties made with chicken, beef, mutton, or buffalo meat, in a 50:50 meat–mushroom ratio. In addition, a 100% mushroom treatment was developed. The most notable treatment was the beef and mushroom mixture due to its high water retention capacity, gel strength, chewiness, and cohesiveness, as well as its less compact and dense structure. These texture characteristics increased the sensory acceptability of the product. Fu et al. [13] replaced chicken breast meat with fresh and ground *Agaricus bisporus* at rates ranging from 10% to 70% substitution in emulsion-type sausages. The moisture content, cooking losses, ester and ketone contents, and polyunsaturated fatty acids increased with the meat substitution, while there were decreases in protein content, pH, lightness, redness, yellowness, texture properties, sensory acceptability, and lipid and protein oxidation. The level of meat substitution comparable to control sausages was 10%. Other studies evaluated the incorporation of dehydrated mushrooms while decreasing the meat content. Özünlü and Ergezer [29] incorporated dried *Pleurotus ostreatus* into the salami formulation at 0 to 5% concentrations. Mushrooms caused a decrease in fat, protein, and color parameters L*, a*, and b*, while preventing lipid and protein oxidation. The increased dried *Pleurotus ostreatus* caused undesirable textural changes, but there were no negative effects on color, flavor, or overall acceptability. Banerjee et al. [30] dehydrated the steam waste of *Flammulina velutipes* to be used to

formulate goat meat nuggets in proportions from 0 to 6%. Improvements in emulsion stability, fiber, ash, phenolics, water-holding capacity, and oxidative stability were observed in nuggets containing *Flammulina velutipes*. The hedonic scale evaluated no negative effects on color and sensory characteristics. The authors recommended adding 4% of the steam waste of *Flammulina velutipes*.

4.6. Combined Functions

It is also possible to evaluate more than one function of mushrooms in a meat product, such as that reported by the Cerón-Guevara group in the substitution of fat, salt, and phosphates by flours of *Agaricus bisporus* and *Pleurotus ostreatus* in liver pâté and in the substitution of fat and salt by the same flours in Frankfurter sausages [31,32]. In this line, Patinho et al. [33] evaluated the potential of *Agaricus bisporus* as a natural antioxidant, salt and fat substitute, and flavor enhancer in beef burgers, concluding that mushrooms act better as partial fat substitutes considering instrumental and sensory responses.

In summary, mushrooms can have several functions in meat products, but to obtain desired characteristics, it is necessary to take into account the species, amount of use in the formulation, the form of use (ground, homogenized, or dehydrated in powder), processing conditions, function, and the type of meat product. These conditions cause physicochemical, nutritional, technological, and sensory changes in meat products; however, in the sensory aspect, most of the studies are limited to only evaluating the sensory acceptability without exploring in depth the sensory attributes and the background of consumers in evaluating the meat product. Taking these factors into account, it could be explained, for example, why in the same type of product, with the same formulation and at the same concentration of addition of the mushroom, the sensory acceptability was favored by one type of mushroom in one study but not in another, as in the case of *Lentinula edodes* in the formulation of buffalo meatballs reported by [16] and Ramle et al. [17]. Therefore, it is necessary to explore consumer opinion to understand the sensory quality of mushroom-enriched meat products.

5. The Need to Include Consumer Insight

5.1. Sensory Methods to Evaluate Consumer Perception

The sensory and hedonic properties of food are key factors in the success of food products, as consumers will repeatedly purchase a product if it presents pleasant sensory characteristics. According to Lawless and Heymann [34], sensory analysis is the scientific method used to evoke, measure, analyze, and interpret responses to products perceived by our senses of sight, smell, taste, and hearing. Sensory science classifies analysis methods into discriminative (assessing differences), descriptive (describing sensory profiles by intensities), and affective (studying the level of liking). Recently, a new group of rapid sensory methods has emerged, where consumers perform descriptive and hedonic sensory tasks in a single session [35,36]. The most commonly used new sensory methods for characterizing the sensory and hedonic qualities of foods include check-all-that-apply (CATA) questionnaires, projective mapping, free sorting tasks, and free comment (FC, also known as "free word association" or "open-ended questions"). In the case of mushroom-enriched meat products, Patinho et al. [19] characterized burgers with the CATA method, using a predefined list of sensory attributes related to appearance, aroma, flavor, and texture.

Regarding spontaneous sensory evaluation based on consumer opinions, the FC method stands out. This method was first applied in sensory and consumer science by ten Kleij and Musters [37]. These authors argued that FC provides semantically relevant information about products directly from the end consumer in their language. The study results showed that the sensory map of the samples obtained by FC was similar to that obtained by traditional descriptive analysis with trained judges. These results, along with the ease

of use of FC, encouraged the international scientific community to sensorially characterize different products using this method [38,39], making complementary methodological variants [40–42], and even proposing new data analyses [43–45], as well as textual analysis [46]. However, the FC method has not been used to sensorially characterize mushroom-enriched meat products.

5.2. Sensory Terminology Related to Mushrooms and Mushroom-Enriched Meat Products

To the best of our search, reports on sensory terminology to characterize mushrooms or meat products containing mushrooms are shown in Table 2. As can be seen, various species of mushrooms have been evaluated in fresh form, as powder diluted in hot water, dehydrated, cooked by different cooking methods, and in meat products containing mushrooms. The sensory attributes are diverse and mostly generated by trained panels. These terms include terms related to appearance, aroma, odor, flavor, and texture. The diversity of terms applies even to the same type of mushroom. For example, the terms "earthy" and "woody" were not used in all cases for *Agaricus bisporus* (Table 2), understanding that these variations may be due to the conditions of use of the mushroom, such as form, processing, and the product where it is being evaluated. It is also important to note that terms can be applied to multiple sensory dimensions. For example, the term "earthy" has been applied to odor and flavor. Other factors that cause differences in the use of terms may include the references used by the panel to generate terms [47], cultural differences of the assessors [4], and familiarity with the product analyzed [5]. Furthermore, the term "umami" is not applied in all cases, contradicting the belief that all mushrooms have umami characteristics [48].

Table 2. Sensory attributes of mushrooms and mushroom-based products reported in different studies.

Species and Form of Use	Related Sensory Attributes	Sensory Panel and Attribute-Generation Method	Reference
Ground *Agaricus bisporus*	Evaluated in a beef burger: flavor: salty, flavorsome (or tasty); texture: juicy, tender.	Consumers and the adaptation of terms from previous studies	[19]
Raw and roasted *Agaricus bisporus* mushrooms (white, crimini, and portobello)	Raw portobello and crimini: aroma: mushroom, hay, woody, cabbage, sulfur; odor: earthy; flavor: sulfur, hay, potato, soybean, sweet, umami, bitter, astringent. Roasted crimini and portobello: aroma: fried, potato, soybean, roasted; flavor: dark meat, fried, salty. White mushroom: low intensity for all attributes.	Trained panel and generation of terms by consensus	[47]
Lentinus edodes powder	Evaluated in pork patties: flavor: soapy, mushroom; texture: juiciness, mealy.	Trained panel and generation of terms by consensus	[49]
Fresh, dried, and powdered mushrooms of various species, evaluated in the form of "meat" (cap and stipe) and "broth" (served in water at 71 °C)	Mushrooms were similarly characterized when evaluated as "meat" and "broth". General observations: Fresh mushrooms: flavor: umami, sweet, earthy–potato, earthy–damp, fermented; aroma: yeasty. Dried mushrooms: flavor: bitter, musty–dusty, astringent, old leather; aroma: burnt. Dried and powdered mushrooms: aroma: burnt–ashy. Specific observations: Species of *Agaricus bisporus*: dried portobello, fresh portobello, fresh Baby portobello, and fresh Button: flavor: musty–earthy–damp, umami; aroma: nutty, sweet aromatics. Dried *Boletus edulis*, *Cantharellus cibarius*, and *Marasmius oreades*: aroma: brown, woody. *Lentinula edodes*, *Pleurotus* spp., *Craterellus fallax*, *Hypsizygus tessulatus*, *Hericium erinaceus*, and *Flammulina velutipes*: flavor: potato, musty–earthy–potato, fermented; aroma: yeasty.	Trained panel and generation of terms by consensus	[48]
Sous vide processed mushroom species	*Agaricus bisporus*: odor: mushroom; flavor: sweet, umami; texture: squeakiness, biting resistance, toughness. *Cantharellus cibarius*: odor: cooked carrot, forest, cardboard; texture: squeakiness, toughness. *Craterellus tubaeformis*: odor: forest, earthy, cardboard. *Boletus edulis*: odor: mashed potato, mushroom; flavor: sweet, umami, squeakiness; texture: biting resistance, crumbliness. *Lactarius camphoratus*: odor: intense odor, roasted, cardboard; flavor: bitter, astringent, pungent; texture: crumbliness.	Trained panel and generation of terms by consensus	[50]
Powders of *Pleurotus ostreatus*, *Pleurotus sajor-caju*, and *Auricularia* ssp. diluted in hot water	*Pleurotus ostreatus*: appearance: ash color, brown color, even appearance; aroma: milled cereal; flavor: boiled crab. *Pleurotus sajor-caju*: appearance: brown color, cream color; aroma: fishy; flavor: umami. *Auricularia* ssp.: aroma: herbal tea; flavor: cold black tea, bitter, aftertaste, astringent, texture: chalky mouthfeel.	Trained panel and generation of terms by consensus	[51]
Cantharellus cibarius dehydrated by different methods	Dried mushrooms by convective drying and freeze drying: appearance: inner color, piece size; flavor: mushroom, fresh, earthy; texture: sponginess. Dried mushrooms by microwave drying and the combination of convective pre-drying and vacuum microwave finish drying: texture: hardness.	Trained panel and generation of terms by consensus	[52]

Table 2. *Cont.*

Species and Form of Use	Related Sensory Attributes	Sensory Panel and Attribute-Generation Method	Reference
Fresh and dried *Pleurotus eryngii* and *Hydnum repandum*	Raw fresh *Hydnum repandum*: appearance: presence of teeth, cap waviness; aroma: intensity of aroma. Raw dried *Hydnum repandum*: appearance: presence of teeth, wrinkles; texture: crunchiness, hardness. Raw fresh *Pleurotus eryngii*: appearance: well-defined gills, velvet touch. Raw dried *Pleurotus eryngii:* appearance: different colors of cap and stem; texture: crunchy. Cooked mushrooms: flavor: umami; texture: hardness, watery, chewy. Cooked *Hydnum repandum*: aroma: intensity of aroma; flavor: bitter aftertaste.	Semi-trained panel and generation of terms by consensus	[53]
Agaricus bisporus cooked with different cooking methods and as a meat substitute in two types of dishes	Mushrooms prepared with different cooking methods: Seared mushrooms: aroma: overall aroma; flavor: toasted–roasted, burnt–charred, smoky. Roasted mushrooms: flavor: nutty, buttery, sweet, salty, umami, buttery, caramelized. Steamed mushrooms: flavor: cardboard–paper and raw mushroom. Sautéed and steamed mushrooms: texture: moisture. Partial meat replacement with sautéed mushrooms in *carne asada* dish: flavor: mushroom, onion, veggie, earthy, salty, rancid–stale oil; texture: oily–greasy mouthfeel, moisture. Partial meat replacement with sautéed mushrooms in beef taco blend: flavor: mushroom, veggie, umami, onion, garlic, earthy, sweet.	Trained panel and generation of terms by consensus	[54]

From the information in Table 2, similarities or differences between mushroom species can also be explored based on sensory terms. The correspondence analysis in Figure 1, which explains 66.86% of the data variability contained in the first two dimensions, clearly shows three groups of mushrooms with marked differences in the number of sensory terms that characterize them. First, *Pleurotus ostreatus*, *Lentinula edodes*, and other less studied species tend to be characterized by the terms fermented, yeasty, musty, earthy, potato, brown, crumbliness, and forest; second, *Pleurotus eryngii* and *Hydnum repandum* are associated with the terms crunchy, presence of teeth, wrinkles, and hardness; finally, the group with the greatest abundance of terms is *Cantharellus cibarius* and *Agaricus bisporus*, although the latter was more extensively studied; they were associated with terms such as umami, sweet, mushroom, nutty, moisture, salty, and earthy, among others. These terms can be useful for sensory characterization of products containing mushrooms by using a predefined list of terms. However, some aspects must be addressed, such as correctly defining each term's sensory dimension (appearance, aroma, odor, flavor, or texture) and the scaling of evaluation from trained assessors to consumers, which is scarce in the literature. In this sense, the impact of each term on consumer sensory acceptance and preference should be considered. Statistical techniques such as penalty–lift analysis are useful to define the impact of sensory attributes on the acceptance of meat products [55], which can be relevant in decision-making regarding the incorporation of mushrooms in the formulation of meat products.

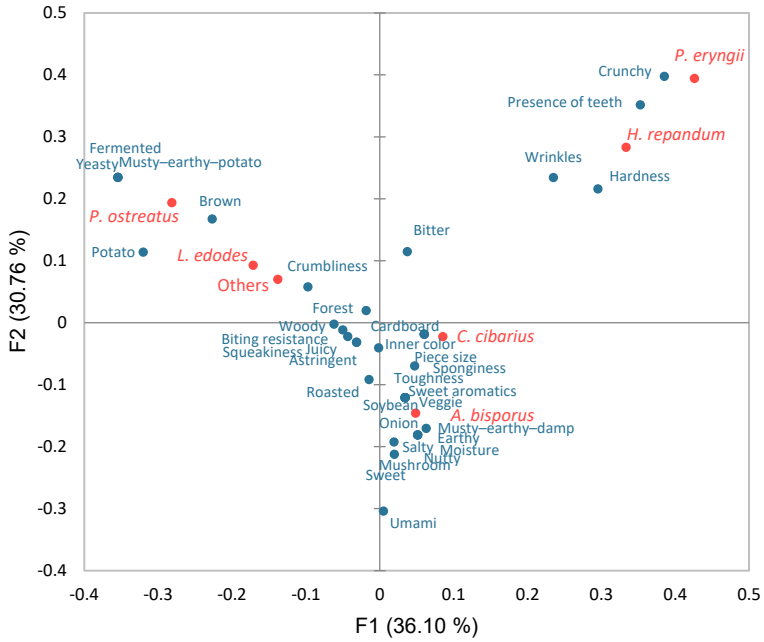


Figure 1. Correspondence analysis of sensory terms used to sensorially characterize edible mushrooms (performed with information from Table 2). Mushroom species in red and sensory terms in blue.

5.3. Challenges in Consumer Perception of Mushroom-Enriched Meat Products

Despite the usefulness of using a predefined list of sensory attributes for the sensory characterization of mushroom-enriched meat products, the relevance of the terms for the product being evaluated must be considered, since the application of a predefined list may be subject to bias, i.e., the terms may not reflect the characteristics of the product or the vocabulary used by the trained assessors and, ultimately, by the consumers. This concern was pointed out by Mahieu et al. [44], who reported that FC provided better characterization and greater richness of terms than the CATA method in the sensory characterization of

wines by consumers. However, some sensory terms seem pivotal for a type of product. For example, our research group focuses on reformulating burgers, where the main drivers of liking are often the attributes "tasty" and "juicy". We verified this fact in beef and fish burgers with consumers from Brazil and Peru [55,56]. These terms also stood out in burgers containing mushrooms, as reported by Patinho et al. [19] (see Table 2), but given the number of terms generated in previous studies, we suggest that more drivers of liking should be evaluated in future studies.

In this regard, some questions can be answered, such as why does a type of mushroom, amount of use, form of use, processing condition, and/or function improve the sensory characteristics of a meat product? What sensory attributes from mushrooms are related to the perception of "tasty" and "juicy" in meat products? Of course, the sensory explanation can be accompanied by instrumental characterization and the identification of key chemical compounds [52,57], which, once identified, methods can be applied to maximize their presence in mushroom by-products [57,58]. However, despite the sensory benefits, consumers may be biased and not perceive mushrooms as tasty [2]. In this context, understanding the background of consumers is crucial because it is an additional element for decision-making on the inclusion of mushrooms in meat products, and under this premise, academic and industrial efforts should aim to increase the popularity of mushrooms as new ingredients in the formulation of meat products with a healthier and more sustainable profile.

6. Conclusions

Mushrooms are an important source of nutrients and bioactive compounds that can be used to formulate meat products. They have the ability to replace fat, salt, synthetic additives, and meat, which is why they are multifunctional. Their effects depend on the species, amount of use, form of use, processing condition, function, and type of meat product. These factors affect the sensory properties of mushrooms and products containing them, which include more than the umami flavor. Efforts are still needed to go beyond the mere determination of sensory acceptability by hedonic scale, in which sensory and consumer science can provide decisive answers for the industrial scaling under a health and sustainability approach. Consumer background is an element to consider when describing mushroom-enriched meat products. To this end, consumer opinion is crucial to identify sensory terms that drive acceptability, an approach that can be explored with the free comment method in future studies.

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