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The potential of the application of *Boletus edulis*, *Cantharellus cibarius* and *Craterellus cornucopioides* in frankfurters: a review

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The potential of the application of *Boletus edulis*, *Cantharellus cibarius* and *Craterellus cornucopioides* in frankfurters: a review

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Abstract. Today, there is increasing demand for the meat industry to produce sausages with partial or complete replacement of commercial antioxidants by natural ones, with minimal or no impact on the quality characteristics. One of the natural additives that are recognized as highly nutritious and rich in antioxidants is mushroom. The three most commonly consumed mushrooms in Serbia are *Boletus edulis*, *Cantharellus cibarius*, and *Craterellus cornucopioides*. This review provides information on the antioxidant and antimicrobial potential of these three mushrooms *in vitro*, and the feasibility of their application in frankfurters. The benefits, limits, and accomplished effects of the addition of mushrooms on lipid peroxidation reduction, microbial inactivation, colour, texture, and sensorial traits are presented with regard to their implementation on the industrial level.

1. Introduction

The contemporary way of life and globalization have resulted in limited time for food preparation and consumption. Meat products belong to a group of perishable foods that can be subjected to bacterial contamination, producing reactions that deteriorate colour, texture, flavour, odour, and sensorial characteristics. Due to increasing demands for meat products that are easy to prepare and consume, there is growing concern about their safety and quality. One of the major problems that can cause deterioration during the storage of meat products is lipid oxidation. This is the oxidation of unsaturated fatty acids when the phospholipid segment of the membrane is oxidized. This oxidation manifests through the formation of numerous advanced lipid oxidation end products (ALEs), which are carriers of rancid odour and taste [1]. Together with the growth of undesirable microorganisms, these changes are recognized as the main factors that influence the shelf life reduction in meat products.

In order to reduce lipid oxidation in meat products and inhibit the growth of microorganisms that can cause deterioration, antioxidant compounds can be added during the process of formulation, incorporated in packaging material, or coated on the surface [2−4]. Generally, there is a well-known trend of the use of synthetic antioxidants such as butylated hydroxytoluene (BHT), that prevent lipid oxidation, simultaneously prolonging shelf life by limiting the formation of free radicals or scavenging peroxide radicals. However, there is a great concern that the use of commercial antioxidants could be toxic for consumers [5]. In this regard, there are rising demands from customers for the greater usage of antioxidants from natural origins in the meat industry, over synthetic antioxidants [6, 7]. Therefore, plants and their extracts are gaining wide attention in the meat industry for their potential usage as antioxidants and antimicrobials, especially because they are generally recognized as safe (GRAS) [8]. Also, they do not have a negative impact on colour, odour, and flavour and they are easy to apply, stable during storage, and cost-effective. The current review aimed to summarize the use of three natural mushroom decoctions to prevent microbiological deterioration and reduce oxidative changes in frankfurters, without adverse changes in technological properties.

2. Mushrooms as a source of antioxidant and antimicrobial compounds

According to a USAID report and analyses from the annual reports of the Institute for Nature Conservation of Serbia, it is reported that *Boletus edulis*, *Cantharellus cibarius*, and *Craterellus cornucopioides* are the most commonly harvested and consumed mushrooms in Serbia [9]. These mushrooms have long been recognized for their wonderful taste. Also, mushrooms are rich in proteins, vitamins, minerals and fibre [10]. On average, dried mushrooms contain about 22% proteins with most of the essential amino acids, about 5% fat, 63% carbohydrates and 10% minerals, which are a good source of vitamins such as thiamine, riboflavin, niacin, and biotin [11]. When it comes to the fat content, most of the 5% fat is in the form of linoleic acid, an essential fatty acid that cannot be synthesized in the human body. In addition to their good flavour and favourable chemical composition, mushrooms have a low glycaemic index and are high mannitol, which is especially beneficial for diabetics.

Besides these nutritive-beneficial traits, some other compounds can be interesting, both for customers and the food industry. Mushrooms are rich in antioxidants, which can be of great interest to consumers due to their protective role in the human body by reducing oxidative damage without any interference. Also, they lower the risk of cancer, promote immune function, balance blood sugar levels, and detoxicate the human body [12, 13]. Mushrooms' phenolic compounds have proven to be tremendous antioxidants in food systems [14]. The exact mechanism of their activity is not established, but it is assumed that phenolics have ability to chelate metals and scavenge free radicals [15]. High amounts of these compounds occur in *Boletus edulis*, *Cantharellus cibarius*, and *Craterellus cornucopioides* [16–18].

3. Antioxidant and antimicrobial potential of selected mushroom decoctions *in vitro* and in frankfurters

Selected mushrooms (*B. edulis*, *C. cibarius* and *C. cornucopioides*) were tested in the form of decoctions. This is the weakest type of the extraction, as well as the most cost-effective and convenient for industrial application. *B. edulis* and *C. cornucopioides* decoctions expressed excellent antioxidant characteristics when the highest concentrations (10 mg/mL) were tested [19, 20], while good antioxidant properties were obtained from *C. cibarius* (21). On the other hand, antimicrobial properties of the tested mushrooms were also significant. All tested mushrooms expressed antimicrobial activity against *L. monocytogenes* and *Y. enterocolitica*, while *C. cornucopioides* showed even more potential against pathogens, *E. coli* and *S. aureus*. These results, in combination with antioxidant properties, recommended these mushrooms for usage in the production of frankfurters, in order to improve their quality and extend the shelf life of final products. Antioxidant and antimicrobial potentials of selected mushrooms, only in methanolic and acetonic extract, were also proven by Kosanic *et al*. [22, 23].

When it comes to the lipid oxidation of meat products, the addition of selected mushroom decoctions into frankfurters caused significant reductions in comparison to control treatment [24]. Antioxidant potential *in vitro* is expressed in a complex matrix such as frankfurters by the reduction of malondialdehyde content, an indicator of secondary lipid oxidation in meat products. It was due to the antioxidant potential of mushrooms, which is credited to the presence of phenols and its bioactive activity [25].

Regarding microbiological stability of frankfurters, total aerobic mesophilic bacteria (TAMB) is among the issues making food spoiled throughout cold storage and TAMB amounts are frequently used as an indicator of the storage stability of frankfurters. The usage of *B. edulis* and *C. cibarius* decoctions in frankfurter production resulted in decreased values of TAMB during two months of chilled storage [24], while *C. cornucopioides* decoction reduced these microorganisms for six weeks (compared with controls). These results are very important, especially for frankfurters with *B. edulis* and *C. cibarius* added, since the shelf life of frankfurters on the Serbian market is about 45 days, and these treatments extended it for two weeks. Also, this could have a financial benefit for manufacturers, since without the addition of commercial antioxidants, considerable extension in shelf life is obtained. It is important to point out that the antimicrobial activity of mushrooms is the consequence of the presence of a considerable amount of natural antibiotics [26]. Also, according to Kurćubić *et al*. [27], antimicrobial activity can be attributed to the hydroxylation of the hydroxyl groups on the phenol ring.

4. Quality assessment of frankfurters with the addition of mushroom decoctions

Commonly, the quality of meat and meat products is evaluated through its colour (28). In the research of Novakovic *et al*. (19, 21), *B. edulis* and *C. cibarius* decoction immediately after the production of sausages did not cause a colour change. Similar results for colour parameters were reported by Pil-Nam *et al*. [29] who added shiitake mushroom powder to frankfurters. To be sure how mushroom decoctions in frankfurters affected the colour, *ΔE* value was calculated. Values can be detected by consumers only when higher than 3 [30]. After two months of cold storage, increased values in *ΔE* were within the limits that indicated a minor colour change, but it still could be detected by consumers. In comparison the addition of other natural components in sausages, such as grape seed flour [31], or sunflower seed oil [32], caused a considerable colour change of frankfurter colour. Therefore, the addition of *B. edulis* and *C. cibarius* had a trivial influence on the colour characteristics of this product. On the other hand, the addition of *C. cornucopioides* caused immediate changes in the colour of sausages, while after two months these changes were drastic [20]. So, it can be stated that from these three evaluated mushrooms, evident colour changes were obtained on the addition of *C. cornucopioides* that could be considered as a negative influence on the quality of the final product.

Besides the colour, another feature that demonstrates the quality of meat products is the texture. Commonly, the method that measures this feature is texture profile analysis, and it is based on the simulation of the food mastication process in the human mouth. Its performance speed corresponds to the mastication sample in the human jaw [33]. The incorporation of all three mushrooms in frankfurters resulted in increased values for hardness and chewiness [19–21]. This could be explained by the higher amount of proteins in sausages that migrated from mushrooms. The higher amount of protein in formulation, the firmer the texture of the final product, due to the creation of a denser protein matrix that is more resistant to compression [34]. These features are exactly the ones that consumers appreciated the most [35], so it could be concluded that mushroom addition improved the quality characteristic of sausages in terms of texture profile.

In the research of Novakovic *et al*. [19], *B. edulis* did not significantly change the appearance and total score values of sausages, in terms of sensorial traits. When it comes to the addition of *C. cibarius* incorporation in sausages [21], during the first 30 days of cold storage, higher scores were obtained for odour, flavour, and overall quality. This could be the consequence of the presence of various compounds in this mushroom that are characterized as flavour enhancers (lenthionine and monosodium glutamate) [19]. On the other hand, the addition of *C. cornucopioides* resulted in slightly lower scores for sensory evaluation, which would be another negative feature of the quality, when it comes to this type of mushroom.

5. Conclusion

B. edulis, *C. cibarius*, and *C. cornucopioides* expressed good antioxidant and antimicrobial potential *in vitro*, so they were used in the production of frankfurters in order to extend shelf life of the final product. Sausages with *B. edulis* and *C. cibarius* were microbiologically stable throughout 60 days of cold storage, meaning the shelf life was extended by 15 days, considering that the shelf life of frankfurters in Serbia is 45 days. This could be an interesting finding for producers, especially because it could reduce expenses and increase profits for meat companies. From the aspect of quality, all mushrooms improved the texture of sausages, but the addition of *C. cornucopioides* caused some negative changes in terms of colour and sensorial traits. Therefore, it can be concluded that *B. edulis* and *C. cibarius* have great potential for usage in the meat industry, in order to extend the shelf life and improve the overall quality of the final frankfurter product.

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