Physical properties (pH and $a_w$ value) of fermented sausages inoculated with Yersinia enterocolitica

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Abstract. Fermented sausages are produced without heat treatment, and the conservative effect is achieved by a combination of three factors: pH, lowering the water activity ($a_w$) and the creation of lactic acid. Here, we summarize the results of the production of fermented sausages inoculated with Y. enterocolitica, with the added starter culture. Number of Y.enterocolitica declined during ripening, as did pH and $a_w$ value. During the ripening process, the $a_w$ of fermented sausages of narrower and wider diameters significantly decreased and was lower in sausages in which starter culture was used. At the end of the production process, there were no significant differences between the physical parameters of sausage quality (pH and $a_w$) among fermented sausages with and without added starter culture, and between sausages with narrower and wider diameters.

1. Introduction

Different types of foods can be the cause of food-borne illnesses, and one of these is the zoonotic infectious agent, Yersinia enterocolitica [1]. Due to the importance of Yersinia in meat, the European Food Safety Authority (EFSA) recommended that it is mandatory to examine pig carcasses for the presence of Y. enterocolitica [2].

The genus Yersinia belongs to the family Enterobacteriaceae. In this genus, three of the 12 species are pathogens, among them Y. enterocolitica, and six biotypes are recognised (five pathogenic and one non-pathogenic). This Gram negative, facultative anaerobe grows in a wide range of temperatures: optimal 28-29°C, minimum -2°C [3]. It grows in a wide pH range, 4.2-10 and at a minimum water activity ($a_w$) of 0.96 [3, 4].

2. Fermented sausages

Fermentation of meat is based on the presence of lactic acid bacteria and lowering pH values. Further, starter cultures produce lactic acid [5], bacteriocins [6] and hydrogen peroxide [7], which act antagonistically in relation to pathogenic micro-organisms [5]. The use of starter cultures, designated for production of favorable microbiota, is to inhibit the growth of undesirable micro-organisms, as a result of fermentation of sugars into lactic acid [8]. Good sustainability of raw fermented sausages is based primarily on the $a_w$ and pH value of the finished product. The water content of dry fermented
sauce is below 35%, but can be less than 30% in many cases, which corresponds to aw of 0.90 or less and makes the product viable [9,4]. Traditional production of fermented raw sausage, in households in Serbia, takes place under uncontrolled conditions (temperature, humidity, and fermentation) during colder seasons. This process relies on the activity of fermentative bacteria that are naturally present in the meat and the production area environment [8]. Preservation of traditional production and authentic products can help small producers and local economies, but it is also important to preserve the traditional knowledge, cultural heritage and regional identity found in often small and underdeveloped locations [10-14].

3. Yersinia, pH and aw in fermented sausages
In central and northern Europe, the fermented reduction in pH (pH 5.6 to 5.8 drops to 4.6 to 4.9) is much more important for sausage preservation than in Mediterranean countries, where a significant reduction in aw is more important [15]. In food with a neutral pH stored at 5 °C, there is a possibility that the number of Y. enterocolitica increase in a short period [16]. Minimum growth pH for Y.enterocolitica is between 4.2 and 4.4. Y. enterocolitica is not capable of growth at pHs below 4.2 or above 9. Y.enterololitica has the potential to multiply during storage of meat and meat products. Storage temperature, vacuum packaging or packaging in a modified atmosphere can encourages bacterial multiplication [15,17]. The ability of Y. enterocolitica to survive at normal pH values is small, particularly at low temperatures [10-12]. According to the Ordinance on the quality of minced meat and semi-finished meat products, bacon should have pH of at least 5 [18]. The presence of an organic acid reduces the ability of Y.enterocolitica multiplying [15,17]. Usually, the aw value of sausage filling or batter at the start of the production process is about 0.96 [19]. On processing, aw continues to decline and the content of protein, fat, ash, and salts rises due to drying ( [20,21], so if a starter culture is used, after four days of ripening, aw is reduced from 0.97 to 0.94. After 12 days of ripening, aw is between 0.89 and 0.90 [22,23]. However, there can be significant diversity in the raw materials, method of making sausages, fermentation and drying conditions. This results in different pH and aw levels at the end of the manufacturing process, so individual fermented sausages can be from pH 4 to 7, or from aw <0.6 to > 0.95 [24,25]. A study [26] on reducing the aw in local sausage production processing has been published.

3.1. Changing the pH of fermented sausages during ripening
The mean pH of all groups of fermented sausages during the ripening significantly declined and at the end of maturation was significantly lower in the wider diameter sausages, and in sausages inoculated with starter culture. On day 0, the mean pH of the sausage stuffing was 6.14 ± 0.10. During ripening, the mean pH of smaller diameter sausage declined, so that at the end of the ripening period (after 18 days) it was 5.32 ± 0.03, and for sausages of the same diameter with the addition of starter culture, the pH was 5.03 ± 0.02. This large difference between the average pHSs was statistically significant (p <0.05). Sausages with wider diameter also showed pH declines after ripening, so in these sausages without and with the addition of starter culture, the mean pH was 5.09 ± 0.07, and 4.91 ± 0.04, respectively (a statistically significant difference, p <0.01). At the end of maturation (day 35), the mean pH of smaller diameter sausages with no added starter culture, was 5.40 ± 0.06, and the sausages with added starter culture, had a mean pH of 5.24 ± 0.08 (a statistically significant difference, p <0.05). At the end of maturation, wider diameter sausages without and with addition of starter culture, were mean pH 5.24 ± 0.03, and 5.07 ± 0.05, respectively (a statistically significant difference, p <0.05).

3.2. Changing the aw values in fermented sausages during ripening
During the ripening process, both fermented sausages with narrower and wider diameter showed significantly decreased aw, but smaller aw decreases occurred in sausages with the starter cultures added.
The mean $a_w$ for sausage stuffing on day 0 was 0.9695 ± 0.0007. The $a_w$ declined during the ripening period, and at the end, on day 18, $a_w$ in smaller diameter sausages with no added starter culture was 0.9110 ± 0.0006, and this was statistically significantly lower than in sausages of the same diameter with the addition of starter culture ($p < 0.01; a_w 0.9211 ± 0.0005$). On day 18, the mean $a_w$ of wider diameter sausages with no starter was 0.9346 ± 0.0008, and this was significantly lower ($p < 0.05$) than the mean $a_w$ of wider diameter sausage with starter (0.9361 ± 0.0008). At the end of maturation, the mean $a_w$ of smaller diameter sausages was 0.9200 ± 0.0007, and the mean $a_w$ of wider diameter sausages was 0.9235 ± 0.0004.

4. Conclusion

The proper, controlled fermentation of raw sausages produces largely safe products that do not contain foodborne pathogens which could cause disease, among which is *Y. enterocolitica*. In fermented sausages, during ripening and drying, different parameters are used to stop/slow/inhibit the growth of pathogenic bacteria, and these parameters act simultaneously. Known parameters include pH decrease, presence of lactic acid, decreases in $a_w$, inhibitory effect of smoke (if the sausages are smoked), presence of starter culture and action of metabolites (bacteriocins), etc.

Inactivation of pathogenic bacteria during the ripening of sausages involves control of their growth, and it is a key step in the production of fermented sausages. Reduction of their number ends or is insufficient if the ripening process does not last long enough or is not optimal (incorrect starter culture, temperature, humidity, circulation), which is why this process should be controlled.

In many European countries, demand for traditional food products is increasing. These products are foods with strong regional characteristics and of local origin, which should be protected and promoted, as a characteristic form of local traditional food production.

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