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Review paper

Production characteristics and safety parameters of Sremska ham

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A b s t r a c t: Sremska ham is a traditional dry-cured meat product manufactured by salting, smoking and drying pork hams in a mainly natural environment. The traditional production process of cured ham in Srem region (Vojvodina, Serbia) is standardized and adjusted to good manufacturing and good hygiene practice procedures. Quality parameters for Sremska ham are well defined, and include mass, ripening time, flavour etc., in order to attain product with standardized and well recognized quality. Sremska ham is produced from pork meat obtained from healthy, well rested, late maturing animals, mass 120 to 150kg. Hams are dry salted and the process itself lasts for 4 to 6 weeks depending on the ham mass. Meat selection based on pH is of great importance in order to achieve proper salt diffusion in ham. Salt diffusion occurs in the desired manner only if the pH of the meat is less than 6.0. Biohazards which can occur during the production of Sremska ham are Clostridium botulinum spores, if conditions for their germination and toxin production exist, mycotoxin producing moulds, and infestation by insect larvae. Those hazards can be eliminated or reduced by maintaining a low temperature during the critical production stages and ensuring sufficient salt content to inhibit C. botulinum growth. Moulds and insects are controlled by maintaining appropriate storage conditions. The manufacturing process of Sremska ham should be based on HACCP principles, while preserving the traditionality of the process.

***Keywords:** Sremska ham, traditional meat product, food safety.*

Introduction

Southern Slavic countries have a long tradition in production of dried meat made from pork, beef or ovine meat. In the Serbian language, besides the term "sunka" which means ham, the terms "prsut" and "prsuta", derived from the Italian word "prosciutto," which also means ham, are often used. Although cured meat production is similar across Europe, there are differences in production process that affect final product characteristics and quality.

The final product can vary in mass, appearance, flavour, texture and salt content, depending on ham mass, type of cut, quantity of added salt and salting duration, smoking intensity, drying and ripening time (*Zlender*, 1986; *Careri et al*., 1993; *Buscailhon et al*., 1994; *Shivazappa et al*., 2002, *Vukovic et al*., 2005b).

Sremska ham is a traditional dry-cured meat product manufactured by salting, smoking and drying of pork hams in a mainly natural environment. It has been produced in the Srem region for centuries, although other parts of Vojvodina are well known for similar products. Sremska ham production starts at the end of autumn or beginning of winter, when low temperatures ensure product safety, and finishes at the end of summer, when higher environmental temperatures contribute to flavour development (*Vukovic*, 2005b).

Cured meat products have certain distinct characteristics depending on the region they are produced in and equipment used for production (*Petrovic et al.,* 2011). Sremska ham has a unique flavour due to the complexity of the production process, but on the other hand, this complexity can pose a risk for food safety, because of the many potential hazards which can occur.

Sremska ham production process

The traditional cured ham production process in the Srem region is standardised and adjusted to good manufacturing and good hygienic practice procedures. The quality parameters of Sremska ham are well defined with regard to mass, ripening time,

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flavour etc., in order to attain product with standardized and well recognized quality (*Vukovic et al.*, 2005a).

Raw material selection

Sremska ham is produced from pork meat obtained from healthy, well rested, matured animals, mass 120 to 150 kg. Meat should be selected from older animals, because their meat contains less water, has a firm texture and more intense colour than meat from young pigs.

Slaughter and carcass processing is performed in the usual way. The ham is cut from the half carcass with a cross cut between the last lumbar and the first sacral vertebrae. The other cut is made at the knuckle. The pelvic bones are usually separated from the ham, in this case producing "short hams", with a mass around 8 kg.

"Long hams" are obtained by cutting ham together with the pelvic region, sometimes with last two vertebrae, and they weigh more than 12 kg. Part of the skin is then removed from the inner ham so salt can more easily diffuse into the deeper tissue. Excess fat is afterwards trimmed and the ham is shaped. The ham is then left for 18 to 24 hours in a cold room (up to 5°C) (*Vukovic*, 2006).

Salting

The hams are dry salted, and the process itself lasts for four to six weeks, depending on the mass of the ham. Meat selection based on pH is of great importance in order to achieve proper salt diffusion in Sremska ham. Salt diffusion occurs in the desired manner only if the meat pH is less than 6.0. Connective tissue membranes are, in that case, ruptured as a result of lactic acid accumulation during postmortem glycolysis and the meat structure becomes open. Special attention must be paid to the red muscles of the ham (*m. gracilis, m. quadriceps femoris* and *m. adductor*), where pH values higher than 6.0 can be expected, but which could result in slow salt diffusion (*Teodorovic et al.*, 2015).

In order to accelerate salt diffusion, it is necessary to loosen up the knee joint by manually flexing it a few times. This procedure allows salt to penetrate the meat near the knee joint, which is especially sensitive to spoilage. It is important to squeeze out blood from the larger blood vessels by pressing ham from the knuckles to the head of the hip bone, because any remaining blood can act as a medium for undesirable bacterial growth (*Vukovic et al.*, 2005a).

Table salt is used for dry salting. Salt is thoroughly rubbed into the ham, especially in any cavities or hollows if they occur and near the bones and blood vessels, as these are the areas where spoilage typically begins. Hams are then stacked one on another, and are restacked every few days. This increases the pressure in the hams, so salt diffusion is faster and all excess water can drain. Salting lasts for four weeks, and hams are then hung on poles so that the salt can diffuse evenly through the tissues during the next eight weeks.

The process of salting and salt diffusion must take place at temperatures less than 5°C, to prevent microbial spoilage and especially because of the risk of potential germination of *Clostridium botulinum* spores (*Vukovic et al*, 2005b; *Teodorovic et al.*, 2015). From the viewpoint of quality and acceptability for consumers, the salt content in Sremska ham does not need to be greater than 6%. However, from the aspect of microbiological stability and to safeguard consumer health, in particular preventing the formation of botulinum neurotoxin (*Vukovic et al.*, 1999; 2005b) which can form in dry-cured ham, at least 4.5% salt is required. This requirement is met by salting ham with 3 to 4% salt, which is less salt than is used in the traditional process, but which results in a product which is more acceptable to consumers, while at the same time remaining microbiologically safe (*Leistner et al.*, 1983; *Vukovic et al.*, 2005b). When the salt diffusion is completed, and the hams become microbiologically stable, they are transferred to higher temperature maturation areas, first at 25 to 30°C and then at 12 to 14°C, where enzymes that participate in the maturation of the product are activated.

Ripening

At this stage of the process, a stable colour and flavour are formed, and the product becomes microbiologically and chemically stable. Before smoking and drying, hams are first rinsed in warm water, which rehydrates the dried skin, as well as removes any mucus and excess salt from the surface. Afterwards, Sremska ham is subjected to cold smoking. This phase takes place under controlled conditions in climate chambers at temperatures from 12 to 25°C. In the case of traditionally smoked ham, classic smokehouses at ambient temperature during the cold, winter months are used. During the first stage of ripening, products are dried at temperatures of 10 to 15°C and relative humidity up to 80%. The second period of maturation occurs at a higher temperature of 16 to 18°C, which contributes to the enzymatic changes which lead to the formation of desirable aroma and texture in the ham. As a result of proteolysis, a softer texture is obtained and the ham is easier to chew (*Vukovic et al.*, 2005b). Studies on Sremska ham (*Vukovic et al.*, 2005b) show the use of such traditional manufacturing processes is justified; in this case, the hams are dried for three months at 15°C and relative air humidity of 75%, followed by a ripening process which lasts another six months.

During ripening, the accumulation of aromatic substances occurs, and these are formed as a result of proteolysis, which takes place under the influence of tissue enzymes. The proteolysis index (PI) is an indicator of the level of maturity of the ham, and indicates the non-protein nitrogen and total nitrogen ratio, expressed in percentages. The optimal PI for dry meat products ranges from 26 to 30% (*Careri et al*, 1993), and for Sremska ham, the PI ranges from 25.5 to 26.6% after a 12 month ripening period. However, during such long-term aging, the fleshy part of the ham (which is not covered with skin) can become over-dried, so producers often put ham that is not matured enough on the market. Hams can be expediently vacuum packaged, which prevents over-drying while allowing enzyme activity to continue, and thus, facilitates the normal ripening process and the formation of acceptable flavour and texture of the product (*Vasilev et al*. 2007a, 2007b).

Quality parameters of Sremska ham

During the production of Sremska ham, weight loss as a result of drying is usually 29 to 39%, being higher if the product is made from lighter hams. The water activity (a_w) ranges from 0.89 to 0.92, which is sufficient to ensure the microbiological stability of the ham. The pH of finished ham is high as a result of proteolysis during the ripening process, and ranges from 5.70 to 5.90 at the end of drying, up to 6.45 to 6.65 at the end of ripening. The meaty part of the product contains 59.8 to 61.9% water, 4.2 to 6.3% fat, 4.9 to 6.3% salt, and 25.8 to 27.2% meat proteins. It is interesting that the degree of oxidation of fat in Sremska ham is low, whereby thiobarbituric acid reactive substances (TBARS) values are up to 0.30 mg of malondialdehyde kg^{-1} (*Vukovic et al.*, 2005a). When ripening occurs in vacuum packaging, the oxidation parameters are even lower and reach only 0.1 mg of malondialdehyde kg^{-1} (*Vukovic et al.*, 2005a, *Vasilev et al.*, 2007a). Sremska ham and other meat products must meet Serbian regulatory requirements that define the quality of this product group: the surface is dry and clean; external appearance, cut appearance, smell, taste, consistency and texture are characteristic for the type of meat and mature product; the appearance, colour, smell and taste of the product originate from smoke, the shape must be characteristic, with a neatly processed border; the colour of the meaty part in cross section should be characteristic and stable; the fatty tissue should be white, while the surface can be yellowish; the ratio between the water content and protein content in the meaty part of the product has to be a maximum of 2.5:1 (Serbia, 2015). According to research conducted by *Vukovic et al.* (2005a), Sremska ham contains an average of 61% water and 26.5% proteins, so the protein to water ratio in the product is 2.26:1, which meets the required limit.

Factors of importance for Sremska ham safety

The food safety system in the Republic of Serbia is based on the principles regulated by EU laws (*European Commission*, 2002) and includes: responsibilities of food and feed business operators**;** traceability of food, and; risk analysis. The main laws, which are the pillar of the whole food safety system in the Republic of Serbia, and which are in accordance with European measures are the Law on Veterinary Matters (*Serbia*, 2010), and the Law on Food Safety (*Serbia*, 2009) and the Law on Animal Welfare (*Serbia*, 2009).

Within the Law on Food Safety (*Serbia*, 2009), there is a legal basis for adoption of bylaws that include: hygiene conditions applied to primary products provided to consumers in small amounts, and; deviations from general and specific conditions applied to small food producers, having in mind that these deviations may be prescribed in the case of traditional method application in some phases of food production and distribution, as well as in cases in which food businesses are situated in areas with special geographic limitations (*Karabasil et al.*, 2015).

Important factors for food safety are based on the principles of the Hazard Analysis and Critical Control Points (HACCP) system. HACCP is an integrated control system applied to the food production chain, with the goal of avoiding potential chemical, physical and microbiological hazards which can endanger consumers' health. The principles of HACCP are described by Codex Alimentarius (*Anon*, 1993).

Identification of potential hazards

The traditional process of obtaining dry ham in natural environments is very difficult to keep under control, and because of this, it could potentially endanger consumer health. In natural ambient conditions, climatic factors are variable. A special problem is to provide the optimal temperature for the salting and salt diffusion phases of production in order to prevent growth of the neurotoxic bacterium *C. botulinum*. In other production stages such as smoking, drying and ripening, products could be contaminated with carcinogenic substances derived from smoke, mycotoxin-producing moulds and insect larvae.

In order to eliminate potential hazards, Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be introduced in the production process. Then, the facility will have optimal hygienic and technological requirements for the implementation of HACCP system.

Botulism

Botulism associated with the consumption of dry hams could occur in many European countries. It usually occurs in regions where hams are produced by individual households and are consumed without heat treatment (*Tompkin*, 1980; *Lücke et al.*, 1982; *Lücke and Roberts*, 1993; *Vukovic,* 2000). According to official figures, in eight out of ten registered cases of botulism, dry ham produced by traditional manufacturing techniques was the source of poisoning (*Vukovic et al.*, 1999; *Vukovic et al.,* 2000; *Vukovic,* 2005a; *Vasilev and Vukovic*, 2008.)

The presence of botulinum toxin could be considered as an indicator of bad hygiene practices during pig slaughter, as well as other omissions during the production process. The main problem is an insufficient quantity of salt as a consequence of slow salt diffusion into the depth of the ham, which does not prevent growth of *C. botulinum.* High environmental temperatures during the salt diffusion phase can be a serious problem in traditional production, when *C. botulinum* spores, if present, could germinate and produce toxin. Moreover, *C. botulinum* type B, which is most often found in dry ham, is non proteolytic, so during growth and toxin production, no signs of spoilage occur in the product which would warn consumers of the danger (*Lücke and Roberts*, 1993). Only 0.1 g of food containing this toxin could lead to a fatal outcome (*Peck and Stringer*, 2004).

Implementation of appropriate control measures during animal transport pre-slaughter, slaughter (prevention of contamination), cooling, storage, meat transport and ham production (prevention of spore germination) play a primary role in preventing the occurrence of botulism in ham. In cases of increased stress, *Clostridia* spores, which could be present in the intestines of healthy animals, can break through the natural intestinal defence barrier, be carried by the bloodstream and enter into the meat (*Lücke and Roberts,* 1993; *Vukovic*, 2005a; *Anon*, 2005). When choosing raw material under hygienic conditions, the pH of the meat should be measured, as well as the temperature in the depths of the pork ham. The optimum temperature is between 0 to 4°C, while the pH should be less than 6.0, because of the slower salt diffusion. The salting should last long enough that the a_w drops below 0.96, and the concentration of salt in the water of the product is higher than 5.0% (*Anon*, 2005; *Vukovic*, 2005a; *Vukovic et al.,* 2005b; *Vasilev and Vukovic*, 2008).

Moulds

Moulds are able to grow on hams during the long curing and drying process, despite the high salt content and low temperatures, which are unable to inhibit these organisms. Smoke has a bactericidal and fungicidal effect. However, fungicides in smoke (phenols, aldehydes) are not always present in sufficient quantities, so they do not effectively stop the growth of moulds on the ham surface. Their concentration decreases over time due to evaporation and diffusion into the deep parts of the meat, where aldehydes react with proteins (*Möhler*, 1978). Most of the moulds able to grow on hams are harmless, but some of them can produce mycotoxins, such as *Penicillium* and *Aspergillus* species (*Hofmann*, 1985), and it is necessary to provide conditions to inhibit their growth and mycotoxin production. Mould growth on meat products can be prevented by adopting some of the following measures: (1) good hygiene during production and storage; (2) smoking of products; (3) ensuing the optimal relative air humidity during ripening and storage (<75%); (4) vacuum packaging; (5) coating products with various mixtures (a mixture of pork fat, flour and spices or a creamy mixture of spices containing 30% of garlic), and; (6) using additives for surface treatment of products (*Teodorovic et al.,* 2015).

Insects

Sremska ham provides an optimal environment for the development of many types of arthropods, which can be a problem during storage. Among arthropods of note are the larvae of cheese fly (*Piophila* *casei*), but less often larvae of other flies (domestic house fly, stable fly, blow fly), *Aglossa pinguinalis* caterpillars (a butterfly), moth larvae (*Dysmassia parietarella*), larder beetle larvae (*Dermestes lardarius*), red-legged ham beetle (*Necrobius rufipes*), flour mite (*Tyrogliphys farinae*) and other insects. Their presence causes disgust and repulsion, and can cause various conditions in consumers, including intestinal myiasis and allergic reaction to flour mite. The larder beetle larvae, for example, digs channels in the ham, rendering it unusable (*Raseta,* 1994).

Regular and thorough enforcement of several measures can prevent insects from infecting hams. These start from the selection of raw materials which must have the specified characteristics, to conditions in the ripening premises, where all surfaces, must be thoroughly cleaned and treated with insecticides. As preparations of choice, the most commonly used are insecticides based on pyrethroids. In addition to these measures, which are implemented in order to combat pests, the important thing is constant control. This work should be conducted several times a year (*Relic et al.,* 2005).

Critical control points in Sremska ham production

Raw material selection (*CCP*)
Cutting and processing of ham
Weight measurement/classification
Preparing hams for salting
Salt mixture preparation
Salting and salt difusion (CCP)
Washing and dripping
Final processing
Smoking
Drying (CCP)
Ripening

Figure 1. Technological procedure for Sremska ham production

Figure 1 shows the technological process of Sremska ham production with marked critical control points (CCP):

At the first step in the process, animals should be slaughtered in registered establishments, using the two knife technique, with a separate, sterile knife for each ham. The raw material for the production of Sremska ham should be obtained by cutting the chilled pork carcass halves in special rooms where the air temperature is lower than 12°C. The temperature in the depths of the meat should be lower than 5°C (*Lücke and Leistner*, 1979; *Leistner*, 2000, *Vukovic*, 2005b). In order to facilitate a normal salt diffusion process, the meat pH should be less than 6.2 (*Sanabria et al.*, 1997), less than 6.1 (*Buscailhon et al.*, 1994), or less than 5.8 (*Leistner* 2000). At a very low pH, proteolytic changes are the most intense and these could lead to a bitter taste and an unacceptably soft structure of meat (*Schivazappa et al*, 2002). As the pH of the meat directly influences the salt diffusion process, the selection of meat according to pH is a CCP in the production of dry ham. The next CCP is the operation of salting and salt diffusion, because of the risk of developing non proteolytic *C. botulinum* type B. The critical limit is a temperature of 4°C, as temperatures below this prevent spore germination until a sufficient salt content develops in the deepest parts of the ham. Drying lasts for three months and if the temperature rises above 15°C, there is a risk of *C. botulinum* proliferation until the a_w decreases below 0.89 to 0.92, sufficiently low to ensure these bacteria do not grow (*Vukovic et al.*, 2005a). Under such conditions, only moulds are able to grow on the surface of the product, and these can be controlled by the measures described above.

Bacterial hazards in the Sremska ham production process can be eliminated or reduced if the temperature in the critical production stages is less than the minimum temperature of growth for *C. botulinum*, and if the content of salt in the product can inhibit this pathogen. Therefore, the manufacturing process of Sremska ham must be based on HACCP principles including appropriate controls at critical points throughout the process.

Conclusion

Sremska ham is a traditional dry-cured meat product manufactured by salting, smoking and drying of pork hams under natural environmental conditions in the geographical area of Srem. The technological process of production of Sremska ham includes: appropriate selection of raw materials, salting, salt diffusion, smoking, drying and ripening. The final product is microbiologically stable and achieves the required characteristic aroma, consistency and texture.

Typical biohazards in Sremska ham include *C. botulinum* spores, if conditions exist for their germination and toxin production, mycotoxin-producing moulds, and insect larvae infestations. Those hazards can be eliminated or reduced by the low temperature maintained during the critical production stages and ensuring sufficient salt content to inhibit *C. botulinum* growth. Moulds and insects can be controlled by maintaining appropriate storage conditions. The manufacturing process of Sremska ham should be based on HACCP principles, while preserving the traditionality of the process.

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