Food Research International 102 (2017) 176–183

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Review

Technological aspects of horse meat products – A review

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ARTICLE INFO

Keywords:
Dry-cured meats
Sausages
Pâté
Foal
Donkey

ABSTRACT

Horse meat and its products can be considered as a food with a high nutritional value. However, due to cases of economically motivated food adulteration by the intentional addition of horse meat beef products in recent years, horse meat has become a controversial issue. Consumer confidence in meat products and the meat industry has diminished, although consumers consider the differences between the food content and the label as the major issue rather than the safety and nutritional characteristics of horse meat. The elaboration of meat products from horse meat (*e.g.* "cecina", dry-cured loin, salami, bressaola and pâté) is also an interesting alternative to other traditional meat products such as dry-cured pork hams, pork sausages and liver pâtés. In this review, the technological aspects, safety and storage stability of meat products elaborated from horse meat will be addressed by highlighting the nutritional and sensory aspects of these meat products. We aim to improve the existing knowledge about horse meat in the view of recent scandals.

1. Introduction

The development of new products in the food industry aims to improve existing products with unfulfilled and altered expectations of food safety, health properties, novelty and convenience, particularly in the last decades (Leroy & Degreef, 2015; Leroy, Geyzen, Janssens, De Vuyst, & Scholliers, 2013). Nutritional improvements are considered as positive changes in view of consumers, who also expect innovations in food convenience as long as such modifications are not too uncustomary (Kühne, Vanhonacker, Gellynck, & Verbeke, 2010). In accordance with this, the use of horse meat in the elaboration of dry-cured meats, sausages and other meat products can fulfill these requirements.

By comparison to other meat producing species such as pork, poultry, bovines or ovines, current horse meat production represents only 0.26% of the total worldwide meat production (FAO, 2017). China was the major producer (26.3% of the world production), followed by Kazakhstan (12.4%), Mexico (11.3%), Russia (6.8%) and Mongolia (3.9%); representing 60.9% of the total word horse meat production (FAO, 2017). On the other hand, it was estimated that the average worldwide horse-meat supply is about 0.10 kg *per capita* (Belaunzaran et al., 2015). Countries where the horse-meat supply *per capita* values are clearly above the world average are Mongolia (5.81 kg), Kazakhstan (4.92 kg), Kyrgyzstan (3.50 kg), Iceland (2.19 kg), Switzerland (0.73 kg), Italy (0.70 kg), Croatia (0.69 kg), Belgium (0.58 kg), Russia and Finland (0.51 kg, each), France (0.27 kg), Malta (0.26 kg), Ukraine and Greece (0.25 kg, each) (Belaunzaran et al., 2015).

Equines are large framed and hindgut fermenter herbivores that can compete advantageously with ruminants for the utilization of pastures and rangelands. The digestive physiology of equines allow then to efficiently transfer the *n*-3 PUFAs from pasture into meat with very low *trans*-FA deposition and low methane emissions per unit of meat produced in comparison to ruminants (Belaunzaran et al., 2015). Horse meat can be considered as a food of high nutritional value containing an elevated proportion of proteins, iron and, *n*-3 fatty acids as well as having a low fat content (Lorenzo, Sarriés, et al., 2014). Although meat production from horse is still lower than that registered for other species such as bovines, porcines, poultry and even game meat, a crescent production (due to the increase in Asia and Europe production) of an

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http://dx.doi.org/10.1016/j.foodres.2017.09.094
Received 8 July 2017; Received in revised form 28 September 2017; Accepted 29 September 2017
Available online 30 September 2017

average of 700,000 tons per year, was registered. Additionally, production of horse meat can contribute the preservation of local breeds, reduction of methane and other greenhouse gases and provide food with enhanced *n*-3 fatty acid content (Belaunzaran et al., 2015).

Traditionally, horses have cohabited with humans for centuries and have been employed over the years as workers on farms, as companions or for recreational or sporting reasons. These historical associations have led to the adoption of the horse as a pet in many cultures the consumption of horse meat is viewed with revulsion (Iwobi et al., 2017). Additional constraints are imposed by certain religions which forbid various meat species. Pork and donkey meat are forbidden (*haram*) to Muslims, pork is forbidden (non-Kosher) to Jews, and devotees of Guan Yin Bodhisattva abstain from eating beef (Thanakiatkrai & Kitpipit, 2017). At the same time, horse meat is also the centre of the controversial issue of the economically-motivated improper adulteration of food. Although the inappropriate changes do not necessarily impose health risk to the consumer, this practice is consumer fraud and affects the behaviour of consumers (Premanandh, 2013). Nevertheless, this situation created a breach in consumer trust, which resulted in a reduction in sales of processed meat. This effect is suggested to be associated with the differences between food content and its label rather than horse meat *per se*. Consumers also attribute the demand for food at a reasonable price, intentional adulteration by the food industry and several other factors associated with food production and distribution as main factors for adulteration in the processed meat sector. In addition, it has been suggested that consumer confidence in processed meat could be restored by a combination of measures such as correct and clear food labelling, increase in product traceability and providing clear and trustworthy information about the origin of food to consumers (Barnett et al., 2016; Regan et al., 2015). Horse meat and its products can be considered as legitimate food ingredients and products for human consumption only if appropriate actions are taken such as slaughter in approved and certified slaughterhouses followed by a veterinary inspection (Bánáti, 2014).

Although the literature about innovative processing technologies (*e.g.* pulsed electric field (PEF), high pressure processing (HPP), shockwaves (SW), and ultrasound (US)) on horse meat and derived products is scarce, over the last years, the great potential of these techniques for meat industry has been demonstrated. In a recent review, the most relevant techniques in cured raw ham manufacture used for pre-treatment (trimming, blade tenderization, and freeze-thawing), curing/salting (tumbling, vacuum impregnation, pulsed pressure, US, PEF, simultaneous thawing/salting), drying/ripening (Quick-Dry-Slice-process, oil drop application, high temperature short time process) and post-processing (vacuum and modified atmosphere packaging, HPP, high pressure carbon dioxide, high pressure carbon dioxide with US) were presented (Bosse et al., 2017).

In this regard, the application of HPP to avoid microbial contamination to extend shelf-life of meat products is a fact, with several HPP-processed products found available at commercial scale right now in international markets (Barba, Koubaa, do Prado-Silva, Orlien, & de Souza Sant'Ana, 2017). Moreover, HPP has also the potential to produce indirectly healthy food, reducing the salt added to meat products. On the other hand, the potential of PEF on cell permeation, and product safety has also been investigated, obtaining interesting results (Blahovec, Vorobiev, & Lebovka, 2017).

In addition, PEF, HPP, shockwaves, and US have been also used in pre- and post-rigor meat for tenderisation, due to their ability to promote physical disruption to muscle structure, thus enhancing proteolysis as well as ageing and subsequent muscle protein denaturation and solubilisation (for a review see Warner et al., 2017). All these processes result in modifications in meat texture and juiciness, thus having the ability to obtain a range of desired textures for meat products.

In this review, we considered the technological aspects, safety and storage stability of meat products elaborated from horse meat with the intent to highlight the nutritional and sensory aspects of these meat products and improve the knowledge about horse meat in the view of recent scandals.

2. Dry-cured loin and "cecina" from horse meat

The production of dry-cured meats began in ancient times when traditional practices such as salting and smoking produced meat products with unique sensory characteristics (Toldrá, 2006). The processing of horse meat into dry-cured meat products involves few steps: preparation of meat pieces (*e.g.* removal of connective tissue); salting period under refrigeration when salt and curing agents penetrate the meat; seasoning with spices, herbs and food additives; and drying-ripening according to the product with controlled temperature, relative humidity and time (Hierro, de la Hoz, & Ordóñez, 2004; Toldrá, 2006). Variations in the sequence of processing and additional steps are reported in literature: the seasoning step after the first drying period (Ren et al., 2015), the smoking and post-salting stages of meat pieces before drying-ripening in "cecina" manufacturing (Lorenzo, 2014a) and stuffing into natural casings after the seasoning period (Lorenzo & Carballo, 2015) yielding meat products with unique characteristics. However, few studies assessed the features and changes in characteristics of dry-cured meats from foal and horse meats during processing (Hierro et al., 2004; Lorenzo, 2014a; Lorenzo & Carballo, 2015; Lorenzo & Carballo, 2016; Lorenzo, Fonseca, Gómez, & Domínguez, 2015; Paleari, Moretti, Beretta, Mentasti, & Bersani, 2003; Ren et al., 2015).

In general, dry-cured horse meat products present a low fat and a high protein content (Table 1). The composition of dry-cured horse meat is characterized by a moisture content of between 36.5 and 56.92%, fat concentration from 0.91 to 6.9% (dry weight), protein content between 79 and 81% (dry weight) and ash concentration from 6.2 and 17.8% (dry weight) (Table 1). The drying-ripening stage influences the composition of the final product due to a reduction in moisture content which affects other characteristics such as water activity (a_w), objective colour and an increase in texture parameters (Lorenzo, 2014a; Lorenzo & Carballo, 2015). Studies regarding the processing of "cecina", dry-cured loin and pastirma from horse meat revealed the average a_w of such products range between 0.83 and 0.93 (Table 2). In addition to dehydration, salting time reduces a_w as reported for "cecina" production by Lorenzo et al. (2015). Authors observed the positive correlations between increasing salting time and reduction of moisture content and a_w. In this regard, the longest salting time of 0.3 day/kg provided the lowest moisture content of 51.30% and a_w of 0.90.

The pH of dry-cured meat product varies according to the processing and retail cut from 5.11 to 6.09 (Table 2). Lorenzo (2014a) observed the pH of fresh horse meat during drying-ripening period increase from 5.94 to 6.09 in "cecina" production. This behaviour was suggested to be associated with the release of alkaline compounds from enzymatic breakdown of proteins (Lorenzo & Carballo, 2015). The pH of the final product can also be influenced by the retail cut as stated by Lorenzo and Carballo (2016). Authors reported significant higher pH value in "cecina" elaborated from knuckle cut (pH = 6.11) in comparison to silverside and topside cuts (pH = 5.88 and 5.89, respectively). During ripening stage, the colour of fresh meat changes from brilliant red to dark red in colour which is characterized by a reduced luminosity (L* value), redness (a* value) and yellowness (b* value). The L* value of final product is between 25.1 and 32.3, between 4.7 and 11.7 for a* value and between 3.1 and 5.9 for b* value (Table 2). These changes were positively associated with moisture content in "cecina" after 60 days (Lorenzo, 2014a) and dry-cured loin after 30 days (Lorenzo & Carballo, 2015). In addition, increasing salting time is related to slight reductions in L* and a* values (Lorenzo et al., 2015).

The shear force for horse and donkey dry-cured meat reported in literature ranges between 2.19 and 10.0 kg/cm^2 (Table 3). Processing, particularly during ripening, was reported to influence shear force as