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Evaluation of innovative immersion vacuum cooling with different pressure reduction rates and agitation for cooked sausages stuffed in natural or artificial casing

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ABSTRACT

Effects of different pressure reduction rates and liquid agitation (523 rpm) on sausage successful rate, cooling time, cooling loss, texture properties, chemical and physical parameters were analysed by ANCOVA. Tested linear pressure drop rate from 320 mbar to 50 mbar was 20 (L 20), 30 (L 30), or 40 (L 40) mbar/min for artificial casing sausages (ACS) and 60 (L 60), 80 (L 80), or 100 (L 100) mbar/min for natural casing sausages (NCS). From 50 mbar until 6.4 mbar, 5 mbar/min was used for both casings. NCS were more suitable than ACS for IVC. The recommended pressure reduction rate was 30 mbar/min for ACS and 60 mbar/min for NCS. ACS under 30 mbar/min with agitation (LA 30) presented significantly higher texture property values than that without agitation (L 30) ($P < 0.05$). Cooling time (to 4 °C) of NCS under 60 mbar/min and agitation (LA 60) was significantly shorter than that without agitation (L 60) ($P < 0.05$). This study could assist meat processors or manufactures when choosing a suitable pressure drop rate for different types of sausages.

1. Introduction

Sausages, stuffed in natural casing or artificial casing, are regarded as one of the oldest types of processed meat products (Harper, Barbut, Lim, & Marcone, 2012; Paula et al., 2011; Savic & Savic, 2002; Sánchez-Zapata et al., 2013; Steen et al., 2014). Natural casings, which are made from sheep, hog, and beef intestines, are traditionally used (Barbut, 2010). Natural casings are tender, have high permeability and a special bite which is believed to be highly valued by consumers (Harper et al., 2012; INSCALL, 2006). However, their preparation can be costly (Harper et al., 2012) and the initial products have comparably higher bacteria counts, which may negatively influence casings' shelf-life (Bakker, Houben, Koolmees, Bindrich, & Sprehe, 1999; Mor-Mur & Yuste, 2010; Saggiorato et al., 2012). During the past few years, artificial casings have gained increasing interest for sausage manufacture, due to their uniform size, shape and strength, flexibility, hygienic quality and comparable longer shelf life (Barbut, 2010; Sebranek, 2010; Harper et al., 2012). However, artificial casings are usually not as permeable, elastic and tension resistant as natural casings, especially after cooking. Knowing casing properties is important for sausage manufacturers, for efficient filling stuffing or to control subsequent preparation steps (such as heating, smoking and so on), as well as to prevent or minimise bursting incidents.

Like freezing (Delgado et al., 2009; Zheng & Sun, 2006), drying (Sun, 1999; Sun & Byrne, 1998; Sun & Woods, 1993, 1994a, 1994b, 1994c, 1997; Delgado & Sun, 2002; Cui et al., 2004) and edible coating (Xu et al., 2001), cooling is a common technique used to preserve the quality of agricultural and food products. Among the cooling techniques, immersion vacuum cooling (IVC) is an innovative cooling method, which is able to achieve a rapid cooling rate compared to traditional cooling methods such as air blast (AB) and immersion cooling (IC), and a much lower cooling loss compared to vacuum cooling (VC) (Cheng & Sun, 2006a; Drummond & Sun, 2008a; Sun & Zheng, 2006; Hu & Sun, 2000; Sun & Brosnan, 1999; Sun & Hu, 2003; Wang & Sun, 2001). The main advantage of evaporative cooling processes is the extremely fast temperature reduction achieved in the product (Pathare et al., 2012). Nevertheless, due to the presence of the surrounding liquid, the cooling time of IVC is comparably longer than that of VC. Therefore, measures to shorten the IVC cooling time would make this technique more competitive and attractive to food manufacturers. Controlling the pressure reduction rates during cooling is believed one of the ways to improve the cooling time (Drummond & Sun, 2012). However, as the IVC cooling effect is achieved through a

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combination of thermal conduction, convection and water evaporation, increasing the pressure drop rate is not the only alternative to reduce the cooling time. For instance, a shorter IVC cooling time of large pork hams (3.8 ± 0.2 kg) was achieved with a slower cooling rate (Feng, Drummond, Zhang, & Sun, 2013). The application of agitation during IVC has been previously suggested, to potentially reduce the IVC cooling time compared to VC (Cheng & Sun, 2006a; Drummond & Sun, 2008a, 2008b; Feng, Drummond, Zhang, Sun, & Wang, 2012). Although employing agitation to IVC offered substantial reduction of IVC cooling time (47.39%) of large pork ham to 4.6 °C (Feng et al., 2013), its effect on cooling smaller foodstuffs like sausages and the extent of its reduction had not yet been investigated.

Compared to the large meat joints previously cooled using IVC, sausages are small products, and thus can be cooled much faster. However, sausages also have the unique characteristic of being “packaged” in permeable casings, made from either natural or artificial materials. Although Irish sausages are typically freshly cooked before consumption, an increasing demand for cooked products is arising from the expansion of the catering and ready-to-eat sector. Rapid chilling increases product throughput and reduces cold room occupation (cooling) prior to storage. Subsequent chilled storage of cooked sausages throughout distribution and display is important for quality purposes, and crucial to insure safety (García & Heredia, 2011). Additionally, the successful use of immersion vacuum cooling to such “packaged” meat products can expand and develop the application of this technology for the processed meat industry, as well as to other packaged food products not previously considered.

In many previous VC and IVC studies, pressure reduction was controlled manually or indirectly. Wang and Sun (2004) obtained different pressure reduction rates by regulating the pump volume flow rate by adjusting position of a vacuum-releasing valve. In this way, instantaneous pressure could not be predicted in advance and pressure reduction rate during the cooling period was not constant or was unable to be exactly controlled. In IVC researches of Cheng and Sun (2006a) and Drummond and Sun (2008b), pressure drop rate was controlled manually by reaching some different desired pressure points at different required time. In this way, the pressure reduction had an approximate linear tendency. However, the achieved pressure reduction rate greatly relied on the experience of the operator. As a result, the experimental repeatability of pressure was very poor and the control of accurate pressure drop rate could not be achieved. For delicate foodstuffs like sausages, accurate pressure drop control is very important, as there is an increased risk of casing bursting with rapid pressure drop rates. It is therefore relevant to investigate the effects of different pressure reduction rates and the limitations intrinsic to the product.

The primary objective of this work is to evaluate the effects of different pressure reduction rates and agitation on cooling parameters and quality attributes of sausages stuffed in natural or artificial casing. To achieve this objective, the feasibility of applying IVC to cooked sausages made from natural hog casings and artificial beef collagen casings should be firstly investigated. Finally, relevant operational parameters that could optimise IVC cooling process without compromising sausage quality attributes were established.

2. Materials and methods

2.1. Sample preparation

Regular jumbo sausages stuffed in natural hog and artificial – beef collagen casings were purchased from a local butcher (Keenan & Kennedy, Finglas, Dublin, Ireland) at the same day from the same batch. The filling for both natural and artificial casings contained lean pork (43.3%), pork back fat (23.9%), rusk, salt-phosphate E450 (6), flavour, enhancer 621 (sodium glutamate), preservative E221, dextrose, spice extracts, gluten, and sulphur dioxide. Five linked sections (sausages) were considered as one unit. The two endings of each unit were fastened by thread while the middle sections were divided by twisting. In order to keep the similar size and shape for repetitions (especially for natural casing sausage which has a great variability in dimension), sausage links were carefully selected according to the shape and size. The average weight, diameter and length of each section were 80.95 ± 15.52 g, 3.07 ± 0.20 cm and 11.31 ± 1.49 cm for natural hog casing sausages and 43.41 ± 12.13 g, 2.44 ± 0.06 cm, 9.23 ± 0.79 cm for artificial beef collagen casing sausages, respectively.

2.2. Cooking and cooling procedures

Each sample unit was steam-cooked in a convection oven set at 83 °C (FCV6, Zanussi, Italy) until sausage core temperature reached 72 °C for 2 min. Samples were transferred into a transparent 5000 ml glass beaker (diameter: 18 cm) after cooking and completely covered with hot water (80 °C). A thermocouple (T-type, Model: SSA12115L700TS, Ellab A/S, Hillerød, Denmark) was perpendicularly inserted into the geometric centre of the sausage filling from the surface of the sausage to record the core temperature of sausage. Another thermocouple was used to monitor water temperature around the sausages. The beaker with samples was placed in the middle of the vacuum chamber (length: 80 cm; width: 45 cm; height: 45 cm) (Fig. 1). A wired mesh (diameter: 17.5 cm) with large holes was used to keep the sausages immersed in the liquid during the cooling procedure, preventing them from floating. For experiments including agitation, the magnetic stirrer was placed at the bottom of the beaker and agitation began from the start of processing (cooling) at the constant speed of 523 rpm. In both experiments (with or without agitation), a specially designed lid suspended at a certain distance above the beaker was utilised to prevent too much water from splashing out, without restricting generated vapour escape. During the cooling procedure, the chamber pressure dropped from atmospheric (1013.25 mbar) to a final pressure of 6.40 mbar. The final pressure of 6.40 mbar was selected because the products' surface started to freeze below this point. Three stages of pressure drop rates were employed, as shown in Fig. 2. Preliminary experiments were conducted to select the suitable pressure drop rates for the two different types of the casing sausages. Chamber pressure was allowed to drop freely from atmospheric to 320 mbar (1st stage) for all runs, after which a pressure drop rate of 60 mbar/min was employed to both artificial and natural casings from 320 to 50 mbar (2nd stage). From 50 mbar to 6.4 mbar, the pressure drop rate was again allowed to drop freely for all runs, and the evacuation rate was effectively regulated by the pump capacity (average: 5 mbar/min, 3rd stage). Results showed that sausages in artificial collagen casings could not withstand the pressure drop rate of 60 mbar/min and always burst during IVC at the second stage, while natural hog casings were undamaged. As a result, distinct pressure reduction rates at the second stage: L 60, L 80, L 100 mbar/min (for natural casing) and L 20, L 30, L 40 mbar/min (for artificial casing) were selected for investigation. The main reason for controlling the pressure drop rate during the second stage was that the most intensive boiling and evaporation happened to this stage during the IVC process. Additionally, controlling pressure reduction rate during this period of intensive evaporation also helps to prevent sausage from bursting during the procedure. The pressure drop rate at the 2nd stage was controlled by an electronic valve placed between the vacuum chamber and the vacuum pump. The valve was