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Effects of different cooling methods on shelf-life of cooked jumbo plain sausages

Chao-Hui Feng, Da-Wen Sun*, Juan Francisco García Martín, Zhi-Hang Zhang

FRCFT, School of Biosystems Engineering, University College Dublin, National University of Ireland, Belfield, Dublin 4, Ireland

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ABSTRACT

Three different cooling methods: commercial cooling and immersion vacuum cooling (IVC) with two different initial water temperatures (20 °C and 80 °C) were applied to cooked sausages. Linear pressure drop rate of 60 mbar/min with agitation was employed in the current experimental trials. Chemical (moisture and pH) and quality (colour and microbial analysis) parameters after cooling were monitored during 29 days of cold room storage (4 °C) and the shelf-lives of the sausages were determined. Results showed that IVC with cold water (IVCC) could achieve not only rapid cooling time to 4 °C (31 min), compared to IVC with hot water (IVCH) (41 min) and commercial cooling (251 min), but also a longer shelf-life. pH of IVCC samples was more stable during cold room storage than the other cooling methods. Core colour of IVCH sausage turned to be darker with time; all the samples became slightly redder after 15 days of storage. It was concluded that IVC could surpass commercial cooling method in terms of cooling time and shelf-life of the sausages. Additionally, IVCC (if the tap water used was hygienic enough) did not introduce external detrimental bacteria and possessed a higher cooling rate than IVCH without compromising the quality properties.

1. Introduction

Due to the rich composition in protein and fat (Paula, Colet, Oliveira, Valduga, & Treichel, 2011) as well as high water activity (Santos, González-Fernández, Jaime, & Rovira, 2003), shelf-life of many types of sausages is very short. They are either eaten immediately or dried to different degrees for preservation. Drying is one of the most common preservation methods for agricultural and food products (Sun & Woods, 1993, 1994a, 1994b, 1994c, 1997; Sun & Byrne, 1998; Sun, 1999; Delgado & Sun, 2002; Cui, Xu, & Sun, 2004) including sausages. For fresh sausages, it was reported that they could only be kept for 8–12 h without refrigeration while dry sausages could be kept for 1–5 weeks (Savic, 1985, p. 52, chaps. 3, 9). During the past couple of years, numerous efforts have been made to extend the sausage shelf-life, either by means of chemical reagents or by physical and package methods. In 2009, Diez, Santos, Jaime, and Rovira (2009) studied the effects of organic acid salts (potassium/sodium L-lactate, OAS), high hydrostatic pressure processing (600 MPa for 10 min, HPP) and the combination of the aforementioned two factors on the shelf-life of cooked Morcilla de Burgos (Spanish sausages). Results showed that OAS effectively reduced *Enterobacteria* population and gently inhibited *Pseudomonads* growth. The shelf-life of OAS-treated samples was consequently extended for up to three weeks. HPP considerably impeded the growth of the microorganisms and the shelf-life was prolonged even to four weeks. The combination of the two treatments showed a strong inhibition of *Enterobacteria* and *Pseudomonads* (Diez et al., 2009).

Shelf-life of sausages packed with different package materials has been comprehensively investigated as well, which included: 1) low-density polyethylene with and without vacuum and oxygen permeability of 500 cm^3 O_2/m^2 day; 2) formal copolymer of ethylene and vinyl alcohol with and without vacuum and oxygen permeability of 5 cm^3 O_2/m^2 day; and 3) nylon polyester with and without vacuum and oxygen permeability of 100 cm^3 O_2/m^2 day. It was discovered that packages (1, 3) without vacuum exhibited higher values in the sensory and oxidative rancidity evaluation (Paula et al., 2011).

In addition, the effect of chitosan film (C-film) and chitosan film with green tea extract (CGT-film) on prolonging sausage shelf-life and quality improvement was studied by Siripatrawan and Noipha (2011). It was concluded that the best results were obtained when sausages were wrapped with CGT-film: shelf-life of CGT-film-wrapped sausage could extend up to 20 days, which was 8 days more than control sample (without film). Furthermore, microbial growth of sausage covered by CGT-film was considerably retarded, probably due to the enhanced antimicrobial effect of

* Corresponding author. Tel.: +353 1 7167342; fax: +353 1 7167493.
E-mail address: dawen.sun@ucd.ie (D.-W. Sun).
URL: http://www.ucd.ie/refrig, http://www.ucd.ie/sun

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green tea extract. As for lipid oxidation, thiobarbituric acid (TBA) value of sausage wrapped by CGT-film was the lowest, which was due to antioxidant effect attributed to green tea polyphenols. Colour and texture of CGT-film wrapped sausages displayed small changes during cold room storage (4 °C) in comparison with control samples (without film) (Siripatrawan & Noipha, 2011).

Besides using chemical reagents or physical and package methods (Arvanitoyannis & Stratakos, 2012) for extending the shelf-life, it is generally recognized that cooling or freezing (Li & Sun, 2002) is an effective method for extending shelf-life of perishable food products. Among various cooling methods, vacuum cooling (Hu & Sun, 2000; Sun & Brosnan, 1999; Sun & Zheng, 2006; Sun & Hu, 2003; Wang & Sun, 2001, 2002), in particular immersion vacuum cooling – an innovative modified vacuum cooling to rapidly chill down the meat product with comparably lower cooling loss (Cheng & Sun, 2007; Dong, Chen, Liu, Dai, & Li, 2012; Feng, Drummond, Zhang, Sun, & Wang, 2012; Schmidt, Aragão, & Laurindo, 2010) – showed a potential to apply to cool sausages (Feng, Drummond, Zhang, & Sun, 2012). Comparative studies on inoculated cooked large beef joint samples cooled by VC, IVC (with hot cooking solution, 80 °C) and AB were carried out by Drummond, Sun, Vila, and Scannell (2009). In the experiments (Drummond et al., 2009), *Geobacillus, stearothermophilus* and *Bacillus atropheaus* were inoculated to the samples and microbiological analysis was performed directly after cooking and cooling, respectively. Results showed that total aerobic counts did not increase in inoculated IVC samples while there was significant increase in VC and AB samples (3 log units) ($P < 0.05$). Earlier, Burfoot, Self, Hudson, Wilkins, and James (1990) reported no significant differences observed in the total viable counts of beef joints (0.94 kg–7.1 kg) cooled by different cooling methods (AB, IC and VC) after 12 h storage (5 °C) (Burfoot et al., 1990) ($P > 0.05$). McDonald, Sun, and Kenny (2000) investigated the effects of four cooling methods, namely AB, slow cooling, IC and VC, on microbiological safety of cooked beef joints (3.75 kg), and stated that VC samples had the best microbiological quality and safety margins: samples cooled by VC displayed significantly lower *Psychrophiles* (4.8) and *Mesophiles* (1.6) counts ($\log_{10}$ no. per gram) than IC samples (5.9 and 3.0, respectively) after 7 days storage ($P < 0.05$).

In all these previous studies on vacuum cooling, the microbial evolution of samples after different cooling methods was monitored for only up to 7 days. In addition, these studies were focused on large meat joints, there is a lack of study on much smaller samples such as sausages, in particular, no study has been conducted on the shelf-life after long term storage for sausages cooled by IVC. Therefore, the aim of the present work was to investigate the effects of different cooling methods (IVC with hot water, cold water and commercial cooling) on shelf-life of cooked jumbo sausages.

2. Materials and methods

2.1. Sample preparation

Two batches of regular plain jumbo sausages with natural hog casing were bought from a local butcher (Fenelons Butchers, Stillorgan, Co. Dublin, Ireland). Five linked sections (sausages) were regarded as one unit. For each unit, two endings were fastened by thread while the middle sections were twisted to divide the section. The average weight, diameter and length of each section were 76.52 ± 1.12 g, 3.51 ± 0.17 cm, and 9.49 ± 0.06 cm, respectively.

2.2. Cooking and cooling processing

Steam cooking (convection oven setting at 83 °C) was employed to cook the sausages until the core temperature reached 72 °C for 2 min. For immersion vacuum cooling, one unit of cooked sausages was transferred into a transparent 5000 ml beaker and completely covered with hot water (80 °C) for IVCH and cold water (20 °C) for IVCC, respectively. An agitation bar was placed at the bottom of the beaker and stirring from the very beginning of the processing at a speed of 523 rpm. Wired meshes with large holes were used to hold the sample under the water surface and above the agitation bar. A special designed lid, which kept a certain distance above the beaker, was used to avoid too much water splashing out while allowing the generated vapour to escape. The linear pressure drop rate was controlled by a program (Labview software, v4.1, National Instruments, USA). Two different stages of pressure drop rates were applied. Linear pressure drop rate of 60 mbar/min was utilized from flash point until 50 mbar for the first stage, 5 mbar/min was used thereafter until a final pressure (6.4 mbar). The condenser in the system was connected to a refrigerated circulator (FP50, Julabo, Germany), setting at 0 °C. For the commercial cooling, samples were cooled according to a survey of common industrial cooling: cooked sausages were immersion cooled in running tap water for 10 min at room temperature and then directly transferred into cold room (4 °C) for cold storage.

Before the experiments, all the equipments were sterilized by using 75% alcohol and all the beakers, meshes, agitation bars were immersed in the disinfectant overnight and sterilized in autoclave in the following day.

The sausages were finally chilled to a core temperature below 4 °C. A range of preliminary experiments were carried out to obtain the optimal cooling conditions, cooling time to 4 °C and cooling profile (detected by T-type thermocouple) for each cooling treatment. After that, experiments were preformed without inserting thermocouple to avoid contamination. Based on preliminary experimental results, cooling time for IVCC, IVCH and commercial cooling were fixed at 31 min, 41 min, and 251 min, respectively. Each sausage unit was sterilely cut into five individual sections, and each section was vacuum packaged (final vacuum level: 10 mbar) separately with low-density polyethylene vacuum bag (length: 30 cm, width: 20 cm). The vacuum packaging bags were transparent, strong and resistant to gas exchange, and they were specifically designed for use with the "WeBo Matic" vacuum packaging systems (C10H, Computer System 3000 Sensor, Geprüfte Sicherheit, Germany). Each section of sausage after packaging was stored in darkness at 4 °C cold room for up to 29 days. Raw sausages were analysed on day 1 whilst treated samples were analysed on days 1, 8, 15, 22, 29. The experiment was repeated in duplicate using different batches of sausages.

2.3. pH and microbiological analysis

The pHs of raw and cooled sausage samples were measured by homogenizing 10 g of the product with 90 ml of distilled water for 2 min, as described by Zdolec et al. (2008). pH values were determined using a digital pH-meter (Thermol Scientific, Orion Star Series, Singapore) and repeated three times.

For microbiological analysis, a slice of 25 g sausage (casing included) was sterilely weighted, then homogenized with 225 ml Ringer solution (Oxoid, Basingstoke, UK) for 2 min using a laboratory blender (Stomacher 400, Seward, London, UK). After 1/10 serial dilution, 0.1 ml of diluted samples were spread on agar plates. Total viable count (TVC) was determined on plate count agar (PCA, Oxoid, Basingstoke, UK), incubated at 30 °C for 48 h. Lactic acid bacteria (LAB) were performed on MRS agar (Fluka, Switzerland) containing 1 ml/l of Tween 80 (Sigma–Aldrich, St. Louis, France) and incubated at 30 °C for 48 h. Enterobacteria determination was tested in VRBGA agar (Fluka, Spain), incubated at 30 °C for 48 h; and Pseudomonads, were determined on the Pseudomonads agar (Oxoid, Basingstoke, UK) with 48 h incubation at 30 °C.