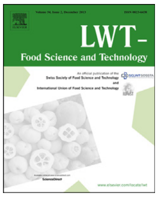
LWT - Food Science and Technology xxx (2014) 1–12

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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



Evaluation of natural hog casings modified by surfactant solutions combined with lactic acid by response surface methodology

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ARTICLE INFO

Article history:
Received 26 November 2013
Received in revised form
4 March 2014
Accepted 8 March 2014

Keywords:
Natural hog casing
Sausage
Surfactant
Lactic acid
RSM

ABSTRACT

The effects of soy lecithin concentrations (X_1, 1:25–1:30), soy oil concentrations (X_2, 0%–2.5%), residence time for surfactant solutions (X_3, 60–90 min) and lactic acid concentrations (X_4, 18–21 ml/kg) on technological properties of hog casings were evaluated by response surface methodology (RSM). The burst pressure, maximum rupture force, and elongation of both uncooked treated casings (UTC) and cooked treated casings (CTC) were determined. The histological structures of UTC and CTC were observed by light microscopy and transmission electron microscope and images illustrated that casings became more porous after treatments. Polynomial regression models on burst pressure of UTC ($P < 0.05$) and CTC ($P < 0.05$), maximum rupture force of UTC ($P < 0.01$) and elongation of CTC ($P < 0.01$) were established. Sausage was made using modified casing with the best resistance of burst pressure or rupture force. Bursting during immersion vacuum cooling did not happen to sausages made from these modified casings.

1. Introduction

Natural casings are widely used in sausage manufacture due to its smoke penetration, excellent sausage flavour, satisfactory elasticity and other beneficial properties (INSCALL, 2006). Sausages prepared from natural casings have a special tender bite, which is generally preferred by consumers compared to other sausages made from artificial casings (INSCALL, 2006). Casings should be strong enough: 1) to resist pressures during batter filling and stuffing; and 2) to hold the batter during the heating and smoking processes (Bakker, Houben, Koolmees, Bindrich, & Sprehe, 1999; Harper, Barbut, Lim, & Marcone, 2012; Simelane & Ustunol, 2005). As natural casings are variable in calibre and elongation capacity, casings can burst during stuffing (Houben, Bakker, & Keizer, 2005; Santos, Müller, Laurindo, Petrus, & Ferreira, 2008). Therefore, there is a high demand for improving casing's properties so as to improve the stuffing efficiency among sausage manufactures (Santos et al., 2008). Houben et al. (2005) investigated the effect of trisodium phosphate on stuffing efficiency. The gliding ability of treated casings increased and so stuffing processing was accelerated. The effects of surfactant solutions (soy oil combined with soy lecithin) on properties of natural hog casings were studied by Santos et al. (2008), and treated casings became much more elastic and tensile than untreated ones. Santos et al. (2008) also mentioned that water vapour permeability (WVP) of casing increased when casings were treated with lactic acid. Although an increase of WVP may be undesirable for the current sausage manufacturing, it would probably facilitate the immersion vacuum cooling (IVC) of these products, by allowing water vapour to escape through casing easily, thus reducing the incidence of sausage bursting during IVC.

Like freezing (Delgado, Zheng, & Sun, 2009; Zheng & Sun, 2006), drying (Sun, 1999; Sun & Byrne, 1998; Sun & Woods, 1993, 1994a, 1994b, 1994c, 1997; Delgado & Sun, 2002; Cui, Xu, & Sun, 2004) and edible coating (Xu, Chen, & Sun, 2001), cooling is a common technique used to preserve the quality of agricultural and food products. For ready-to-eat foods, cooling is also a very important step to ensure safety before consumption. As an improvement of vacuum cooling (Sun & Zheng, 2006; Hu & Sun, 2000; Sun & Brosnan, 1999; Sun & Hu, 2003; Wang & Sun, 2001), immersion vacuum cooling is an innovative cooling method, especially for cooked meats (Cheng & Sun, 2006; Drummond and Sun, 2010; Feng, Drummond, Zhang, Sun, & Wang, 2012), which has the potential to achieve a high cooling rate (compared to conventional cooling methods) with a low cooling loss (compared to vacuum cooling). Although IVC offers greater advantages for reducing cooling time of large products, using this technology on large

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http://dx.doi.org/10.1016/j.lwt.2014.03.012

batches of cooked sausages would also be advantageous. From the research point of view, the application of IVC to such products allows a study how this particular food system of comminuted meat filled in a natural permeable membrane (casing) responds to this evaporative cooling process. Our previous studies (Feng, Drummond, Zhang, & Sun, 2012a, 2012b) indicated that the sausages were able to be cooled to below 4 °C by IVC. However, there was an increased risk of casing bursting when a high pressure drop rate was applied in IVC process. Therefore, there is a need to increase the strength of the casing in order to improve its performance during IVC process.

Response surface methodology (RSM) is widely used to model and optimise food processes (Azarpazhooh & Ramaswamy, 2012; Battaiotto, Lupano, & Bevilacqua, 2013; Deswal, Deora, & Mishra, 2014; Emadzadeh, Razavi, & Mahallati, 2012; Noshad, Mohebbi, Shahidi, & Mortazavi, 2012; Saxena, Bawa, & Raju, 2012; Tiwari, O'Donnell, Muthukumarappan, & Cullen, 2009; Xi and Wang, 2013; Yu, Ramaswamy, & Boye, 2012). It can interpret the relationship between the responses and variables, especially when a response is affected by one or more factors and the effect of the factors over the response is completely unknown (Murphy, Gilroy, Kerry, Buckley, & Kerry, 2004). The experimental design provided by RSM can also greatly reduce the number of experiments, compared with the full factorial experimental design (Arroyo-López, Orlić, Querol, & Barrio, 2009; Shih, Kuo, Hsieh, Kao, & Hsieh, 2008; Tiwari, Muthukumarappan, O'Donnell, & Cullen, 2008). Several previous studies designed by RSM were carried out by a single run for each of the different variable with replicates only at the centre points (Gan et al., 2007; Gu et al., 2005; Velioğlu, Velioğlu, Boyaci, & Şefik, 2010). Previous studies focused on applying RSM to optimising ingredients of sausages like frankfurters (Pereira et al., 2011), bologna (Cofrades, Guerra, Carballo, Fernández-Martín, & Jiménez Colmenero, 2000) and pork sausages (Murphy et al., 2004; Pietrasik, 1999). However, analysis of the effects of different chemical reagents on mechanical attributes of casing using RSM has not been done.

In order to accelerate IVC cooling rate of cooked sausages without increasing the incidence of bursting, the properties of natural hog casings were modified by a combination of surfactant solutions (soy lecithin and soy oil) and lactic acid. The objective of this study is to evaluate the effects of soy lecithin and soy oil concentration, residence time after submitting to surfactant, and the concentration of lactic acid on resulting mechanical properties of natural casing. Following this, the most suitable modified casing for IVC processing was selected and validated. The results of this study may provide a modified casing suitable for IVC of sausages for the industry.

2. Materials and methods

2.1. Modified casing

Segments (length: 70 cm, thickness: 0.02 cm) of natural hog casings (Irish Casing Co. Ltd., Tullamore, Co. Offaly, Ireland) were firstly rinsed with distilled water (25 °C) for 10 min to eliminate the salt on the surface. The desalted casings were then submerged in surfactant solutions, composed by lecithin and soy oil at different ratios to water (25 °C) for residence time of 60, 75, 90 or 105 min. Afterwards, treated casings were removed from the surfactant solution (without rinsing) and gently mixed with a slush salt (NaCl) containing lactic acid. The corresponding time for casing stored in slush salt (25 °C) was the same as the residence time for casing treated in surfactant solution. Casings without treatment (control) were desalted by tap water (25 °C) and submerged in distilled water before tests.

2.2. Burst pressure

Burst pressures of uncooked treated casing (UTC) and cooked treated casing (CTC) were measured using a method described by Benli et al. (2008). All the casings were rinsed with tap water (25 °C) for 5 min to eliminate all the modified solution before tests. A segment of casing (length: 22.0 cm) was tied up onto a horizontally placed plastic pipe (length: 34.1 cm; outside diameter: 1.5 cm; inside diameter: 1.3 cm) with seven sets of four holes (diameter: 0.4 cm, 2.0 cm between each hole) (Fig. 1(a)). In other words, the casing was evenly filled through 28 water outlets from the pipe. One end of the pipe was connected to a water source and a pressure transducer, and the other end was connected to a shut-off valve. In order not to damage the casing, the two casing segment's ends were firstly protected by soft natural rubber segments and then tied up using cable ties. For uncooked casing, tap water (20 °C) was used to fill the casing at the constant flow rate of 1 L/min. After switching off the valve, the internal pressure of the casing increased. Burst pressure was defined as the pressure required to break the casing. For cooked treated samples, casings were firstly loaded onto the pipe and then horizontally immersed into a circulating hot water bath (80 °C) (GD120, Grant Instruments Ltd., Chelmsford, UK) for 5 min before testing (simulating cooking). Casings remained submerged in the hot water during the whole test, and the flowing water used to fill the casing was from the outlet of the water bath (80 °C). The device was the same as that used for measuring the uncooked one. Burst pressure data were recorded using a data logger (Squirrel SQ2040, Grant Instrument Ltd., Chelmsford, UK) which was connected to the pressure transducer (Eirelec LG4.0, Digitron Italia, Ferentino, Italy) with 0.09 s acquisition interval. The pressure transducer was calibrated according to the method of "dead weight calibration" (Bell, Bignell, & Dunlop, 1992). The water flow rate was controlled using a valve and a flow meter (FR2000 Acrylic Flowmeters, Key Instruments, Trevose, PA, USA).

2.3. Maximum rupture force and elongation

The maximum rupture force was defined as the force to break a segment of casing. The test device was similar to that described in the experiment of Benli et al. (2008). In the current case, a solid aluminium bar (diameter: 1.94 cm; length: 15.5 cm) was split axially into two equal halves (Fig. 1(b)). A casing (length: 10.0 cm) was rinsed with tap water before loading onto the bar. The ends of each half bar were fixed to support brackets that were fixed to a tension testing system (H50KS-0043, Tinius Olsen Ltd, Surrey, UK). The force for cooked casings was determined in the same manner as for uncooked casings, with the only difference being that casings were loaded onto the two half bars and firstly submerged into the hot water bath (80 °C) for 5 min (simulating cooking) before tests. The lower bracket was fixed, while the upper bracket was attached to a load cell (1 kN, H1K, Tisnius Olsen Ltd, Surrey, UK) to measure the force. The cross-head speed was 5 mm/min.

The elongation was determined by the following equation:

$$\text{Elongation}\ (\%) = \frac{E_m - E_i}{E_i} \times 100\% \qquad (1)$$

where E_m is the extension at the maximum rupture force and E_i is the initial extension.

2.4. Experimental design

The simultaneous effects of four treatment variables on burst pressure, maximum rupture force and elongation were studied using

Please cite this article in press as: Feng, C.-H., et al., Evaluation of natural hog casings modified by surfactant solutions combined with lactic acid by response surface methodology, *LWT - Food Science and Technology* (2014), http://dx.doi.org/10.1016/j.lwt.2014.03.012