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Original scientific paper

Ensuring the safety of cooked and smoked sausages of a narrower diameter, in a cellulose casing, by heat treatment

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A R T I C L E I N F O

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A B S T R A C T

The aim of this work is to ensure the safety of finely chopped cooked sausages stuffed in a cellulose casing, diameter 21 mm. Safety is ensured by thermal treatment of the level of pasteurization in a chamber under a defined thermal treatment program. By monitoring the temperature in the product's thermal center at different control positions in the chamber, temperatures of 75.26°C–77.11°C were determined with a thermocouple. In doing so, the products spent 8–9 minutes at a temperature higher than 70°C, and 18–20 minutes at a temperature higher than 55°C. Considering that it is a small diameter product, the heat intensively penetrates to the thermal center and thus ensures the safety of the product. However, due to the relatively short time of the heat treatment, the pasteurization values (pv) at the control points were in the range of 18.3–26 minutes. Therefore, we conclude that ensuring the safety of products with a narrower diameter is achieved only by controlling the temperature in the thermal center of the product, and not with pv values. Considering that this sausage is a perishable product, it is necessary to provide a proper cold chain (0–4°C) after manufacture so that the product remains suitable for consumption within the period defined in a shelf-life study.

1. Introduction

In recent years, there has been an increased demand for minimally processed, high-quality, convenient food products, with fewer additives and longer shelf life (*Balamurugan et al.*, 2018). In-package thermal pasteurization is widely used to eliminate pathogens in ready-to-serve foods, and factors affecting the inactivation of pathogens and shelf-life extension have been extensively studied (*McCormick et al.*, 2006). Pasteurization is a mild heat treatment in which food is heated to below 100°C. It is used to minimize health hazards from pathogenic micro-organisms in low-acid foods and to extend the shelf-life of acidic foods such as fruit juices for several days or weeks by the destruction of spoilage micro-organisms and/or enzyme inactivation. (*Fellows*, 2009). Pasteurization is a relatively mild heat treatment, compared to heat sterilization, and it causes smaller changes to the nutritional, functional, and sensory characteristics of most foods. However, the shelf life of pasteurized foods is usually only extended by a few days or weeks, compared to many months with the more severe heat sterilization treatments (*Fellows*, 2022). Pasteurized products include all those meat products which during production were exposed to the preservative effect of temperature below the boiling point of water, whereby a temperature of at least 70°C is achieved in the thermal

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center, in accordance with the Regulations, or whereby the heat treatment procedure is such that a temperature of at least 65°C is reached in the thermal center of the product, over the time period required to reach a pasteurization value (pv) equal to or above 40 (*Official Gazette of the Republic of Serbia*, 2019). Temperatures of 72°C and 74°C are generally defined in the hazard analysis and critical control point (HACCP) documentation of food business operators as critical limits for the assessment of pasteurization for meat products (*Raseta et al.*, 2021).

Sausage is one of the earliest forms of food processing and became an art distinctive to particular locations during Middle Ages and a means of preserving meat (*Ebunoluwa et al*., 2022). Sausage is minced meat or a combination of meats blended with seasonings and spices stuffed into a casing or container (*Savell and Smith*, 2009). Cooked sausages are meat products that contain meat batter as a base and are preserved by heat treatment, usually pasteurization (*Vuković*, 2012). Smoked sausages are very popular and there are two types, uncooked and cooked; raw smoked sausages are made from cured or uncured meat that is ground and mixed with spices, salt, or other non-meat items and stuffed into casings to form sausages that are then smoked and refrigerated. Cooked smoked sausages include emulsion type and coarse ground sausages (*Topel et al.*, 2013).

In accordance with the current domestic legislation (*Official Gazette of the Republic of Serbia*, 2019) cooked sausages are meat products obtained from meat, fatty tissue, connective tissue, offal, blood products, and supplements, where part of the filling can be meat dough and which, after being filled into casings or molds, are heat-treated at the temperature of pasteurization, with or without smoking. Salt, brining salts, water, spices, spice extracts, sugars, and additives can be used as additives in the production of cooked sausages, smoke aromas, and natural aromas.

Cellulose casings are one of the most popular types of artificial casings that are used in meat processing, with the others being collagen and plastic (*Marchello and Garden-Robinson*, 2017). Cellulose casings have stronger mechanical properties than other sausage casings, making them the preferred skin material for cooked and/or smoked products (*Sreenath and Jeffries*, 2011). Cellulose is a fibrous material that plays a structural role in plants, where it withstands large osmotic pressure and has a load-bearing function (*Savić and Savić*, 2016). Cellulose is another glucan, but unlike α-amylose and amylopectin, the glucose units are linked by β(1–4) bonds. When heated, cellulose fibers break down at 180°C (without melting) and burn at temperatures exceeding 290°C. Cellulose does not dissolve in water, diluted acids, or in many organic solvents (*Thompson et al.*, 1995).

2. Materials and methods

Cooked sausages were produced by thermal treatment of the stuffed batter in an artificial cellulose casing (Figure 1). During filling, care was taken to ensure that the casing was well filled with stuffing, without damage, deformations, or creases.

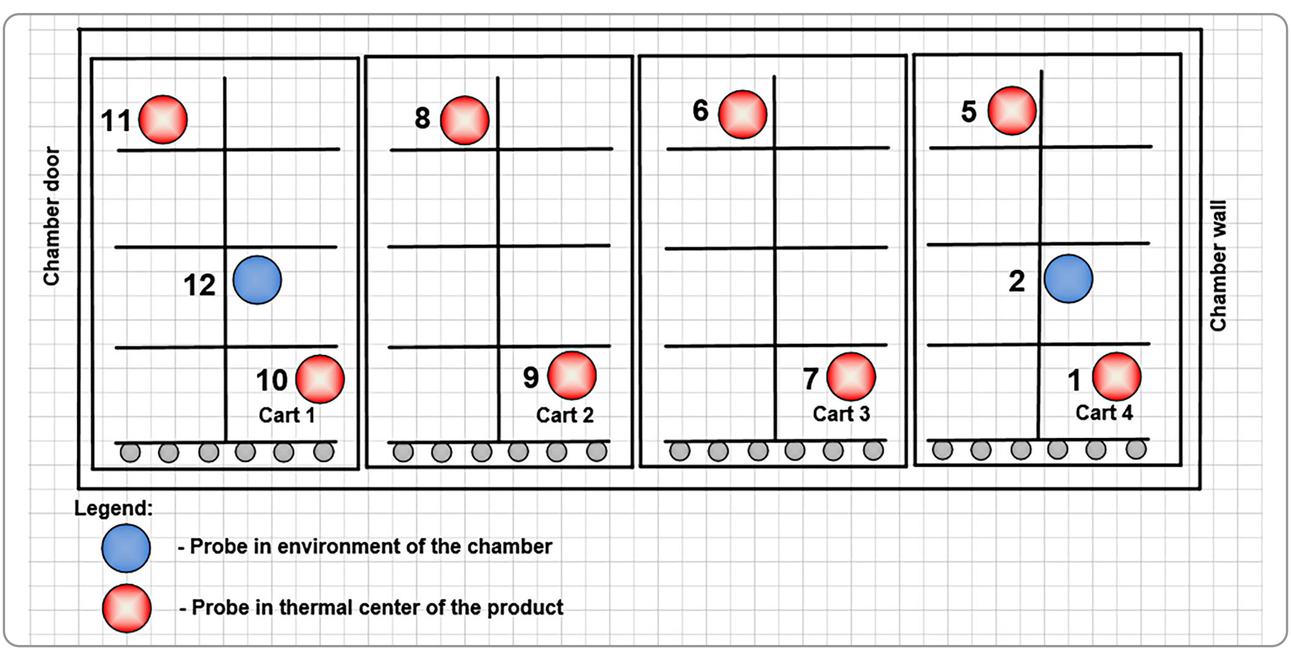

Figure 1. Stuffed batter in artificial cellulose casing placed on the cart before pasteurization

Figure 2. Cooked sausages on the cart after pasteurization

Figure 3. Plan of placement of probes in the thermal center of the product (red color) and in the autoclave medium — environment of the chamber (blue color), seen from the side

There were no air bubbles, gelatinous mass, or separated fat under the casing. The production of meat batter is the most sensitive operation in the production process of cooked sausages. The basic ingredient of cured sausages, in addition to the meat batter, is fat tissue. The sequence of adding the additives is of particular importance when making the filling for cooked sausages. First, phosphate is added (its role is to relax the myosin complex in the muscle tissue so that the proteins can bind water), then nitrite salt, and finally starch is added to draw water.

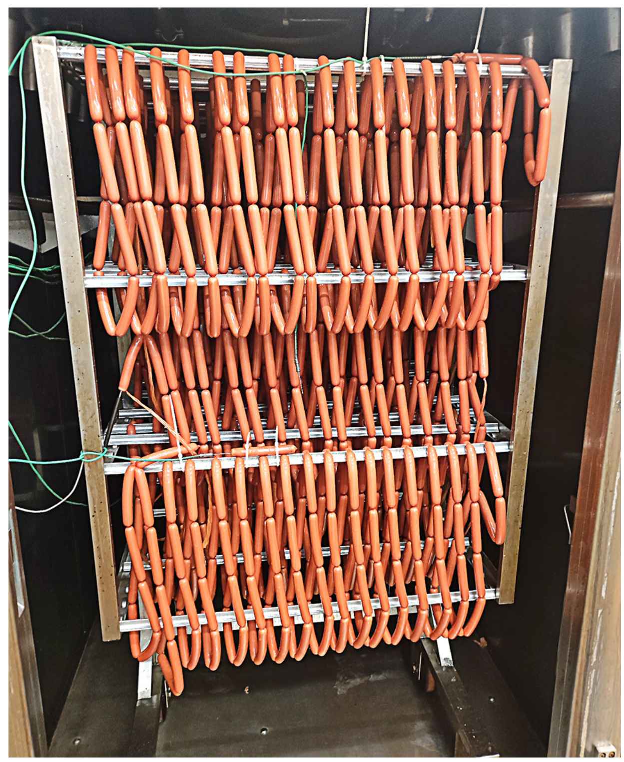

Figure 4. Arrangement of probes on the cart with the product in the chamber

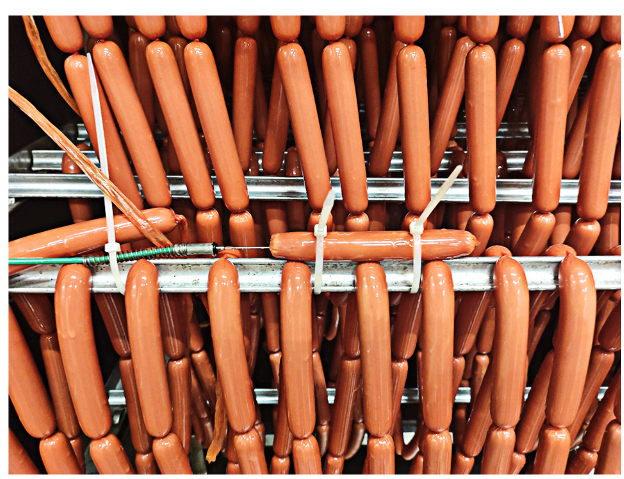

Figure 5. Probe placed in the thermal center of the product on a cart

The basis of quality is quality raw material. Fresh meat intended for the production of cured sausages retains its freshness if the number of microorganisms on its surface is small and if they cannot multiply in further processing. That is why the initial level of contamination in fresh meat as a raw material is decisive for the fresh and desirable taste of cured sausage (*Brauer*, 2010).

The heat treatment process consisted of several production steps, according to the previously set regime in chamber no. 1, Maurer type. The production steps consisted of the following stages:

1. Cooking up to 55°C, medium chamber, in an atmosphere of saturated water vapor for 10 minutes
2. Drying at 55°C for 35 minutes
3. Smoking and cooking at 55°C, medium chamber for 10 minutes
4. Drying at 55°C for 10 minutes
5. Cooking at 78°C, medium chamber in an atmosphere of saturated water vapor, until reaching 74°C in the thermal center of the product, for 15 minutes

The total time of heat treatment was 80 minutes.

Produced in this way, the cooked sausages were tender and juicy, with a pleasant characteristic taste that was complemented by the smell of smoke and spices (Figure 2)

Measurements were carried out in the heat treatment chamber during the regular production of finely chopped sausage in a cellulose casing. Measurements were performed with Ellab thermocouple (E-Val Pro, serial number 411982, validated software — US FDA, 21 CFR part 11, GMP, ver. 4.6.1.0), and the Ellab software, Val-Suite Prover, was used to prepare the technical report, 5.2.015.

Thermocouples with compensating cables were used, a total of 10 probes, of which 8 were placed in the thermal center of the product, in accordance with FAO recommendations (Channels 1, 5, 6, 7, 8, 9, 10, and 11), while 2 were placed in the medium (Channels 2 and 12) as depicted in Figures 3, 4, and 5.

By placing the probes in the manner shown in Figure 4, the possible falling out of the probe was

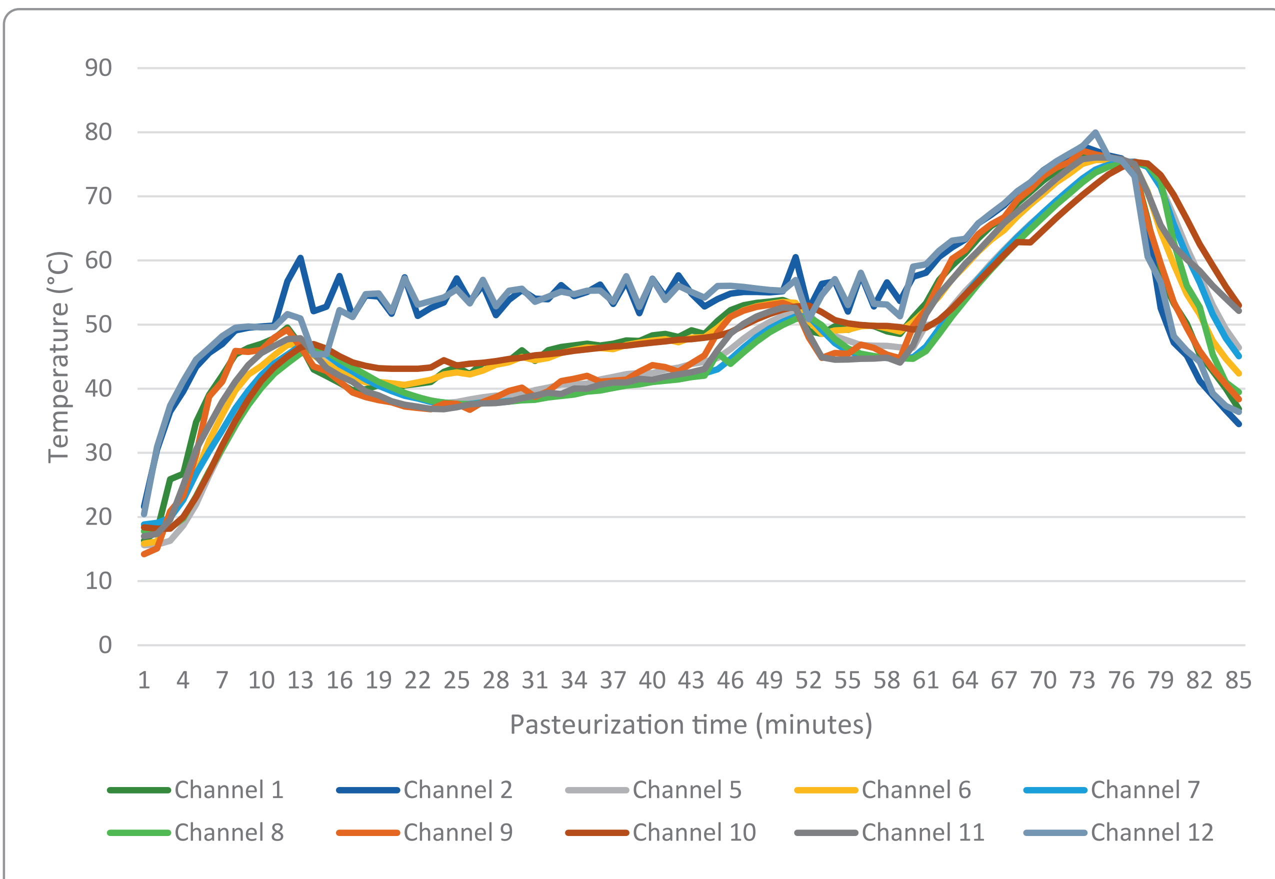

Figure 6. Temperature in the thermal center of the product and in the chamber environment during the pasteurization process

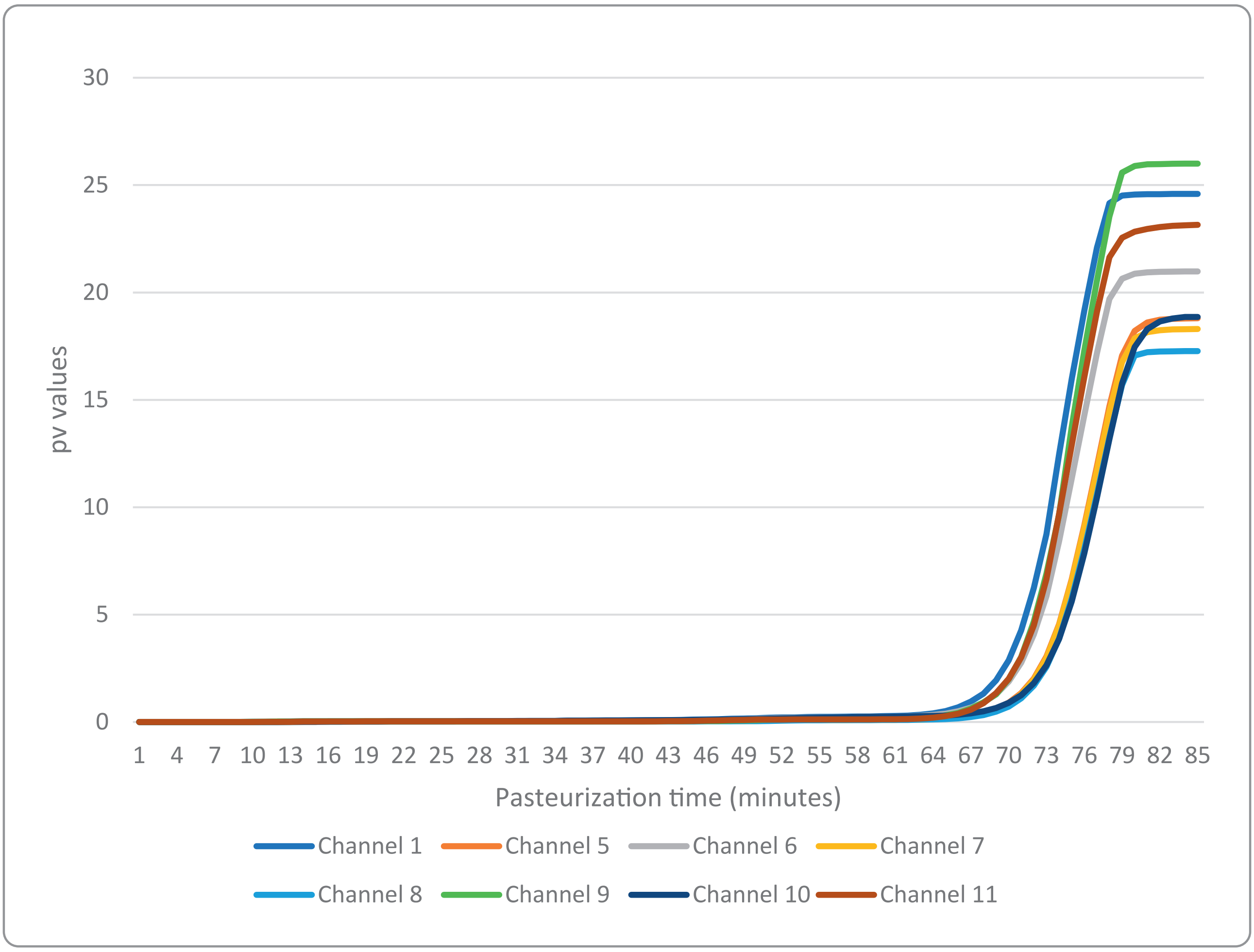

Figure 7. pv value during the pasteurization process

prevented; this can occur because the cellulose coating breaks very easily.

Temperature and pv values were recorded at one minute intervals.

3. Results and discussion

The process of monitoring the pasteurization of cooked sausages of a narrower diameter (21 mm) is presented Figures 6 and 7. Figure 6 presents the temperature in the thermal center of the product and in the chamber environment during the heat treatment. Figure 7 shows the pv values during the procedure monitoring.

The conclusions of monitoring the pasteurization process of cooked sausages of a narrower diameter (21 mm) are presented in Table 1.

Analyzing the obtained results, we can conclude that the process of heat treatment of finely ground sausages in a cellulose casing was uniform considering the obtained results (for 8–9 minutes, the thermal center of the product was at a temperature above 70°C and for 18–20 minutes, was at a temperature above 55°C). The maximum temperatures reached in the thermal center of the product were from 75.26°C to 77.11°C, which is in accordance with the legal regulations (*Official Gazette of the Republic of Serbia*, 2019). In this way, the safety of the product that was pasteurized under the given regime was ensured.

The use of p-value in the optimization of pasteurized sausages confirms and ensures the safety of the product in the defined storage conditions (*Raseta, et al.,* 2021). Given that the diameter of the sausage was small, 21 mm, heat penetration took place intensively during heat treatment, as did heat loss during cooling. Therefore, there was not enough time to generate a pv value for 40 minutes. The obtained pv values ranged from 18.8 minutes (Channel 5) to 26 minutes (Channel 9). This is the very reason the pv value is not suitable as a safety parameter for sausages with a narrower diameter. Also, the heat treatment regime included pasteurization of this product for 18 minutes (Channels 1, 7, 8, and 9), 19 min-

Table 1. Measurement results obtained by monitoring pasteurization in chamber no. 1. Maurer type

Probe channel	Position of the probe	Max. achieved core temperature (°C)	Time spent above 70°C (minutes)	Time spent above 55°C (minutes)	pv values (minutes)
1	Thermal center	76.69	9	18	24.59
2	Environment of the chamber	80	/	/	/
5	Thermal center	75.46	8	19	18.80
6	Thermal center	75.71	9	19	20.98
7	Thermal center	75.36	8	18	18.30
8	Thermal center	75.26	8	18	17.27
9	Thermal center	77.11	9	18	26.00
10	Thermal center	75.35	9	18	18.89
11	Thermal center	76.06	9	19	23.15
12	Environment of the chamber	80	/	/	/

utes (Channels 5, 6, and 10), and 20 minutes (Channel 11). Out of a total of 80 minutes of the heat treatment program, the finely chopped sausages spent only 18–20 minutes at pasteurization temperatures. Also, due to the porosity of the cellulose casing, during drying and smoking operations and during heat treatment, the product loses water and acquires a more desirable color. The cart with the product was weighed before being sent to heat treatment and after the pasteurization process was completed. The average weight of the cart was 95.36±0.25 kg before heat treatment and 85.52±0.24 kg after heat treatment. The measurements were made on a floor scale in the heat treatment room.

4. Conclusion

Thermal pasteurization is an important unit operation to the food industry for producing high-quality foods with extended shelf-life in refrigeration or cold storage

Ensuring the safety of products with a narrower diameter is achieved only by confirming the required temperature in the thermal center of the product, and not by confirming pv values.

To ensure the safety and quality of pasteurized cooked sausages within the defined shelf life, they need to be under cold chain conditions (from 0° to 4°C) during storage, transport, and trade.

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