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Optimization of pasteurization of meat products using pasteurization values (p-values)

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Abstract. This study aimed to examine the effect of shortening the effective heat treatment time by 15 minutes for finely and coarsely chopped sausages and canned meat in pieces packed in polyamide casings with diameters of 75 and 90 mm. Product safety was ensured in accordance with legislation and with the producer food safety system. Optimization led to a decrease in p-values for finely chopped sausages (diameter 90: 148.8 → 97.64 minutes; diameter 75: 111.2 → 58.4 min), coarsely chopped cooked sausages (diameter 90: 115.5 → 79.1 min; diameter 75: 245.3 → 106.6 min) and for canned meat in pieces (diameter 90: 249.7 → 95.91; diameter 75: 213.9 → 48.42 min). The use of p-value in optimization confirms the pasteurization level and ensures the safety of the product in the defined storage conditions. It is also possible to compare the levels of heat treatment for different products that are differently packaged.

1. Introduction

Thermal processing is still one of the most effective methods for inactivating undesirable microorganisms in foods. Heat is used to inactivate pathogens and in aid in development of typical flavours, aromas, texture, and colour of a boiled (cooked) food [1]. 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 geothermal centre, in accordance with the Regulations [2], while the required time duration at the defined temperature in the geothermal centre is not stated in the Regulations.

Pasteurized meat products belong to easily perishable foods, with physicochemical properties (water activity (a_w), pH) that enable the growth of microorganisms. Destruction of microorganisms during heat treatment depends on temperature and heating time, and the peak of destruction depends on the natural resistance, number, and phase of reproduction of microorganisms, as well as on the properties of the substrate [3]. Therefore, in production, it is necessary to provide the conditions for ensuring a cold chain so that the product retains the quality properties it possesses for its defined shelf life. To ensure the safety and quality of pasteurized products within defined shelf life, they need to be under cold chain conditions (conditions of storage, transport, and trade at temperatures from 0° to 4°C).

The optimization of the heat treatment process described herein was aimed at a complete understanding of the pasteurization process while ensuring the safety and quality of meat products within their defined shelf life. In this way, the consumption of energy required for the realization of heat treatment of pasteurization levels is reduced, while the aroma of the product is intensified.

Pasteurization destroys vegetative forms of bacteria, while spores survive. The lethality of the pasteurization process is that necessary to destroy *Enterococcus faecium* according to the 5D concept, which is > 40 [2]. The D-value (decimal reduction time) is the time necessary to reduce by 90% a microbial population present in a well-defined medium, and it is indicative of the thermal resistance of a microorganism at a constant temperature [4]. Knowledge of the D-values for a particular micro-organism makes it possible to design thermal processes that target that specific organism [5]

The limit for pasteurization value (hereafter, p-value) is calculated based on the time for a one decimal reduction of the stated microorganism, relative to the average level of contamination (10^6 cfu/g) multiplied by product weight, and is expressed in minutes.

This research aims to optimize the pasteurization process by applying p-values, which improve the overall process control, reduce costs, and improve the sensory properties of the product, which is less exposed to the effects of elevated temperature.

2. Materials and Methods

Systematic monitoring of the pasteurization process was performed in real-time over one year in a meat industry production plant during regular production. Heat treatment was validated for finely chopped sausages (diameters 90 and 75 mm), coarsely chopped sausages (diameters 90 and 75 mm) and canned meat in pieces (diameters 90 and 75 mm). Validation of a minimum pasteurization time was done for each specific food-thermal process, by inserting a thermocouple into the “coldest” spot of the food, and ensuring that this point is submitted to the minimum pasteurization value required [1]. Validation was realized during regular production in Eller brand heat chambers (single door chamber that can accommodate 4 trolleys) before and after shortening the effective pasteurization time by 15 minutes. Accurate and precise recording of the temperature in the geothermal centres was realized using a thermocouple, ELLAB, model E Val Pro, with six compensating cables. The thermocouple is a simple, widely used component for measuring temperature [6]. Special attention was paid to the placement and fixation of probes in the geothermal centre while ensuring the defined positions during pasteurization. The thermocouple allowed us to monitor the temperature in real-time during pasteurization. The time frame was monitored within the Ellab E Val Pro thermocouple software, in minutes at which the mass of the product was at specific temperatures during heat treatment (55°C, 70°C, 72°C and 74°C were recorded).

The temperature of 55°C is important because it is considered at that level, heat treatment of pasteurization level is initiated, in accordance with the method of determining the p-value according to Vukovic and Nitsch [7]. The temperature of 70°C is defined as the limit to be reached during pasteurization in a geothermal centre [2]. Temperatures of 72°C and 74°C are generally defined in the HACCP documentation of food business operators as critical limits for the assessment of pasteurization for meat products.

The time frame for maintaining the temperature in the geothermal centre for these temperatures (55°C, 70°C, 72°C, and 74°C) was determined. Then, based on the mass of the product and the heat treatment graph, the p-value was calculated.

The p-value is determined from the lethal effects measured at the cold point of the product during the heat treatment. The pasteurization process is validated by monitoring F_{70} values in relation to the thermoresistant microorganism *Enterococcus faecium*, integrating temperatures of over 55°C at the geothermal point of meat products [3]. Using D-values of a heat resistant *Enterococcus faecium* E-20 strain as a basis, parameters for pasteurization that effectively eliminate vegetative, non-spore forming bacteria can be developed [8]. One of the ways to obtain p-values, which was applied in this paper, is the computational method, which was developed by Vukovic and Nitsch in 2004 [7]. The method is based on Gaussian integration.

Immediately after the end of the active phase of pasteurization, after reaching the HACCP defined values in the geothermal centre (72°C and 74°C for meat products with or without mechanically separated meat), temperature measurement continued during the cooling phases.

All validated meat products were stuffed into polyamide casings in two diameters, 90 and 75 mm, and during heat treatment were exposed to the preservative heat in controlled conditions of the chamber in one programmed cooking step at 80°C medium temperature.

The list of products that were optimized by applying p-values, and the defined pasteurization programs before and after shortening the heating times are given in Table 1.
Optimized pasteurization time meant a shortening of the effective pasteurization time by 15 minutes.

Cooling was performed with water (temperature 13-14°C) by showering the meat products on the pasteurization trolleys. The cooling dynamics consisted of two steps of active intensive showering for 4 minutes, followed by a 1.5-minute break. After that, the cooling process was repeated by showering until the temperature in the geothermal centre of the product dropped to the value of 55°C at the hottest control point. After that, the pasteurization process was finished, and the product was further sent for cooling to the circulating air cooling room.

The validation process was performed regularly for one year, using six probes placed diagonally in the trolleys, in the geothermal centre of products differently positioned. Since the optimization of the heat treatment process must have the imperative of ensuring food safety, the lowest results obtained in the validation procedure of the regular and optimized regime were monitored and considered.

3. Results and Discussion

The results of monitoring the time frames at which the product was at set temperatures during defined pasteurization time, and the calculated p-values are presented in Table 1.

Table 1. Validation of pasteurization during defined time

Meat product	Diameter (mm)	Mass of the product (kg)	The time frame for the product during heat treatment at defined limits (min)				p-value (min)
			55°C	70°C	72°C	74°C	
Finely chopped sausages	90	2,060	104	48	37	25	148.8
	75	1,706	72	33	26	19	111.2
Coarsely chopped sausages	90	2,114	95	38	27	18	115
	75	1,698	98	49	43	34	245.3
Canned meat in pieces	90	2,056	101	56	48	37	249.7
	75	1,723	90	48	41	32	213.9

The results of monitoring the time frames at which the product was at set temperatures during optimized pasteurization time, and the calculated p-values are presented in Table 2.

Table 2. Validation of pasteurization during optimized time

Meat product	Diameter (mm)	Mass of the product (kg)	The time frame for the product during heat treatment at defined limits (min)				p value (min)
			55°C	70°C	72°C	74°C	
Finely chopped sausages	90	2,072	93	37	25	13	97.64
	75	1,712	62	28	21	6	58.4
Coarsely chopped sausages	90	2,102	80	30	19	12	79.1
	75	1,709	84	35	28	18	106.6
Canned meat in pieces	90	2,061	97	38	25	10	95.91
	75	1,763	56	22	15	7	48.42

It was noticed that the products, after the interruption of the pasteurization process, suffer an additional temperature increase of 2-4°C in the geothermal centre, due to the additional effect of the generated heat, and then begin to cool.

The optimization of finely chopped cooked sausages indicates that it is possible to reduce the pasteurization time by 15 minutes while ensuring food safety. For this food, p-values decreased from the regular 148.8 minutes (diameter 90 mm) to the optimized 97.64 minutes, and from the regular 111.2 minutes (diameter 75 mm) to the optimized 58.4 minutes. The obtained p-values ensure the safety of the products obtained in this way because they are in accordance with the legal regulations [2].

The optimization of coarsely chopped cooked sausages indicates that it is possible to reduce the pasteurization time by 15 minutes while ensuring food safety. For this food, p-values decreased from the regular 115 minutes (diameter 90 mm) to the optimized 79.1 minutes, and from the regular 245.3 minutes (diameter 75 mm) to the optimized 106.6 minutes. The obtained p-values ensure the safety of the products obtained in this way because they are in accordance with the legal regulations [2]. The results of the regular pasteurization process, especially with a diameter of 75 mm, indicate the too intense thermal process that needlessly increases production costs through energy consumption while reducing the nutritional value of the product.

The optimization of canned meat in pieces indicates that it is possible to reduce the pasteurization time by 15 minutes while ensuring food safety. For this food, p-values decrease from the regular 249.7 minutes (diameter 90 mm) to the optimized 95.91 minutes, and from the regular 213.9 minutes (diameter 75 mm) to the optimized 48.42 minutes. The obtained p-values ensure the safety of the products obtained in this way because they are in accordance with the legal regulations [2]. The results of the regular pasteurization process, for both diameters (90 and 75 mm), indicate the too intense thermal process that needlessly increases production costs through energy consumption, while reducing the nutritional value of the product. In order to meet the expectations of the demanding consumers and become competitive on the market, it is important that during the development of optimized products, special attention is paid to its sensory properties [9].

The obtained validation results indicate that the safety of the products was ensured, but that the pasteurization process itself was uneven and that it varied significantly from product to product, without taking into account the size and shape of the packaging.

The results show that an optimized pasteurization regime using p-values can make a significant contribution to producing products with better nutritional value through milder pasteurization regimes and without compromising product safety. By shortening the pasteurization time, the conditions are created to increase productivity.

For validation of the pasteurization, in the heating chamber, it is necessary to correctly place the top of the control probe in the geothermal centre of the product. Workers in charge must have the appropriate skills to repeat this procedure during each cooking, to obtain accurate results.

During the commercialization of an optimized pasteurization regime, shelf life studies for the optimized product is required, while special attention should be paid to the provision of the cold chain after production, in retail.

4. Conclusion

Each optimization process for pasteurization-level heat treatment must be adapted to the production facility and specific production conditions. Since this is a level of heat treatment that does not destroy all microorganisms, those that cause spoilage as well as pathogens, it is necessary to properly cool meat products, and then to provide and secure the cold chain in transport and retail. It is also necessary to re-perform the risk analysis within the food safety assurance system for the optimized product.

The use of p-value in optimization confirms the pasteurization level and ensures the safety of the product in the defined storage conditions. It is also possible to compare the levels of heat treatment for different products that are differently packaged. This provides more complete insights into the production process, reduces unnecessary costs, contributes to a better taste of products of higher nutritional value, and increases productivity by creating space for more production batches.

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