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Cooking Process Optimization in Canned Beef Production Using the Response Surface Method

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ABSTRACT

Introduction: Canning food is one of the good methods of food preservation. This method will create a good shelf if the principles of preparation are observed. In this regard, the present study aimed to optimize the cooking time and pressure for canned beef production.

Methods: In this study, three levels of pressure (1, 1.2 and 1.4 bars) and three cooking times (9, 15 and 18 minutes) were applied. Response surface method was used for pH, phloem weight, water-soluble solids (Brix), and protein content and sensory examinations in the produced products.

Results: The results showed that the phloem, weight and the general acceptance of the samples decreased with the increasing of processing time and pressure. Only the linear parameter of process time had a significant effect on the pH at the level of 5%, which increased slightly with the pH of the samples.

Conclusion: The results of process optimization showed that the surface response method is an appropriate approach for optimizing the cooking process in the preparation of canned veal.

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Introduction

The preservation and storage of food products have been received great attention due to the limited shelf life of various food products and growing population rate. With each day passing, the importance of food preservation and extending of its shelf life are becoming more evident mainly due to positive economic impact on marketing. The history of food preservation coincides with the evolutionary stages of the human and their nutritional requirements. Many decades, food preservation has been one of the major concerns of human especially when was trying to keep and preserve food out of the reach of intruder creatures for several season (1). Meat is one of the most important sources of animal protein. Meat is rich in valuable proteins that contain essential amino acids such as histidine, isoleucine, leucine, methionine, and tryptophan, as well as fats that are regarded as important source of energy. Moreover, meat contains fatty acids such as linoleic acid and arachidonic acid, as well as minerals (such as phosphates and sulfates), vitamins (especially B vitamins), and carbohydrates (such as glycogen). These ingredients highlight the inevitable values of this product for human (2, 3). Considering the high nutritional values of the meat and its high perishability, there is a substantial need for optimization of long-term storage conditions for this product. Thermal treatment during canning process is one of the methods used for the long-term preservation. This method effectively destroys all the factors that may contribute to meat spoilage during storage and transportation. Canning is one of the effective ways and confers foods with a desirable shelf life if it is performed following a standard procedure (4). Considering the huge scale of the international trade and its economic value, preserving procedures with the lowest quality loss such as canning is preferred (5). In canned meat products, two-step thermal treatment is primarily used to improve the edible quality of the meat and to minimize the microbial and chemical activities (6). Canned meat is routinely sterilized through saturated steam using autoclave (7). Changing the specifications of thermal treatment (temperature and time) can affect the sterilization period (8) and thus our main qualitative considerations including

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reduced processing time (9), energy saving, nutrients preserving, and repressing the quality loss during the initial storage (10). High processing temperatures reduce the amounts of thermally-labile essential ingredients (e.g., proteins, vitamins, lipids, and minerals) and promote the production of undesirable compounds and modify the nutritional and sensory specifications (11). Studies have shown that prolonged treatments can alter the sensory and nutritional values of canned products which can be attributed to chemical interactions between food ingredients and metal. As fish products are rich of unsaturated lipids, they are more likely to undergo oxidation during the heating process and storage which deteriorates their desirable quality (12). It has been reported that thermal treatment increases the hardness and reduces the brittleness of meat mainly due to the efflux of water from meat (13). In this regard, the aim of this study was to assess the effects of different cooking periods and pressures on some quality features of canned veal using the response surface method.

Materials and Methods

Preparation of veal and canned food

Fresh veal samples with health certificates were procured from approved centers in Urmia city. Meat was manually separated from bones, fats, and skin using special knives and cut into 3x3x3 cm pieces using a slicer (Ruhler). A cooking pot (Ruhler) was used to cook the veal using steam at three pressure levels (1, 1.2, and 1.4 bars) and three time periods (9, 15, and 18 minutes). The canning process was performed using a production line (Steal Mark Mondini, Italy) and commercialized sterile horizontal autoclaves. Canned products underwent the following tests.

Measuring the pH

To measure pH, a pH meter (Meterohm, Switzerland) was initially set with two buffer solutions with pH of 4 and 7. Then 50 to 75 grams of the homogenized sample was poured into a 100 mL beaker, and its pH was read at 25 °C (14).

Determining the Strainer's Weight

First, the weight of the sieve was determined and recorded. Then the contents of the package were poured into the sieve which was held for about five minutes in a way that would facilitate the separation of the liquid phase (oil). After the complete passage of the liquid through the sieve, the sieve and its contents were weighed and the total weight of the drained material was calculated using equation 1 (15).

Equation 1) $W = A/B$

In relation 1, W, A, and B represent the percentage ratio of the total drained weight, the weight of the contents on the sieve (grams), and the net weight of the canned product, respectively.

Soluble Solids in Water (The Brix Value)

A part of the homogenized sample was poured on a filter paper and strained. Then the Brix value was immediately measured using a refractometer (Abe, Japan) (16).

Protein quantification

The amount of protein in samples was measured using a fully automated Kjeldahl instrument following the three digestion, distillation, and titration steps. After titration, the amount of nitrogen was calculated using equation 2, where the protein factor was considered as 6.25 (17).

Equation 2) $N\ (\%) = \frac{(X-14/008)}{(W)}$

In this equation, "N", "X", and "W" represent nitrogen %, the titer value, and the weight of the dried sample, respectively.

Sensory Evaluation

The sensory specifications of the samples were assessed through a taste test. Ten judges were chosen among trained individuals to evaluate the characteristics of the samples produced. For this purpose, the overall acceptance rate was determined using equation 3. The evaluation coefficients of 1, 3, 4, and 2 were applied for color, chewability, taste, and smell, respectively, on a 1-5 scale (one being the lowest and five being the highest score) (18).

Equation 3) $Q = \frac{\sum(P \times G)}{\sum P}$

In the equation above, "Q" indicates the overall acceptance (the quality value of the samples produced); "P" represents the rating coefficient of the specifications assessed, and "G" is the assessment coefficient of specifications.

Statistical Analysis

Response surface methodology (RSM) using a central composite design was used to evaluate the study's fixed parameters. The pressure of the cooking pot (X1), the process time (X2), strainer weight, Brix value, pH, protein content, and overall acceptance were regarded as dependent variables. Using this methodology, it was possible to estimate all the coefficients of the quadratic regression model and the reciprocal impacts of the factors. The most important objective of the present study was to assess the reciprocal effects of factors and identify the optimal condition for producing canned veal, therefore, the RSM statistical model was chosen for data analysis. Statistical analyses were performed in Design Expert software version 12. A total of 13 runs were considered according to our specified levels and factors. The value of α=1 was considered for this section.

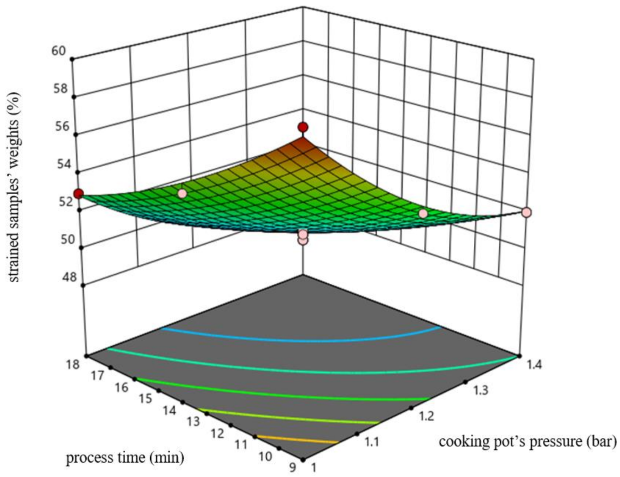

Figure 1. The effects of the cooking pot's pressure and the process time on strained samples' weights

Table 1. Model selection for the features analyzed

Models	Strained weight		Brix		pH		Protein		Overall acceptance	
	Sum of squares	P	Sum of squares	P	Sum of squares	P	Sum of squares	P	Sum of squares	P
Intercept	35235.25		616.17		312.13		7618.16		138.94	
Linear model	94.04	<0.001	11.04	<0.001	0.003	0.0405	36.33	<0.001	4.83	<0.001
Simple quadratic model	2.25	0.25	0.001	1.00	0.0006	0.323	0.250	0.086	0.0625	0.379
Quadratic polynomial model	11.24	0.002	0.15	0.33	0.0014	0.352	0.027	0.852	0.4746	0.011
Cubic polynomial model	1.08	0.21	0.08	0.56	0.0023	0.118	0.167	0.428	0.0083	0.890
Residual	1.27		0.32		0.0017		0.412		0.1756	
Total	35345.14		627.77		312.14		7655.35		144.49	

Results

Strainer Weight

As shown in Table 1, the quadratic polynomial model was the best model for interpreting the effects of operating parameters on the weights of strained samples. The results also showed that changes in the pressure of the cooking pot, the process time, reciprocal effects, and the quadratic parameters of these variables (except for the quadratic parameter of the process time) had significant effects on the weights of strained samples at the level of $P<0.05$ (Table 2). As shown in Figure 1, with an increase in the process time and the pressure of the cooking pot, the weights of strained samples decreased. According to the results of variance analysis (Table 3), it can be noted that the largest impact on the weight of strained samples was related to the linear parameter of the process time. Table 3 shows the model predicting the effects of the pressure and process time on the weights of strained samples.

Table 2. The analysis of variance of the parameters measured

Source	Strained weight		Brix		pH		Protein		Overall acceptance	
	Sum of squares	P	Sum of squares	P	Sum of squares	P	Sum of squares	P	Sum of squares	P
Model	107.53	<0.001	11.04	<0.001	0.0034	0.405	36.33	<0.001	5.36	<0.001
X_1	54.00	<0.001	6.00	<0.001	0.0006	0.340	8.17	<0.001	2.16	<0.001
X_2	40.04	<0.001	5.04	<0.001	0.0028	0.045	28.17	<0.001	2.67	<0.001
$X_1 X_2$	2.25	0.036	-	-	-	-	-	-	0.062	0.167
X_1^2	5.96	0.004	-	-	-	-	-	-	0.284	0.0133
X_2^2	1.43	0.078	-	-	-	-	-	-	0.0402	0.256
Residual	2.36	-	-	-	-	-	-	-	0.184	-
Lack of fitness	1.09	0.480	0.23	0.793	0.0051	0.114	0.684	0.182	0.164	-
Net error	1.27	-	0.32	-	0.0009	-	0.172	-	0.020	0.0213
Sum of complete squares	109.89	-	11.60	-	0.0094	-	37.19	-	5.55	-

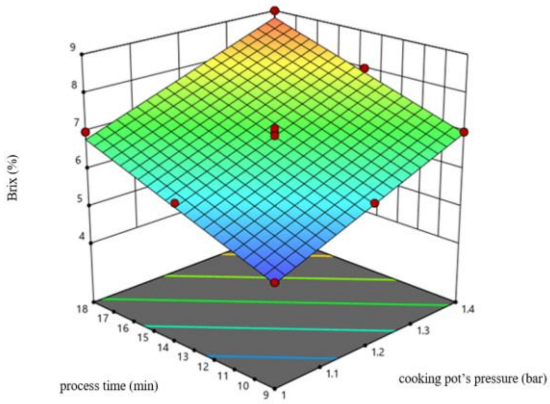

Figure 2. The effects of the cooking pot's pressure and the process time on samples' Brix values

Table 3. The fit models for the parameters analyzed

No.	The variable measured	The model obtained	R^2	R^2-adj	CV
1	Strained weight (%)	$y= +149.65 - 114.38\,X_1 - 2.53\,X_2 - 0.833X_1X_2 + 36.72X_1^2 + 0.035\,X_2^2$	0.978	0.963	1.11
2	Brix (%)	$y= -1.86 - 5.00\,X_1 + 0.203\,X_2$	0.952	0.942	3.42
3	pH	$y= +4.77 + 0.05\,X_1 + 0.04\,X_2$	0.763	0.636	0.499
4	Protein (%)	$y= +10.71 + 5.83\,X_1 + 0.48\,X_2$	0.977	0.972	1.21
5	Overall acceptance	$y= +19.04 - 20.37\,X_1 - 0.142\,X_2 - 0.139X_1X_2 + 8.02X_1^2 + 0.0059\,X_2^2$	0.967	0.943	4.96

Brix (soluble solids)

Data analysis indicated that only the linear parameters had significant effects on the Brix values of the samples. The results showed that an increase in the process time and the pressure of the cooking pot, increases the Brix of the canned products (Figure 2). As shown in Table 2, the quadratic and reciprocal impacts of the variables on the Brix of the samples were not significant, so they were excluded from the analytic model described in Table 3.

pH

According to Table 1, the linear model fitted the best into the pH data. As shown in Table 2, only the linear parameter of the process time had a significant effect on pH at the threshold of $P<0.05$. On the other hand, with an increase in the process time and the pressure of the cooking pot, the pH of the samples increased slightly, and the highest impact on pH was related to the linear parameter of the process time. Table 3 describes the model predicting pH trends during the canning process.

Protein Content

According to the results of model analyses (Table 1), the linear model is the best model fitted into the data related to protein content, similar to the Brix and pH values. Furthermore, the linear parameter of the process time had the greatest impact on the protein content of the samples. Figure 4 indicates that the protein content of the samples increases with prolonged processing time and elevated pressure of cooking pot.

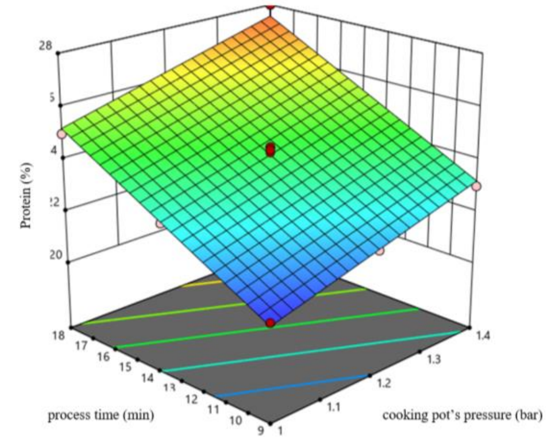

Figure 4. The effects of the cooking pot's pressure and the process time on the protein content of the samples

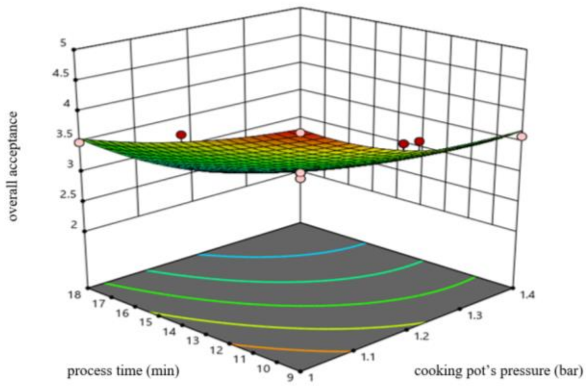

Figure 5. The effects of the cooking pot's pressure and the process time on the overall acceptance of the samples

Overall Acceptance

The simple quadratic model was used for fitness analysis of the data related to the overall acceptance of the products (Table 1). Likewise, the linear parameters of the processing time and the cooking pot's pressure, as well as the quadratic parameter of the cooking pot's pressure were the only variables showing significant impacts on overall acceptance. The results indicated that prolonged processing time and elevated pressure of cooking pot are related to decreased overall acceptance scores given by the evaluators (Figure 5).

Table 4. Comparison of the data predicted with experimental data in the optimal condition of canned veal production

	Strained weight (%)	Brix (%)	pH	Protein (%)	Overall acceptance
Predicted values	52.90	6.80	4.91	25.21	3.56
Experimental values	52.87	6.84	4.88	25.20	3.50

Optimization of Canned Veal Production

In order to identify the optimal condition for canned veal production, the cooking pot's pressures in the range of 1 to 1.4 bar and the processing time of 9 to 15 minutes were evaluated to achieve the maximum values of strained weight, Brix, and overall acceptance. According to the results, the best outcome was achieved in a cooking pot's pressure of one bar and a processing time of 18 minutes (Table 4), delivering the overall acceptance of 0.729. The comparison of the data retrieved by the software and those obtained from complementary tests (both at the optimal point) indicated the high accuracy of the predicted specifications.

Discussion

McAfee *et al.* (18) and Rashidi (19) stated that red meat is a good source of protein and essential elements such as iron, zinc, and vitamin B. The freshness of the primary meat can have a large impact on the quality of the final canned product. In addition, the processing steps greatly affect the quality and nutritional value of canned meat (18,19). As we observed, increased processing time and elevated cooking pot's pressure will lead to decreased weight of strained samples which can be attributed to water efflux from the veal tissue during the canning process. On the other hand, pressure elevation can dissociate water molecules from veal meat and intensify the exit of water molecules. Duranton *et al.* (20), in their study, assessed the effects of extreme pressure and temperature during processing on the quality of meat products and stated that high processing temperatures and pressures lead to the denaturation of meat proteins and resulting in a reduction in the water holding capacity (20). Ma *et al.* (21) also investigated the effects of high temperatures on canned shrimp texture and showed that high temperatures prompted the exit of water into the extracellular fluid and as a result, a reduction in the weight of the product which was consistent with the results of the present study (21). Mohammadi *et al.* (22) assessed the effects of manipulating the processing time and the cooking pot's pressure in the preparation of canned chicken and showed that increasing the processing time and the cooking pot's pressure will decrease the weights of strained samples which was in parallel with our observation (22).

Our findings indicated that with the increase in the process time and the cooking pot's pressure, the Brix values of canned products increased. This phenomenon can be explained by the enhanced veal's water-soluble material efflux following long-term processing time and cooking pot's pressure elevation. Accordingly, we noticed that the escape of soluble solids from meat tissue may be probable reason for elevated concentrations of water-soluble material (i.e., Brix) in canned food (23, 24).

As noted, the pH of the samples increased slightly following an increase in the processing time and the pressure of the cooking pot. Poulter *et al.* (25) demonstrated that the use of high processing pressures could slightly boost the pH of meat by inducing structural changes in its acidic amino acids (25). Ma *et al.* (26) also found that the use of a high-pressure technology slightly increased the pH of red thigh meat (26). Bouton *et al.* (27) reported that increasing the processing temperature boosted the pH of sheep muscle meat (27), which agreed with our findings. Fletcher *et al*. (28) stated that cooking increases the pH in chicken meat, which is consistent with the results of the present study, and in this way, the increase in pH with the increase in cooking time in our study can be justified (28).

Our results showed that longer processing time and higher pressure of the cooking pot will elevate the protein content of products. The protein content is an important quality indicator of meat and a key determinant of meat's nutritional quality. Studies have shown that storage temperature and duration, the initial status of the raw material, and thermal manipulations can affect the proteins contents of meat (29, 30). On the other hand, García-Arias *et al.* (31) believed that increased protein content after cooking is related to reduction in moisture percentage (31). Nonetheless, it is noteworthy that in most studies, protein content had been calculated based on nitrogen quantification which might not reflect the true amount of proteins (6). Consequently, an increase in nitrogen-containing non-protein compounds during the cooking process can be a contributing factor for protein content. In a study by García-Arias *et al.* (10) investigating the effects of storage temperature and duration on the chemical constituents of white fish tuna, it was reported that proteins and fats increased by 5.6% and 5.5%, respectively after canning; however, the moisture content declined by 11%. This increase in protein and fat content can be explained by their stability while moisture reduction may be related to extracellular fluid loss during thermal process in the pre-cooking stage (10).

In the present study, sensory assessments disclosed a fall in the overall acceptance of veal canned under increased processing time and the cooking pot's pressure. This assessment encompassed the organoleptic properties of the meat, including its color, taste, and texture. In this regard, reports by Jouquand *et al.* (32) and Babatunde *et al.* (33) indicated that the cooking process could significantly affect the texture, taste, and overall acceptance of meat (32, 33). Also, according to a report by Fletcher *et al.* (34), cooking reduces the acceptance of meat in terms of color (34). Likewise, Mohammadi *et al.* (22) stated that increased processing time and elevated cooking pot pressure could diminish the overall acceptance of canned chicken which was in accordance with our results (22).

Conclusion

Considering our results, the present study showed that processing time extension and elevated cooking pot's pressure decline the weight of strained samples and the overall acceptance of meat; however, its soluble solids and proteins content increased. Overall, the surface response method is an appropriate approach for optimizing the cooking process in the preparation of canned veal.

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Conflict of Interest

The authors declared no conflict of interest.

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