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High efficiency process on the salted eggs preparation through the parameters optimization by using taguchi method

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Abstract

This article presents experimental data on the salting process of salted eggs, which is one of the methods commonly used to increase the shelf life and taste of eggs. To achieve the highest desired salt content, this research uses Taguchi's experimental method to optimize temperature, pressure, and sanding parameters in the salting process. Experiments were conducted with various temperatures, pressures, and different types of sandpaper to identify the most effective combination of parameters. Experimental results show that the optimal conditions to achieve the highest salt content are at a temperature of 30°C, a pressure of 10 psi, and sandpaper with a size of 1200 grit. Under these conditions, the average salt content obtained is approximately 4.06%. This research makes an important contribution to developing a more efficient salting process for salted eggs and produces a higher quality product. By using Taguchi's experimental method, key parameters were identified and optimized, allowing producers to increase the production of salted eggs with a more consistent and higher salt content according to market needs.

Keywords

Taguchi method, Salted eggs, High efficiency

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Introduction

Currently, salted duck eggs are increasingly popular, information obtained from previous researchers shows that as many as 30% of salted egg producers have produced salted eggs with varying flavors, both in the form of boiled eggs and grilled eggs [1]. So, the process of salting the eggs is needed. The salt solution enters the egg through the pores of the egg shell into the egg white and into the egg yolk by diffusion [2]. Increasing salt levels can deactivate the breakdown enzyme [3]. Can impact longer consumption time.

Based on direct observations in the salted egg making community, it is known that the average salting process takes more than 2 weeks. From several literatures, data shows that the salting process takes around 10-14 days [4]. For example, the salting process for salted egg production states that the egg salting process takes around 17 days [5]. In other research, the salting process took around 21 days [6]. This condition certainly makes the process not efficient and can have an impact on reducing the quality of the salted eggs produced. So far, the right method and parameters have not been found to speed up the salting time. A shorter time means speeding up production and extending the consumption time for salted eggs because the process of salting salted eggs has a longer shelf life [7]. In general, the traditional salting process is carried out using various media and salt percentages at atmospheric pressure. The traditional salting process is exemplified in Figure 1.

Figure 1. Eggs salting process potential by small industry and middle enterprise in Rawamerta Karawang West Java [8]

Several researches on the egg salting process were carried out by Kaewmanee et al. who observed the effect of pressure on the egg yolk, by varying the salt concentration by 0%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% w/w [9]. Further research was carried out using the pressure pulsed method by Wang et al. [10], by varying the pressure by 90 kPa, 100 kPa, and 160 kPa. The salting process uses fifty units of salted duck eggs processed with 1.5 kg of salt in 10 L of water for 17 days (salt concentration around 15% by weight). The next process is a boiling process for 2 hours and followed by smoking for 3 hours—smoked salted duck eggs which immediately turn dark brown with spots on the surface. After leaving it for one day, the black spots are removed by wiping with a cloth to make it look shiny brown [11]. Other research to optimize salted egg salting process using pulsed pressure, with a pressure of 180 kPa for 48 hours was carried out by Yuan et al, with oil exudation results that were directly proportional to the salting process time, namely 21.93% for 12 hours, 41.62 % for 24 hours, 63.54% for 36 hours, and 80.95% for 48 hours [12].

Further research into the process of making smoked salted eggs was carried out, using soil and crushed ash as a medium with a salting time of 10 days [13]. Further research was carried out at a temperature of 28°C, 15% salt, 0.4% carrageenan, resulting in salted egg yolks with a golden yellow and sandy texture, egg whites with a medium salty taste [14]. In further research, data was obtained that the duck egg salting process

carried out in Brebes, Central Java, was carried out for 17 days [15]. From another literature, data shows that the conventional/traditional salting process requires an egg salting process of around 10 to 21 days. Then research simulating the flow of compressed air was carried out in a salting tube, the eggs were placed on a rack, using a temperature of 25°C and a pressure of 120 kPa. For more than 48 hours. As well as varying the position of the compressed air inlet and outlet [16].

From the literature above, data is obtained that pressure parameters have an impact on the salting process needed to achieve optimal results. This research aims to obtain optimal parameters so that it can speed up the process of salting salted eggs. To help overcome the problem of long time in the traditional salting process [17], This research proposes a process for salting salted eggs using the Taguchi method. That has been done by previous researchers who used the Taguchi method to obtain optimal parameter settings in the die casting process [18]. This research uses 3 parameters and 3 levels of Taguchi experiments. The parameters that will be used are surface roughening treatment with sandpaper, pressure (PSI), and temperature (°C). The ANOVA graph depicts the interaction of parameter ratios on data processing [19]. Taguchi and ANOVA methods are used to analyze the tensile-shear strength of Zn-Coated Steel and Low Carbon Steel welded joints [20]. The results of salting eggs will be measured qualitatively using salt content parameters in salted eggs using a salinity meter. The salting results are evaluated based on standards SNI 01-4277-1996 [21]. The research results have succeeded in speeding up the time for salting salted eggs to 3 days.

Methods

The research lasted for 5 months, from June to November 2023, which was did at the Manufacturing Laboratory of Buana Perjuangan University, Karawang. Variables include sandpaper roughness, temperature (°C), and pressure (PSI), while fixed variables include salting time, control variables include the composition of the salting media, and the amount of salt. Bonded variable in this research is salt content (%).

Tools and device's

To facilitate pressure and temperature parameters simultaneously, an incubator tube is needed. Before testing is carried out, the design and manufacture of the incubator is completed first. The materials and equipment needed to make an incubator that will be used in experimental testing include tool components, welding equipment. As carried out by N.Y Rohman et al, conducting research in the form of a tube-shaped tool made from 316 stainless steel which is capable to applied pressure of 4-6 bar, has accelerated the process of salting eggs for 4-7 hours [22]. Another study carried out the design of a tool for salting quail eggs, pressure 1 bar, for 30-90 minutes, with a salt content in quail eggs of 1.63% -2.3% [23].

In the process of salting eggs, salt mixture is needed. In the egg salting process carried out by Nurbaety et al, 1 brick powder, 2 salt, and 3 rubbing ash, Nurbaety et al salted the process for 2 weeks, getting good egg yolks [24]. Another study used 3 brick powder, 2 rubbing ash, and 1 salt as a comparison [25]. Meanwhile, the salting material in this test. Used 5-8 duck eggs, clay (2), sand (1), red brick fragments (1), salt (2), water (2) for one iteration. Clay mixed with sand and red brick fragments, salt and water as the poultry pasta that used in this research. then input the salting results into Taguchi software for data processing. Meanwhile, some of the tools and device that will be used in this research are scales, measuring cups, salinity meters, 800, 1000 and 1200 sandpaper.

5-8 eggs are needed to carry out the experiment. Because after the salting process, 5 eggs will be broken to separate the egg yolk and egg white. Egg whites containing salt will measured using a salinity meter. 2 eggs will be boiled to determine the appearance and texture of the egg yolk.

Salting incubator tube

The Salting Incubator is a special device designed to process eggs into salted eggs with an efficient and effective design, producing quality salted eggs. Equipped with accurate temperature and pressure gauges, this incubator can monitor the environment in detail, as shown in Figure 2. This tool is made of 6-inch PVC material and is equipped with instruments such as a pressure gauge, compressor and thermometer. The test scheme is clearly depicted in Figure 2a the top of the tube contains an air ventilator, pressure gauge and heater. In Figure 2b the tube body is inside the frame. To ensure a precise and consistent egg salting process.

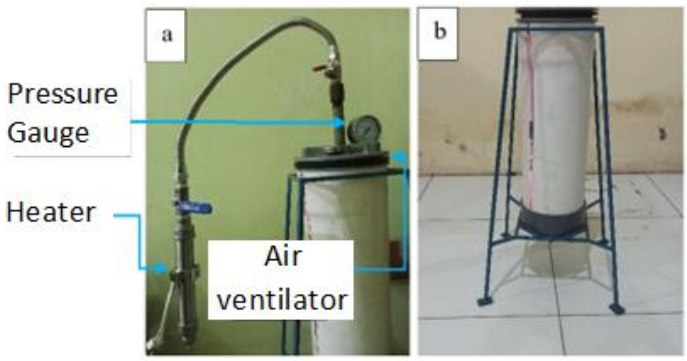

Figure 2. a) Upper part and b) Bottom part

Then, the salting process is presented in Figure 3. The salting incubator operates based on a working principle which includes setting temperature, pressure and surface roughening parameters using sandpaper. The temperature is maintained at an optimal level for the egg salting process, while the pressure is monitored accurately via a pressure gauge. Roughing the surface of the egg is done using sandpaper at certain stages, ensuring that the layer of salt penetrates well into the egg. With precise control over temperature, pressure and surface roughening, this incubator delivers consistently high-quality salted egg yields.

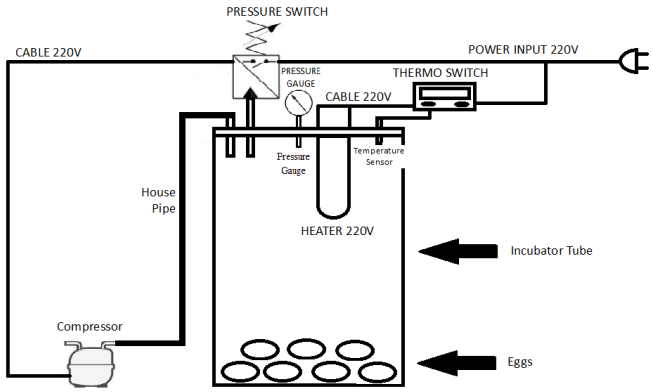

Figure 3. Schematic diagram of the salting process

Taguchi experimental design

Taguchi experiments are carried out by varying input variables [26], sanding roughness, pressure, and temperature. Meanwhile, the salt concentration in salted eggs is measured as an outcome variable. The experiment will use the Taguchi experiment matrix using 3 input factors and level. experimental design as in Table 1.

Table 1. Experimental design for salting process using Taguchi Method

Code	Parameter of salting	Information	Experiment Level		
			1	2	3
A	Sanding paper grade (Mesh)	P. T*	800	1000	1200
B	Pressure (PSI)	P. T*	5	10	15
C	Temperature (°C)	P. T	30	32	34
t	Time (day)	Fixed Variable			

Note: P.T.= Parameter Taguchi as fixed variable

Signal to noise ratio (S/N Ratio)

The calculation of the S/N ratio depends on the desired quality characteristics. In general, the characteristics of S/N ratio data are that the bigger the better, the smaller the better, and the nominal value is the best. In this progress report, salt content is selected as the output parameter. The characteristic of salt content data is that the higher the better, so the S/N ratio with the characteristic 'larger is better' was chosen. The calculation of the S/N ratio for each case is shown in equations 1, 2, and 3.

Larger is better [27]:

$$\text{S/N ratio} = -10 \log 10 \frac{1}{n_0} \sum_{i=1}^{n_0} \frac{1}{y_i^2} \qquad (1)$$

Nominal is the best [27]:

$$\text{S/N ratio} = -10 \log 10 \frac{\bar{y}^2}{s^2} \qquad (2)$$

Smaller is better [27]:

$$\text{S/N ratio} = -10 \log 10 \sum_{i=1}^{n_0} \frac{y_i^2}{n_0} \qquad (3)$$

Were n being number of samples, y is responds factor, $\bar{y}$ is average respon factor, and so is the variance of the response factor.

In the context of this research, the success rate is measured through the S/N ratio, focusing on salt content as a critical parameter. Analysis of this S/N ratio data provides a deep understanding of product quality, enabling the identification of patterns and trends that are vital for improving production processes. Through equations 1, 2, and 3, the S/N ratio calculation is carried out using statistical software.

Result and discussion

Salt concentration analysis

The salting incubator that has been made is used to process duck eggs which will be made become salted eggs. Then the salt content value in salted eggs that had been processed for 3 days was measured using a salinity meter. The results from the salinity meter were used as input data into the Taguchi method as listed in Table 2. The results of the salt content test showed that the 8th iteration gave the most optimal results with the highest value reaching 7.9 in the 2nd sample. The average of all samples tested showed a salt content above 2.0%, meeting the standard SNI 01-4277-1996 [21]. This incubator was provided salting process of salted egg results that comply with the desired quality standards. The results of salt content testing are presented in Table 2.

Table 2. Matrix experimental result of salting process for 3 days.

Iterasi	Sandpaper Grade	Pressure (PSI)	Temperature (°C)	Salt content (%)				
				S1	S2	S3	S4	S5
1	800	5	30	4,2	3,4	4	4,1	3,8
2	800	10	32	5,1	5,1	6,7	5,4	3,3
3	800	15	34	2,9	3,4	2,2	3,2	3,6
4	1000	5	32	3,7	3,7	3	3,3	4,2
5	1000	10	34	5,7	5,9	3,6	5,2	5,3
6	1000	15	30	4,4	3,2	2,6	2,7	3,6
7	1200	5	34	3,8	4,8	3	3,9	3,3
8	1200	10	30	6,4	7,9	4,6	4,6	4,6
9	1200	15	32	2,7	2,3	4,3	3,5	2,8

During the salt content testing process, photos are taken for visual documentation purposes. These photos record test conditions, procedures, and results in detail. The use of photographs allows for regular monitoring and re-evaluation of each test step, in time to ensure data integrity and clarify the context of analysis results. With comprehensive documentation, the testing process and analysis results become more detailed and transparent, making it easier to interpret and re-understand when necessary. The results of salting duck eggs are shown in pictures to provide a clear visual picture. The results and photos of salting duck eggs are presented in Figure 4a. until Figure 4i. representing egg yolk on iterasi 1 until iterasi 9.

In, Lilian Xu et al research reported that after the salting process the egg yolk became hard [28]. The hardened egg yolk is shown in Figure 4. In every iterasi after salting process the egg yolk become hard. Based on Figure 5, it shows there are thin oil around the egg yolk. As mentioned by M. Zheng et al, the quality characteristics of

salted egg yolk are thin oil around the egg yolk and salty taste [29]. In Figure 5a until Figure 5i, shows the eggs after salting process then boils for 15 minutes.

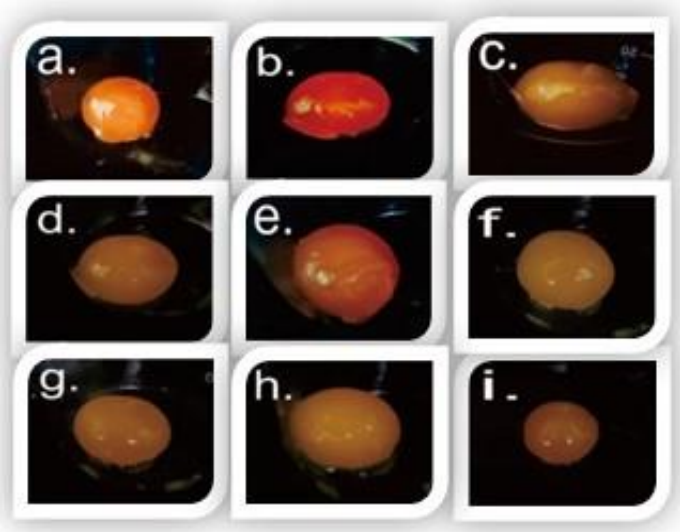

Figure 4. a) egg yolk iterasi 1, b) egg yolk iterasi 2, c) egg yolk iterasi 3, d) egg yolk iterasi 4, e) egg yolk iterasi 5, f) egg yolk iterasi 6, g) egg yolk iterasi 7, h) egg yolk iterasi 8 and i) egg yolk iterasi 9

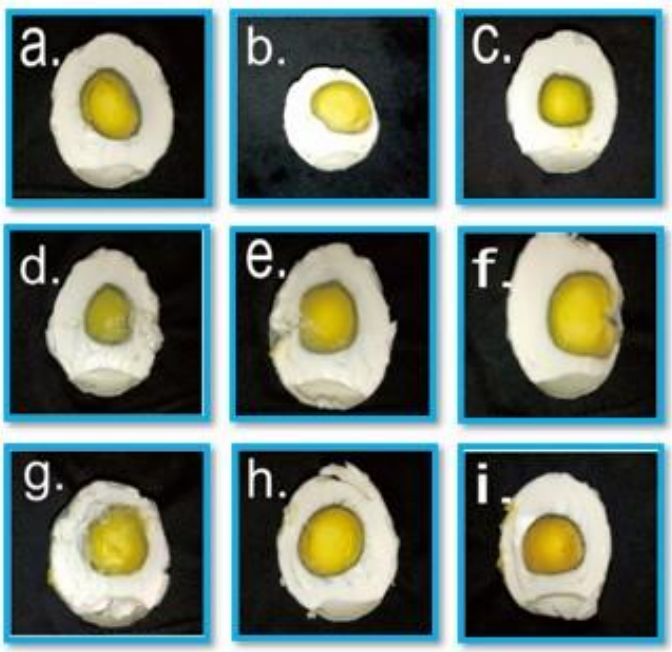

Figure 5. a) boils egg iterasi 1, b) boils egg iterasi 2, c) boils egg iterasi 3, d) boils egg iterasi 4, e) boils egg iterasi 5, f) boils egg iterasi 6, g) boils egg iterasi 7, h) boils egg iterasi 8, and i) boils egg iterasi 9

Analysis S / N ratio

In analyzing the impact of each parameter level, evaluation is carried out through S/N ratio analysis. The average S/N ratio at levels 1, 2, and 3 was calculated, reflecting the level of impact. Research shows that pressure has significant differences according to the increase level, while sanding parameters shows less impact on the results. The validation results of the S/N ratio are depicted in Figure 6. Based on Figure 6, optimal salting process parameters are achieved with maximum settings for each parameter: sandpaper at 1200, pressure at 10 PSI, and temperature at 34°C. This can be identified including the arrangement of eggs when salting them in an incubator in a pile. Causes

a decrease in the process of salt absorption into eggs. The solution found by uses a rack when salting process of salted eggs and mixing the ingredients evenly. These both aspects have an important role in achieving maximum results. By applying a rack, high pressure air circulation will be even and ensure consistent salt distribution during the salting process. In addition, even mixing helps maintain consistent taste and moisture levels around the surface of the salted eggs. These second factors work synergistically to produce salted eggs with a uniform taste, appropriate texture and overall optimal quality [16].

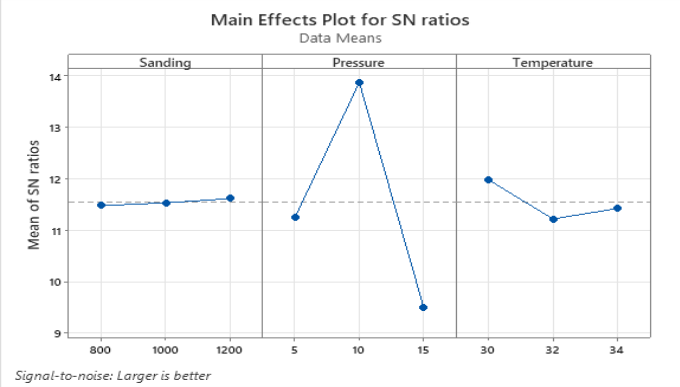

Figure 6. S / N ratio for salt concentration in salted eggs

Effort to obtain an optimal average salt content, the Taguchi Method also recommends setting the same parameters as in the previous graph, namely sandpaper at 1200, pressure at 10 PSI, and temperature at 34°C. These results confirm that the combination of these parameters provides the best quality salted egg salting results in accordance with the desired standards.

The impact of input parameters on the response variable of salt concentration in the salted egg salting process is confirmed in Table 3. Pressure has the largest delta value of 4.38, indicating a significant influence. Temperature and sandpaper also influence, with delta values of 0.792 and 0.111 respectively. The S/N ratio response table for each salted egg salting parameter can be found in Table 3, providing a detailed description of the contribution of each parameter to the salting results. Interaction plot for salt concentration average show in Figure 7. This research confirms previous research conducted by Liu et al, that pressure is a parameter that significantly affects research results [30].

Table 3. S / N ratios for salting process larger is better as the option

Response Table for Signal to Noise Ratios
Larger is better

Level	Sandpaper	Pressure	Temperature
1	11,504	11,277	12,01
2	11,53	13,876	11,218
3	11,615	9,497	11,421
Delta	0,111	4,38	0,792
Rank	3	1	2

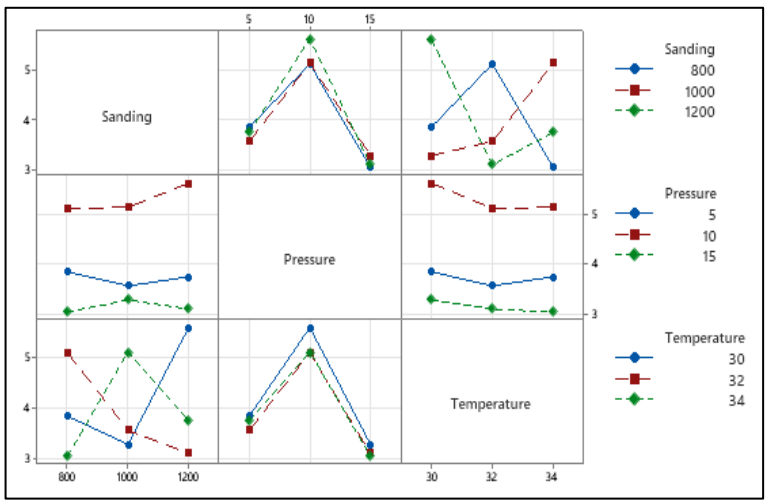

Figure 7. Interaction plot for salt concentration average

Conclusion

This research uses S/N ratio analysis and the Taguchi Method to optimize the salted egg salting process. The research results stated that pressure had a significant influence on salt content, followed by temperature and sandpaper. Optimal settings at 10 PSI pressure, 34°C temperature, and 1200 sandpaper produce the best quality salted eggs. These results are confirmed by Table 3, which shows the largest delta value at pressure (4.38) as well as Table 2 which provide a detailed description of the contribution of each parameter. Interactions between variables are also displayed in Figure 6, providing further insight into the complexity of the relationships between parameters. In conclusion, this research provides an in-depth overview of the influence and interaction parameters on salted egg salting results, guiding the industry in achieving the desired product quality by optimizing process variables appropriately.

Acknowledgments

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