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# CHICKEN BAKING BY EXPERIMENTAL DESIGN TECHNIQUE USING FACTORIAL DESIGN METHOD

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**Abstract**
This research is to study an experimental design in a factorial using real chicken. The objective is to study how real factory. Bake chicken to increase efficiency. Bake chicken to get quality chicken. Carrying out a trial in a chicken factory, by the way real. By the start of the study status of implementation of goals and objectives and the benefits it offers and the final step is to try to make a completion percentage of chickens. Base on the statistical significance with α level of 0.05, the optimal conditions for each type of chicken are as follows: The temperature and time for the chicken oven are 150 degree Celsius and 45 minutes to yield 92 percentages of chicken and the mean that confirmed the experimental results was at 92.6 percentages.
**Keywords**: design of experiment, analysis of variance, factorial design, oven machine

## INTRODUCTION

Thailand is a country with a large population of chicken meat consumption. Chicken dishes have been invented widely. And baking chicken for food is the most popular dish. Suitable for consumption of all genders and ages, cheaper than other types of meat. Famous chickens of Thailand and popular for consumption are:

1. Khao Suan Kwang Grilled Chicken Its origin is in Khao Suan Kwang District. Khon Kaen Province

2. Wichian Buri Grilled Chicken originated in Wichian Buri District. Phetchabun Province

3. Chirapan Grilled Chicken originated in the Phra Khanong area. Bangkok

4. Kai Yang Nittaya originated in Nonthaburi Province.

5. Bang Tan Grilled Chicken originated in Ban Pong District. Ratchaburi

6. Grilled Chicken 5 Stars is a grilled chicken franchise of CP Group.

First started in 1985, chicken baking nowadays has invented and designed a lot of chicken baking machines because baking chicken each time takes a long time to bake. [Source: http://en.wikipedia.org/wiki/]

So in this research, the project organizers have an idea to design an experiment using the factorial method by experimenting with a chicken dryer to analyze the experimental design for efficient chicken drying, and lead to further development.

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## RESEARCH OBJECTIVES

1. for experimental design in chicken dryer by using factorial method.
2. To control the chicken baking in the chicken dryer to complete the plan.
3. To study the factors affecting the roasting of chicken.

### Chicken Theory

For thousands of years, humans have caught wild fowls. To be raised as domestic chickens in the country, chickens have been raised for about 3000 years. Chickens raised in Babylon were brought from India in 2500 years, and about 100 years later, they were bred to the country. Greece in Rome, chickens have been raised since before the turn of the century. But raising chickens in earnest only started about 100 years ago, and what has helped in raising chickens in the past was cockfighting. Which is both sports games and gambling which is considered as an incentive for general chicken farmers later, humans have an increased need for food. The meat and eggs of the battered chicken are delicious. Provide high nutritional value it has been very popular. Causing the development of chicken breeds until the breeding was carried out around the world chicken ancestry Chicken is a type of bird. The ancestry comes from reptiles. As it appears, fossil evidence of the first bird species in the world has been found. in the Bavarian region of Germany in the year 1861, the remains are approximately 130 million years old, are semi-reptile birds. Is that the mouth has teeth It has claws sticking out from the tips of the wings and a long tail bone. Which is characteristic of reptiles At the same time, it has feathers covering its body like a bird. Scientists now call the remains “Archiopteryx” from “Archaeopteryx.” It evolved from generation to generation until it became a bird of varying shape, color, and character. Different from more than 9,000 species can be classified as a large group of 27 ranks and 1 in 27 ranks is Galliformes, which is the order of wild fowls, turkeys, guinea fowls, pheasants, etc., and if these chickens are separated into families. Wild hens and pheasants belong to the family. Phasianidae, stock chickens belong to the family Numididdae, and turkeys belong to the genus. Meleagrididae [Source: http://en.wikipedia.org/wiki/]

## THEORETICAL FRAMEWORK

### Adaptation Strategy

The process of baking chicken has been around for a long time. No research has been done on how much heat control is appropriate, and how much time will make the chicken complete or crispy on the outside, tender on the inside, including the weight of the chicken to be baked

In this research, a study was conducted to design an experiment using the factorial design method. To find the right value the main parameters were determined,

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namely testing time and temperature. To find the most suitable common factor the desired result is chicken wholeness (Inside and outside the chicken must be perfect) especially the weight of the chickens tested in this research choose the size of the chicken weight equal to one kilogram throughout the experiment.

## METHOD EXPERIMENTAL

### Factorial Design

Design means an experiment that takes into account the effect of a combination of all possible levels of factors in a given experiment, factorial design has many advantages and is a design that is more efficient than experimental design. Moreover, factorial design is essential when interactions occur. It is also possible to estimate the effect of one factor at different levels of another. Factorial design there are several types, including

1. Two-factor factorial design the simplest type of design involves two factors A and B. Factor A consists of a level and Factor B contains b levels. The figure of the factorial design is that each replication of an experiment consists of all cofactor trials ab trials and usually has a total number of n replicas.

2. Design $2^k$ Factorial Designs is a basic design to create a block to use to create a result surface. For example, adding Design $2^2$ will result in Central Composite Design, which is one of a very important designs of a square yield surface model. (Second-Order Response Surface Model), (Myers, R.H. and Montgomery, D.C, 1995).

The design concept of the experiments has been in use since Fisher's work in agricultural experimentation. Fisher successfully designed experiments to determine the optimum treatments for the land to achieve a maximum yield (Montgomery, D. C., 2000). The first step in designing any experiment is recognizing the problem. This is followed by the determination of the effective factors with their levels and specifying a response variable. Then, based on the objectives, one must select a suitable experimental design and carry out the experiments accordingly. The obtained data would be studied using the analysis of variance (ANOVA) method, leading to the determination of the factors with a significant effect on a response variable. Finally, a model can be worked out which represents the response variable as a function of the already determined significant factors. The choice of the experimental design depends on the type of problem, the number of factors, as well as their levels (Roy, R, 2001). The full factorial design considers all possible combinations of a given set of factors. Since most of the industrial experiments usually involve a significant number of factors, a full factorial design results in a large number of experiments (Montgomery, D.C, 1991). And according to (Hill and Hunter, 1966) RSM method was introduced by (G.E.P., Wilson K.B, 1951) suggested to use a first-degree polynomial model to approximate the response variable. They acknowledged that this model is only an approximation, not accurate, but such a

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model is easy to estimate and apply, even when little is known about the process (Response surface methodology (accessed, January 22, 2007).

### Experimental Strategy

The experimental design is designed by the experimenter who wants to find answers from the process or system that the experimenter needs. An experiment or test or a series of tests where the expectation of changing variables into a process or system will result in a change in response variables in experimental engineering is important in production design. New process development and process Improvement the main objective is to develop a strengthened process in which external variations will have little impact on the process (Myers, R.H. and Montgomery, D.C, 1995).

### Factorial Designs

The factorial experimental design allows for the study of the influence of factors on the process and concurrently when the experiments are performed, rather than changing the factor level. Either because it will make work more efficient in terms of both time saving and cost, and can also analyze the influence (Interaction) between factors by mutual influence (Interaction) is the result of the factors together In many processes, if the factorial experiment is not performed, the effect of interaction may not be evident. Screening design in most process development and production tasks. There are a large number of variables that are likely to contribute to the improvement of selection, reducing the number of these variables by selecting the variables that are very important to the quality of the product. Only the variables that are important to the process can be considered, or under the “Vital Few” principle, the selection may be able to determine the optimum (optimal) of the variables. Including the experiment to find the best value (Optimization) to tell whether the response (response) has a straight line mathematical relationship equation or a full factorial experimental design curve in the full experiment. Factorial the response is measured at all conditions of all factor levels in the experiment, where the combination of factor levels is a condition that requires an experiment to measure the response where the factorial Each experiment is called run, and an experiment is performed to measure the response and all datasets in every run are called design (Myers, R.H. and Montgomery, D.C, 1995).

## LITERATURE REVIEWS

Guidelines for using factorial design techniques have scholars have applied such principles widely as, (Magno de Oliveira et al, 2018) have studied and researched experimental planning factorial: A brief Review found that in this paper, we present concepts related to optimization of multivariate procedures with emphasis on experimental design systems experiments and their application in studies of various areas of knowledge, proving its efficiency in the analysis of multivariate systems. (Dey, 2011) have presented Factorial designs have the advantage of allowing the

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presumption of the effects of interaction between the various factors in addition to providing greater accuracy to estimate the effects of individual factors. (Brereton, 2018) have conducted research studies on Factorial Experiments two levels have the advantage of the fact does not always refer to a quantitative parameter can be used for qualitative questions, but also have pitfalls. They have only an approximation within experimental range. Costa et al. (2006) have considered the factorial design as an important statistical tool capable of generating precise and accurate results, and enable the evaluation of multivariate way systems, optimizing all the variables that were part of the experimental system. Since Chagas et al (2013)have studied and researched using a factorial arrangement 5 x 2 to evaluate the performance and pathophysiological of tambaquis responses (Colossoma macropomum) fed with feed supplemented with β-glucan corresponding to five different concentrations of immunostimulatory two sampling times. (Jaynes et al., 2013) have considered the experimental factorial design is effective in the study of two or more factors. (Wu & Hamada, 2009) have referred the main effect may be defined as the change in the response due to a change in the factor level. The effect of interaction between the factors understands that the difference of a factor is not the same at all levels of the other factors. The main set of effects and interaction effects are the factor effects. Amaral et al (2017) used the experimental design for assessing the production of protease Aspergillus niger (SIS18) present in agroindustrial waste media, whey and cream residue. In his work took 22 type, ie adopted two levels +1 and -1 with two variables represented by the serum concentrations of glucose and Leite to the Leite and cream and residual glucose concentration for the second residue tested.

From the research mentioned above, it can be seen that the approach and application of the experimental design with the factorial design method are widely used. The experimental design by the factorial design method gave significant confidence in the experimental results. This research, as well, has the concept of principle to be applied to the research for this experiment.

**Percentage of Completion**

The maturity percentage of chickens depends on 3 important factors. The weight of the chicken is one variable that affects the percentage of ripening of chickens.in terms of statistical data; this is for the convenience of those who are interested in using it. To be more efficient by specifying the factors and setting the parameters as detailed as follows

1. Response Characteristic in this research want to study the results obtained from the experiment is Percentage of chicken cooked after baking and set as Response Variable: Y

2. Control Factors and their level obtained from the experiment using statistical tools to find the confidence intervals of the factors shown in Table 1

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**Table 1: Control factors**

| Control Factors | Low | High |
|---|---|---|
| Time (minute) | 15 | 45 |
| Temperature(degrees Celsius) | 150 | 250 |

**Remarks:**

1. Control time (Time) Time for baking chicken refers to the timer while the temperature reaches the point of the experiment until the time of stopping the experiment.

2. Temperature control (Temperature) the temperature of chicken baking means that the temperature is kept constant throughout the experiment.

Experiments with broiler chickens are available in the general market, as shown in the Figure 1 and the main ingredients for marinating the chicken meat to have an appetizing aroma, as shown in Figure 2.

**Figure 1: Chickens that have been cleaned and prepared for the experiment**

**Figure 2: the main ingredient for flavoring chicken meat**

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## Statistical data analysis and determination of the optimal value of each factor

After obtaining the data on the percentage of maturity of chicken after baking that was designed, the data were statistically analyzed to determine the coefficients of the factors affecting the percentage of chicken and the values of the various coefficients. In this statistical analysis process, Minitab Release 19 was also used as a tool to assist in this analysis, and the values of the factors were used to predict the values according to the Equation.

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i<j} \sum \beta_{ij} x_i x_j + \varepsilon$$

(1)

Where $\beta$ are the coefficients which have calculated using an appropriate method such as the least square method. When the result estimated surface is an adequate approximation of the true response function, the results will be approximately equivalent to analysis of the actual system. The model parameters can be approximated whenever proper experimental designs are used to collect the data. The DOE simulation was accomplished with three parameters: between rubber of clearance, spindle of speed and rice of moisture respectively. It was performed according (see Table II and III), and Diagram of chicken baking production process in Figure 3. A model fitting was accomplished for the first $2^2$-CCD in Table 1. According (S. Bangphan, P. Bangphan , C. Ketsombun and T. Sammana, 2016).

After the experimental design with the factorial design method, as shown in Table 2 weaving design as shown in Table 3, and after the experiment is complete therefore, the results of the experiments were confirmed or the experiments were repeated with the appropriate factors. By repeating the experiment five more times.

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**Figure 3: Chickens baking was used in the experiment (Designed by the researcher himself)**

**Table 2: Units for parameters properties**

| Stdorder | Runorder | Centerpt | Blosks | Temp | Time | % |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 150 | 15 | - |
| 9 | 2 | 1 | 1 | 150 | 15 | - |
| 2 | 3 | 1 | 1 | 250 | 15 | - |
| 6 | 4 | 1 | 1 | 250 | 15 | - |
| 3 | 5 | 1 | 1 | 150 | 45 | - |
| 7 | 6 | 1 | 1 | 150 | 45 | - |
| 12 | 7 | 1 | 1 | 250 | 45 | - |
| 5 | 8 | 1 | 1 | 150 | 15 | - |
| 10 | 9 | 1 | 1 | 250 | 15 | - |
| 11 | 10 | 1 | 1 | 150 | 45 | - |
| 8 | 11 | 1 | 1 | 250 | 45 | - |
| 4 | 12 | 1 | 1 | 250 | 45 | - |

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**Table 3: the experimental records confirmed the effect of roasting the chicken**

| Times | Perfection | Times | Perfection | Times | Perfection |
|---|---|---|---|---|---|
| 1 | - | 5 | - | 9 | - |
| 2 | - | 6 | - | 10 | - |
| 3 | - | 7 | - | 11 | - |
| 4 | - | 8 | - | 12 | - |

## Research Results

A. DOE and Surface Response Methodology the DOE simulation was accomplished with two parameters: between time, and temperature respectively. It was performed according (see Table 1 and 4), and chicken baking in Figure 3. A model fitting was accomplished for the first $2^2$-CCD in Table 4. The independent (Time, and Temperature) and the dependent variables were fitted to the second-order model equation and examined in terms of the goodness of fit. The analysis of variance (ANOVA) was used to evaluate the adequacy of the fitted model. The R-square value (determination coefficient) provided a measure of how much of the variability in the observed response values could be explained by the experiment factors and their interactions. According (S. Bangphan, P. Bangphan, C. Ketsombun and T. Sammana, 2016).

DOE order defines the sequence that variables should be introduced in response surface analysis. See Table III shows the results according to simulated analysis performed in MINITAB Release 19.00 used for simultaneous optimization of the multiple responses. The desired goals for each variable and response were chosen. All the independent variables were kept within range while the responses were either maximized. The significant terms in different models were found by analysis of variance (ANOVA) for each response. Significance was judged by determining the probability level that the F-statistic calculated from the data is less than 5%. The model adequacies were checked by R2, adjusted-R2 (adj-R2).The coefficient of determination, R2, is defined as the ratio of the explained variation to the total variation according to its magnitude. It is also the proportion of the variation in the response variable attributed to the model and was suggested that for a good fitting model, R2 should not be more than 75 %. A good model should have a large R2, adj-R2. Response surface plots were generated with MINITAB Release 19.00 According (S. Bangphan, P. Bangphan, C. Ketsombun and T. Sammana, 2016).

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**Table 4: Central Composite Design for Optimization**

| Stdorder | Runorder | Centerpt | Blosks | Temp | Time | % |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 150 | 15 | 65 |
| 9 | 2 | 1 | 1 | 150 | 15 | 63 |
| 2 | 3 | 1 | 1 | 250 | 15 | 74 |
| 6 | 4 | 1 | 1 | 250 | 15 | 77 |
| 3 | 5 | 1 | 1 | 150 | 45 | 89 |
| 7 | 6 | 1 | 1 | 150 | 45 | 92 |
| 12 | 7 | 1 | 1 | 250 | 45 | 50 |
| 5 | 8 | 1 | 1 | 150 | 15 | 60 |
| 10 | 9 | 1 | 1 | 250 | 15 | 72 |
| 11 | 10 | 1 | 1 | 150 | 45 | 94 |
| 8 | 11 | 1 | 1 | 250 | 45 | 50 |
| 4 | 12 | 1 | 1 | 250 | 45 | 50 |

Response surfaces equations were obtained from design of experiments. Using all values (tests 1 to 12) to the system analysis, the following polynomial equations were generated. According (S. Bangphan, P. Bangphan, C. Ketsombun and T. Sammana, 2016).

The Estimated Regression Coefficients for completeness of chicken using data in uncoded units:

$$\hat{y} = 69.25 + 0.75(Time) + (-7.08)(Temp) + (-12.90)(TimexTemp) \quad (2)$$

Equation (2) is generate the graphic shown in Figure 3 shows optimal solutions considering time, temperature respectively. There is a range between 15 and 45 minute of time where it is allowable to use other distances and there is a range between 150 and 250 of degree Celsius where it is allowable to use other distances (see Table 1. Control factors). Result of the analysis of variance is shown in Table 5. Therefore, this study can conclude that the true response surface is explained by the linear model. To study the effects of three factors, 6 = 12 runs and three replicate are required. Due to space limitations, the treatments, factor values, and the corresponding responses are not shown. Analysis of variance method (ANOVA) is used to find factors with significant effects. Effects X1,X2, X1X1, X2X2, and X1X2

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DF are found to be significant ,that is the most significant effect and time is insignificant, has significant interactions with all other factors. Result of estimated regression coefficients for the response (completeness) function as estimated effects and coefficients for completeness shown in Table 6. This analysis is carried out for a significance level of 5%, i.e., for a confidence level of 95%. The model adequacies was checked by adjusted-R2 (adj-R2) of 98.37%. According (S. Bangphan, P. Bangphan, C. Ketsombun and T. Sammana, 2016).

**Table 5: Analysis of Variance for the Experimental Results of the Central Composite Design**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Main Effects | 2 | 608.83 | 304.42 | 77.72 | 0.000(Sig) |
| **Time** | **1** | **6.75** | **6.75** | **1.72** | **0.226(Non Sig)** |
| Temp | 1 | 602.08 | 602.08 | 153.72 | 0.000(Sig) |
| 2Way Interactions | 1 | 2002.08 | 2002.08 | 511.17 | 0.000(Sig) |
| Time*Temp | 1 | 2002.08 | 2002.08 | 511.17 | 0.000(Sig) |
| Residual Error | 8 | 31.33 | 3.92 | | |
| Pure Error | 8 | 31.33 | 3.92 | | |
| Total | 11 | 2642.25 | | | |

**Table 6: Estimated Effects and Coefficients for Completeness (coded units)**

| Term | Coef | T | P |
|---|---|---|---|
| Constant | 69.25 | 121.21 | 0.000 |
| Time | 0.75 | 1.31 | 0.226(Non Sig) |
| Temp | -7.08 | -12.40 | 0.000 |
| Time*Temp | -12.92 | -22.61 | 0.000 |
| S = 1.97906 PRESS = 70.5 | | | |
| R-Sq = 98.81% R-Sq(pred) = 97.33% R-Sq(adj) = 98.37% | | | |

After experimenting with the factorial design method in the type of central composite design, it was found that the integrity of the chicken after baking was at the trial run the sixth order at a temperature equal to 150 degrees Celsius and the time was 45 minutes, the percentage of internal and external integrity of the chicken was 92, as shown in Figure 4.

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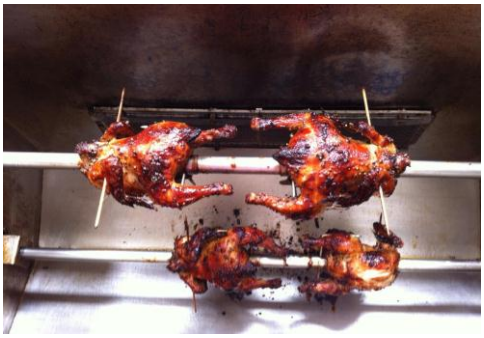

**Figure 4: the optimal internal and external integrity of the chicken**

The effect of Temperature and Time is on the estimated response surface of completeness is depicted in the Figure 5, the Temperature remains constant in its maximum level of 250 degree Celsius. It can be noted that the completeness increases when the Time increases, the explanation is same, as stated earlier, however with the increase in Temperature, completeness decreases, this is because when Temperature increases, there will be an undesirable heat loss which does not contribute to completeness. The response taken from Table IV revealed that the square coefficients of Temp (X1), and Time (X2), have a remarkable effect on the percentage of good rice yield. Moreover, all the linear and interaction terms of three factor presented in significant effects on the percentage of good rice yield at 5% probability level. Since all coefficients of the above Equation (2) are all negative, the response surface is suggested Time have a maximum point in Figure 6. A significantly chicken baking was observed as temperature addition increased ($P < 0.05$, Figure 6). This can be partly attributed to the higher Temperature, higher, and Time of these. Using low percentage of completeness yielded bigger specific volumes, Temperature, and subsequently higher Time values. In Figure 6 presents a graphical representation of one of the response surfaces generated through RSM using a full quadratic model of Temperature (X1), and Time (X2) to predict the percentage of completeness. As depicted, the normalized search direction to maximize the chicken baking is (-1, +1).

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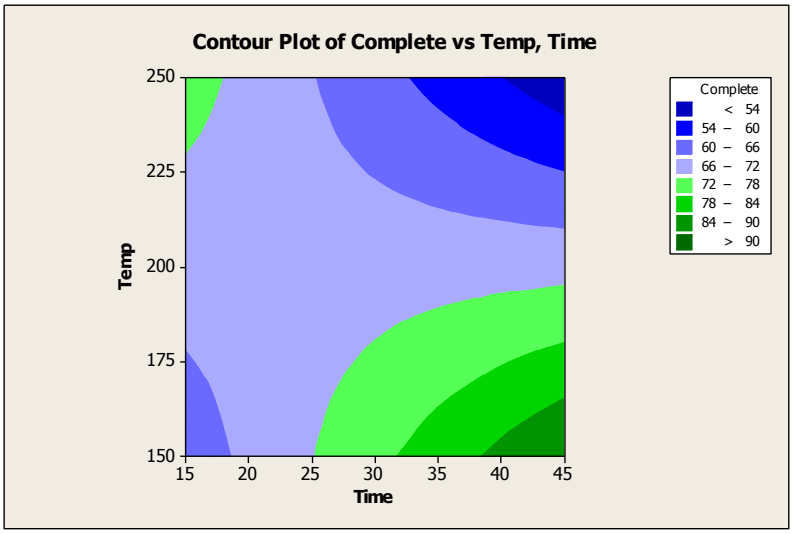


**Figure 5: Contour plot of complete vs. Temp, Time**

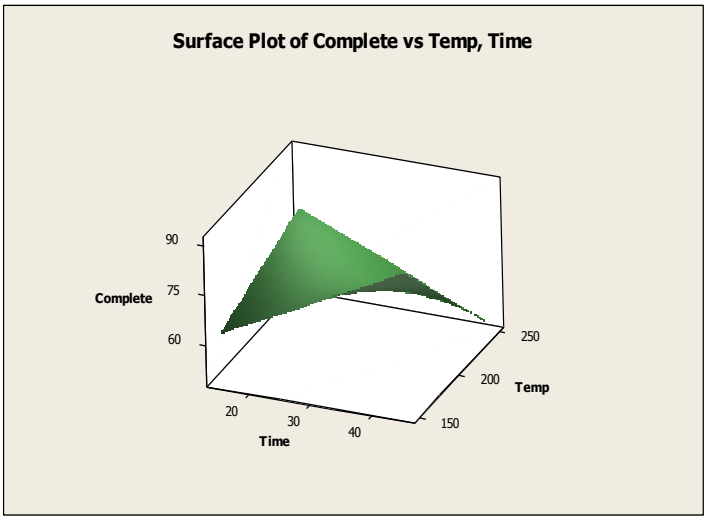


**Figure 6: Surface plot of complete vs. Temp, Time**

The check of the normality assumptions of the data is then conducted, it can be seen in Figure 7 that all the points on the normal plot come close to forming a straight line. This implies that the data are fairly normal and there is no deviation from the normality. This shows the effectiveness of the developed model.

Optimal value of factors affecting broiler percentage after baking. The percentage of completeness is 90, satisfaction is 0.833333 the optimum factor between time and temperature is 45 minutes, and 150 degrees Celsius as shown in Table 7.

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The figure 8 shows the optimal value, and the most suitable factors in this experiment.

## Verification experiments

After obtaining the appropriate factor value from the prediction is the time and temperature of the chicken then take the factor value. Two who went to do a chicken baking experiment to check the percentage of good chicken after baking? Which from the experiment of roasting chicken 5 experimental units shown in table 8.

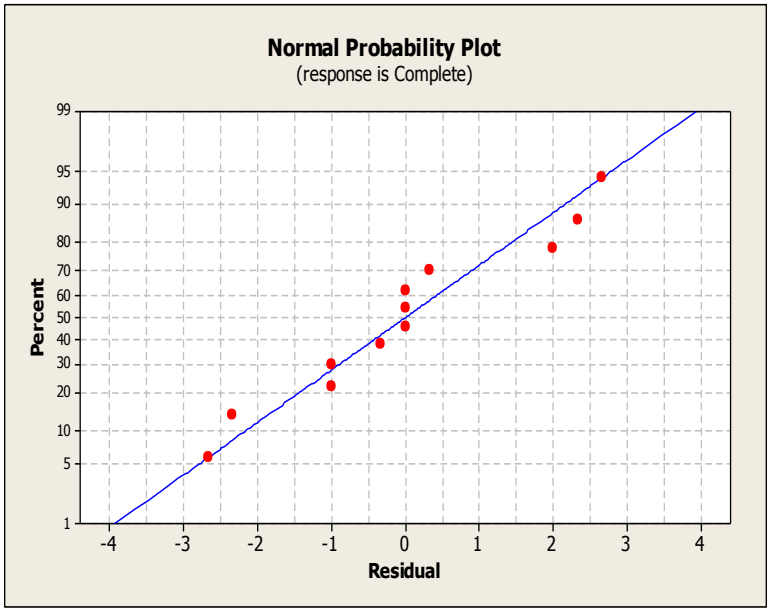


**Figure 7: Normal probability plots**

**Table 7: Optimal Value of Factors Affecting Broiler Percentage after Baking**

| **Response Optimization** | | | | | |
|---|---|---|---|---|---|
| Parameters | | | | | |
| Goal | Lower | Target | Upper | Weight | Import |
| Completeness Maximum | 80 | 92 | 92 | 1 | 1 |
| Global Solution<br>Time = 45<br>Temp = 150 | | | | | |
| Predicted Responses | | | | | |
| Completeness = 90, desirability = 0.833333 | | | | | |
| Composite Desirability = 0.833333 | | | | | |

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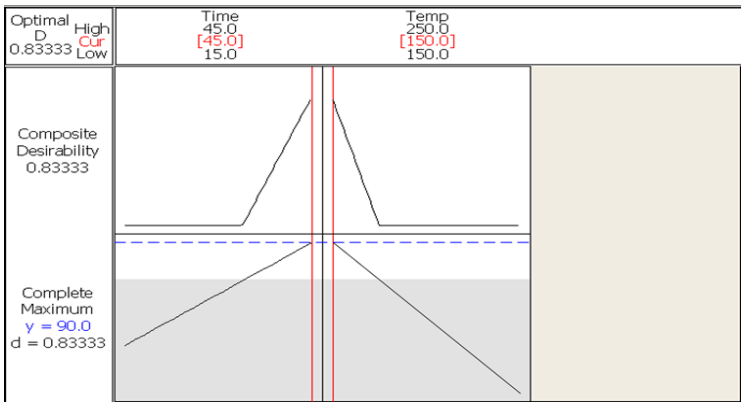


**Figure 8: the graph shows the optimum point for each factor of broiler chickens**

**Table 8: experimental confirmation**

| The times | percentage of chicken |
|---|---|
| 1 | 95 |
| 2 | 90 |
| 3 | 95 |
| 4 | 92 |
| 5 | 91 |
| average | 92.6 |

## CONCLUSION

The results of this study have clearly indicated RSM is an effective method for optimization of completeness. Response surface methodology was successfully applied to optimize temperature and time in chicken baking that was not chicken completeness. When productions into the formulation, the optimized levels of R-Squire (adjust) was 98.73 % and standard deviation was 1.97906 yielded good quality chicken baking. This study clearly showed that RSM was one of the suitable methods to optimize the best operating conditions to maximize the baking removing. Graphical response surface and contour plot were used to locate the optimum point. The statistical fitted models and the contour plot of response can be used to predict values of responses at any point inside the experimental space and can be successfully used to optimize the brown rice peeling machine. Also, the size and

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amount of this surface degradation was noticeably increased as a function of exposure time. The surface methodology was used. The optimal composition of the chicken baking established by a central composite design (run order 12) was: temperature 150 degree Celsius, and rice of time 45 minute. The optimal values for the chicken baking parameters were completeness of 92 %.

This research selected an experimental design based on factorials design as a tool that would greatly assist in the chicken baking process. There is significant confidence in the production process. This makes the quality of baking chicken more efficient, can control the factors studied, namely the temperature and time of efficacy were tested with equal broiler weights 1.0 kilograms (constant throughout the experiment).

As for the chicken dryer, the researcher has designed it for farmers or target groups who want to use it for the benefit of broiler production, which is currently quite popular for consumption.

The experimental design of the roasting process in Thailand does not report the results of experiments from operators who operate chicken baking. In this research, the researcher studied the most suitable conditions for roasting chicken for the best quality. Most suitable as shown above. In addition to the best results, Other common factors It has the same effect as Ingredients for seasoning, fermentation, marinating time for chicken meat It has a significant effect on the production process.

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