UNIVERSITI MALAYSIA KELANTAN

OPTIMISATION OF RESPONSE SURFACE METHODOLOGY (RSM) FOR ESTIMATION OF BROILER QUAIL'S BASAL DIET

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DECLARATION

I hereby declare that the work embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities or institutions.

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I certify that the report of this final year project entitled Optimisation of Response Surface Methodology (RSM) For Estimation of Broiler Quail's Basal Diet by Nur Afiqah Binti Ab. Wahab, matric number F15A0125 has been examined and all the correction recommended by examiners have been done for the degree of Bachelor of Applied Science (Animal Husbandry Science) with Honours,

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OPTIMISATION OF RESPONSE SURFACE METHODOLOGY (RSM) FOR ESTIMATION OF BROILER QUAIL'S BASAL DIET

ABSTRACT

The aim of this research was to optimise the utilisation of Response Surface Methodology (RSM) for estimation of basal feed requirement of broiler quail using three sources of ingredients. The sources were Tapioca starch as carbohydrate source, Black Soldier Fly Larvae (BSFL) as protein source and turmeric as immunity booster. The ration of feed formulation was studied by using a standard RSM design called a central composite design (CCD). It is well suited for fitting a linear surface, which usually works well for process optimisation. The Design-Expert Software Version 7.0 was used to estimate the feed requirement for broiler quail by insert the three factors and Japanese quail was used in this research. A total of 120 quails age 1 day were allocated in 20 cages replicates each with six quails and were given different treatment in each 20 cages. The treatment consisted of 20 different feed formulation which follow the predicted experimental data by Design-Expert Software Version 7.0. The feeding trial was done for 14 days. In this study, three responses that were measured during the experiment were Average Daily Gain (ADG), Feed Conversion Ratio (FCR) and Survival Rate (SR). The results indicated that the graph effect of factor towards response shows the increasing of ADG and decreasing of FCR value from 1.43169 g to 1.60831 g and 3.85698 g to 3.12302 g respectively when the percentage of BSFL was increased. As for SR, the value increased from 71.1156 to 78.5844 when the percentage of turmeric was increased. The desirability of the three responses also high as the desirability was 0.861 which was close to d=1. In conclusion, BSFL and turmeric gave the most positive impact towards the three responses compared to tapioca starch.

Keywords: Tapioca starch, Japanese quail, turmeric, Black Soldier Fly Larvae, survival rate

Pengoptimuman *Response Surface Methodology* (RSM) Untuk Anggaran Diet Asas Puyuh Pedaging

ABSTRAK

Tujuan penyelidikan ini adalah untuk mengoptimumkan penggunaan *Response Surface Methodology* (RSM) untuk menganggarkan keperluan makanan asas burung puyuh pedaging menggunakan tiga sumber ramuan. Sumbernya adalah kanji ubi kayu sebagai sumber karbohidrat, *Black Soldier Fly Larvae* (BSFL) sebagai sumber protein dan kunyit sebagai penggalak daya tahan. Catuan formulasi makanan dikaji dengan menggunakan reka bentuk ukuran RSM yang disebut *Central Composite Design* (CCD). Model ini sesuai untuk memasang permukaan linear, yang biasanya berfungsi dengan baik untuk pengoptimuman proses. *Design-Expert Software* Versi 7.0. digunakan untuk menganggarkan keperluan makanan untuk puyuh pedaging dengan memasukkan tiga faktor dan burung puyuh Jepun digunakan dalam penyelidikan ini. Sebanyak 120 puyuh berumur 1 hari diperuntukkan dalam 20 sangkar yang berulang dengan enam puyuh dan diberi rawatan yang berbeza dalam setiap 20 sangkar. Rawatan ini terdiri daripada 20 formulasi makanan yang berbeza yang mengikuti data percubaan yang diramalkan oleh *Design-Expert Software* Versi 7.0. Percubaan makan dilakukan selama 14 hari. Dalam kajian ini, tiga respon yang diukur semasa eksperimen ialah Purata Kenaikan Harian (ADG), Nisbah Penukaran Makanan (FCR) dan Kadar Daya Tahan Hidup (SR). Hasilnya menunjukkan bahawa graf kesan faktor terhadap respon menunjukkan peningkatan ADG dan penurunan nilai FCR dari 1.43169 g kepada 1.60831 g dan 3.85698 g kepada 3.12302 g masing-masing apabila peratusan BSFL meningkat. Bagi SR nilai meningkat dari 71.1156 hingga 78.5844 apabila peratusan kunyit meningkat. Keinginan dari tiga respon juga tinggi kerana keinginan ialah 0.861 yang hampir kepada d = 1. Kesimpulannya, BSFL dan kunyit memberikan impak yang paling positif terhadap tiga respon berbanding kanji ubi kayu.

Kata kunci: kanji ubi kayu, puyuh Jepun, kunyit, *Black Soldier Fly Larvae*, kadar daya tahan hidup

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LIST OF ABBREVIATION AND SYMBOLS

ANOVA	Analysis of Variance
CCD	Central Composite Design
RSM	Response Surface Methodology
ADG	Average Daily Gain
FCR	Feed Conversion Ratio
SR	Survival Rate
CP	Crude Protein
3D	Three Dimensional
2D	Two Dimensional
g	Gram
%	Percentage
R^2	Correlation Coefficient

CHAPTER 1

INTRODUCTION

1.1 Research Background

The feed cost is 60-70% of the total cost of production in poultry industry and it is considered a large percentage (Thirumalaisamy *et al*., 2016). For economic reasons, this supply of nutrients should be at least cost effective thus the supply must at least fulfil the basal diet requirements. The feeds of broiler quails is needed for growth, maintenance and to increase body weight as broiler quails bred for meat. Previous research stated that choose ingredients to maximise nutrient availability rather than simply meeting energy or amino acid levels is necessary during formulating the broiler diet. It is also explained that in formulating broiler diets, the main emphasis is placed on the crude protein (CP), because protein is the critical constituent of poultry diets, and together with the other main nutrients such as carbohydrates, fat, water, vitamins and minerals is essential for life.

However, protein is also one of the most expensive ingredients in poultry diets (Beski, Swick & Iji, 2015).

Therefore, nutritionally and economically, proper protein usage is essential in all feedings systems and wasteful usage increase the cost of production (Beski *et al*., 2015). Response surface methodology (RSM) is a collection of statistical and mathematical techniques that can be used to define the relationships between the response and the independent variables. Application of RSM can be used to determine nutrient requirements in broiler quails especially protein sources (Mehri, Davarpanah & Mirzaei, 2012)

In this study, three source of ingredients were studied which were tapioca starch as carbohydrate source, Black Soldier Fly Larvae (BSFL) as another protein source and turmeric rhizome as immunity booster using utilisation of Response Surface Methodology (RSM). A lot of research have been done using RSM as an application in their study. For example, in previous research the estimation of ideal ratios of methionine and threonine to lysine in starting broiler chicks using response surface methodology have been studied (Mehri *et al*., 2012). This technique has been very popular for optimisation studies in recent years. Response surface methodology has several advantages compared with classic experimental designs. The first advantage is RSM gives a large amount of information on multiple inputs from a small number of runs. Second, the joint effects (e.g., synergism, antagonism) of independent variables that are used simultaneously in the experiment can be observed by using RSM (Bas and Boyaci, 2012).

1.2 Problem Statement

The high growth rate and feed efficiency are the two main targets in poultry production. Previous research stated that to minimise feed cost and maximise broiler performance, the concept of ideal protein as a tool for feed formulation has been suggested (Baker *et al*., 2002). Broilers have high dietary protein requirements. However, protein sources available that can be used in poultry diets are costly. In order to reduce the cost in feed formulation, other alternative ingredients that contain high protein and carbohydrate but low in cost such as tapioca starch, BSFL and turmeric need to be studied.

The application of Response Surface Methodology (RSM) bring the ease in the feed formulation as it is minimise the experimental number required to conduct and also save the time and cost. The importance of this study was to estimate feed requirement for Japanese quails using RSM as to cover the problem related to the feed cost in poultry industry. This study also important to increase the growth of broiler quail which was Japanese quail in short period of time.

1.3 Hypothesis

To estimate the efficiency of feed formulation for broiler quails with three main ingredients (TS, BSFL and TR) using Response Surface Methodology (RSM).

H_0 = the efficiency of feed formulation for broiler quails with three main ingredients (TS, BSFL and TR) using Response Surface Methodology (RSM) would not bring any significant.

H_1 = the efficiency of feed formulation for broiler quails with three main ingredients (TS, BSFL and TR) using Response Surface Methodology (RSM) would bring significant.

1.4 Objectives

The main objectives of this study are:-

1. To investigate significance amount of the three main ingredients used in this study: TS, BSFL and TR for feed formulation using RSM.
2. To optimise the feed formulation process (in terms of the use of different amount of the three main ingredients) for Japanese quails by using Response Surface Methodology (RSM).

3. To evaluate the growth performance of Japanese quails fed by different rations formulated.

1.5 Scope of Study

This research was focus on two main scopes to justify the objectives and prove the validity of the hypothesis stated. Firstly, this research was focus on estimation the significant amount of ingredient between three sources which are protein and carbohydrate source for feed formulation using RSM. Secondly, this research was started the feeding trial and monitor the growth performances of Japanese quail. These results was obtained by several methods include feed formulation, uses of experimental design to estimate the significance ingredient and data analysis of quail body weight.

1.6 Significance Study

Tapioca starch (TS) as carbohydrate source and turmeric rhizome as immunity booster that can be easily found and obtained whether in market or Agro Techno Park in UMK. This two sources of carbohydrate and antibiotic are low in cost. They also have high content of carbohydrate and antibiotic which is suitable and necessary in broiler quails. As for black soldier fly larvae, it has to be bred it in the laboratory using manure or other kind of source such as food waste and dead fish. Black soldier fly larvae can also convert manure from cattle, chickens or pigs into a product containing approximately 40% of protein and 35% of fat in dry matter which is high in protein (Moula, Scippo & Douny, 2017). These are very low cost and abundant to be used as source of ingredients in broiler quails feed formulation.

CHAPTER 2

LITERATURE REVIEW

2.1 Response Surface Methodology (RSM)

Response surface methodology (RSM) is a collection of mathematical and statistical techniques useful for analysing the effects of several independent variables on the response. RSM has an important application in the process design and optimisation as well as the improvement of existing design.

This methodology is more practical as it arises from experimental methodology which includes interactive effects among the variables and eventually, it depicts the overall effects of the parameters on the process. In the last few years, RSM has been applied to optimise and evaluate interactive effects of independent factors in numerous chemical and biochemical processes (Amini, Younesi, Bahramifar, Lorestani, Ghorbani *et al.*, 2008).

RSM which is a technique for designing experiment helps researchers to build models, evaluate the effects of several factors and achieve the optimum conditions for desirable responses in addition to reducing the number of experiments. Analysis of variance (ANOVA) provides the statistical results and diagnostic checking tests which enables researchers to evaluate adequacy of the models. Central composite design (CCD) in RSM was used to design the experiments, build models and determine the optimum conditions (Ghafari *et al.*, 2009).

2.2 Broiler Industry in Malaysia

Broiler meat is a primary protein source for the majority of Malaysian populations. Malaysia is one of the highest poultry consumers in the world with a per-capita consumption of 35.3kg in 2011. In 2010, broiler production in Malaysia contributed 53.2% of the total livestock production which was valued at RM10.85 billion. This industry has experienced high self-sufficient level, which was achieving 128.1% in 2011 (Syauqi, Zaffrie & Hasnul, 2015).

The overall production of broiler has expanded steadily, in line with the growth in local demand and could be exported to some countries. Currently, Malaysia is exporting live birds and processed poultry products to Singapore and some Middle East countries. Singapore is the largest poultry market where over 1.716 Million live birds were exported every day in 2014. Malaysia is taking an advantage of its geographical proximity to penetrate Singapore's market. Even though Malaysia can export its broiler, it still imports broiler meat products for processing industries. Government tightly controls the imports of poultry meat. The importers are only allowed to import certain portion of broiler meat, such as breasts and whole legs. In 2012, China was the main supplier of broiler meat to this country, followed by Thailand, Denmark and the Netherlands (Syauqi *et al*., 2015).

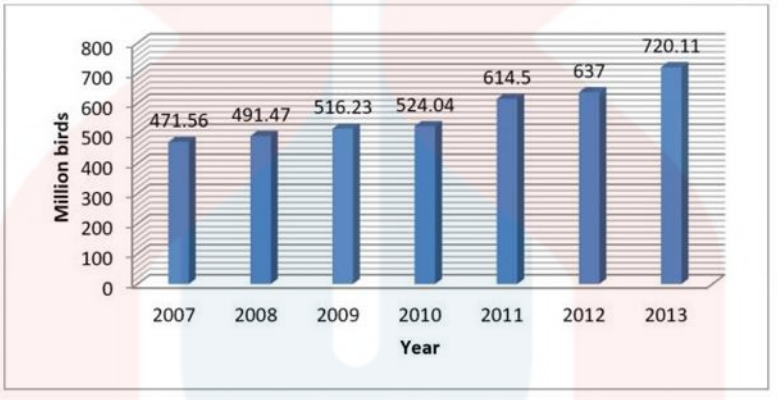

Figure 2.1: Commercial broiler production (2007-2013)

Source: Syauqi (2015).

2.3 Broiler Quails Production

The Japanese quail is the most common species of quail found mainly in East Asia. It was considered as a subspecies of the common quail, but it was distinguished as its own species in 1983. The scientific name for this quail is Coturnix c. japonica (Boon P, 1999). Populations of the Japanese quails are known to inhabit mainly Russia and East Asia (including China, India, Japan and Korea). They are also available and found in some other Asian countries such as Cambodia, Laos and Vietnam (Anynomous, 2018).

This small bird has white streaks on mottled gray-brown upperparts, white eyebrow, gray breast with black-gray streaks, rufous sides with white streaks, white belly, gray bill, tan legs and a short tail. The male's throat and face are rufous while female's is white with a black-gray border (Vest, 2013). In some parts of the world, quails are kept as poultry birds both for the small amount of meat that they contain and for the quail's brightly coloured eggs. Although quails are omnivorous animals, they tend to have a primarily vegetarian diet eating seeds, wheat, barley, flowers and fruits but they will also eat insects such as worms and grasshoppers. Around 95% of the quail's diet is thought to consist of plant matter (Zergnet, 2018).

Japanese quail are hardy birds that thrive in small cages and are inexpensive to keep. They are affected by common poultry diseases but are fairly disease resistant (Anynomous, 2007). Japanese quail mature in about 6 weeks and are usually in full egg production by 50 days of age. Ricklefs mentioned that Japanese quail has the fastest growth rate in the family Phasianidae (Boon P, 1999).

2.4 Tapioca Starch

Tapioca starch is obtained from the roots of the cassava plant which the scientific name is *Manihot esculenta*. The name cassava is generally applied to the roots of the plant, whereas tapioca is the name given to starch and other processed products. Cassava products were long used as a raw material for compound feedstuffs until their use declined after the Second World War when grains became cheaper than cassava products in Europe. The large central pith of the cassava roots is the starch-reserve flesh and can range in starch content from as low as 15% to as high as 33%. Cassava, similar to feed grains, consists almost entirely of starch and is easy to digest. Many feeding experiments have shown that cassava provides a good quality carbohydrate which may be substituted for maize or barley and that cassava rations are especially suitable for swine, dairy cattle and poultry.

The amount of cassava and its products fed to animals as scraps in the tropical regions must be fairly large, but there is no way of estimating it. Sheeba and Padmaja observed that the processing can prolong the palatability and shelf-life of cassava products. Poultry feed compose of more than 90 percent of all commercial livestock feeds produced. It will make a greatest impact if cassava can be include into commercial poultry feeds as cassava can substitute the maize in poultry feed. However, to achieve satisfactory performance of stock on cassava-based diets certain precautions need to be taken.

One of the precautions is to overcome dustiness as the poultry may found difficulty to consume the feed if the feed is higher in dustiness. Most of the present studies observed that satisfactory growth response has been obtained for growing chicken at 10%

incorporation of cassava flour (lafun) or cassava peel into the diet as well as 40% inclusion of cassava flour or 20% inclusion of cassava peel in layer's diet is satisfactory for egg production. Combination of cassava root and leaves in ratio 4:1 could substitute maize in poultry diets and lower the feed cost without a loss in weight gain or egg production (Apata & Babalola, 2012).

2.5 Turmeric

Turmeric is a member of the Curcuma botanical group, which is part of the ginger family of herbs, the Zingiberaceae. Its botanical name is *Curcuma longa*. Two closely related plants, *Curcuma petolata* and *Curcuma roscoeana*, are natives of Cambodia and are grown for their decorative foliage and blossoms. All curcumas are perennial plants native to southern Asia. They grow in warm, humid climates and thrive only in temperatures above 60°F (29.8°C). India, Sri Lanka, the East Indies, Fiji, and Queensland (Australia) all have climates that are conducive to growing turmeric. The plant grows to a height of three to five feet and has oblong pointed leaves with bears funnel-shaped yellow flowers ("Turmeric", 2018)

In India, the rhizome of turmeric has a rich history as spice, food preservative and colouring agent. It has also been used for centuries in traditional medicine (Kermanshahi, 2007). Turmeric is widely used in indigenous medicine in Asia as an antimicrobial, endogenous stimulant, antiflatulent and anti-inflammatory agent (Samarasinghe, 2003).

Turmeric has high carbohydrate content (65g) than protein content (7.8g). However, in feed formulation turmeric can be added as an antibiotic for broiler quail.

2.6 Black Soldier Fly Larvae

The black soldier fly which scientific name is *Hermetia illucens* (Linnaeus), only has two wings and does not possess a stinger. The black soldier fly is often associated with the outdoors and livestock, usually around decaying organic matter, they have been used to reduce animal manure in commercial swine and poultry facilities. Black soldier fly larvae are a promising source of protein and lipid for animal feeds (Liland *et al*., 2017).

The black soldier fly has been studied for its capability to convert organic waste to high-quality protein, control certain harmful bacteria, insect pests and use as feed for a variety of animals. Although BSF larvae contain high protein levels (from 37 to 63% dry matter; DM), and other macronutrients and micronutrients important for animal feed, the available studies on including BSF larvae in feed rations for poultry, pigs and fish suggest that it could only partially replace traditional feedstuff, because high or complete replacement resulted in reduced performances (Barragan-Fonseca, Dicke & Loon, 2017).

It is significant to use BSFL as an ingredient in feed formulation in broiler quail. It is because the high content of protein that required in broiler quail diets especially during starter age (1-4 weeks). Besides, we choose BSFL because in poultry feed based on maggots, like larvae of black soldier fly (*Hermetia illucens*) is an attractive option to substitute current ingredients which are expensive and often in direct or indirect competition with human food (Moula *et al.*, 2017).

2.7 Feed Conversion Ratio

Feed conversion ratio (FCR), defined as the feed requirement per unit of body weight gain, is commonly used as an indicator for the economic evaluation of pig breeding and fattening enterprises. Fattening experiments, and particularly metabolism studies, show that FCR depends on nutritional factors such as the quantity, composition and digestibility of the feed, and on the other hand on animal and environmental factors, such as breed, sex, age, body weight, body weight gain, management and health.

The coherence of these factors has been discussed intensively by the Pig Commission at the annual meetings of the E.A.A.P. The feed component of FCR is often expressed as the amount of energy instead of the mass of feed. It is also helpful to convert the body weight gain component of FCR from mass into energy dimensions. When FCR is expressed in terms of energy units (e.g., intake of metabolisable energy (ME) and energy retention (RE) per day), it is equivalent to the inverse of the gross efficiency of energy utilisation (kt).

The feed conversion ratio in terms of metabolisable energy required per kg body weight gain depends on the following nutritional and physiological parameters which are the level of feeding, the maintenance requirement of the animal, the production requirement and composition of body weight and body weight gain in terms of protein and fat (Wenk, Pfirter and Bickel, 1980).

2.8 Average Daily Gain

Average Daily Gain is the amount of weight gained per day for the animal gained over a given period of time. The average gram daily weight gains play an important role in the optimum growth of the broiler. Under normal practical conditions, a broiler must gain an average of 65 grams or more per day. The average daily weight gain is not uniform for each week and varies considerably depending on age and sex (Butcher & Nilipour, 2004).

Body weight gain in broilers were caused by several factors which are environmental factor, disease control, feed quality and management. Firstly, in environmental factor when there are temperature variances during the brooding period, the growth of the chicks will be negatively affected resulting in poor growth and poor flock uniformity. In very hot weather, birds eat less and target weights will not be attained. High ammonia levels as well as dusty, poorly ventilated houses will also affect body weight gain.

Secondly, erosive diseases such as reovirus, infectious bursal disease (Gumboro), mycoplasma, sub-clinical Newcastle disease and infectious bronchitis will all impact negatively on the growth patterns of broilers. Coccidiosis control is always essential and be aware of the impact of sub-clinical coccidiosis. Excessive applications of vaccines, especially the vaccines against respiratory disease like Newcastle disease, can affect performance. Care must be taken to ensure that there is sufficient protection against disease challenges, without over-vaccinating.

As for the feed quality and availability, it is vital that your feed contains the correct levels of nutrients required by the broilers for optimum growth.

Meanwhile, for the stocking density, the number of drinkers and feeders need to be sufficient to supply feed and water to the broilers, and that access is not impeded by incorrect height adjustments of the equipment.

In management factor, new findings indicate that using at least a 6 to 8 hours period of darkness after the end of the first week is an overall benefit in broiler health status, which will outweigh the possible slightly lowered body weight gains. In fact, most growers have found that there's been no negative effect on the growth rate and there has certainly been a positive impact on the reduction in the incidence of Ascites (water belly) and heart attacks (Versfeld, 2017).

CHAPTER 3

METHODOLOGY

3.1 Materials Experimental Design using Response Surface Methodology (RSM)

As for this method, it is important to choose wisely the suitable experimental design before applying the RSM methodology. The experimental design has two types, which are a first-order model and second-order model. The first-order model is used to investigate the linear relationship of two parameters. It is different for a second-order model which is used when the system involved two or more than two parameters.

Central composite design (CCD) is the most popular type of second-order model experimental design based response surface methodology which can fit a full linear model. Three parameters were investigated in this study and hence the numeric factors were set at three. After that, the CCD model proceeds with the face-centered option with alpha, α equal to 1 were chosen. Face-centered option indicated that only three levels were studied, which were minimum (low), medium (middle) and maximum (high). From the design, a total number of experimental runs were 20 runs in which each of the operating conditions was different (Bezerra, Santelli, Oliveira, Villar, & Escaleira, 2008).

Table 3.1 Experimental design by using Central Composite Design (CCD).

Variables	Name	Units	Low Level (-1)	High Level (+1)
A	Tapioca Starch	%	0.2	21
B	Black Soldier Fly Larvae	%	15	25
C	Turmeric	%	0.5	2.5

3.2 Preparation of Tapioca Starch Sample

Tapioca starch was obtained from the market and prepared to mix with other ingredients.

3.3 Preparation of Turmeric Rhizome Sample

As for the preparation of turmeric rhizome into powder sample, we took turmeric between 7-10 months of age ("How to make turmeric powder", 2016). The first step was to wash the turmeric rhizome thoroughly then boiled to soften the rhizome thus drying process could take place faster. The boiling process took place for around 45 minutes. After that, the drying process started with slicing the rhizome into small pieces. The purpose is to increase the surface area for drying. The forced air drying used to dry turmeric rhizome for 1.5-2 hours at around 60 ^{0}C ("How to make turmeric powder", 2016). The last step is to grind the rhizome that has undergone a drying process. The grinding process was done using an electric blender and we have to make sure that the large particle was crushed well.

3.4 Preparation of Black Soldier Fly Larvae Sample

The BSFL sample was prepared by obtained from the supplier Nutrition Technologies Sdn. Bhd. in a form of BSFL powder.

3.5 Average Daily Weight Gain

The experiment was done for 14 days which is during the brooding period to measure the quails' body weight for every 20 treatments with a different ration of 3 ingredients (refer Table B1). There were 6 quails in every 20 treatments so the average body weight of Japanese quails was calculated to be included in the data collection. The body weight of the 6 quails was measured by using the electronic balance every day for 14 days. For average daily weight gain (ADG), it can be estimated by using the formula:

$$ADG = \frac{(W2 - W1)}{n}$$

ADG = Average Daily Gain

W2 = Final weight

W1 = Initial weight

n = the number of days taken from initial weight to the present weight.

3.6 Feed Intake

The Japanese quails were fed twice a day which in the morning and evening in each treatment. The amount of feed consumed by the quails for a day was calculated by weighing the balances of feed in the morning and evening. As it can be estimated or calculated the intake per day in each treatment by deducting the total of feed given with residue feeds. The formulated feed was given 60 g for a day to the quails. Feed intake was calculated by using the formula:

$$\text{Average feed intake} = \frac{\text{Feed intake}}{\text{N quail}}$$

N = Number of quail

3.7 Feed Conversion Ratio (FCR)

The gain per feed intake was estimated in 14 days. The calculation was using the formula:

$$\text{Feed conversion ratio} = = \frac{\text{Feed intake}}{\text{ADG}}$$

ADG = Average Daily Gain

$$ADG = = \frac{W2 - W1}{n}$$

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Development of Regression Model Equation for Response 1 (ADG)

A standard response surface methodology called central composite design (CCD) was used in this study in order to investigate the effect of independent variables on ADG of quail with minimal experimental runs. As shown in Table 4.1, a model of summary statistic generated by the Design Expert Software Version 7.0 suggested that linear model was the best model that fit the experimental response 1 which is ADG. This suggested model based on the value of adjusted R-squared and the predicted R-squared which are 0.4502 and 0.2979 respectively.

Table 4.1: Model summary statistics of ADG (R1)

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	0.30	0.5370	0.4502	0.2979	2.26	Suggested
2FI	0.31	0.6211	0.4462	0.2509	2.41	
Quadratic	0.27	0.7765	0.5753	0.4563	1.75	
Cubic	0.33	0.7999	0.3663	-1.2929	7.36	Aliased

Table 4.2 shows the linear model for R^2 for Average Daily Weight Gain (ADG). From the Table, C.V is defined as the coefficient of variant was purposely for measuring the consistency of the experiment. A low percentage of C.V (within 10%) was desirable to show the consistency of the experiment (Halim, Kamaruddin & Fernando, 2008). In this study, unfortunately, high C.V was obtained which is 20.06%. Besides, 0.5370 of R^2 value in the table was obtained. The correlation coefficient or R^2 was used to measure the fit of the model and the model will be more accurate if the R^2 value was closed to 1.00. In this study, the R^2 value is quite close to 1.00 and it showed that only 53.7% of the response variability can be explained by the model. It is the same goes with adjusted R^2 and predicted R^2 which were 0.4502 and 0.2979 respectively. The value of both adjusted and predicted R^2 was not closed to value 1.00. Other than that, adequate precision was used to measure the signal to noise ratio where a ratio greater than 4 was desirable (Ghafari, Aziz, Isa & Zinatizadeh, 2009). In this study, adequate precision was 8.457 which showed an adequate signal and fitness of the model.

Table 4.2: The standard deviation and linear model for Response 1.

Std. Dev.	0.30	R-Squared	0.5370
Mean	1.52	Adj R-Squared	0.4502
C.V. %	20.06	Pred R-Squared	0.2979
PRESS	2.26	Adeq Precision	8.457

RSM generated an empirical polynomial regression model in terms of coded factors which reflects the significance of variables towards efficiency of Average Daily Weight Gain (ADG). The empirical formula for polynomial regression model in terms of coded factors was represented by Equation 4.1. According to Equation 4.1, the coefficient with one factor stands for the effect of that particular factor.

The coded equation can be used to examine the significance of the factors towards the experimental response (ADG) by comparing the coefficient. Besides, the positive sign in the coded equation represented that ADG will be increased with the respective parameters. On the other hand, the negative sign indicated the negative effect towards the experimental response (Subash, Zalina & Ahmad, 2007). In this study, a factor that has the biggest positive influence towards ADG was factor B (BSFL) which have value +0.066 in the equation. Coefficient A and C have a negative value so it is showed that the two factors which are Tapioca and Turmeric give negative effect towards ADG.

$$ADG = +1.52 - 0.34*A + 0.066*B - 0.066*C \quad (4.1)$$

4.2 Statistical Analysis for Response 1 (ADG)

The analysis of variance (ANOVA) was used to further justify the adequacy and significance of the models. The mean square of the linear model was obtained by dividing the sum of squares of each variation sources with its respective degree of freedom. In the study, the F-test was used to test the statistical significance of the model. On the other hand, the p-value was used to check the significance and pattern of interaction between the experimental parameters (Ghafari et al., 2009). A good significant term model was indicated by a larger F and smaller p-value. From Table 4.3, the F value of the model was 6.19 and p-value was 0.0054 which showed that the model was significant. If the value of p-value was less than 0.05, the model terms are considered as statistically significant and if the contrast which is insignificant the values greater than 0.1000. From Table 4.3, the results showed that coefficient A was considered as significant model terms for ADG. It is concluded that factor A (Tapioca) was the most important factor in ADG as the F value for this factor also was the largest which is 17.27.

Table 4.3: ANOVA for Response Surface Linear Model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	1.72	3	0.57	6.19	0.0054	significant
A-Tapioca	1.60	1	1.60	17.27	0.0007	significant
B-BSFL	0.060	1	0.060	0.64	0.4338	
C-turmeric	0.060	1	0.060	0.64	0.4338	

4.3 Predicted Values versus Actual Values for Response 1 (ADG)

Firstly, Table 4.4 showed the predicted and actual values for ADG which actual values are the experimental data obtained during the experimental run while the predicted values are the anticipated values generated by CCD model of Design-Expert Software Version 7.0. The highest actual value of ADG was 2.30 g and was differ slightly with the predicted value which is 2.10 g. Secondly, the error terms are examined using the data whether it is normally distributed by plotting a normal probability plot of residuals as shown in Figure 4.1. As observed, the data points were laid reasonably close to the linear line which indicates the residuals were small and distributed normally. On the other hand, Figure 4.2 shows the relationship between actual and predicted values of responses for ADG. From the diagnostic plot, the residuals were scattered around the straight line and indicate that the developed linear model was inadequate to predict the response of Average Daily Weight Gain over the range of parameters studied.

Table 4.4: The actual and predicted values of ADG in CCD model.

Standard Order	Actual Value	Predicted Value	Residual	Internally Studentized Residual	Externally Studentized Residual
1	1.90	1.86	0.037	0.143	0.138
2	1.00	1.18	-0.18	-0.680	-0.668
3	2.00	2.00	4.717E-003	0.018	0.018
4	1.70	1.31	0.39	1.498	1.565
5	2.10	1.73	0.37	1.419	1.469
6	1.20	1.04	0.16	0.596	0.584
7	1.90	1.86	0.037	0.143	0.138
8	1.00	1.18	-0.18	-0.680	-0.668
9	2.30	2.10	0.20	0.774	0.764
10	1.30	0.94	0.36	1.357	1.397
11	1.40	1.41	-8.609E-003	-0.033	-0.032
12	1.70	1.63	0.069	0.261	0.253
13	1.30	1.63	-0.33	-1.261	-1.287
14	1.00	1.41	-0.41	-1.555	-1.634
15	1.80	1.52	0.28	0.942	0.939
16	1.00	1.52	-0.52	-1.750	-1.884
17	1.50	1.52	-0.020	-0.067	-0.065
18	1.70	1.52	0.18	0.606	0.593
19	1.60	1.52	0.080	0.269	0.261
20	1.00	1.52	-0.52	-1.750	-1.884

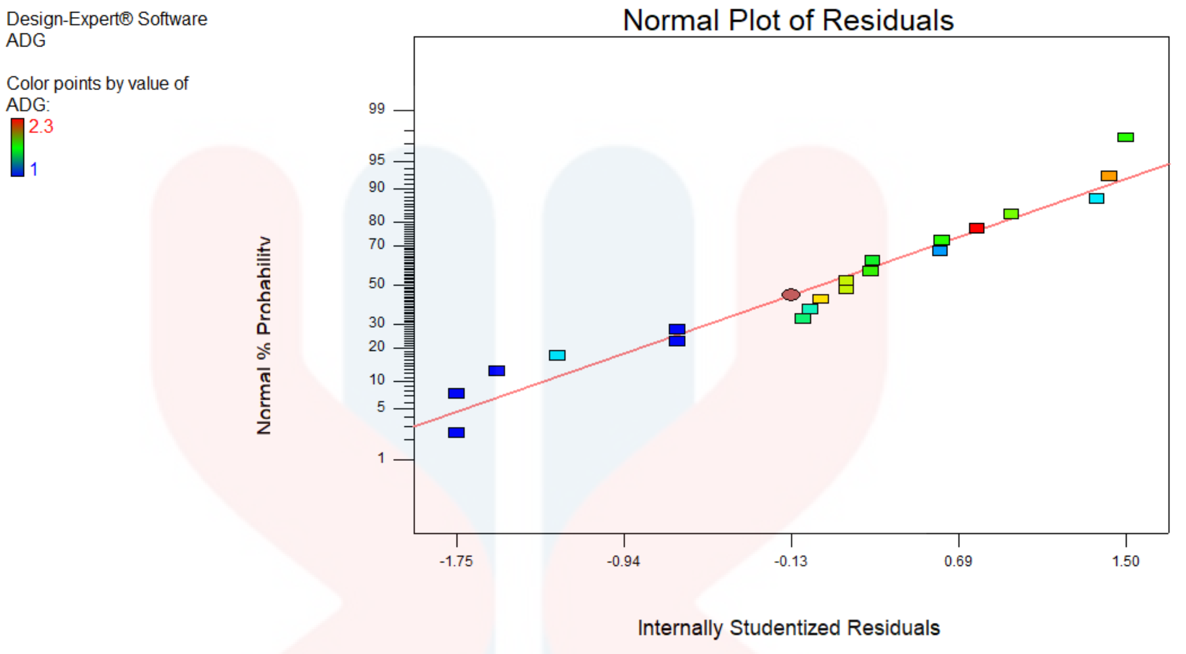

Figure 4.1: Normal probability plot of residual of Average Daily Gain

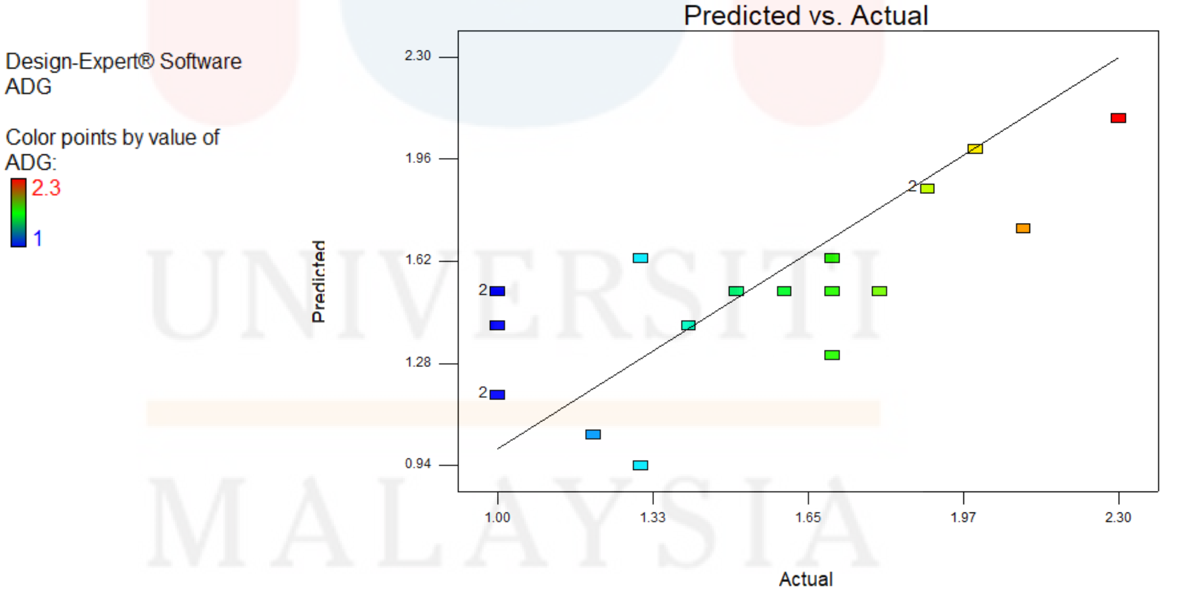

Figure 4.2: Diagnostic plot for predicted values versus actual values of ADG

4.4 Optimisation of feed for Response 1 (ADG)

A three-dimensional (3D) response surface graph and two-dimension (2D) contour plot were obtained to examine the effect of a variable on the ADG while keeping other variables as constant. Besides, the 3D plot and 2D response surface graph were also aimed to identify the optimum level of the variable to achieve optimum ADG.

4.4.1 Effect of Tapioca starch on ADG (Average Daily Weight Gain)

Figure 4.3 (a) and 4.3 (b) shows the effect of Tapioca on ADG while keeping Turmeric as a constant which is 1.50%. From the figure, the value of ADG was decreased when the Tapioca percentage was increased. The colour changes from yellow (high) to blue (low) show the decreasing of ADG value from 1.7927 to 1.2473. The reason for ADG decreased with the increasing of tapioca was that tapioca starch did not have any effect on body weight gain as stated in previous research which observed supplementation of cassava yeast to broiler diets did not improve growth rate (Chumpawadee, Chinrasri & Santaweesuk, 2009).

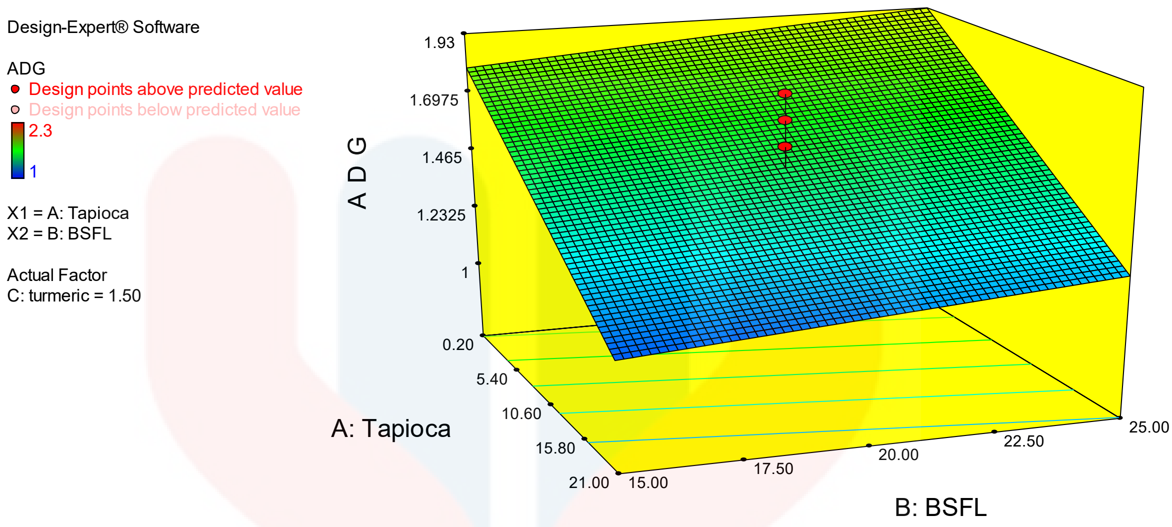

Figure 4.3 (a): 3D response surface graph of an effect of tapioca (%) on ADG (g).

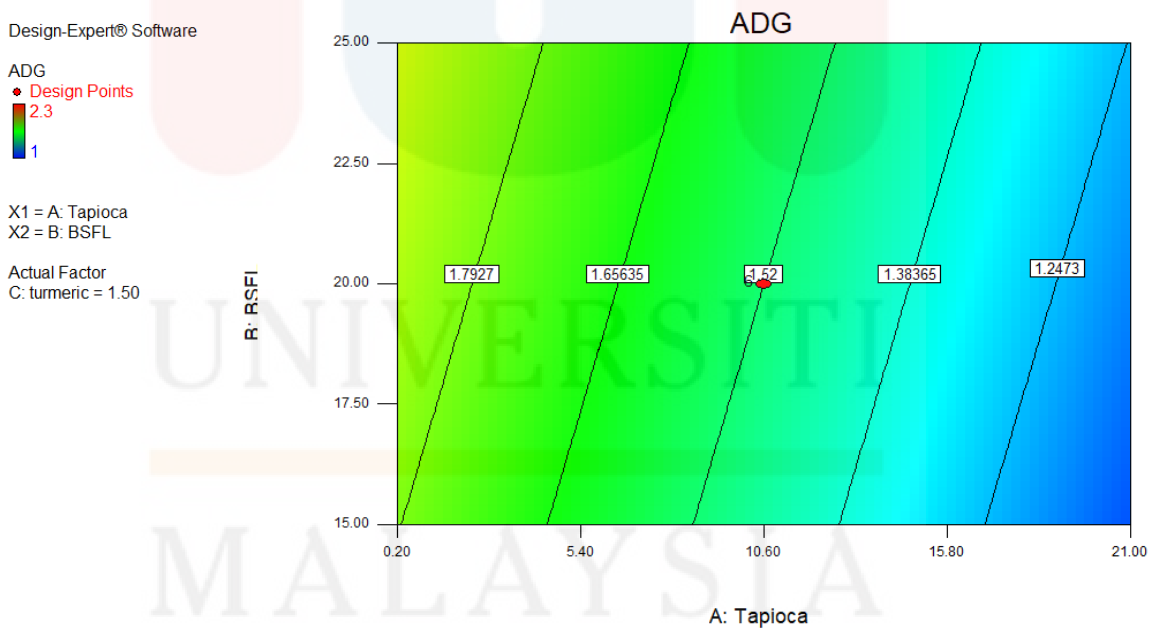

Figure 4.3 (b): 2D contour plot of an effect of tapioca (%) on ADG (g).

4.4.2 Effect of BSFL on ADG (Average Daily Weight Gain)

Figure 4.4 (a) and 4.4 (b) shows the effect of BSFL while keeping tapioca as a constant is 10.60%. As observed in both of the figures, the changing colour from blue (low) to green (high) show the increasing of ADG from 1.43169 to 1.60831 when the percentage of BSFL was increased.

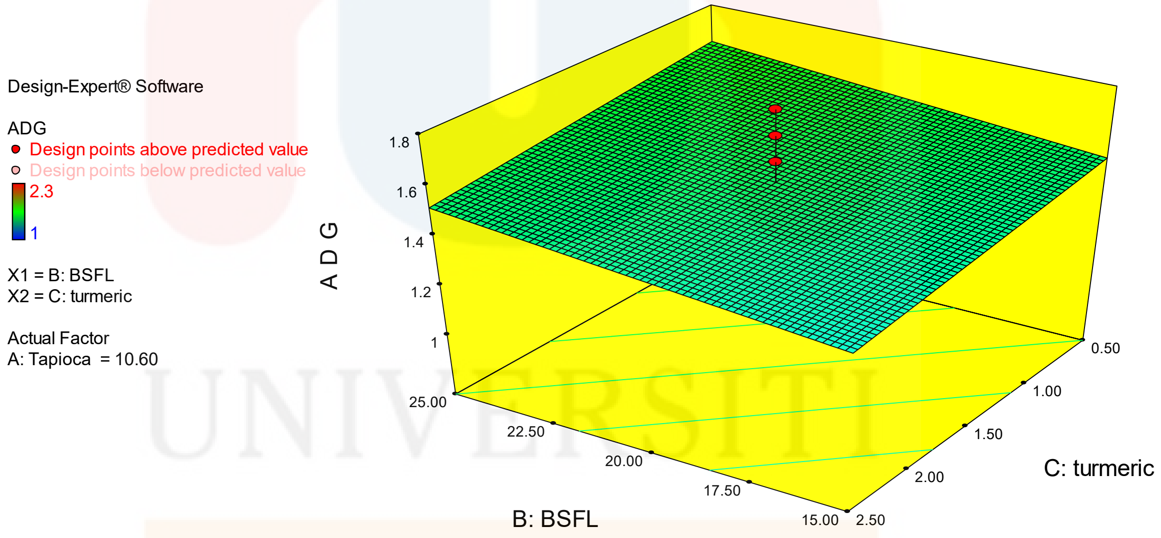

Figure 4.4 (a): 3D response surface graph of an effect of BSFL (%) on ADG (g).

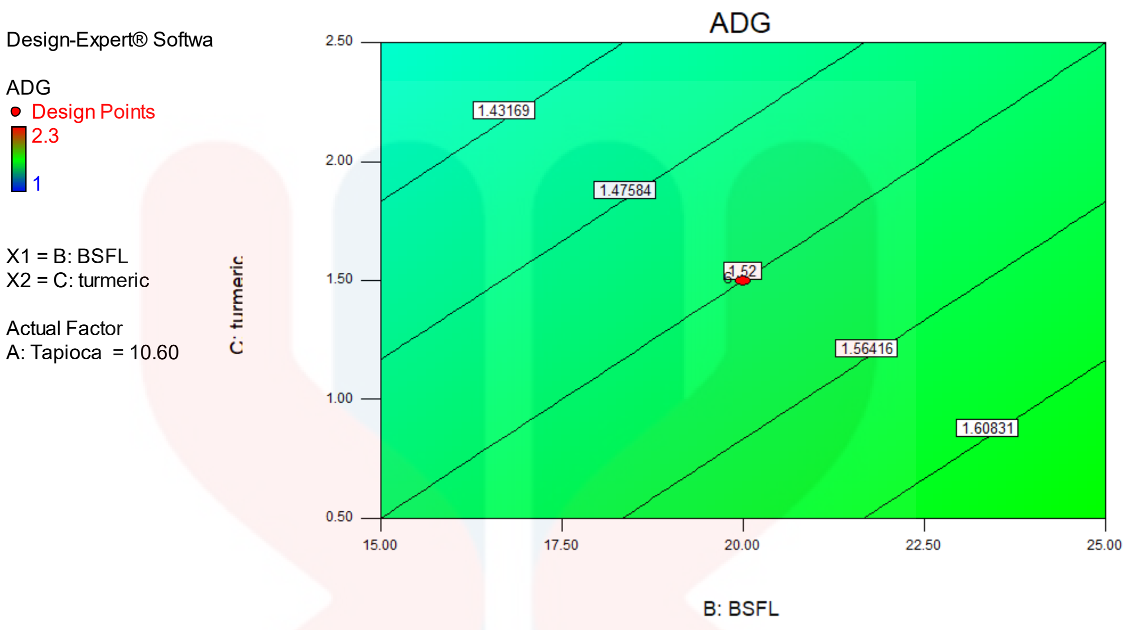

Figure 4.4 (b): 2D contour plot of an effect of BSFL (%) on ADG (g).

4.4.3 Effect of Turmeric on ADG (Average Daily Weight Gain)

Figure 4.5 (a) and Figure 4.5 (b) shows the effect of turmeric while keeping tapioca as constant. From the figure, the value of ADG was decreased when the turmeric percentage was increased. The colour changes from yellow (high) to green (low) show the decreasing of ADG value from 1.83216 to 1.79011. As turmeric contains curcumin which functions as antioxidant and antibacterial activities so it cause no effect on body weight gain (Abou-Elkhair, Ahmed & Selim, 2014).

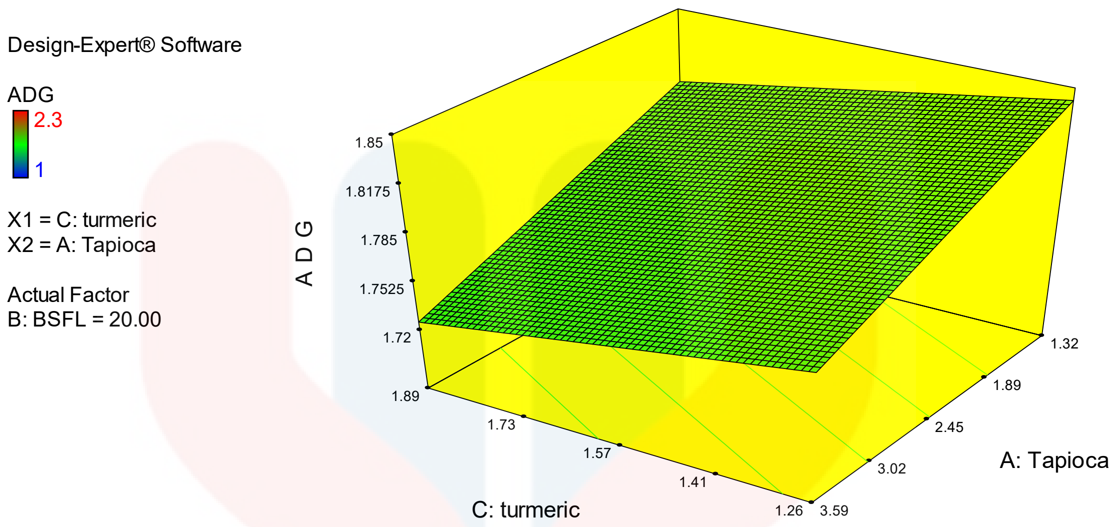

Figure 4.5 (a): 3D response surface graph of an effect of Turmeric (%) on ADG (g).

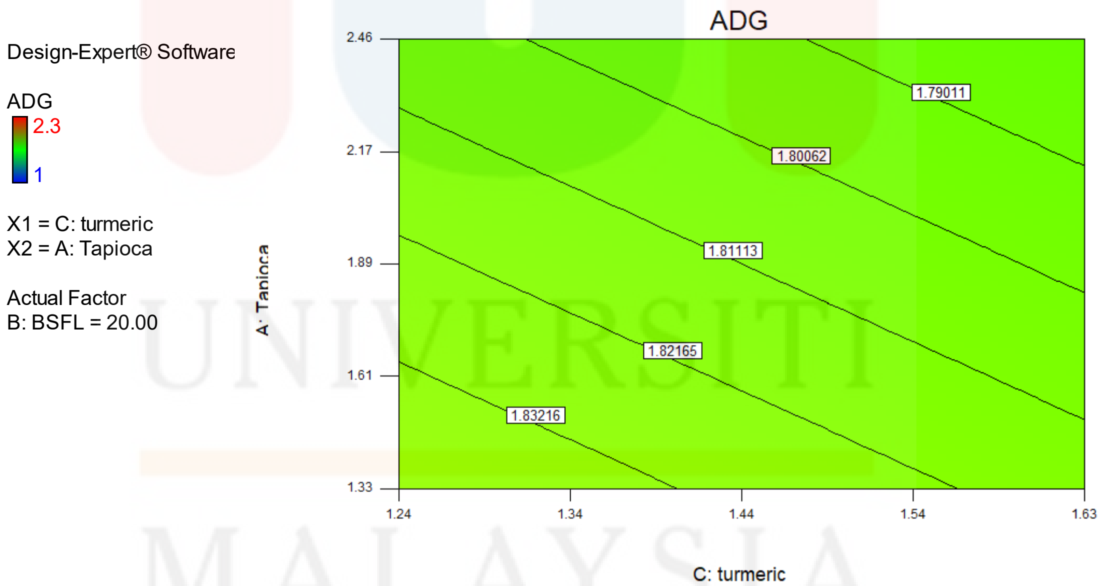

Figure 4.5 (b): 2D contour plot of an effect of Turmeric (%) on ADG (g).

4.5 Development of Regression Model Equation for Response 2 (FCR)

According to the sequential model sum of squares generated by the Design Expert Software Version 7.0, the highest order polynomials for a model were selected where the additional terms were significant and the models were not aliased. In this context, the linear model was suggested as the best model that fit the experimental response 2 which is the Feed Conversion Ratio (FCR). This suggested model based on the value of adjusted R-squared and the predicted R-squared which are 0.2161 and -0.0980 respectively.

Table 4.5: Model summary statistics of FCR (R2)

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	1.21	0.3399	0.2161	-0.0980	38.77	Suggested
2FI	1.17	0.4953	0.2624	-0.6341	57.70	
Quadratic	1.31	0.5171	0.0824	-1.7199	96.05	
Cubic	1.11	0.7914	0.3396	-10.1126	392.42	Aliased

Table 4.6 shows the linear model for Feed Conversion Ratio (FCR). In this study, unfortunately, high C.V was obtained which was 34.59%. Besides, 0.3399 of R^2 value in the table was obtained. The correlation coefficient of R^2 was used to measure the fit of the model and the model will be more accurate if the R^2 value was closed to 1.00.

In this study the R^2 value is very low and not close to 1.00 and response variability cannot be explained by the model. It is the same goes with adjusted R^2 and predicted R^2 which were 0.2161 and -0.0980 respectively. The value of both adjusted and predicted R^2 was not closed to value 1.00.

Table 4.6: The standard deviation and linear model for Response 2.

Std. Dev.	1.21	R-Squared	0.3399
Mean	3.49	Adj R-Squared	0.2161
C.V. %	34.59	Pred R-Squared	-0.0980
PRESS	38.77	Adeq Precision	5.203

RSM generated an empirical polynomial regression model in terms of coded factors which reflects the significance of variables towards efficiency of Feed Conversion Ratio (FCR). The empirical formula for polynomial regression model in terms of coded factors was represented by Equation 4.2.

The coded equation can be used to examine the significance of the factors towards the experimental response (FCR) by comparing the coefficient. Besides, the positive sign in the coded equation represented that FCR will be increased with the respective parameters. On the other hand, the negative sign indicates the negative effect towards the experimental response (Subash *et al*., 2007). In this study, a factor that has the biggest positive influence towards FCR was factor A (tapioca) followed by factor C (turmeric) that showed positive value. However, coefficient B has a negative value and this indicated that factor B which is BSFL give negative effect towards FCR.

$$FCR = +3.49 + 0.83*A - 0.40*B + 0.15*C \quad (4.2)$$

4.6 Statistical Analysis for Response 2 (FCR)

A good significant term model was indicated by a larger F and smaller p-value. From Table 4.7, the F value of the model was 2.75 and p-value was 0.0772 which show that the model was not significant. If the value of p-value was less than 0.05, the model terms are considered as statistically significant and if the contrast which is insignificant the values greater than 0.1000. From Table 4.7, the results showed that coefficient A was considered as significant model terms for FCR. It is concluded that factor A (Tapioca) was the most important factor in FCR as the F value for this factor also was the largest which is 6.53.

Table 4.7: ANOVA for Response Surface Linear Model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	12.00	3	4.00	2.75	0.0772	not significant
A-Tapioca	9.52	1	9.52	6.53	0.0211	significant
B-BSFL	2.16	1	2.16	1.49	0.2405	
C-turmeric	0.32	1	0.32	0.22	0.6472	

4.7 Predicted Values versus Actual Values for Response 2 (FCR)

Firstly, Table 4.8 shows the predicted and actual values for FCR which actual values are the experimental data obtained during the experimental run while the predicted values are the anticipated values generated by CCD model of Design-Expert Software Version 7.0. The highest actual value of FCR was 7.30 g and was differ with the predicted value which was 4.57 g. Secondly, the error terms are examined using the data whether it is normally distributed by plotting a normal probability plot of residuals as shown in Figure 4.6.

As observed, the data points were laid reasonably close to the linear line which indicates the residuals were small and distributed normally. On the other hand, Figure 4.7 shows the relationship between actual and predicted values of responses for FCR. From the diagnostic plot, the residuals were scattered around the straight line and indicate that the developed linear model was inadequate to predict the response of Feed Conversion Ratio over the range of parameters studied.

Table 4.8: The actual and predicted values of FCR in CCD model.

Standard Order	Actual Value	Predicted Value	Residual	Internally Studentized Residual	Externally Studentized Residual
1	3.27	2.90	0.37	0.358	0.348
2	7.30	4.57	2.73	2.646	3.416
3	1.84	2.10	-0.26	-0.257	-0.249
4	2.88	3.77	-0.89	-0.867	-0.860
5	2.11	3.21	-1.10	-1.062	-1.067
6	5.20	4.88	0.32	0.315	0.306
7	2.24	2.41	-0.17	-0.164	-0.159
8	4.81	4.08	0.73	0.709	0.697
9	2.60	2.09	0.51	0.494	0.482
10	3.00	4.89	-1.89	-1.821	-1.980
11	2.60	4.16	-1.56	-1.499	-1.566
12	3.00	2.82	0.18	0.173	0.167
13	2.53	3.23	-0.70	-0.677	-0.665
14	4.32	3.75	0.57	0.552	0.539
15	3.51	3.49	0.020	0.017	0.016
16	5.02	3.49	1.53	1.301	1.332
17	2.69	3.49	-0.80	-0.680	-0.668
18	4.58	3.49	1.09	0.927	0.922
19	2.30	3.49	-1.19	-1.012	-1.012
20	4.00	3.49	0.51	0.434	0.422

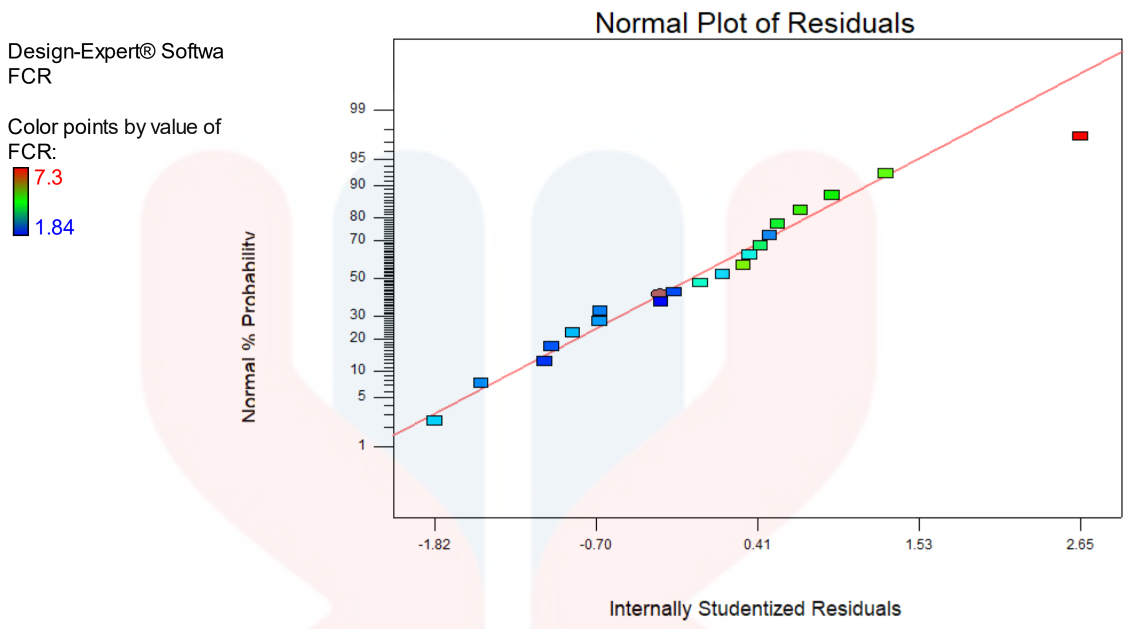

Figure 4.6: Normal probability plot of residual of Feed Conversion Ratio

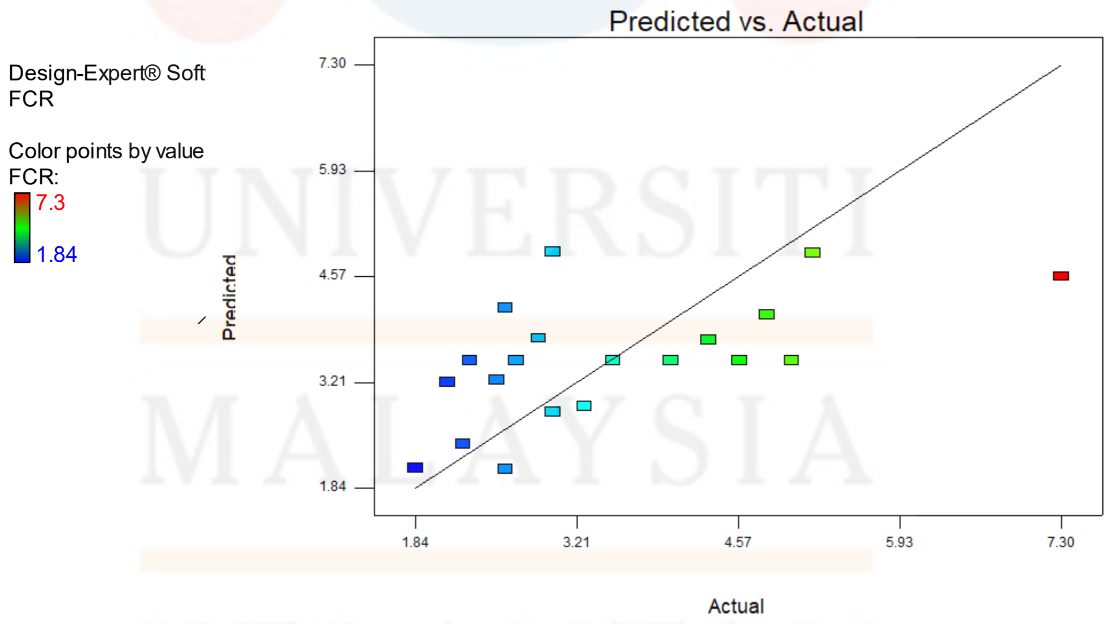

Figure 4.7: Diagnostic plot for predicted values versus actual values of FCR

4.8 Optimisation of feed for Response 2 (FCR)

A three-dimensional (3D) response surface graph and two-dimension (2D) contour plot were obtained to examine the effect of a variable on the FCR while keeping other variables as constant. Besides, the 3D plot and 2D response surface graph were also aimed to identify the optimum level of the variable to achieve optimum FCR.

4.8.1 Effect of Tapioca starch on FCR (Feed Conversion Ratio)

Figure 4.8 (a) and 4.8 (b) shows the effect of Tapioca on FCR while keeping Turmeric as a constant which is 1.50%. From the figure, the value of FCR was increased when the Tapioca percentage was increased. The colour changes from blue (low) to green (high) show the increasing of FCR value from 2.66795 to 4.31205. This can be concluded that the effect of Tapioca was not giving good effect to FCR as good FCR is in the lowest value.

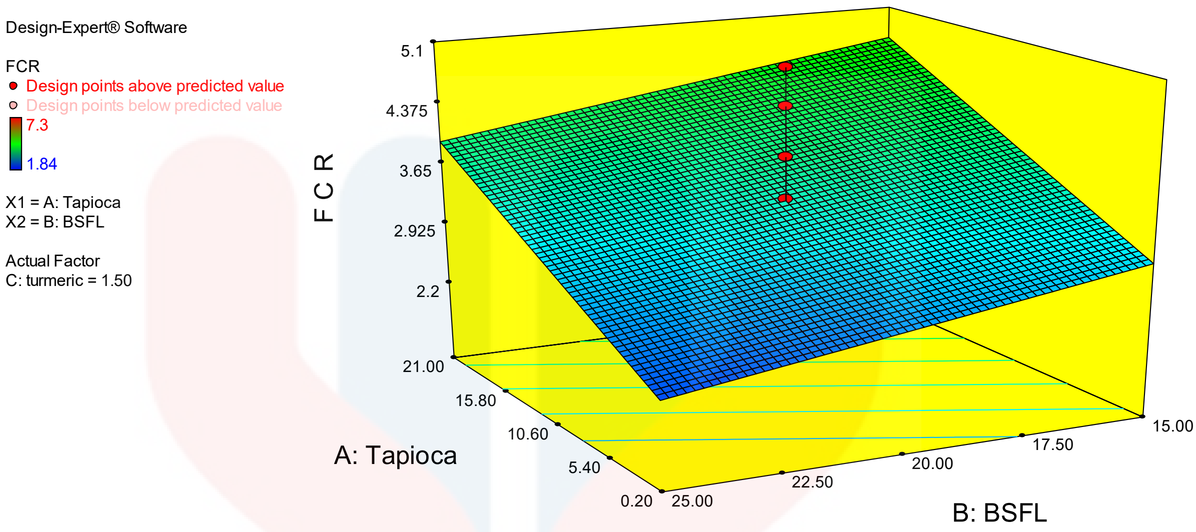

Figure 4.8 (a): 3D response surface graph of an effect of Tapioca (%) on FCR (g).

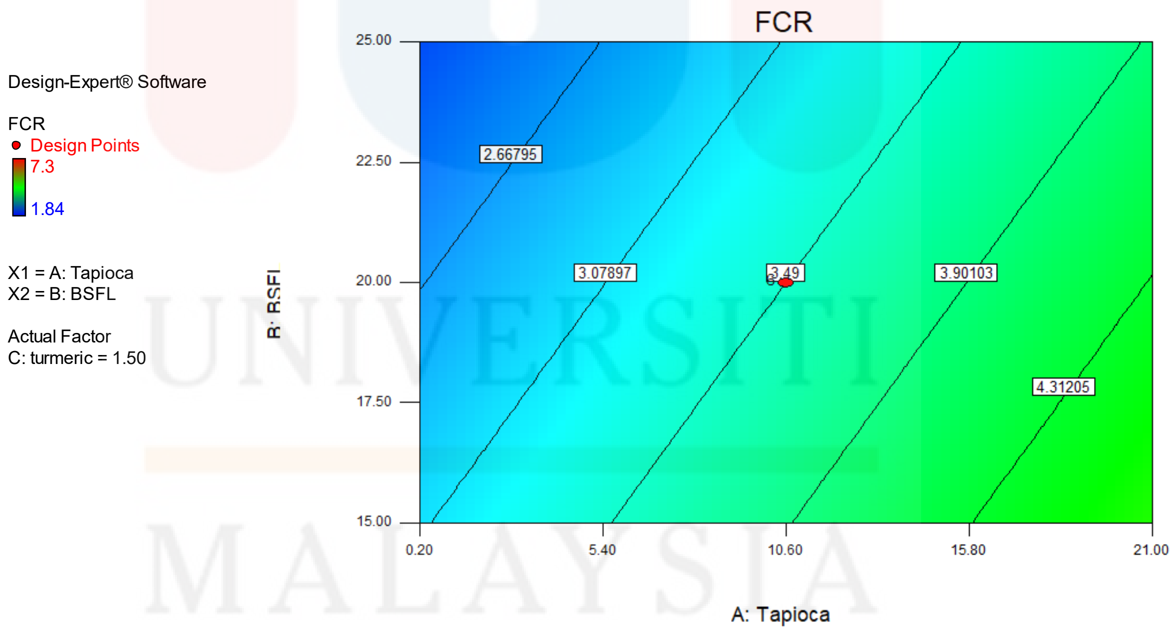

Figure 4.8 (b): 2D contour plot of an effect of Tapioca (%) on FCR (g).

4.8.2 Effect of BSFL on FCR (Feed Conversion Ratio)

Figure 4.9 (a) and 4.9 (b) shows the effect of BSFL on FCR while keeping Tapioca as constant. As observed in both of the figures, the changing colour of green to blue show the decreasing value of FCR from 3.85698 to 3.12302 when the percentage of BSFL increased. The lower the value of FCR, the higher the performance of the quails. So BSFL gives good effect towards FCR.

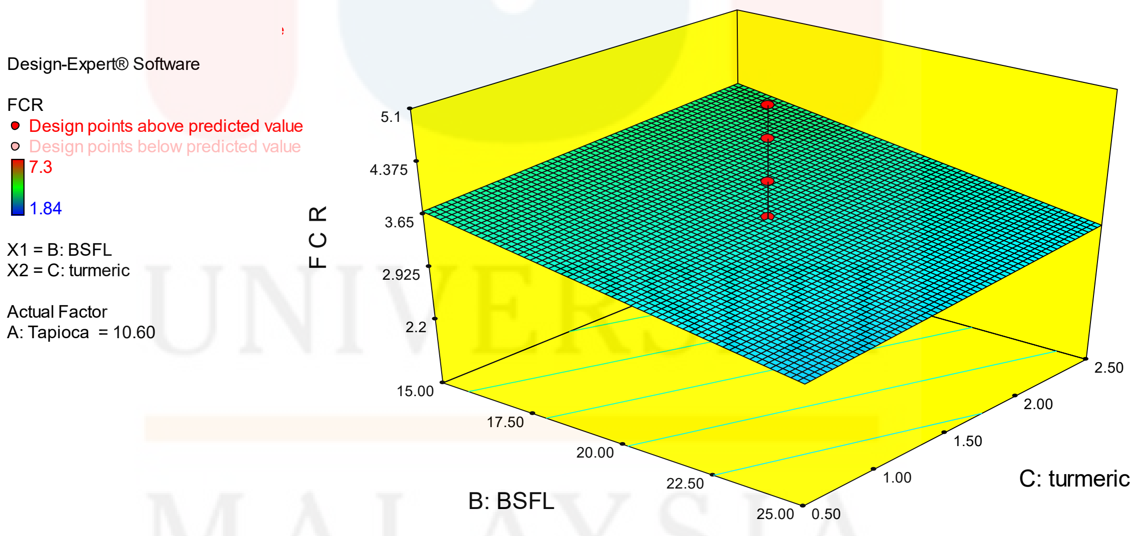

Figure 4.9 (a): 3D response surface graph of an effect of BSFL (%) on FCR (g).

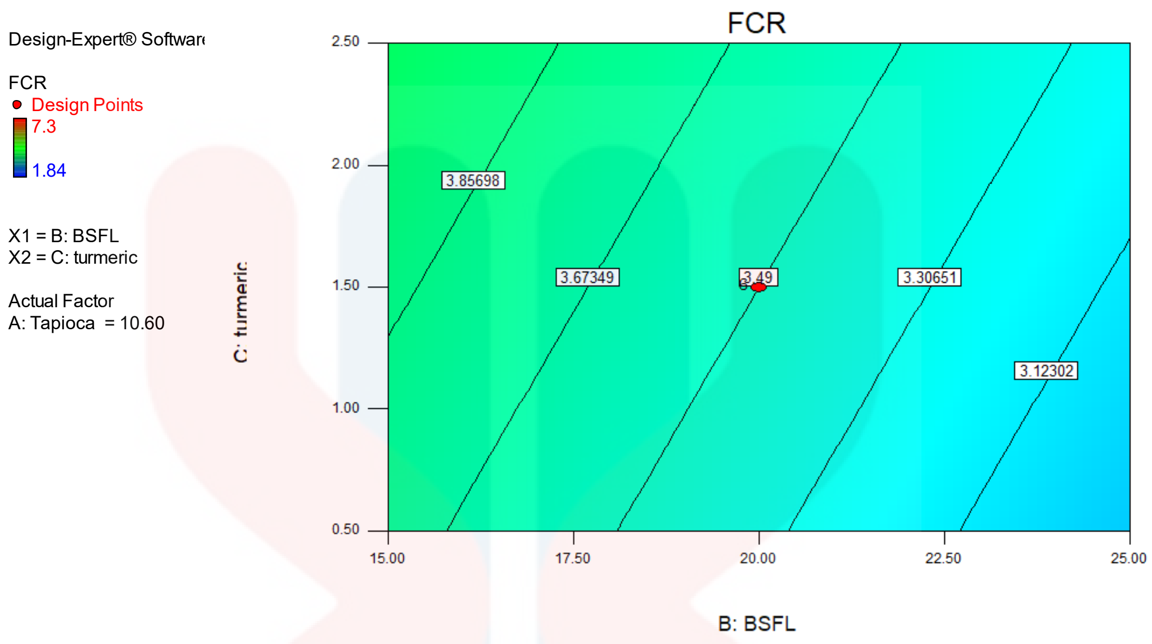

Figure 4.9 (b): 2D contour plot of an effect of BSFL (%) on FCR (g).

4.8.3 Effect of Turmeric on FCR (Feed Conversion Ratio)

Figure 4.10 (a) and Figure 4.10 (b) shows the effect of turmeric while keeping BSFL as constant. From the figure, it is shown that FCR increase with the increasing percentage of turmeric and the value was increased from 3.33097 to 3.34355. It can be concluded that turmeric did not give a good effect on FCR because a good FCR was with the lowest value.

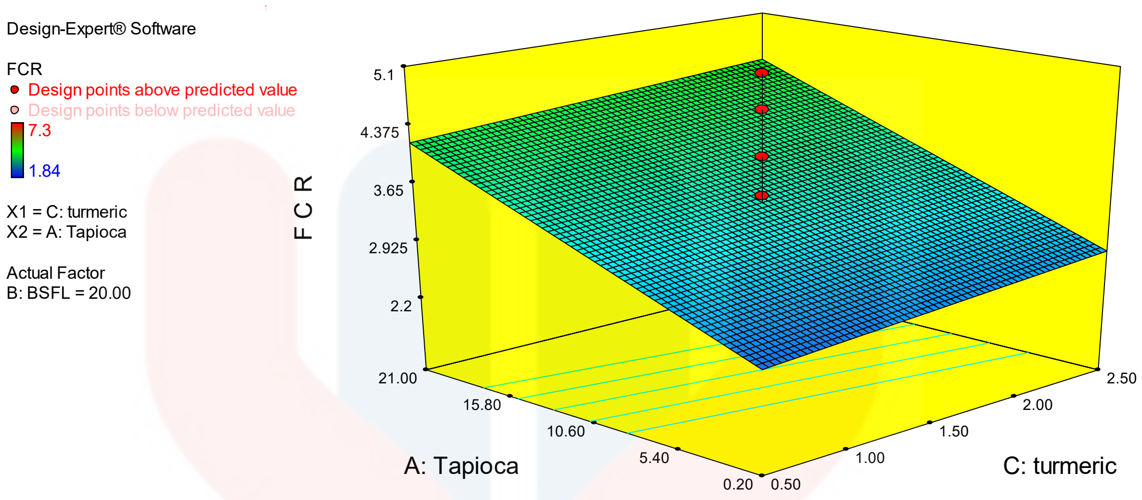

Figure 4.10 (a): 3D response surface graph of an effect of Turmeric (%) on FCR (g)

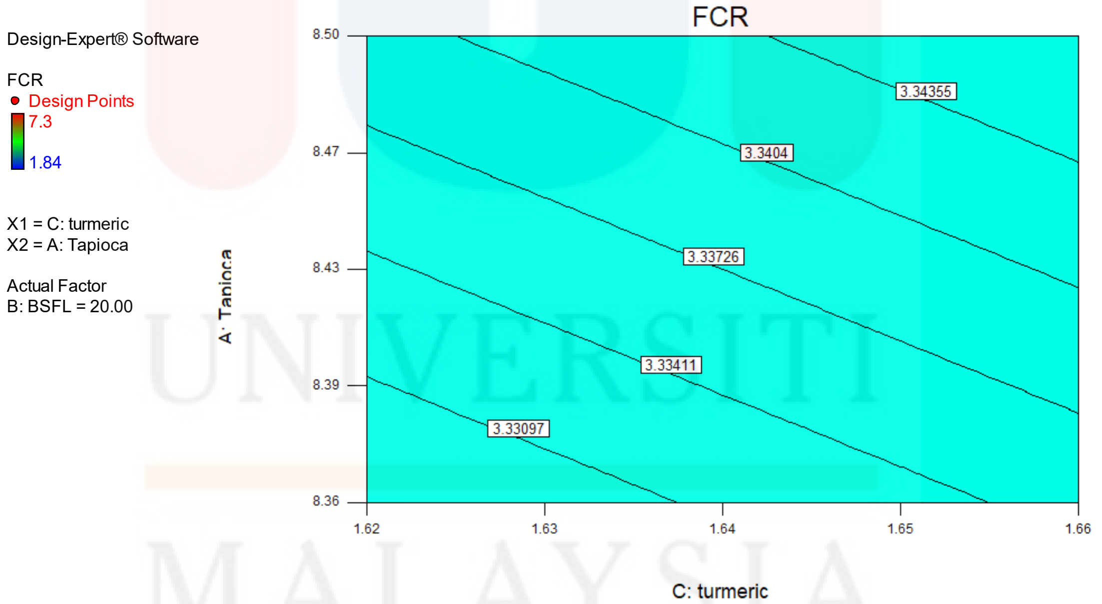

Figure 4.10 (b): 2D contour plot of an effect of Turmeric (%) on FCR (g).

4.9 Development of Regression Model Equation for Response 3 (SR)

According to the sequential model sum of squares generated by the Design Expert Software Version 7.0, the highest order polynomials for a model were selected where the additional terms were significant and the models were not aliased. In this context, the linear model was suggested as the best model that fit the experimental response 3 which is Survival Rate (SR).

Table 4.9: Model summary statistics of SR (R3)

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	24.75	0.2149	0.0677	-0.1934	14899.66	Suggested
2FI	25.73	0.3108	-0.0072	-0.9647	24528.73	
Quadratic	29.33	0.3110	-0.3091	-2.1291	39064.79	
Cubic	29.06	0.5941	-0.2855	-12.2685	1.657E+005	Aliased

Table 4.10 shows the quadratic model for R^2 for Survival Rate (SR). In this study, unfortunately, high C.V was obtained which is 33.07%. Besides, 0.2149 of R^2 value in the Table was obtained. The correlation coefficient of R^2 was used to measure the fit of the model and the model will be more accurate if the R^2 value was closed to 1.00.

In this study, the R^2 value was very low and was not close to 1.00 and it show that only 21.49% of the response variability can be explained by the model. It is the same goes with adjusted R^2 and predicted R^2 which were -0.3091 and -2.1291 respectively. The value of both adjusted and predicted R^2 was not closed to value 1.00. Other than that, adequate precision was used to measure the signal to noise ratio where a ratio greater than 4 was desirable (Ghafari et al., 2009). In this study, adequate precision was 4.072 show an adequate signal and fitness of the model.

Table 4.10: The standard deviation and linear model for R^2 for R3.

Std. Dev.	24.75	R-Squared	0.2149
Mean	74.85	Adj R-Squared	0.0677
C.V. %	33.07	Pred R-Squared	-0.1934
PRESS	14899.66	Adeq Precision	4.072

The empirical formula for polynomial regression model in terms of coded factors was represented by Equation 4.3. According to Equation 4.3, the coefficient with one factor and two factors stand for the effect of that particular factor and interaction effect between the factors respectively.

The coded equation can be used to examine the significance of the factors towards the experimental response (SR) by comparing the coefficient. Besides, the positive sign in the coded equation represented that SR will be increased with the respective parameters. On the other hand, the negative sign indicates the negative effect towards the experimental response (Subash et al., 2007). In this study, the factor that has the biggest positive influence towards SR was factor B (BSFL) followed by factor C (turmeric) that showed positive value. However, coefficient A has a negative value and this indicated that factor A which is Tapioca give negative effect towards SR.

$$SR = +74.85 -3.59*A +13.40*B +2.01*C \quad (4.3)$$

4.10 Statistical Analysis for Response 3 (SR)

A good significant term model was indicated by a larger F and smaller p-value. From Table 4.11, the F value of the model was 1.46 and p-value was 0.2628 which show that the model was not significant. If the value of p-value was less than 0.05, the model terms are considered as statistically significant and if the contrast which is insignificant the values greater than 0.1000. From table 4.11, the results showed that all the source was considered as not significant model terms for SR as the value was greater than 0.1000.

Table 4.11: ANOVA for Response Surface Linear Model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	2683.36	3	894.45	1.46	0.2628	not significant
A-Tapioca	175.81	1	175.81	0.29	0.5995	
B-BSFL	2452.18	1	2452.18	4.00	0.0627	
C-turmeric	55.38	1	55.38	0.090	0.7675	

4.11 Predicted Values versus Actual Values for Response 3 (SR)

Firstly, Table 4.12 shows the predicted and actual values for SR which actual values are the experimental data obtained during the experimental run while the predicted values are the anticipated values generated by CCD model. The highest actual value of SR was 100% and was differ slightly with the predicted value which is 89.82%. Secondly, the error terms are examined using the data whether it is normally distributed by plotting a normal probability plot of residuals as shown in Figure 4.11. As observed, the data points were laid reasonably close to the linear line which indicates the residuals were small and distributed normally. On the other hand, Figure 4.12 shows the relationship between actual and predicted values of responses for SR. From the diagnostic plot, the residuals were scattered around the straight line and indicate that the developed linear model was inadequate to predict the response of Survival Rate over the range of parameters studied.

Table 4.12: The actual and predicted values of SR in CCD model.

Standard Order	Actual Value	Predicted Value	Residual	Internally Studentized Residual	Externally Studentized Residual
1	33.00	63.02	-30.02	-1.419	-1.470
2	17.00	55.85	-38.85	-1.837	-2.002
3	100.00	89.82	10.18	0.481	0.469
4	83.00	82.65	0.35	0.017	0.016
5	83.00	67.05	15.95	0.754	0.743
6	50.00	59.88	-9.88	-0.467	-0.455
7	83.00	93.85	-10.85	-0.513	-0.501
8	100.00	86.68	13.32	0.630	0.618
9	83.00	80.88	2.12	0.099	0.096
10	83.00	68.82	14.18	0.665	0.653
11	83.00	52.31	30.69	1.438	1.493
12	83.00	97.39	-14.39	-0.674	-0.662
13	100.00	71.46	28.54	1.338	1.374
14	67.00	78.24	-11.24	-0.527	-0.514
15	66.00	74.85	-8.85	-0.367	-0.357
16	50.00	74.85	-24.85	-1.030	-1.032
17	100.00	74.85	25.15	1.043	1.046
18	33.00	74.85	-41.85	-1.735	-1.864
19	100.00	74.85	25.15	1.043	1.046
20	100.00	74.85	25.15	1.043	1.046

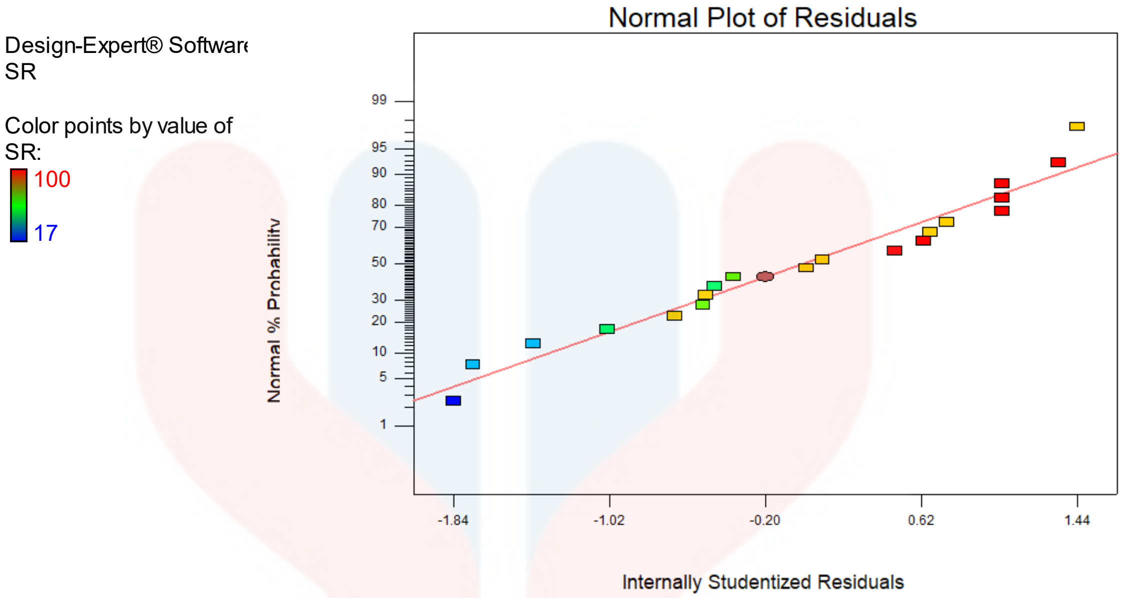

Figure 4.11: Normal probability plot of residual of Survival Rate.

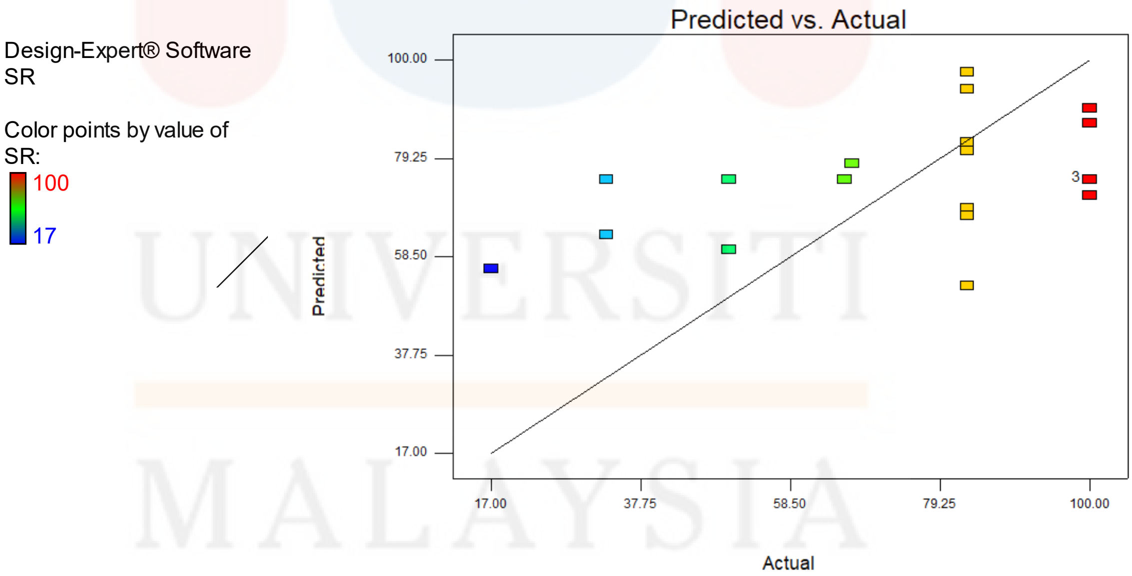

Figure 4.12: Diagnostic plot for predicted values versus actual values of SR.

4.12 Optimisation of feed for Response 3 (Survival Rate)

A three-dimensional (3D) response surface graph and two-dimension (2D) contour plot were obtained to examine the effect of a variable on the Survival Rate (SR) while keeping other variables as constant. Besides, the 3D plot and 2D response surface graph were also aimed to identify the optimum level of the variable to achieve optimum SR.

4.12.1 Effect of Tapioca on SR (Survival Rate)

Figure 4.13 (a) and 4.13 (b) shows the effect of Tapioca on SR while keeping Turmeric as a constant which was 1.50%. From the figure, SR was decreased with the increasing of tapioca. It is because of the dustiness of tapioca starch that leads to higher mortality and thus decreased the survival rate.

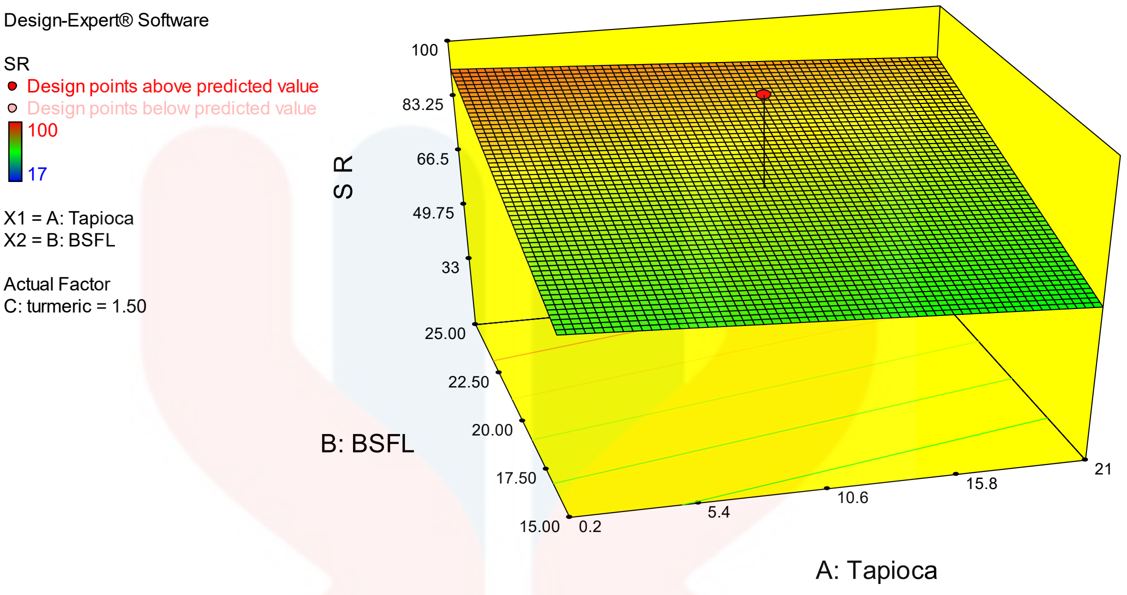

Figure 4.13 (a): 3D response surface graph of an effect of Tapioca (%) on SR (g).

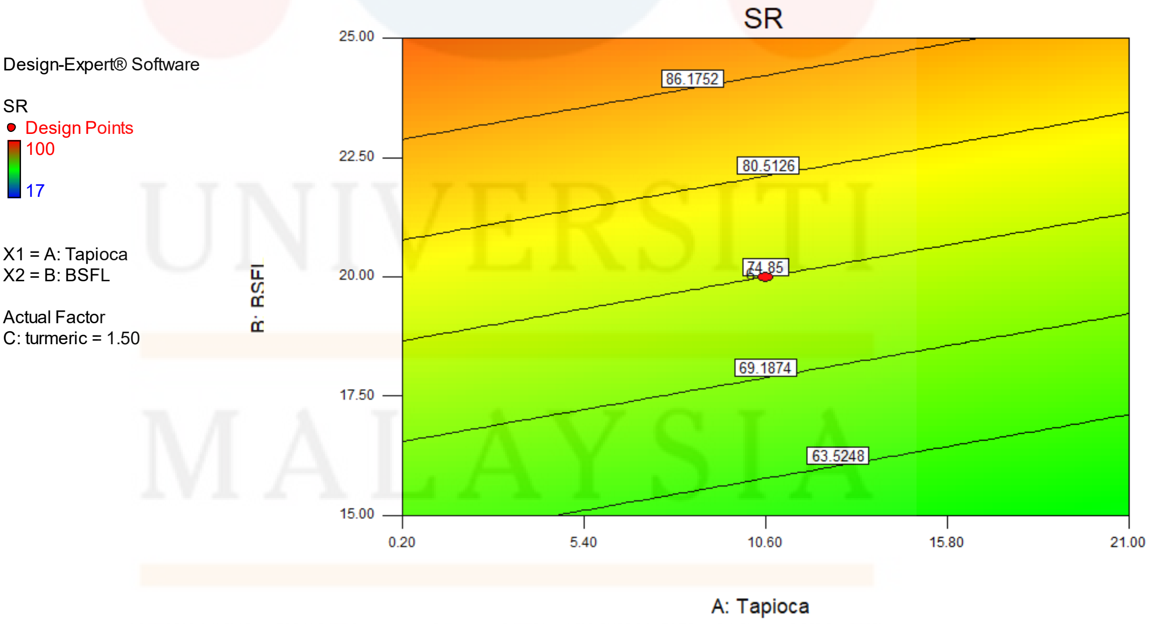

Figure 4.13 (b): 2D contour plot of an effect of Tapioca (%) on SR (g).

4.12.2 Effect of BSFL on SR (Survival Rate)

Figure 4.14 (a) and 4.14 (b) shows the effect of BSFL on SR while keeping tapioca as constant. As observed in both of the figures, the changing colour of green to red show that increasing of higher SR (from 64.5743 to 85.1257) at the red zone. The SR increased with the increasing percentage of BSFL.

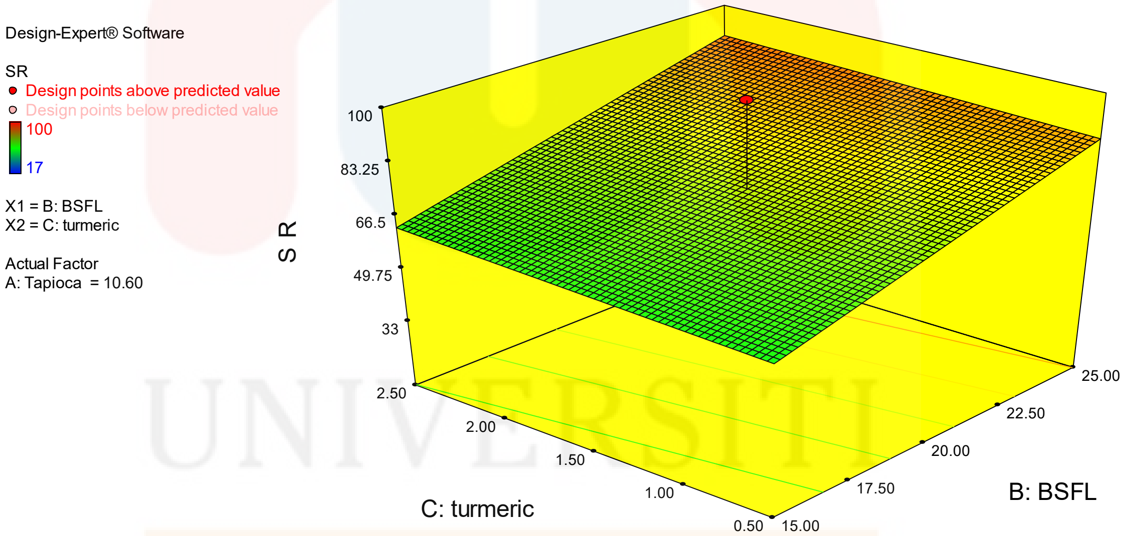

Figure 4.14 (a): 3D response surface graph of an effect of BSFL (%) on SR (g).

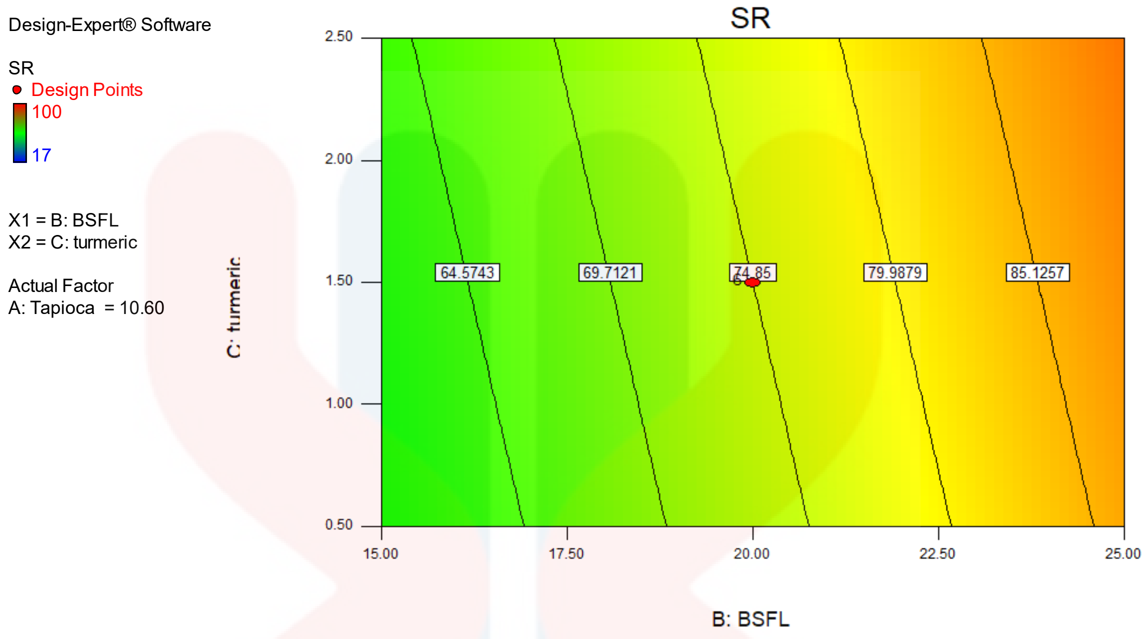

Figure 4.14 (b): 2D contour plot of an effect of BSFL (%) on SR (g).

4.12.3 Effect of Turmeric on SR (Survival Rate)

Figure 4.15 (a) and Figure 4.15 (b) shows the effect of turmeric while keeping BSFL as constant. As observed in both figures, the green zone in 3D response surface graph and 2D contour plot change to yellow colour shows the increasing of higher SR at the yellow zone. The SR value increased from 71.1156 to 78.5844 when the percentage of turmeric was increased. In this study, turmeric as immunity booster had been proven by the increasing of survival rate when the percentage of turmeric used in the ration was increased.

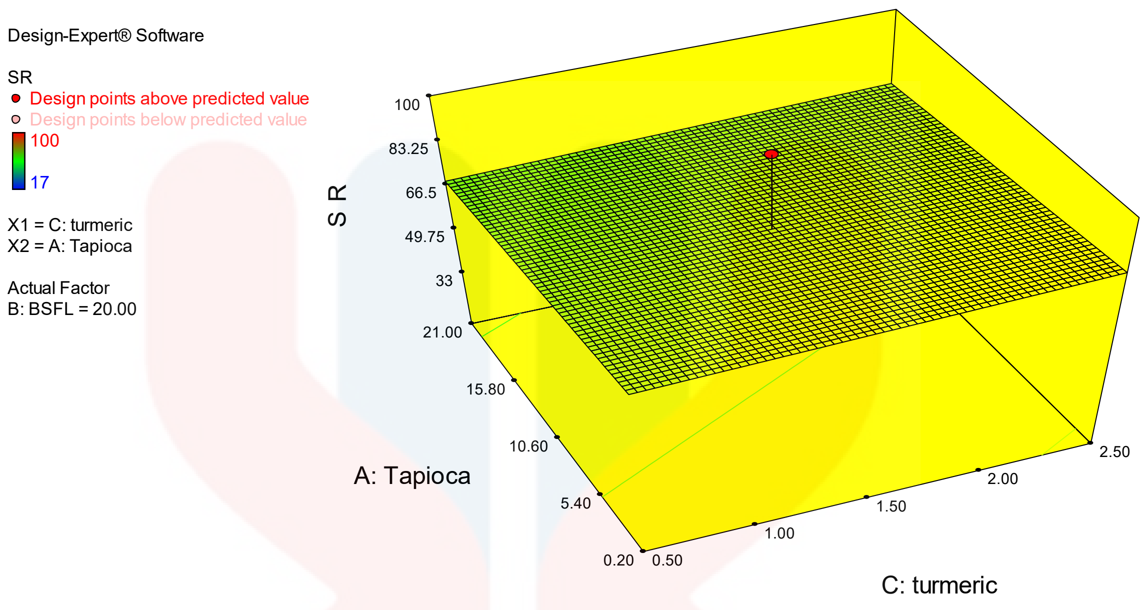

Figure 4.15 (a): 3D response surface graph of an effect of Turmeric (%) on SR (g).

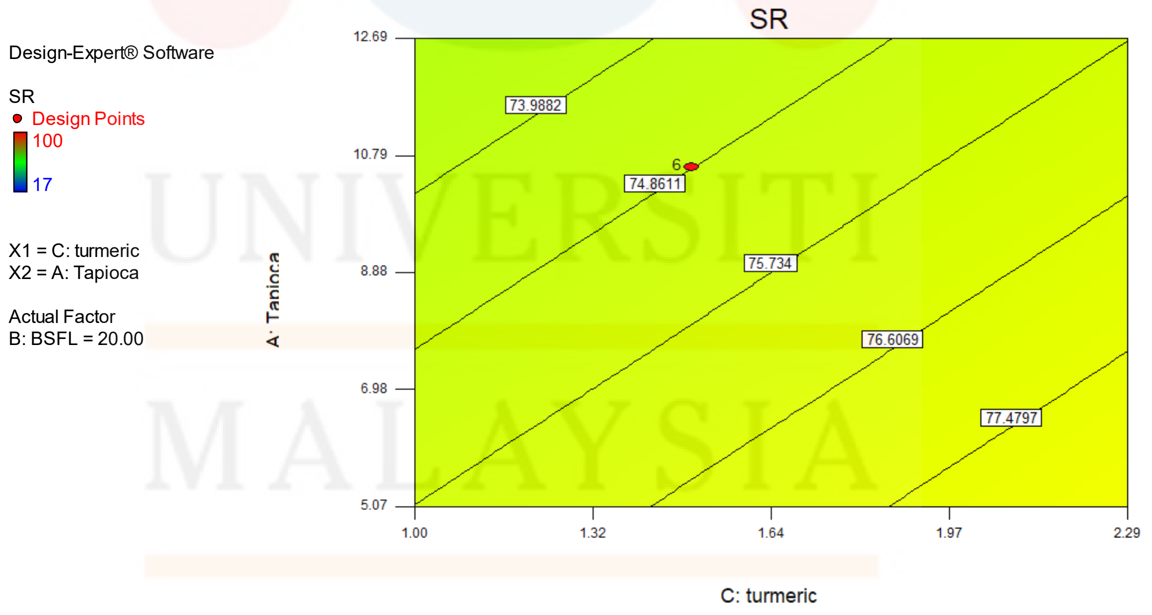

Figure 4.15 (b): 2D contour plot of an effect of Turmeric (%) on SR (g).

4.13 Numerical Optimisation of Desirability Function for R1, R2 and R3.

The main purpose of numerical optimisation is to achieve the optimum condition for ADG, FCR and SR by using three factors which are factor A (Tapioca), factor B (BSFL) and factor C (Turmeric). Optimisation is a complex process because when one response is improved may cause negative effects on another response. However, if the desirability function (DF) is used, the best compromise condition between the responses can be attained (Li, Ma, Zhou & Xu, 2007).

The DF scale has the range from 0 to 1, which d=0 show the response is completely unacceptable or lesser desirability and d=1 show that the response is acceptable or larger desirability (Jahani, Alizadeh, Pirozifard & Qudsevali, 2008). In general, the 'desirability' of the corresponding response increases when the value 'd' is increased. The best optimisation point for ADG and SR were selected based on the highest DF while for FCR was selected based on the lower DF.

Based on Figure 4.16, the ramps show that the optimum value for factor A, B and C are 0.20%, 25.00% and 0.50% respectively. The optimum level of three factors lead to the optimum value of ADG which is 1.99528 g, FCR is 2.10459 g and SR is 89.8241% at desirability 0.861. As the desirability is 0.861 which is close to d=1, it can be concluded that the response has higher desirability.

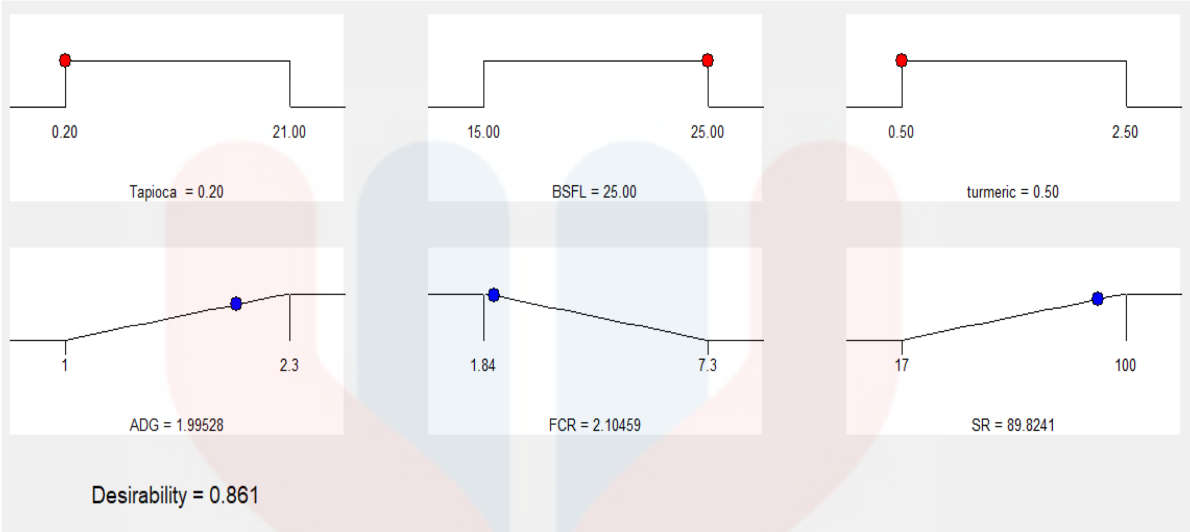

Figure 4.16: The rams for desirability function.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As a conclusion, the outcome of the study had shown some findings about the effects of the three ingredients or factor towards the three responses which are ADG, FCR and SR of the Japanese quail. First, for the response 1 (ADG) coded equation shows that BSFL was the most influential factor. The graph effect of a factor towards response also shows the increasing of ADG value from 1.43169 g to 1.60831 g when the percentage of BSFL was increased.

Second, for the response 2 (FCR) it can be said that tapioca was the most influential factor in FCR and gave the biggest positive influence based on the coded equation. However, the graph effect of a factor towards response shows decreasing value of FCR from 3.85698 g to 3.12302 g when the percentage of BSFL increased which indicate that the BSFL gave the good effect toward FCR.

Third, for the response 3 (SR) it shows that BSFL was the most influential factor in SR based on the coded equation in RSM. On the other hand, graph effect of factor towards response shows the SR value increased from 71.1156 to 78.5844 when the percentage of turmeric was increased. The SR also increased (from 64.5743 to 85.1257) with the increasing percentage of BSFL. This indicates that BSFL and turmeric gave good effect toward survival rate of quails. The desirability of the three responses also high as the desirability was 0.861 which was close to d=1.

The thing was three main ingredients which were tapioca starch, BSFL and turmeric are beneficial ingredients in feed formulation. However, the performance of the Japanese quails is not improved by using these three basic ingredients. The body weight of Japanese quails did not increase a lot during 14 days of feeding trial.

All the objectives of the study were successfully achieved which first was the significant amount of the three main ingredients used in this study can be investigated using RSM. Second, the feed formulation process (in terms of the use of different amount of the three main ingredients) for Japanese quails by using Response Surface Methodology (RSM) can be optimised. Third, the growth performance of Japanese quails fed by different rations formulated can be evaluated.

5.2 Recommendation

The Response Surface Methodology (RSM) is suitable for estimation of the feed formulation ratio. In this study, the application of RSM brings the ease in the feed formulation as it minimise the experimental number required to conduct.

As for the recommendation, further studies may be carried out in the future in order to improve the usage of this application. In the future study, other types of the ingredient may be used in order to give beneficial effect towards ADG, FCR and survival rate. For instances, usage of other ingredients like pumpkin seed can replace tapioca starch function to increase the average daily gain of quails.

Besides, in this study, the feeding trial was only done for 14 days and this was not enough to observe the quail performances accurately. It is recommended to prolong the trial period for more than 14 days in the future study.

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APPENDIX A

Figure A1: Preparation of quails' feed.

Figure A2: The feed formulated based on the ration suggested by RSM.

Figure A3: The brooding cage for Japanese quails.

Figure A4: Quails age 1 day old located in brooding cage.

Figure A5: The brooding area for Japanese quails.

Figure A6: Disinfectant sprayed

Figure A7: The blending process of the ingredients

Figure A8: The quails fed the formulated feed.

Figure A9: The turmeric sliced into pieces

Figure A10: The turmeric ready to be put into oven

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	27	30	25	7.7
2	13/11/2018				30	23	30	21	9
3	14/11/2018				30	25	30	23	10
4	15/11/2018				35	30	35	20	12.25
5	16/11/2018				35	21	35	23	13.33
6	17/11/2018				35	23	30	10	13.40
7	18/11/2018				30	20	30	16	13.75
8	19/11/2018				30	15	30	18	14
9	20/11/2018				30	5	30	0	15.17
10	21/11/2018				35	0	35	10	17.75
11	22/11/2018				35	3	35	11	18.8
12	23/11/2018				35	20	35	16	18.9
13	24/11/2018				35	32	35	23	19.25
14	25/11/2018				35	29	35	14	21.8

Figure A11: Record keeping of broiler quails for treatment 1

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	25	30	23	9
2	13/11/2018				30	29	30	20	9.75
3	14/11/2018				30	22	30	20	10
4	15/11/2018				35	26	35	26	14.5
5	16/11/2018				35	17	30	4	15.33
6	17/11/2018				30	21	30	10	17.5
7	18/11/2018				27	17	30	19	18.5
8	19/11/2018	1		5	30	20	30	12	18.5
9	20/11/2018				30	14	30	5	18.7
10	21/11/2018				35	10	35	0	20.9
11	22/11/2018				35	20	35	5	25.4
12	23/11/2018				35	23	35	14	27.9
13	24/11/2018				35	21	35	0	32.4
14	25/11/2018	1		4	35	10	35	12	34.25

Figure A12: Record keeping of broiler quails for treatment 2

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	25	30	22	8.2
2	13/11/2018				30	24	30	21	9.25
3	14/11/2018				30	20	30	25	11
4	15/11/2018				35	28	35	20	15.25
5	16/11/2018				35	30	35	23	17.83
6	17/11/2018				30	25	30	19	19.5
7	18/11/2018				27	15	30	13	22.8
8	19/11/2018	1	5		30	20	30	3	22.8
9	20/11/2018				30	15	35	20	23.5
10	21/11/2018				35	22	35	19	24.5
11	22/11/2018				35	10	35	0	28.8
12	23/11/2018				35	15	35	4	32.8
13	24/11/2018				35	19	35	15	35.2
14	25/11/2018				35	13	35	0	40.5

Figure A13: Record keeping of broiler quails for treatment 3

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	22	30	20	8.2
2	13/11/2018				30	25	30	21	8.75
3	14/11/2018				30	20	30	23	9.25
4	15/11/2018				35	28	35	30	14.75
5	16/11/2018				35	25	35	23	14.83
6	17/11/2018				30	21	30	22	18.4
7	18/11/2018				25	10	30	17	23
8	19/11/2018				30	20	30	21	23.5
9	20/11/2018				30	18	35	20	24.8
10	21/11/2018				35	25	35	15	26.1
11	22/11/2018				35	10	35	20	27.6
12	23/11/2018				35	15	35	5	31.1
13	24/11/2018				35	25	35	23	32.6
14	25/11/2018	1		5	35	20	35	10	35.25

Figure A14: Record keeping of broiler quails for treatment 4

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	26	30	24	8
2	13/11/2018				30	22	30	21	8.75
3	14/11/2018				30	24	30	20	10
4	15/11/2018				35	27	35	25	10.25
5	16/11/2018				35	23	35	29	18.17
6	17/11/2018				30	21	30	20	21.5
7	18/11/2018				30	19	30	14	24.7
8	19/11/2018				30	20	30	0	25
9	20/11/2018				35	15	35	23	26
10	21/11/2018				35	20	35	17	27.2
11	22/11/2018				35	15	35	5	28.5
12	23/11/2018	1	5		35	10	35	19	31.8
13	24/11/2018				35	16	35	10	33.0
14	25/11/2018	3	2		35	10	35	14	34.5

Figure A15: Record keeping of broiler quails for treatment 5

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	27	30	24	7.7
2	13/11/2018				30	25	30	22	8.25
3	14/11/2018				30	20	30	25	8.5
4	15/11/2018				35	28	35	27	9
5	16/11/2018				35	21	35	24	14.33
6	17/11/2018				30	18	30	6	15.7
7	18/11/2018				30	27	30	20	17
8	19/11/2018				30	10	30	4	18.7
9	20/11/2018				30	19	30	27	20.3
10	21/11/2018				35	20	35	15	21.6
11	22/11/2018				35	10	35	20	22.1
12	23/11/2018				35	13	35	5	26.5
13	24/11/2018				35	20	35	10	29.5
14	25/11/2018				35	25	35	20	30.25

Figure A16: Record keeping of broiler quails for treatment 6

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	25	30	20	8.5
2	13/11/2018				30	19	30	18	9
3	14/11/2018				30	20	30	23	10.5
4	15/11/2018				35	27	35	21	10.8
5	16/11/2018				35	24	35	20	16.33
6	17/11/2018				30	29	30	15	18.5
7	18/11/2018				30	14	30	10	20.7
8	19/11/2018				30	19	30	15	20.7
9	20/11/2018				30	25	35	18	21.3
10	21/11/2018				35	23	35	21	22.8
11	22/11/2018				35	14	35	20	24.5
12	23/11/2018				35	19	35	10	26.7
13	24/11/2018				35	10	35	5	29.2
14	25/11/2018	1		5	35	15	35	3	32

Figure A17: Record keeping of broiler quails for treatment 7

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	21	30	23	8.5
2	13/11/2018				30	27	30	20	8.75
3	14/11/2018				30	20	30	19	9
4	15/11/2018				35	28	35	24	9.75
5	16/11/2018				35	21	35	15	14.67
6	17/11/2018				30	23	30	19	15.7
7	18/11/2018				30	20	30	10	17.2
8	19/11/2018				30	15	30	25	17.9
9	20/11/2018				30	21	35	28	18.3
10	21/11/2018				35	24	35	15	19.05
11	22/11/2018				35	21	35	20	20.5
12	23/11/2018	1		5	35	25	35	19	22.7
13	24/11/2018				35	15	35	10	27.6
14	25/11/2018				35	8	35	0	32

Figure A18: Record keeping of broiler quails for treatment 8

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	25	30	20	9.2
2	13/11/2018				30	22	30	21	9.5
3	14/11/2018				30	19	30	22	9.75
4	15/11/2018				35	30	35	24	10
5	16/11/2018				35	25	35	21	13
6	17/11/2018				35	23	35	19	15
7	18/11/2018				30	20	30	18	17.2
8	19/11/2018				30	14	30	27	17.7
9	20/11/2018				30	25	30	20	18.17
10	21/11/2018				35	19	35	24	18.42
11	22/11/2018				35	13	35	21	18.72
12	23/11/2018				35	25	35	27	19.5
13	24/11/2018				35	20	35	23	21
14	25/11/2018				35	21	35	19	22.4

Figure A19: Record keeping of broiler quails for treatment 9

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	27	30	24	8.4
2	13/11/2018				30	20	30	21	9
3	14/11/2018				30	19	30	20	9.75
4	15/11/2018				35	30	35	22	10
5	16/11/2018				35	25	35	15	13.67
6	17/11/2018				30	23	30	11	16.5
7	18/11/2018				30	19	30	17	18.5
8	19/11/2018				30	20	30	21	18.75
9	20/11/2018				30	22	30	27	19.7
10	21/11/2018				35	21	35	15	20.4
11	22/11/2018				35	13	35	20	22.7
12	23/11/2018				35	27	35	25	23.65
13	24/11/2018				35	20	35	17	27.25
14	25/11/2018				35	18	35	15	29.25

Figure A20: Record keeping of broiler quails for treatment 10

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	20	30	23	9.5
2	13/11/2018	1		5	30	18	30	19	9.6
3	14/11/2018				30	21	30	19	9.75
4	15/11/2018				35	32	35	30	10
5	16/11/2018				35	29	35	33	12.2
6	17/11/2018				30	24	30	15	15.45
7	18/11/2018				30	27	30	19	19.7
8	19/11/2018				30	15	30	20	21.2
9	20/11/2018				30	20	30	19	26.17
10	21/11/2018				35	30	35	29	26.4
11	22/11/2018				35	23	35	15	27.9
12	23/11/2018				35	21	35	10	30.1
13	24/11/2018				35	27	35	5	34.35
14	25/11/2018				35	17	35	13	39.4

Figure A21: Record keeping of broiler quails for treatment 11

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	24	30	25	8.5
2	13/11/2018				30	20	30	20	9
3	14/11/2018	1		5	30	21	30	18	10.75
4	15/11/2018				35	30	35	30	11
5	16/11/2018				35	28	35	25	13.4
6	17/11/2018				30	18	30	17	15.2
7	18/11/2018				35	20	30	27	18.2
8	19/11/2018				30	25	30	22	19.5
9	20/11/2018				30	16	35	30	20.5
10	21/11/2018				35	27	35	25	21
11	22/11/2018				35	20	35	23	22.3
12	23/11/2018				35	25	35	21	24.1
13	24/11/2018				35	30	35	19	25.9
14	25/11/2018				35	27	35	21	26.5

Figure A22: Record keeping of broiler quails for treatment 12

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	23	30	27	8
2	13/11/2018				30	21	30	26	8.7
3	14/11/2018				30	20	30	21	9.25
4	15/11/2018	1		5	35	29	35	28	10
5	16/11/2018				35	31	35	33	10.7
6	17/11/2018				30	28	30	17	11.5
7	18/11/2018				30	21	30	15	12.67
8	19/11/2018				30	10	30	21	13
9	20/11/2018				30	15	30	20	13.5
10	21/11/2018				35	30	35	28	14
11	22/11/2018	1		4	35	23	35	20	15.7
12	23/11/2018	1		3	35	29	35	21	17.5
13	24/11/2018	2		1	35	18	35	25	19.4
14	25/11/2018				35	23	35	19	21.75

Figure A23: Record keeping of broiler quails for treatment 13

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	25	30	24	9
2	13/11/2018				30	21	30	16	10.25
3	14/11/2018				30	20	30	19	11
4	15/11/2018				35	30	35	29	11.75
5	16/11/2018				35	32	35	30	12.3
6	17/11/2018				30	23	30	20	14
7	18/11/2018				30	20	30	15	15.17
8	19/11/2018				30	12	30	28	15.17
9	20/11/2018				30	10	30	19	15.5
10	21/11/2018				35	25	35	30	16.2
11	22/11/2018				35	18	35	24	17.4
12	23/11/2018				35	21	35	19	19.1
13	24/11/2018	1		5	35	25	35	20	22.5
14	25/11/2018				35	12	35	15	29.2

Figure A24: Record keeping of broiler quails for treatment 14

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	21	30	18	8
2	13/11/2018				30	17	30	24	9.25
3	14/11/2018				30	20	30	27	10
4	15/11/2018				35	31	35	24	10.75
5	16/11/2018				35	30	35	29	13.4
6	17/11/2018				35	25	35	10	17.52
7	18/11/2018				35	20	30	17	21
8	19/11/2018				30	15	30	5	25.4
9	20/11/2018				30	21	30	24	26.1
10	21/11/2018				35	18	35	31	26.85
11	22/11/2018				35	25	35	29	28.1
12	23/11/2018				35	20	35	21	31.6
13	24/11/2018				35	29	35	24	34.2
14	25/11/2018				35	27	35	20	35.4

Figure A25: Record keeping of broiler quails for treatment 15

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	21	30	23	10
2	13/11/2018				30	19	30	23	10.25
3	14/11/2018				30	21	30	20	10.75
4	15/11/2018				35	29	35	27	11
5	16/11/2018				35	30	35	31	15.6
6	17/11/2018				35	24	35	20	18.2
7	18/11/2018				35	20	30	19	21
8	19/11/2018				30	15	30	26	21.5
9	20/11/2018				30	20	30	23	21.75
10	21/11/2018				35	29	35	20	23.2
11	22/11/2018				35	26	35	30	25.7
12	23/11/2018				35	25	35	19	26
13	24/11/2018				35	20	35	15	27.5
14	25/11/2018				35	20	35	23	28.6

Figure A26: Record keeping of broiler quails for treatment 16

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	19	30	18	10
2	13/11/2018				30	20	30	17	10.75
3	14/11/2018				30	22	30	20	11.25
4	15/11/2018				35	27	35	30	11.75
5	16/11/2018				35	24	35	31	13.2
6	17/11/2018				35	30	35	17	15.5
7	18/11/2018				30	19	30	10	19.67
8	19/11/2018	1		5	30	15	30	25	20.4
9	20/11/2018				30	20	30	19	20.9
10	21/11/2018				35	27	35	17	21.4
11	22/11/2018				35	22	35	10	21.9
12	23/11/2018				35	24	35	19	22.4
13	24/11/2018				35	21	35	15	23.1
14	25/11/2018	2		3	35	20	35	19	23.5

Figure A27: Record keeping of broiler quails for treatment 17

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	24	30	20	8
2	13/11/2018				30	19	30	20	8.25
3	14/11/2018				30	21	30	22	8.75
4	15/11/2018				35	30	35	30	9.3
5	16/11/2018				35	32	35	29	11.5
6	17/11/2018				35	27	35	16	14.2
7	18/11/2018				35	19	30	15	16
8	19/11/2018				30	10	30	23	16.25
9	20/11/2018				30	14	30	20	16.7
10	21/11/2018				35	30	35	27	17.25
11	22/11/2018				35	25	35	20	17.5
12	23/11/2018				35	20	35	23	18
13	24/11/2018				35	26	35	29	19.8
14	25/11/2018	2		4	35	21	35	14	20.2

Figure A28: Record keeping of broiler quails for treatment 18

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	24	30	20	10
2	13/11/2018				30	17	30	22	10.25
3	14/11/2018				30	20	30	25	10.75
4	15/11/2018				35	26	35	22	11
5	16/11/2018				35	25	35	30	12.5
6	17/11/2018				30	19	30	12	14.1
7	18/11/2018				30	15	30	16	15.3
8	19/11/2018	3		3	30	13	30	25	15.8
9	20/11/2018				30	24	30	22	16
10	21/11/2018				35	25	35	19	16.25
11	22/11/2018				35	30	35	12	17.4
12	23/11/2018				35	25	35	20	19
13	24/11/2018				35	15	35	12	23.7
14	25/11/2018				35	30	35	14	26.5

Figure A29: Record keeping of broiler quails for treatment 19

Day / Week	Date	Amount			Amount of Feed (g)				Average Weight (g) / Quail
		Death	Expel	Balance	Morning	Balance	Evening	Balance	
1	12/11/2018				30	21	30	19	9
2	13/11/2018	1		5	30	24	30	18	9.25
3	14/11/2018				30	20	30	21	9.5
4	15/11/2018				35	32	35	27	10.2
5	16/11/2018				35	30	35	29	12.5
6	17/11/2018				30	15	30	16	14.2
7	18/11/2018				30	10	30	15	15.83
8	19/11/2018				30	20	30	20	15.83
9	20/11/2018	1		4	30	19	30	27	16
10	21/11/2018				35	30	35	21	16.25
11	22/11/2018				35	15	35	10	17.8
12	23/11/2018	1		3	35	20	35	15	20.1
13	24/11/2018				35	5	35	3	25.5
14	25/11/2018	1		2	35	10	35	2	33.3

Figure A30: Record keeping of broiler quails for treatment 20

Day/weeks	Date	Temperature (°C)	Humidity
1	12/11/2018	32.2	60
2	13/11/2018	34.4	53
3	14/11/2018	29.2	73
4	15/11/2018	28.9	78
5	16/11/2018	26.8	83
6	17/11/2018	28.6	77
7	18/11/2018	30.1	70
8	19/11/2018	26	80
9	20/11/2018	26.8	83
10	21/11/2018	35	45
11	22/11/2018	35.2	50
12	23/11/2018	30.5	71
13	24/11/2018	35	50
14	25/11/2018	32.5	62

Figure A31: Record keeping of temperature

APPENDIX B

Table B1: RSM design for ration feed formulation

Run	Factor 1 A: Tapioca %	Factor 2 B: BSFL %	Factor 3 C: Turmeric %	Response 1 ADG g	Response 2 FCR g	Response 3 SR %
1	21.00	25.00	2.50	1	4.81	100
2	10.60	20.00	1.50	1.8	3.51	66
3	-6.89	20.00	1.50	2.3	2.6	83
4	0.20	25.00	2.50	1.9	2.24	83
5	0.20	15.00	0.50	1.9	3.27	33
6	10.60	20.00	1.50	1.6	2.3	100
7	10.60	28.41	1.50	1.7	3	83
8	21.00	25.00	0.50	1.7	2.88	83
9	10.60	20.00	1.50	1	4	100
10	10.60	20.00	1.50	1.5	2.69	100
11	0.20	15.00	2.50	2.1	2.11	83
12	28.09	20.00	1.50	1.3	3	83
13	21.00	15.00	0.50	1	7.3	17
14	10.60	11.59	1.50	1.4	2.6	83
15	0.20	25.00	0.50	2	1.84	100
16	10.60	20.00	-0.18	1.3	2.53	100
17	10.60	20.00	1.50	1	5.02	50
18	10.60	20.00	3.18	1	4.32	67
19	21.00	15.00	2.50	1.2	5.2	50
20	10.60	20.00	1.50	1.7	4.58	33

$$\text{Parameter} = \frac{Percentage\ of\ parameter}{Total\ parameter\ percentages} \times 98$$

Table B2: Feed calculation for treatment.

Treatment	Tapioca Starch (%)	Black Soldier Fly Larvae (%)	Turmeric (%)	Vegetable Oil (%)
1	42.43	50.52	5.05	2
2	32.36	61.06	4.58	2
3	0	91.16	6.84	2
4	0.71	88.45	8.84	2
5	1.25	93.63	3.12	2
6	32.36	61.06	4.58	2
7	25.64	68.73	3.63	2
8	44.26	52.7	1.05	2
9	32.36	61.06	4.58	2
10	32.36	61.06	4.58	2
11	1.11	83.05	13.84	2
12	55.51	39.52	2.96	2
13	56.38	40.27	1.34	2
14	43.85	47.95	6.21	2
15	0.76	95.33	1.91	2
16	33.95	64.05	0	2
17	32.36	61.06	4.58	2
18	30.75	58.02	9.23	2
19	53.45	38.18	6.36	2
20	32.36	64.05	4.58	2