Optimization of Response Surface Methodology (RSM) For Estimation of Feed Requirement Broiler Chicken.

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A thesis submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Animal Husbandry Science) with Honours

Faculty of Agro Based Industry
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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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Student

Name : Aisah binti Zainol

Date :

I certify that the report of this final year project entitled Optimization of Response Surface Methodology (RSM) For Estimation of Feed Requirement Broiler Chicken" by Aisah binti Zainol, matric number F15A0260 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, Faculty of Agro-Based Industry, Universiti Malaysia Kelantan.

Approved by:

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Supervisor

Name :

Date :

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LIST OF ABBREVIATIONS AND SYMBOLS

RSM	Responce Surface Methodology
CCD	Central Composite Design
BSFL	Black Soldier Fly Larvae
DVS	Department of Veterinary Service
FCR	Feed Conversion Ratio
MOL	*Moringa oleifera* leaves
DM	Dry matter
CP	Crude protein
NDF	Neutral detergent fibre
α	Alpha
ANOVA	Analysis of variance
R^2	Correlation coefficient
DF	Desirability function

Optimization of Response Surface Methodology (RSM) for Estimation of Feed Requirement Broiler Chicken

ABSTRACT

In this study, the feed requirement was being estimated to know the most preferred value that is needed by broiler chicken. The broiler chicken was observed to evaluate their growth by the different mix of the parameter in feed formulation. There were three parameters, which are *Moringa oleifera* (24.5% to 74%), black soldier fly larvae (5% to 25%) and turmeric (0.5% to 1.0%). Meanwhile the responses in this studies were the average daily weight gain (g/d), survival rate (%) and feed conversion ratio. The *Moringa oleifera* leaf, black soldier fly larvae and turmeric rhizome were being prepared by the drying technique before being crushed in the powder form and formulated. The 120 starter broiler chicken was given with crumb form of feed for 14 days for 20 group that consist 6 chicks per group. This optimization studied were conducted by using the Response Surface Methodology (RSM) technique with Central Composite Design (CCD) method to design the value for the three parameters that needed in the feed formulation. The models were linear for ADWG, quadratic for SR and FCR does not have model were being chosen by CCD. The effect of the parameter has been studied by using the 3D response surface graph and 2D contour plot. The optimum level for average daily weight gain that predicted by RSM was 6.05g/d which percentages of *Moringa oleifera* was 7.63%, turmeric was 0.75% and black soldier fly larvae was 15%. For optimum level survival rate was 58.97% which percentages of *Moringa oleifera* was 49.25%, turmeric was 0.75% and black soldier fly larvae was 31.82%. And for optimum level feed conversion ratio was 0.5 which percentages of *Moringa oleifera* was 49.25%, turmeric was 0.75% and black soldier fly larvae was 31.82%.

Keywords: *Broiler Chicken, Response Surface Methodology (RSM), Central Composite Design (CCD), Moringa oleifera, Black Soldier Fly Larvae, Turmeric.*

Pengoptimuman Kaedah Gerak Balas Permukaan untuk Anggaran Keperluan Bahan Makanan Ayam Pedaging

ABSTRAK

Dalam kajian ini, keperluan bahan makanan ternakan akan dianggarkan untuk mengetahui nilai yang paling sesuai ynag diperlukan oleh ayam pedaging. Ayam pedaging akan diperhatikan untuk menilai perkembangan mereka dengan campuran yang berbeza parameter dalam perumusan makanan ternakan.Terdapat tiga parameter, iaitu *Moringa oleifera* (24.5% hingga 74%), larva lalat askar yang hitam (5% hingga 25%) dan kunyit (0.5% hingga 1.0%). Manakala, gerak balas dalam kajian ini ialah purata kenaikan berat badan harian, kadar kemandirian dan kadar penukaran makanan. Daun *Moringa oleifera*, larva lalat askar hitam dan rizom kunyit akan disediakan teknik pengeringan sebelum di kisar dalam bentuk serbuk dan dirumuskan.120 ekor anak ayam pedaging diberi makan ternakan dalam bentuk serbuk kasar untuk 14 minggu untuk 20 kumpulan yang mempunyai 6 ekor anak ayam broiler. Pengoptimuman ini dikaji akan dijalankan dengan menggunakan Kaedah Gerak Balas Permukaan dengan Reka Bentuk Komposit Berpusat untuk reka nilai untuk tiga parameter yang diperlukan dalam perumusan makanan ternakan. Model linear untuk ADWG, kuadratik untuk SR dan FCR tidak mempunyai model ialah dipilih oleh CCD. Kesan parameter akan dikaji dengan menggunakan graf permukaan gerak balas 3D dan plot kontur 2D. Tahap optimum untuk purata kenaikan berat badan harian optimum yang diramal oleh RSM ialah 6.05g/d yang mana peratusan *Moringa oleifera* ialah 7.63%, kunyit ialah 0.75% dan larva lalat askar hitam ialah 15%. Untuk tahap optimum kadar kemandirian ialah 58.97% yang mana peratusan *Moringa oleifera* ialah 49.25%, kunyit ialah 0.75% dan larva lalat askar yang hitam ialah 31.82%. Dan untuk kadar penukaran makanan ternakan tahap optimum ialah 0.5 yang mana peratusan *Moringa oleifera* ialah 49.25%, kunyit ialah 0.75% dan larva lalat askar hitam ialah 31.82%.

Kata kunci : *Ayam Pedaging, Kaedah Gerak Balas Permukaan, Reka Bentuk Komposit Berpusat, Moringa oleifera,Larva Lalat Askar Hitam, Kunyit.*

CHAPTER 1

INTRODUCTION

1.1 Research Background

Feed formulation is the designs of the feed that contain all requirement nutrient that has proper proportion include carbohydrates, protein, vitamin, mineral, lipids (fat and oils) and water. These nutrients are important to provide energy, growth and to regulate normal body function for poultry. In formulating the feed nutrient composition, palatability, digestibility, effect cost are important aspects to be considered. The ration of feed formulation must be used in the right amount to reduce the over or under use of nutrient that will affect the poultry performance.

Moringa oleifera is a herbaceous herb that originates from India. *Moringa* is a plant that can grow anywhere because it can tolerate the high climate environment. It can found in the tropical country. *Moringa* is a plant that can give benefit to humans including for health requirement. These plants are edible from all parts including leaves, bark, flower, fruit, root and as well as seeds. These plants are usually used in traditional medicine.

Black soldier fly larvae (*Hermetia Illucens*) are the larvae that can live and grow in decaying matter such as animal manure or compost material and can produce in large amount. Their adult was small and black in colour. They are usually pest in the bee industry that will destroy the bee's colonies. The adult had mouthparts that are not functioning and only spend their time mates and reproduce their new generation. These larvae are commonly be used in many countries as poultry feed. Feeding chicken with BSF larvae is particularly well suited to the traditional system of poultry production which is the most common poultry production system in most developing countries (Moula et al., 2017).

Turmeric *(Curcuma longa)* is the plant that grows as a perennial herb. The turmeric was an asexual plant that can be planted by using a cut of rhizomes parts. It can grow in the shade and in an open area. The rhizome has usually been used as natural food colouring due to its yellow colour and also been used as medicine for the internal and external injured cure such as the inflammation of skin or digestive system problem. The rhizomes part also can be dried to make the powder form that is easily been used. It leaves also been used in cooking for the aroma.

Response surface methodology (RSM) is software to make the experimental design to estimate the different variables of the study. In this study there are three variables that are being studied which are *Moringa oleifera*, black soldier fly larvae and turmeric to know the optimal value for the broiler chicken feed formulation. The method that been used in this study is central composite design.

1.2 Problem statement

The insufficient nutrition will affect the weight of the broiler chicken due to less amount of important nutrient from the feed intake. For instance, the insufficient supply of protein supplement will affect their growth because protein is essential for the formation of new cell and growth. The feed cost is one of the main aspects that must be considered because it is important in the feed consumption but it is costly. Broiler chicken feeds are expensive because it is from imported sources. So the nutrient that needs by the broiler decreases due to lacking feed intake that rich with important nutrient. The low cost of feed resources is important to broiler chicken but the sufficient nutrient level aspect also needs to be considered. So, to overcome the high cost of broiler chicken feed the resources were being used in feed been to choose from the sources that easy to get and low cost.

1.3 Objectives

The main objectives of this study are:

1. To formulate broiler chicken feed consisting *Moringa oleifera*, black soldier fly larvae and turmeric by using Response Surface Methodology (RSM).
2. To observe the average daily weight gain, survival rate and feed conversion ratio of broiler chicken on the different formulation.

1.4 Scope of Study

The scope of this study is to investigate the optimal amount that needs in the nutrient requirement in broiler chicken feed formulation using three different parameters, which is *Moringa oleifera* (24.5% to 74%), turmeric (0.5% to 1.0%) and black soldier fly larvae (5% to 25%). The optimisation of the nutrient requirement will be performed using response surface methodology (RSM) with the design of central composite design. The optimisation technique that was studied is using a 2D contour plot and 3D response surface graph.

1.5 Significance of the study

By using Response Surface Methodology (RSM), the optimum chicken broiler feed formulation could be obtained. This software will help scientists to develop precise feed formulation without any excessive or insufficient intake. Therefore, optimal growth performances of broiler chicken could be achieved.

CHAPTER 2

LITERATURE REVIEW

2.1 Poultry production

Poultry is the bird that reared for meat, egg and feather purposes. The poultry that raised for meat purposes is called as a broiler. While for poultry that raised for the egg purposes are called as a layer. Their reared way is also different between their purposes. Based on chicken breed type, input and output level, mortality rate, type of producer, the purpose of production, length of broodiness, growth rate and a number of chicken reared (Abebe et al, 2015). For meat purposes, the growth performances and carcass quality are essential. But for the egg purposes, where be raised for good quality of the egg.

Poultry is the most widely of the livestock industry in the South East Asia countries including Malaysia, Indonesia, Thailand, Philipines and Vietnam. Poultry consumption around the world is predicted to grow by 27 to 28 million tons by 2023 with 40% of that growth in Asia ("Iowa Economic Development Authority", 2017). It is expected that the demand of the poultry industry will rise around the globally including South East country due the increasing the demand for poultry supply among the people.

2.1.1 Poultry consumption in Malaysia

The high demand of chicken for protein sources in Malaysia because its low cost compared to red meat protein sources. The high demand of the chicken is also because Malaysia people mostly are Muslim that So, the HALAL factor is important in the food sources. So, because the low cost and HALAL factor of the chicken it is that makes the poultry production in Malaysia were expanding rapidly. The country's poultry meat per capita consumption is the highest in the world. Malaysians consume 1.8 million chickens and 2.8 million chicken eggs daily ("Iowa Economic Development Authority", 2017). Per Capita Consumption of Poultry Meat is shown in Table 2.1.

Table 2.1: Per Capita Consumption of Poultry Meat

Per Capita Consumption of Poultry (Year)	**Per Capita Consumption in Kilogram (kg)**
2010	43.3
2011	43.6
2012	44.4
2013	46.5
2014	49.8
2015	50.7

Source: Department of Veterinary Service (DVS)

2.1.2 Broiler Production

Broiler production is the industry that focuses on the reared and prepared of poultry for their meat purpose. The aim of a broiler producer is to grow birds so that they meet one or more production targets. Depending on business strategy, the objective may be to grow the birds as quickly, or as cheaply as possible, or to ensure that they reach given market weight on a given date (Frost et all, 2003). In the broiler production, the volume is important to offset the small unit of profit. The objectives of broiler production are also to achieve the required flock performance in terms of bird welfare, live weight, feed conversion, uniformity, and meat yield within economic constraints ("Aviagen", 2014). Every factor that affects the cost of production needs to be considered because the combined effect of each factor determines the profit.

The key success of broiler is the types of the chicken breed which is good genetic or the good quality of chick. Then, the important key is the feeding and watering management for broiler which is enough and no feed wastage. The environment is also the important aspects in broiler business which is the location of the plant, farm layout, housing design and enough equipment. The house temperature, humidity, ventilation and light are also important. The management also must be carried out wisely which are brooding management, feeding management and waste management. The disease control also the aspect that needs for the broiler business which is the isolation of disease or sick animal, farm hygiene and sanitation, vaccination and medication.

2.1.3 Brooding Management

Brooding management is the phase of the rearing chicks and cares recently hatched chicks together for two weeks after hatching. During this phase, the chicks are sensitive and have the high of mortality rate. The principal of brooding management are the newly arrival chicks quality, preparation of enough space, provide heat (suitable temperature), feed and water, proper and special management and health care of newly arrival chicks. A brooding period is an important period in raised before they were growing out and been market. From the small scale to large scale plant, there are many ways the brooding type be carried out to reduced the rate of mortality.

The newly hatched chicks need heat at the start of brooding until they produce their own feather and can control their internal body temperature. Naturally, chicks were reared through natural brooding which is they get heat from the hen to keep warm until they grow out. But in the modern poultry production industry, the chicks get the heat from artificial heat sources which are brooders or heaters (Abebe et al., 2015). The newly hatched chick cannot control their body temperature are because their thermoregulatory system does not well develop yet. Thermoregulatory is the ability to regulate body temperature which is chicks survival only depend on grower to provide a suitable environmental temperature ("Brooding Guide for Optimum Breeder Development," 2013).

The artificial heat sources have been obtained to the chick if there are extreme weather condition such as in night or raining day. During the brooding period, the chicks can be brooder in cages or floor. The brooding area will be closed and the brooder or heater will be used as well as the litter to make the chicks warm. Irregular floor temperatures can cause chicks to huddle in pockets or under equipment. Also, the irregular litter can interfere the chick mobility and restrict access to feed and water due to the not suitable height of feed and water lines ("Brooding Guide for Optimum Breeder Development," 2013). The enough space also must be provided to maintain the heat and reduce the brooding area are too cold if space is larger or too hot and crowded if space is too smaller.

2.1.4 Broiler Production In Malaysia

Broiler productions are the larger industry that undergoes the white meat production at Malaysia due to the high demand. As of September 2011, there are a total of 3,179 broiler farms in Peninsula Malaysia (Majid & Hassan, 2014). The broiler farms by the state that undergo the broiler farms are shown in Table 2.2.

The higher demands of the broiler chicken also because almost the population of the world consume and especially to Malaysia. So this industry increased widely to fulfil its higher demand. The more demand of the broiler chicken is also because of the cost of the meat that is cheap compared to another livestock industry. The poultry industry plays a significant role in the Malaysian economy in the provision of a cheap source of protein to its multi-ethnic population (Abdurofi et all, 2017). The poultry industry also easy because the short cycle of the chicken life cycle due to the faster of the chicken to grow to the adult and market size.

Table 2.2: Broiler Farms by State (as of September 2011) (Majid & Hassan, 2014).

State	**Number of farms**	**Broiler population Number ('000)**	**Total of percentages (%)**
Kedah	703	37,248.5	32.1
Pulau pinang	592	25,663.2	22.1
Perak	335	9,928.0	8.6
Selangor	299	8,112.3	7.0
Negeri Sembilan	248	7,222.8	6.2
Melaka	233	6,579.8	5.7
Johor	200	6,267.8	5.4
Pahang	187	5,915.0	5.1
Terengganu	187	5,139.1	4.4
Kelantan	182	3,729.5	3.2
Perlis	13	180.0	0.2
Total	3,179	115,986.0	100.0

Source: Department Of Veterinary Services (DVS 2011)

2.2 Feed For Broiler

The factor increases of the livestock industry, so feed production also increased to fulfil the demand for the good sources of the feed to the livestock. There are many companies that produce the feed for the livestock. The differences age, species and need of the livestock that make the feed production industry was rising. The feed sources also have been imported widely from another country to fulfil the demand of the chicken feed.

Broiler chicken has the different stages including starter stages, grower stages and finisher stages. The size of feed is different between the stages of the broiler chicken because of the different ability to consume the feed. Feed physical form is one of the most important factors, which confound the effect of particle sizes on the digestibility of nutrients and growth performance (Zang et al., 2009). The feed also divided into various type and size including crumble, pellet and so on. But for the grower stages, the pellet is the good alternatives because of the various benefit of it. Compared with mash, pellets enhance bird performance by decreasing feed wastage, alleviating selective feeding, destroying pathogens, improving palatability and increasing nutrient digestibility (Lv et al., 2015).

2.3 Nutrition Requirement for Broiler

The birds obtain the energy for growth and metabolic functions from their feed in the form of carbohydrates, proteins and fat (Tallentire et al., 2016). This nutrient will maintain the growth and health of broiler by providing the sufficient value of nutrition requirement.

The requirement of protein is essential for the production of the tissue and feather. This requirement usually forms as the crude protein. The broiler requirement for crude protein describes the requirements for amino acids, the building blocks of protein (Tallentire et al., 2016). The sources of protein requirement usually come from animal protein including fish meal and meat meal. An examples of plant protein including soybean meal and coconut meal.

The requirement for the energy usually comes from the feed that contains the high of fibre including corn, rice, wheat and grain. Energy is necessary for maintaining the bird's basic metabolic functions and body weight growth (Tallentire et al., 2016). The maintain level of the energy feed for the broiler can maintain them. The requirement for the micronutrient is essential for growth and development of broiler and to regulate the better body function. The micronutrient that needs by the broiler is vitamin and mineral.

For vitamin are consist of water-soluble vitamin and fat-soluble vitamin. Water-soluble vitamins include the B-complex vitamins. Vitamins classified as fat-soluble include A, D, E and K. The fat-soluble vitamins can be stored in the liver and other parts of the body (Tallentire et al., 2016). The mineral requirement consists of the major and trace elements. The major minerals include calcium, phosphorus, potassium, sodium, chlorine, sulphur and magnesium. Trace minerals include iron, iodine, copper, manganese, zinc and selenium (Tallentire et al., 2016). The ration formulation of different stages of broiler chicken is shown in Table 2.3.

Table 2.3: Ration formulation for starter, grower and layer (Abebe et al., 2015)

Ingredient	**Starter (%)**	**Grower (%)**	**Layer (%)**
Maize	45.9	52.9	50.4
Wheat bran	7.5	7.5	7.5
Dried and grounded trifolium	2	2	2
Grounded bone and meat	4	4	4
Noug seed cake	37	30	30
Limestone	1	1	4.5
Grounded bone	2	2	1
Salt	0.35	0.35	0.35
Vitamin & mineral mix	0.25	0.25	0.25
Chicken ration formulated by feed win software using different ingredients			
Noug seed cake	10	10	10
Maize	45	60	55
Wheat bran	10	10	10
brewery dried grain	3	5	5
Soya bean meal	12	3	8

Salt	0.5	0.5	0.5
Alfalfa	3	0.5	1
Limestone	1.5	2	3.5
Sesame cake	15	9	7

2.4 Feed Conversion Ratio

The feed wastage often occurs in livestock production which can affect the feed intake of livestock and the cost of feed. So, feed conversion ratio will be calculated to observe the feed intake by the livestock. In the broiler chicken, the feed conversion ratio is the important aspect because it will determine the production and profit of the company. The feeding of industrial broiler chickens is often criticized because of the extensive use of feed sources which are neither socially nor ecologically sustainable (Pauwels et al., 2015).

Feed conversion ratio (FCR) is a measure of how well a flock converts feed intake into live weight and provides an indicator of management performance, and also profit at any given feed cost ("Optimizing Broiler Feed Conversion Ratio," 2011). In other words, FCR is a measure of an animal's efficiency in converting feed mass into increased body mass, including least amount of feed that is required for unit body weight gain. Animals that have a low FCR are considered efficient users of feed (Poultry Meat & Eggs, 2010). The formulation of feed conversion ratio is stated as Equation 2.1 (Samarakoon and Samarasinghe, 2012)

$$FCR = \frac{Feed\ intake}{Weight\ gain} \qquad (2.2)$$

There is the opinion on the feed conversion ratio that says if an FCR is increased, is generally considered an economic disadvantage but if the scavenger diet can be obtained at much lower cost than the commercial diets, this perspective might change. For example, in a rural situation, where a scavenger diet can (partially) be found in the environment and is available at libitum, our results suggest that scavenging chickens might achieve the same bodyweights as when they were fed a commercial diet. Still, factors such as disease, water availability and housing must be controlled (Pauwels et al., 2015)

2.5 *Moringa oleifera*

Moringa oleifera is the plant that rich with protein, vitamin and mineral. *Moringa oleifera* as a protein-rich plant has attracted much attention over the years throughout the world with strong recommendations for feeding to non-ruminants and ruminants alike (Moiforay et al.,2016). But the richest nutrition of the *Moringa oleifera* is on leaves part. The leafy part of *Moringa* could thus be used as a protein supplement for poultry (Melesse et al., 2011).

There is the study show that the *Moringa oleifera* fresh leaves (MOL) contained 25% DM, 22.73% CP and 27.63% NDF on DM basis (Mohammed et al., 2012). *Moringa oleifera* is a plant that has many benefits for the chicken. There are the authors have reported the use of Moringa in poultry diets with evidence of better performance in terms of growth and egg production (Moiforay et al., 2016). There are also the studies that state, on a dry matter basis, *Moringa oleifera* leaves contained 27.2% protein, 5.9% moisture, 17.1% fat, and 38.6% carbohydrates (Abbas, 2013).

2.6 Black Soldier Fly Larvae

Black soldier fly larvae are the protein sources that are cheap because can be found everywhere. Insect or larvae can live at a wide range of area because they can easily adapt to new environment because their body structural that is flexible. These larvae can grow on a wide range of decomposing organic materials, from fruits and vegetables to kitchen wastes, rendered fish and poultry, pigs and cattle manure, thus being potentially interesting in reducing environmental criticisms by transforming waste invaluable biomass (Cullere et al., 2016).

BSFL are the larvae that easily been found at Peninsular Malaysia because their habitat can easily be found on the animal manure or the decaying materials. BSFL are the larvae that contain the high level of protein that same as another plant protein sources. The insects represent a great opportunity to meet the demand and partly/totally replace conventional protein feed sources (Cullere et al., 2016). These larvae can also reduce the number of competitors for the consumption sources between animal and human for the nutrient requirement. For instance, soybean that can also be consumed by humans for the protein requirement.

BSFL also the insect that has high hygienic because they are not harmful to be as feed for livestock. They are harmless, lacking both stingers and functional mouthparts (Mohammed et al., 2017). There is a study that says which are on dry-matter basis BSFL contained 40-45% protein, 30-35% fat, 11-15% ash, 4.8-5.1% calcium, and 0.6%

phosphorous, as well as a range of amino acids and minerals (Rana et al., 2015). And also a study showed that BSFL had high percentages in crude protein (42.6%), making it suitable to replace fish meal in the diets of poultry. The ether extract content was 36.9% and ash composition was 15.3% (Mohammed et al., 2017)

2.7 Turmeric

The function of the turmeric is act as the natural healer to the injured or inflammation without effect the animal health. Turmeric has antioxidant, antibacterial, antifungal, antiprotozoal, antiviral, anti-inflammatory, anticarcinogenic, antihypertensive, and hypo cholesteremic activities (Sethy et al., 2017). Many benefits of the turmeric make it as the good nutrient that needs by livestock. Broilers diet supplemented with *Curcuma longa* improved weight gain, which was depressed by infection with *Eimeria acervulina* when compared to a standard diet (Khan et al., 2012). And also the addition of *Curcuma longa* as feed additive resulted in better growth, feed consumption and feed conversion ratio (FCR) in broilers (Khan et al., 2012). So, the curcumin has essentials effect to the broiler chicken to consume.

There are some researchers reported that the curcumin take in the chicken diet would not have any good effect on the chicken. There is no effect of supplementation of 0.2% turmeric in the feed on feed intake, weight gain or FCR (Khan et al., 2012). There is also another research reported that there was no beneficial effect to the chicken performances. The supplementation of turmeric has no significant effect on feed intake, weight gain and feed conversion ratio of broiler chicks (Khan et al., 2012). There are study say that found turmeric contain 8.92% moisture, 2.85% ash, 4.60% crude fibre and 6.85% fat. It also contains 9.40% crude protein and 67.38% carbohydrate (Ikpeama et al., 2014).

2.8 Response Surface Methodology

Response surface methodology software is software to estimate the optimal value of a different type of the variable by optimizing technique. Another function of RSM is a collection of statistical and mathematical methods that are useful for modelling and analyzing engineering process (Alireza et al., 2013). Optimizing refers to improving the performance of a system, a process, or a product in order to obtain the maximum benefit from it (Bezerra et al., 2008).

Traditionally, optimization in analytical chemistry has been carried out by monitoring the influence of one factor at a time on an experimental response. While only one parameter is changed, others are kept at a constant level (Bezerra et al., 2008). This showed that the optimization often been done by converting one variable, while the other variable will be the same.

At some stages in the application of RSM as an optimization technique are (Bezerra et al., 2008). Firstly, the selection of independent variables of major effects on the system through screening studies and the delimitation of the experimental region, according to the objective of the study and the experience of the researcher. Secondly, the choice of the experimental design and carrying out the experiments according to the selected experimental matrix. After that, the mathematic–statistical treatment of the obtained experimental data through the fit of a polynomial function. Then, the evaluation of the model's fitness and the verification of the necessity and possibility of performing a displacement in a direction to the optimal region. Finally, obtaining the optimum values for each studied variable.

RSM aim is to find a suitable approximation for the true functional relationship between the dependent variable (response) (Y) and the set of independent variables (factors) ($X1$, $X2$, . . .) (Gönen & Aksu, 2008). The dependent variable is the factor that will depend on the independent variable. In other words, if the independent variables are changes it will affect the dependent variable as well. Because the dependent variable is the variable that has been observed.

In response surface methodology there four factors of experimental design that be used including two-level full factorial design, face-centered central composite design, Box-Behnken design and three-level full factorial design (Rakic et al., 2014). The design of RSM is shown in Figure 2.1.

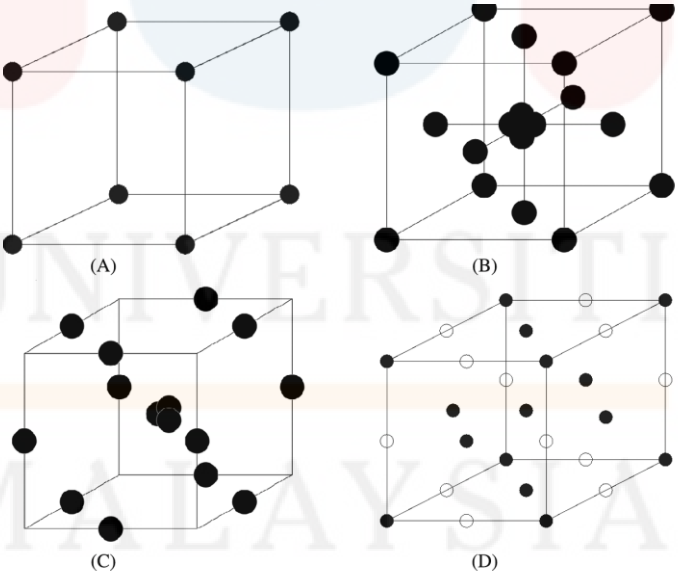

Figure 2.1: The schematic representation of experimental designs for three factors: (A) two-level full factorial design; (B) face-centered central composite design; (C) Box-Behnken design; and (D) three-level full factorial design.

2.8.1 Central Composite Design (CCD)

For a second-order response surface model, the central composite designs (CCDs), are introduced by Box and Wilson (1951), are the most commonly used designs because the CCDs have many good statistical properties (Park & Park, 2010). This design is the usually used in the experimental designs.

Full uniformly routable central composite designs present the following characteristics (Bezerra et al., 2008). Firstly, require an experiment number according to $N = k2 + 2k + c_p$, where k is the factor number and (cp) is the replicate number of the central point. Where N: a total number of the experiment, k: number of point factor and c_p: *central point. Secondly,* the α-values depend on the number of variables and can be calculated by $\alpha = 2(k-p)/4$. Finally, all factors are studied in five levels (−α, −1, 0, +1, +α). That is the minimum value (−1), middle value (0), a maximum value (+1) and the outer points (−α and +α). The full central composite design for optimization of two and three variables are shown in Figure 2.2 above.

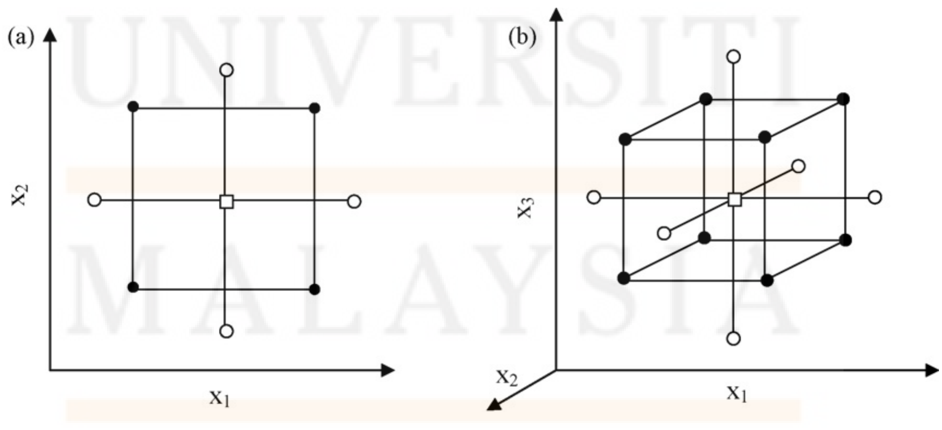

Figure 2.2 : Central composite designs for the optimization of: (a) two variables (α = 1.41) and (b) three variables (α = 1.68). (●) Points of factorial design, (○) axial points and (□) central point.

CHAPTER 3

MATERIALS AND METHOD

3.1 Materials

The material that is used in this study are *Moringa oleifera* leaf, black soldier fly larvae powder, turmeric rhizome, vegetable oil, sawdust/shredded paper, airtight zip bag, and 120 broiler chicken

3.2 Equipment

The equipment used in this study are weighing scale, electric blender, forced air drying oven, heater, drinker, feeder, thermometer and iron net. Design Expert Software Version 7 was used in this study.

3.3 Method

3.3.1 Preparation of *Moringa oleifera* sample

The *Moringa oleifera* leaf that bought from the supplier was dried in the forced air drying oven for 2 hours at 70°C until it dry. After that, it was being crushed by using the electric blender until it formed a crumb.

3.3.2 Preparation of Turmeric sample

The fresh turmeric rhizome that bought from Jeli market was dried in the forced air drying oven for 24 hours at 60°C until it dry. After that, it was crushed by using the electric blender until it formed a crumb.

3.3.3 Preparation of Black soldier fly larvae sample

For the black soldier fly larvae were got from the Nutrition Technologies Sdn Bhd in the form of the powder.

3.3.4 Design experimental by using Response Surface Methodology (RSM) technique

The feed formulation of broiler chicken was designed by using Response Surface Methodology (RSM) with the Central Composite Design (CCD) model. The three variables were entered to the Central Composite Design (CCD) that was *Moringa oleifera*, Turmeric and Black soldier fly larvae and the units were expressed in the percentages. The lower level (-1) and also the high level (+1) were entered into RSM software to formulate the feed.

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

Variables	**Name**	**Units**	**Low Level (-1)**	**High Level (+1)**
A	*Moringa oleifera* (Gadzirayi, Masamha, Mupangwa, & Washaya, 2012)	%	24.5	74
B	Turmeric (AL-Sultan, 2003)	%	0.5	1.0
C	Black soldier fly larvae (Onsongo, 2017)	%	5	25

The value of the parameter was shown by this design for 20 runs by different quantity on each formulation of the feed. The detailed 20 runs of the formulation are shown in Table 3.2.

Table 3.2: Total experimental runs generated using CCD.

Run	**A** ***Moringa oleifera* (%)**	**B** **Turmeric (%)**	**C** **Black Soldier Fly larvae (%)**
1	24.50	1.00	5.00
2	74.00	0.50	5.00
3	74.00	1.00	25.00
4	49.25	0.33	15.00
5	7.63	0.75	15.00
6	49.25	0.75	15.00
7	49.25	1.17	15.00
8	24.50	0.50	25.00
9	49.25	0.75	15.00
10	49.25	0.75	15.00
11	49.25	0.75	15.00
12	49.25	0.75	-1.82
13	49.25	0.75	15.00
14	49.25	0.75	31.82
15	74.00	1.00	5.00
16	24.50	0.50	5.00
17	90.87	0.75	15.00
18	49.25	0.75	15.00
19	74.00	0.50	25.00
20	24.50	1.00	25.00

2.2.5 Optimization studies

The optimisation studies were carried out by using Design Expert Software Version 7 that was comparing between actual experimental data that we get from the studies and with the predicted experimental data that were given by software. The Design Expert Software Version 7 undergoes analysis for three experimental responses (R), which were R1 for average body weight gain (g/d), R2 for survival rate (%) and R3 for feed conversion ratio. Then, a series of evaluation was done which was an analysis of variance (ANOVA), development of polynomial regression model equation, the diagnostic plot for predicted value versus actual values and diagnostic plot for normal probability plots of residual. After that, the data was observed and analysed by using a 2D contour plot and 3D surface plot.

2.2.6 Preparation of Feed formulation

The formulation was formulated by the value that gets by using response surface design for 20 different formulations. The four ingredients needed in this formulation which moringa oleifera leaf powder, black soldier fly larvae powder, turmeric rhizome powder and vegetable oil (3ml). All the ingredients were mixed well and were put into an air zipper bag. The feed was in crumble form that suitable for the starter broiler chicken to fed. The feed that was got from the software then was calculated to get 100% which was shown in Appendix A (Table A22).

2.2.7 Preparation of the Broiler chicken

The 120 broiler chickens were purchased from the broiler chicken supplier. The broiler chicken was reared from the starter stages for two weeks from 2 to 14 days. In these stages, the chicks were reared carefully by the brooding system due to the higher mortality rate in this phase because the chick is not able to control their heat. The heating, litter, feed and water been supplied for the new arrival chicks. The vaccination for anti-stress was also given to the chicks for a day.

The chicks were divided into 20 groups that consisted six of broilers chicken for each group treatment by using the iron net to separate them. The record keeping was done for first-day arrival until the end of 2 weeks. The record keeping that recorded were the temperature, the dead and expelled chicks, the feed intake and leftover of the feed by the chicks every day and as well as the body weight of the chicks for once of two days.

2.2.8 Feeding Trial

Each group was fed by using a different formulation that contains different amount of *Moringa oleifera* leaf, black soldier fly larvae and turmeric. The feed was given in the morning and in the evening for each group. The chick was consumed 25 gram per chicken per day.

At the end of the experiment, the body weight of broiler chicken was been collected one for two days. The body weight was collected every 2 days of 20 groups of treatment.

2.2.9 Measurement and Sampling

For average daily weight gain (ADWG), it can be estimated by using the formula of:

$$\text{ADWG (g/d)} = \frac{W2-W1}{n} \qquad (3.1)$$

Where W2 is the final weight

W1 is the initial weight

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

For survival rate (SR), it can be estimated by using the formula of :

$$\text{SR (\%)} = \frac{S1}{S2(6)} \times 100 \qquad (3.2)$$

Where S1 is the final survival number of chicks

S2 is the initial number of chicks

For feed conversion ratio (FCR), it can be estimated by using formula:

$$\text{FCR} = \frac{Feed\ intake}{ADWG} \qquad (3.3)$$

$$\text{ADWG (g/d)} = \frac{W2-W1}{n}$$

Where W2 is the final weight

W1 is the initial weight

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

(Dauda et al., 2014)

CHAPTER 4

RESULT AND DISCUSSION

4.1 Development of Regression Model Equation for Response 1 (Average Daily Weight Gain)

As shown in Table 4.1, the model summary statistics of average daily weight gain that were generated by the Design Expert Software Version 7 were suggested that linear model was the best model that fit the experimental response 1, which is average daily weight gain while the cubic model is aliased.

Table 4.1: Model Summary Statistics of Average Daily Weight Gain (R1).

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	1.47	0.5418	0.4559	0.2251	58.17	Suggested
2FI	1.59	0.5601	0.3570	-0.9288	144.79	
Quadratic	1.55	0.6807	0.3934	-1.2738	170.69	
Cubic	0.86	0.9405	0.8116	-1.9190	219.13	Aliased

Table 4.2 shows the standard deviation and quadratic model R-squared (R^2) for average daily weight gain (R1). In this study, a relatively low correlation coefficient, R^2 value which was 0.5418 which is not near to 1. The value of the R^2 indicates that the model can explain 54.18% of the response variability.

Table 4.2: The Standard Deviation and Quadratic Model R^2 For R1.

Std. Dev.	1.47	R-Squared	0.5418
Mean	2.65	Adj R-Squared	0.4559
C.V. %	55.33	Pred R-Squared	0.2251
PRESS	58.17	Adeq Precision	8.124

The Predicted R^2 was 0.2251 and the adjusted R^2 was 0.4559 which was not closed as predicted by the model. In this study, the adequate precision was 8.124, that indicates an adequate signal and fitness of the model. The Adequate Precision means that the signal to noise percentage, where a ratio higher than 4 is desirable (Othman et al., 2017).

The empirical polynomial regression model was generated by RSM in terms of a coded factor which reflects the interaction and significance variables towards efficiency of average daily weight gain. The Equation 4.1 shows the empirical second order polynomial regression model in terms of coded factors.

$$\text{Average Daily Weight Gain} = 2.65 - 1.58A + 0.067B + 0.68C \qquad (4.1)$$

From Equation 4.1, A is the *Moringa oleifera*, B is the Turmeric and C is the Black soldier fly larvae. The one factor in equation indicates that the factor is the effect of the particular factor. The positive sign in the coded equation is mean the positive effect of the variables, while negative sign means the negative effect (Bhatia et al., 2007).

So, in this study, the negative sign of factor A (*Moringa oleifera*) are definite that it has a negative effect on average daily weight gain in which the increasing factor A will cause the decreases in the average daily weight gain of the chicken. In other words, the large coefficient value (1.58) of factor A definite that it has the most significant impact on average daily weight gain compared to other factors.

4.2 Statistical Analysis for Response 1 (Average Daily Weight Gain)

From Table 4.3 are showed the analysis of variance (ANOVA) table for response surface quadratic modal of average daily weight gain. ANOVA was used to estimate the significance of model coefficients and the *p* values indicated the significance of each coefficient, which also showed the interaction strength between each independent variable (Ahmad et al., 2013). From the table, the model F-value of 6.31 implies there is a 0.50% chance that a model F-value this large could occur due to noise. From the tables show that the model was significant. If the p-values of Prob > F less than 0.0500 (95% confidence level) it indicates that the model terms are significant (Garg & Magotra, 2017). While if the values greater than 0.1000 indicate the model terms are not significant.

Table 4.3: ANOVA table for response surface quadratic modal of Average Daily Weight Gain.

Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	40.67	3	13.56	6.31	0.0050	significant
A-*Moringa oleifera*	34.25	1	34.25	15.93	0.0011	significant
B-Turmeric	0.062	1	0.062	0.029	0.8676	
C-Black Soldier Fly larvae	6.36	1	6.36	2.96	0.1046	

4.3 Predicted Values Versus Actual Values for Response 1 (Average Daily Weight Gain)

In this study, the actual values of the response are the experimental result that was obtained during the experimental run, while the predicted value is of response are the value that generated by the Design Expert Software Version 7. Table 4.4 shows the table of predicted values versus actual values for average weight gain. The highest actual values were 6.80g/d which were 7.63% of *Moringa oleifera*, 0.75% of turmeric and 15% of black soldier fly larvae. This actual response of average body weight gain was a different little bit with the predicted responses, which was 6.05g/d.

Figure 4.1 shows the normal probability plot of residual for average daily weight gain that is used to examine the error term which is normally distributed. From the figure, the data can be closed to the linear, indicates that the data were small and distributed normally. Meanwhile, Figure 4.2 shows the diagnostic plot for predicted values vs actual values of average daily weight gain. From the diagnostic plot, the residual is not distributed in the linear line. This indicates that the data were not distributed normally.

Table 4.4: The predicted values versus actual values for average weight gain.

Run Order	Actual Value	Predicted Value	Residual	Internally Studentized Residual	Externally Studentized Residual
16	3.90	3.48	0.42	0.332	0.323
2	-0.30	0.32	-0.62	-0.492	-0.480
1	3.50	3.62	-0.12	-0.094	-0.091
15	1.40	0.45	0.95	0.757	0.747
8	1.60	4.85	-3.25	-2.593	-3.297
19	1.70	1.68	0.018	0.015	0.014
20	4.80	4.98	-0.18	-0.146	-0.142
3	-0.20	1.82	-2.02	-1.609	-1.702
5	6.80	5.31	1.49	1.176	1.192
17	0.60	-0.013	0.61	0.485	0.473
4	2.60	2.54	0.063	0.050	0.048
7	1.60	2.76	-1.16	-0.920	-0.916
12	-0.80	1.50	-2.30	-1.822	-1.981
14	5.10	3.80	1.30	1.030	1.032
13	4.00	2.65	1.35	0.945	0.941
18	2.60	2.65	-0.050	-0.035	-0.034
11	4.10	2.65	1.45	1.015	1.016
9	2.30	2.65	-0.35	-0.245	-0.238
6	4.30	2.65	1.65	1.155	1.168
10	3.40	2.65	0.75	0.525	0.513

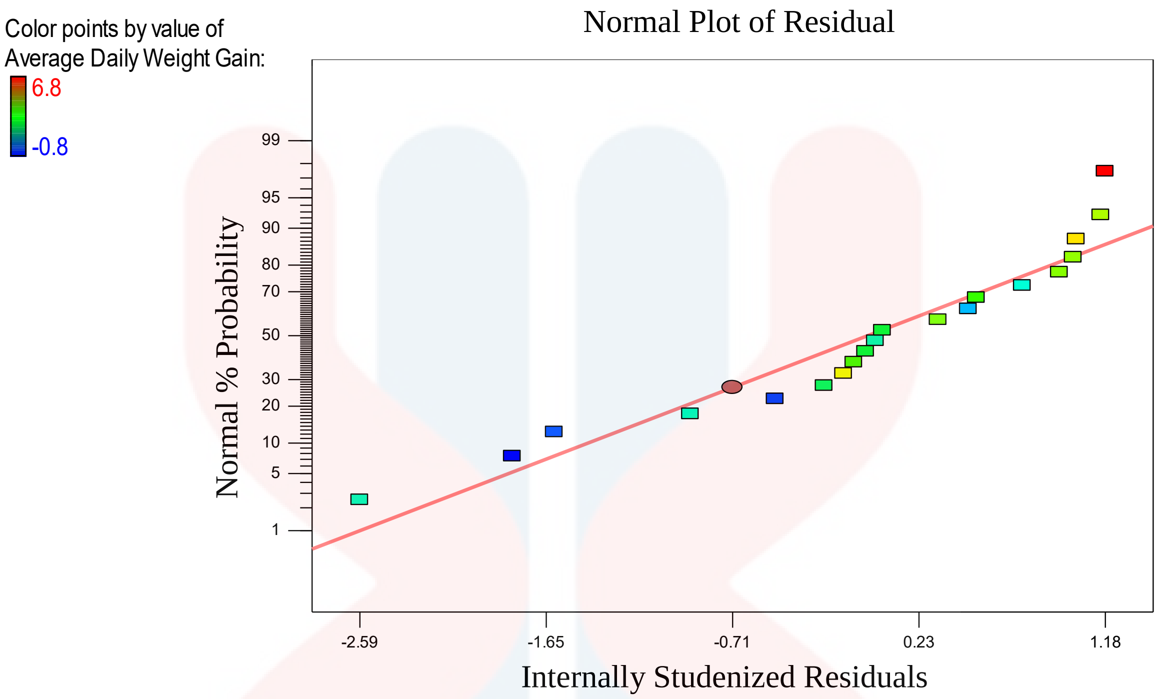

Figure 4.1: Normal probability plot of residual for average daily weight gain

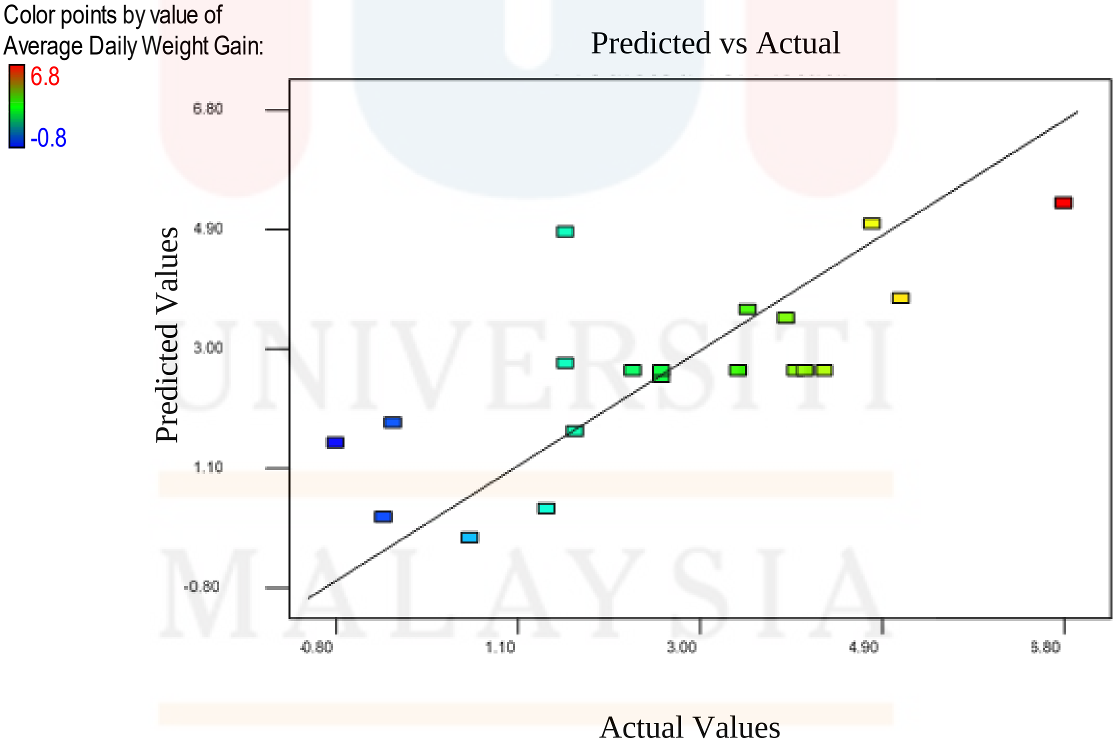

Figure 4.2: Diagnostic plot for predicted values vs actual values of average daily weight gain.

4.4 Optimisation of feed for Response 1 (Average Daily Weight Gain)

A two-dimension (2D) contour plot and three-dimensional (3D) response surface graph were obtained to examine the effect of the potential relationship between variables on the average daily weight gain while keeping others variable as constant. A 2D contour plot and 3D response surface graph were acted to identify the optimum level of variables that when to achieve the optimum average daily weight gain.

4.4.1 Effect of *Moringa oleifera* and Turmeric on Average Daily Weight Gain

Figure 4.3(a) and 4.3(b) shows the effect of *Moringa Oleifera* and turmeric on the average daily weight gain while the black soldier fly larvae which were 15% kept constant. From the figure, it shows that the single interaction. At the percentages between 25.50% to 36.88% of *Moringa oleifera* while the black soldier fly larvae are kept constant which is 15% made the average daily weight gain increases which are 3.75g/d. While, if the percentages of *Moringa oleifera* are between 61.63% to 74.00%, the average daily weight gain of chicken decreased to 1.55g/d.

From this figure, we can observe that the increasing value of *Moringa oleifera* in the feed was decreased the average daily weight gain of broiler chicks. This effect was reported that the net revenue from birds dropped as the level of *Moringa oleifera* meal in the diets increased. This occurrence could be attributed to the depressed weight gain recorded for birds fed these diets (Zanu et all, 2011).

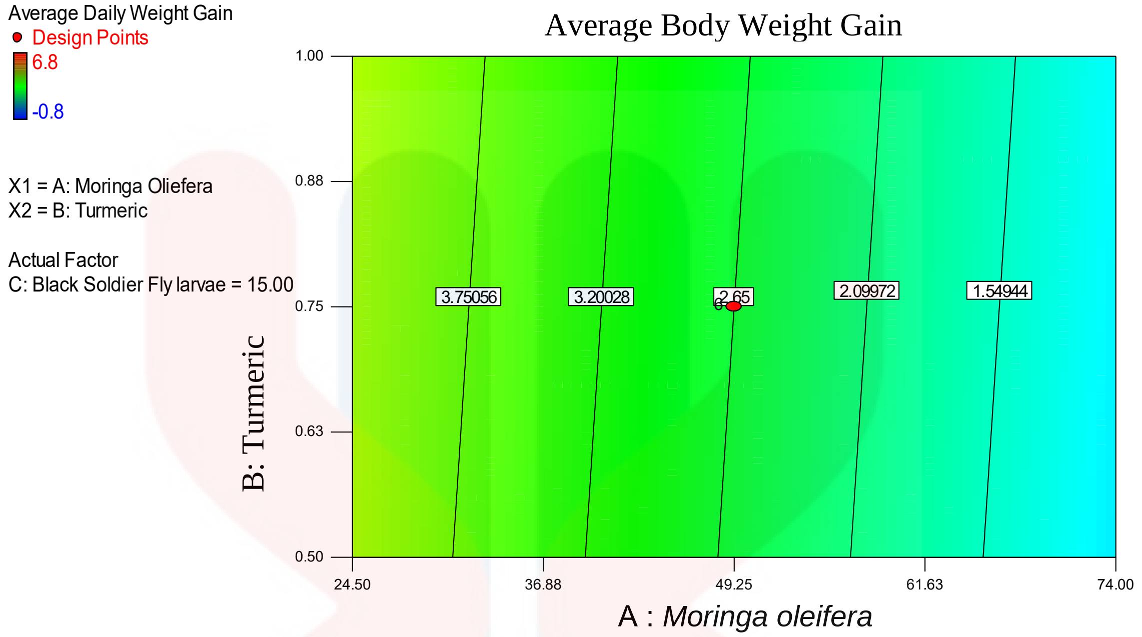

Figure 4.3(a): 2D contour plot of interaction between *Moringa oleifera* and Turmeric on Average Daily Weight Gain (g/d).

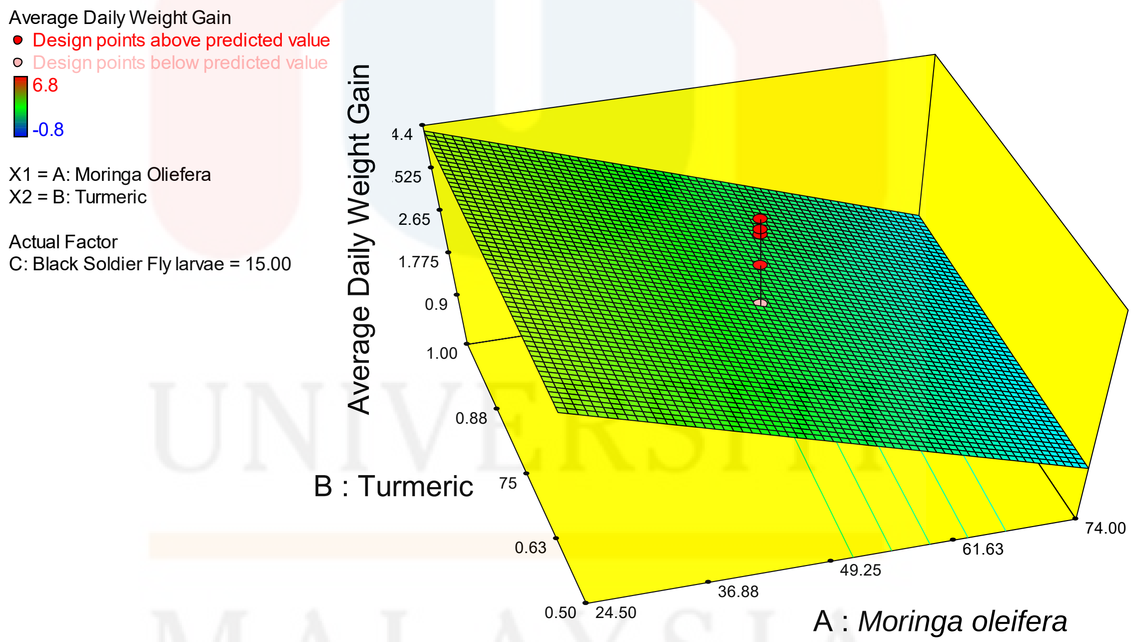

Figure 4.3(b): 3D response surface graph of interaction between *Moringa oleifera* and Turmeric on Average Daily Weight Gain (g/d).

4.4.2 Effect of *Moringa oleifera* and Black Soldier Fly Larvae on Average Daily Weight Gain

Figure 4.4(a) and 4.4(b) shows the effect of *Moringa oleifera* and black soldier fly larvae on the average daily weight gain while the turmeric which is 0.75% was kept constant. From the figure, at the percentages, 36.88% of *Moringa oleifera* and at percentages between 10% to 15% of black soldier fly larvae while the turmeric is kept constant which is 0.75% will make the average daily weight gain increases which are 4.16g/d. While, if the percentages of *Moringa oleifera* are between 61.63% to 74% and black soldier fly larvae are between 15% to 20%, the average daily weight gain of chicken will decrease to 1.14g/d. From this figure, we can observe that the increasing value of *Moringa oleifera* and black soldier fly larvae in the feed will decrease the average daily weight gain of broiler chicks.

So, to increase the average daily weight gain the increasing of black soldier fly larvae is necessary, and also the decreasing percentages of *Moringa oleifera*. There are the studies that stated that they found the used of black soldier fly larvae to chicken as complete diet will increase the growth performance in term of the growth rate of the chicken (Cullere et al., 2016).

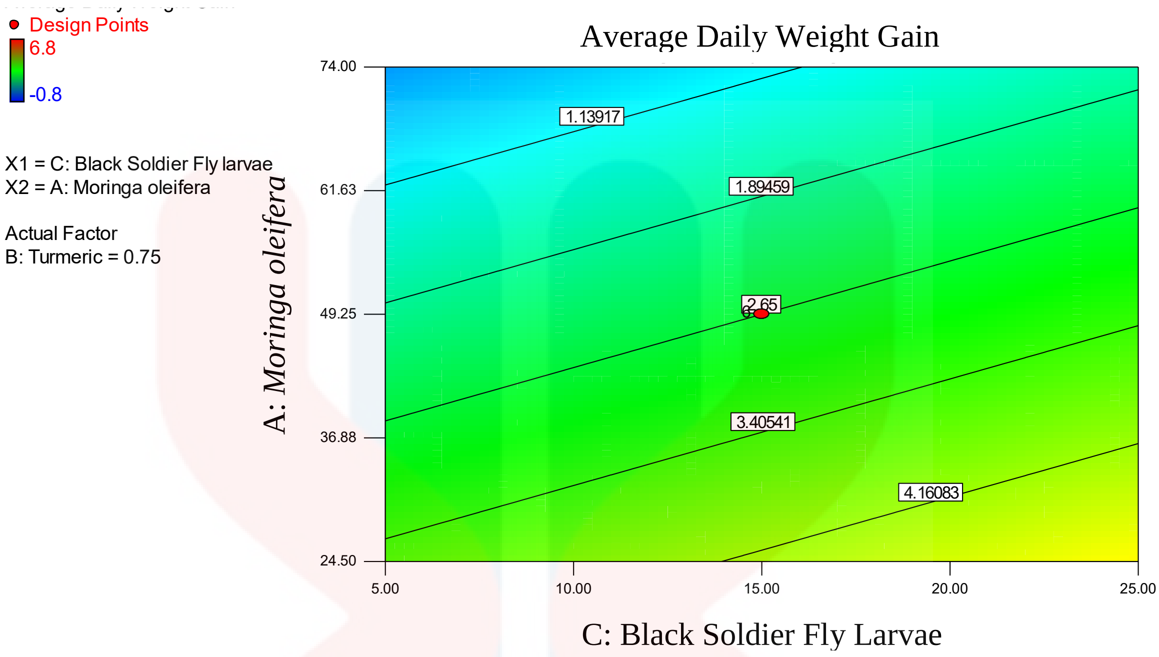

Figure 4.4(a): 2D contour plot of interaction between *Moringa oleifera* and Black Soldier Fly Larvae average daily weight gain (g/d).

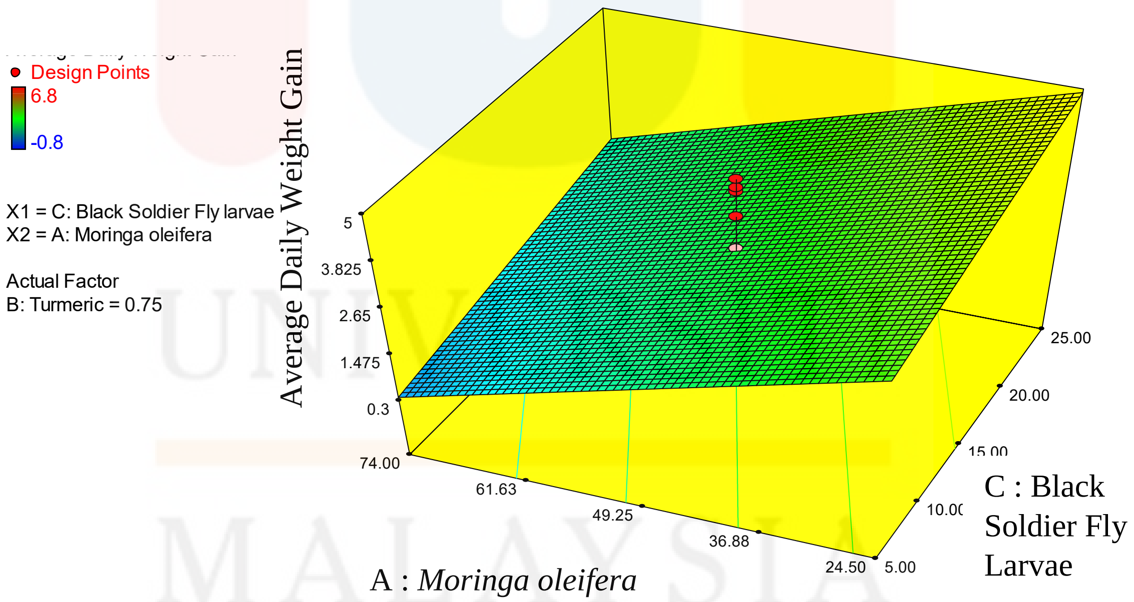

Figure 4.4(b): 3D response surface graph of interaction between *Moringa oleifera* and Black Soldier Fly Larvae average daily weight gain (g/d).

4.4.3 Effect of Turmeric and Black Soldier Fly Larvae on Average Daily Weight Gain

Figure 4.5(a) and 4.5(b) shows the effect of turmeric and black soldier fly larvae on the average daily weight gain while the *Moringa oleifera* which was 59.95% are kept constant. From the figure was also show the single interaction. If the percentages of black soldier fly larvae are between 5% to 10%, the average daily weight gain of chicken decreased to 1.47g/d.

From this figure, we can observe that the decreasing value of black soldier fly larvae in the feed will decrease the average daily weight gain of broiler chicks that were shown by the change of colour from green to blue.

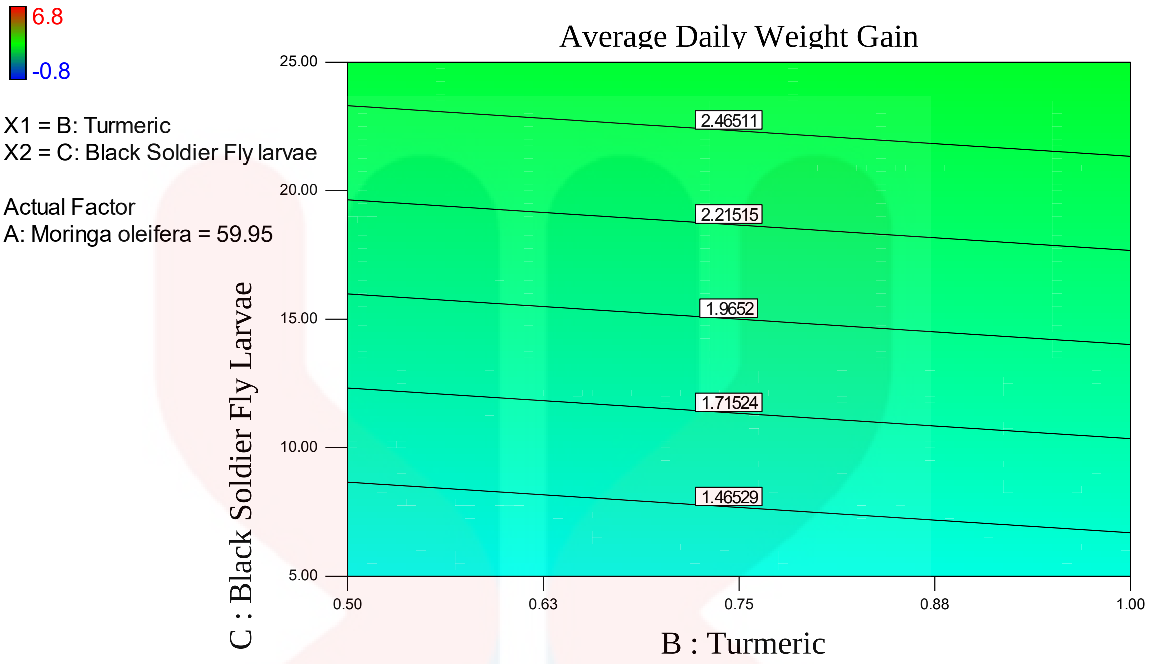

Figure 4.5(a): 2D contour plot of interaction between Turmeric and Black Soldier Fly Larvae average daily weight gain (g/d).

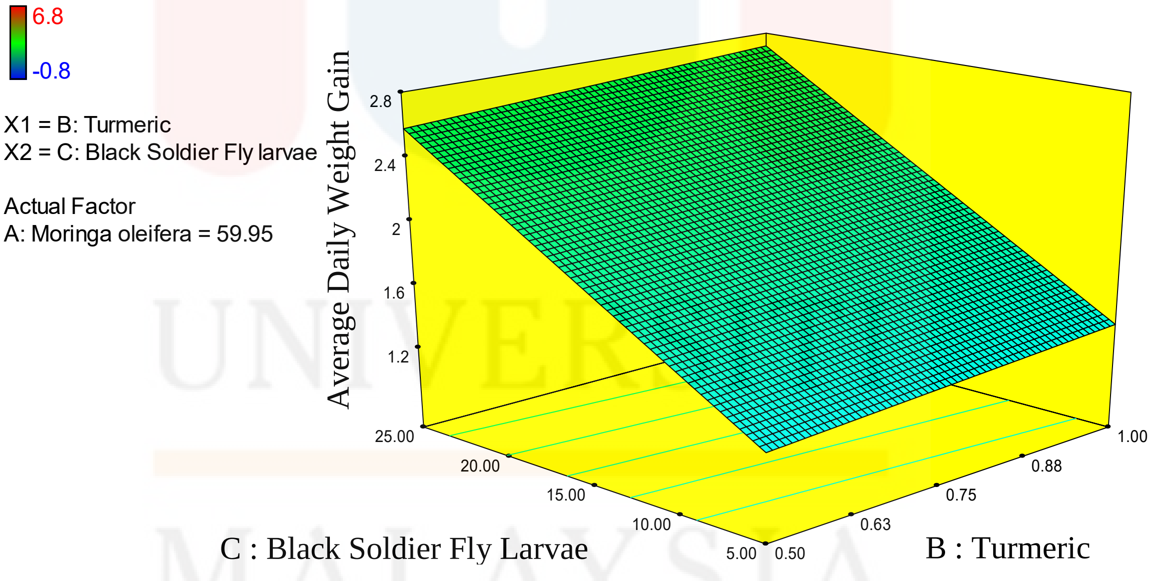

Figure 4.5(b): 3D response surface graph of interaction between Turmeric and Black Soldier Fly Larvae average on daily weight gain (g/d).

4.5 Development of Regression Model Equation for Response 2 (Survival Rate)

As shown in Table 4.5, the model summary statistics of survival rate that were generated by the Design Expert Software Version 7 suggested that quadratic model was the best model that fit the experimental response 2, which is survival rate while the cubic model is also aliased.

Table 4.5: Model Summary Statistics of Survival Rate (R2).

Source	**Std. Dev.**	**R-Squared**	**Adjusted R-Squared**	**Predicted R-Squared**	**PRESS**	
Linear	30.61	0.1724	0.0173	-0.2833	23239.98	
2FI	33.49	0.1950	-0.1765	-1.7238	49327.53	
Quadratic	26.93	0.5994	0.2389	-1.3515	42585.51	Suggested
Cubic	21.03	0.8534	0.5358	-6.3577	1.332E+005	Aliased

Table 4.6 shows the standard deviation and quadratic model R-squared (R^2) for survival rate (R2). In this study, a relative low R^2 value, which was 0.5994 which is not near to 1. The value of the R^2 indicates that 59.94% of the response variability can be explained by the model.

Table 4.6: The Standard Deviation and Quadratic Model R^2 For R2.

Std. Dev.	26.93	R-Squared	0.5994
Mean	29.90	Adj R-Squared	0.2389
C.V. %	90.08	Pred R-Squared	-1.3515
PRESS	42585.51	Adeq Precision	4.011

The Predicted R^2 was -1.3515 and the adjusted R^2 was 0.2389 which were not closed as predicted by the model. A negative Predicted R^2 implies that the overall mean is a better predictor of response than the current model. In this study, the adequate precision was 4.011, that indicates an adequate signal and fitness of the model. The adequate precision measures the signal to noise ratio. A ratio greater than 4 is desirable.

The empirical polynomial regression model was generated by RSM in terms of a coded factor which reflects the interaction and significance variables towards efficiency of survival rate. The Equation 4.2 were showed the empirical second order polynomial regression model in terms of coded factors.

$$\text{Survival Rate} = 55.94 - 11.31A - 1.65B + 9.90C - 4.13AB + 4.12\,AC + 4.12BC - 16.66A^2 - 16.66B^2 - 4.82C^2 \quad (4.2)$$

From Equation 4.2, the biggest positive sign of factor C (Black Soldier Fly Larvae) are definite that it has a positive effect on survival rate in which the increasing factor C will cause the increases in the survival rate of the chicken. And then were followed by interaction of factor AC (*Moringa oleifera* and Black Soldier Fly Larvae) and as well as the interaction of factor BC (Turmeric and Black Soldier Fly Larvae. Compared to individual effect and a quadratic effect that has a negative effect on the survival rate of chicken.

4.6 Statistical Analysis for Response 2 (Survival Rate)

Table 4.7 shows the analysis of variance (ANOVA) for response surface quadratic modal of survival rate. From the table, the model F-value of 1.66 implies there is a 21.97% chance that a model F-value this large could occur due to noise. From the tables show that the model was not significant. If there are many insignificant model terms (not counting those required to support hierarchy), the model reduction may improve the model.

Table 4.7: ANOVA table for response surface quadratic modal of Survival Rate.

Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	10855.75	9	1206.19	1.66	0.2197	not significant
A-*Moringa oleifera*	1747.84	1	1747.84	2.41	0.1517	not significant
B-Turmeric	37.07	1	37.07	0.051	0.8257	not significant
C-Black Soldier Fly larvae	1338.04	1	1338.04	1.84	0.2043	not significant
AB	136.12	1	136.12	0.19	0.6741	not significant
AC	136.12	1	136.12	0.19	0.6741	not significant

BC	136.13	1	136.13	0.19	0.6741	not significant
A^2	3999.55	1	3999.55	5.51	0.0408	
B^2	3999.55	1	3999.55	5.51	0.0408	
C^2	334.14	1	334.14	0.46	0.5127	not significant

4.7 Predicted Values versus Actual Values for R2 (Survival Rate)

Table 4.8 shows the table of predicted values versus actual values for survival rate. The highest actual values are 100% of survival rate which are consist 49.25% of *Moringa oleifera*, 0.75% of turmeric and 31.82% of black soldier fly larvae. This actual response of survival rate was different with the predicted responses, which was only 58.97%.

Figure 4.6 shows the normal probability plot of residuals for survival rate that is used to examine the error term is normally distributed. From the figure, the data was closed to the linear. This indicates that the data were small and distributed normally. While Figure 4.7 shows the diagnostic plot for predicted values vs actual values of survival rate. From the diagnostic plot, the residuals are also not distributed in the linear line.

Table 4.8: The predicted values versus actual values for Survival Rate.

Run Order	Actual Value	Predicted Value	Residual	Internally Studentized Residual	Externally Studentized Residual
16	33.00	24.99	8.01	0.517	0.498
2	0.000	2.37	-2.37	-0.153	-0.145
1	33.00	21.70	11.30	0.730	0.712
15	0.000	-17.43	17.43	1.126	1.143
8	0.000	28.29	-28.29	-1.828	-2.125
19	0.000	22.16	-22.16	-1.432	-1.524
20	33.00	41.49	-8.49	-0.549	-0.529
3	0.000	18.87	-18.87	-1.219	-1.253
5	33.00	27.85	5.15	0.305	0.291
17	0.000	-10.21	10.21	0.605	0.584
4	33.00	11.59	21.41	1.268	1.314
7	0.000	6.05	-6.05	-0.358	-0.342
12	0.000	25.67	-25.67	-1.521	-1.646
14	100.00	58.97	41.03	2.431	3.607
13	67.00	55.94	11.06	0.450	0.431
18	67.00	55.94	11.06	0.450	0.431
11	33.00	55.94	-22.94	-0.933	-0.926
9	50.00	55.94	-5.94	-0.242	-0.230
6	33.00	55.94	-22.94	-0.933	-0.926
10	83.00	55.94	27.06	1.100	1.114

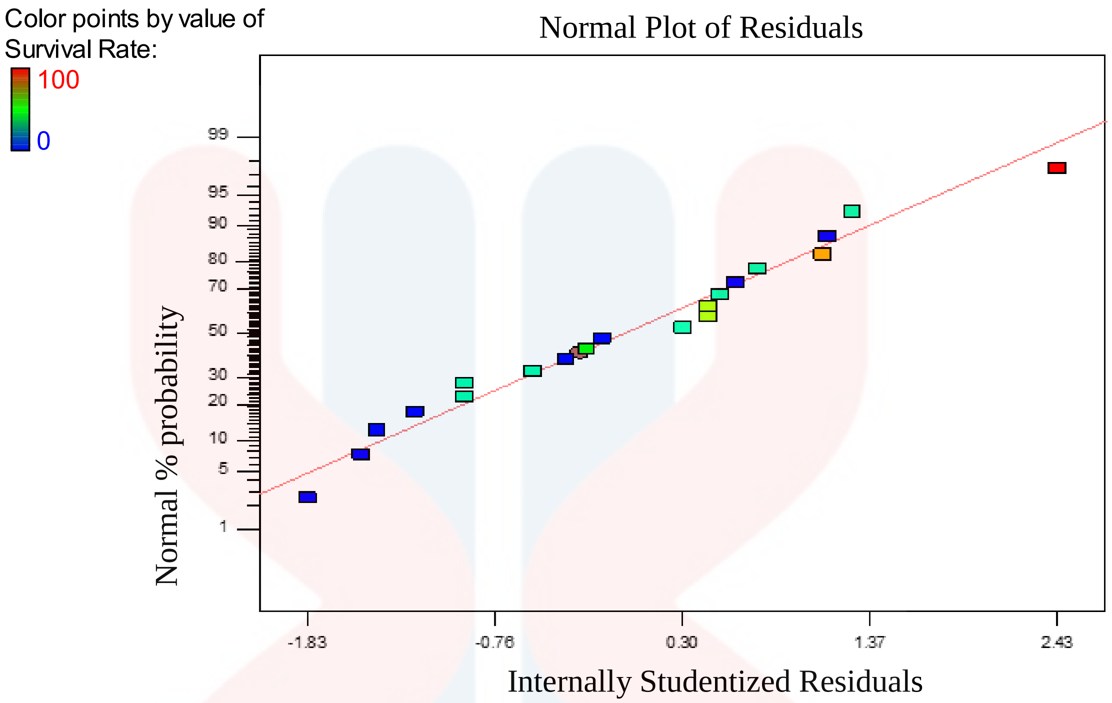

Figure 4.6: Normal probability plot of residual of survival rate.

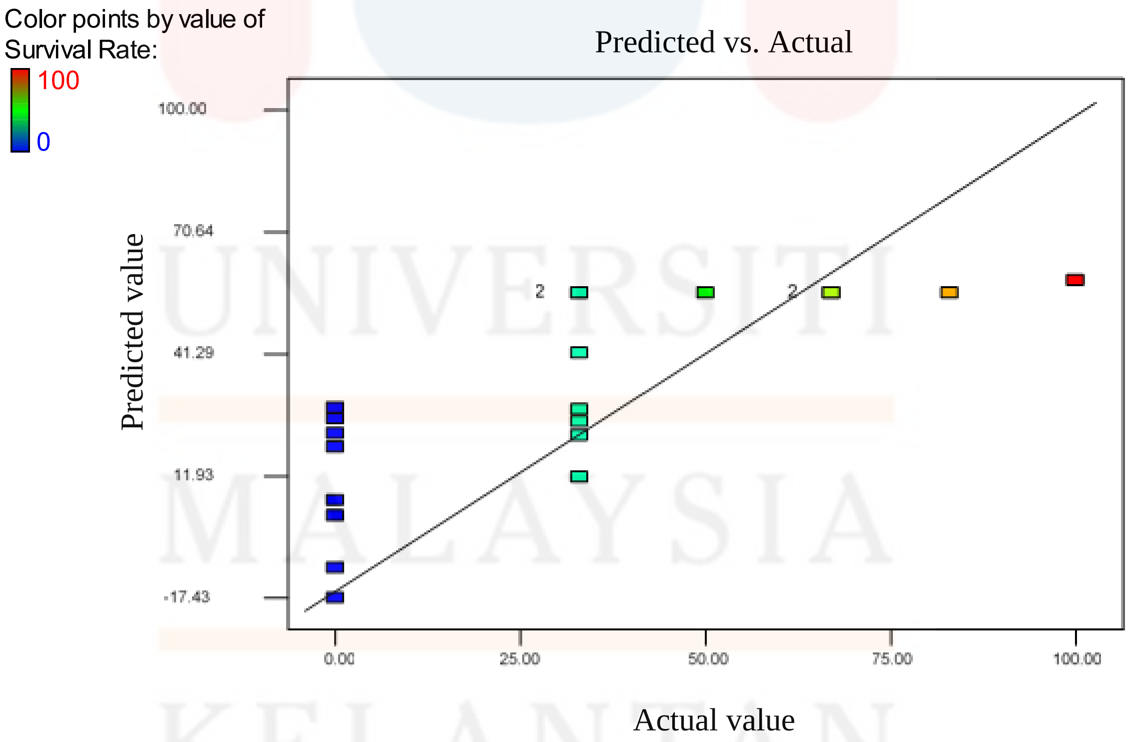

Figure 4.7: Diagnostic plot for predicted versus actual values.

4.8 Optimisation of feed for Response 2 (Survival Rate)

A two-dimension (2D) contour plot and three-dimensional (3D) response surface graph were obtained to examine the effect of the potential relationship between variables on the survival rate while keeping others variable as constant. Figure 4.8(a), Figure 4.8(b), Figure 4.9(a), Figure 4.9(b), Figure 4.10(a) and Figure 4.10(b) show the effect of variables on the survival rate.

4.8.1 Effect of *Moringa oleifera* and Turmeric on Survival Rate

Figure 4.8(a) and 4.8(b) shows the effect of *Moringa oleifera* and turmeric on the survival rate while the black soldier fly larvae which are 15% kept constant. From the figure, at the percentages between 49.25% to 61.63% of *Moringa oleifera* and between 0.88% to 1% of turmeric while the black soldier fly larvae are kept constant which is 15% will make the survival rate increases to 40.42% .

So, in this study, the survival rate decreased if the feed high in *Moringa oleifera*. There is the study showed that *Moringa oleifera* leaf meal generally has the bitter taste. This can indicate that the inclusion *Moringa oleifera* reduced the palatability consequently reduce the feed intake of broiler diets (Onunkwo et al., 2015). If the chicken feed intake is reduced, this will make the mortality rate increases.

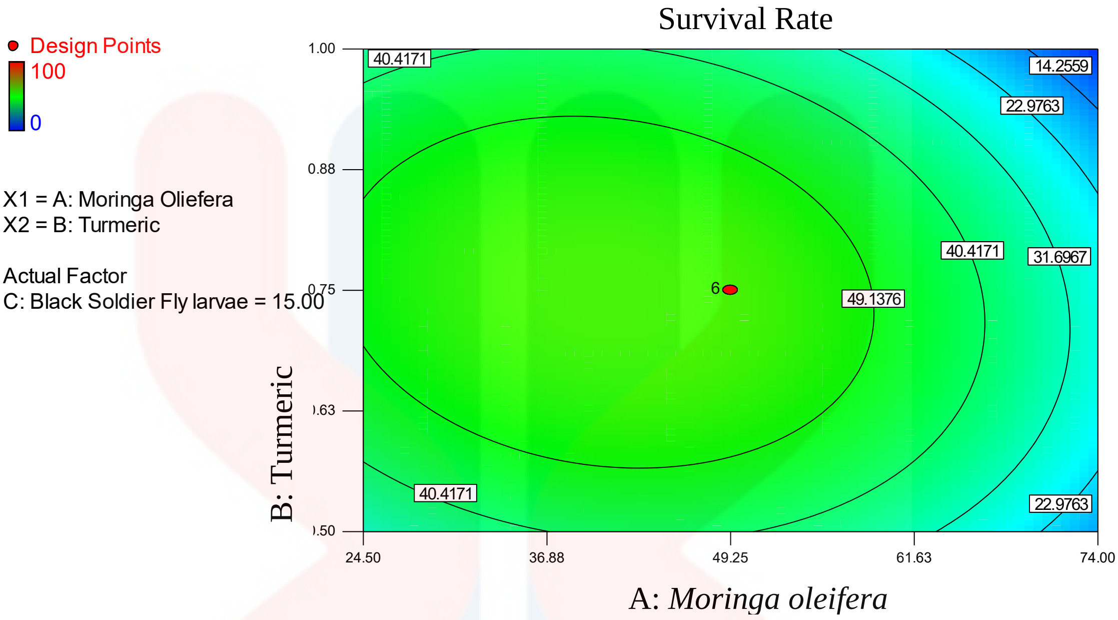

Figure 4.8(a): 2D contour plot of interaction between *Moringa oleifera* and Turmeric on Survival Rate (%).

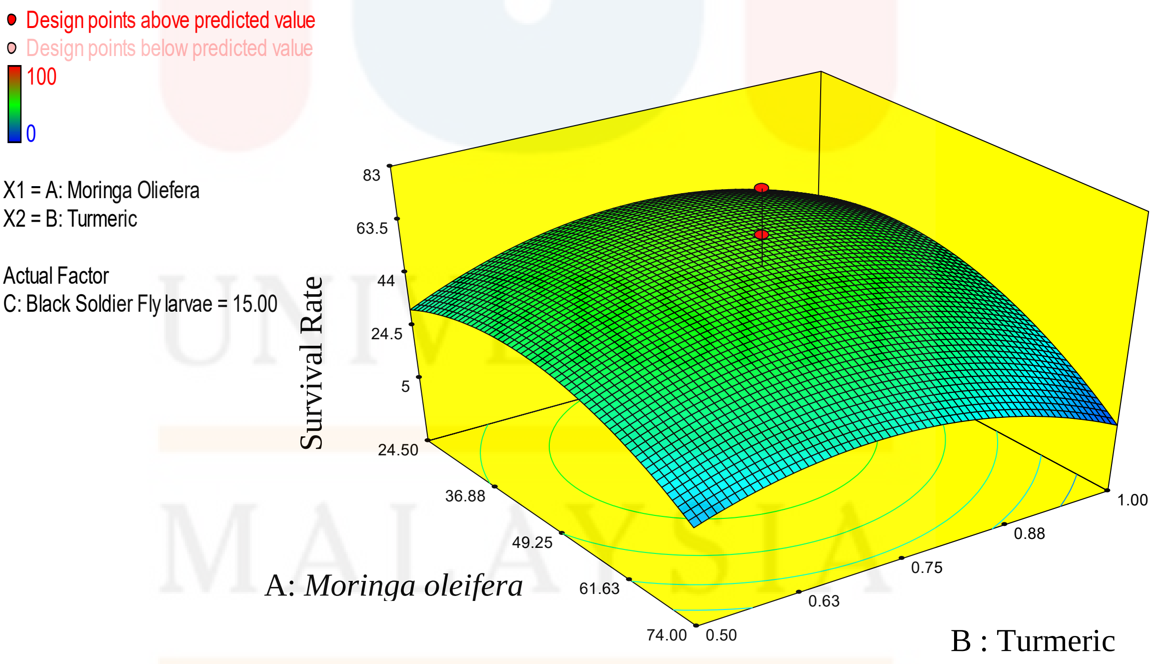

Figure 4.8(b): 3D response surface graph of interaction between *Moringa oleifera* and Turmeric on Survival Rate (%).

4.8.2 Effect of *Moringa oleifera* and Black Soldier Fly Larvae on Survival Rate

Figure 4.9(a) and 4.9(b) shows the effect of *Moringa oleifera* and black soldier fly larvae on the survival rate while the turmeric which was 0.75% was kept constant. From the figure, if the percentages of *Moringa oleifera* are between 61.63% to 74% and black soldier fly larvae are between 5% to 10%, the survival rate of chicken decrease to 17.91%. From this figure, we can observe that the increasing value of *Moringa oleifera* and black soldier fly larvae in feed decrease the survival rate of broiler chicks.

So in this study, the survival rate of chicken was decreased if the feed high in *Moringa oleifera* and lower in black soldier fly larvae. There is the study stated that the black soldier fly larvae meal could replace soybean meal as the protein sources, but only in little quantity obtain the optimum performances in spring chicken feeding and poultry diets (Dahiru et all, 2016). But not good if too lower or higher values, the black soldier fly larvae meal shows fed to the chicken in the proximate amount for the best result of survival rate.

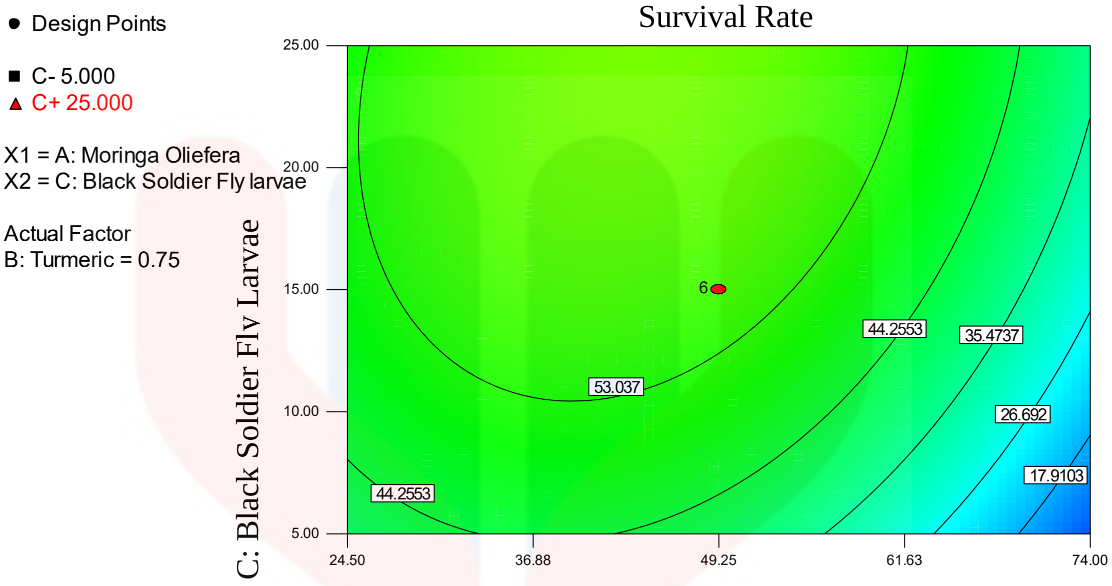

Figure 4.9(a): 2D contour plot of interaction between *Moringa oleifera* and Black Soldier Fly Larvae on Survival Rate (%).

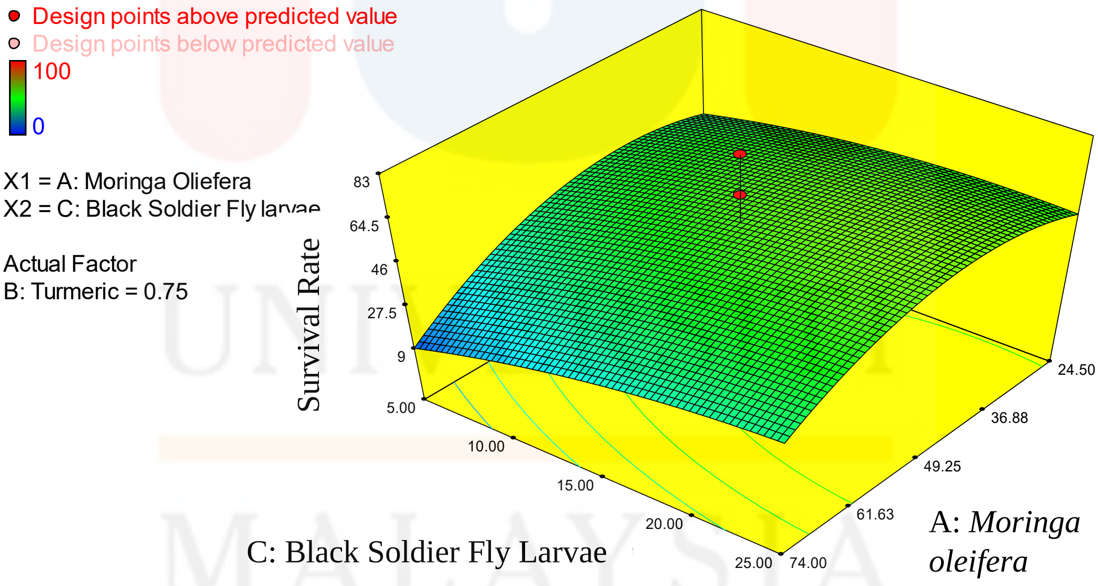

Figure 4.9(b): 3D response surface graph of interaction between *Moringa oleifera* and Black Soldier Fly Larvae on Survival Rate (%).

4.8.3 Effect of Turmeric and Black Soldier Fly Larvae on Survival Rate

Figure 4.10(a) and 4.10(b) shows the effect of turmeric and black soldier fly larvae on the survival rate while the *Moringa oleifera* which was 49.25% was kept constant. From the figure, if the percentages of turmeric are between 0.88% to 1% and black soldier fly larvae are between 5% to 10%, the survival rate of chicken will decrease to 25.85%. From this figure, we can observe that the increasing value of turmeric and lower the black soldier fly larvae in the feed decreases the survival rate of broiler chicks.

So, the survival rate of broiler chicken will decreases if the high in turmeric and lower in BSFL. There a study proved that does not have any positive effect on broiler diets that following the inclusion of turmeric (Sethy et al., 2016).

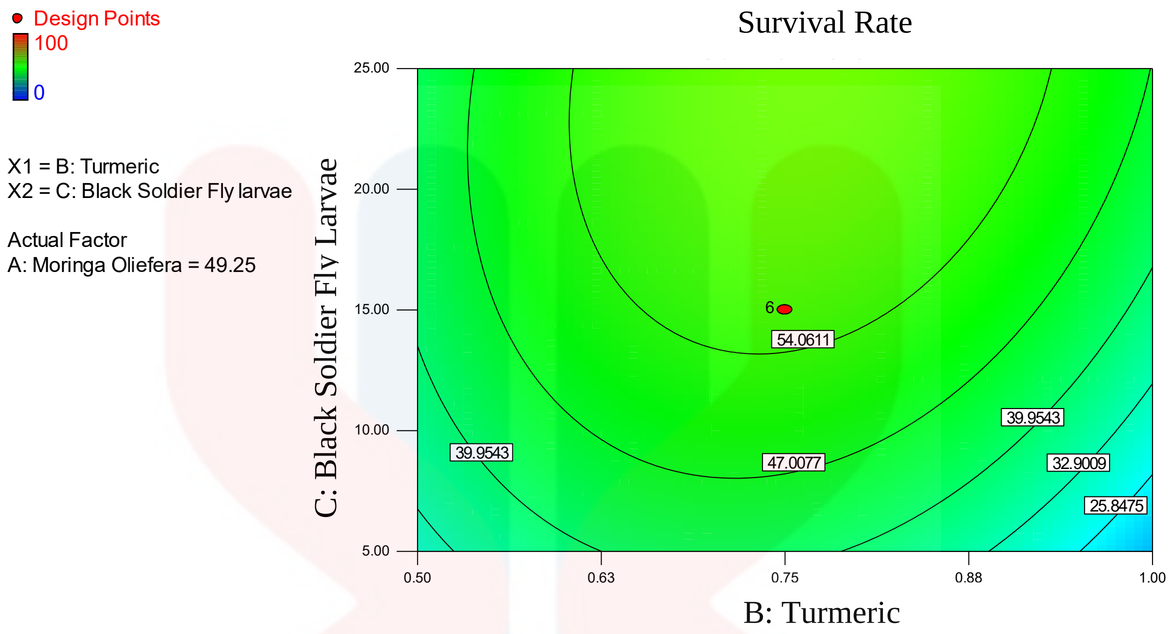

Figure 4.10(a): 2D contour plot of interaction between Turmeric and Black Soldier Fly Larvae on Survival Rate (%).

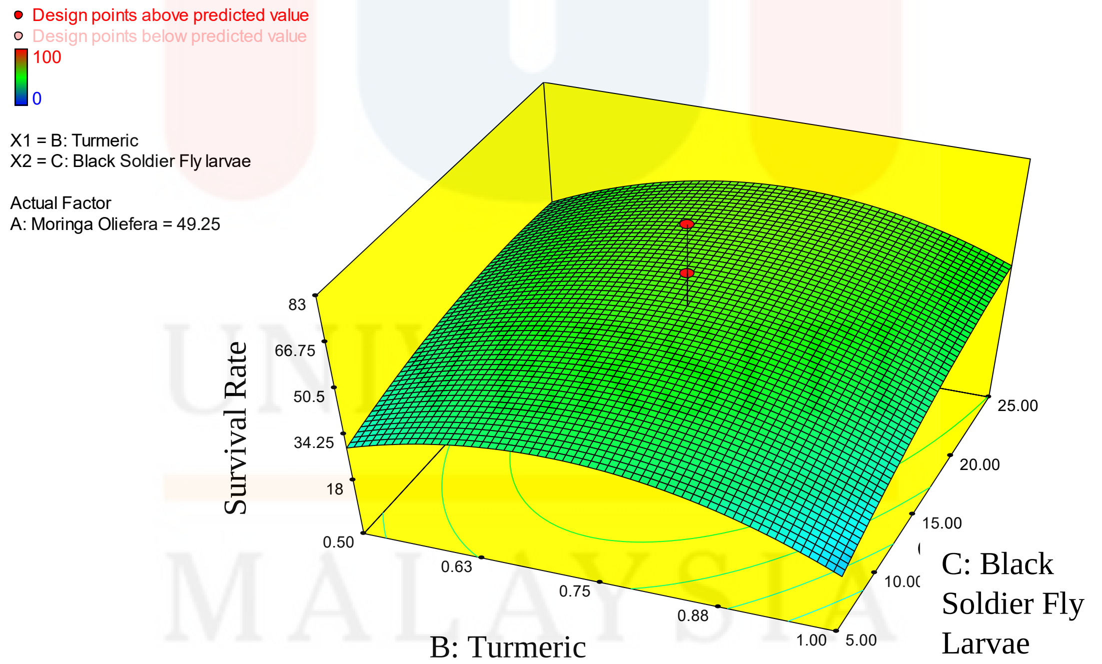

Figure 4.10(b): 3D response surface graph of interaction between Turmeric and Black Soldier Fly Larvae on Survival Rate (%).

4.9 Development of Regression Model Equation for Response 3 (Feed Conversion Ratio)

As shown in Table 4.9, the model summary statistics of feed conversion ratio that were generated by the Design Expert Software Version 7 have no suggested model and the cubic model is also aliased. From this table, it can indicate that there are no have any model that fit which this response. While the aliased of the cubic model.

Table 4.9: Model Summary Statistics of Feed Conversion Ratio (R3).

Source	**Std. Dev.**	**R-Squared**	**Adjusted R-Squared**	**Predicted R-Squared**	**PRESS**	
Linear	0.17	0.1005	-0.0682	-0.6224	39.67	
2FI	1.24	0.1837	-0.1931	-1.8923	70.72	
Quadratic	1.16	0.4479	-0.0489	-2.9951	97.68	
Cubic	0.65	0.8955	0.6691	-14.2553	372.98	Aliased

Table 4.10 shows the standard deviation and quadratic model R-squared (R^2) for Feed Conversion ratio (R3). In this study, a relative low R^2 value, which is 0.4479 which is not near to 1. The value of the R^2 indicates that 44.79% of the response variability can be explained by the model.

Table 4.10: The Standard Deviation and Quadratic Model R^2 For R3.

Std. Dev.	1.16	R-Squared	0.4479
Mean	1.50	Adj R-Squared	-0.0489
C.V. %	77.71	Pred R-Squared	-2.9951
PRESS	97.68	Adeq Precision	4.155

The Predicted R^2 was -2.9951 and the adjusted R^2 was -0.0489 which was not closed as predicted by the model. A negative Predicted R^2 implies that the overall mean a better predictor of response than the current model. In this study, the adequate precision was 3.698, that indicates an adequate signal and fitness of the model. The adequate precision measures the signal to noise ratio. A ratio greater than 4 is desirable.

The empirical polynomial regression model was generated by RSM in terms of a coded factor which reflects the interaction and significance variables towards efficiency of survival rate. Equation 4.3 showed the empirical second order polynomial regression model in terms of coded factors.

$$\text{Feed Conversion Ratio} = 1.64 + 0.30\,A - 0.18B + 0.25C - 0.063AB + 0.11AC - 0.49BC + 0.35A^2 - 0.035B^2 - 0.53C^2 \quad (4.3)$$

From Equation 4.3, the biggest positive sign of factor A (*Moringa oleifera*) is also are definite that it has a positive effect on feed conversion ratio. Which is the increasing factor A will cause the increases in the feed conversion ratio of the chicken. And these were followed by individual factor C, interaction of factor AC (*Moringa* *oleifera* and Black Soldier Fly Larvae) and quadratic factor. Compared to individual effect, interaction effect and the quadratic effect that has a negative effect on the feed conversion ratio of chicken.

4.10 Statistical Analysis for Response 3 (Feed Conversion Ratio)

Table 4.11 shows the analysis of variance (ANOVA) for response surface quadratic modal of feed conversion ratio. From the table, the model F-value of 0.90 implies there is a 55.71% chance that a model F-value this large could occur due to noise. From the tables show that the model was not significant. If there are many insignificant model terms (not counting those required to support hierarchy), the model reduction may improve the model.

Table 4.11: ANOVA table for response surface quadratic modal of Feed Conversion Ratio.

Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	10.95	9	1.22	0.90	0.5571	not significant
A-*Moringa oleifera*	1.21	1	1.21	0.90	0.3657	not significant
B-Turmeric	0.42	1	0.42	0.31	0.5878	not significant
C-Black Soldier Fly larvae	0.82	1	0.82	0.61	0.4533	not significant
AB	0.031	1	0.031	0.023	0.8821	not significant
AC	0.10	1	0.10	0.075	0.7897	not significant
BC	1.90	1	1.90	1.41	0.2627	not significant

A^2	1.80	1	1.80	1.33	0.2750	not significant
B^2	0.018	1	0.018	0.013	0.9100	not significant
C^2	4.06	1	4.06	3.00	0.1137	not significant

4.11 Predicted Values Versus Actual Values for Response 3 (Feed Conversion Ratio)

Table 4.12 shows the table of predicted values versus actual values for feed conversion ratio. The better actual values are 0.80 of feed conversion ratio which is consist 49.25 % of *Moringa oleifera*, 0.75% of turmeric and 15.00% of black soldier fly larvae and also that consists 7.63% of *Moringa oleifera*, 0.75% of turmeric and 15% of black soldier fly larvae. This actual response of feed conversion ratio was different with the predicted responses, which not achieve the value that was only of -0.82 and -1.34 of FCR.

Figure 4.11 shows the normal probability plot of residual for feed conversion ratio that is used to examine the error term which is normally distributed. From the figure, the data can be seen was close to the linear, this indicates that the data were small and distributed normally. While Figure 4.12 are showed the diagnostic plot for predicted values vs actual values of feed conversion ratio. From the diagnostic plot, the residuals are also not distributed in the linear line.

Table 4.12: The predicted values versus actual values for Feed Conversion Ratio.

Run Order	Actual Value	Predicted Value	Residual	Internally Studentized Residual	Externally Studentized Residual
16	1.40	0.62	0.78	1.164	1.691
2	0.00	1.12	-1.12	-1.676	* -2.67
1	1.60	1.37	0.23	0.343	0.466
15	0.80	1.62	-0.82	-1.223	-1.792
8	2.10	1.86	0.24	0.354	0.481
19	2.00	2.81	-0.81	-1.212	-1.773
20	1.20	0.66	0.54	0.807	1.127
3	0.00	1.36	-1.36	-2.033	* -3.59
5	0.80	2.14	-1.34	-1.839	* -2.67
17	5.30	3.14	2.16	2.966	* 10.09
4	2.10	1.84	0.26	0.363	0.431
7	1.80	1.24	0.56	0.764	0.929
12	0.00	-0.27	0.27	0.375	0.445
14	1.10	0.55	0.55	0.752	0.914
13	1.30	1.64	-0.34	-0.321	-0.137
18	1.90	1.64	0.26	0.245	0.104
11	1.40	1.64	-0.24	-0.226	-0.096
9	2.30	1.64	0.66	0.622	0.269
6	1.20	1.64	-0.44	-0.415	-0.177
10	1.60	1.64	-0.040	-0.038	-0.016

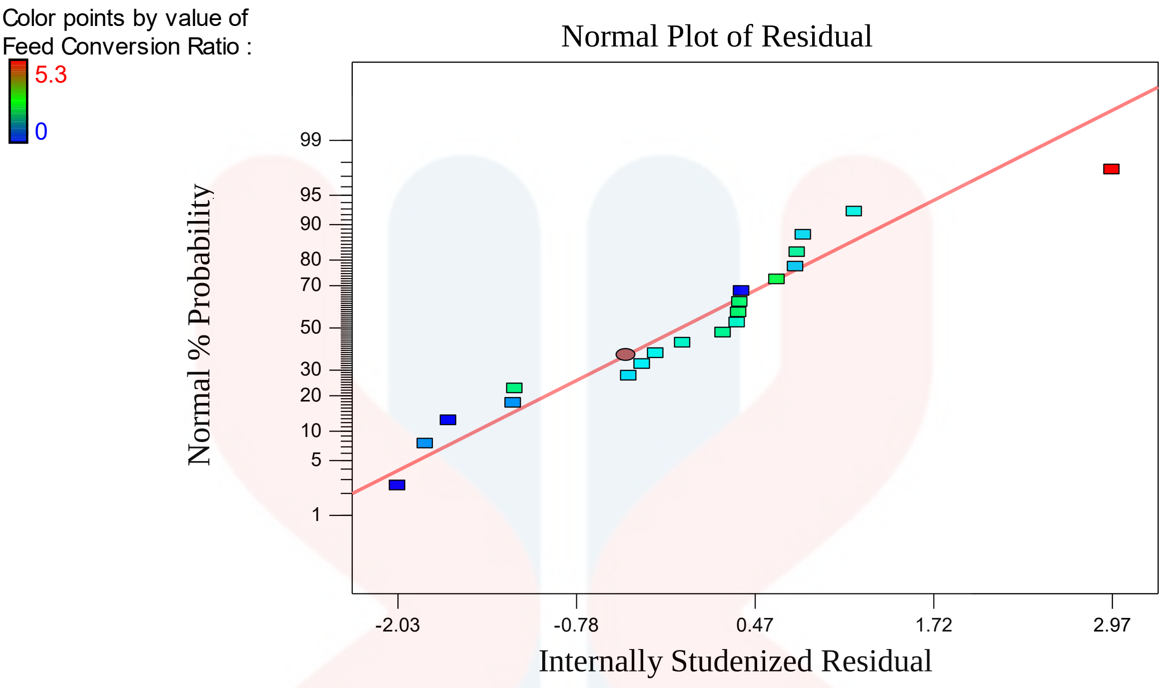

Figure 4.11: Normal probability plot of residual for Feed Conversion Ratio.

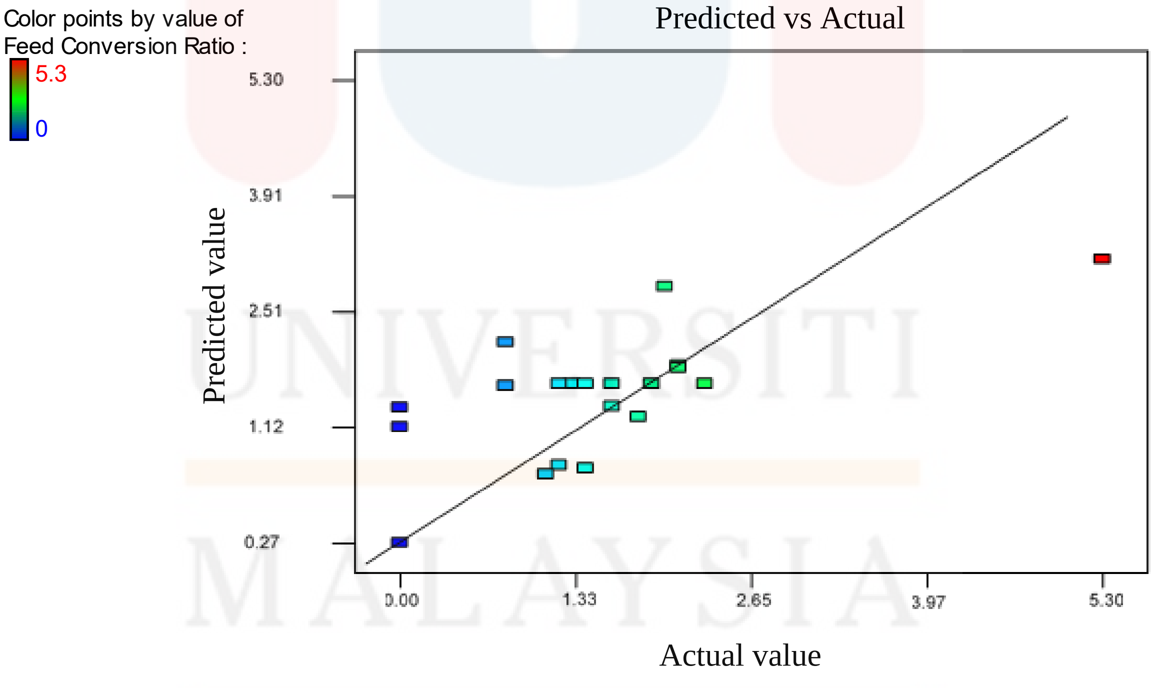

Figure 4.12: Diagnostic plot for predicted versus actual values.

4.12 Optimisation of Feed for Response 3 (Feed Conversion Ratio)

A two-dimension (2D) contour plot and three-dimensional (3D) response surface graph were obtained to examine the effect of the potential relationship between variables on the feed conversion ratio while keeping others variable as constant. Figure 4.13(a), Figure 4.13(b), Figure 4.14(a), Figure 4.14(b), Figure 4.15(a) and Figure 4.15(b) show the effect of variables on the feed conversion ratio.

4.12.1 Effect of *Moringa oleifera* and Turmeric on Feed Conversion Ratio

Figure 4.13(a) and 4.13(b) shows the effect of *Moringa oleifera* and turmeric on the feed conversion ratio while the turmeric 15% are kept constant. From the figure, at the percentages, *Moringa oleifera* between 61.63% to 74% and between 0.63% to 0.75% of turmeric while the black soldier fly larvae are kept constant which is 15% will make the feed conversion ratio increases which are 2.31. Meanwhile, if the percentages of *Moringa oleifera* are between 49.25% to 61.63% and turmeric are between 0.88% to 1%, the feed conversion ratio of chicken decrease to 1.57.

From this figure, we can observe that the decreased value of *Moringa oleifera* and turmeric in the feed decrease the feed conversion ratio of broiler chicks. There is a study showed that the higher level of *Moringa oleifera* leaf meal reduce the feed intake but if inclusion is up to 10% it has no effect on feed intake and lives weight gain (Gakuya et al., 2014)

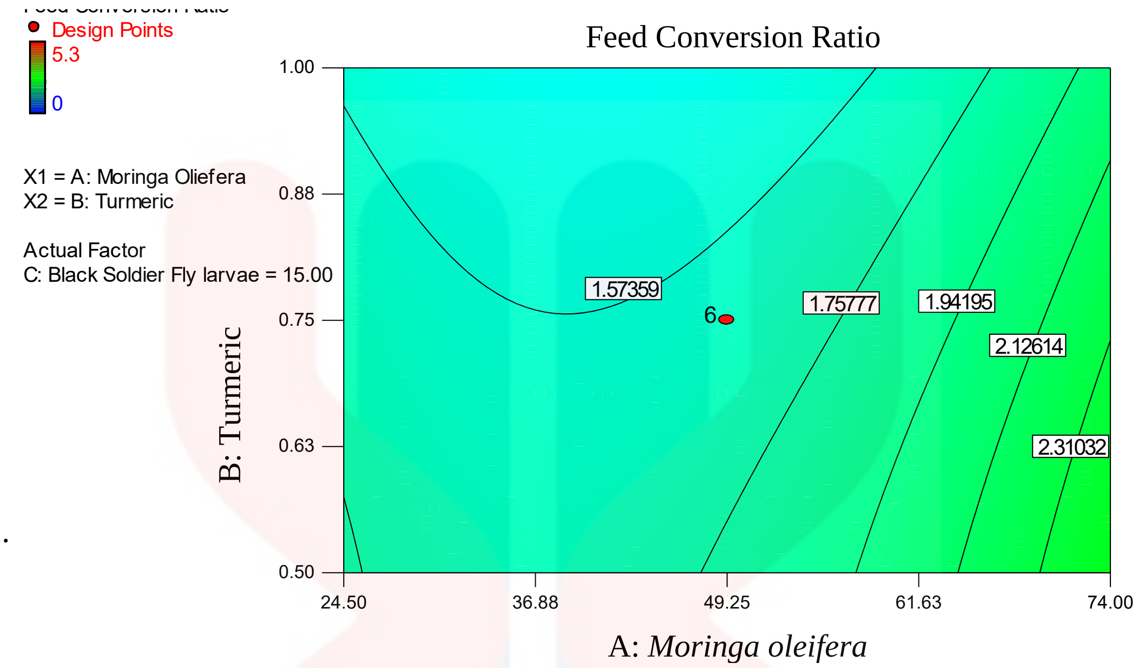

Figure 4.13(a): 2D contour plot of interaction between *Moringa oleifera* and Turmeric on Feed Conversion Ratio.

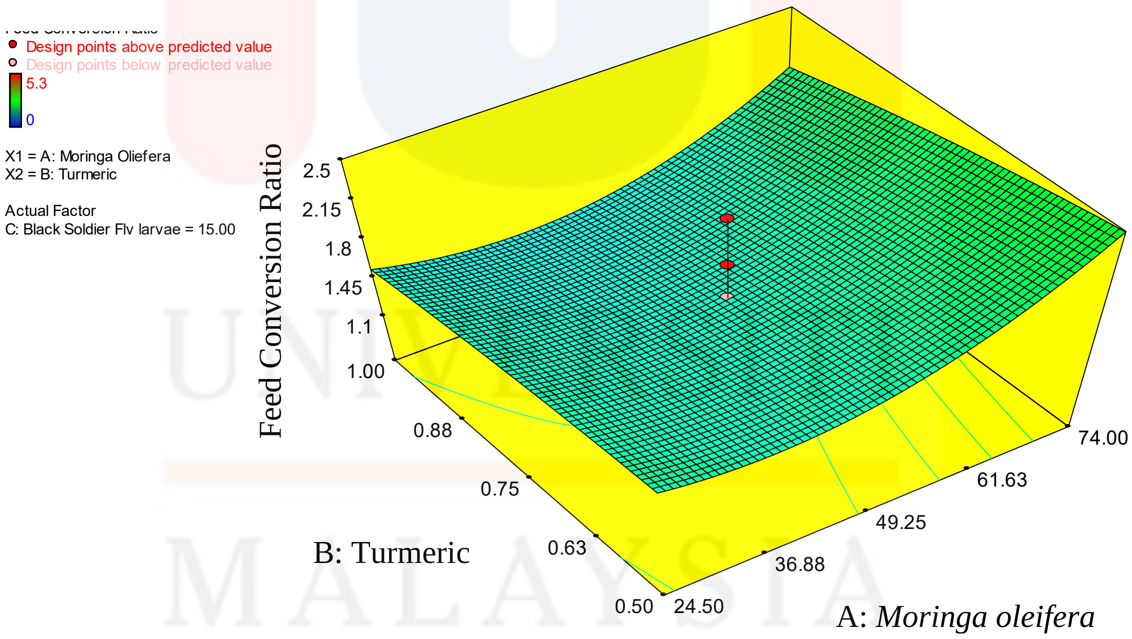

Figure 4.13(b): 3D response surface graph of interaction between *Moringa oleifera* and Turmeric on Feed Conversion Ratio.

4.12.2 Effect of *Moringa Oleifera* and Black Soldier Fly Larvae on Feed Conversion Ratio

Figure 4.14(a) and 4.14(b) shows the effect of *Moringa oleifera* and black soldier fly larvae on the feed conversion ratio while the turmeric 0.75% are kept constant. From the figure, at the percentages, *Moringa oleifera* between 61.63% to 74% and between 15% to 20% of black soldier fly larvae while the turmeric is kept constant which (0.75%) cause the feed conversion ratio increases to 2.10.

From this figure, it showed that the increasing the percentages of Moringa oliefera and black soldier fly larvae increase the feed conversion ratio. The increasing FCR of chicken indicates that it is not are positive effects to the chicks. Meanwhile, if the percentages of *Moringa oleifera* are between 61.63% to 74% and black soldier fly are between 5% to 10%, the FCR of chicken decrease to 1.09. So, it can be concluded that the low percentages of turmeric will make the better FCR value for chicks.

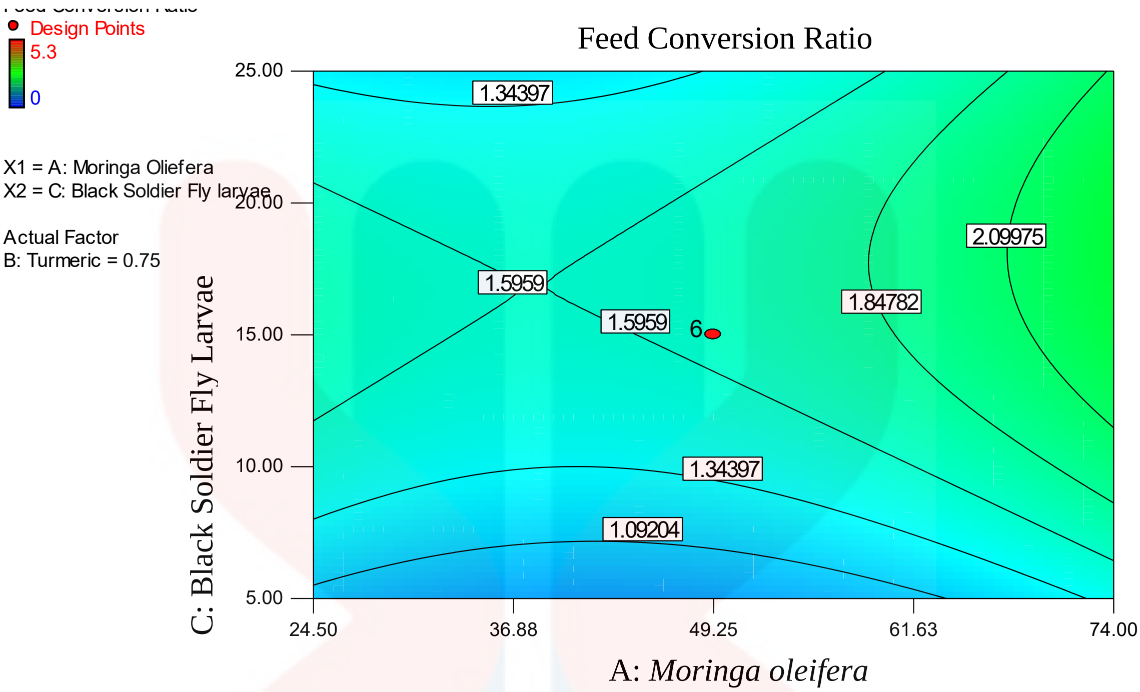

Figure 4.14(a): 2D contour plot of interaction between *Moringa oleifera* and Black Soldier Fly Larvae on Feed Conversion Ratio.

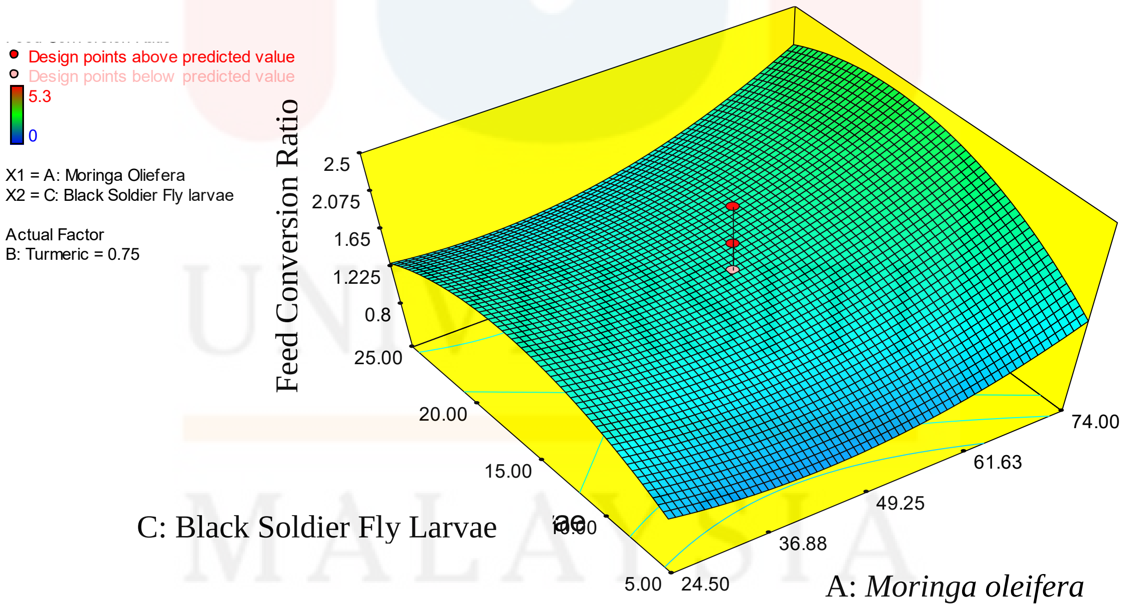

Figure 4.14(b): 3D response surface graph of interaction between *Moringa oleifera* and Black Soldier Fly Larvae on Feed Conversion Ratio.

4.12.3 Effect of Turmeric and Black Soldier Fly Larvae on Feed Conversion Ratio

Figure 4.15(a) and 4.15(b) shows the effect of turmeric and black soldier fly larvae on the feed conversion ratio while the turmeric which 49.25% are kept constant. From the figure, it shows the green colour change to a blue colour that indicates the interaction between turmeric and black soldier fly larvae on the feed conversion ratio are does not give the positive effect to the chicks because the graph appears to drop.

From the figure, at the percentages of turmeric between 0.50% to 0.63% and between 5% to 10% of black soldier fly larvae while the *Moringa oleifera* are kept constant (49.25%) render the feed conversion rate 0.77. Meanwhile, if the percentages of turmeric are between 0.63% to 0.75% and turmeric are 15% and above, the feed conversion ratio of chicken is 1.78. From this figure, we can observe that the increasing the black soldier fly larvae in the feed increase the FCR of chicken. The increased FCR indicate that the feed is not increasing the weight of chicken although were consumed more. There are the studies that stated the choice of black soldier fly larvae as feed-in period six weeks did not effect on chicken performance, indicating its high nutritional value (Ruhnke et al., 2018).

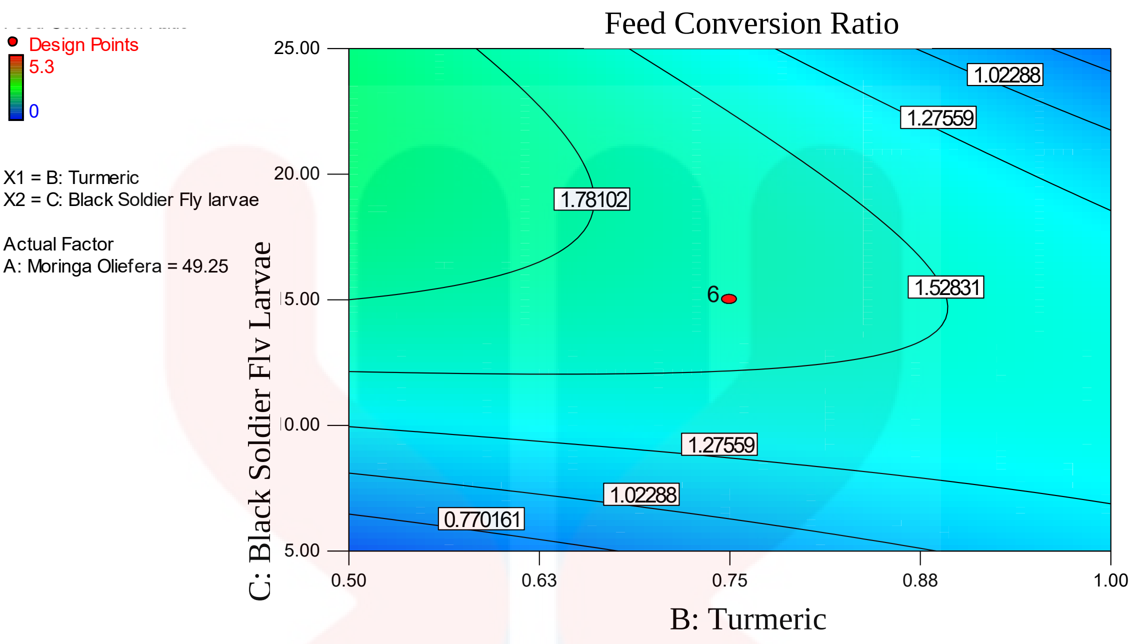

Figure 4.15(a): 2D contour plot of interaction between Turmeric and Black Soldier Fly Larvae on Feed Conversion Ratio.

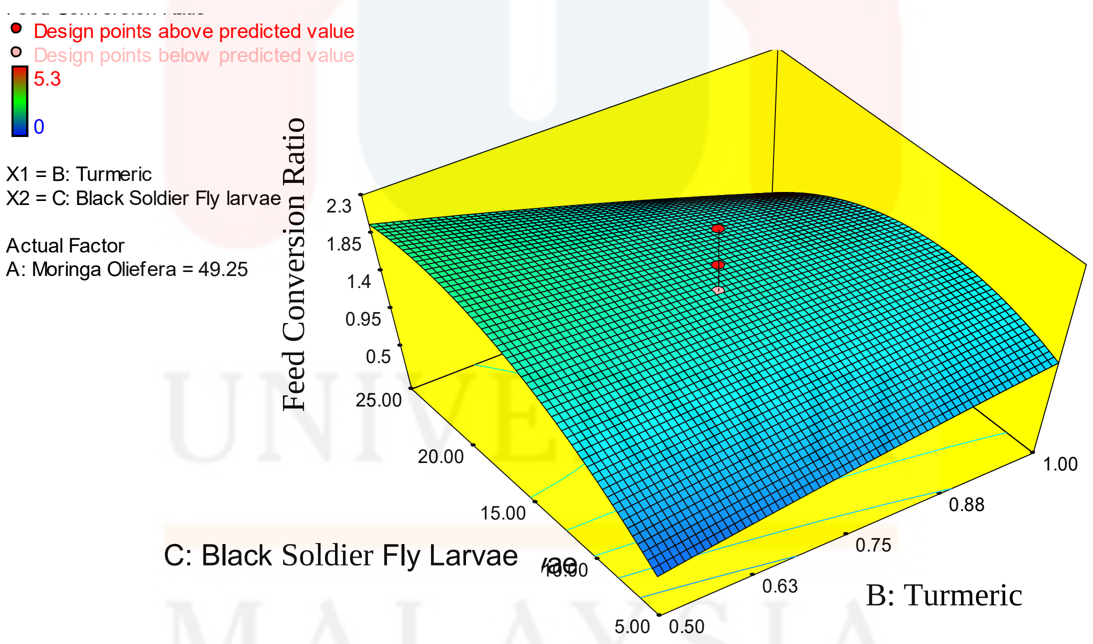

Figure 4.15(b): 3D response surface graph of interaction between Turmeric and Black Soldier Fly Larvae on Feed Conversion Ratio.

4.13 Numerical optimisation of Desirability Function for All Response (R1, R2 And R3).

The aim of numerical optimisation of desirability is to get the optimum percentages of feed formulation by using *Moringa oleifera*, turmeric and black soldier fly larvae. The optimization is the technique to make the design be more effective as possible (Mwaniki et al., 2017). In other words, the optimization is the method to improve our study which is in this study to improve the feed formulation for the performances of broiler chicken.

So, in this study, the Design Expert Software version 7 will generate the most optimum value of feed formulation that desire to get the optimum performances of broiler chicken by generate using the scale of the desirability function (DF). The DF has a range between 0 to 1, which is if the d=0 means that the response is unacceptable (lesser desirability) while if the d=1, means that the response is acceptable (larger desirability). The value of d increases if the desirability of response is increases (Li et al., 2007).

Figure 4.16 shows the ramp function graph for desirability function of all response from the figure, it shows the desirability function of all response which is Average daily weight gain, survival rate and feed conversion ratio. From the figure, the linear ramp is created between the minimum value and maximum value are act as a guide for the estimation of desirability. From the figure, it shows that if the feed is content 31.29% of *Moringa oleifera*, 0.86% of turmeric and 25% of Black soldier fly larvae, the response which are the average daily weight gain, survival rate and feeds conversion ratio were got 4.51 g/d, 56.6 % and 0.96. From the figure, it is shown that the desirability is 0.725. That suggested that all the response are quite a desire because the desirability is not too higher nor too lesser.

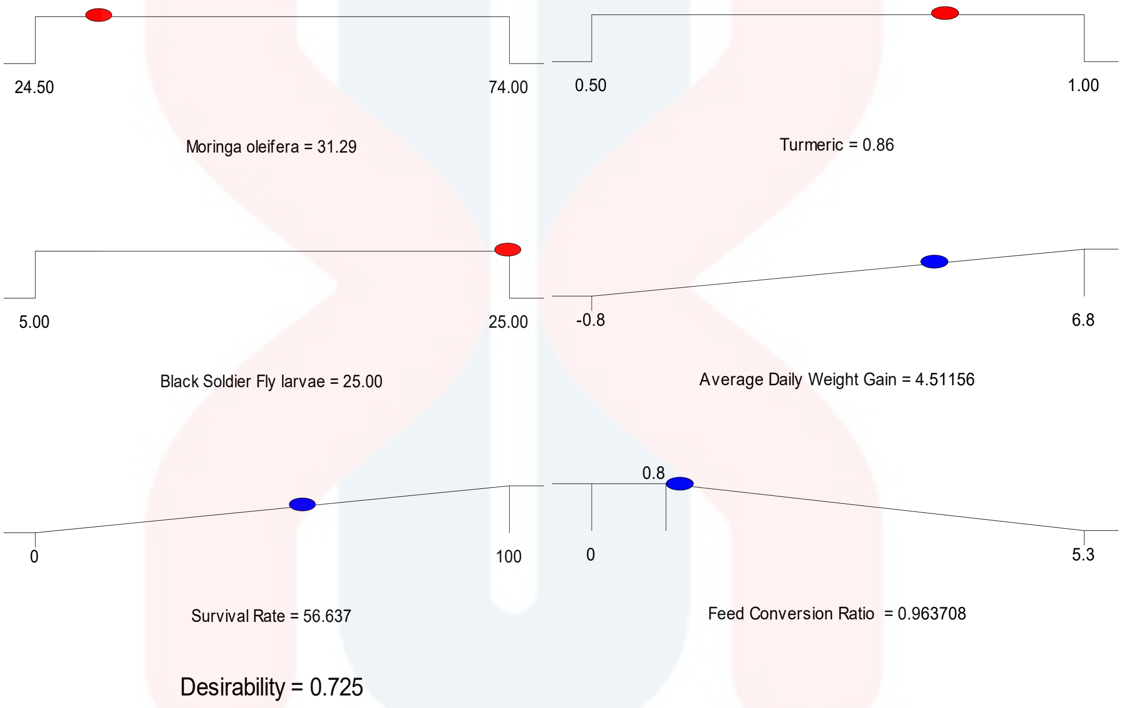

Figure 4.16 : Ramp function graph for desirability function of all response.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The correlation coefficient, R^2 of average daily weight gain are 0.6807, survival rate is 0.5994 and feed conversion ratio are 0.4479 revealed the not fitness of the model. In this study, an empirical polynomial regression model and ANOVA also were be developed to study the individual, interaction and quadratic effect of the factors on the average daily weight gain, survival rate and feed conversion ratio. For the average daily weight gain, the result suggested that the linear model was the best model that fit the experimental response. For the survival rate, the result suggested that the quadratic model was the best model that fit the experimental response. While for feed conversion ratio, the result did not suggest any model that fit the experimental response. For all response, interaction effect has been studied.

From the experimental data, the optimum level for average daily weight gain was 6.80g/d in which the percentages of *Moringa oleifera* are 7.63%, turmeric is 0.75% and black soldier fly larvae are 15%. For optimum level survival rate was 100% which percentages of *Moringa oleifera* is 49.25%, turmeric is 0.75% and black soldier fly larvae is 31.82%. The optimum level feed conversion ratio was 0.8 which percentages of *Moringa oleifera* are 7.63% and 74%, turmeric is 0.75% and 1% and black soldier fly larvae are 15% and 5%.

From predicted data model that generated by Design Expert Software Version 7, the optimum level for average daily weight gain was 6.05g/d which percentages of *Moringa oleifera* are 7.63%, turmeric is 0.75% and black soldier fly larvae is 15%. For optimum level survival rate was 58.97% which percentages of *Moringa oleifera* are 49.25%, turmeric is 0.75% and black soldier fly larvae are 31.82%. The optimum level feed conversion ratio was 0.5 which percentages of *Moringa oleifera* are 49.25%, turmeric is 0.75% and black soldier fly larvae are 31.82%.

Design Expert Software Version 7 also generate the ramp function graph for desirability function of all response. So, RSM has suggested the feed is content 31.29% of *Moringa oleifera*, 0.86% of turmeric and 25% of black soldier fly larvae, the response which are the average daily weight gain, survival rate and feeds conversion ratio were got 4.51g/d, 56.6% and 0.96 which the desirability are 0.725. So, it can be concluded that the desirability of all the response is quite a desire.

So, from the study, it can be concluded that the *Moringa oleifera*, black soldier fly larvae and turmeric percentages must be improved for the feed requirement of starter broiler chicken in this study to get the excellent average daily weight gain, survival rate and feed conversion ratio.

5.2 Recommendation

The further studies need to be carried out by continuing the predicted experiment data that been generated by Design Expert Design Software Version 7. Secondly, the studies of the same parameter which is *Moringa oleifera*, turmeric and black soldier fly larvae for the grower broiler chicken diet could be executed. Or parameter on the starter broiler chicken which could be replaced the *Moringa oleifera* with tapioca. Thirdly, do the proximate analysis on all of the formulation should be performed. Finally, other design of RSM. Such as Box-Behnken Designs (BBD) and Full factorial design should be explored.

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APPENDIX A

Table A1: Record keeping of broiler chicks for treatment 1.

TREATMENT/CAGE: 1

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	44	
2	31/10/2018				72	60	72	62		
3	1/11/2018				60	42	60	41	48	
4	2/11/2018				60	44	35	8		
5	3/11/2018		2	4	23	0	23	0	52	
6	4/11/2018				23	2	23	0		
7	5/11/2018	1		3	17	0	17	0	54	
8	6/11/2018	1		2	12	0	12	0		
9	7/11/2018				12	0	12	0	61	
10	8/11/2018				12	0	12	0		
11	9/11/2018				12	0	12	0	65	
12	10/11/2018				12	0	12	0		
13	11/11/2018				12	0	12	0	73	
14	12/11/2018				12	0	12	0	93	

Table A2: Record keeping of broiler chicks for treatment 2.

TREATMENT/CAGE:2

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	41	
2	31/10/2018				72	61	72	63		
3	1/11/2018				60	49	60	46	45	
4	2/11/2018				60	52	35	39		
5	3/11/2018				35	33	35	35	40	
6	4/11/2018	4	2	0	0	0	0	0		

Table A3: Record keeping of broiler chicks for treatment 3.

TREATMENT/CAGE: 3

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	41	
2	31/10/2018	1		5	72	72	72	70		
3	1/11/2018				60	58	60	47	42	
4	2/11/2018				60	55	35	22		
5	3/11/2018		1	4	29	28	23	22	40	
6	4/11/2018		4	0	23	23	0	0		

Table A4: Record keeping of broiler chicks for treatment 4.

TREATMENT/CAGE: 4

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	41	
2	31/10/2018				72	62	72	70		
3	1/11/2018				60	53	60	48	49	
4	2/11/2018				60	41	35	5		
5	3/11/2018		1	5	35	3	29	0	51	
6	4/11/2018				29	0	29	4		
7	5/11/2018				23	0	17	0	47	
8	6/11/2018				17	0	17	0		
9	7/11/2018		1	2	12	0	12	0	56	
10	8/11/2018				12	0	12	0		
11	9/11/2018				12	0	12	0	64	
12	10/11/2018				12	0	12	0		
13	11/11/2018				12	0	12	0	69	
14	12/11/2018				12	0	12	0	77	

Table A5: Record keeping of broiler chicks for treatment 5.

TREATMENT/CAGE: 5

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	42	
2	31/10/2018				72	63	72	53		
3	1/11/2018				60	38	60	33	51	
4	2/11/2018				60	25	35	0		
5	3/11/2018				35	0	35	0	54	
6	4/11/2018				35	0	35	2		
7	5/11/2018	3		3	17	10	17	0	63	
8	6/11/2018		1	2	12	0	12	0		
9	7/11/2018				12	0	12	0	86	
10	8/11/2018				12	0	12	0		
11	9/11/2018				12	0	12	0	105	
12	10/11/2018				12	0	12	0		
13	11/11/2018				12	0	12	0	113	
14	12/11/2018				12	0	12	0	138	

Table A6: Record keeping of broiler chicks for treatment 6.

TREATMENT/CAGE:6

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	45	
2	31/10/2018				72	55	72	57		
3	1/11/2018				60	40	60	39	51	
4	2/11/2018				60	47	35	0		
5	3/11/2018				35	0	35	0	51	
6	4/11/2018				35	14	35	0		
7	5/11/2018	1	1	4	23	0	23	0	59	
8	6/11/2018				23	0	23	0		
9	7/11/2018				23	0	23	0	63	
10	8/11/2018				23	5	23	0		
11	9/11/2018	1	1	2	23	12	23	6	66	
12	10/11/2018				23	2	12	0		
13	11/11/2018				12	0	12	0	85	
14	12/11/2018				12	0	12	0	105	

Table A7: Record keeping of broiler chicks for treatment 7.

TREATMENT/CAGE: 7

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	42	
2	31/10/2018				72	65	72	47		
3	1/11/2018				60	42	60	36	49	
4	2/11/2018				60	45	35	17		
5	3/11/2018		2	4	29	24	23	0	50	
6	4/11/2018		1	3	17	8	17			
7	5/11/2018	2	1	0						

Table A8: Record keeping of broiler chicks for treatment 8.

TREATMENT/CAGE: 8

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	41	
2	31/10/2018				72	65	72	65		
3	1/11/2018				60	44	60	37	45	
4	2/11/2018				60	41	35	0		
5	3/11/2018				35	23	35	0	53	
6	4/11/2018				35	21	35	2		
7	5/11/2018		1	5	35	32	29	2	57	
8	6/11/2018		1	4	23	12	23	0		
9	7/11/2018	2		2	12	4	12	12	55	
10	8/11/2018	2		0	0	0	0	0		

Table A9: Record keeping of broiler chicks for treatment 9.

TREATMENT/CAGE: 9

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	43	
2	31/10/2018				72	67	72	65		
3	1/11/2018				60	52	60	39	45	
4	2/11/2018				60	42	35	16		
5	3/11/2018				35	16	35	0	51	
6	4/11/2018				35	9	35	0		
7	5/11/2018				35	0	35	0	51	
8	6/11/2018				35	0	35	0		
9	7/11/2018	1	1	4	29	5	29	0	64	
10	8/11/2018				23	5	23	0		
11	9/11/2018				23	0	23	0	73	
12	10/11/2018				23	4	23	0		
13	11/11/2018		1	3	17	0	17	0	74	
14	12/11/2018				17	0	17	0	75	

Table A10: Record keeping of broiler chicks for treatment 10.

TREATMENT/CAGE: 10

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	41	
2	31/10/2018				72	53	72	56		
3	1/11/2018				60	38	60	30	48	
4	2/11/2018				60	36	35	0		
5	3/11/2018				35	3	35	0	50	
6	4/11/2018				35	5	35	0		
7	5/11/2018	1		5	29	0	29	0	58	
8	6/11/2018				29	0	29	0		
9	7/11/2018				29	0	29	0	67	
10	8/11/2018				29	0	29	0		
11	9/11/2018				29	0	29	0	68	
12	10/11/2018				29	0	29	0		
13	11/11/2018				29	0	29	0	78	
14	12/11/2018				29	0	29	0	89	

Table A11: Record keeping of broiler chicks for treatment 11.

TREATMENT/CAGE: 11

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	43	
2	31/10/2018				72	54	72	55		
3	1/11/2018				60	38	60	34	50	
4	2/11/2018				60	43	35	0		
5	3/11/2018				35	18	35	0	51	
6	4/11/2018				35	19	35	0		
7	5/11/2018				35	0	35	0	57	
8	6/11/2018	2		4	29	0	23	0		
9	7/11/2018	1	1	2	12	0	12	0	65	
10	8/11/2018				12	0	12	0		
11	9/11/2018				12	0	12	0	86	
12	10/11/2018				12	0	12	0		
13	11/11/2018				12	0	12	0	85	
14	12/11/2018				12	0	12	0	100	

Table A12: Record keeping of broiler chicks for treatment 12.

TREATMENT/CAGE: 12

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	47	
2	31/10/2018				72	68	72	67		
3	1/11/2018				60	54	60	44	43	
4	2/11/2018				60	53	35	19		
5	3/11/2018		1	5	29	22	29	24	44	
6	4/11/2018		1	4	23	17	29	28		
7	5/11/2018		4	0	12	9	0	0	42	

Table A13: Record keeping of broiler chicks for treatment 13.

TREATMENT/CAGE: 13

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	41	
2	31/10/2018				72	61	72	63		
3	1/11/2018				60	47	60	39	45	
4	2/11/2018				60	49	35	0		
5	3/11/2018				35	2	35	0	56	
6	4/11/2018				35	10	35	0		
7	5/11/2018	2		4	23	0	23	0	56	
8	6/11/2018				23	0	23	0		
9	7/11/2018				23	0	23	0	58	
10	8/11/2018				23	0	23	0		
11	9/11/2018				23	0	23	0	68	
12	10/11/2018				23	0	23	0		
13	11/11/2018				23	0	23	0	93	
14	12/11/2018				23	0	23	0	97	

Table A14: Record keeping of broiler chicks for treatment 14.

TREATMENT/CAGE: 14

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	39	
2	31/10/2018				72	69	72	38		
3	1/11/2018				60	34	60	32	47	
4	2/11/2018				60	43	35	0		
5	3/11/2018				35	0	35	0	63	
6	4/11/2018				35	0	35	0		
7	5/11/2018				35	32	60	0	55	
8	6/11/2018				35	0	35	0		
9	7/11/2018				35	0	35	0	73	
10	8/11/2018				35	0	35	0		
11	9/11/2018				35	0	35	0	82	
12	10/11/2018				35	0	35	0		
13	11/11/2018				35	0	35	0	91	
14	12/11/2018				35	0	35	0	110	

Table A15: Record keeping of broiler chicks for treatment 15.

TREATMENT/CAGE: 15

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	42	
2	31/10/2018				72	64	72	64		
3	1/11/2018				60	47	60	50	45	
4	2/11/2018				60	58	35	34		
5	3/11/2018		3	3	23	20	23	21	49	
6	4/11/2018				17	17	17	16		
7	5/11/2018		3	0	17	17	0	0		

Table A16: Record keeping of broiler chicks for treatment 16.

TREATMENT/CAGE: 16

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	44	
2	31/10/2018				72	62	72	64		
3	1/11/2018				60	42	60	40	48	
4	2/11/2018				60	58	35	0		
5	3/11/2018				35	0	35	0	55	
6	4/11/2018		1	5	29	0	29	0		
7	5/11/2018	1		4	23	0	23	0	57	
8	6/11/2018	1		3	17	0	17	0		
9	7/11/2018				17	0	17	0	53	
10	8/11/2018	1		2	12	0	12	0		
11	9/11/2018				12	0	12	0	64	
12	10/11/2018				12	0	12	0		
13	11/11/2018				12	0	12	0	73	
14	12/11/2018				12	0	12	0	99	

Table A17: Record keeping of broiler chicks for treatment 17.

TREATMENT/CAGE: 17

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	42	
2	31/10/2018				72	60	72	64		
3	1/11/2018				60	49	60	40	46	
4	2/11/2018				60	41	35	8		
5	3/11/2018				35	18	35	0	44	
6	4/11/2018				35	20	35	4		
7	5/11/2018	2	1	3	35	25	17	5	46	
8	6/11/2018	2	1	0	12	9	0	0		

Table A18: Record keeping of broiler chicks for treatment 18.

TREATMENT/CAGE: 18

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	41	
2	31/10/2018				72	64	72	28		
3	1/11/2018				60	46	60	33	46	
4	2/11/2018				60	43	35	20		
5	3/11/2018				35	14	35	0	52	
6	4/11/2018				35	18	35	2		
7	5/11/2018				35	12	35	0	51	
8	6/11/2018		1	5	35	12	29	0		
9	7/11/2018		1	4	23	2	23	0	59	
10	8/11/2018				23	1	23	0		
11	9/11/2018				23	0	23	0	65	
12	10/11/2018				23	1	23	0		
13	11/11/2018				23	2	23	0	69	
14	12/11/2018				23	0	23	0	78	

Table A19: Record keeping of broiler chicks for treatment 19.

TREATMENT/CAGE: 19

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	43	
2	31/10/2018				72	64	72	63		
3	1/11/2018				60	44	60	39	50	
4	2/11/2018				60	40	60	0		
5	3/11/2018	1		5	35	0	35	11	47	
6	4/11/2018	1	1	3	17	0	17	0		
7	5/11/2018		1	2	12	0	12	0	54	
8	6/11/2018				12	0	12	0		
9	7/11/2018	2		0	0	0	0	0	58	

Table A20: Record keeping of broiler chicks for treatment 20.

TREATMENT/CAGE: 20

Day / Week	Date	Amount			Amount of Feed (g)				Average weight (g) / chick	Record
		Death	Expel	Balance	Morning	Balance	Evening	Balance		
1	30/10/2018				72	72	72	72	42	
2	31/10/2018				72	63	72	61		
3	1/11/2018				60	38	60	36	53	
4	2/11/2018				60	32	35	0		
5	3/11/2018				35	0	35	0	55	
6	4/11/2018				35	6	35	3		
7	5/11/2018	1		5	29	0	29	0	63	
8	6/11/2018	2		3	17	0	17	0		
9	7/11/2018				17	0	17	0	68	
10	8/11/2018	1		2	12	0	12	0		
11	9/11/2018				12	0	12	0	81	
12	10/11/2018				12	0	12	0		
13	11/11/2018				12	0	12	0	91	
14	12/11/2018				12	0	12	0	110	

Table A21: Record keeping of temperature.

Day/weeks	Date	Temperature (°C)	
1	30/10/2018	Morning	27
		Evening	30.4
2	31/10/2018	Morning	27.2
		Evening	33.3
3	1/11/2018	Morning	24.5
		Evening	29.7
4	2/11/2018	Morning	26.5
		Evening	31.1
5	3/11/2018	Morning	26.7
		Evening	28.7
6	4/11/2018	Morning	29.9
		Evening	29.7
7	5/11/2018	Morning	27
		Evening	25
8	6/11/2018	Morning	27.1
		Evening	28.5
9	7/11/2018	Morning	26.6
		Evening	29.5
10	8/11/2018	Morning	27.1
		Evening	33.2
11	9/11/2018	Morning	26.6
		Evening	31.8
12	10/11/2018	Morning	25.7
		Evening	34
13	11/11/2018	Morning	23.5
		Evening	28
14	12/11/2018	Morning	26.7
		Evening	28

Table A22: Feed Calculation for treatment.

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

Treatment	***Moringa oleifera* (%)**	**Turmeric (%)**	**Black Soldier Fly Larvae (%)**	**Vegetables Oil (%)**
1	78.72	3.21	16.07	2
2	91.22	0.62	6.16	2
3	72.52	0.98	24.5	2
4	74.74	0.50	22.76	2
5	31.98	3.14	62.87	2
6	74.25	1.13	22.62	2
7	73.78	1.75	22.47	2
8	48.02	0.98	49	2
9	74.25	1.13	22.62	2
10	74.25	1.13	22.62	2
11	74.25	1.13	22.62	2
12	96.53	1.47	0	2
13	74.25	1.13	22.62	2
14	58.99	0.90	38.11	2
15	90.65	1.23	6.13	2
16	80.03	1.63	16.33	2
17	83.52	0.69	13.79	2
18	74.25	1.13	22.62	2
19	99.5	0.49	24.62	2
20	47.54	1.94	48.51	2

APPENDIX B

Figure B1 and B2: *Moringa Oliefera* leaf and turmeric rhizome

Figure B3 and B4: Preparation of feed formulation

Figure B5: Preparation of feed formulation

Figure B6 and B7: Preparation of feed formulation

Figure B8 and B9: Preparation of chicken feeder and drinker

Figure B10: Broiler chicks treatment 12 on day 14