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EVALUATION OF NUTRITIONAL VALUE OF YELLOW MEALWORM (*Tenebrio molitor*) REARED ON FRUIT WASTE

A thesis Submitted by

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BSZGM-F20-019

SUPERIOR UNIVERSITY

BS ZOOLOGY

Department of Biological Sciences

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In the Partial Fulfilment for the Award of
Bs Zoology

Supervisor: Dr. Usman Elahi

Department of Biological Sciences
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2024

UNDERTAKING BY STUDENT

I Javeria Altaf Regd.No. Bszgm-f20-019 declare that the contents of my research project entitled " Evaluation of nutritional value of yellow mealworm reared on fruit waste" are based on my own research findings and have not been taken from any other work except the references and has not been published before.

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SUPERVISOR CERTIFICATE

I Usman Elahi certify that the contents and the form of research project submitted by Javeria Altaf Regd. No. BSZGM-F20-019 have been found satisfactory.

I hereby accept the full responsibility of the supervisorship of mentioned above student and recommend it for the award of the degree of (Bs Zoology).

Date: 10-06-2024

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Declaration of Originality

I Javeria Altaf hereby solemnly declare that this project:

a) is my original work, except where otherwise acknowledged in the text
b) has not been published earlier and
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Javeria Altaf

Dedication

Dedicated to My Family

In dedicating this research thesis to my family, I express my deepest gratitude for their unwavering support and understanding throughout this scholarly endeavor. Their encouragement has been a constant source of motivation, propelling me forward during moments of doubt and challenge. To my parents, whose guidance and sacrifices have laid the foundation for my academic pursuits, I owe an immeasurable debt of gratitude. To my siblings, whose unwavering belief in my abilities has been a source of strength, thank you for your enduring support. This thesis is a reflection of the values installed in me by my family and serves as a tribute to their love, encouragement, and belief in my potential.

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In the name of Allah, the most compassionate, the most merciful.

I express my heartfelt thanks to the Almighty “ALLAH” for granting me the wisdom and insight to accomplish this undertaking.

I wish to convey my sincere appreciation to my supervisor for his invaluable guidance and unwavering support throughout this study. His wisdom and encouragement have been instrumental in the successful completion of this project. I am indebted to him for creating an environment conducive to learning and growth.

Lastly, I extend my deepest gratitude to my family members for their unwavering support and encouragement. Their belief in me has been a constant source of motivation, without which I would not have been able to achieve this milestone.

Javeria Altaf

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LIST OF ABBREVIATIONS

NFE	Nitrogen free extract
MWM	Mealworm meal
EAAI	Essential amino acid index
DM	Dry Matter
FAO	Food and Agricultural Organization
CFIA	Canadian Food Inspection Agency
ADG	Average Daily Gain
FCR	Feed Conversion Ratio

ABSTRACT

A rapidly increasing population size may cause shortages in protein content of human diet. Another major factor contributing to the increased population is the growing amount of waste. Nowadays, organic waste is emerging as a major problem in urban areas. “Mealworms” known as “*Tenebrio molitor*” larvae are the preferred solution to this problem because of their high amount of proteins, rich nutritional value, eco-friendly and can be used for different purposes. They are simply cultivated and reared on a consistent manner, thus they are providing a reliable protein source regardless of their diet. Furthermore, mealworm larvae are commercially available not only for keeping pets but also for feeding animals in zoos and farm animals as well, revealing their possible prospects. In this study, 50 beetles were reared on fruit wastes that include apple, banana, guava, orange etc. Wheat bran used as culturing substrate. The assay was conducted for about 3 months in winter season. The temperature was maintained at 25 to 25C and humidity was maintained at about 65% to 70%. After their rearing, nutritional value of mealworms was analyzed at Animal Nutritional Lab, UVAS, Pattoki. In this experiment, nutrient content of yellow mealworm (YM), including CP, CF, moisture content, and NFE was assessed. Kjeldahl method was used for protein analysis, and Soxhlet technique was applied for the assessment of fat. Proximate analysis indicates that the values of CP = 56.83 %, CF= 23.10%, moisture = 7.89%, crude ash = 5.3 %, NFE = 11.67% which is slightly different from previous studies. As the MWM was added in Indigenous Desi Chicken feed, ADG and FCR were increased as they fed on active ingredients and resulted in ≤ 0.001 significant P-value. Therefore, the larvae of *Tenebrio molitor* (mealworms) are abundant in nutrients, containing high amount of protein and lipids. On the other hand, using fruit waste is better means for confronting with waste pollution because it is a cheap and excellent organic material. These findings suggest that, mealworms have a great potential to be fed to Indigenous Desi Chicken in order to aid in their growth as a source of protein.

CHAPTER NO. I

INTRODUCTION

Population is expanding rapidly. The requirement for food sources escalates. Poultry meat, a commonly available and affordable food source for humans [1].Insects enriched with proteins could be an economical alternative to expensive protein supplements for chickens [2]. Protein sources rank as the second most significant component in the poultry sector [3]. Soybean and fish meal have been traditionally used as protein source while formulating feeds for Indigenous Desi chicks, laying hens and other poultry birds. Soybean is most ideal due to its protein content, adequate amino acids proportion, whereas fishmeal serves an important protein source around the globe [1]. However, soybean and fish meals are expensive and scarce. In recent years, insect meal has come to the frontline as the affordable substitute for poultry feed which is rich in protein [1].

Yellow mealworms (Tenebrio molitor) they're insects emerging as sustainable protein sources, packed with vital nutrients. Yellow mealworm is an important insect which may be used as substitute for soybean meal or fishmeal providing valuable protein, energy and fatty acids. Mealworms are abundant in protein, comprising 45.83% of their nutritional composition. Additionally, they contain significant levels of lysine at 4.51% and methionine at 1.34% [4]. The crude protein (CP) in mealworm meal (MWM) ranges between 25 and 60 percent while the fats range from 15 to 40 percent [1]. The research scope comprises of the following points. Firstly, the study will analyze the nutritional values of yellow mealworms on fruit waste, which primarily includes macronutrients, micronutrients, amino acids, fatty acids, and minerals as well. The second part of the research will be about the sustainability of the mealworm farm based on the fruit waste through material balance, greenhouse gas emissions, and waste reduction investigation. Additionally, Mealworm used as bio-indicators to monitor environmental conditions [3]. Moreover, it has been suggested as a valuable ingredient in chicken feed formulations, offering potential benefits in Indigenous Desi Chicken [3].

Existing study include, mealworm feed on wheat bran, mare potatoes [5]. The mealworms are being fed a blend of semolina, flour, and oat flakes. [6]. However, there is a gap in understanding the impact of rearing mealworms on fruit waste on their nutritional composition. This study aimed to raise mealworms using fruit waste such as (apple cores, banana, Orange peels, etc) maintaining optimal temperature and humidity conditions. After rearing, evaluate the nutritional content of the mealworms, including protein content, amino acid profile, fat content, crude ash, and other relevant factors. The purpose of this research is to determine the nutritional value of yellow mealworms fed on fruit waste in order to discover whether mealworm farming is a possible substitute for protein. Life cycle monitoring will encompass larval development, pupation, and adult reproduction. Evaluating economic viability will include setup and operating costs, exploring the potential for increased protein yield with reduced waste. Thus, to assess the suitability of mealworms as a protein supplement in Indigenous Desi Chicken in replacement with soybean meal and fish meal.

CHAPTER NO. II

LITERATURE REVIEW

Research remains essential as commercial insect farms feed T. molitor with synthetic diet, hence the need for more studies on the subject [1]. The primary sources of protein, in Chicken feed are typically fish meal and soybeans. [1]. Due to the high demand of soybean and fishmeal their prices are high. Besides, the widespread use of soybean brings forth some environmental problems like deforestation, shrinkage of water resources and chemical application [1]. The quality of using fish meal also largely depends on fish catch that is prone to extinction of marine resources [1].

The farming of insects is one of the growing trends has been liked by many people; insects are treated as animal feeds and human foods [2]. Furthermore, Insect meal contains components like chitin, lauric acid and antimicrobial peptides that contribute to the health of chickens. [6]. There is a diversity of insects with over 1 million species identified [6]. As early as 1975, Meyer-Rochow purposed the concept of using insects for both humans and animals consumption [6]. In 2017, the EU (Commission Regulation European Union) approved seven types of insects for use as pet food and aqua feed sources [6]. In 2021, they were also admitted for use in poultry and pig sectors too [6]. Despite reservations insects are being recognized as protein sources for the future due to their eco-friendly production compared to traditional protein sources like (fishmeal,soymeal,cottonseed etc) [6]. Insects have short lifespans, breed extensively, and convert plant protein into animal protein very well [7].

Vermicomposting is the process of turning organic debris into worm castings (manure).

The farming of mealworm insects is one of the growing trends has been liked by many people; The mealworm, *Tenebrio molitor* is characterized by rapid growth rate, early sexual maturity, high feeding capacity and extensive reproductive capabilities and has been extensively used for vermicomposting [2].

Yellow mealworm important insects used as alternative source of protein [1].Whereby EAAI value in MWM is greater than that of soybean meal and is equal to or greater than fishmeal [2]. Mealworms are the juvenile form of darkling beetles of the genus *Tenebrio [8]*. Mealworms are nocturnal and often found in dim light [8]. There are two types of mealworms commonly found [8]. One is the yellow mealworm, scientifically known as *Tenebrio molitor*, and the other is the black mealworm, *Tenebrio obscurus [8]*. Yellow mealworms get their name from their honey-like yellow color and are also known as European mealworms [8]. Mealworms are cylindrical larvae with a tough exoskeleton and six small legs, progressing through four life stages: eggs, larva, pupa, adult beetle [8]. Found in decaying organic matter, they scavenge grains, vegetables, and detritus. Reproduction occurs through eggs laid by adult darkling beetles [8]. People use them widely as feed for pets, as fishing bait, and even as a food source for themselves [8]. Mealworms have a life cycle lasting between 280 and 630 days [9].

The female *Tenebrio molitor* beetles usually oviposit around 250-500 eggs, it takes 3 to 9 days for eggs to hatch and reach larval stage within temperature 25°C [9]. The juvenile stage can last 1 to 8 months and the larvae have light yellow-brownish color [9]. Pupation takes 5 to 28 days at temperature 18°C, followed by an adult phase lasting 2 to 3 months [9]. Larvae typically measure between 2.0-3.5 cm or larger, while adults are approximately 1 cm in size. [9]. They can take poor-quality vegetable waste and turn it into high-quality protein and energy sources, which is an incredibly effective process from one end to the other within a short time [10]. In commercial settings, *Tenebrio molitor* beetles are mainly fed flour (such as wheat, oats, and maize) or cerebral bran, supplemented with vegetables and fruits to provide moisture [9].

Mealworm farming provides a promising solution for enhancing food and feed security. These insects grow and reproduce quickly [4]. Mealworm meal prices are reasonable [11]. The composition of amino acid of yellow mealworm is comparable to soybean meal used as a reference [12]. In China, Mealworm is a famous dish for local people [3]. In Uganda, poultry farmers, feed traders, processors are receptive to the idea of utilizing insects, like mealworms, as a protein alternative in chicken diets [13]. However, the nutritional value differs between dried and fresh mealworms [13]. Fresh mealworms have around 20% protein, 13% fat, and 62% moisture, while dried ones have higher protein (53%), fat (28%), and lower moisture (5%) levels [13].Since 2000, the insect industry has seen rapid growth, marked by the emergence of several companies across the USA, Canada, China, South Africa, and Europe [14]. Mealworms grow fast, don't need a lot of resources, and can change regular kitchen scraps into topnotch protein food for chickens (17). Mealworms can be reared on many cultural substrates such as animal manure, wheat straw, maize straw etc.

Microbiological analysis of mealworms with a focus on *Escherichia coli (E. coli)* and *Salmonella spp.* showed that they were not present thereby showing the safety in consuming meal worms by humans and animals [1]. Nutritionists argue that such food may pose danger to health if not carefully selected and dried but some of them prefer to feed live (fresh) insects to birds in order to keep them healthy [1]. Use of fresh MWM in poultry diets has been reported: however, no case is reported for fish diet [1]. Meat quality was also improved following the inclusion of insect meal into diets for indigenous Desi chicks due to the functional constituents in the insects [1]. Also, the whole fat MWM diet can be effective in reducing certain bacteria clustering in Desi Chicken[1]. It has lesser impacts on the environment, like global warming, decrease in diversity of species and soil erosion which have been associated with conventional production practices [2].

One of the major challenges is caused by the escalating the human population is increase in waste generated by economic works [4]. By 2025, global urban populations are set to double [15]. For instance, the (FAO) reported that in 2007 alone, 1.6 billion tones of food waste were generated worldwide [15]. To combat landfill overflow, researchers are exploring methods to reduce organic waste, such as utilizing mealworms [15]. Insects hold potential for waste recycling, nutrition for animals/humans, sustainability grows [15]. Research has delved into the nutritional value of insect larvae, especially muscoid (*Diptera*) larvae, recommended for waste recycling like poultry manure [16]. Early uses of insects like mealworms as animal food sources for their high protein content have been documented [16].

As the world's population increasingly escalates, food steadily gets consumed, which affects chicken meat production Sustainable feeds are an important matter and yellow mealworm manifest potential as an alternative one [10]. Yellow mealworm shows promise for feed [10]. Using insects instead of traditional feed helps to increase efficiency and reduce hunger risk [17]. Fish feeds contribute to 50% of aquaculture costs, leading to increased prices [17].Yellow mealworms, the most popular insects in Europe's bioconversions, produce valuable and high in nutrients food from waste [17].

Small-scale poultry farming which is very important for poverty reduction and protein supply [18]. Increased feed costs and climate change represent the main hurdles for farmers [18]. Research considers farmers' attitude towards adding yellow mealworm to poultry feed for further enhancing the goal of sustainable development, a circular economy, and food security [18].

In the Nordic countries, the dependence on local animal feed production is relatively low [19].Involving the use of mealworms from local agricultural by-products will enlarge a regional feed ingredient supply [19]. Mealworms have high digestibility (~90%) for both dry matter (DM) and crude protein (CP) [19]. Research reveals that the fact that mealworm-based feed won't negatively affect birds' growth and it reduces the feed conversion ratio instead of soybean meal (SBM) [19]. In-vitro study shows insect meal digestibility of DM is similar to SBM and slightly lower CP rumen digestibility because of high fat content [19]. Meanwhile, their unsaturated fat may cause an improvement in methane emissions [20].

Insect rearing is environmentally promising due to low greenhouse gas emissions [21]. Insects require minimal land to produce 1 kg of [21]. In Asian countries, insect has been seen as food for its high protein content since long time ago [14]. North and South Korea have contrasting approaches to insect use: North Korea forbids insects being included in animal feed since they account for semi-animal proteins whereas South Korea uses both in human and animal diets [14]. South Korea decided to have insect legislation deregulated in 2015, and can be used without a specific rule and requirement [14]. In Canada, the Animal Feed Division, Animal Health Directorate, of the CFIA is responsible for feed regulations and accepts feed and feed ingredients records [14].

Mealworms, also known as *Tenebrio molitor*, have high magnesium (mg) and zinc (z) but lack calcium (ca) [22]. They're rich in niacin, pyridoxine, riboflavin, folate, and vitamin B12 [22]. Their protein-fat-carb ratio rivals beef and poultry [22]. Calcium-enriched diets are used to address their calcium deficiency [22]. Commercial mealworm farming is more environmentally friendly than chicken or beef production, requiring similar energy but less land and emitting fewer greenhouse gases and ammonia [23]. The mealworm beetle's microbiota is affected by antibiotics, reducing bacterial diversity and load, yet they maintain stability against environmental conditions [24]. Non-fertile mealworms show poor performance [24]. This indicates that the microbiota contributes to the effectively digesting and removing of harmful phytochemicals [24]. Using antibiotics in other insects may lead to shortened development periods and reduced egg production [24]. Furthermore, when dried mealworm meal is used as protein source in Desi Chicken, it helps in better growth and production performance of chicken as well as improves immune and act as anti-microbial agent for microbiota in chicken’s gut.

CHAPTER NO. III

MATERIALS AND METHODS

1. Setting:

Rearing mealworms was conducted at experimental unit by maintaining their habitat and hygiene. Nutritional analysis of worms was conducted in Animal Nutrition Lab, Department of Animal Nutrition, Faculty of Animal Production and Technology, University of veterinary and Animal Sciences, Ravi Campus, Pattoki.

2. Research design:

50 beetles were brought from a Local market shop Rumi farming Karachi and reared on fruit waste at temperature 25-30°C, 65-70%humidity. After rearing, their nutritional composition was analyzed in the assigned laboratory.

3. Sample size:

50 beetles were reared in container Wheat bran as a substrate and Fruit waste (apple, orange, guava. Banana, etc) used as a food source.

4. Sampling technique:

In rearing of mealworms mainly uses kitchen trimmings as a natural environment that has high concentrations of the minerals and vitamins. A good, vented container preferably made of plastic or wood coupled with a lid for humidity. That includes fruit wastes such as fruit like (apple, banana, grapes, etc.). Wheat bran or oats acts as a layer of bedding under which meal worms will pupate and be maintained with correct humidity. Evaluating feed potential, growth capacity and nutritional quality of Yellow Mealworm. 50 Beetles will purchased from a Rumi farmer a local market in Karachi as a sample. A good, vented container preferably made of plastic or wood coupled with a lid for humidity. Firstly, investigate the influence of food to their mortality and/or lifecycle. For 20 days, the beetles are reared in a plastic container of 750 ml (width 5inch, length 7inch, height 2.5inch). 20g fruit waste was offered to the beetles into 20g of wheat bran provides as a substrate. Afterwards, a small number of *Tenebro molitors* larvae are introduced into the separate container in an effort to ensure uniformity. The larvae need to eat, and for this purpose; a moisture-retaining sponge or cotton ball can serve as a water source. The beetles are maintained at an ambient temperature of 25°C, at 70% relative humidity, and under constant dark surroundings. HTC1 temperature, humidity meter (Didilog Electronics) is a device to measure humidity. Larva consume 20g feed in 3 days. Then, after 20 days adults are relocated in new containers as their room for nestlings is vacant. Larvae remain in the container. The rearing environment must have a constant room temperature of about 24–27 °C, with natural sunlight or low intensity artificial light. Moisture level monitoring, as well as the general health and development of mealworms is accomplished by subjecting regular inspections. Understanding the nutritional profile of mealworms raised on fruit waste is essential for performed following tests.

Fig 1.1: (a) Darkling beetles feed on fruit. (b) Vermibed of mealworms contains wheat bran as substrate and fruit waste as a food source.

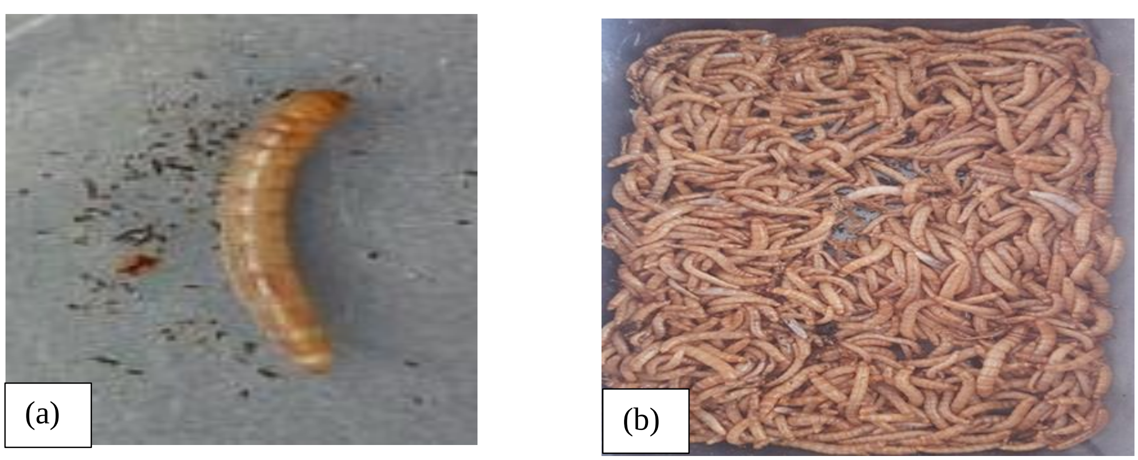

Fig 1.2: (a) juvenile of darkling beetle at day 1. (b) Adult mealworms after rearing of 120 days.

PROXIMAT ANALYSIS:

Crude Ash Determination:

Weighing 1-2 grams of sample into previously weighed porcelain crucible. A crucible will be used for the heat treatment, which will be concentration-heated on an oxidizing flame until no smoke appears. Next, the crucible is put in a muffle furnace which will be set at 550°C and heated for 4 hours. At the end of 4 hours, the crucible was put in a drying chamber (desiccator) and allowed to cool to ambient temperature. The crucible, is filled with ash, was weighed immediately to avoid absorption of moisture. The weight of the empty crucible was subtracted from the weight noted in the preceding step to get the ash weight.

Formula:

$$\text{Ash\%age} = \frac{\text{weight of Ash}}{\text{weight of sample}} \times 100$$

Dry Matter Estimation:

The weighing dish was drying in the hot air oven for 1 hour at a temperature of 105°C. After 1 hour, the dish will be put in a desiccator, and after cooling down, it was weighed (a). Approximately 5 grams of the sample was taken in the dry dish, and noted the total weight of the dish and sample combined (b). The dish, containing the sample, will now be set in the drying oven with a temperature of 105°C for 1 hour.

Afterwards, the temperature will be gradually lowered to 65°C until the weight becomes stable. The dish was cooled down in a desiccator. The combined weight of the dried sample and dish was noted (c), than the weight of the dried empty dish was deducted from this total. The formula below was used to calculate the dry matter.

Formula:

$$\text{Dry method \%} \ \frac{\text{Weight of sample}}{\text{weight of sample before drying}} \times 100$$

Protein Analysis:

Total protein content was determined using protein analysis methods such as the Kjeldahl method. The feed sample of Mealworm will weigh 1-2 grams. The feed sample was heated with concentrated sulfuric acid (H2SO4) alongside the digestion mixture. The resulting digested material, (NH4)SO4, was diluted and distilled with 40% NaOH solution. Approximately 40-50 ml of distilled water were poured into the digested material, before transferring the mixture into a volumetric flask. A 10 ml portion of this diluted material, along with 10 ml of 40% NaOH, was introduced into the Kjeldahl apparatus. The NH3 gas released during distillation was gathered in a 2% boric acid solution with the addition of 1-2 drops of methyl red or mixed indicator. Another 10 ml portion of the distilled material was transferred into a conical flask. The sample was titrated against N/10 H2SO4. The nitrogen percentage was multiplied by 6.25 to determine the protein percentage in the sample. The estimation of C.P is conducted through 3 sequential steps:

- Digestion,
- Dilution or Distillation,
- Titration.

Ether Extraction:

The feed sample is boiled in the presence of ether by using the Soxtherm apparatus. This warmed ether dissolves the fat from the sample and we get fat free material. The feed sample was weighed, 1-2 grams of the sample was carefully placed onto a 10x10 filter paper. The filter paper was then be folded and securely stapled to prevent any excretion of the feed sample. The folded filter paper, containing the feed sample, was placed into the thimble of the Soxtherm apparatus and closed tightly. In a beaker, 30-40 ml of ether was poured, and the beaker was positioned on a heater plate to boil the ether. As the ether boils, it was rise and flow towards the thimble, facilitating the dissolution of fat from the sample. Tap water was introduced into the process to cool down the boiled ether through condensation. This process was continued for 30 minutes, and the step was repeated 2-3 times to ensure thorough fat extraction. The warmed ether was dissolve the fat from the sample, resulting in the production of a fat-free material.

Formula:

$$\text{E.E\%age} = \frac{\text{Initial weight}}{\text{Final wight of sample}} \times 100$$

Moisture analysis:

Mealworm samples were dried in an air-circulating oven at 70–80°C to determine the moisture content.

Statistical analysis:

After determining normality and homoscedasticity, The data was displayed as the average value ± the standard error and analyzed using a one-way ANOVA with the GLM method in IBM SPSS Statistics software for Windows (version 25.0, IBM Corp., Armonk, NY, USA). A 2 x 2 factorial arrangement was employed to analyze the data from low crude protein group. Treatment variances were evaluated using Tukey's honestly significant difference (HSD) test at a 5% significance level. The purpose of this statistical method is to enable the detection of significant differences between the experimental groups and to give a solid analysis.

Nitrogen Free Extract:

The nitrogen-free extract was determined by deducting the %age of ash, CP, and CF extract from 100.

Formula:

NFE% = 100 – (ash %age + crude fiber %age + ether extract %age + protein %age)

Duration of study:

Laval stage of mealworm was fed on fruit waste for about 3 months.

Ethical considerations:

All the birds and the experimental protocols in this study received approval from the Department of Animal Care and Use Committee of Superior University, Lahore, Pakistan.

Data collection procedure:

Human sources, articles, internet.

FACILITIES AVAILABLE/PLACE OF WORK:

Department of Biological Sciences, Faculty of Sciences Superior University, Lahore

CHAPTER NO.IV

RESULTS

This area explains the results of the study of the rearing of yellow mealworms grown by different types of fruit waste. This study was intended to determine the impact of the fruit waste feed on the growth, survival, and nutrient content such as protein and lipid content, of the larvae. The experiment period was 4 months long, and data was compared with that of a control group feeding on a typical commercially reared mealworm diet present in previous studies.

Growth of Mealworms:

The eggs of mealworms are white, bean shaped, and 1.25 mm long in size. During their development they molt between 9-20 times, shedding their outer cover and gradually increase in size each time they molt. Table 1.1 illustrates the variations in weight of yellow mealworms throughout the experiment.

Table 1.1: Shows the weight (g) of juvenile and adult mealworms.

Weight of juvenile at initial	0.014 g
Weight of adult mealworm	0.108 g
Total weight of live mealworms	51.987g

Length and Width of the Yellow mealworms:

Table 1.2: Shows the length of juvenile and adult mealworms.

Length of juvenile at initial	0.75 cm
Length of adult mealworm	1.5 cm

Nutrient Composition:

The nutritional compositions of yellow mealworms that are reared on fruit waste are shown below, Including fat content, crude protein, moisture, ash content, NFE. The comparison has been made with [8], which utilize wheat bran as feed.

Table 1.4: Shows the proximate analysis between our results and Hussain et al. (2017).

Tests	Our experiment results (%)	Hussain et al. (2017) (%)
Moisture	7.89%	5.78%
Crude protein	56.83%	45.83%

Crude fat	23.10%	34.2%
Crude ash	5.3 %	3.97%
Nitrogen free extract	11.67%	–

Statistical Analysis:

Table 1.5 illustrated the values of ADG, FCR, along with descriptive analysis for the variables included in the study. It also showed the one-way ANOVA was utilized to assess the significant differences on the growth performance between control group and experimental group of desi chicken.

Table 1.5 Effects of mealworms on the growth performance of Indigenous desi Chicken.

Treatment	**Initial Weight**	**Final Weight**	**FI**	**ADG**	**FCR**
C	550	600	65	7.14285	9.2480
M	550	650	70	14.2857	4.9234
SEM	0.97062	5.83952	0.57354	0.84814	0.53300
P value	1.000	≤ 0.001	–	≤ 0.001	≤ 0.001

C = Control group, M= Experimental group, ADG= Average Daily Gain, FCR= Feed Conversion Ratio, SEM = Stand. Error Mean

CHAPTER NO.V

DISCUSSION

Mealworm production has already reached an industrial level. Raising mealworms on fruit waste requires creating the optimal conditions for the mealworms to thrive and effectively break down organic matter. Key factors like temperature, moisture, PH balance, and the ratio of carbon to nitrogen are vital for the success of vermicomposting. Selecting suitable bedding material and consistently maintaining the mealworm habitat are vital for keeping the worm population healthy. In this experiment two groups of mealworms were studied. In the initial phase of the experiment approximately 50 beetles were raised in optimal conditions with temperature ranging from 25 c to 27 c. After 20 days, beetles lay eggs and the larva was grow on fruit waste with optimal temperature of 25 c to 30c and 65% humidity. It was observed that mealworms growth rate was normal. Another case, mealworms groups was studied in which mealworms were reared at temperature 17 c -20 c and 30% humidity with constant darkness. It was noted that mealworms growth rate was decrease but no instances of mortality were observed. Than, it can be concluded that mealworms could survive on low temperature and humidity. Additionally, Mealworm larvae grow faster when humidity is approximately 70% around them. In contrast, the larval growth slows down under 30%, humidity and when the humidity level goes down to 13% they almost no progress is observed (Fraenkel, 1950), [25]. Temperature is another factor of great importance in their growth. While Fiore (1960) was observed that larva reached their maximum weight of 175mg at a temperature of 30°C, while at a temperature of 20°C, their weight peaked at 100mg, it should be mentioned that 30°C is the optimum temperature since it led to the highest number of moults; there were as many as 19 moult cases occurring during the life cycle [3].

Nutritional value might be crucial in determining reproduction efficiency of the mealworms. The characteristics of mealworms are greatly affected by feeding material, and nature of Vermibed. These factors effect on nutritional composition of mealworms. When analyzing the CP, CF, crude ash, moisture, NFE, slight differences were observed. The CP content was observed slightly greater than the 53.0% stated by Khan et al. (2017), 47.83% reported by Hussain et al. (2017), [3,4]. The CP content was lower than the 63.34% reported by Ravzanaadii N. (2012) [16]. The observed crude ash content was greater than the 3.97 % documented by Hussain et al. (2017), [4], but was lower than the 4.04 % reported by Hong J. (2020), [9]. The moisture value was greater than the 5.3 % indicated by Ravzanaadii et al. (2012), [16], but it was lower than the 9.89 % reported by Kim et al. (2017), [7]. The CF value was greater than the 21.6% noted by Bovera et al. (2015), [3]. But it was lower than 34.2% reported by Hussain et al. (2017), [4]. The nitrogen free extract content was greater than the 2.87 % disclosed by Toviho et al. (2022), [6]. Furthermore, Tenebrio molitor larvae are rich in essential polyunsaturated fatty acids (PUFAs), such as omega-3 and omega-6 acids. They are generally contained approximately 46.1 to 47.3 grams per 100 grams of omega-3 acid and 31.1 to 31.6 grams per 100 grams of omega-6 acid. Conclusively, the result of this study does not differ significantly from past works except in the elemental composition of the mealworms. The protein composition varied in the same way as ash, moisture content, CF and NFE. Such changes indicate that factors like feed type and environmental condition altered the nutrient content of mealworms. More studies are needed for improving the mealworm nutritional value.

The results provide by table 1.5 contain vital information about growth performance of broiler which are different groups, namely the control group and experimental group. Firstly, comparing the descriptive analysis both groups, indicates that the overall body weight gain, ADG, FCR for experimental group was significantly less than ($p < 0.005$) as compared to control group. The results shows that the dietary regime with provided mealworm could partly have better growth and efficiency in broiler compared to standard feed provided to the control group. Secondly, the one way-ANOVA results shows the significant difference in growth between control and experimental group. The findings revealed the notable impact of mealworm feed on desi chicken growth (F (116.514, $p < 0.005$). Feed supplementation of desi chickens with mealworms at a rate of 10-60 g/kg has resulted in increased weight gain without significantly affecting intake levels. On the contrary, adding 5% mealworms into the diet yielded positive effects on the live weight of the broilers compared to the ones in the control group. For the moment, mealworm farming fulfills the purpose of generating the protein quantities needed to meet the current and future market demands. Due to the escalating cost of adding soybean meal and fish meal to poultry feed, it demands looking into new sources of protein. Fortunately, we have lots of different alternative options which we can consider, such as house fly maggots, termites, snails, grasshoppers, silkworm caterpillars and earth worms. Studies have shown out *T. molitor* can be beneficial both in protein supply and reduce waste. To conclude, feeding on selected substrates affected the nutritional composition of the mealworm larvae. Subsequently, this needs further research as well. However, further research is required to examine the potential of utilizing of mealworms as a substitute protein source for soybean, thereby reducing waste and potentially lowering feed expenses without compromising bird performance.

CHAPTER- VI

CONCLUSION

The research demonstrated that yellow mealworms raised on fruit waste was an achievable way of producing protein for Chicken feed as a sustainable option. The mealworm growth rate and survival rate was found to be normal on the fruit waste and comparable to those on conventional diets. Incorporating mealworms to the diet of Indigenous Desi chickens has been shown to significantly enhance various aspects of their health and productivity. This dietary change results in a successfully increase in the growth rate of these chickens, leading to faster development and larger overall size. Moreover, mealworms provide a high level of protein, essential for muscle growth and general health. They also supply a wealth of vital nutrients, ensuring a balanced diet that strengthens the chickens' immune systems and promotes overall well-being. This innovative feeding method not only improves the nutritional value of the chickens' diet but also presents a sustainable and efficient farming solution. By utilizing the nutritional advantages of mealworms, poultry farmers can achieve better growth performance and healthier flocks, ultimately boosting productivity and profitability. Additionally, more studies will be necessary to improve their nutritional content as well as evaluate economic feasibility and scale up for implementation in poultry production systems. Further research should be conducted to precise quantities of mealworms for maximum growth and health benefits without adverse effects and Conduct detailed nutritional analysis of mealworms at different stages to determine the best incorporation time for highest nutrient content and bioavailability.

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