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Evaluation of full-fat and defatted black soldier fly larvae (*Hermetia illucens*) meal as an alternative source of functional feed ingredients

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ABSTRACT

This research work presents the proximate, minerals and anti-nutritional factors of full-fat and defatted black soldier fly larvae (Hermetia illucens) meal. The Black soldier fly larvae was reared and supplied by a commercial company (The Fly Colony, Ilishan Remo, Ogun State), Harvested larvae was dried in an oven at 90OC and milled afterwards using local blender. Milled Black Soldier Fly Larvae meal was defatted using food grade hexane. Results from the proximate analysis showed that full-fat and defatted BSFL meals had appreciable amount of dry matter (96.29% and 92.54%), crude protein (46.03% and 54.53%), and also with high value for ether extract which are 29.91% and 10.81% respectively. The meals also had lower values of crude fibre (6.80% and 6.94%). The mineral analysis showed that the meals had sodium (0.48% and 0.54%), potassium (1.79% and 1.87%), calcium (0.29% and 0.30%), while the micro minerals showed that full-fat and defatted BSFLM had appreciable concentration of iron (874mg/kg and 893mg/kg), zinc (97.67mg/kg and 114.80mg/kg) and copper (34.59mg/kg and 46.41mg/kg). the anti-nutritional factor constituents of full-fat and defatted BSFLM showed that phytate concentration was (0.09% and 0.17%), tannin (0.12% and 0.24%), haemagluttinin (39.74HU/mg and 55.37HU/mg) and trypsin inhibitor (11.68TIU/mg and 18.70TIU/mg) respectively. This study showed that full-fat and defatted BSFLM can be good sources of protein, ether extract, carbohydrate and minerals. Therefore, these meals can be exploited as commercial source to supplement livestock feedstuff.

Keywords: *Full-fat and defatted Black soldier fly larvae meal, proximate, minerals, anti-nutrients, livestock*

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INTRODUCTION

The livestock sector continues to experience increasing pressure to meet the rising demand for high-value animal protein. The demand for animal products is expected to double in developing countries by 2030 (Vasileska and Rechkoska, 2012). Despite the global pandemic (Covid-19) which had greater effect on human mortality rate and economies of nations, the quest for food production to meet with demands had consistently increased. In Nigeria specifically, poultry industry growth index as at mid-2020 was estimated to be around 2 million birds with a total value of over ₦16 trillion (NIAS, 2020). Thus, there is need for significant investment in livestock production in other to sustain the growing demands and population.

There is emerging global interest in the use of insect protein as a potential alternative source to replace expensive conventional major protein sources, particularly fishmeal and soybean meal in animal feeds (van Huis *et al.,* 2013), this is because the crude protein content of insect meals has been demonstrated to range between 35% and 77%, with 33%-36% of lipid content (Makkar *et al.,* 2014; Josefiak *et al.,* 2016; Hatab *et al.,* 2020). Black soldier fly larvae (BSFL) are rich in both protein and lipids, and contain an amino acid profile suitable for several species (Newton *et al.,* 2005). These high levels of lipid dilute the level of crude protein content in BSFL. The defatting of the BSFL would provide a product of a

relatively higher crude protein content and result in a by-product of lipid, which has potential as a biofuel (Leong *et al.,* 2016).

The development of innovative, cost-effective, and environmentally friendly options such as farming of black soldier fly larvae (BSFL) on organic waste and recycling the waste into high-quality nutrient-rich biomass is increasingly being considered as an attractive, viable and sustainable alternative source of protein (38%-62% CP) to substitute animal and plant-based sources in animal feeds (van Huis *et al.,* 2015; Makkar *et al.,* 2014).

It is evident that these larvae meals contain adequate amount of nutrients that can be made available for livestock production, it is therefore the aim of this study to provide proximate, minerals and anti-nutritional contents of these full-fat and defatted Black soldier fly larvae meal.

MATERIALS AND METHODS

Source and processing of black soldier fly larvae (BSFL) meal

The Black soldier fly larvae was reared and supplied by a commercial company (The Fly Colony, Ilishan Remo, Ogun State) in 2 batches. The 2 batches of BSFL used for these experiments were produced under the same conditions: fed the same poultry manure as a substrate. Larvae was harvested after 14 days (enough time for larvae to have reached mature stage). Harvested larvae was dried in an oven at 90^{O}C (Peters *et al.,* 2017) and milled afterwards using JTC OmniBlend V Heavy duty professional blender TM-800 Model.

Determination of proximate and gross energy of full-fat and defatted BSFLM

The full-fat and defatted Black Soldier fly larvae meal and their respective feeds were analyzed chemically for proximate composition and gross energy according to the official methods of analysis described by the Association of Official Analytical Chemist (AOAC, 2006).

Mineral determination

Minerals were analyzed by dry ashing the samples at 550^{0}C to constant weight and dissolving the ash in volumetric flask using distilled, de-ionized water with a few drops of concentrated hydrochloric acid. Sodium, calcium and potassium were determined using Jenway Digital Flame Photometer (PFP7 Model). Phosphorus was determined using the vanado-molybdate colorimetric or spectrophotometric method. Mn, Mg, Zn, Cu, Fe and Se were determined by Atomic Absorption Spectrophotometer using Buck 200 AAS. All determinations were done in triplicate.

Determination of anti-nutritional factors

Haemagglutinin determination

The haemagglutinin in the test ingredients were determined according to the method Liener, (1955).

Procedure

0. 20g of defatted sample was weighed into a screw cap centrifuge tube. 10ml of 0.1M phosphate and 10ml of 0.85% NaCl were added. The mixture was shaken at room temperature for shir on a UDY shaker. The suspension after 18hrs was centrifuged at 1,500 rpm for 15minutes. The supernatant obtained was transferred into a separate clean screw cap centrifuge tube by decantation. The haemagglutinin inhibition activity was tested by preparing a set of haemagglutinin standard solutions by serial dilution % range 0 to 1.0ml of the stock haemagglutinin. Extract of sample were pipetted into a triplicate set of test tubes with each set for each level of haemagglutinin. Each sample and standard spoliation were treated with 0.9% satrain of sample as well as standard solutions will be read on a spectronic 21D spectrophotometer. The Haemagglutinin activity is calculated using the formula:

HU/mg= 98.56 (Absorbance of sample- absorb blank).

Determination of trypsin inhibitor (TIA)

The caesin digestion method

The trypsin inhibitor in the test ingredients were determined according to the method of Kakade *et al.* (1974).

Procedure

0.2g of defatted ground sample was weighed into a centrifuge tube. 10ml of 0.1M Phosphate buffer added and shook on a shaker at room temperature for 1hr. the suspension was centrifuged at 5000rpm in a centrifuge for 5min. The content was later filtered through a Whatman no 42 filter paper into a 250ml conical flask. 0.2, 0.4, 0.6, 0.8 and 1.0ml of filtrate were pipette into a set of triplicate set of test-tubes (one set for each level of extract). The final volume is adjusted to 2ml by the addition of 0.1M phosphate buffer. These test-tubes were arranged into a water bath maintained at 37^{0}C. A blank was prepared by adding 6ml of 5% TCA solution to one set of triplicate tubes. 2ml of 2% casein solution was added to all the tubes which was previously kept at 37^{0}C to incubate for 20mins. The reaction of casein was stopped the addition of 6ml of 5% TCA solution and this was allowed to proceed for 1hr at room temperature. The mixture was later filtered at room temperature through a Whatman No 42-filter paper into

100ml conical flask. 0.2, 0.4, 0.6, 0.8 and 1.0ml of stock trypsin solution were also pipetted into a triplicate set of test-tubes (one set for each level of trypsin) as above and treated similarly as sample to the point of filteration.

The absorbance of the filtrates of both samples and standard trypsin solution were read on a spectrophotometer at a wavelength of 280nm. The actual absorbance of the sample is the difference between absorbance of stock trypsin filtrate and that of sample filtrate. The absorbance of blank was also read. One trypsin inhibitor unit (TIU) is arbitrarily defined as an increase of 0.01 absorbance units at 280nm in 20mins per 10ml of the reaction mixture under the conditions mentioned herein. Trypsin Inhibitor Unit for each sample was calculated using the formula:

$$Trypsin\ Inhibitor\ Unit = change\ in\ absorbance\ of\ sample\ extract \div 0.01 \times mg\ protein\ in\ sample$$

Phytate determination

The phytate in the test ingredients were determined according to the method of Maga, (1983).

Procedure

2g of each sample was weighed into 250ml conical flask. 100mls of 2% Hydrochloric Acid was added to soak each sample in the conical flask for 3 hours. This was filtered through a double layer of hardened filter paper. 50ml of each filtrate was placed in 0.50ml conical flask and 107mls distilled water was added in each case to give proper acidity. 10mls of 0.3% Ammonium Thiocyanate (NH_4SCM) solution was added into each solution as indicated. This was titrated with standard iron (III) chloride solution which contained 0.00195g Iron per ml. The end point was slightly brownish-yellow which persisted for 5 minutes. The % phytic acid was calculated using the formula:

$$\%\ \text{Phytic Acid} = \text{Titre value} \times 0.00195 \times 100 \times 3.55/\text{Wt of sample}$$

Tannin determination

The tannin in the test ingredients were determined according to the method of (Swain, 1979 & AOAC., 1984)

Procedure

0.20g of sample was measured into a 50ml beaker 20ml of 50% methanol was added and covered with parafilm and placed in a water bath at 77-80^{o}C for 1 hour. It was shaking thoroughly to ensure a uniform mixing. The extract was quantitatively filtered using a double layered Whatman No 41-filter paper into a 100ml volumetric flask, 20ml water added, 2.5ml folin-Denis reagent and 10ml of 17% na2Co3 were added and mixed properly. The mixture was made up to mark with water mixed well and allow to stand for 20min. The bluish –green color will develop at the end of range 0-10ppm were treated similarly as 1ml sample above. The absorbance of the Tannic acid standard solutions as well as samples were read after color development on a spectronic 21D spectrophotometer at a wavelength of 760nm. % Tannin was calculated using the formula.

$$\%\text{TANNIN} = \text{absorbance of sample} \times \text{average gradient factor} \times \text{Dilution factor/Wt of sample} \times 10{,}000$$

Data analysis

All data analyses were done using IBM® SPSS version 20.0. The data were then subjected to descriptive analysis where the separation of means and standard deviation was computed. The data collected was subjected to analysis of variance (ANOVA) according to Steel and Torie (1980). The significant means were separated using the Duncan's Multiple Range Test as described by Duncan (1955).

RESULTS AND DISCUSSION

The proximate composition of full fat and defatted Black soldier fly larvae meal are as presented in (Table 1). The proximate composition of the two BSFL meal differed mainly in terms of CP, EE and NFE contents. The Full Fat BSFLM showed a lower CP content than Defatted BSFLM (46.03 and 54.53%) respectively. The higher CP content of the DBSFLM could be attributed to dilution effect of fat in the FFBSFLM which reduces the CP content, when the larvae biomass is defatted, the protein digestibility significantly improved to 75%, indicating the impact of fat content on protein availability (Traksele *et al.,* 2021). The figure for FFBSFLM in this study (46.03%) is higher than those reported by Spranghers *et al.* (2017); 43.1%, Shumo *et al.* (2019); 41.1%, Onsongo *et al.* (2018); 43.9%, but lower than that reported by Sumbule *et al.* (2021) ;47%. While CP for DBSFLM obtained in this study (54.53%) was higher than that reported by Yildirim-Aksoy *et al.* (2020); 21.6% but lower than those reported by Schiavone *et al.* (2017); 55.42%.

On the contrary, the DBSFLM showed a lower EE content (10.81%) than the FFBSFLM (29.91%), the figure obtained in this study for FFBSFLM is lower than those reported by Spranghers *et al.* (2017); 38.6% and Shumo *et al.* (2019); 30.1% but higher than those reported by Zulkifli *et al.* (2022); 28.43% and Rawski *et al.* (2020); 29.8%. The variation in crude protein and ether extract may be due to the substrate where the larvae are reared (Makkar *et al.,* 2014).

Table 1: Proximate composition of Full-fat and Defatted BSFLM;

Parameters %	FFBSFLM	DBSFLM	% Difference
Dry matter	96.29 ± 0.03	92.54 ± 0.04	-3.89
Crude protein	46.03 ± 0.08	54.53 ± 0.06	18.47
Ether extract	29.91 ± 0.02	10.81 ± 0.03	-63.86
Crude fibre	6.80 ± 0.03	6.94 ± 0.02	2.06
Ash	3.63 ± 0.01	3.88 ± 0.02	6.89
Nitrogen free extract	9.93 ± 0.03	16.40 ± 0.01	65.16
Gross energy (kcal/g)	5.89 ± 0.00	5.72 ± 0.00	-2.89

± Standard deviation

*% differences represent the magnitude of differences between the parameters and was calculated as ($P_{DBSFLM} - P_{FFBSFLM}$)/ $P_{FFBSFLM}$ * 100 where P is the concentration of the parameters as described by Cummins *et al.,* 2017).

Table 2: Macro mineral composition of FFBSFLM AND DBSFLM.

Parameters %	FFBSFLM	DBSFLM	% Difference
Sodium	0.48 ± 0.00	0.51 ± 0.00	6.25
Potassium	1.79 ± 0.00	1.87 ± 0.00	4.47
Calcium	0.29 ± 0.00	0.30 ± 0.00	3.45
Phosphorous	0.38 ± 0.00	0.36 ± 0.00	-5.26
Magnesium	0.15 ± 0.00	0.16 ± 0.00	6.67

± Standard deviation

*% differences represent the magnitude of differences between the parameters and was calculated as ($P_{DBSFLM} - P_{FFBSFLM}$)/ $P_{FFBSFLM}$ * 100 where P is the concentration of the parameters as described by Cummins *et al.,* 2017).

Table 3: Macro mineral composition of FFBSFLM AND DBSFLM

Parameters mg/kg	FFBSFLM	DBSFLM	% Difference
Zinc	97.67 ± 0.02	114.80 ± 0.03	17.54
Copper	34.59± 0.03	46.41 ± 0.02	34.17
Iron	874.23 ± 0.02	893.46 ± 0.01	2.20
Manganese	173.27 ± 0.01	189.58 ± 0.01	9.41
Selenium	5.30 ± 0.04	6.16 ± 0.02	16.23

± Standard deviation

*% differences represent the magnitude of differences between the parameters and was calculated as ($P_{DBSFLM} - P_{FFBSFLM}$)/ $P_{FFBSFLM}$ * 100 where P is the concentration of the parameters as described by Cummins *et al.,* 2017).

FFBSFLM in this study contained ash of 3.63% similar to 3.93% reported by Karimi *et al.* (2023). The figure obtained in this study is lower than that obtained by De Souza Vilela *et al.* (2021);10.4% and Tyshko *et al.* (2021); 6.59% but higher than figure reported by Spranghers *et al.* (2017); 2.7%. For DBSFLM, ash recorded in this study (3.88%) was lower than those reported by Tyshko *et al.* (2021); 8.1% and Yildirim-Aksoy *et al.* (2020); 9.3%. CF content of FFBSFLM in this study was 6.80%, higher than that reported by Spranghers *et al.* (2017); 4.1%, but lower than those reported by Zulkifli *et al.* (2022); 9.48% and Onsongo *et al.* (2018); 21.3%. For DBSFLM, we recorded 6.94% in this study, which is slightly lower than those reported by Yildirim-Aksoy *et al.* (2021); 7.4%. The variation in CF content in BSFLM may be related to developmental stages and the closer to metamorphic adults, the higher the fiber content (Wang *et al.,* 2020). A major constituent of the CF of BSFLM is a polysaccharide found in the exoskeleton of the insect called chitin, several studies have explored chitin's role in enhancing nutrient digestibility in poultry, they suggest that a moderate inclusion level of this insoluble fiber stimulates the development of the gizzard and the production of digestive enzymes, thereby improving the digestion of starch, lipids and other dietary components (Razdan and Petterson, 1994; Lokman *et al.,* 2019; Jha and Mishra, 2021). The average DM content recorded in this study ranged from 92.55-96.29%), which is similar to that reported by Kirimi *et al.* (2023); 93.19%. The higher dry matter content will give it a storage advantage.

The result of the macro and micro mineral composition of FFBSFLM and DBSFLM are shown in (Table 2 and 3) respectively. The sodium level for FFBSFLM is 0.48% and DBSFLM is 0.51%, this element is required by the body to regulate blood pressure and blood volume, it helps regulate the fluid balance in the body, it also helps in the proper functioning of the muscles and nerves (Payne, 1990). Figures obtained in this study is comparable with

Table 4: Antinutritional factors of FFBSFLM AND DBSFLM.

Parameters %	FFBSFLM	DBSFLM	% Difference
Haemagluttinin (HU/mg)	39.74 ± 0.04	55.37 ± 0.02	39.33
Phytate	0.09 ± 0.01	0.17 ± 0.01	88.89
Tannin	0.12 ± 0.01	0.24 ± 0.01	100
Trypsin inhibitor (TIU/mg)	11.68 ± 0.02	18.70 ± 0.04	60.10

± Standard deviation

*% differences represent the magnitude of differences between the parameters and was calculated as ($P_{DBSFLM} - P_{FFBSFLM}$)/ $P_{FFBSFLM}$ * 100 where P is the concentration of the parameters as described by Cummins *et al.,* 2017).

those reported by Shumo *et al.* (2019); 0.33%. Potassium level obtained in this study is 1.79% for FFBSFLM and 1.87% for DBSFLM. High amount of potassium in the body was reported to increase iron utilization (Adeyeye, 2002). This report agrees with report by Shumo *et al.* (2019) who obtained 1.7% for potassium in his study but was lower than that obtained by Spranghers *et al.* (2017) who obtained 6% in his study. The calcium content of the samples were found to be 0.29% and 0.30% for FFBSFLM and DBSFLM respectively, these figures fall within range of figures reported by Spranghers *et al.* (2017) who obtained 0.12%, and Shumo *et al.* (2019) who reported 0.19%. Calcium is essential for bone formation in poultry, and its deficiency can cause rickets, osteomalacia, and poor production performance (Bai *et al.,* 2022). BSFL can provide sufficient calcium to meet the requirement of broilers and layers, and may even reduce the need for supplemental limestone or oyster shell in the diet (Schiavone *et al.,* 2019).

The concentration of phosphorous in the samples were estimated as 0.38% for FFBSFLM and 0.36% for DBSFLM, these values are comparable to that reported by Spranghers *et al.* (2017) ;0.41% but higher than that reported by Shumo *et al.* (2019); 0.1%. Phosphorous is involved in many metabolic processes, such as energy production, nucleic acid synthesis, and acid-base balance. Phosphorous deficiency can impair growth, bone development and egg production in poultry (Valable *et al.,* 2018). BSFL can offer a more sustainable and efficient source of phosphorous for poultry, as they contain mainly non-phytate phosphorous that is highly digestible and bioavailable (Schiavone *et al.,* 2017).

Magnesium was 0.15% in FFBSFLM and 0.16% in DBSFLM, these values is within range reported by Shumo *et al.* (2019);0.1% but lower than that reported by Zulkilfi *et al.* (2022); 0.25%. Magnesium is a constituent of bone and teeth and is closely associated with Ca and P. Magnesium is important in tissue respiration, especially in oxidative phosphorylation leading to formation of adenosinetrisphosphate (ATP). It is also involved in normal muscular contraction; Ca stimulates muscles, while Mg relaxes the muscles (Guthrie, 1989).

FFBSFLM and DBSFLM in this study presented high values for zinc (97.67mg/kg and 114.80mg/kg respectively), these values are comparable to those reported by Saputra and Lee (2023); 61.71mg/kg for FFBSFLM and 138.08mg/kg for DBSFLM. Zinc plays a very important role in protein and carbohydrate metabolism and also help in mobilizing vitamin A from its storage site in the liver and facilitates the synthesis of DNA and RNA necessary for cell production (Guthrie, 1989).
The concentration of copper in the samples were found to be 34.59mg/kg for FFBSFLM and 46.41mg/kg for DBSFLM, these figures are higher than those reported by Fisher *et al.* (2020); 7.8mg/kg and Spranghers *et al.* (2017); 10mg/kg. Copper is important in diets because it is required for the utilization of iron in haemoglobin formation (Robert *et al.,* 2003). It is also essential for cellular respiration, free radical defence, neurotransmitter functions and tissue biosynthesis (Guthrie, 1989).

The values for iron in FFBSFLM is 874.23mg/kg while DBSFLM had 893.46mg/kg, these values are higher than those reported by Saputra and Lee (2023); 341.35mg/kg for FFBSFLM and 529.57mg/kg for DBSFLM. Iron helps in the formation of blood, it also helps in the transfer of oxygen and carbondioxide from one tissue to another (Guthrie, 1989), its deficiency causes nutritional anaemia and decrease in haemoglobin content. However, excess iron interferes with normal bone formation and lowers phosphorous and manganese availability (Olomu, 1995), FFBSFLM and DBSFLM are rich sources of iron. Manganese was 173.27mg/kg for FFBSFLM and 189.58mg/kg for DBSFLM, comparable with values obtained by Spranghers *et al.* (2017); 200mg/kg and Fisher *et al.* (2020); 185.1mg/kg. Manganese plays an important role in all mental functions and aids in transfer of oxygen from lungs to cells, it is important as an activator for enzyme reactions concerned with carbohydrate, fat and protein metabolism (Guthrie, 1989). The concentration of selenium in the samples were found to be 530mg/kg for FFBSFLM and 616mg/kg for DBSFLM. Selenium is necessary for the normal functioning of the immune system and thyroid gland (Sharadamma *et al.,* 2011).

In this study, the mineral composition of DBSFLM were higher than those found in FFBSFLM, implying that the defatting process led to increase in mineral content of the meal, this is in line with findings reported by Zozo *et al.* (2022) and Saputra and Lee (2023). The anti-nutritional factors contained in full fat and defatted BSFLM are as shown in (Table 4). Table 4 reveals that, the larvae meals

are higher in haemaglutinin and trypsin inhibitor compared tannin and phytate. BSFLM is increasingly recognized as a promising source of protein for animal feed due to its high protein content, favourable amino acid profile, and sustainable production. However, like many insect-based sources, BSFLM contains several anti-nutritional factors (ANFs) that may limit its use without proper processing or supplementation. Among these ANFs, phytate, tannin, haemaglutinin and trypsin inhibitors are of particular concern due to their potential to interfere with nutrient absorption and utilization (Surendra *et al.,* 2016).

Phytate also known as phytic acid, is an anti-nutrient commonly found in plant based and insect based derived meals. It serves as the principal storage form of phosphorous in many biological systems but can negatively impact nutrient bioavailability. In BSFLM, phytate binds to essential minerals such as Ca, Fe, Mg and Zn, forming insoluble complexes that are poorly absorbed in the digestive tract (Ravindran *et al.,* 1994). Phytate also affects protein digestibility by binding to proteins and digestive enzymes, thereby hindering enzymatic activity and reducing the overall digestibility of the meal (Kumar *et al.,* 2010). According to Makkar *et al.* (2014), the concentration of phytate in FFBSFLM typically ranges from 0.1%- 0.2%, which is higher than the value obtained in this study (0.09%).

To mitigate the negative effects of phytate, several strategies such as enzymatic treatments with phytase, heat processing, or fermentation can be employed to breakdown phytate molecules and improve nutrient availability (Huber *et al.,* 2016). Dong *et al.* (2000) suggested fortifying diets with supplemental zinc when feeds contain phytic acid.

Tannins are a group of polyphenolic compounds that can bind to proteins and carbohydrates forming complexes that reduce the digestibility of both nutrients. According to Makkar *et al.* (2014), in FFBSFLM tannins are present in low concentrations, generally below 0.1% of dry matter, which is about the value obtained in this study (0.12%). Despite their relatively low levels, tannins can still negatively impact feed intake, palatability and nutrient absorption, especially in species sensitive to tannin's effect such as poultry and some fish species (Hagerman and Butler, 1989).

The binding of tannins to dietary proteins not only reduces protein digestibility, but also affects the activity of digestive enzymes such as trypsin and amylase, by forming tannin-enzyme complexes (Hagerman and Butler, 1989), processing techniques such as soaking, boiling and fermentation can reduce tannin levels and improve nutritional quality of BSFLM (Francis *et al.,* 2002).

Haemagglutinins, also known as lectins, are proteins which cause agglutination of erythrocytes (red blood cells) *in vitro.* These proteins can bind to carbohydrates on the surface of erythrocytes and cause agglutination or clumping of red blood cells, potentially leading to reduced nutrient absorption and adverse physiological effects (Liener, 1994), they can also interfere with the integrity of the intestinal mucosa, reducing the surface area available for nutrient absorption. Values obtained for haemagglutinin in this study was high ranging from 39.74HU/mg – 55.37HU/mg for FFBSFLM and DBSFLM. According to Mora *et al.,* (2001), heat treatment such as boiling and roasting is effective in denaturing haemagglutinin and significantly reducing their activity. Dong *et al.* (2000) suggested pelletizing of feed as a means of eliminating this compound.

Trypsin inhibitors are anti-nutritional factors that interfere with the activity of trypsin, a key digestive enzyme involved in protein hydrolysis, these inhibitors can significantly reduce protein digestibility and utilization, as they prevent the breakdown of proteins into absorbable amino acids (Liener, 1994). Values obtained for trypsin inhibitor in this study was 11.68TIU/mg and 18.70TIU/mg for FFBSFLM and DBSFLM which is above 5mg/g, the level above which protein digestibility and growth performance are affected according to Rumsey, (1973).

The levels of trypsin inhibitors in BSFLM can be reduced through heat treatment or enzymatic hydrolysis, which denatures the inhibitors and restores enzymatic activity (Kumar *et al.,* 2010).

Conclusion

The results of this study demonstrate that both full-fat and defatted Black Soldier Fly larvae meal represent promising alternative protein sources for livestock feed. In addition to their protein content, these meals provide essential ether extract, carbohydrates, and a broad spectrum of bioavailable minerals, highlighting their nutritional value. These characteristics affirm their potential as sustainable and efficient feed ingredients within modern livestock production systems.

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