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The Nutrient Profile of Processed and Unprocessed Maggot Meal from Three Substrates

Alamba SR*, Solomon SG, Obande RA, Olufeagba SO and Ataguba GA

Department of Fisheries and Aquaculture, Joseph Sarwuan Tarka University, Nigeria

***Corresponding author:** Alamba Simi Rose, Department of Fisheries and Aquaculture, Joseph Sarwuan Tarka University, PMB: 2373, Makurdi, Nigeria, Email: rosesimialamba@gmail.com

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Abstract

The proximate composition of housefly larvae (Musca domestica) maggot meal produced from a four (4) days old larvae raised in a mixture of three substrates: cow manure + cow blood (CMM), swine manure + cow blood (SMM), and poultry manure + cow blood and harvested on day 4 were determined. Harvested maggots were oven-dried at constant temperature (90^{o}c) at different time regimes (35minutes, 45minutes, and 55minutes). Each treatment was named according to the substrate source and processing time: (CMM_{35}, CMM_{45}, CMM_{55}, SMM_{35}, SMM_{45}, SMM_{55}, PMM_{35}, PMM_{45}, PMM_{55}). Results revealed that maggot meal contains 35.95-43.62% crude protein, fat ranged between 8.00-16.86%; Ash content ranged between 5.82-9.30%; crude fibre was between 1.15-2.91%, Moisture content was between 2.00-8.80% and nitrogen free extract (NFE) ranged between 29.2-45.74%. Amino acids analysis identified 19 amino acids including 10 essential amino acids (EAA). The amino acids in CMM, SMM, PMM include: arginine, valine, lysine, methionine, leucine, isoleucine, histidine, tryptophan, phenylalanine, threonine, alanine, aspartate, glutamate, glycine, tyrosine, cysteine, proline serine and asparagine. The methionine content in the meals ranged between 3.78- 4.66 g/100g protein. The treatment CMM55 recorded the highest level of methionine (4.66 g/100g protein) compared to 2.49 g/100g protein in fishmeal. The crude protein of maggot meal is maximized if with poultry manure-derived maggot meal that is oven processed for 55 minutes (43.62%).

Keywords: Amino Acids; Protein; Manure; Maggot Meal; Fishmeal

Abbreviations: CMM: Cow Maggot Meal; SMM: Swine Maggot Meal; PMM: Poultry Maggot Meal; NFE: Nitrogen Free Extract; EAA: Essential Amino Acids; FM: Fish meal; HSD: Honestly Significant Difference; ANOVA: Analysis of Variance.

Introduction

The annual growth of the aquaculture industry in the last two decades stood estimated at 7 - 9% [1,2]. However, the future growth of the aquaculture industry will be largely affected by the availability of suitable, quality, and economical feeds.

In Nigeria, current government policies to promote self-sufficiency in food production and reduce the importation of fish have been a significant boost in raising interest growing the fisheries industry in the country. However, Aquaculture production in Nigeria is faced with some challenges with aquaculture. The cost of feeding is a significant factor affecting the development of aquaculture in Nigeria [3]. Similarly, Hasan, et al. reported that feed is widely regarded as becoming a major constraint to the growth of aquaculture production in many developing countries.

Fagbenro OA, et al. [4] reported that in Nigeria, 60% of the cost of fish feed is accounted for by commercial pellets while supplementary fish feeds account for 40% of the cost. Similarly Sogbesan, et al. [5] indicated that the cost of commercial fish feeds accounts for about 70% of fish farming ventures in Nigeria. This huge percentage is due mainly to the fact that most of the protein ingredients such as fishmeal are imported at the same time locally available alternatives like soya beans and groundnuts also serve as food for humans.

Fishmeal is a conventional source of protein in animal feed because it has a good balance of amino acids vitamin content, palatability and growth factors [6,7]. According to Sugiura S, et al. [8] fishmeal is the central ingredient in commercial fish feeds, especially those used for rearing carnivorous species such as catfishes, salmon, trout, and many marine fishes. About 43% of global fish meal production is utilized by the aquaculture sector [9,10]. However, it is scarce and expensive [11,12].

The search for alternative and sustainable proteins is a significant issue of major importance that needs viable solutions in the short term, making insects an increasingly valuable and attractive fish-feed protein source [13]. Most insects have a better balance of essential amino acids (methionine and lysine) than most grains [14,15]. Several attempt to partially or completely replace fishmeal with other inexpensive and relatively abundant nutrient-rich animal protein sources examples include maggots and other non-conventional insects like winged termites, crickets, cockroaches, locusts, earthworms, garden snails, shrimp waste, poultry waste and plant protein sources such as sunflower, rape seed, soybean meal and cottonseed meal [16-19].

Houseflies utilise decaying organic waste such as manure, vegetables, and exposed food materials to produce animal protein and the larvae can be used to produce a meal (maggot meal). The use of housefly maggots as supplements in the diets of catfish species (*Clarias gariepinus* and *Heterobranchus longifilis*) is reported in Nigeria [20]. Ajani EK, et al. [21] reported that replacing fishmeal with 50 and 100% maggot meal reduced the cost of fish production by 18 and 28%. It, therefore, implies that maggot meal offers an excellent opportunity for the development of low-cost fish feeds.

This study analyzed the nutritional and amino acid profiles of unprocessed and processed housefly larvae (maggots) produced from cow, swine, and poultry manure. In addition, we compared the profiles for maggot meal with the values for fishmeal described in the scientific literature.

Materials and Methods

Maggot Production and Maggot Meal Processing

Maggots used for this study were grown on three organic substrate mixtures comprising cow manure + cow blood (CMM), swine manure + cow blood (SMM) and poultry manure + cow blood (PMM). The cow blood was used as fly attractant. The substrate beds were made wet with water daily. The manure was exposed for the housefly (*Musca domestica*) to lay eggs and was later kept under shade to allow for the development of larvae. Larvae were harvested on day 4 of larval formation using the floatation method.

The manure and larvae were first immersed in water causing the larvae to float. The floating larvae were collected by sieving through a 3mm-mesh size net [22]. The larvae collected were rinsed several times until they attained their characteristic white colour. After the rinsing process, they were blanched in hot water and then exposed to the sun in trays followed by oven drying at a temperature (90℃) at different time regimes (35 minutes, 45 minutes, and 55minutes). Processed larvae were milled using a blender to yield maggot meal. Each treatment was named according to the substrate source: CMM_{35}, CMM_{45}, CMM_{55}, SMM_{35}, SMM_{45}, SMM_{55}, PMM_{35}, PMM_{45}, PMM_{55}, CMMunp, PMMunp and PMMunp.

Laboratory Analysis

The proximate composition AOAC [23] of the unprocessed (raw) and variously processed maggot meal samples was determined to obtain the crude protein, ash, fat, moisture, carbohydrate and crude fibre contents. Moisture was determined by standard methods as described in AOAC [24]. Crude protein contents were determined by Kjeldahl method according to AOAC [25]. Ash contents determination was carried out by standard methods described in AOAC [25], method 942.05. Fat determination (ether-extract) was carried out by procedures described in AOAC [25], method 945.16. Determination of Crude fibre was done using AOAC [25], method 978.10.

The amino acid profile of maggot meal was carried out using Computerized Dihybrid Amino Acid Analyzer by Search Instrument Ltd England.

Statistical Analysis

Data were analysed using R v. 4.0.0. Descriptive statistics were obtained using Rmisc package in R (Hope, 2013) as well as reshaped. Analysis of Variance (ANOVA) was conducted using agricolae package, emmeans package and multiple comparisons were made using multcomp and viewed using multcomp. Mean separation was done using Tukey's Honestly Significant Difference (HSD) as implemented in multcomp and emmeans.

Results and Discussion

Crude protein content ranged between 35.95-43.62g/100g (Table 1); the highest value of 43.62% in treatment PMM_{55} obtained in this study is proof of the high protein content of this particular housefly maggot meal when compared to fishmeal. The crude protein content obtained in this study falls within the range of 43.3 to 46.7% reported by Fasakin EA, et al. [26]; they further stated that the crude protein content level of maggot depends on the drying methods. Awoniyi TAM, et al. [27] also recorded a range of 43 to 62 % crude protein. However, the percentage of crude protein obtained in this study is higher than that reported by Ogunji JO, et al. [28] and Alphonsus OA, et al. [29] with CP of 39.55% and 25% respectively. The fat content of 8.00-16.86% (Table 1) obtained in this study shows that the treatments generally have as much fat as in fish meal (8-11%) as stated in https://www.feedipedia.org. Similarly, Ogunji JO, et al. [28] reported a range of 12.5-21% which is within the level obtained in this study. The Crude fibre values of 1.15-2.91% obtained for maggot meal in this study is minimal compared to fish meal. Carbohydrates indicated high values which ranged between 29.2-45.75%, and a low value of 22.60% was reported by Ayo (2016). Ash content values recorded between 5.82-9.30% in this study were low compared to 18.4%reported for fish meal by feedipedia (https://www.feedipedia.org) and 10-12% reported by Abdur R, et al. [30]. However, Alphonsus OA, et al. [29] reported a value of 6.25% which is within the obtained range values for this study.

The amino-acid content was analysed, and the results showed that maggot meal contains 19 amino acids, including 10 essential amino acids (Tables 2 & 3). The high availability of essential amino acids in this study is consistent with the result reported by Aniebo AO, et al. [31] and Alphonsus OA, et al. [29].

Furthermore, this study supports the report by Ipinmoroti MO, et al. [32] which indicated the presence of favorable amino acids similar to fish meal.

Samples	(%) Protein	Fat	Fibre	Ash	Moisture	Carbohydrates
CMM35	38.05 ± 0.00^{c}	8.00 ± 0.00^{a}	2.90 ± 0.00^{f}	9.30 ± 0.00^{e}	2.45 ± 0.00^{c}	39.30 ± 0.00^{e}
CMM45	38.71 ± 0.01^{de}	8.34 ± 0.00^{b}	2.91 ± 0.01^{f}	9.20 ± 0.00^{e}	2.45 ± 0.00^{c}	41.40 ± 0.03^{f}
CMM55	40.34 ± 0.01^{g}	8.15 ± 0.00^{a}	2.85 ± 0.00^{f}	9.20 ± 0.00^{e}	2.45 ± 0.00^{c}	38.51 ± 0.48^{e}
SMM35	35.95 ± 0.00^{a}	9.21 ± 0.01^{d}	1.96 ± 0.00^{cd}	8.15 ± 0.00^{d}	2.00 ± 0.00^{a}	45.74 ± 0.01^{h}
SMM45	36.77 ± 0.00^{b}	9.00 ± 0.00^{c}	1.93 ± 0.00^{cd}	8.15 ± 0.00^{d}	2.20 ± 0.00^{b}	44.95 ± 0.01^{h}
SMM55	38.93 ± 0.01^{ef}	9.78 ± 0.00^{e}	1.87 ± 0.00^{bc}	8.15 ± 0.00^{d}	2.20 ± 0.00^{b}	42.27 ± 0.01^{g}
PMM35	40.16 ± 0.01^{g}	16.86 ± 0.00^{k}	1.15 ± 0.00^{a}	6.85 ± 0.00^{c}	3.00 ± 0.00^{d}	34.98 ± 0.01^{d}
PMM45	42.20 ± 0.00^{h}	16.22 ± 0.00^{j}	1.16 ± 0.00^{a}	6.80 ± 0.00^{c}	3.15 ± 0.00^{de}	32.47 ± 0.01^{b}
PMM55	43.62 ± 0.00^{i}	15.96 ± 0.00^{i}	1.23 ± 0.00^{a}	6.80 ± 0.00^{c}	3.20 ± 0.00^{e}	29.20 ± 0.01^{a}
CMMunp	38.45 ± 0.00^{d}	12.70 ± 0.10^{h}	1.83 ± 0.01^{b}	6.70 ± 0.10^{c}	8.50 ± 0.10^{g}	35.25 ± 0.05^{d}
SMMunp	39.25 ± 0.20^{f}	10.03 ± 0.01^{f}	2.09 ± 0.05^{e}	6.40 ± 0.00^{b}	8.80 ± 0.00^{h}	35.30 ± 0.10^{d}
PMMunp	40.12 ± 0.00^{g}	12.41 ± 0.01^{g}	1.97 ± 0.01^{d}	5.82 ± 0.03^{a}	8.20 ± 0.00^{f}	33.70 ± 0.10^{c}
p-value	2.0×10^{-16}	2.0×10^{-16}	2.0×10^{-16}	2.0×10^{-16}	2.0×10^{-16}	2.0×10^{-16}

Table 1: Proximate analysis of unprocessed maggots and processed maggots under constant (90^{o}c) temperature at different time regimes. Means in the same column followed by different superscripts differ significantly ($p<0.05$).
Means in the same column followed by different superscripts differ significantly ($p<0.05$)
CMM_{35}= cow maggot meal oven dried for 35minutes
CMM_{45}= cow maggot meal oven dried for 45minutes
CMM_{55}= cow maggot meal oven dried for 55minutes
SMM_{35}= swine maggot meal oven dried for 35minutes
SMM_{45}= swine maggot meal oven dried for 45minutes
SMM_{55}= swine maggot meal oven dried for 55minutes
PMM_{35}= Poultry maggot meal oven dried for 35minutes
PMM_{45}= Poultry maggot meal oven dried for 45minutes
PMM_{55}= Poultry maggot meal oven dried for 55minutes
CMM_{unp}= Unprocessed maggots from cow manure
SMM_{unp}= Unprocessed maggots from swine manure
PMM_{unp}= Unprocessed maggots from poultry manure

Samples	(g/100g protein) Tryptophan	Histidine	Leucine	Isoleucine	Phenylalanine	Valine	Lysine	Methionine	Threonine	Arginine
CMM35	4.84 ± 0.00^{g}	1.34 ± 0.01^{e}	1.84 ± 0.01^{f}	4.01 ± 0.01^{hi}	8.78 ± 0.01^{f}	3.87 ± 0.01^{de}	3.63 ± 0.00^{g}	3.71 ± 0.01^{h}	$2.70 \pm 0.00b^{c}$	3.71 ± 0.00^{a}
CMM45	4.95 ± 0.01^{h}	1.36 ± 0.01^{e}	1.82 ± 0.00^{ef}	4.08 ± 0.00^{i}	8.81 ± 0.01^{f}	3.84 ± 0.04^{d}	3.72 ± 0.01^{h}	4.00 ± 0.00^{j}	2.83 ± 0.00^{cd}	4.16 ± 0.01^{ab}
CMM55	4.94 ± 0.01^{h}	1.53 ± 0.01^{f}	1.76 ± 0.01^{cd}	3.98 ± 0.00^{h}	8.88 ± 0.00^{f}	3.76 ± 0.01^{d}	3.81 ± 0.01^{i}	4.66 ± 0.00^{k}	2.90 ± 0.00^{de}	4.30 ± 0.01^{abc}
SMM35	3.01 ± 0.01^{d}	1.05 ± 0.00^{c}	2.96 ± 0.01^{i}	3.04 ± 0.01^{g}	7.93 ± 0.00^{e}	3.87 ± 0.01^{de}	3.85 ± 0.00^{ij}	3.26 ± 0.00^{g}	3.46 ± 0.00^{f}	3.45 ± 0.00^{a}
SMM45	3.21 ± 0.01^{e}	1.06 ± 0.01^{cd}	2.74 ± 0.00^{h}	2.01 ± 0.01^{e}	7.25 ± 0.01^{d}	3.75 ± 0.00^{d}	3.87 ± 0.01^{j}	3.72 ± 0.01^{h}	3.54 ± 0.01^{f}	3.80 ± 0.01ab
SMM55	3.62 ± 0.01^{f}	1.13 ± 0.01^{d}	2.25 ± 0.00^{g}	2.85 ± 0.00^{f}	7.34 ± 0.01^{d}	3.84 ± 0.01^{d}	4.01 ± 0.01^{k}	3.78 ± 0.01^{i}	3.87 ± 0.01^{g}	3.83 ± 0.01^{ab}
PMM35	2.29 ± 0.00^{a}	0.69 ± 0.00^{a}	1.69 ± 0.01^{b}	0.63 ± 0.01^{a}	3.31 ± 0.00^{a}	2.38 ± 0.01^{a}	1.74 ± 0.01^{a}	1.06 ± 0.01^{a}	1.61 ± 0.00^{a}	6.16 ± 1.49^{bcd}
PMM45	2.38 ± 0.00^{b}	0.65 ± 0.01^{a}	1.72 ± 0.00^{bc}	0.94 ± 0.01^{b}	3.36 ± 0.01^{a}	3.41 ± 0.01^{c}	2.74 ± 0.00^{e}	1.74 ± 0.01^{d}	2.64 ± 0.01^{b}	7.69 ± 0.01^{d}
PMM55	2.36 ± 0.01^{b}	0.82 ± 0.01^{b}	1.77 ± 0.00^{de}	1.27 ± 0.01^{d}	3.42 ± 0.00^{a}	4.12 ± 0.00^{f}	2.87 ± 0.00^{f}	1.66 ± 0.01^{c}	2.54 ± 0.01^{b}	7.78 ± 0.00^{d}
CMMunp	2.67 ± 0.01^{c}	1.00 ± 0.02^{c}	1.51 ± 0.01^{a}	1.07 ± 0.01^{c}	5.69 ± 0.01^{c}	3.10 ± 0.00^{b}	2.37 ± 0.01^{b}	2.68 ± 0.00^{f}	3.05 ± 0.01^{e}	6.70 ± 0.10^{cd}
SMMunp	2.23 ± 0.01^{a}	1.06 ± 0.02^{c}	1.50 ± 0.00^{a}	1.09 ± 0.01^{c}	4.72 ± 0.08^{b}	3.11 ± 0.05^{b}	2.65 ± 0.01^{d}	2.08 ± 0.00^{e}	3.02 ± 0.00^{e}	5.83 ± 0.03^{abcd}
PMMunp	2.40 ± 0.02^{b}	1.02 ± 0.00^{c}	1.50 ± 0.02^{a}	0.99 ± 0.03^{b}	4.73 ± 0.05^{b}	4.00 ± 0.06^{ef}	2.57 ± 0.01^{c}	1.44 ± 0.02^{b}	2.70 ± 0.10^{bc}	4.60 ± 0.20^{abc}
p-value	$<2.0 \times 10^{-16}$	3.38×10^{-14}	$<2.0 \times 10^{-16}$	$<2.0 \times 10^{-16}$	$<2.0 \times 10^{-16}$	2.32×10^{-13}	$<2.0 \times 10^{-16}$	$<2.0 \times 10^{-16}$	2.36×10^{-13}	4.35×10^{-5}

Table 2: Essential amino acids profile of unprocessed maggots and processed maggots at constant temperature (90^{o}c) at different time regimes.

Means in the same column followed by different superscripts differ significantly ($p<0.05$)

CMM_{35}= cow maggot meal oven dried for 35minutes
CMM_{45}= cow maggot meal oven dried for 45minutes
CMM_{55}= cow maggot meal oven dried for 55minutes
SMM_{35}= swine maggot meal oven dried for 35minutes
SMM_{45}= swine maggot meal oven dried for 45minutes
SMM_{55}= swine maggot meal oven dried for 55minutes
PMM_{35}= Poultry maggot meal oven dried for 35minutes
PMM_{45}= Poultry maggot meal oven dried for 45minutes
PMM_{55}= Poultry maggot meal oven dried for 55minutes
CMM_{unp}= Unprocessed maggots from cow manure
SMM_{unp}= Unprocessed maggots from swine manure
PMM_{unp}= Unprocessed maggots from poultry manure

Samples	(g/100g protein) Alanine	Aspartate	Glutamate	Glycine	Tyrosine	Cysteine	Proline	Serine	Asparagine
CMM35	2.52 ± 0.00^{cd}	5.14 ± 0.00^{e}	2.42 ± 0.00	7.83 ± 0.01^{g}	9.62 ± 0.01^{g}	3.13 ± 0.01^{de}	2.85 ± 0.00^{a}	4.84 ± 0.00^{f}	3.62 ± 0.01^{d}
CMM45	2.43 ± 0.01^{c}	5.46 ± 0.01^{f}	2.52 ± 0.01	7.85 ± 0.01^{g}	9.73 ± 0.01^{g}	3.12 ± 0.01^{de}	3.05 ± 0.01^{ab}	4.95 ± 0.01^{f}	3.87 ± 0.01^{de}
CMM55	2.31 ± 0.01^{b}	5.74 ± 0.00^{g}	3.16 ± 0.01	7.84 ± 0.04^{g}	8.72 ± 0.00^{ef}	3.26 ± 0.00^{ef}	3.35 ± 0.00^{bcd}	4.94 ± 0.01^{f}	4.05 ± 0.00^{ef}
SMM35	2.98 ± 0.01^{f}	5.82 ± 0.00^{g}	1.75 ± 0.00	6.34 ± 0.00d	8.11 ± 0.01^{d}	3.05 ± 0.01^{d}	3.15 ± 0.00^{ab}	3.01 ± 0.01^{b}	4.26 ± 0.00^{f}
SMM45	2.85 ± 0.00^{e}	5.23 ± 0.01^{e}	1.77 ± 0.01	7.57 ± 0.01^{f}	8.43 ± 0.01^{de}	3.13 ± 0.01^{de}	3.56 ± 0.00^{cde}	3.21 ± 0.01^{bcd}	4.62 ± 0.00^{g}
SMM55	2.00 ± 0.00^{a}	4.62 ± 0.01^{d}	1.72 ± 0.00	8.52 ± 0.00^{h}	8.14 ± 0.00^{d}	3.42 ± 0.00^{f}	3.77 ± 0.00^{e}	3.62 ± 0.01^{e}	4.24 ± 0.00^{f}
PMM35	4.19 ± 0.02^{h}	3.26 ± 0.00^{b}	3.21 ± 0.01	1.49 ± 0.00^{a}	8.36 ± 0.00^{d}	2.81 ± 0.00^{b}	3.21 ± 0.00^{abc}	3.24 ± 0.00^{cd}	1.19 ± 0.00^{a}
PMM45	4.23 ± 0.01^{h}	3.37 ± 0.01^{b}	9.82 ± 6.51	4.53 ± 0.02^{b}	8.42 ± 0.01^{de}	2.96 ± 0.01^{bcd}	7.72 ± 0.01^{h}	3.40 ± 0.01^{de}	1.60 ± 0.01^{b}
PMM55	4.64 ± 0.01^{i}	2.96 ± 0.01^{a}	3.48 ± 0.00	4.66 ± 0.01^{b}	8.76 ± 0.01^{f}	3.00 ± 0.00^{cd}	7.12 ± 0.00^{g}	3.48 ± 0.01^{e}	1.64 ± 0.01^{b}
CMMunp	2.24 ± 0.04^{b}	4.64 ± 0.04^{d}	2.70 ± 0.10	6.65 ± 0.05^{e}	7.06 ± 0.02^{c}	3.03 ± 0.01^{cd}	3.60 ± 0.20^{de}	3.10 ± 0.10^{bc}	3.75 ± 0.15^{d}
SMMunp	2.61 ± 0.01^{d}	3.70 ± 0.10^{c}	1.75 ± 0.05	5.85 ± 0.05^{c}	6.60 ± 0.20^{b}	2.85 ± 0.05^{bc}	3.40 ± 0.10^{bcde}	2.70 ± 0.10^{a}	3.89 ± 0.09^{de}
PMMunp	3.73 ± 0.05^{g}	3.01 ± 0.01^{a}	2.05 ± 0.05	4.70 ± 0.10^{b}	4.40 ± 0.00^{a}	2.50 ± 0.10^{a}	4.55 ± 0.05^{f}	3.01 ± 0.01^{b}	2.00 ± 0.02^{c}
p-value	$<2.0 \times 10^{-16}$	2.23×10^{-16}	0.283	$<2.0 \times 10^{-16}$	9.94×10^{-15}	3.16×10^{-8}	1.27×10^{-14}	1.80×10^{-13}	1.39×10^{-14}

Table 3: Non-essential amino acids profile of unprocessed maggots and processed maggots at constant temperature (90^{o}c) at different time regimes.
Means in the same column followed by different superscripts differ significantly ($p<0.05$)
CMM_{35}= cow maggot meal oven dried for 35minutes
CMM_{45}= cow maggot meal oven dried for 45minutes
CMM_{55}= cow maggot meal oven dried for 55minutes
SMM_{35}= swine maggot meal oven dried for 35minutes
SMM_{45}= swine maggot meal oven dried for 45minutes
SMM_{55}= swine maggot meal oven dried for 55minutes
PMM_{35}= Poultry maggot meal oven dried for 35minutes
PMM_{45}= Poultry maggot meal oven dried for 45minutes
PMM_{55}= Poultry maggot meal oven dried for 55minutes
CMM_{unp}= Unprocessed maggots from cow manure
SMM_{unp}= Unprocessed maggots from swine manure
PMM_{unp}= Unprocessed maggots from poultry manure

When compared with the amino acid profile of fish meal it was observed that one of the most limiting essential amino acids methionine, was recorded to be higher in CMM and SMM with values ranging between 3.78-4.66 g/100g protein, treatment CMM_{55} recorded the highest level of 4.66 g/100g protein compared to 2.49 g/100g protein in fishmeal (https://www.feedipedia.org) (Figure 1).The high values of methionine in this study support the work of Aniebo

AO, et al. [31], who recorded high methionine values in maggot meal compared to fish meal and with those of other conventional protein sources. Isoleucine content in this study ranged between 0.09-4.08g/100g protein (Table 2); CMM treatments generally have higher contents with the highest level of 4.08g /100g protein recorded compare to fish meal 3.87 g/100g protein (Figure 1).

All treatments in this study contain higher levels of tryptophan (between 2.23-4.95 g/100g protein Table 2) compared to fishmeal (0.92) with the lowest and highest values recorded in SMMunp Figure 4 and CMM_{45} Figure 1 respectively. The presence of tryptophan in this study is contrary to the findings of Aniebo AO, et al. [31], who reported the complete absence of tryptophan in their research of essential amino acids in maggot meal.

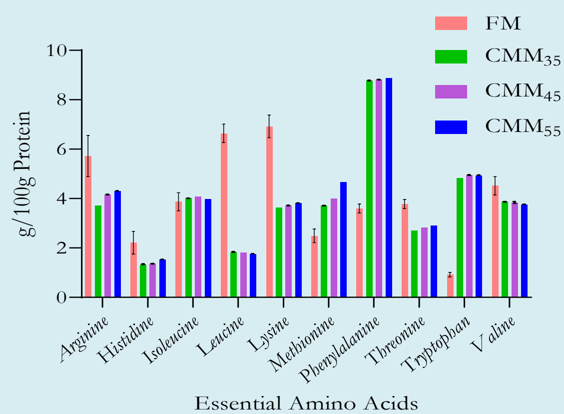

Figure 1: Comparison of amino acids from various treatments of processed cow maggot meal (CMM) and Fish meal (FM).

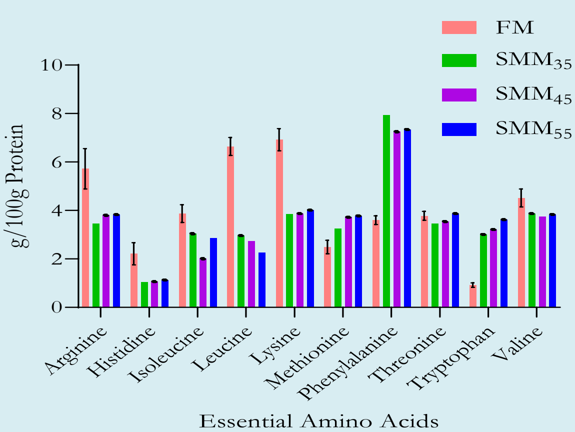

Figure 2: Comparison of amino acids from various treatments of processed swine maggot meal (SMM) and fish meal (FM).

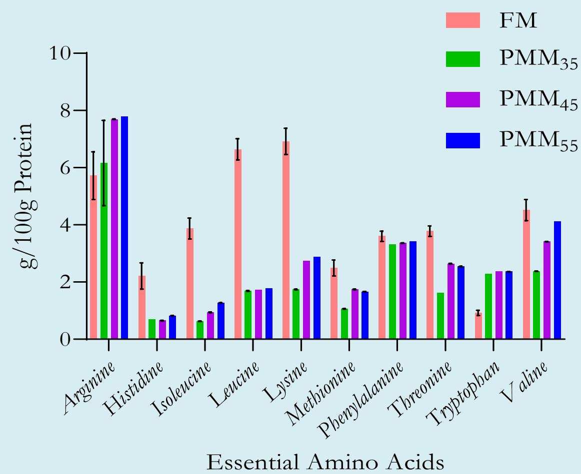

Figure 3: Comparison of amino acids from various treatments of processed poultry maggot meal (PMM) and fish meal (FM).

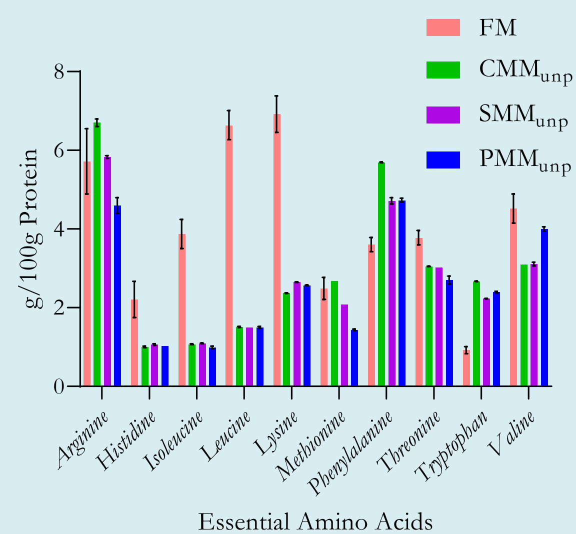

Figure 4: Comparison of amino acids from various treatments of unprocessed housefly maggot (CMMunp, SMMunp and PMMunp) and Fish meal (FM).

Note: Fishmeal data was obtained from feedipedia@ https://www.feedipedia.org/node/11687. Fishmeal with 60 – 68% crude protein on a wet weight basis was used to present the data on feedipedia.

In terms of arginine, the values observed in this study ranged between 3.45-7.78 g/100g protein, higher levels exist in all treatments of poultry maggot meals (Figure 3) and unprocessed (raw) maggots (Figure 4). PMM_{55} recorded the highest content level of 7.78 g/100g protein compared to fish meal 5.72 (feedipedia: https://www.feedipedia.org). Furthermore, arginine content in all the treatments minimally increased with longer processing time (oven-drying) under constant temperature (90°c). Glycine values range from 1.49-8.52 g/100g protein, Cow maggot meal (CMM) and swine maggot meal (SMM) treatments recorded higher levels (Table 3). SMM_{55} recorded the highest level of 8.52 g/ 100g protein compared to fish meal 6.4. Higher proline content was observed in treatment PMM_{45} with a value of 7.72 g/100g protein than fishmeal with 4.2g/100g protein. This nutrient analysis study showed higher serine levels in cow maggot meal (CMM) treatments than fishmeal with the highest value of 4.95 g /100g protein (CMM_{45}) than fish meal 4.2

Conclusion

Crude protein of maggot meal is maximized if with poultry manure-derived maggot meal that is oven processed for 55 minutes (43.62%). Processing of maggot meal derived from cow manure and swine manure at any duration (35-55 minutes) in the oven produces a meal that has higher levels of methionine, phenylalanine, and tryptophan compared to fishmeal. In addition, maggot meal from poultry manure dried in the oven for 35-55 minutes produces a meal that has higher arginine and tryptophan than fishmeal. All non-oven processed maggot meals had higher levels of phenylalanine and tryptophan than fishmeal.

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