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Production of Superworm Larvae (*Zophobas Morio Fabricius*, 1776) with Azolla and Soft Pollard as Substrate: It's Effect as Substitute to Protein Source on the Growth Performance, Carcass Yield, and Economics of Broiler Chicken

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ABSTRACT

The study was conducted to assess the potential of superworm larvae *Zophobas morio* as protein source in broiler chicken ration. A total of 50 grams of larvae was cultivated in a controlled environment and then allocated into uniformly-sized boxes, following a completely randomized design (CRD) with 12 replications per treatment involving combined substrates: A) azolla-soft pollard, B) azolla-rice bran D2, and C) azolla-ground yellow corn. The larvae produced using azolla-soft pollard substrate were used as the protein ingredient in the subsequent experiment. The selection of the larvae was based on the highest yield and lowest neutral detergent fiber value. One hundred twenty-eight (128) day-old broiler chicks were distributed to the 4 dietary treatments in randomized complete block design with cage location as the blocking factor. Ration were formulated to contain 0%, 2%, 4%, and 6% superworm larvae meal (SLM) as protein ingredient. The experimental design used was Randomized Complete Block Design (RCBD) and data gathered were analyzed using one-way analysis of variance of SAS university edition. Broilers under control group exhibited better growth performance compared to those with SLM inclusion. However, gradual improvement in growth performance and economic analysis for birds fed at 6% SLM inclusion was observed. Moreover, increase in carcass and gizzard weight was also observed when SLM was included at 4% and 6% in the diet. Incorporating 6% superworm larvae meal (SLM) into the diets of broiler chickens can lead to a gradual enhancement in their growth performance. To minimize chitin content, it is recommended to harvest superworms at a lower instar stage.

Keywords: Broiler, chitin, insect, superworm larvae, *Zophobas*

INTRODUCTION

The increasing demand for protein in the animal farming industry is driven not

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only by its expansion but also due to limited low-cost protein sources (Van Huis 2013). The compensation of amino acid shortages from plant origin feed by incorporating expensive fish meal to expensive SBM-based rations (Agazzi 2016) results to costly poultry feed. Consequently, incurring feed accounting less than the average 70% from the total production cost using cheaper protein feeds has been a challenge to the poultry industry (Norrie 2021).

Insects produced through controlled cultivation and collection, has emerged as viable alternative animal diet (Liu & Pipan 2020). Despite its nutritional value and potential as a feed source, the use of superworms (*Zophobas morio*) have been overlooked. Superworm larvae, along with other insects, shows promising insect-based feed production, especially in poultry (Rumbos & Athanassiou 2021). Benzertiha et al (2019) investigated the effect of *Tenebrio molitor* and *Zophobas morio* as functional feed additives for broiler chickens, observing positive growth performance and immune system traits with the inclusion of 0.2% and 0.3% of these insect full-fat meals, respectively.

The choice of substrate used in the production of superworm meal greatly influences its yield and chemical composition, yet this area remains relatively understudied. As a result, the sustainable production of alternative animal protein sources has emerged as a captivating research field.

MATERIALS AND METHODS

Experiment 1. Production of Superworm Larvae Meal

A total of 2,000 two-month-old *Zophobas morio* were isolated to facilitate pupation, as crowded conditions prevent larvae from successfully reaching this stage (Tschinkel, 1993). Pupation lasts for 14 days, after which the larvae molt into beetles (Soon, 2021). Egg trays and modified layered cartons were used as shelters and for egg deposition and hatchery. The substrates were preheated at temperatures between 35-55°C for 5 minutes to eliminate potential pest. Beetles were transferred to a new bin with fresh substrate to continue their reproductive cycle, while the eggs were left with the substrate for observation until harvest, which typically occurred after 10-12 weeks (Thijs, 2021). At this stage, superworm larvae are considered XL-sized (Van Den Burg, 2022).

Manual sieving with 2mm screen was done to isolate worms from excreta. Superworms were equally distributed to similar sized trays 30.48 cm x 17.78 cm x 7.62 cm and placed in a wooden rack 101 cm x 101 cm x 164 cm. Three substrates (soft pollard, rice bran D2, and ground corn) at 100 g were used alongside with fresh azolla.

Production of superworm larvae with azolla and soft pollard as substrate

Table 1. Changes in the amount of supplement and substrate used in the production of superworm larvae

WEEK	AZOLLA, g	SOFT POLLARD, g	RICE BRAN D2, g	GROUND CORN, g
1st	10-15 grams	100	100	100
2nd	20-25 grams	100	100	100
3rd	25-30 grams	150	150	150
4th	35-40 grams	200	200	200

Replenishment of substrates were applied every week and increased thereafter to provide sufficient moisture to growing larvae. Table 1 shows the amount of azolla and the specific substrate given to the worms.

Design and Treatments

The study was laid out in a Completely Randomized Design (CRD). Twelve (12) layers of the rack. Each layer was assigned 3 substrate treatments on random with 50 grams of superworms per replicate.

Experiment 2. Performance of Broilers fed with Superworm Meal Larvae

A total of 128-day-old chicks (Cobb Strain) were obtained from a verified local supplier and was vaccinated against New Castle Disease (NCD). The study followed a Randomized Complete Block Design (RCBD) with 8 cage locations as blocks. Each block was assigned 4 dietary treatments, randomly arranged with 4 birds per treatment. The area was disinfected as a biosecurity measure. The superworm larvae meal (SLM) was oven dried at 60°C until constant weight was achieved and then finely powdered using a Wiley mill. The powdered SLM was incorporated into the home mixed ration (HMR), following the nutrient requirement for broilers of PHILSAN (2010). The broiler carcasses were fabricated in compliance with the Philippine National Standard (PNS, 2019) for slaughter on the 36th day.

Table 2. Home Mixed Ration Formulation for Broiler with Inclusion rates of Superworm Meal at 2%, 4%, & 6%.

INCLUSION RATE, %									
INGREDIENTS	BOOSTER			STARTER			FINISHER		
	2%	4%	6%	2%	4%	6%	2%	4%	6%
Corn Yellow	47.39	45.94	44.50	39.28	38.51	38.10	38.21	37.18	38.98
SB Low Protein	39.15	38.57	37.98	29.44	29.25	28.90	24.36	23.75	23.70
Copra Expeller	0.00	0.00	0.00	5.00	5.00	5.00	19.50	10.00	9.60
Wheat Pollard Soft	0.00	0.00	0.00	4.46	3.52	2.24	0.46	3.00	3.00
Molasses	0.00	0.00	0.00	1.50	1.50	1.50	2.00	2.00	2.00
Coconut Oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.40	3.20
Rice Bran D1	3.00	3.00	3.00	10.00	10.00	10.00	15.00	11.80	8.50
Superworm Larvae Meal	2.00	4.00	6.00	2.00	4.00	6.00	2.00	4.00	6.00
Acetic Acid	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65
Monocalcium Phosphate	1.59	1.60	1.61	1.35	1.37	1.39	1.24	1.25	1.28
Limestone	1.01	1.02	1.03	1.05	1.05	1.05	0.99	0.87	1.00
Choline Chloride	0.01	0.01	0.01	0.10	0.10	0.10	0.01	0.01	0.01
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Zinc Oxide	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Mastersorb Toxin Binder	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Enzyme Elaya	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin Elaya	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
DL Methionine> AA	0.15	0.16	0.17	0.09	0.09	0.08	0.03	0.04	0.04
L-lysine	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.00
L-Threonine	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00

Table 3. Guaranteed Analysis of the Home- Mixed Ration for Broiler.

Actual %												
NUTRIENT NAME	BOOSTER	BOOSTER ACTUAL			STARTER	STARTER ACTUAL			FINISHER	FINISHER ACTUAL		
	Requirement	2%	4%	6%	Requirement	2%	4%	6%	Requirement	2%	4%	6%
Weight, kgs	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Crude Protein, %	21.50	21.50	21.50	21.50	19.30	19.30	19.30	19.30	18.00	18.00	18.00	18.00
ME, %	2800.00	2824.61	2812.65	2800.70	2700.00	2700.00	2700.00	2707.09	2700.00	2700.00	2700.21	2702.53
Calcium, %	0.84	0.90	0.90	0.90	0.81	0.86	0.86	0.86	0.76	0.81	0.76	0.81
Available Phosphorus, %	0.45	0.45	0.45	0.45	0.41	0.41	0.41	0.41	0.38	0.38	0.38	0.38
Lysine, %	1.12	1.21	1.19	1.17	0.97	1.04	1.00	1.00	0.86	0.90	0.88	0.86
Methionine, %	0.48	0.49	0.49	0.50	0.38	0.40	0.39	0.38	0.32	0.33	0.32	0.32
M + C, %	0.84	0.84	0.84	0.84	0.68	0.72	0.71	0.69	0.59	0.63	0.62	0.61
Threonine, %	0.78	0.81	0.79	0.78	0.62	0.78	0.70	0.69	0.57	0.66	0.64	0.63
Tryptophan, %	0.22	0.26	0.26	0.26	0.19	0.23	0.23	0.22	0.16	0.21	0.20	0.20

Statistical Analysis

Data were analyzed in one-way analysis of variance (ANOVA) in RCBD using

SAS university edition. Differences among treatments were declared significant at P<0.05 using trend analysis. The results were presented as mean values and standard error of the means.

RESULTS AND DISCUSSIONS

Yield and chemical composition of superworm larvae meal

Shown in Table 4 is the yield and chemical composition of the superworm larvae meal (SLM) produced using combination of azolla and concentrate feeds as substrates. Results showed that yield was highest when SLM were fed azolla-soft pollard combination in D7 (p<0.0001), D14 (p<0.0001), D21 (p<0.0001), and D28 (p<0.0001) compared to azolla-rice bran D2 and azolla-ground corn as substrates. However, in the chemical analysis (Table 5), the superworm larvae given azolla-wheat pollard substrate had the lowest DM (43.60%), CP (18.08%), EE (34.95%), NDF (43.14%), ash (1.99%), and gross energy (6103.75 cal/g) when compared to other substrates.

Table 4. Yield (g/0.1458 ft^3) of superworm larvae given a combination of azolla-feed concentrates as substrates

DAY	SOFT POLLARD	RICE BRAN D2	GROUND CORN	SEM	P-VALUE
7	93.42 ^{a}	68.18 ^{c}	82.31 ^{b}	1.16	<.0001
14	114.00 ^{a}	88.18 ^{c}	104.62 ^{b}	1.92	<.0001
21	146.92 ^{a}	109.45 ^{c}	130.92 ^{b}	2.03	<.0001
28	183.00 ^{a}	142.09 ^{c}	161.08 ^{b}	2.48	<.0001

* Means of the same superscripts are not significant

Table 5. Chemical composition of superworm larvae given a combination of azolla-feed concentrates as substrates

ITEM	SOFT POLLARD	RICE BRAN D2	GROUND CORN	SEM	P-VALUE
DM, %	43.60 ^{c}	56.14 ^{a}	49.64 ^{b}	1.41	<.0001
CP, %	18.08 ^{a}	20.73 ^{a}	18.40 ^{a}	2.56	0.4709
EE, %	34.95 ^{b}	42.46 ^{a}	45.18 ^{a}	1.18	0.0003
NDF, %	43.14 ^{b}	53.84 ^{a}	51.69 ^{a}	3.47	0.0066
Ash, %	1.99 ^{a}	2.34 ^{a}	2.38 ^{a}	0.01	0.0888
GE, cal/g	6103.75 ^{b}	6503.50 ^{a}	6428.00 ^{a}	1111.271	<.0001

* Means of the same superscripts are not significant

According to Oonincx et al (2015), nutrition is the key driver of the nutrient makeup of the insect's body. SLM had higher yield across each week with azolla-soft pollard combination. However, the larvae composition was chemically inferior, and larvae given other substrates must have matured earlier, increasing nutrients like chitin and NDF values. Higher NDF dictates high indigestible fractions not suitable for broiler. The researcher chose azolla-soft pollard for mass production due to its higher yield and low NDF. On the study of Pinotti and Ottoboni (2021), black soldier fly (BSF) demonstrated efficient bio-conversion of high-fiber by-products, converting fiber into fat which can be related to the worms being fed with fibrous substrate in this study.

Broiler Performance

Feed Intake

Table 6 shows the voluntary feed intake (VFI) of broilers given SLM inclusion in the ration. At D7 to D21, there were cubic trends ($p<0.0001$ across all weeks) where VFI dropped when 2% of SLM was compounded in the broiler ration. However, VFI increased at a slower rate from 4% to 6% SLM inclusion. Slow increase in VFI from 4% to 6% was not sustained at D28 and D35, when quadratic trend ($p<0.0041$ and $p<0.0001$, respectively) was obtained. Nevertheless, the total VFI was showing cubic trend ($p=0.0013$) where gradual increase was noted when broilers were given SLM from 2% to 6%.

Table 6. Shows the voluntary feed intake (VFI) of broilers fed with varying levels superworm larvae meal in the ration

DAY	A (CONTRO	B (2%SLM)	C (4%SLM)	D (6%SLM)	SEM	DIET	LINEAF	QUADRATI	CUBIC
7	211.63	152.23	166.47	164.4	2.95	<.0001	<.0001	<.0001	<.0001
14	428.28	314.06	306.06	328.13	7.34	<.0001	<.0001	<.0001	<.0001
21	652.5	457.47	476.94	581.69	15.50	<.0001	<.0001	<.0001	<.0001
28	763.79	719.2	727.24	726.9	7.42	0.0007	0.0031	0.0041	0.0602
35	850.38	832.71	832.11	834.41	1.81	<.0001	<.0001	<.0001	0.0946
Total	2906.58	2475.67	2508.82	2635.52	23.51	<.0001	<.0001	<.0001	0.0013

According to Andersen (1995), the palatability of SLM is influenced by the presence of chitin, which acts as a resilient component of the insects' bodies. Reduced VFI observed in broilers fed with SLM may be attributed to the chitin content in the larvae. High NDF composition of SLM, indicates bulkiness structure due to chitin of superworm, resulted to poor VFI. Bovera et al. (2015) reported low VFI in broilers fed *Tenobrio Molitor* meal compared to those fed full soybean meal diet. Additionally, Khatun et al. (2003) observed reduced VFI when broilers were fed silkworm pupae at 2%, 4%, and 6% as a partial replacement for fish meal. However, the gradual increase in VFI at 4% and 6% SLM in the diet could be attributed to a compensatory mechanism aimed at satisfying the nutrient requirements of the broilers.

Weight gain, daily gain, and body weight

Presented in Table 7 and Table 8 are the weight gain (WG) and average daily gain (ADG) of broilers given SLM inclusion in the ration. Both WG and ADG were observed higher when broilers were given control diet (Diet A). The WG had dropped when the broilers were given SLM inclusion in the broiler ration. However, the trend was cubic at D7 (p<0.0001), quadratic at D14 (p<0.0001), cubic at D21 (p=0.006), quadratic at D28 (p<0.0013), quadratic at D35 (p<0.0367) and cubic in overall gain (p=0.0002).

Table 9 shows the weekly bodyweight of the broilers given a diet of SLM. Data showed that across all weeks, the trend was cubic. Highest BW were recorded in broilers given the control diet and the least when the birds received 2% SLM inclusion. When broilers were given 4% SLM, BW were apparently increased and this observation slightly improved further at 6% SLM inclusion in the broiler's diet.

Table 7. Weight gain (g) of broiler chicken fed with varying levels superworm larvae meal in the ration

DAY	A (CONTROL)	B (2% - SLM)	C (4% -SLM)	D (6% -SLM)	SEM	DIET	LINEAR	QUADRATIC	CUBIC
7	152.56	86.69	102.50	105.72	3.98	<.0001	<.0001	<.0001	<.0001
14	261.22	152.97	153.16	191.06	13.11	<.0001	<.0001	<.0001	0.0821
21	372.75	191.97	232.59	320.69	18.62	<.0001	0.0552	<.0001	0.006
28	412.50	278.44	273.19	299.69	21.74	0.0005	0.002	0.0013	0.3294
35	290.81	226.19	229.38	237.34	16.27	0.0345	0.0424	0.0367	0.3961
Total	1489.84	936.25	990.81	1154.5	27.6505	<.0001	<.0001	<.0001	0.0002

Table 8. Average daily gain (g) of broiler chicken fed with varying levels superworm larvae meal in the ration

DAY	A (CONTROL)	B (2% - SLM)	C (4% -SLM)	D (6% -SLM)	SEM	DIET	LINEAR	QUADRATIC	CUBIC
7	21.80	12.38	14.64	15.10	0.57	<.0001	<.0001	<.0001	<.0001
14	37.32	21.85	21.88	27.30	1.87	<.0001	<.0001	<.0001	0.0821
21	53.25	27.43	33.23	45.81	2.66	<.0001	0.0553	<.0001	0.0060
28	58.93	39.78	39.03	42.81	3.11	0.0005	0.002	0.0013	0.3298
35	41.54	32.31	32.77	33.91	2.32	0.0345	0.0424	0.0367	0.3961
Average	42.57	26.75	28.31	32.99	0.79	<.0001	<.0001	<.0001	0.0002

Table 9. Body weight (g) of broiler chicken fed with varying levels superworm larvae meal in the ration

DAY	A (CONTROL)	B (2% - SLM)	C (4% -SLM)	D (6% -SLM)	SEM	DIET	LINEAR	QUADRATIC	CUBIC
7	195.53	128.19	143.97	147.75	3.82	<.0001	<.0001	<.0001	<.0001
14	456.75	281.16	297.12	338.81	13.54	<.0001	<.0001	<.0001	0.0002
21	829.50	473.13	529.72	659.50	13.70	<.0001	<.0001	<.0001	<.0001
28	1242.00	751.56	802.91	959.19	24.29	<.0001	<.0001	<.0001	0.0001
35	1532.81	977.75	1032.28	1196.53	27.58	<.0001	<.0001	<.0001	0.0002

Broiler chickens are provided with different protein sources, which include animal-derived options such as superworms, owing to their high protein content. When birds are provided with highly digestible protein and energy, it results in improved performance in terms of WG, ADG, and BW. The broilers given the control diet (Diet A) had lower indigestible fractions compared to SLM-based ration. The presence of chitin in SLM may have influenced overall digestibility. According to Merzendorfer and Zimoch (2003), chitin is not digestible by poultry, especially broilers, but it may have prebiotic effects.

In this study, control was superior among all SLM diets in terms of WG, ADG, and BW (Quennedey et al., 1995). The SLM used was the 18th instar, XL size, with a chitin content of 3.9-6% (Adámková et al., 2017). Chitin levels in insects vary widely, as influenced by species, sex, and instar (Henriques et al., 2020). Higher VFI at 4% and 6% SLM inclusion was observed, indicating a compensatory mechanism to meet broilers' requirements. This led to increased digestible protein and energy, resulting in higher WG, ADG, and BW for broilers given 4% and 6% SLM.

Feed efficiency

Feed conversion ratio (FCR) is a measure of feed efficiency in broilers with lower values perceived as more efficient conversion of feed to meat. As shown in Table 10, broilers were more efficient given the commercial diet across all weeks. Among the SLM diets, FCR were noted to be lower as the level of inclusion increased from 2% to 6%. It demonstrated a cubic trend in the booster stage (p=0.0449), quadratic trend thereafter at D14 (p=0.0015), D21 (p=0.0049), and D28 (p=0.0093). In addition, the average FCR can be seen to have a cubic trend with slight reduction in FCR from 2% to 6% inclusion of the SLM in the broiler ration.

Table 10. Feed conversion ratio (g) of broiler chicken fed with varying levels superworm larvae meal in the ration

DAY	A (CONTROL)	B (2% - SLM)	C (4% -SLM)	D (6% -SLM)	SEM	DIET	LINEAR	QUADRATIC	CUBIC
7	1.39	1.81	1.63	1.58	0.08	0.0069	0.2670	0.0045	0.0449
14	1.65	2.15	2.08	1.79	0.14	0.011	0.4849	0.0015	0.4756
21	1.77	2.55	2.19	1.91	0.21	0.0181	0.9130	0.0049	0.1210
28	1.96	2.62	2.71	2.50	0.15	0.0102	0.0210	0.0093	0.7165
35	2.99	3.77	3.76	3.66	0.24	0.0900	0.0719	0.0794	0.5243
Ave	1.95	2.58	2.48	2.29	0.06	<.0001	0.0028	<.0001	0.0238

Feeds with low digestible values require processing methods to enhance nutrient bioavailability. In the case of 18th instar SLM, chitin content was higher compared to earlier stages (Quennedey et al., 1995). Ramos-Elorduy et al., (2002) found that *Tenebrio molitor*'s proximate analysis varied with age, hindering protein digestion. Chitin constitutes a similar proportion of insect weight as observed in other species (Henriques et al., 2020). Drying and reducing particle size of SLM do not significantly improve digestibility since monogastric animals lack the necessary chitin-digesting enzymes. Consequently, broilers fed SLM-based diets showed higher feed conversion ratios (FCR) and lower weight gains (WG) compared to those on the control diet (Diet A) throughout the study period.

Economic analysis

Cost to produce (CTP) accounts all direct expenses in broiler production and its BW at harvest; the higher value means more expensive to produce a unit weight of broiler. On the other hand, high BPEF indicates efficient broiler production with optimal performance. As shown in Table 11, the broilers control diet had a lower CTP and higher BPEF compared to broilers with SLM inclusion. The trend for CTP and BPEF were cubic (p=0.0056 and p=0.0035) implying improvement in these indicators when SLM were given at 4% and 6% inclusion rate. Meanwhile, in Table 12 are the net income (NI) and return above feed cost (RAFC) of broiler chicken with SLM. It consistently showed higher NI and RAFC when the broilers were given commercial diet against broilers given diet with SLM. Noteworthy, the broilers on 6% SLM had relatively higher NI and RAFC.

Table 11. Cost to produce (Php) and production efficiency factor of broiler chicken fed with varying levels superworm larvae meal in the ration

DAY	A (CONTROL)	B (2% - SLM)	C (4% -SLM)	D (6% -SLM)	SEM	DIET	LINEAR	QUAD RATIC	CUBIC
CTP, Php	75.97	106.83	101.82	88.46	2.241 1	<.0001	0.0015	<.0001	0.0056
BPEF	79.30	38.28	41.94	52.75	2.597 2	<.0001	<.0001	<.0001	0.0035

Table 12. Net income and return above feed and chick cost of broiler chicken fed with varying levels superworm larvae meal in the ration

ITEM	DIET A (CONTROL)	DIET B (2% - SLM)	DIET C (4% - SLM)	DIET D (6% - SLM)
Sales				
Dressed Wt, Kg	1.07	0.72	0.70	0.83
Price/Kg BW, PhP	130.00	130.00	130.00	130.00
Gross Income, PhP	139.55	93.63	91.59	107.66
Expenses				
Feed Cost, PhP	30.28	18.20	19.22	20.01
Cost of *Z. morio,* PhP	0.00	0.33	0.33	0.33
Cost of substrate, PhP	0.00	21.00	21.00	21.00
Cost of chick, PhP	45.00	45.00	45.00	45.00
Sub Total, PhP	75.28	84.53	85.55	86.34
Net Income, PhP	64.27	9.10	6.04	21.33
RAFC, PhP	109.27	75.43	72.37	87.66

It is demonstrated in this study that production of SLM at small-scale level incurred higher expenses as shown in the economic parameters. It resulted to higher production cost due to the cost of the substrates for breeders and larvae. Considering the current local market rate, the cost of fresh superworm larvae would amount to PhP700.00 per kilogram. Processing it to meal form reduces its yield more than 50% which is not economically viable in low-cost technology.

Carcass yield

Table 13 shows dressing percentage (DP) and the different meat and visceral yield of broilers given SLM in their ration. The DP showed a quadratic relationship ($p=0.006$) where higher DP can be observed in broilers given Diet A (72.93% DP) and lower DP for broilers given SLM in their ration. The control diet led to increased protein deposition, resulting in higher DP. This trend similar trend in DP was also observed in birds fed with 6% SLM in the diet. Quadratic trends were also obtained in primal meat cuts: wings ($p<0.0001$), thigh ($p<0.0001$), drumstick ($p<0.0001$); but, for the breast was cubic trend ($p=0.0431$). Broilers on Diet A had higher yield in all primal cuts compared to those fed SLM. This is due to the control group's higher WG, ADG, and BW. Similar observations were made among the birds given 6% SLM. For the visceral yield, no significant differences were observed in the heart weight ($p=0.1006$), but a linear trend was taken in the gizzard yield ($p=0.0402$) with broilers given 6% SLM having heavier gizzard. According to Mbhele et al. (2019), incorporating BSFLM increased gizzard weights, indicating the challenge of chitin content. The trend for liver weight was cubic ($p<0.0001$), with control had heavier livers than those given SLM. Among the SLM groups, broilers fed 6% SLM had the heaviest liver.

Table 13. Dressing percentage, carcass yield and visceral yield of broiler chicken fed with superworm larvae meal inclusion in the ration

ITEM	A (CONTROL)	B (2%-SLM)	C (4%-SLM)	D (6%-SLM)	SEM	DIET	LINEAR	QUADRATIC	CUBIC
DP, %	72.93	69.12	67.80	70.20	0.85	0.0009	0.0115	0.0006	0.7251
Wings, g	192.50	137.88	133.94	145.13	8.29	<.0001	<.0001	<.0001	0.2224
Thigh, g	153.06	102.88	96.31	115.00	4.24	<.0001	<.0001	<.0001	0.2976
Drumstick, g	154.60	108.06	106.06	125.81	3.88	<.0001	<.0001	<.0001	0.1313
Breast, g	297.88	173.50	182.25	219.69	10.85	<.0001	0.0001	<.0001	0.0431
Back, g	251.75	170.50	165.13	209.31	10.21	<.0001	0.0057	<.0001	0.5478
Heart, g	6.56	5.88	5.88	6.56	0.28	0.1006	1.000	0.0146	1.000
Gizzard, g	29.56	29.25	28.88	31.75	0.71	0.0402	0.065	0.0358	0.3091
Liver, g	35.63	27.56	23.88	27.63	1.07	<.0001	<.0001	<.0001	0.5131

CONCLUSION

Azolla-soft pollard concentrate substrate demonstrates superior growth performance in rearing superworms, making it a compelling choice for enhancing their production. The choice of substrate significantly influences the composition of superworm meal, with notable variations observed among the substrates. Low NDF values in the azolla-soft pollard concentrate substrate was observed which was ideal of production. SLM can be incorporated into animal rations at similar or higher levels but should be lower in terms of instar due to its chitin content. Incorporating 6% superworm larvae meal (SLM) into broiler chicken diets can gradually enhance the growth performance of the chickens. At 6% inclusion rate, the gizzard is proven to increase in mass due to higher presence of chitin resulting to more gizzard activity.

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