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Growth performance and carcass characteristics of Kuroiler chicks fed on Silkworm pupae (*Bombyx mori*) diet

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Utilization of silkworm pupae meal for feed will partially meet the protein feed deficiency, and fish meal competing uses. Silkworm pupa was used as a fishmeal substitute at different levels in poultry feeds to determine the growth performance and carcass characteristics after feeding day old Kuroiler chicks for 8 weeks. Fishmeal was substituted with Silkworm pupae at percentages of 25 (T3), 50 (T2) and 100 (T1) with a commercial feed as a control with 100% fish meal (T0). Seventy-two, one day old female chicks were procured from a reputable hatchery and housed in wooden cages. Four diets were assigned to each cage and replicated three times having 18 chicks per treatment in a completely randomized design. At 8 weeks of age, two birds were slaughtered and carcasses obtained to assess the yield. High growth results were observed in T1. Feed intake differed significantly (p<0.05). Live weight gain had a significant difference across treatments (p<0.05). Dressed weight was affected by the replacement of fish meal with silkworm pupae (p<0.05) and the dressed chicken components were not significantly different (p>0.05). This study recommends the utilization of silkworm pupae-based feeds in 100% total replacement resulting in optimal growth performance.

Key words: Fish meal, Kuroiler chicks, growth performance, Silkworm pupa.

INTRODUCTION

The demand for poultry meat and eggs especially in developing countries continues to surge due to the rapid population growth therefore, it is necessary to enhance adequate production to meet population needs (Trostle and Seeley, 2013; Mottett and Tempio, 2017). Poultry meat demand per capita is estimated to reach 2.8% per year from 2013 to 2022 (Windhorst, 2006). Optimum poultry production involves various factors that come into play and a key factor among them is feedstuff (Ravindran, 2013). Nutrition plays a critical role towards performance and productivity; therefore, it is necessary to formulate diets satisfy growth requirements (Khobondo et al., 2015). Poultry feeds comprise various food resources such as cereal grains and their by-products, soybean

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meal, animal by-products meals, fats and vitamin premixes (Cheeke, 2005).

Poultry require highly digestible feed sources with an adequate supply of energy, protein, essential amino acids, minerals, vitamins and most importantly water for improved and optimum performance. Nutrient requirements by birds tend to vary according to species, age and purpose of production for either meat or eggs (Ravindran, 2013). Dietary protein plays a critical role in supplying amino acids for enhancement of muscle growth and synthesis of egg protein (Oladokun and Johnson, 2012). Some of the protein ingredients for feed stuff in poultry diets entail cottonseed meal, rapeseed meals and soybean meal which are obtained from plant sources (Chinrasri et. al., 2009). Feed ingredients, key among them being animal protein sources are declining in supply and the major reason is the high competition between poultry, human population and other animals causing a rise in their cost (Ijaiya and Eko, 2009). Animal protein sources include meat meals, termites, maggots, earthworm, blood meal, feather meal and fishmeal which is the best highly ranked quality protein for monogastric animals like poultry (Anjum et al., 2014).

Fish meal is most preferred as it gives a balanced amount of all essential nutrients comprising amino acids, phospholipids, fatty acids and mineral content aimed at optimum development, growth and reproduction (Barlow, 2003). Fish meal is brown, powdery with high amounts of proteins, fat and minerals and apart from being nutrient dense; it is highly digestible hence widely utilized in feeds (Karimi, 2006). Fish meal and soy meal being the most used protein sources have been proved to contribute immensely to land occupation, primary production use, acidification, climate change, energy use and water dependence (Agazzi et al., 2016). Despite the continous utilization of fish meal in poultry diets, overfishing has drastically limited the supply leading to high market prices. Therefore alternative protein sources of comparable nutritive value are necessary to make the poultry industry a sustainable venture (Józefiak and Engberg, 2015).

Insects have been recommended as a nutrient rich sustainable alternative protein source that can effectively promote food security by inclusion in feeds (Rumpold and Schluter, 2013). This is due to ability to perform optimally on organic side streams, excellent feed conversion efficiency, low emmissions of green house gases and cold blooded. Moreover in the western world they have been used in industrial mass production (Veldkamp and Bosch, 2015).

According to Van Huis (2013), insects can effectively replace fish meal and even fish oil to reduce the stress that has been channelled to marine over-exploitation and high demand for soybean fuelled by the growing global population. Some of the insect species that have been used in industrial production include Black Soldier Fly (*Hermetia illucens*), the yellow mealworm (*Tenebrio molitor*), Silkworm (*Bombyx mori*) and several grasshopper species (Van Huis, 2013; Veldkamp and Bosch, 2015). This therefore points out that Insect used for feeds are more sustainable due to its reliable and low cost of production owing to their physical sizes. In view of the poultry production constraints that are prevalent in the feed industry, one of the animal protein ingredients that can sufficiently substitute the declining volumes and adulterated fish meal is silkworm pupae meal.

Silkworm pupae (SWP) is a protein rich feed ingredient, which is a waste product from silk reeling during silk production and contains high nutritional value with a crude protein of 50 to 80% defatted meal hence ranks higher than the protein of soybean, fish or beef (Makkar et al., 2014). Its amino acid profile compares well with fish meal and is derived four times in a year (Khatun et. al., 2003; Singh and Jayasomu, 2002). Silkworm pupae has been utilized as a fertilizer or disposed off in the surroundings. This waste brings about dire consequences like per-oxidation caused by the high lipid content and unappealing odors (Makkar et al., 2014).

This study sought to find out the effect of replacing fish meal with silkworm pupae on growth performance, carcass characteristics and sensory evaluation of Kuroiler chicks fed on the various substitution percentages of silkworm pupae for a period of 8 weeks.

MATERIALS AND METHODS

Research site

The study was conducted at the National Sericulture Research Center under KALRO (Kenya Agricultural and Livestock Research Organization) in Kandara, Thika.

Research design

This study adopted a complete randomized design due to the homogeneity of the experimental units and having only one source of variation. It involved 3 replications with 24 chicks per replication and 24 for each treatment amounting to 72 in sum total.

Experimental diets

Test diets were formulated based on the Kenya Agricultural and Livestock Research Organization guidelines for the Kuroiler breed. The diets are as shown in Table 1. Four dietary treatments containing silkworm pupae meal were incorporated in various percentage ratios and administered to 18 birds per treatment in 3 replications of 6 birds each. The diets included: Control, T0 (0% SWP meal), T1 (100% SWP meal), T2 (50% SWP meal), T3 (25% SWP meal). These diets replaced fish meal (*Rastrineobola argentea*). The feed was formulated to be iso-caloric and iso-nitrogenous using a linear model of Excel Solver to give the least cost ration containing essential nutrients which are necessary to meet requirements of animal growth, maintenance, production and reproduction without affecting quality at a least cost. All the feed ingredients were obtained from Munene Industries in Thika town, medications and vaccines were sought from J&J Veterinary and other feeding equipment like drinkers and feeding troughs were

Table 1. Chick mash feed formulation for treatment 0 (T0), 1(T1), 2 (T2) and 3(T3).

Ingredient	Ingredients amounts			
	T0 (100%FM)	T1 (100%SWPM)	T2 (50%SWPM)	T3 (25% SWPM)
Whole maize	10 kg	10 kg	10 kg	10 kg
Maize germ	17 kg	17 kg	17 kg	17 kg
Wheat pollard	13 kg	13 kg	13 kg	13 kg
Wheat bran	10 kg	10 kg	10 kg	10 kg
Sunflower cake	5 kg	5 kg	5 kg	5 kg
Cotton seed cake	6 kg	6 kg	6 kg	6 kg
Soya meal	3.4 kg	3.4 kg	3.4 kg	3.4 kg
Lime	2.07 kg	2.07 kg	2.7 kg	2.07 kg
Bone meal	700 g	700 g	700 g	700 g
Fishmeal	3 kg		1.5 kg	2.25 kg
Silkworm pupae		3 kg	1.5 kg	0.75 kg
Mycotoxin binder	50 g	50 g	50 g	50 g
Salt	14 g	14 g	14 g	14 g
Premix	20 g	20 g	2o g	20 g
Tryptophan	70 g	70 g	70 g	70 g
Lysine	3.0 g	3.0 g	3.0 g	3.0 g
Methionine	10 g	10 g	10 g	10 g
Coccidiostat	60 g	60 g	60 g	60 g
ME^2(kcal/kg)	2990	2890	2860	2850

FM- fish meal. SWPM- Silk worm pupae meal. ME- Metabolisable energy.

sourced from Jua kali Section in Thika. Dried silkworm pupae were also derived from the silk lab in the National Sericulture Research Centre, Thika as a by-product of silk reeling. They were ground into fine flour at the feed miller in Munene industries and mixed with the other feed materials using a feed mixer.

Housing and biosecurity

The chicken house was thoroughly cleaned with water and then disinfected with kerol. All drinkers and feeders were also thoroughly cleaned and disinfected before use. Cages were constructed using plywood, timber and wire mesh in a story form and partitioned into 16 pens to accommodate 6 chicks sufficiently in each treatment separately. Each pen measured 100 cm by 60 cm with a height of 50 cm. Wood shavings were spread in every cage to a thickness of 5 inches for bedding and partially controlled temperatures ranging from 23 to 27°C. Separated feeders and drinkers were used in each pen for provision of water and feed. Twelve, 100 watts bulbs were used to provide warmth to the chicks in each pen and they were hung at the height of 20 cm above the brooder. They were used during the experiment to provide warmth and lighting for continuous eating. Every pen had an iron made feeder with 8 small holes allowing the entry of the chick heads alone and a plastic invertible 4 L drinker. In the course of their growth, the feeders were changed to suspended plastic feeders. Ventilations and aerations were provided to regulate temperatures from causing harm to the chicks.

Experimental birds

The study used 96 one day old Kuroiler chicks obtained from Ziwani poultry farm in Ngoliba and reared for 8 weeks. Initial weights of all the chicks were taken and 6 chicks assigned to each of the 16 pens administering different treatments. The chicks were feather sexed from the hatchery and all were females. The vaccination schedule was followed strictly as specified by KARLO against diseases like Newcastle, Gumboro and fowl typhoid and cholera. The chicks were fed on a standard diet comprising of four experimental diets in equal measures. The feeders and drinkers were washed daily and fresh feed was administered to the chicks each with water *ad libitum*. This experiment lasted 8 weeks, which is the period for chick mash.

Data collection

Some of the variables that were under study included growth rate, weight gain, feed intake, feed conversion ratio, carcass yield and sensory evaluation. All the weights were measured using the modern digital kern PFB scale.

Feed intake and growth

Initial live weights of birds were measured at the beginning of the experiment. All the chicks in every pen were weighed using electronic scales (Model kern PFB) on a weekly basis and their average obtained. Feeds administered daily were weighed on the modern kern weighing balance and recorded. Records on feed consumed were also taken and weight gain noted daily and weekly respectively for a period of 8 weeks.

Feed intake was monitored and increased weekly by 2 kg. Daily feed intake was measured by subtracting the weight of refusals from that of the feed offered per day and difference was divided by total number of birds and was calculated as follows:

Feed intake = Total feed intake (g) - Total feed remainder (g)

Average daily gain (ADG) = (Final weight - Initial weight) (g)/Time

(days)

$$\text{Feed conversion ratio was calculated as} = \frac{\text{Total amount of feed consumed}}{\text{Total amount of weight gained}}$$

Any dead bird was taken to J&J Veterinary for a postmortem to investigate the possible causes of death and ways to avert any further deaths. The mortality rate was calculated as:

$$\text{Mortality rate} = \frac{\text{No. of dead birds}}{\text{Total number of chicks}} \times 100$$

Growth rate was also obtained by taking weekly weights of all chicks from each replicate and obtaining an average. Eventually before slaughter all birds were weighed to calculate the final yield in weight due to the diets. Therefore, growth rate was calculated as:

$$\frac{\text{Final weight- Initial weight}}{\text{No. of days}}$$

Weight gain was also calculated as:

Weight gain = Final weight - Initial weight

Carcass characteristic

At the end of the 8th week on the 57th day, all birds were subjected to an overnight fast to evaluate carcass weight, breast and thigh weight and viscera. Slaughtering was done at the sericulture research site located within the study area. Two birds from each treatment were randomly picked, tagged and their live weight taken. The two birds from each treatment were slaughtered by cervical dislocation at the neck. The feathers of the birds were plucked after scalding in hot water at 70°C. The legs were carefully cut at the tibia femur joint. The abdomen was incised mid ventral using a sharp knife and the entire carcasses of the birds were weighed, feathers, carcass weight excluding the head and viscera. Internal organs (heart, liver, kidney and gizzard) were also obtained to evaluate their weight. Dressed carcasses were preserved in a freezer for 24 h. Weights of thigh bone, wings, back and breast were taken to estimate the yield. The percentage of each component was obtained by dividing the weight of the component by the live weight as shown:

$$\%\ \text{component} = \frac{\text{Weight of the component (g)}}{\text{Live weight (g)}} \times 100$$

Dressing percentage was calculated as:

$$\frac{\text{Carcass weight (g)}}{\text{Live weight (g)}} \times 100$$

Sensory evaluation

Sensory evaluation involves analyzing, measuring a product's characteristics and features as interpreted by the responses of human senses of smell, taste, touch, sight and tenderness. Based on the four diets, a sensory evaluation was undertaken from the birds slaughtered from the diets.

Meat preparation

The thigh and breast muscles were used for sensory evaluation. After the carcass was defrosted in running water and the carcass components obtained, they were subjected to heat treatment at 200°C for 45 min, boiled without any additive or spice in a Sufuria and thereafter chopped into small sizes and wrapped in disposable plates.

Panelists' selection and training

Thirteen semi-trained volunteers who were obtained through capture method took part in the sensory evaluation. The panelists consisted of 3 females and 10 males with ages ranging between 20 and 55 years recommendable for laboratory/ analytical method. Room temperature water was provided to each panelist for cleansing their palates in between samples to prevent carryover tastes with a resting period of 40 s in between the samples according to Lawless (2013). Every panelist was given serviettes and small containers into which samples of the meat from all the diets were spit. Questionnaires were given to panelists to demonstrate their degree of satisfaction to the samples. Panelists were advised to gargle water in their mouth. A 9-point hedonic scale was used by the panelists to give a score of their reactions. The sensory parameters under study included taste, aroma, texture and color evaluated as follows: 9=Like extremely 8=Like very much 7=Like moderately 6=Like slightly 5=Neither like nor dislike 4=Dislike slightly 3=Dislike moderately 2=Dislike very much and 1=Dislike extremely.

Chemical analysis

Chemical composition of the experimental diets and silk worm pupae meal and entire formulated feed was done prior to feeding using the procedures determined by the Association of Official Analytical Chemists (AOAC, 1990). Formulated feed and silkworm pupae were subjected for quality tests at KALRO- HRI (Horticulture Research Institute) and Spectralab respectively as indicated by NRC (1994).The dry matter content was first determined by weighing the samples and thereafter placed in a 105°C oven for 12 to 16 h. The samples were reweighed and the dry matter and moisture were obtained. Ash content was obtained by burning the samples at 600°C for 3 h in a muffle furnace. The Kjeldahl method was used to measure the crude protein content of the sample involving an automatic Kjeldahl digestion unit- DKL/20 combined with UDK 159 automatic Kjeldahl analyzer. The nitrogen content of the sample was first obtained then converted to a crude protein estimate by multiplying the nitrogen content by 6.25. Sulfuric acid and potassium hydroxide were mixed to measure the crude fiber content. The crude fat content was obtained by drying and grinding the samples then extracted with an organic solvent for 4 h and the remaining residue is weighed upon drying. Table 2 highlights the nutritional composition of silkworm pupae and fishmeal used in this study and Table 3 shows the nutritional composition of the four diets.

Statistical analysis

The data on weight gain, feed intake, carcass characteristics and sensory evaluation were analyzed and presented using one-way analysis of variance (ANOVA) and the SWP inclusion levels of 25,

Table 2. Chemical composition of SWP and fish meal.

Chemical	SWP	Fish meal (*Rastrineobola argentea*)
Dry matter	91.6538	93.0
Moisture	8.3462	10.11
Crude ash	4.6487	50.2
Crude fat	27.6056	29.4
Crude fiber	3.1924	21.3
Crude protein	57.8561	50.03
Metabolizable energy (Kcal/kg)	4318.8732	2948

Table 3. Chemical composition of experimental diets.

Chemical	T0	T1	T2	T3
Crude protein	18.45	18.92	18.31	18.14
Crude fiber	8.51	8.78	8.23	8.45
Dry matter	91.21	90.42	90.17	90.38
Crude ash	8.57	8.27	8.46	8.69
Crude oil	5.95	6.59	5.44	5.64
Metabolizable energy (Kcal/kg)	2989.54	2857.45	2843.80	2845.40

50 and 100% treatments. The statistical package R i386 3.5.3version software was employed for data analysis and presentation using a general linear model where diet was the independent variable. The significance between treatment means was tested at a significance level of 5%. Least Significant Difference test was used as a post-hoc test and mean effects were deemed statistically significant at $p<0.05$.

Ethical considerations

This research was approved for study by the Jaramogi Oginga Odinga University Ethics Review Committee on March 2020 and assigned the application approval number 7/14/ERC/11/19-7.

RESULTS

Growth performance

Chick initial weights at the start of the experiment were similar in all of the four treatments as shown in Table 4. The chicks exhibited a rapid and robust growth rate pattern during the study period. There was no significant difference in chick weights in weeks 1, 2, 4, 5 and 7 ($p>0.05$). However, the weights were statistically significant at week 3, 6 and 8 ($p<0.05$). Treatment 0 and 1 showed no significant differences in terms of final chick weights while Treatment 2 and 3 showed the major significant differences in weights. There was a significant effect on feed intake across treatment levels ($p<0.05$). Feed intake had no significant difference across treatment diets in the first four weeks but a statistically significant difference was noted towards the subsequent weeks till the end of the experiment. Diet T1 had a higher feed intake which was followed closely by T0, T2 and T3. The treatment diets had no significant effect on the feed conversion ratio ($p>0.05$) and the substitution levels of 100% fish meal and 25%FM recorded lower FCRs than silkworm pupae substituted treatments of 100 and 50%SWP during the entire feeding period (Table 5).

Carcass characteristics

Slaughter and dressed weight differed significantly across the diets ($p<0.05$). Treatments T1 and T0 had higher slaughter weight and carcass weight followed by T2 and T3 (Table 6). A higher dressing percentage was noted in all treatments except for 25% substitution. There was no significant effect noted on SWP meal substitution on the chicken carcass components like heart ($p=0.463$), liver ($p=0.118$), wings ($p=0.155$), back ($p=0.102$) and breast ($p=0.155$) weights upon treatments however the kidney, thigh and viscera noted a significant effect ($p<0.05$) for the treatment diets.

Sensory evaluation

The SWP meal inclusion in the Kuroiler birds had no significant effect on color, taste, odor and texture on the cooked breast meat across all the diets ($p>0.05$). All the

Table 4. Effect of substituting fish meal with silkworm pupae on weekly chick weights.

Treatment	Wee 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
	Mean±SE	**Mean±SE**	**Mean±SE**	**Mean±SE**	**Mean±SE**	**Mean±SE**	**Mean±SE**	**Mean±SE**
T0	68±7.2^{a}	140±8.3^{a}	247±6.9^{a}	319±21.8^{ab}	516±20.3^{a}	661±23.7^{a}	762±36.2^{a}	995±50.8^{a}
T1	76±6.0^{a}	140±8.1^{a}	250±20.8^{a}	332±29.8^{ab}	476±40.7^{ab}	561±43.4^{ab}	746±85.9^{a}	1014±51.6^{a}
T2	72±2.9^{a}	118±9.8^{a}	261±9.8^{a}	349±21.35^{a}	502±49.2^{ab}	606±41.2^{a}	755±51.4^{a}	912±24.7^{b}
T3	70±2.2^{a}	146±13.2^{a}	192±13.8^{b}	257±30^{b}	395±14.6^{b}	474±20.6^{c}	640±25.6^{b}	780±11.1^{c}
LSD	16.48	33.38	45.86	85.17	111.81	110.30	178.59	126.11
P-Value	0.751	0.304	0.0307	0.148	0.133	0.0249	0.399	0.01
Experimental diets	**T0**	**T1**	**T2**	**T3**	**LSD**	**P-*value***		
Initial weight	68.64±7.2	76.25±6.0	72.03±209	70.57±2.2	16.48	0.751		
Final weight	995.30±50.8^{a}	1014.26±51.6^{a}	912.75±24.7^{b}	780.33±11.1^{c}	126.10	0.01		
FCR	2.72	2.92	2.95	2.30	0.7066	0.206		

Means (± standard error) within a row followed with a similar superscript letter are not significantly different. ($p>0.05$); **LSD**= least significant difference test. **FCR**= feed conversion ratio. **T0**= 100% fish meal, **T1**= 100% silkworm pupa meal **T2**= 50% silkworm pupa, **T3**= 25% silkworm pupa.

Table 5. Effect of substituting silkworm pupae with fish meal on feed intake.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	FCR
	Mean ±SE	**Mean ±SE**	**Mean ±SE**	**Mean ±SE**	**Mean ±SE**	**Mean ±SE**	**Mean ±SE**	**Mean ±SE**	
T0	136.07±17.93	173.62±19.79	308.72±18.10	404.88±40.36	362.77±50.19	426.27±62.40	528.39±62.21	574.43±25.27	2.72
T1	100.76±9.4	147.26±14.34	276.14±38.97	366.44±53.84	420.48±51.12	503.11±19.79	574.43±7.48	547.24±17.17	2.92
T2	101.21±11.78	141.97±13.54	236.97±52.87	385.88±39.71	422.94±45.76	529.11±30.67	547.24±4.77	528.39±19.90	2.95
T3	111.13±25.20	123.09±21.54	265.44±37.96	239.66±6.84	187.95±12.94	205.44±16.63	300.23±16.61	300.24±23.98	2.30
LSD	56.10	57.55	127.18	127.89	140.22	120.96	105.99	71.18	0.71
P-value	0.471	0.313	0.646	0.0643	0.0147	0.00103	0.00117	0.0105	0.206

LSD= least significant difference test. FCR= feed conversion ratio. T0= 100% fish meal, T1= 100% silkworm pupa meal T2= 50% silkworm pupa, T3= 25% silkworm pupa.

treatments noted a point 6 upwards on the hedonic scale. Based on the results obtained from the 13 participants, sensory evaluation data, in terms of color, birds on treatment T0 with 100% FM were highly preferred in all the replications followed by the birds in T3 that contained 25% SWP substitution followed by the 50% SWP and 100% SWP. The texture and mouth feel were generally similar across the diets with no difference noted. The same rating was used by the participants on the other traits of taste/flavor, odor/smell and texture/mouth feel as shown in Table 7.

DISCUSSION

Silkworm pupae which is protein rich nutritionally

Table 6. The effect of inclusion of silkworm pupae in kuroiler chicks on the carcass characteristics.

Parameter	**T0**		**T1**		**T2**		**T3**		**LSD**	***P*-value**
Slaughter weight in grams	989.07		1046.67		948.43		815.85		125.08	0.0152
Dressed weight in grams	859		923		835		698		127.25	0.02
Weight in grams	**Wt(g)**	**%**	**Wt(g)**	**%**	**Wt (g)**	**%**	**Wt(g)**	**%**	**Wt(g)**	**%**
Heart	5.55	0.65	4.89	0.52	5.14	0.62	4.32	0.62	1.72	.463
Liver	17.23	2.00	17.83	1.93	18.96	2.27	14.20	2.03	4.05	.118
Kidney	7.21	0.84	6.79	0.74	7.21	0.86	4.79	0.68	1.49	.0131
Gizzard	41.37	4.82	44.27	4.79	41.37	4.95	31.66	4.54	7.62	.0257
Thigh	103.71	12.07	111.98	12.13	103.71	12.42	84.28	12.07	11.63	0.0034
Wings	43.91	5.11	42.78	4.63	43.91	5.26	33.38	4.78	10.82	.155
Back	144.28	16.79	138.83	15.4	144.28	17.28	104.85	15.02	34.93	.102
Breast	171.44	19.96	206.59	22.38	171.44	20.53	125.92	18.04	72.93	.155
Viscera	155.86	14.88	161.68	16.34	152.67	16.10	125.36	15.36	13.82	.00134

Table 7. Sensory evaluation based on cooked carcasses obtained from the treatments.

Parameter	**Experimental diets**					
	T0	**T1**	**T2**	**T3**	**LSD**	***P-Value***
Color (appearance)	7.72	6.54	6.63	6.81	1.652	0.46
Taste/flavor	7.36	7.18	6.36	7.00	1.420	0.52
Odor/Smell	7.454	7.00	6.545	6.272	1.856	0.594
Texture/Mouth feel	7.818	8.09	7.091	7.181	1.242	0.303

Colour, taste, odor and texture were evaluated on a 9-point hedonic scale with score: 0 **=**Dislike extremely to 9 **=** Like extremely

with a good amino acid profile has been used to substitute and supplement fish meal in monogastric animal feeds including broilers, rabbits, pigs and fish (Makkar et al., 2014). Utilizing SWP as a partial or complete replacer for fish meal will heighten production in the poultry industry in terms of eggs and meat and diversify the protein alternatives while maintaining the growth performance indicators. The Kuroiler breed which has an improved genetic compared to the usual local indigenous chicken holds the potential to foster and achieve household food security due to its active scavenging nature and the availability of alternative protein feeds which constrain most households due to the unavailability of quality fish meal. The results obtained from this study demonstrated a positive effect on growth performance, carcass characteristics, yield and also overall consumer acceptability. Optimum results were obtained under replacement levels of 50% (T2) and 100% SWP (T1) in terms of growth performance and carcass yield surpassing the control diet with 100% FM (T0). The crude protein obtained in silkworm (57.8561%) was higher than previous results obtained by Pereira et al. (2003) at 51.1%, Khan (2018) at 54% and Tomotake et al. (2010) at 55.6% and lower than Khan et al.

(2005) at 65% and Makkar et al. (2014) at 60.7%. The crude fat obtained is higher than Jintasatapomr (2012) at 26.49% but higher than Tomotake et al. (2010) at 25.7%. It is presumed that fiber contained by insects is signified by the chitin in their exoskeleton (Finke, 2007). The fiber content was quite low but ranging within most studies which is between 3 and 4% dry matter (Finke, 2002). Chitin levels in the exoskeleton are the greatest contributor of the ash content. The high protein content obtained for this study may be as a result of the high protein content of the mulberry landraces, favorably warm and humid climate and absence of anti-nutritional factors. The high crude fat could be due to genotypic characteristics and warm and humid environmental conditions that do not lead to breakdown of fat to maintain body temperature. The high ash content in fish meal could also be due to low quality or human adulterations (Ravindran, 2013). Fish meal had a CP of 50.03% lying within the range of 40 to 50% also confirmed by NRC (1994). The crude protein of fish meal has been deteriorating and contains some impurities originating from the primary source especially water bodies to the animal feed outlets (Nalwanga et al., 2009).

Treatment T1 with the highest level of silkworm pupae replacement of fish meal at 100% contained the highest crude fat (6.59%) and crude fiber (8.78%) but with the lowest ash content (8.27%). The high fiber can be attributed to the chitin that forms the exoskeleton of the pupae and the storage conditions in which the cocoons were kept causing drying and hardening of the pupae. The high ash content in Treatment T0 could have been due to fish meal which contained some impurities or foreign substances that come along from the fishing ground (Nalwanga et al., 2009).

Past studies demonstrate that inclusion of dried SWP in replacement of soybean meal and fish meal performed positively influencing growth parameters (Ullah et al., 2017; Khatun et al., 2005). This found out that silkworm pupae substitution at different levels had a significant effect on the final live weight of the poultry birds. These findings however contradict those of Ijaiya and Eko (2009) who found no significant difference in substituting fish meal with different levels of silkworm caterpillar meal (*Anaphe infracta*) on the growth of finishing broiler chicken. This high growth performance could be attributed to a sufficient supply of essential amino acids most importantly tryptophan, digestibility of nutrients and an improved rate of protein retention supporting this study which had the best performing substitution at 100% which is above 50% (Ullah et. al., 2017).

The reason for the high FCR in higher substitution percentages of silkworm can be attributed to the fact that silkworm pupae contain high amounts of chitin that results to low digestibility and thus necessitating a higher feed consumption to compensate the energy requirements (Jintasataporn, 2012). There was no significant effect ($p>0.05$) in feed conversion rate across the treatment levels with an increased FCR for every increase in silkworm pupae. This is in line with the findings of Ijaiya and Eko (2009), Ullah et al. (2017) and Khatun et al. (2003).

Meat qualities such as water holding capacity, shear force, drip loss, cook loss, collagen content, protein solubility, cohesiveness, fat binding capacity are parameters considered in meat evaluation. The diet of the birds significantly impinges upon meat quality and consumer preference (Mir et al., 2017). Colour, appearance and texture are crucial factors that consumers look at before they contemplate to buy poultry (Liu et al., 2004). Poultry meat colour is largely influenced by the haem-iron rich compounds like myoglobin, haemoglobin and cytochrome. Differences in meat colour may be associated with myoglobin content, composition of the diet and bird sources (Wideman et al., 2016). Mentang et al. (2013) also obtained the same results when they used 18 trained assessors who could not identify any significant difference between the diets up to 100% substitution.

The taste and flavor also had no significant differences across the diets with the control being the most preferred due to the rich amino acids and fatty acids from fish meal which happen to be deficient or in low amounts in silkworm pupae meal. The smell/ odor did not differ across the diets and there was no significant difference across the diets therefore it can be concluded that SWP inclusion does not affect consumer preference.

Conclusion

Based on the findings on Kuroiler growth performance under SWP based feed; it shows that SWP has a positive significant effect on growth performance traits like feed intake, weight and daily feed intake. Therefore, the study concluded that silkworm pupae can be used effectively to replace fish meal while influencing growth positively. The study also found out that the SWP based diets had a significant effect on carcass yield but did not have any effect on the carcass components and even the sensory evaluation. This study therefore concluded that an increase in SWP pupae in partial or total replacement of fish meal at percentages of 50 to 100% in kuroiler chicks will not affect negatively carcass characteristics and its sensory traits. This study results provide sufficient information for incorporating insects in feed diets for optimum poultry production especially the sericulture industry which is at its nascent stages in Kenya. Through the silkworm pupae obtained as a by-product from the sericulture industry, food security will be achieved. Further research should be directed into the long-term storage, preservation and quality maintenance of silkworm pupae over long periods to prevent anti-nutritional growth factors. Finally, there is need to research also on consumer acceptability of animal products fed on silkworm pupae.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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