Pakistan J. Zool., vol. 49(4), pp 1463-1470, 2017. DOI: http://dx.doi.org/10.17582/journal.pjz/2017.49.4.1463.1470

Silkworm (*Bombyx mori*) Meal as Alternate Protein Ingredient in Broiler Finisher Ration

Rafi Ullah[1], Sarzamin Khan[1,*], Abdul Hafeez[1], Asad Sultan[1], Nazir Ahmad Khan[2], Naila Chand[1] and Naseer Ahmad[1]

[1]*Department of Poultry Science, The University of Agriculture, Peshawar, 25130, Pakistan*

[2]*Department of Animal Nutrition, The University of Agriculture, Peshawar, 25130, Pakistan*

ABSTRACT

The present study was conducted to evaluate the effect of replacing soybean meal with silkworm meal on production performance, hematology and carcass traits in broilers at finisher phase. Five isonitrogenous and isocaloric diets were uttered with the step-wise *i.e.* 0% (D1), 25% (D2), 50% (D3), 75% (D4) and 100% (D5) replacement of soybean meal with silkworm meal in commercial broiler rations. A total of 150 day-old broiler chicks (Ross 308) were randomly distributed into fifteen replicate groups (n=10), and consequently reared on five experimental diets according to a completely randomized design. Feed intake was higher in D4 group in comparison with other groups ($P < 0.05$). Live body weight was higher in D4 group than D2, D3 and D5 groups ($P < 0.05$). FCR and dressing percentage were similar among the all groups ($P > 0.05$). Albumin was higher in D1 group in comparison with other groups ($P < 0.05$), however, other blood parameters and carcass characteristics indicated no significant differences ($P > 0.05$). Cost per kg of feed gradually decline with increasing dietary level of SCM inclusion levels ($P < 0.05$), indicating higher economic benefit. However, the gross return per bird and profit per kg meat were higher for diet D4 ($P < 0.05$). It was revealed that replacement of soyabean meal with silkworm meal did not affect broiler performance and carcass quality; therefore silkworm meal may effectively be used as a low-cost protein constituent in the broiler finisher ration.

Article Information
Received 18 October 2016
Revised 20 November 2016
Accepted 24 December 2016
Available online 26 July 2017

Authors' Contributions
RU designed, planned and executed experimental work. NA, NC and NAK collected nad processed samples, and helped in lab work. AS analyzed the data. SK wrote the article. AH helped in preparation of manuscript.

Key words
Soyabean meal, Broilers performance, Carcass quality, Hematology, FCR.

INTRODUCTION

Broiler producers are facing much difficulty with availability and higher prices of feed ingredients (Khatun *et al*., 2003). In most animal production systems, feed takes the largest part of the production costs, and most of it is contributed by the cost incurred on protein-ingredients, particularly in monogastric animals such as poultry which could not synthesize essential amino acids. Feed ingredients, especially animal protein sources are very expensive and scarce due to high competition among poultry, human and other animals resulting in the escalating.

Poultry production relies heavily on a plant-seeds based protein supplements, especially soybean meal due to its excellent amino acid composition and high level of digestibility (Willis, 2003). In many countries such as Pakistan, the production of soybean is limited and most of the soybean used in production of poultry ration is imported from other countries, making it very expensive. Moreover, next to the rising prices, conventionally used protein ingredients are not ecologically or economically sustainable, and many of the traditional protein ingredients are forecast to be in short supply within the next ten years mainly due to an increase in the human population and unfavourable climatic conditions (Barona *et al*., 2010; FAO, 2012). The increasing cost of protein ingredients has provided impetus to the poultry industry to explore alternative low-cost, sustainable sources of protein ingredients in poultry ration (Ramos-Elorduy *et al*., 2002; Das *et al*., 2009). Therefore, there is a growing interest in the use of some of the protein-rich insect speices as a low-cost protein ingredient in poultry ration (Van-Hhuis *et al*., 2013). Insects grow and reproduce very fast, had high feed conversion efficiency and can be fed on bio-wastes materials. Insects can convert organic wastes into high value food and feed resource, and on average 1 kg of insect biomass can be produced from 2 kg of feed biomass (Collavo *et al*., 2005). Recent studies haves shown that it is technically feasible to produce insects on a large scale and to use them as an alternative, sustainable protein rich ingredient in poultry ration (Veldkamp *et al*., 2012).

* Corresponding author: dr.zaminaup@gmail.com
0030-9923/2017/0004-1463 $ 9.00/0
Copyright 2017 Zoological Society of Pakistan

According to our knowledge, limited work has been done on the nutritional value of silkworm caterpillar meal produced in Pakistan as animal feed. Therefore, the present study was designed to assess silkworm meal as an alternate potential protein ingredient in poultry feed.

MATERIALS AND METHODS

Preparation of silkworm meal

Dried silkworm pupae with their chitinous covering was obtained from the Changa Manga Silk Industries at District Kasur, Pakistan (31° 05′ N latitude 73° 58′ E longitude). In silk production, the silkworms are killed in the pupa stage before they produce enzymes for disruption of silk cocoons. Simultaneously, the cocoon is removed and used for silk production, and large quantities of spent pupa are produced as byproducts which are often discarded in the open environment or used as fertilizer.

During the present study, the spent silkworm pupae were obtained from two consecutive batches at two weeks interval. The spent pupas were dried, crushed manually and the chitinous matter was removed. The pupa matter was then ground and used for the preparation of experimental diets.

Table I.- Ingredient and chemical composition (%) of experimental rations for broiler at starter phase.

	Diets* (soybean: silkworm)				
	D1 (100:0)	**D2 (75:25)**	**D3 (50:50)**	**D4 (25:75)**	**D5 (0:100)**
Ingredients					
Corn	58.8	59	59	59	59
Broken Rice	2	2.3	2.8	3.3	3.8
Cotton meal	4	4	4	4	4
Guar meal	4	4	4	4	4
Sunflower meal	2.1	2.1	2.1	2.1	2.1
Soya bean meal	10	7.5	5	2.5	0
Silk worm meal	0	2	4	6	8
Maize gluton meal (30%)	7.4	7.4	7.4	7.4	7.4
Fishmeal 50%	4	4	4	4	4
Rice polish	5	5	5	5	5
Molasses	1	1	1	1	1
Lime stone	0.4	0.4	0.4	0.4	0.4
Rock phosphate	1	1	1	1	1
Lysine	0.1	0.1	0.1	0.1	0.1
Methionine	0.1	0.1	0.1	0.1	0.1
Vitamins Minerals premix	0.1	0.1	0.1	0.1	0.1
Metabolizable energy (kcal/kg)	3027	3025	3018	3011	3006
Calculated chemical composition[†]					
Crude protein	20.3	20.1	20.2	20.1	20.2
Ether extract	4.20	4.21	4.23	4.19	4.24
Fiber	3.95	3.91	3.93	3.91	3.94
Ash	5.48	5.42	5.44	5.45	5.47
Calcium	0.77	0.76	0.77	0.79	0.78
Phosphorous	0.31	0.29	0.30	0.31	0.31
Lysine (% of total amino acids)	1.36	1.36	1.37	1.38	1.39
Methionine (% of total amino acids)	0.46	0.52	0.58	0.64	0.70
Cysteine (% of total amino acids)	0.34	0.34	0.33	0.33	0.33

*D1, control diet; D2, 25%; D3, 50%; D4, 75% and D5, 100% of the soybean meal was replaced with silkworm meal. [#]Provides per kg of diet: Mn, 80 mg; Zn, 60 mg; Fe, 60 mg; Cu, 5 mg; Co, 0.2 mg; I, 1 mg; Se, 0.15 mg; choline chloride, 200 mg; vitamin A, 12000 IU; vitamin D3, 2400 IU; vitamin E, 50 mg; vitamin K3, 4 mg; vitamin B1, 3 mg; vitamin B2, 6 mg; niacin, 25 mg; calcium-d-pantothenate, 10 mg; vitamin B6, 5 mg; vitamin B12, 0.03 mg; d-biotin, 0.05 mg; folic, acid 1 mg. [†]g/100 g DM until otherwise stated.

Experimental design, diets and management of experimental birds

A total of 150 one-day-old broiler chicks (Ross 308) were randomly divided into fifteen replicate groups with 10 birds per replicate. Each replicate group was housed in 10 × 10 feet cages, in the same poultry shed. The 15 replicates were randomly assigned to five experimental diets with 3 replicates per diet according to a completely randomized design (CRD). The five diets were formulated with the step-wise *i.e.* 0% (D1), 25% (D2), 50% (D3), 75% (D4) and 100% (D5) replacement of soybean meal with a silkworm meal in a commercial broiler ration. The experimental feeds were pelleted using an experimental pellet machine at the University of Agriculture Peshawar. All five diets were formulated on iso-nitrogenous and iso-caloric basis. The ingredient and chemical composition of the five experimental diets is given in Table I.

Throughout the experiment, feed and water were provided *adlibitum*. During the starter phase, all birds were fed with control diet. Experimental diets were introduced to broilers at 22 days of age. The trial continued till 42 days of age and data on feed intake of each replicate was recorded on daily basis. The individual body weight of the birds was recorded at the beginning of the study and thereafter weekly. Feed conversion ratio was calculated on weekly basis, for each experimental unit.

Carcass traits and hematology

At the end of the study, the blood samples were collected for hematological study. Three birds per replicate were randomly selected and weighed. After collection of blood samples, birds were slaughtered for determination of slaughter weight, dressed weight, weights of body parts cuts as well as various carcass traits. Carcass weight was measured by defeathering and removal of feet, head and viscera. Dressing percentage was calculated by dividing the carcass weight over live body weight.

Economics of the different ration (Cost analysis)

Economics of the research study was calculated in terms of total expenditure incurred and gross return. Operational cost per chick was calculated according to the market rate. The cost of silkworm used was included. Mean gross return per chick was calculated according to market rate of live bird on per kg basis. Cost per kg meat was calculated on basis of total feed consumed while net return were calculated on basis of per kg meat sale out. The cost per kg feed consistently declined with the increasing proportion of silkworm meal in the broiler diets.

Statistical analysis

The effect replacing soybean meal with a silkworm meal on the production performance parameters, blood profile and carcass traits was analyzed according to General Linear Model (GLM) procedure of Statistical Analysis System (SAS, 2009). The model used was:

$$Y_{ij} = \mu + D_i + \epsilon_{ij}$$

Where, Y_{ij} is the dependent variable, μ, is the overall mean, D_i is the fixed effect of experimental diets (i = 1-5) and ϵ_{ij} is the random error. When significant ($P < 0.05$) differences were detected, post-hoc analyses were carried out using the Tukey-Kramer test to compute pair-wise differences in the means. Replicate was used as experimental unit.

RESULTS

Data on the performance of birds is summarized in Table II. Feed intake was higher in D4 group in comparison with other groups ($P < 0.05$). Live body weight was higher in D4 group than D2, D3 and D5 groups ($P < 0.05$), and lowest in D5 group in comparison with other groups ($P < 0.05$). FCR and dressing percentage were not affected ($P > 0.05$).

Table II.- Effect of replacing soybean meal with silkworm meal on feed intake (g), body weight gain (g), feed conversion ratio (FCR) and dressing percentage of broilers.

Diets[#] (SBM:SWM)[†]	Feed intake (g) (Mean ± SE)	Live body weight (g) (Mean ± SE)	FCR (Mean ± SE)	Dressing percentage (Mean ± SE)
D1 (100:0)	4428.6± 9.94^{b}	2092.3 ± 2.85^{ab}	2.12 ± 0.021	68.43 ± 0.34
D2 (75:25)	4412.1 ± 11.62^{b}	2044.0 ± 2.37^{bc}	2.16 ± 0.078	67.01 ± 0.23
D3 (50:50)	4424.8 ± 5.39^{b}	2026.0 ± 4.42^{bc}	2.18 ± 0.040	68.80 ± 0.39
D4 (25:75)	4572.4 ± 12.33^{a}	2143.3 ± 4.33^{a}	2.13 ± 0.069	69.51 ± 0.41
D5 (0:100)	4434.7 ± 8.89^{b}	2003.7 ± 4.70^{c}	2.21 ± 0.043	68.72 ± 0.43
Significance	***	***	NS	NS

$^{a\text{-}c}$, means with different letters within the column differs at $P < 0.05$; ***, $P < 0.001$; NS, Non-significant.
#D1, control diet; D2, 25%; D3, 50%; D4, 75% and D5, 100% of the soybean meal was replaced with silkworm meal.
[†] SBM, soybean meal; SWM, silkworm meal.

The effect of replacement of soyabean meal with silkworm meal on haematological parameters is shown in Tables III and IV indicates the same on carcass quality. Albumin was higher in D1 group in comparison with other groups ($P < 0.05$), however, other blood parameters and carcass characteristics indicated no significant differences ($P > 0.05$).

Table V shows economics of replacing soyabean meal with silk worm meal. Cost per kg feed was lowest in D5 in comparison with other groups ($P < 0.05$). Cost of total feed consumed per bird was lowest in D4 than other groups ($P < 0.05$), however total cost per kg meat remained the same among all diets groups ($P > 0.05$). Gross return per bird as well as profit per kg meat was higher in D1 and D4 in comparison with other groups ($P < 0.05$).

Table III.- Effect of varying replacement levels of silkworm meal for soyabean meal on hematological parameters of finishing broiler chickens.

Parameters	Diets* (soybean: silkworm)					
	D1 (100:0)	D2 (75:25)	D3 (50:50)	D4 (25:75)	D5 (0:100)	Significance
Blood Sugar (mg/dl)	12.93	12.52	12.91	12.52	12.41	NS
Total Protein(mg/dl)	4.14	4.08	4.06	3.96	3.93	NS
Cholesterol (mg/dl)	2.85	2.81	2.84	2.92	2.78	NS
Albumin (mg/dl)	01.60^{a}	01.35^{c}	01.44^{b}	01.42^{b}	01.32^{b}	***
RBC (103/mm^{3})	2.94	2.72	2.85	2.92	2.79	NS
WBC (103/mm^{3})	9.39	9.68	9.53	9.47	10.06	NS
PCV (%)	31.90	31.68	31.74	31.47	31.79	NS
HB (g/dl)	10.68	10.72	10.68	10.44	10.45	NS
MCV (%)	108.53	116.95	111.46	107.70	114.20	NS
MCH (%)	36.32	39.58	37.51	35.72	37.50	NS
MCHC (%)	33.47	33.84	33.67	33.19	32.89	NS

For abbreviations, see Table II.

Table IV.- Effect of varying replacement levels of silkworm meal for soyabean meal carcass characteristics parameters of finishing broiler chickens.

Parameters	Diets* (soybean: silkworm)					
	D1 (100:0)	D2 (75:25)	D3 (50:50)	D4 (25:75)	D5 (0:100)	Significance
Live body weight (g)	2092.3^{ab}	2044.0^{bc}	2026.0^{bc}	2143.3^{a}	2003.7^{c}	***
Dressed weight (g)	1431.3	1367.0	1394.0	1489.3	1377.0	NS
Dressing (%)	68.43	67.01	68.80	69.51	68.72	NS
Viscera (%)	25.27	23.17	25.42	26.21	24.81	NS
Head (%)	2.34	2.32	2.35	2.36	2.33	NS
Wings (%)	12.28	12.49	12.45	12.44	12.47	NS
Breast (%)	13.31	12.95	12.71	13.39	12.3	NS
Back (%)	12.61	12.41	12.19	12.65	11.71	NS
Gizzard (%)	2.54	2.31	2.68	2.51	2.57	NS
Lungs (%)	0.75	0.74	0.76	0.77	0.73	NS
Heart (%)	0.60	0.57	0.67	0.66	0.59	NS
Liver (%)	2.68	2.76	2.72	3.49	3.36	NS
Kidney (%)	0.46	0.49	0.57	0.60	0.58	NS

For abbreviations, see Table II.

Table V.- Economics* of replacing soybean meal with silkworm meal in broiler finisher ration.

DIETS (SBM:SWM)	Cost/kg feed	Cost of total feed consumed/bird	Total cost/kg meat	Gross return/ bird	Profit/kg meat
D1 (100:0)	44.01[a]	194.9[a]	117.04[a]	303.3[a]	58.48[ab]
D2 (75:25)	43.42[b]	191.1[c]	117.97[a]	296.38[bc]	55.24[ab]
D3 (50:50)	42.63[c]	188.6[d]	117.78[a]	293.77[bc]	55.14[b]
D4 (25:75)	42.12[d]	192.5[b]	113.18[a]	310.78[a]	68.18[a]
D5 (0:100)	41.61[e]	184.5[e]	117.06[a]	290.53[c]	55.96[ab]

*All values are given in Pakistan Rupees (1US$ = Rs. 105); Kg/meat sale out on Rs. 145/-

DISCUSSION

Due to high cost conventional sources of animal protein, researchers are focussing on exploring alternate economical protein sources. In recent years, different species of insects and flies have emerged as a new, low-cost alternative protein sources in animal feed (Sun *et al*., 2013; Sanchez-Muros *et al*., 2014; Veldkamp and Bosch, 2015). Therefore, the present study was conducted to evaluate the effect of replacement of soyabean meal with silkworm meal in broiler finisher ration.

Feed intake and weight gain was affected with the inclusion of silkworm meal in the feed, and the highest feed intake and body weight was recorded for diet containing 75% soyaben meal replaced with silkworm meal. It may be endorsed to silkworm meal because our results are inline with findings of Khatun *et al*. (2003), (2005) and Loselevich *et al*. (2004) who have reported that SCM has pleasant taste and is palatable and acceptable by both broilers and laying birds. Moreover, the findings of the present study are in agreement with the observations of Rahman *et al*. (1996) and Khatun *et al*. (2003) who attributed the improved growth performance of SCM fed broilers to balanced amino acids profile of SCM. In another study, Ijaiya and Eko (2009) reported a higher weight gain with 75% replacement of fish meal with silkworm meal. However, the intake and production performance reduced with 100% replacement of fish meal with silkworm meal (Ijaiya and Eko, 2009; Dutta and Dutta, 2012). In the present study birds showed low performance with 100% replacement of soybean meal with silkworm meal. The literature suggests that this could be due to the adverse impact of high fat content on intake and the inability of young chicks to utilize the crude fibre integral in the exoskeleton (made of chitin) of the silkworm caterpillar (Fagoonee, 1983; Makkar *et al*., 2014; Valerie *et al*., 2015). Another study shows that the protein requirement at the finisher phase depends more on the amino acid profile than the total nitrogen content (Fadiyimu *et al*., 2003).

In the present study, FCR of the birds showed no significant differences at any inclusion level of SCM. The literature suggests that improved performance of broilers with the replacement of soybean meal with silkworm meal (up to 75%) could be related to its higher content of essential amino acids, minerals and energy (Khatun *et al*., 2003). Moreover, Fogoonee (1983) argued that the silkworm meal contain growth prompting factors such as ecdysteroid activity (a hormone involved in protein synthesis and tissue formation), though this has not been confirmed since. In the present study the highest feed intake and live body weight was observed with 75% replacement of soybean meal with silkworm meal. The reasons for best FCR with the 75% replacement level may be due to a more optimal supply of essential amino acid profile (particularly tryptophane), nutrient digestibility and an increased rate of protein accumulation (Khan *et al*., 2015). In the present study, dressed yield was not affected due to replacement of soyabean meal with silkworm meal. Our results are in contrast with Khatun *et al*. (2008) who observed highest dressing percentage for the dietary groups containing higher level of fish meal replacement with silkworm meal. Similarly, Kumur *et al*. (1992) reported that the dressed weight of broilers increased almost linearly on increasing dietary levels of silkworm pupae meal.

The analysis of blood parameters except blood albumin showed no significant differences among the different diet groups in the present study. However, our results are within the normal ranges as reported by Anon (1980). The significant differences observed in the blood albumin in the present study may be due to protein of silkworm meal and its use, as reported by Nandeesh *et al*. (1998) and Tona *et al*. (2006).

In the present study, cost per kg of feed gradually decline with increasing dietary level of SCM inclusion levels, indicating higher economic benefit. Moreover, the gross return per bird and profit per kg meat were higher for diet with 75% replacement of soyabean meal with silkworm

meal. Decrease in the cost of production per unit of feed intake and gain in weight with increasing level of SCM inclusion in the diet in present study agreed with the report of Atteh and Ologbenla (1993), Khatun *et al*. (2003) and (2005). Although no direct comparisons could be made for economics due to lack of literature data, Fagoonee (1983), Konwar *et al*. (2008) and Dutta and Dutta (2012) reported that replacing 50% of the fish meal with silkworm meal in broiler ration supported optimum growth performance and improved the profit margin due to its much lower cost.

CONCLUSIONS

The results of the present study showed that silkworm meal may be replaced with soybean meal in the broiler finisher ration without having adverse effect on blood profile and carcass quality. Moreover, the best results in terms of feed intake and live body weight may be achieved with 75% replacement of soybean meal with silkworm meal in the commercial broiler finisher ration.

Conflict of interest statement

The authors declare that there is no conflict of interests regarding the publication of this article.

REFERENCES

AOAC, 1995. Association of Official Analytical Chemists, 16th ed. *Animal feeds: Official method of analysis*. Arlington, VA, USA.

AOAC, 2005. Association of Official Analytical Chemists, 18th ed. *Animal feeds: Official method of analysis*. Arlington, VA, USA.

Anon, 1980. *Guide to the care and use of experimental animal*. Canadian Council of Animal Care. Ottawa Canada. 185–190.

Atteh, J.O. and Ologbenla F.D., 1993. Replacement of fish meal with maggot in broiler diet: Effect on performance and nutrient retention. *Nig. J. Anim Prod.,* **20**: 44-49.

Awoniyi, T.A.M., Adetuyi, F.C. and Akinyosoye, F.A., 2004. Microbiological investigation of maggot meal, stored for use as livestock feed component. *J. Fd. Agric. Environ.,* **2**: 104-106.

Barona, E., Ramankutty, N., Hyman, G. and Coomes, O.T., 2010. The role of pasture and soybean in deforestation of the Brazilian Amazon. *Environ. Res. Lett.,* **5**: 1-9. https://doi.org/10.1088/1748-9326/5/2/024002

Charlton, A.J., Dickinson, M., Wakefield, M.E., Fitches, E., Kenis, M., Han, R., Zhu, F., Kone, N., Grant, M., Devic, E., Bruggeman, G., Prior, R. and Smith, R., 2015. Exploring the chemical safety of fly larvae as a source of protein for animal feed. *J. Insec. Fd. Feed,* **1**: 7-16. https://doi.org/10.3920/JIFF2014.0020

Collavo, A., Glew, R.H., Huang, Y.S., Chuang, L.T., Bosse, R. and Paoletti, M.G., 2005. House cricket small-scale farming. In: Ecological implications of mini livestock: Potential of insects, rodents, frogs and snails (ed. M.G. Paoletti), Science Publishers, Enfield, NH, pp. 519-544.

Crawshaw, R., 1994. *A review of nutritional qualities for pigs, poultry and ruminant animals*. National Renderers Association, London, UK, pp. 1-6.

Cserhati, T. and Forgacs, E., 1999. *Chromatography in food science and technology*. Technomic Publishing, Lancaster, USA, pp. 158-298.

Das, M., Ganguly, A. and Halder, P., 2009. Space requirement for the mass rearing of two common Indian acridid adults (Orthopetra: Acrididae) in laboratory condition. *Am.-Euras. J. Agric. environ. Sci.,* **6**: 313-316.

Dutta, A.S. and Dutta, K.S., 2012. Growth of poultry chicks fed on formulated feed containing silk worm pupae meal as protein supplement and commercial diet. *J. Anim. Feed Res.,* **3**: 303-307.

Fagoonee, I., 1983. Possible growth factors for chickens in Silkworm pupae meal. *Br. Poult. Sci.,* **24**: 295-300.

Fadiyimu, A.A., Ayodele, A.O., Olowu, P.A. and Falorunsho, O.R., 2003. *Performance of finishing broilers fed graded levels of termite meals as replacement for fish meal*. Proceedings of the 28th Annual Conference of the Nigerian Society for Animal Production, 28: 211-212.

FAO, 2011. *World livestock 2011-livestock in food security*. Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO, 2012. *FAOSTAT*. Food and Agriculture Organization of the United Nations (FAO), Rome.

Hwangbo, J., Hong, E.C., Jang, A., Kang, H.K., Oh, J.S., Kim, B.W. and Park, B.S., 2008. Utilization of house fly-maggots, a feed supplement in the production of broiler chickens. *J. environ. Biol.,* **30**: 609–614.

Ijaiya, A.T. and Eko, E.O., 2009. Effect of replacing dietary fishmeal with silkworm (*Anapheefracta*) caterpillar meal on growth digestibility and economics production of starter broiler chicken. *Pakistan J. Nutr.,* **8**: 845-849. https://doi.org/10.3923/pjn.2009.845.849

Ji, H., Jian-Lu, Z., Ji-Qin, H., Xiao-Fei, C. and Chao, L.F., 2015. Effect of replacement of dietary fish meal

with silkworm pupae meal on growth performance, body composition, intestinal protease activity and health status in juvenile Jian carp (*Cyprinus carpio* var. Jian). *Aquacul. Res.,* **46**: 1209-1221. https://doi.org/10.1111/are.12276

Kerese, I., 1984. *Method of protein analysis*. Ellis Harwood Publishers, pp. 336-365.

Khan, S., Khan R.U., Sultan A., Khan, M., Hayat S.U. and Shahid M.S., 2016. Evaluating the suitability of maggot meal as a partial substitute of soybean on the productive traits, digestibility indices and organoleptic properties of broiler meat. *J. Anim. Physiol. Anim. Nutr*. **100**: 649-656.

Khan, S., Khan R.U., Sultan A., Khan, M., Hayat, S.U., Shahid, M.S., 2016. Evaluating the suitability of maggot meal as a partial substitute of soybean on the productive traits, digestibility indices and organoleptic properties of broiler meat. *J. Anim. Physiol. Anim. Nutr.,* **100**: 649-656. https://doi.org/10.1111/jpn.12419

Khatun, R., Howlider, M.A.R., Rahman, M.M. and Hasanuzzaman, M., 2003. Replacement of fish meal by silkworm pupae in broiler diets. *Pakistan J. biol. Sci.,* **6**: 955-958. https://doi.org/10.3923/pjbs.2003.955.958

Khatun, R., Azmal, S.A., Sarker, M.S.K., Rasid, M.A., Hussain, M.A. and Miah, M.Y., 2005. Effect of silkworm pupae on the growth and egg production performance of Rhode Island Red (RIR) Pure line. *Int. J. Poult. Sci.,* **4**: 718-720. https://doi.org/10.3923/ijps.2005.718.720

Khatun, R., Azmal, S.A., Sarker, M.S.K., Rasid, M.A., Hussain, M.A. and Miah, M.Y., 2005. Effect of silkworm pupae on the growth and egg production performance of Rhode Island Red (RIR) Pure line. *Int. J. Poult. Sci*., **4**: 718-720.

Konwar, P., Konwar, B.K., Ahmed, H.F., Nath, N.C. and Ghosh, M.K., 2008. Effect of feeding silkworm pupae meal with enzyme supplementation on growth performance of broilers. *Indian Vet. J.,* **85**: 47-49.

Kumur, A., Hasan, S.B. and Rao R.J., 1992. Studies on the performance of broiler fed silkworm moth meal. *Int. J. Anim. Sci.*, **7**: 227-229.

Longvah, T., Mangthya, K. and Ramulu, P., 2011. Nutrient composition and protein quality evaluation of eri silkworm (*Samia ricinii*) prepupae and pupae. *Fd. Chem.,* **128**: 400-403. https://doi.org/10.1016/j.foodchem.2011.03.041

Loselevich, N., Steingab, H., Rajamrodov, Z. and Drochner, W., 2004. *Nutritive value of silkworm pupae for ruminant*. 116 VDLUFA Kongress. Hrsg: Qualitatssicherung in landwiets chaftlichen productions system Rostock Bonn, pp, 108.

Makkar, G., Harinder, P.S., Tranb, B., Philippe, V.H. and Ankers, A., 2014. Review: State-of-the-art on use of insects as animal feed. *Anim. Feed Sci. Technol.,* **197**: 1-33. https://doi.org/10.1016/j.anifeedsci.2014.07.008

Nandeesha, M.C., Srikantha, G.K., Keshavanatha, P., Varghesea, T.J., Basavarajaa, N. and Dasa, S.K., 1990. Effects of non-defatted silkworm-pupae in diets on thegrowth of common carp, Cyprinus carpio. *Biol. Wastes*, **33**: 17–23.

NRC, 1994. *Nutrient requirements of poultry*. Ninth Revised Edition, 1994, National Academy Press, Washington D.C.

Ojewola, G.S., Okoye, F.C. and Ukoha, O.A., 2005. Comparative utilization of three animal protein sources by broiler chickens. *Int. J. Poult. Sci.,* **4**: 462-467. https://doi.org/10.3923/ijps.2005.462.467

Okah, U. and Onwujiariri, E.B., 2012. Performance of finisher broiler chickens fed maggot meal as a replacement for fish meal. *J. Agric. Technol.,* **8**: 471-477.

Patil, S.R., Amena, S., Vikas, A., Rahul, P., Jagadeesh, K. and Praveen, K., 2013. Utilization of silkworm litter and pupal waste-an eco-friendly approach for mass production of *Bacillus thuringiensis*. *Biores. Technol.,* **131**: 545-547. https://doi.org/10.1016/j.biortech.2012.12.153

Ramos-Elorduy, J., Gonzalez, E.A., Hernandez, A.R. and Pino, J.M., 2002. Use of *Tenebrio molitor* (Coleoptera: Tenebrionidae) to recycle organic wastes and as feed for broiler chickens. *J. econ. Ent.,* **95**: 214-220. https://doi.org/10.1603/0022-0493-95.1.214

Rao, P.U., 1994. Chemical composition and nutritional evaluation of spent silk worm pupae. *J. Agric. Fd. Chem.,* **42**: 2201-2203. https://doi.org/10.1021/jf00046a023

Rahman, M.A., Rahaze, M., Mazed, M.A. and Mahata, S.C., 1996. Replacement of costly fish meal by silkworm pupae in diet of mirroa corp (Cyprinus carpio). *Pak. J. Sci. Indust. Res.*, **39**: 64-67.

SAS, 2009. *Statistical analysis system user's guide*: Statistics, Version 9.2. SAS Institute, Inc., Cary, NC, USA.

Sanchez-Muros, M., Barroso, F.G. and Manzano-Agugliaro, F., 2014. Insect meal as renewable source of food for animal feeding: a review. *J. Clean. Prod.,* **65**: 16-27. https://doi.org/10.1016/j.

jclepro.2013.11.068

Sengor, E., Yardimci, M., Okur, N. and Can, U., 2008. Effect of short-term pre-hatch heat shock of incubating eggs on subsequent. *S. Afr. J. Anim. Sci.,* **38**: 58-64. https://doi.org/10.4314/sajas.v38i1.4110

Solomon, S.G., Yusufu, I.I, 2005. *The amino acid profile, proximate and mineral composition of silkworm caterpillar* (Anaphe infracta) *meal as possible alternative to fish meal in the diets of cultural fish species*. Department of Fisheries and Aquaculture. University of Agriculture, Makurdi Nigeria, pp, 10-15.

Sun, T., Long, R.J. and Liu, Z.Y., 2013. The effect of a diet containing grasshoppers and access to *freerange* on carcase and meat physicochemical and sensory characteristics in broilers. *Br. Poult. Sci.,* **54**: 130-137. https://doi.org/10.1080/00071668.2012.756575

Tona, G.O., Togun, V.A. and Oladele B.A., 2006. *Effect different levels of cocoa bean shell on the haematological characteristics of mature cocks*. Proceedings of 11 Annual Conference of Animal Science Association; Ibadan, Sept.: 35-37.

Trivedy, K., Kumar, S.N., Mondal, M. and Kumar-Bhat, C.A., 2008. Protein banding pattern and major amino acid component in de-oiled pupal powder of silkworm, *Bombyx mori* Linn. *J. Ent.,* **5**: 10-16. https://doi.org/10.3923/je.2008.10.16

Van Huis, A., Itterbeeck, V.J., Klunder, H., Mertens, E., Halloran, A., Muir G. and Vantomme P., 2013. *Edible insects Future prospects for food and feed security*. FAO Forestry Paper 171.

Veldkamp, T. and Bosch, G., 2015. Insects: a protein-rich feed ingredient in pig and poultry diets. *Anim. Front.,* **5**: 45-50.

Veldkamp, T., van Duinkerken, G., van Huis, A., Lakemond, C.M.M., Ottevanger, E., Bosch, G. and van Boekel, M.A.J.S., 2012. Insects as a sustainable feedingredient in pig and poultry diets – a feasibility study. In: *Rapport 638-Wageningen Livestock Research*. Available at: http://www.wageningenur.nl/upload_mm/2/8/0/f26765b9-98b2-49a7ae435251c5b694f6_234247%5B1%5D.

Valerie, H., Tran, G., Giger-Reverdin, S. and Lebas F., 2015. *Silkworm pupae meal*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. Available at: http://www.feedipedia.org/node/199.

Usub, T., Lertsatitthanakorn, C., Poomsa-ad, N., Wiset, L.,Yang, L. and Siriamornpun, S., 2008. Experimental performance of a solar tunnel dryer for drying silkworm pupae. *Biosys. Engin.,* **101**: 209-216. https://doi.org/10.1016/j.biosystemseng.2008.06.011

Willis, S., 2003. *The use of soyabean meal and full fat soyabean meal by the animal feed industry*. Proceedings of the 12th Australian Soyabean Conference, pp. 1-8.