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# Utilization of silkworm pupae meal as an alternative source of protein in the diet of livestock and poultry: A review

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## Abstract
The Silkworm pupae commonly known by different names in different places. Out of the world's total production about 90% of the world production results from the cocoons of the domesticated mulberry Silkmoth (*Bombyx mori)*, a Bombycidae moth. The spent pupae are produced in large quantities and are a major by-product of silk production. For 1 kg of raw silk, 8 kg of wet pupae (2 kg of dry pupae) are produced. After reeling silk from the cocoons the fresh spent silkworm pupae are normally thrawn nearby without proper disposal. These fresh silkworm pupae are highly degradable product which causes environmental pollution and off smell in the near vicinity areas. In silk producing areas, the disposal of huge quantity of pupae can cause serious environmental problems. Moreover, the costs of conventional protein sources such as soybean meal and fishmeal are very high and moreover their availability in the future will be limited. Therefore utilization of these valuable resources for feeding of livestock and poultry is a better way to reduce the environmental impact of silk industry. Silkworm pupae meal (SWPM) is a protein-rich feed ingredient of animal origin with a high nutritional value. On dry matter (DM) basis its crude protein content ranges from 50% to more than 80% (defatted meal). The lysine (6-7% of the protein) and methionine (2-3% of the protein) contents are particularly high. Silkworm pupae meal is relatively poor in minerals (3-10% DM) as compared to other animal by-products.

**Keywords:** Silkworm pupae, protein source, livestock, poultry feeding

## Introduction
The Silkworm pupae commonly known by different names such as Silkworm pupae meal (SWPM), Silkworm pupae, Silkworm meal, Spent silkworm pupae, defatted silkworm pupae meal, Deoiled silkworm pupae meal, Non-defatted silkworm pupae meal, Non-deoiled silkworm pupae meal, Eri silkworm pupae meal, and Muga silkworm pupae meal in different places [54].
The caterpillars of the moth species raised for reeling silk are the Silkworms. Out of the world's total production about 90% of the world production results from the cocoons of the domesticated mulberry Silkmoth (*Bombyx mori)*, a Bombycidae moth [54]. Silk is also produced from other domesticated or wild Saturniidae moth species, notably the Eri silkmoth *Samia cynthia ricini*, the Assam silkmoth *Antheraea assamensis*, the tussore (or tussah) moth *Antheraea mylitta* and the small tussore *Antheraea paphia* [26, 32]. When the silkworm enters the pupa phase, it builds a protective cocoon made of raw silk. At the end of pupation, the pupa releases an enzyme that creates a hole in the cocoon and the moth emerges. In order to produce silk, the pupae are killed by boiling, drying or soaking in NaOH before they produce the enzyme [6, 19]. The spent pupae are produced in large quantities and are a major by-product of silk production [6]. For 1 kg of raw silk, 8 kg of wet pupae (2 kg of dry pupae) are produced [35].
Spent silkworm pupae are a waste material often discarded/thrown in the open environment or used as fertilizer [61], which can causes severe environmental pollution and a loss of valuable resources. These pupae can be extracted to yield valuable oil used in industrial products such as paints, varnishes, pharmaceuticals, soaps, candles, plastic and bio-fuels [50]. The extracted meal is sometimes used for the production of chitin, the long-chain polymer of N-acetylglucosamine which is the main component of the exoskeleton [48]. The human being are also used to eat Silkworm pupae since long before in Asian silk-producing countries, and are considered as a delicacy in regions of China [27], Japan [33], Thailand [61], India [26] and elsewhere.

Owing to its high protein content, silkworm pupae meal has been used to fed livestock, notably for monogastric species (poultry, pigs and fish), but also for ruminants [50].

Fresh spent silkworm pupae are easily perishable due to their high moisture content, therefore spent pupae are generally sun-dried and ground [53; 59; 19]. Defatted silkworm pupae meal is less perishable and has high protein content than undefatted meal [1]. After drying, the spent silkworm pupae should be ground properly to assure more uniform mixing in rations [12]. Silkworm litter (or silkworm dregs), another by-product of silkworm rearing, is a mixture of excreta [35], sloughs (moulting residues) and mulberry leaves [4].

There are different species of Silkworm such as *Bombyx mori* L. (Bombycidae); *Antheraea assamensis*; *Antheraea mylitta*; *Antheraea paphia*; *Samia cynthia ricini* (Saturniidae) etc. [54]. There are four types of natural silk which are commercially known and produced in the world. Among them mulberry silk (*Bombyx mori* L.) is the most important and contributes as much as 90 per cent of world production, therefore, the term "silk" in general refers to the silk of the mulberry silkworm. Three other commercially important types fall into the category of non-mulberry silks namely: Eri silk; Tasar silk; and Muga silk [54]. There are also other types of non-mulberry silk e.g. Anaphe silk, Fagara silk, Coan silk, Mussel silk and Spider silk which are mostly wild and exploited in Africa and Asia [54].The present paper reviews the utilization of Silkworm pupae as an alternate source of protein in livestock and poultry feeding in different countries for better production and prevention of environmental pollution.

**Mulberry silk**

Bulk of the commercial silk produced in the world comes from this variety and often generally refers to mulberry silk. Mulberry silk comes from the silkworm, *Bombyx mori* L which solely feeds on the leaves of mulberry plant. These silkworms are completely domesticated and reared indoor systems. Around 90 percent of the world silk production is contributed by Mulberry silk [54].

**Tasar silk**

The tasar silkworms belong to the genus Antheraea and they are all wild silkworms [54]. There are many varieties Tasar silk worm such as the Chinese tasar silkworm *Antherae pernyi Guerin* which produces the largest quantity of non-mulberry silk in the world, the Indian tasar silkworm *Antheraea mylitte Dury*, next in importance, and the Japanese tasar silkworm *Antheraea yamamai Querin* which produces green silk thread and is peculiar to Japan [54].

The Chinese and Japanese tasar worms mostly feed on oak leaves and other allied species. The Indian tasar worms feeds mainly on leaves of Terminalia and several other minor host plants. The worms are either uni- or bivoltine and their cocoons like the mulberry silkworm cocoons can be reeled into raw silk [54].

**Eri silk**

Eri silkworm (*Samia ricinii*) is a traditional source of food in northeast India, where it is grown primarily for silk and food uses. Eri silk belongs to either of two species namely *Samia ricini* and *Philosamia ricini*. *P. ricini* (castor silkworm) is reared on castor oil plant leaves to produce a white or brick-red silk called as Eri silk [54].

**Muga silk**

The muga silkworms (*Antheraea assamensis*) produce an extraordinary golden-yellow silk thread which is very attractive and strong are also belong to the same genus as tasar worms. The Sualkuchi area of Assam, India is famous for Muga silkworms and feed on Persea bombycina and Litsaea monopetala leaves and those of other species. The small quantity of muga silk produced is mostly used for the making of traditional dresses in Assam [54].

**Anaphe silk**

The anaphe silk is produced by silkworms of the genus Anaphe: *A. moloneyi Druce, A. panda Boisduval, A. reticulate Walker, A. ambrizia Butler, A. carteri Walsingham, A. venata Butler and A. infracta Walsingham.* The tribal folks normally used collect from the forest and spin the fluff into a raw silk which is soft and fairly lustrous. The silk obtained from *A. infracta* is known locally as "book", and those from *A. moleneyi* as "Trisnian-tsamia" and "koko" (Tt). The fabric is elastic and stronger than that of mulberry silk [54].

**Fagara silk**

This silk is obtained from the giant silk moth *Attacus atlas L*. and a few other allied species or races found in the Indo-Australian bio-geographic region, China and Sudan. They spin light-brown cocoons nearly 6 cm long with peduncles of varying lengths (2-10 cm) [54].

**Coan silk**

The larvae of *Pachypasa atus D.*, from the Mediterranean bio-geographic region (southern Italy, Greece, Romania, Turkey, etc.), feed primarily on trees such as pine, ash cypress, juniper and oak. They spin white cocoons measuring about 8.9 cm x 7.6 cm. In prehistoric times, the crimson-dyed apparel worn by the dignitaries of Rome was the product of this silk. Because of the limited output and the emergence of superior varieties of silk, commercial production came to an end long ago [54].

**Mussel silk**

The tough brown filament, or byssus, is secreted by the mussel to anchor it to a rock or other surface. The byssus is combed and then spun into a silk popularly known as “fish wool”. The Mussel silk is obtained from a bivalve, Pinna squamosa, found in the shallow waters along the Italina and Dalmatian shores of the Adriatic. This silk is a non insect variety. Its production is largely confined to Taranto, Italy [54].

**Spider silk**

Spider silk is also another non-insect variety which is soft and fine, but also strong and elastic. The commercial production of this silk comes from certain Madagascan species, including *Nephila* the fourth and fifth abdominal segments, about a dozen individuals are confined by their abdominal part to a frame from which the accumulated fibre is reeled out four or five times a month [54]. Owing to high cost of production, spider silk is not used in the textile industry; however, durability and resistance to extreme temperature and humidity make it indispensable for cross hairs in optical instruments [54].

**Impact on Environment**

After reeling silk from the cocoons the fresh spent silkworm pupae are normally thrawn nearby without proper disposal. These fresh silkworm pupae are highly degradable product which causes environmental pollution and off smell in the near vicinity areas. In silk producing areas, the disposal of huge quantity of pupae can cause serious environmental problems [61]. Therefore utilization of these valuable resources for feeding of livestock and poultry or for the production of valuable biological substances like chitin, protein, oil and fatty acids (α-linolenic acid) is a better way to reduce the environmental impact of silk industry.

**Nutritional Significance**

Silkworm pupae meal (SWPM) is a protein-rich feed ingredient of animal origin with a high nutritional value. On dry matter (DM) basis its crude protein content ranges from 50% to more than 80% (defatted meal) [11]. The lysine (6-7% of the protein) and methionine (2-3% of the protein) contents are particularly high. However, the true protein in silkworms was found to correspond to only 73% of the crude protein content [11]. The presence of chitin and insoluble protein may also explain the presence of fibre, and values of 6-12% DM of ADF have been reported [11; 18]. The pupae meal (undefeated) is rich in fat, typically in the range of 20-40% on DM basis. Defatted Silkworm meal contains less than 10% oil which is rich in polyunsaturated fatty acids, notably linolenic acid (18:3), with values ranging from 11 to 45% of the total fatty acids as reported [18; 38; 53]. Silkworm pupae meal is relatively poor in minerals (3-10% DM) as compared to other animal by-products. The crude protein value of Silkworm litter varies extremely i.e. between 15 and 58% DM [4; 35].

**Table 1:** Chemical composition of silkworm pupae meal (non-defatted)

| Crude protein (% in DM) n=10 | Crude fibre (% in DM) n=3 | Ether extract (% in DM) n=8 | Ash (% in DM) n=8 |
|---|---|---|---|
| 60.7 + 7.0 | 3.9 + 1.1 | 25.7 + 9.0 | 5.8 + 2.4 |
| (51.6, 70.6) | (2.5, 5.8) | (6.2, 37.1) | (3.3, 10.6) |

DM, dry matter; n = 9 for all the values; values are mean + standard deviation; values in parentheses are minimum and maximum values; Gross energy = 25.8 MJ/kg DM

**Sources:** Coll *et al.* [5]; Fagoonee [9]; Gohl [12]; Gowda *et al.* [13]; Hossain *et al.* [15]; Hossain *et al.* [16]; Ioselevich *et al.* [18]; Jintasataporn [19]; Longvah *et al.* [26]; Narang and Lal [34]; Rao [38].

**Table 2:** Chemical composition of silkworm pupae meal (defatted)

| Crude protein (% in DM) n=10 | Crude fibre (% in DM) n=3 | Ether extract (% in DM) n=8 | Ash (% in DM) n=8 | Ca (g/kg DM) n=4 | P (g/kg DM) n=4 |
|---|---|---|---|---|---|
| 75.6 + 10.8<br>(48.9, 83.3) | 6.6 + 3.1<br>(4.3, 10.2) | 4.7 + 2.7<br>(1.0, 8.5) | 6.8 + 4.1<br>(2.1, 14.6) | 4.0 + 3.6<br>(1.0, 9.1) | 8.7 + 4.8<br>(3.3, 15.0) |

DM, dry matter; Gross energy = 22.0 + 0.4 MJ/kg DM (n=3); values are mean + standard deviation; values in parentheses are minimum and maximum values

**Sources:** Hossain *et al.* [16]; Jintasataporn [19]; Khan and Zubairy [20]; Lakshminarayana and Thirumala Rao [24]; Lin *et al.* [25].

**Table 3:** Amino acid composition of silkworm pupae meal (defatted)

| Amino acids | g/16 g Nitrogen | Range |
|---|---|---|
| Alanine | 4.4 + 0.2 | 4.0- 4.6 |
| Arginine | 5.1 + 0.3 | 4.7- 5.4 |
| Aspartic acid | 7.8 + 0.7 | 6.9- 8.6 |
| Cystine | 0.8 + 0.5 | 0.3- 1.4 |
| Methionine | 3.0 + 0.4 | 2.3- 3.4 |
| Lysine | 6.1 + 0.4 | 5.8- 6.7 |
| Isoleucine | 3.9 + 0.2 | 3.7- 4.1 |
| Leucine | 5.8 + 0.2 | 5.6- 8.0 |
| Phenylalanine | 4.4 + 0.3 | 4.1- 4.8 |
| Threonine | 4.8 + 0.3 | 4.5- 5.2 |
| Tryptophan | 1.4 + 0.2 | 1.2- 1.6 |
| Glutamic acid | 8.3 + 0.7 | 7.5 - 8.9 |
| Histidine | 2.6 + 0.1 | 2.4 - 2.8 |
| Proline | 5.2 | 4.0 - 6.5 |
| Serine | 4.5 + 0.2 | 4.2 - 4.7 |
| Glycine | 3.7 + 0.3 | 3.4- 3.1 |
| Tyrosine | 5.5 + 0.2 | 5.3- 5.8 |
| Valine | 4.9 + 0.2 | 4.6- 5.1 |

n=5 for all values except cystine (n=4)

**Source:** Lin *et al.* [25].

**Possible limitations**

Silkworm pupae meal does not appear to contain toxic components. In poultry, notably, the mortality of birds fed diets containing silkworm meal is similar to that of animals fed more conventional protein sources [8]. It was observed that Supplementation of SWPM at different levels replacing conventional fishmeal in the diet of poultry reduced the growth rate in broilers. However upto 10 per cent level it can be used safely in the diet of broilers.

**Ruminants**

Silkworm meal (SWPM) is very rich sources of protein and can supplement in ruminants diet, due to its highly undegradable protein content and favourable amino acid profile [18]. There is a limitation of its use as ruminant feed due to high oil content. Therefore, fat extraction of silkworm pupae meal is of prime criteria when it is fed in large amounts [18]. Narang and Lal [34] reported that Silkworm meal could safely replaced 33% of groundnut cake (GNC) in fattening diets for Jersey calves without affecting performance, resulting in a cheaper diet. They also found that the protein digestibility of the silkworm meal-based diet was higher than that of the groundnut cake diet.

Effective *in situ* nitrogen degradability of silkworm pupae meal is relatively low. The effective degradability values (5%/h outflow rate) for undefatted silkworm pupae were 29% and 25% as reported by many researchers [2; 18] and only 20% for defatted meal [3] resulting in good proportion of undegradable protein, especially from the defatted meal, richer in protein. The two major limiting amino acids for milk production, Lysine and methionine are considered to have a low *in situ* disappearance of 26% (24 h incubation, 5%/h outflow rate), indicating that the bypass protein fractions of silkworm pupae meal are good sources of lysine and methionine for ruminants diets [42].

Ioselevich *et al.* [18] fed a basal diet of barley and hay (75:25) in lambs, the iso-nitrogenous substitution of a potato protein supplement with undefatted silkworm meal resulted in similar increases in nitrogen and energy retention. The crude protein digestibility of defatted Tussore silkworm pupae fed with wheat straw and molasses to sheep was about 70% [20].

**Pigs**

The information available on the utilization of silkworm pupae in the diet of pig is scanty. Few experiments showed that silkworm pupae meal was a good replacement for conventional protein sources. In a study carried out in Brazil, up to 100% replacement of soybean meal in diets for growing and finishing pigs with undefatted silkworm meal resulted no effect on growth performance and carcass characteristics. However, there was a negative effect on intake when the substitution rate was more than 50%, which was attributed either to the higher energy density of the diet or to a lower palatability. The lower intake was compensated by a better feed conversion rate, which may have been due to the higher lysine content of the silkworm-based diet [5]. In India, silkworm meal could fully replace fish meal (upto 100%) in the diet of growing and finishing pigs without any significant effect on carcass and meat quality and blood parameters [29; 30; 31]. The Silkworm excreta or litter can be incorporated in pig diets at recommended inclusion rate are about 7% and should not exceed 10% [4, 56].

**Poultry**

The conventional source of protein used in poultry diet is fishmeal and Soyabean which costly. Silkworm pupae meal is a valuable cheaper alternate protein source that can be used in poultry feeding, though it is of slightly lower quality than fish meal. High amino acid digestibilities (lysine 94%, methionine 95%) were determined in geese [36].

**Broilers**

Several trials have conducted in many countries of the world shown that replacing 50% of the main protein source (fish meal) in most of the experiments is usually safe, though mineral supplementation may be required. Total replacement is sometimes possible but tends to result in a lower performance. Normally inclusion rates are typically in the range of 5-10% range [54].

Growth stimulating effect in growing chicks correlated with the activity of ecdysteroid, a hormone involved in the metamorphosis of the pupae indicated in a study [9; 10], though this has not been confirmed since. Broilers fed deoiled silkworm pupae meal treated with 70% acetone for a time period of 12 hours was shown to improve the performance [61]. Several researchers carried out experiments while replacing conventional protein sources with silkworm meal in poultry feeds are summarized in the table 4 as follows.

**Table 4:** Research carried out in different countries on silkworm pupae meal

| Country of Study | Diets for trial | Results | Reference |
|---|---|---|---|
| India | Laying hens: comparison to other alternative feeds | Better technical and economic performance for silkworm meal compared to other feeds (feed-to-egg conversion ratio, egg size, shell thickness, grading, light yellow yolk, no mortality, feed cost, cost per dozen eggs). | Saikia *et al.* [41] |
| India | Layer chicks: substitution 0-100% of fish meal | Deoiled silkworm meal replaced 100% fish meal. | Virk *et al.* [61] |
| Mauritius | Broiler Chicken: Replacement 0-100% of fish meal | 50% replacement of fish meal had no adverse effect on growth performance but 100% replacement had adversely affected the growth performance. | Fagoonee [10] |
| Turkey | Broiler Chicken: Replacement 50-100% of fish meal or meat and bone meal | Observed detrimental effect on weight gain and feed efficiency. | Tas [49] |
| India | Broiler Chicken:: Replacement 0-50% of fish meal (5% diet) | 50% replacement of conventional fish meal had a negative effect on growth performance and feed efficiency which was overcome with addition of salt and/or mineral mixture. | Reddy *et al.* [40] |
| Brazil | Pigs: Replaced soya oilcake meal with Silkworm meal at different levels | Non-defatted silkworm pupae meal could partially replace soya oilcake meal in diets for growing and finishing pigs with no significant effects on growth and carcass traits. However, a negative effect on intake was observed when the substitution rate exceeded 50%. However, the lower intake was compensated for by a higher feed conversion rate. | Coll *et al.*[5] |
| India | Broiler Chicken: Replacement 0-100% of fish meal | Upto 50% replacement had not any adverse effect without Ca and P supplementation.However,100% replacement was detrimental to feed efficiency. | Purushothaman and Thirumalai [37] |
| India | Layer chicks: substitution 0-100% of fish meal (6% diet) | Reduction of intake and weight gain in diets based on 50-100% silkworm meal. | Deshpande *et al.* [7] |
| India | Broiler Chicken: Replacement 0-100% of fishmeal (Diet 5% SWPM+0% WSPM, 2.5% FM+2.5% SWPM, 0% FM+5% SWPM) | Slightly depressed growth rate but overall no adverse effect of Muga silkworm pupae meal at 100% substitution level in broilers diet. | Sapcota *et al.* [43] |
| Bangladesh | Broiler Chicken: Diet (6% FM+0% SWP, 4% FM+2% SWP, 2% FM+4% SWP, 0% FM+6% SWP | Increased growth rate with increasing levels of SWP in the diet. Feed intake decreased significantly and FCR increased significantly at 28 and 42 days of age. Significantly decreased the total cost of production per kg live broiler and significantly increased profit per broiler with the increase in SWP level. | Khatun *et al.*[22] |
| India | Breeder male: Substitution | substitution of fish meal at 50 and 100% with silkworm pupae meal was | Mahanta *et* |

| | | | |
|---|---|---|---|
| | 0-100% of fish meal | detrimental to the breeding performance of breeder males | *al.*[28] |
| India | Broiler Chicken: Diet (5% SWPM+0% WSPM, 2.5% FM+2.5% SWPM, 0% FM+5% SWPM) | Conventional fishmeal of broilers diet could be replaced with 100% Muga silkworm pupae meal without any adverse effect on carcass characteristics. | Sheikh *et al.* [46] |
| Bangladesh | Layer chicks: 6 to 8% silkworm meal replacing a protein concentrate | Profitability, growth and egg production performance of Rhode Island Red (RIR) Pure Line was higher with 6% silkworm meal and the feed cost/kg was gradually declined with the increasing dietary levels of silkworm pupae (SWP). | Khatun *et al.* [21] |
| India | Broiler Chicken: Diet (5% SWPM+0% WSPM, 2.5% FM+2.5% SWPM, 0% FM+5% SWPM) | Muga silkworm meal replacing 100% of fish meal gave the best results in terms of economics of production. | Sheikh and Sapcota [47] |
| India | Broiler Chicken: Substitution 0-100% of fish meal with or without enzyme supplementation | Silkworm pupae meal could replace fish meal without adverse effects. Silkworm meal with enzymes improved growth performance and decreased feed intake. The best performance was obtained with 50% silkworm pupae with supplementation of enzymes. | Konwar *et al.*[23] |
| Pakistan | Broiler Chicken: Substitution 0-100% of fish meal | Cost per kg gain gradually declined with increasing dietary level of Silkworm Caterpillar meal indicating higher economic benefit. Cheaper Silkworm Caterpillar meal can be an excellent substitute for fish meal in formulating diets for starter broiler chicks leading to increased economic gains | Ijaiya and Eko [17] |
| India | Broiler Chicken: Diet (5% SWPM+0% WSPM, 2.5% FM+2.5% SWPM, 0% FM+5% SWPM) | The 100% fish meal supplemented diet resulted in a higher live-weight gain but the 50% silkworm diet gave higher nitrogen and calcium retention. | Sheikh and Sapcota [45] |
| India | Broiler Chicken: Replacement 0-100% of fish meal | Tussore silkworm meal replaced 50% of fish meal resulted increased profit margin due to much lower cost of silkworm meal compared to fishmeal. This shows that with a linear increase of incorporation of SWP in the poultry feed there is corresponding decrease in cost per unit of feed. | Sinha *et al.* [44]; Dutta *et al.*[8] |
| India | Broiler Chicken: Substitution 0-100% of fish meal | Replacement of fish meal with fermented silkworm pupae or fresh silkworm pupae resulted a better feed conversion ratio and absence of fishy taint in the meat. | Rao *et al.* [39] |
| India | Pig: Substitution 0-100% of fish meal | Silkworm Pupae meal could fully replace fish meal in the diet of growing and finishing pigs without altering carcass and meat quality and blood parameters | Medhi [29]; Medhi *et al.*[30]; Medhi *et al.* [31] |
| Thailand | Broiler Chicken: Replacement 0-100% of fish meal (0-20% diet) | A mixture of defatted and as such basis silkworm pupae meal replaced fishmeal at 10% inclusion level had little adverse effect on broiler growth but no adverse effect on percentage of muscle yield and sensory test. Higher inclusion levels were detrimental to feed conversion and muscle yield. | Jintasataporn [19] |
| China | Fish: Replaced dietary FM protein with SWPM at 0, 50%, 60%, 70% or 80% levels | The final body weight and specific growth rate of fish in the SP60, SP70 and SP80 groups were significantly lower than those for fish in the SP0 group ($P < 0.05$). The study demonstrates that it is practical to replace 50% of the Jian carp dietary FM protein with SP, higher SP levels are not recommended and that oxidation status of the SP should be carefully assessed. | Hong *et al.* [14] |
| Pakistan | Layer chicken: Substitution soybean meal at 0, 25,50,100% by SWPM | Body weight, feed intake, hen day production (%), egg weight, feed conversion ratio, Blood profile and egg quality parameters did not differ significantly. It could be concluded that silkworm meal can be effectively used as an alternative protein source to soybean meal without any adverse effects on the layers. | Ullah *et al.*[51] |
| Pakistan | Broiler chicken: Substitution soybean meal at 0, 25,50,75 &100% by SCM | Cost per kg of feed gradually decline with increasing dietary level of SCM inclusion levels, indicating higher economic benefit. It was revealed that replacement of soyabean meal with silkworm meal did not affect broiler performance and carcass quality. | Ullah *et al.*[52] |

## Conclusion

The reviews of the present paper indicated that the conventional soybean meal or fish meal may be replaced with silkworm pupae meal in the diet of livestock and poultry for economic production. The silkworm pupae meal has no adverse effect on the production performances of livestock and poultry. Moreover the environmental pollution could be minimized by suitable processing and proper utilization of the precious resources.

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