



Effect of partial replacement of protein supplement with silkworm (*Bombyx mori* L.) pupa meal on production performances in crossbred (HS × GH) grower pigs

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ABSTRACT

Eighteen crossbred (HS × GH) castrated grower pigs (3 months old, body wt. ranged from 13 to 14 kg) were divided into three groups of six each in a randomized block design to investigate the partial replacement of conventional protein sources with silkworm pupae (*Bombyx mori*) meal on production performance. Three different diets were prepared for feeding of experimental animals. These were namely - T1: standard grower ration without silkworm pupa meal and designated as control diet, T2: standard grower ration supplemented with 1.5% silkworm pupa meal by replacing 2.5% protein supplements which include mixture of groundnut cake and soyabean meal and standard grower ration supplemented with 3% silkworm pupa meal by replacing 5% protein supplements. The pigs were fed on the experimental grower rations twice daily in the morning and evening. The average dry matter intake was found similar in T1, T2 and T3 groups. Digestibility coefficients (%) of dry matter, crude protein, ether extract and crude fiber was increased in silkworm pupa meal supplemented groups. Nitrogen balance (g/d) was found positive across all the groups and was increased in supplemented groups in comparison to control. The average body weight gain (g/day) was found higher in silkworm pupa supplemented groups. The cost (₹/kg gain) was reduced in T2 and T3 groups in comparison to T1 group. The feed conversion efficiency (FCR) was higher T2 and T3 groups than control group. From this study, it is concluded that silkworm pupa meal can be supplemented @ 3% level by replacing 5% protein supplements in grower crossbred pigs to improve growth, nutrient utilization, feed conversion efficiency and also to reduce the feed cost.

Keywords: Crossbred Pigs, Growth, Nutrient utilization, Silkworm pupa meal, Supplementation

In pig farming, feed cost alone represents 65 to 75% of the variable costs and it plays a major role in determining the profitability of a piggery farm. Limited production along with increasing demand of feed ingredients results in high rise of their price. Moreover, high cost of protein ingredients such as groundnut cake and soyabean meal increase the cost of the pig diets. In this context, pig producer need to look for locally available alternate cheaper source of protein ingredient for making the pig production more profitable. Silkworms and its byproducts are one of such protein feed ingredients and can substitute the conventional protein ingredients in pig ration.

Silkworms are the caterpillars of moth species raised for silk. Nearly, 90% of the world silk production results from the cocoons of the domesticated mulberry silkworm *Bombyx mori*, a Bombycidae moth. It is also produced from other domesticated or wild Saturniidae moth species,

notably the Eri silkworm *Samia cynthia ricini*, the Assam silkworm *Antheraea assamensis*. The spent pupae are produced in large quantities and are a major by-product of silk production (Datta 2007). For 1 kg of raw silk, 8 kg of wet pupae (2 kg of dry pupae) are produced (Patil *et al.* 2013). Spent silkworm pupae are a waste material often discarded in the open environment or used as fertilizer (Wei *et al.* 2009). It can be extracted to yield valuable oil used in industrial products such as paints, varnishes, pharmaceuticals, soaps, candles, plastic and bio-fuels (Trivedy *et al.* 2008). The world production of silkworm cocoons suitable for reeling was about 485,000 tons in 2011. By subtracting the amount of raw silk (161,000 t), it can be assumed that 324,000 tons of fresh pupae (65,000 t dry) were produced in 2011 (FAO 2012). However, these FAO estimates are much lower than the official statistics from China, where a figure of 440,000 t of dry pupae produced in 2009 has been cited (Wei *et al.* 2009). The main silk producers are China, India, Uzbekistan, Brazil, Thailand and Vietnam (FAO 2012). Due to its high protein content, silkworm pupae meal has been found suitable as a livestock

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feed, notably for monogastric species (poultry, pigs and fish), but also for ruminants (Trivedy *et al.* 2008, Sheikh *et al.* 2018). The lysine content of silk worm pupa meal is very high which ranged from 6 to 7% of the protein contents (Sheikh *et al.* 2018) which is very much essential for improving pig production. There is little literature available on use of substitution of conventional protein sources with silkworm pupa meal in pigs. Therefore, in this study, silkworm pupa meal was supplemented at different levels by replacing conventional protein mixture e.g. groundnut cake and soybean meal to see its effect on production performances in crossbred grower pigs.

MATERIALS AND METHODS

The study was carried out at ICAR-National Research Centre on Pig Farm located at Rani, Guwahati, Assam, India. It was carried out after the approval by the Institute Animal Ethic Committee for providing necessary protection of animals used for experimental and other scientific purposes. Animals were housed in a well-ventilated sty. Healthy surroundings and proper cleanliness of animals and shed were maintained throughout the experimental period. Drinking water was available round the clock and feeding was done twice daily at 9:30 AM and 2:30 PM.

Preparation of silkworm pupa meal: Freshly collected silkworm pupa was dried at hot air oven at 70°C till complete drying. Then dried silkworm was grinded using mixer grinder. The grinded silkworm was kept in polythene bag till used in the experimental ration.

Experimental animals and design of experiment: Eighteen crossbred (Hampshire × Ghungroo) grower pigs (3 months old, body wt. ranged from 13 to 14 kg) of either sex were divided into three groups of six each in a randomized block design. Three different diets were used for feeding of the experimental animals. The diets were - T1: standard grower ration without addition of dried silkworm pupa meal and designated as control diet; T2: standard grower ration supplemented with 1.5% dried silkworm pupa meal by replacing 2.5% protein supplements which include mixture of groundnut cake and soyabean meal and T3: standard grower ration supplemented with 3% dried silkworm pupa meal by replacing 5% protein supplements which include mixture of groundnut cake and soyabean meal (ingredient composition of diets are shown in Table 1). Dried silkworm pupa meal was added on w/w basis to the experimental diets. The lysine and methionine were balanced in all the rations as per requirement. The pigs were fed on the experimental grower rations twice daily in the morning and evening. The nutrient requirement of pigs was made as per Bureau of Indian Standard (BIS 1986). The experiment was conducted for a period of three months. Fortnightly body weight of the experimental animals was recorded using digital balance. A metabolic trial for 5 days duration was conducted at the middle of the feeding experiment.

Conduction of metabolic trial: Experimental pigs were shifted from grower sty to metabolic cages during

Table 1. Ingredient composition (w/w) of experimental diet

Ingredient	T1 Parts	T2 Parts	T3 Parts
Maize grain	60.0	60.0	60.0
Wheat bran	12.0	13.0	14.0
Silkworm pupa meal	0.0	1.5	3.0
Soyabean meal	15.0	13.0	12.0
GN Cake	11.5	11.0	9.5
Mineral mixture	1.0	1.0	1.0
Salt	0.5	0.5	0.5
Total, kg	100.0	100.0	100.0
Lysine	100.0 g	100.0 g	100.0 g
Phytase	20.0 g	20.0 g	20.0 g

T1, 0% Silkworm pupa meal; T2, 1.5% silkworm pupa meal; T3, 3% silkworm pupa meal.

conduction of metabolic trial. Weight of the individual pigs was recorded before and after the conduction of metabolic trial. Daily feed offered and residue left was collected. These were dried to constant weight using hot air oven at 100°C. From the difference of intake and residue left, actual dry matter intake was calculated. First day collected faeces and urine were discarded. Faeces and urine voided during 24 h was recorded and daily representative quantity was brought to the laboratory for sampling. Proximate composition was done as per AOAC (1990). N-balance was calculated from difference between the total N intake and total N excreted. Nitrogen absorbed was calculated from the difference between total N intake and faecal N excretion. Nitrogen absorbed as per cent intake was calculated from the per cent ratio of nitrogen absorb and nitrogen intake. Net protein utilization (NPU) was calculated from the per cent ratio of N balance and N intake. Biological value (BV) was calculated from the per cent ratio of N balance and N-absorbed.

Statistical analysis: Mean and standard error were estimated for different parameters namely feed intake, nutrient digestibility, nitrogen balance, feed conversion ratio (feed gain ratio), feed cost per kg gain, average daily weight gain and effect of different treatments were analyzed by general linear model using PROC GLM of SAS 9.4 software (SAS institute Inc. 2014).

RESULTS AND DISCUSSION

Proximate composition: The crude protein content (% DM) of the experimental rations was ranged from 18.01±0.51 to 18.06±0.17 (Table 2). Nitrogen free extract content (% DM) of the experimental rations was ranged from 65.60±0.86 in T2 to 67.12±0.20 in T3. The crude protein and NFE content of silk worm pupae meal was 59.61±0.77 and 10.24±2.35, respectively (Table 2). Similar protein content of silk worm pupa was also reported by other researchers (Fagonee 1983, Longvah *et al.* 1994, Rao 1994, Hossain *et al.* 1997, Pereira *et al.* 2003). The ether extract content of silk worm pupae is 14.21±1.71. In contrast to this finding, Yhoun-Aree *et al.* (2014), reported a lower level of ether extract content of silk worm pupa. These

Table 2. Proximate composition (on % DM) of experimental diets

Parameter	T1	T2	T3	Silkworm pupae meal
OM %	94.15±0.16	93.60±0.18	94.33±0.08	92.23±1.68
CP %	18.06±0.17	18.01±0.51	18.03±0.05	59.61±0.77
CF %	7.94±0.18	8.26±0.19	7.45±0.02	8.17±1.61
EE %	1.44±0.08	1.72±0.03	1.73±0.06	14.21±1.71
Ash %	5.85±0.16	6.40±0.18	5.67±0.08	7.78±1.68
NFE %	66.70±0.42	65.60±0.86	67.12±0.20	10.24±2.35
DM %	89.43±0.41	89.34±0.02	89.64±0.24	19.36±0.44

T1, 0% Silkworm pupa meal; T2, 1.5% Silkworm pupa meal; T3, 3% Silkworm pupa meal; OM, Organic matter; CP, Crude protein; CF, Crude fibre; EE, Ether extract; NFE, Nitrogen free extract; DM, Dry matter.

Table 3. Effect of supplementation of silkworm pupa meal on nutrient utilization in crossbred grower pigs

Parameter	T1	T2	T3	P value
DMI, g/day	804.60±1.54	804.17±0.18	805.91±1.03	0.518
ADG, g/day	506.25±52.58	525.00±52.36	564.50±36.34	0.648
FCR (Feed gain ratio)	1.84±0.19	1.76±0.15	1.61±0.11	0.598
Feed cost/kg gain (₹)	44.87±4.64	44.78±3.80	42.80±2.83	0.911

T1, 0% Silkworm pupa meal; T2, 1.5% silkworm pupa meal; T3, 3% silkworm pupa meal; DMI, Dry matter intake; ADG, Average daily gain; FCR, Feed conversion ratio.

variations of protein value of silk worm pupae may be due to differences in agro-climatic conditions, composition of diet offered to them, etc.

Dry matter intake, growth, feed conversion ratio and nutrient digestibility: The average dry matter intake (g/d) was 804.60±1.54, 804.17±0.18 and 805.91±1.03 respectively in T1, T2 and T3 groups and was found similar across all the groups (Table 3). The average daily gain (ADG, g/d) was 506.25±52.58, 525.00±52.36 and 564.50±36.34 respectively in T1, T2 and T3 groups and was found similar across all the groups. There was no difference on ADG between groups. Similarly, feed conversion ratio was found similar among the groups. The feed cost/kg gain was 44.87±4.64, 44.78±3.80 and 42.80±2.83 respectively in groups T1, T2 and T3 respectively (Table 3) which was statistically found similar across the group.

The digestibility of all the nutrients were found higher in silk worm pupae supplemented groups and the same was found significantly higher ($P<0.05$) for DM, CP, EE and CF in T2 and T3 groups in comparison to T1 group. The digestibility coefficients (%) of DM, OM, CP, EE, CF and

NFE was increased by 1.88, 1.34, 2.34, 1.71, 5.64 and 0.67% respectively in T2 group while same was increased by 2.70, 2.10, 4.06, 4.49, 5.43 and 0.94% in T3 group in comparison to T1 group. The trend of increased digestibility of nutrients were found higher with increased level of silk worm pupae meal in the diet (Table 4).

Similarly, Datta *et al.* (2012) found that replacement of fish meal with silk worm pupa meal @ 0, 25, 50, 75 and 100% level in commercial poultry diet did not affect the feed intake. However, they observed non-significant decreased in feed intake at 75 and 100% replacement of fish meal with silk worm pupa meal. In this study, nutrients digestibility was found higher in the silk worm pupae supplemented groups in comparison to control group. Average daily gain in weight was higher in groups supplemented with silk worm pupae meal which might be due to higher biological value of silk worm pupae meal protein. High ADG in supplemented groups (T2 and T3) were associated with higher FCR in those groups and thereby reduced the cost of production per kg gain by ₹ 0.09 and ₹ 2.07 in T2 and T3 groups respectively. Medhi *et al.* (2009a and 2009b) reported that substitution of fish

Table 4. Effect of supplementation of silkworm pupa meal on digestibility coefficients of nutrients in crossbred grower pigs

Parameter	T1	T2	T3	P value
DM %	82.27 ^a ±0.57	84.15 ^{ab} ±0.31	84.97 ^b ±0.40	0.049*
OM %	84.44±0.62	85.78±0.27	86.54±0.28	0.083
CP %	78.99 ^a ±0.36	81.33 ^{ab} ±0.54	83.05 ^b ±0.09	0.011*
EE %	80.13 ^a ±0.51	81.84 ^{ab} ±0.52	84.62 ^b ±0.53	0.02*
CF %	69.24 ^a ±0.20	74.86 ^b ±0.72	74.67 ^b ±0.96	0.018*
NFE %	87.93±0.97	88.60±0.36	88.87±0.35	0.607

T1, 0% Silkworm pupa meal; T2, 1.5% silkworm pupa meal; T3, 3.0% silkworm pupa meal; ^{a,b,c}different superscript in a column differ significantly (* $P<0.05$); DM, Dry matter; OM, Organic matter; CF, Crude fibre; EE, Ether extract; NFE, Nitrogen free extract.

Table 5. Effect of supplementation of silk worm pupae meal on N-balance and N, utilization in crossbred (HS× GH) grower pigs

Parameter	T1	T2	T3	P value
Nitrogen Intake, g/d	23.54±0.15	23.48±0.32	23.60±0.22	0.941
Faecal Nitrogen, g/d	4.58±0.25	3.97±0.35	4.27±0.14	0.376
Urinary Nitrogen, g/d	5.15 ^a ±0.18	2.96 ^b ±0.04	2.25 ^c ±0.12	0.001**
Total nitrogen excretion, g/d	9.73 ^a ±0.07	6.93 ^b ±0.39	6.53 ^b ±0.26	0.007**
Nitrogen balance, g/d	13.82 ^a ±0.22	16.55 ^b ±0.07	17.07 ^b ±0.05	0.004**
Nitrogen absorbed, g/d	18.97±0.40	19.51±0.03	19.33±0.08	0.373
Nitrogen absorbed as % intake	80.56±1.17	83.12±1.25	81.90±0.43	0.340
Net protein utilization, %	58.68 ^a ±0.56	70.51 ^b ±1.25	72.35 ^b ±0.86	0.004**
Biological value, %	72.50 ^a ±1.97	82.83 ^b ±2.07	88.34 ^c ±0.60	0.0003**

T1, 0% Silkworm pupa meal; T2, 1.5% Silkworm pupa meal; T3, 3% Silkworm pupa meal; N, Nitrogen, FN, Faecal nitrogen; UN, Urinary nitrogen; NPU, Net protein utilization; BV, Biological value; a, b, c, different superscript in a row differ significantly (*P<0.05, **P<0.01).

meal with silk worm pupa @ 0, 50 and 100% level did not affect the serum biochemistry as well as carcass characteristics of pigs. In contrast to this finding, Ullah *et al.* (2017) reported that replacement of soyabean meal with silk worm pupa meal @ 0, 25, 50, 75 and 100% had similar effect across treatment in terms of feed intake, growth, nutrient digestibility, feed conversion ratio in White Leghorn bird. They had also reported that replacement of soybean meal with silkworm meal at 50% replacement in the ration had resulted in non-significantly better performances in the laying hens. Similarly, Kurbanov *et al.* (2015) had found higher growth rate and feed utilization in fish fingerlings fed the diets containing 50:50 mixture of fish meal and silkworm pupa meal and found lower in those fed 100% of either silk worm pupa meal or fish meal.

Nitrogen balance: Nitrogen intake (g/d) was 23.54±0.15, 23.48±0.32 and 23.60±0.22 respectively in groups T1, T2 and T3 respectively which was found similar across the group. Faecal excretion of N was found similar while urinary nitrogen excretion was decreased (P<0.01) with increased level of silkworm pupae meal in the diet. Nitrogen balance (g/d) was found positive across all the groups and values were 13.82±0.22, 16.55±0.07 and 17.07±0.05 in groups T1, T2 and T3 respectively. The nitrogen balance was increased (P<0.01) at silkworm pupa meal supplemented groups in comparison to un-supplemented group. The balance was found similar in supplemented group. The absorbed N (g/d) was insignificantly higher (P>0.05) in T2 and T3 groups in comparison to T1 group. Similarly, there was no significant difference in absorbed nitrogen as per cent intake while net protein utilization and biological values were significantly higher (P<0.01) in T2 and T3 groups in comparison to T1 group (Table 5).

The nitrogen balance was found positive across all treatment groups. This is because the crude protein content (%) of silk worm pupae is slightly higher than either ground nut cake or soybean meal. In this study, it was found higher (P>0.05) value of absorbed N as per cent intake while significantly higher (P<0.01) value of net protein utilization and biological value were found in T2 and T3 groups. The higher biological value of protein of silk worm pupae meal

might be due to its higher digestibility. This indicated that inclusion of silk worm pupae meal up to 3% have positive effect on N utilization which was reflected in improvement (P>0.05) of growth of experimental animals in T2 and T3 groups (Table 5).

From this study, it is concluded that silk worm pupae meal can be supplementation at 3% level by replacing 5% protein ingredients mainly groundnut cake and soyabean meal in grower crossbred pigs to improve growth, nutrient utilization, feed conversion efficiency and also to reduce the feed cost.

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