



Rational Analysis of Selected Non-conventional Animal Protein Sources on Performance of Commercial Broiler

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ABSTRACT

Background: At global level suppletion for protein production is always high. Among the various protein production industries poultry farming is measured as one of the major contributors. In Indian poultry production, South Indian states contributing maximum proportion are exclusively by Andhra Pradesh and Tamil Nadu. With Tamilnadu's Namakkal being a center, contributing a highest fraction of Indian meat and egg production. However, the feed cost is dignified as major consideration of poultry producers. Especially, cost of key protein feed sources like soya increases up to triple fold in a year. Thus, the study intended to focus on alternative non-conventional feed sources for broilers.

Methods: In the present investigation, non-conventional animal protein sources like black soldier fly larva, silk worm pupae and earthworm meals replaced 25%, 35% and 50% of soya meal in standard feed formulations for the commercial broiler Cobb500. The efficacy of these non-conventional protein sources were tested through parameters like feed intake and weight gain.

Result: The calculated feed conversion rates were clearly indicated the impact of the feed formulations. Minimum replacement *i.e.* 25% of these sources were resulted most benefits in all phases of the broilers and increased concentrations of 35 and 50% of black soldier fly larvae, silk worm pupae and earthworm meals were not ensued much benefits in performance as well as meat quality of the Cobb500 birds. Intake of the feed with high concentrations of non-conventional protein sources were slightly varied with standard values especially during finisher phase. However, the gain of the body weight is much affected due to poor digestion and absorption. The study revealed that even though minimal replacement of non-conventional animal protein sources enhance the broiler performances, high concentrations of the resources were counterproductive to utilize the maximum benefits. However, the feed processing like extrusion, crystallization and removal of coliform could yield precise potential of high concentrations of these non-conventional animal protein sources.

Key words: Body weight, Cobb500, Feed intake, Feed processing, Non-conventional sources.

INTRODUCTION

Human population has grown from 1 billion in 1800 to 8.2 billion in 2025. To accommodate this growth, global food production is expected to increase by 35-56% within 2050 (Van Dijk *et al.*, 2021). The global livestock sector has grown by 45% in the last 20 years, reaching 337 million tonnes in production in the year 2020, where the vast majority was derived from three species: chicken (35%), pig (33%) and cattle (20%) (FAO, 2022). Thus, the demand for poultry meat consumption is increasing annually (Mace and Knight, 2022). Because, poultry meat is readily consumed due to its nutritional value and in many countries for cultural reasons, it is an alternative to other meats. There has been an increase in broiler production of more than 25% from 2011 to 2021 (Grzinic *et al.*, 2023). Globally, the largest producers of broiler meat are Asia with 35% of global production and followed by South America with 18.5% (GUS, 2023).

The poultry sector in India has undergone a paradigm shift in structure and operation which has been its transformation from a mere backyard activity into a major commercial agri based industry over a period of four decades. The growth of industry also marked by an increase in the size of the poultry farm. The industry continues to evolve with advancements in breeding, nutrition

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and management practices to meet the growing demands for chicken meat. 93.1% of chicken meat production globally is estimated to come from specialized (mostly highly intensive) broiler production systems, with 5.4% from layers and 1.5% from backyard systems which plays a significant role in some countries.

In commercial broiler production cost accounts for almost 52.7% spend for feed alone (Vissers *et al.*, 2019). Poultry feed price is a significant facet of the poultry industry (Carvalho *et al.*, 2021). Poultry farmers need to be able to determine the cost of feed for their animals so they can plan their budget and set competitive prices for their production (Mallick *et al.*, 2020).

Broiler growth is the result of dietary nutrient content and feed intake. Feed intake is affected by feed form. The best feed intake occurs on good quality crumble, mini-pellets or pellets (Ross broiler management handbook, 2014). Over the years, meat chicken selection has focused on improving feed conversion efficiency (FCR), growth rate, meat yield and quality. This has resulted in chickens with a high feed conversion ratio and fast growth rate; moreover, the meat is tender and widely accepted globally.

Among the numerous elements of the technological process of growing young poultry for meat which ensure its high productivity and viability as well as the proper payment of feed with high-quality products and important role is given to full-fledged feeding (Sobolev *et al.*, 2019). Also need to emphasis on requirement of proper dietary formulations with all essential amino acids and seasonal impacts (Nagaraja *et al.*, 2024; Saravanakumar *et al.*, 2024; Rambabu *et al.*, 2025).

Most of the countries are deficient in protein rich feed with a simultaneous increasing demand for it, with soybean meal being one of the most important protein sources. With rising prices, a trend toward regional feed and food supply, import-independence and sustainability, the (partial) replacement of soybean meal became a topical issue in livestock feeding (Liebl *et al.*, 2022).

Commercial and small holder poultry enterprises are growing, thereby increasing the demand for poultry feeds. Soya bean and fishmeal have traditionally been the main protein sources in poultry feeds, but with the growth of the poultry sector and the world's population, they are failing to meet the increasing demand. The high cost and lack of availability of commercial protein sources at times, are known as some of the main limitations of efficient animal production. In livestock and poultry production, feed accounts for the largest single cost, making up approximately 60 to 80% of the total cost (Chisoro Prince, 2015; Waithaka, 2022). So, alternative protein sources for livestock are instantly needed.

Non-conventional animal protein sources like black soldier fly larvae *i.e.* *Hermetia illuceus*, silk worm pupae *i.e.* *Bomby mori* and earthworms *i.e.* *Lumbricus rubellus* were selected to find their actual potential on the performances of commercial broilers. Black soldier fly larvae contains high amount of proteins ranging between 32% and 50% (Veldkamp, 2012; Khan, 2018; Anankware *et al.*, 2018). Several studies revealed that the use of BSFL improves the growth performance of broilers (Khusro *et al.*, 2012; Veldkamp and Bosch, 2015; Jozefaik *et al.*, 2016; Allegretti *et al.*, 2017; Khan, 2018; Vilela *et al.*, 2021). Silk

worm pupae are discarded after reeling of silk as waste (Yu *et al.*, 2018). The silkworm pupae have more than 50% protein with amino acids profile which was reported to be similar to that of fish meal (Ullah *et al.*, 2017). Therefore, after the reeling process the insect body remained in the cocoon can be used as feed for commercial broilers. Similarly, the use of earthworm as an alternative protein source in poultry feed is an opportunity for providing environmental services via cleaner technologies (Parolini *et al.* 2020). Among the selected these three non-conventional protein sources, wide range of studies were available on black soldier fly larva, however application studies on silkworm and earthworm were inadequate. The present study envisioned to equate through their efficacy on selected commercial broiler Cobb500. The study intended to find the definite relative potential of these non-conventional animal protein sources without much processing. Because, most of the rural broiler farms are replaced with commercial varieties only, however the farmers still facing financial struggles especially through feed production.

MATERIALS AND METHODS

The present experiment was conducted during the period from March 2024 to April 2025 at a private poultry farm, Elumathur (11°14'28.0N" 77°49'40.2"E), Erode district of Tamil Nadu, India. The study was conducted with complete block design with 8 replicate cages of 6 birds per cage. The feed formulation which prescribed by Bureau of Indian Standards (2007) was the standard combination for the present investigation. Without altering any other composition including fiber, ash and minerals the test combinations were formulated by replacing the percentage of major protein source of the standard feed formulations *i.e.* soya meal. Usual protein replacements like fishmeal and other animal protein sources are not included in the present formulations. The test combinations formulated with black soldier fly larvae, silkworm pupae and earthworm were replace the soya meal by 25%, 35% and 50%. Thus, each alternative animal protein sources were tested in three combinations including BSFL1 (25%), BSFL2 (35%), BSFL3 (50%), SWP1 (25%), SWP2 (35%), SWP3 (50%), EW1 (25%), EW2 (35%) and EW3 (50%). Birds of Cobb 500 breed were tested with every individual formulation and the mean values were statistically calculated. Feed formulations were tested throughout all three phases of the broilers including Broiler Pre-Starter (BPS) *i.e.* 1 to 7 days, Broiler Starter (BS) *i.e.* 8 to 21 days and Broiler Finisher (BF) *i.e.* 22 to 42 days.

Feed intake (FI), body weight (BW) and feed conversion ratio (FCR) were recorded with the Standard reference chart. Feed conversion ratio (FCR) was calculated through dividing the volume of feed intake by body weight with the unit of gm/bird. Black soldier fly larva powder and silk worm larva powder were purchased commercially. While, the

earthworms were collected in the field and powder were prepared after proper drying. During the investigation proper physical parameters including temperature, humidity, pH of water, aeration, brooding time, lighting time, vaccination schedule and debeaking process were followed for all testing groups. However, feed additives and antibiotics were excluded to avoid the antagonistic or synergistic effects of alternative animal proteins.

RESULTS AND DISCUSSION

Recorded feed intake for the standard feed formulation group in broiler pre-starter, broiler starter and broiler finisher were 540.32 ± 0.69 mg/bird, 1060.57 ± 0.78 mg/bird and 4070.28 ± 1.30 mg/bird respectively. Body weight gain during the standard feed intake were 450.69 ± 0.95 mg/bird, 661.48 ± 1.04 mg/bird and 1803.48 ± 0.48 mg/bird. Calculated cumulative feed conversion ratio for the three phases were 1.2, 1.6 and 2.3.

Black soldier fly larva (BSLF)

Volume of test formulations of BSFL i.e BSFL1, BSFL2 and BSFL3 consumed by broiler pre-starter were 532.56 ± 1.08 mg/bird, 526.81 ± 0.98 mg/bird and 461.48 ± 0.85 mg/bird, by broiler starter 1041.99 ± 1.02 mg/bird, 1021.74 ± 0.89 mg/bird and 1019.57 ± 0.83 mg/bird, by broiler finisher were 4074.50 ± 1.04 mg/bird, 4032.16 ± 0.96 mg/bird and

4044.33 ± 0.80 mg/bird. Gain of body weight by BSFL for pre-starter were 441.97 ± 1.02 gm/bird, 429.31 ± 0.92 gm/bird and 419.06 ± 0.89 gm/bird, body weight gain for broiler starter were 652.48 ± 0.90 gm/bird, 658.14 ± 0.89 gm/bird and 480.14 ± 0.94 gm/bird, in broiler finisher phase it was recorded as 1791.49 ± 0.93 gm/bird, 1752.03 ± 0.85 gm/bird and 1624.32 ± 1.04 gm/bird. Feed conversion ratio (FCR) were calculated as 1.2, 1.2 and 1.1 for broiler pre starter, 1.6, 1.6 and 2.1 for starter and 2.3, 2.3 and 2.4 for finisher (Fig 1 and Table 1).

Silk worm pupae (SWP)

Feed intake during pre-starter phase for SWP1, SWP2 and SWP3 were 537.65 ± 0.87 gm/bird, 520.73 ± 0.76 gm/bird and 507.81 ± 0.93 gm/bird respectively, at broiler starter phase 1039.57 ± 0.96 gm/bird, 1018.74 ± 0.94 gm/bird and 1044.32 ± 0.97 gm/bird and at finisher phase 4075.50 ± 1.04 gm/bird, 3997.91 ± 0.92 gm/bird and 4036.25 ± 0.97 gm/bird. Recorded body weight after the intake of SWL in three testing formulations were 438.47 ± 1.04 gm/bird, 415.06 ± 0.95 gm/bird and 416.81 ± 0.88 gm/bird for pre-starter, 651.48 ± 1.04 gm/bird, 602.82 ± 0.96 gm/bird and 610.15 ± 0.93 gm/bird for starter and 1770.49 ± 1.05 gm/bird, 1621.08 ± 0.92 gm/bird and 1685.16 ± 0.96 gm/bird for finisher phase. Calculate FCR for pre-starter were 1.2, 1.3 and 1.2, for starter 1.6, 1.7 and 1.7 for finisher 2.3, 2.5 and 2.4 (Fig 1 and Table 2).

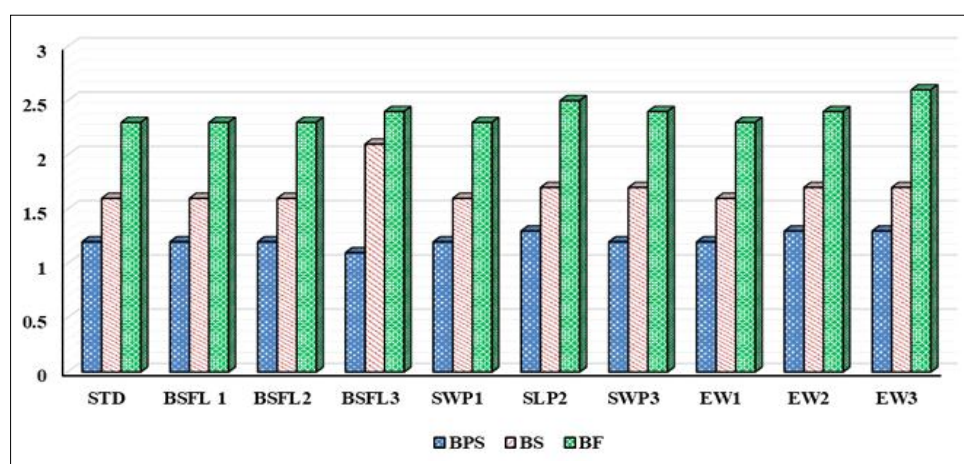


Fig 1: Calculated feed conversion ratio (FCR) of birds during broiler pre starter (BPS), broiler starter (BS) and broiler finisher (BF) phases with standard feed formulation (STD) and three different formulations of black soldier fly larva (BSFL), silk worm pupae (SWP) and earth worm.

Table 1: Feed intake and body weight values of for black soldier fly larva (Mean $\pm$ SE).

Parameters	Phase	Control	BSFL 1	BSFL2	BSFL3
Feed intake (FI)	BPS	540.32 $\pm$ 0.69	532.56 $\pm$ 1.08	526.81 $\pm$ 0.98	461.48 $\pm$ 0.85
	BS	1060.57 $\pm$ 0.78	1041.99 $\pm$ 1.02	1021.74 $\pm$ 0.89	1019.57 $\pm$ 0.83
	BF	4070.28 $\pm$ 1.30	4074.50 $\pm$ 1.04	4032.16 $\pm$ 0.96	4044.33 $\pm$ 0.80
Body weight (BW)	BPS	450.69 $\pm$ 0.95	441.97 $\pm$ 1.02	429.31 $\pm$ 0.92	419.06 $\pm$ 0.89
	BS	661.48 $\pm$ 1.04	652.48 $\pm$ 0.90	658.14 $\pm$ 0.89	480.14 $\pm$ 0.94
	BF	1803.48 $\pm$ 0.48	1791.49 $\pm$ 0.93	1752.03 $\pm$ 0.85	1624.32 $\pm$ 1.04

Earthworm (EW)

Testing feed formulations with earthworm *i.e.* EW1, EW2 and EW3 were consumed by test birds during pre-starter phase at the rate of 543.07±0.92 gm/bird, 536.98±0.91 gm/bird and 529.48±1.04 gm/bird during starter phase at the rate of 1051.99±0.91 gm/bird, 1042.16±0.93gm/bird, 1019.49±1.04 gm/bird and during the finisher phase were 4074.50±0.97 gm/bird, 4057.33±0.97 gm/bird and 4060.75±0.95 gm/bird. By the intake of EW feed formulations the recorded body weight were 442.06±0.92 gm/bird, 419.31±0.97gm/bird and 423.47±1.04 gm/bird at pre-starter phase, 639.98±0.91 gm/bird, 611.15±0.93gm/bird and 614.48±1.04 gm/bird at starter phase, 1770.49±1.04 gm/bird, 1712.01±0.91gm/bird and 1595.41±1.03 gm/bird at finisher phase. Feed conversion ratio for starter were 1.2, 1.3 and 1.3, for grower 1.6, 1.7 and 1.7 and for finisher 2.3, 2.4 and 2.6 (Fig 1 and Table 3).

At present economic conditions non-conventional animal protein sources (NCAPS) are excellent resource to replace the costlier conventional protein sources like soya meal, fishmeal and deoiled seed cakes. Apart from cost reduction, the NCAPS can be produced by using less land and water with environmental hazards (Onsonco *et al.*, 2018; Sumbule *et al.*, 2021; Gadzama, 2024). Furthermore, the present study focused on potential enhanced performances of NCAPS in commercial breed to take the laboratory level research to field level. The study tested the potential of black soldier fly larvae, silkworm pupae and earth worms with their three different formulations in each source *i.e.* 25%, 35 and 50% replacement of soya meal, fish meal and de-oiled seed cakes which are major common conventional crude protein sources in poultry feed. However, among the suggested standard nutrient requirements for broilers by BIS (2007) crude fibers, acid insoluble ash, salts, calcium,

available phosphorus, linoleic acids and synthetic methionine were not altered during the feed preparation. Formulated feeds were with black soldier fly larvae, silkworm pupae and earthworm were tested with specific one of the commercially popular broiler breed Cobb 500. Because, few studies have indicated the better performances of the breed with low cost feed.

Performances of the broiler birds were measured during the three different phases including broiler pre-starter (1 to 7 days), starter (8 to 21 days) and broiler finisher (22 to 42 days) through performance indicators like feed intake, body weight and feed conversion ratio.

BSFL

Throughout their three phases including pre-starter, starter and finisher 25% and 35% BSFL meal shown the remarkable positive influences in the study. These results were similar to various earlier studies (Schiafone *et al.*, 2019; Ipema *et al.*, 2020; Christian *et al.*, 2020; Vilella, 2021; Attivi *et al.*, 2022; Mat *et al.*, 2022). However, present study recorded slightly downward feed intake, body weight gain and feed conversion ration with 50% BSFL replacement. It may be due to less compatibility of soya and BSFL meal in equal proposition and difficulty in absorption which ultimately resulted the deviations from standard indicator values with special reference to feed conversion ratio during grower and finisher phases.

Study of Miah (2020) revealed that silkworm (*Bombyx mori*) is rich source of crude proteins and provides lipids with a high amount of omega-3 fatty acids. The α -lipids of silkworm meal contains high amount of α -linolenic acids with reported values ranging from 11 to 45% of the total fatty acids (Rao, 1994; Usab *et al.*, 2008). The study suggested 25% of silkworm meal is ideal composition for

Table 2: Feed intake and body weight values for silk worm pupae-SWP (Mean±SE).

Parameters	Phase	Control	SWP1	SWP2	SWP3
Feed intake (FI)	BPS	540.32±0.74	537.65±0.87	520.73±0.76	507.81±0.93
	BS	1061.59±0.89	1039.57±0.96	1018.74±0.94	1044.32±0.97
	BF	4081.58±0.78	4075.50±1.04	3997.91±0.92	4036.25±0.97
Body weight (BW)	BPS	451.52±0.98	438.47±1.04	415.06±0.95	416.81±0.88
	BS	669.91±0.59	651.48±1.04	602.82±0.96	610.15±0.93
	BF	1801.78±0.62	1770.49±1.05	1621.08±0.92	1685.16±0.96

Table 3: Feed intake and body weight values for earthworm-EW (Mean±SE).

Parameters	Phase	Control	EW1	EW2	EW3
Feed intake (FI)	BPS	541.23±0.70	543.07±0.92	536.98±0.91	529.48±1.04
	BS	1059.12±0.89	1051.99±0.91	1042.16±0.93	1019.49±1.04
	BF	4079.87±0.56	4074.50±0.97	4057.33±0.97	4060.75±0.95
Body weight (BW)	BPS	448.95±0.54	442.06±0.92	419.31±0.97	423.47±1.04
	BS	668.52±0.82	639.98±0.91	611.15±0.93	614.48±1.04
	BF	1801.91±0.86	1770.49±1.04	1712.01±0.91	1595.41±1.03

Note: BS- Broiler pre starter (1 to 7 days); Broiler starter (8 to 21 days); BF- Broiler finisher (22 to 42 days); STD- Standard values; BSFL- Black soldier fly larva; SWP- Silk worm pupae; EW- Earth worm.



Image 1: The impact of the 50% concentrations of silkworm pupae and earthworm meals respectively.

cobb50 broiler birds. While, 50% replacement modifies the fatty acid profile of chicken breast meat which reducing n-6/n-3 PUFA ratio. The present study also found that low weight gain at high concentration of silk worm pupae meal. Studies found that the chitin content of the silkworm pupae meal which also act as prebiotic component by improving immune response of the birds (Bovera *et al.*, 2015). Cultured birds with low concentration (25%) of the meal provide best benefits likely attributable to the lower dietary chitin content (Image 1).

Use of earth worm as alternative protein source is limited to the 80 years (Parolini *et al.*, 2020). Under controlled conditions earthworms break organic manure and good animal feed with high grade protein (Edwards, 1985). Present investigation found that minimum concentration *i.e.* 25% of all three meals have better performance. While, increase of earthworm composition slightly reduces the feed intake and drastically reduce the gain of birds body weight. The high earthworm concentration may affect the digestion and absorption of nutrients.

The birds fed with high concentrations of silkworm and earthworm meal noticed with stunt growth, improper feather development and deprived vision, which clearly indicated the poor feed conversions. Poor feed conversions in high concentrations may be result of simple processing of alternative non-conventional protein sources. Present investigation indorsing that enzymatic treatments, coliform removal and crystallization may increase the feed conversion efficacy of these conventional protein sources. Thus the present study found that these sources are enormously potential nutritious alternative and suggested the poultry men to utilize conventional animal protein sources by applying suitable technique to replace costlier protein source including soya meal.

CONCLUSION

In an attempt of the rational analysis of selected non-conventional animal protein sources including black soldier fly larvae, silkworm pupae and earthworm meals on performance of commercial broiler, the study found that dietary replacement with twenty five percentage of these

non-conventional protein sources without any complex processing resulted in remarkable feed cost reduction up to fourteen percentage. However, increasing the concentration of these non-conventional sources without processing is not desirable for the commercial broilers. Thus the study suggested rural poultry farms where not much advanced feed processing systems are not available can adopt the replacement of these of non-conventional sources up to twenty five percentage in view of increasing profit. In addition, this adoption also results in improved meat quality and significant environmental advantages towards sustainable and secure global feed system.

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Informed consent

All animal procedures for experiments were approved by university.

Conflict of interest

The authors declares that there is no conflict of interest in this study.

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