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Meal worm (*Tenebrio molitor*) as potential alternative source of protein supplementation in broiler

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Abstract

Protein is major nutrient costing higher value compared to other counterparts. A number of attempts have been made since long to find substitutes that could act as an effective and cheaper source of protein in poultry diet. Currently there has a great interest to assess the potential of different types insect meal in poultry nutrition as protein source. A preliminary study was undertaken to examine the potential benefits of locally produced meal worm supplementation in broiler birds on feed intake, body weight gain, feed conversion ratio (FCR), dressing percentage, antibody titer again ND and mortality. At the end birds from different experimental groups were slaughtered, dressed and cooked for meat sensory qualities. Meal worm larvae were grown at laboratory level, killed with 5% concentrated salt solution and oven dried 40ºC for 48-72 hrs. Meal worm is rich in protein 45.83%, lysine 4.51% and methionine 1.34%. A total of 120 day-old broiler chicks were randomly allotted to four replicated (n=3; 10 birds/replicate) dietary treatments i.e. WM-1, WM-2, WM-3 that received 50, 100, 150g meal worm, respectively with WM-0 served as control. Supplementation of meal worm did not affect feed intake, however significantly improved body weight gain of birds in all supplemented groups by 84 to 185 g in absolute. FCR of WM-0 was poor (2.01) and significantly improved in WM-3 group (1.75). Carcass yield was improved in all meal worm supplemented groups compared to control. It was interesting to note that sensory meant qualities including heamagglutination antibody titer against Newcastle disease and mortality among different groups was not significantly altered. It could be deduced from present findings that meal worm has the potential to improve bird performance with affecting meat quality. However, further research work is warranted to replace soybean with worm meal to examine it impact as alternative protein in minimizing feed cost without compromising bird performance.

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Introduction

Feed is the major segment (60-70%) in the cost of poultry production (Abidin *et al*., 2011). There is still a great increase has been seen in the price of poultry feed ingredients specially soybean meal in the last decade. This has led nutritionist to search alternative sources of protein that are cheaper and comparable in term of nutritive value to other commonly used protein meals used in poultry diet (Okah and Onwujiariri, 2012). A number of efforts have been made previously to minimize poultry cost using locally available alternative protein sources (Bhuiyan, 1998; Awoniyi *et al.,* 2004; Ojewola *et al*., 2005). Recently there has been a great interest to grow insect and process them as an alternative feed ingredient due to its high nutritive profile and essential amino acids also due to high price of fish meal its deteriorated quality (Akpodiete and Inoni, 2000; Etuk *et al*., 2003; Karimi, 2006).. Research suggests that insect based feeds are comparable with fishmeal and soybean meal (Huis *et al*., 2013). There is however inconsistent and equivocal information available on the nutritive value of mealworm and its implications as poultry feed ingredient.

Mealworm (*Tenebrio molitor*) are common feedstuffs for pet animals including small mammals and reptiles and are a formidable source of insect protein with about 44-70% in their body tissues (Romas-Elorduy, 1987). Agriculturally, edible insects such as mealworm have great potential because they contain superior grade of protiens, lipids, carbohydrates and vitamins (De Foliart, *et al*., 2009) that may provide a possible alternative source of nutrition for poultry broilers. Studies that explored the potential of *Tenebrio molitor* for massive human and animal consumption have also shown that ground mealworm emit no ammonia excretion (Oonincx, *et al* 2010). Insect rearing could be one of the ways to enhance food and feed security (van Huis *et al.,* 2013). They grow and reproduce easily, have high feed conversion efficiency and can be reared on bio-waste streams. One kg of insect biomass can be produced from on average 2kg of feed biomass (Collavo *et al.,* 2005). Insects can feed on waste biomass and can transform this into high value food and feed resource. A desk study (Veldkamp *et al.,* 2012) has demonstrated that it is technically feasible to produce insects on a large scale and to use them as alternative sustainable protein rich ingredient in pig and poultry diets, particularly if they are reared on substrates of bio-waste and organic side streams.

To understand the importance of mealworm in poultry feed present study was planned to investigate the supplemental impacts of meal worm produce in small sacale in labs. Dired mealworms were added to poultry diet at different level to observe the growth performance carcass yield, antibody titer again newcastel disease and meat quality attributes.

Material and methods

This study was conducted in collaboration at the Poultry Research Unit of the University of Agriculture and Veterinary Research Institute, Peshawar, Pakistan.

Bird's husbandry

Before the commencement of study all equipments, gears and premises were cleaned and disinfected. One hundred and twenty day-old chicks were procured from commercial hatchery. These chicks were randomly distributed in replicated (n=3; 10 birds/replicate) groups (n=4) in cleaned floor cages (10x10 sq. ft). Experimental groups were designated as Control (MW-0), MW-1, MW-2 and MW-3 received 1, 2 and 3g dried meal worm per kg of diet. During the course of experiment optimum managemental conditions were provided and birds had an ad libitum access to feed and water. This trial was lasted for 6 weeks. Experimental ration was formulated and mixed in feed mill unit in mash form. Meal worm larvaes were produced in the research lab using darkling beetles, fed on wheat bran as growth media. Fresh larvae were harvested, killed and dried at 60^{o}C. Ground mealworms were mixed in the feed for the experiment. Prior to mixing dried meal were found to contain permissible level of mycotoxin (5ppb) and no bacterial growth. Experiment was lasted for four weeks.

Lab analyses

Proximate analyses of dried meal worm were carried out using standard procedures of the Association of Official Analytical Chemists (AOAC 2000). Amino acid and minerals contents of mealworm sample were performed by the methods of the Association of Official Analytical Chemists (AOAC, 1990). The PICO TAG method with modification was employed for determining the amino acid from standard curves based on peek area measurement by PICO TAG amino acid analyzer (Deng *et al*., 2004).

Production traits

Feed intake, body weight gain, feed conversion ratio (FCR), dressing percentage, HI antibody titer against ND and mortality were recorded and feed cost and gross return was determined. Data were statistically analyzed using standard procedure of ANOVA in a completely randomized design using Statistical package SAS (1998). Least significant difference test (LSD) was used for separation of means (Jan *et al*., 2009).

Findings of the research study

Proximate analysis and amino acid profile

The proximate composition of worm meal including dry mater, crude protein, ash, fats, crude fibre level, the amino acid and mineral profile are give (Table 1). A considerable amount of crude protein (45.83%) and crude fat (34.20%) were recorded. Almost all essential amino acids Methionine (1.34) Lysine (4.51) were observed as in worm meal analyzed in present study (Table1). No significant ($P \leq 0.05$) difference was seen in the feed intake of different groups Table 2. Weight gain was significantly improved in treated groups. Group WM-3 (1423.3±3.92) had significantly higher weight gain followed by group WM-2 (1346.3±5.48) and group WM-1 (1322.0±2.08). Mean FCR for supplemented groups was significantly better ($P \leq 0.05$) as compared control group. Overall FCR was poor in group WM-0, control (2.011±0.01) followed by group WM-1 (1.88±0.05) and least value was found in group WM-3 (1.75±0.01).

Table 1. Nutrient profile of dried mealworm used in the experiment.

Ingredients %	Percentage/(mg/g of mineral/kg)	Amino acid profile	(grams/100g of meal worm)
Moisture	5.78	Alanine	4.34 ± 0.3
Ash	2.51	Arginine	2.21 ± 0.2
Crude Protein	45.83	Aspartic acid	3.23 ± 0.7
Crude Fat	34.2	Cystine	3.62 ± 0.2
Crude Fiber	3.97	Glutamic acid	4.75 ± 0.6
		Glycine	2.65 ± 0.2
Calcium	3.82	Histidine	1.65 ± 0.2
Phosphorous	0.07	Isoleucine	4.51 ± 0.3
Iron	0.63	Lucecine	5.32 ± 0.2
Zinc	1.02	Lysine	4.51 ± 0.3
Copper	0.123	Methionine	1.34 ± 0.4
Potassium	0.085	Proline	2.34 ± 0.2
		Phenylalanine	1.54 ± 0.4
		Serine	3.45 ± 0.2
		Threonine	1.64 ± 0.3
		Tyrosine	2.32 ± 0.3
		Valine	4.42 ± 0.2

Effect of meal worm supplementation on production performance

Table 2. Effect of meal worm supplementation on feed take, weight gain and FCR.

Group	Feed intake	Body Weight Gain	Feed conversion ratio (FCR)
	Mean ± SE	Mean ± SE	Mean ± SE
WM-1	2491.7±3.52	1322.0^{c}±2.08	1.88^{b}±0.05
WM-2	2485.7±1.45	1346.3^{b}±5.48	1.84^{c}±0.07
WM-3	2485.0±4.35	1423.3^{a}±3.92	1.75^{d}±0.01
WM-0	2498.3±4.05	1238.3^{d}±1.66	2.01^{a}±0.01
P-value	0.0897	0.0000	0.0000

Means followed by different superscripts are significantly different α=0.05.

Dressing percentage was calculated on last day of the experiment. The statistical analysis showed that dressing percentage was significantly ($P \leq 0.05$) higher for higher supplemented group WM-3 (66.10±0.25) as compared to WM-0 (63.28±0.13).

At the end of experiment antibody titer against Newcastle disease virus for all experimental groups showed non-significant result. This indicates that meal worm supplementation had no adverse effects on heamagglutination antibody titer.

Numerically it was higher in group WM-3 (6.56±0.88) followed by group WM-1 (4.66±0.33) and least was found in group WM-2 (4.45±0.33). The mortality in control group was higher as compared to supplemented groups (Table 3).

Table 3. Dressing percentage antibody titer and mortality of broiler fed with meal worm.

Group	Dressing Percentage	Antibodies titer against ND	Mortality
	Mean ± SE	Mean ± SE	Mean ± SE
WM-1	63.277^{c}±0.31	4.66±0.33	3.33±0.33
WM-2	64.167^{b}±0.21	4.45±0.33	3.33±0.33
WM-3	66.108^{a}±0.25	6.56±0.88	0.00±0.00
WM-0	63.282^{c}±0.13	5.33±0.88	6.66±0.66

Means followed by different superscripts are significantly different α=0.05

Organoleptic study of broiler meat fed with meal worm

It was observed that organolyptic properties evaluation i.e. taste, tenderness, juiciness, flavor and color were not influenced by the addition of mealworm in the diet of broilers. They all were not significantly ($P \leq 0.05$) different among the experimental groups (Table 4).

Table 4. Organoleptic Study of broiler meat fed with meal worm.

Group	Taste	Tenderness	Juicines	Color	Flavor
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
WM-1	2.35±0.08	2.41±0.03	2.35±0.36	2.45±0.07	2.54±0.17
WM-2	2.33±0.36	2.37±0.15	2.33±0.12	2.44±0.26	2.54±0.36
WM-3	2.33±0.37	2.37±0.48	2.32±0.06	2.47±0.13	2.53±0.15
WM-0	2.44±0.48	2.42±0.38	2.37±0.38	2.49±0.51	2.57±0.18

Economics of meal worm supplementation (PKR)

Economics of meal worm (MW) supplementation was calculated in terms of feed cost, meal worm cost, operational cost, total expenses, gross return and net profit. The economics is shown table 4.9. Gross return and net profit was significantly higher ($P < 0.05$) for group WM-3 (43.55±0.40) followed by group WM-1 (41.95±0.49), WM-2 (38.66±0.83) and lowest return (35.71±0.33) was WM-0 control group. Highest gross return and net profit in group B may be attributed to the quantity and quality (amino acid composition) of protein in the meal worm (Table 5).

Table 5. Economics of meal worm supplementation (PKR).

Group	Mean (PKR) ±SE					
	Feed Cost	MW Cost	Op: Cost	Total Exp	G. Return	Net Profit Net profit
WM-1	115.83^{c} ± 0.17	3.73^{c} ±077	50.00±0.0	169.56^{c} ± 0.182	211.52^{c} ± 0.33	41.95^{a} ± 0.49
WM-2	119.30^{b} ± 0.07	7.450^{b}±0.77	50.00±0.00	176.75^{b} ± 0.078	215.41^{b} ± 0.87	38.66^{b} ± 0.83
WM-3	123.00^{a} ± 0.21	11.17^{a} ± 0.017	50.00±0.00	184.18^{a} ± 0.22	227.73^{a} ± 0.62	43.55^{a} ± 0.40
WM-0	112.42^{d} ± 0.18	0.00^{d} ± 0.00	50.00±0.00	162.42^{d} ± 0.182	198.13^{d} ± 0.26	35.71^{c} ± 0.33

Means followed by different superscripts are significantly different α=0.05.

Discussion

Proximate analysis, amino acid profile and mineral composition of meal worm

Mealworms (*Tenebrio molitor* L.) are common feedstuffs for animals including a formidable source of insect protein with about 44-70% in their body tissues (Ramos-Elorduy, 1987).

Agriculturally, edible insects such as the yellow mealworm have great potential because they contain superior grade of proteins, lipids, carbohydrates and vitamins (De Foliart *et al.*, 2009) that may provide a possible alternative source of nutrition for poultry broilers.

The potential for insects as livestock feeds may also have an environmental impact as they cost less energy, use less land area and leave less environmental footprints during production (Pimental *et al*., 1975).

Performance of birds

Meal worm supplementation in basal diet of poultry showed that the overall body weight gain and FCR for supplemented groups was significantly higher (P≤0.05) as compared control group regardless of feed intake. Nutritional attributes of the insects and insect meal and their use as a component in the diets of ruminants, poultry (both broiler and laying hen) and fish species, potential constraints, if any in using them as alternative feed resources and future research areas.

Furthermore, earlier the mealworm (*Tenbrio moliotor*) as a diet for African catfish, Clariasgariepinus, was tested for alternative protein source. As a result, catfish showed a good performance of growth and utilization efficiency when it was fed on 80% of mealworm-based diet. In addition our study is supported by (Ng *et al*., 2001) who suggested that mealworm is highly nutritive diet and acceptable as an alternative protein source.

In very limited experiments, Gould and Moses (1951) force-fed darkling beetle adults and larvae (whole and acerated) one time to chicks and found no adverse effects. Skewes and Monroe (1991) attempted to compare performance of broiler chickens in commercial grow out houses with different population densities of darkling beetle adults and larvae; have no adverse relationships between eating of darkling beetle on chick mortality, feed conversion, condemnation rate, and production cost were detected. Mealworm have great potential because they contain superior grade of proteins, lipids, carbohydrates and vitamins that may provide a possible alternative source of nutrition for poultry broilers.

Dressing percentage antibody titer and mortality

The findings of Khatun *et al*. (2003) found highest dressing percentage for birds fed with silkworm pupae meal instead of fishmeal.

Wijayasinghe and Rajaguru, (1977) also supported our study as they found highest dressing percentage for experimental group fed with 10% silkworm pupae meal (protein source) as compared to those fed with fishmeal.

Again limited research work on this part of the study but many researchers (Teguia *et al.,* 2002; Okah and Onwujiariri, 2012) found better dressing percentages with dietary supplementation of maggot meal or silkworm (insect protein) may be used to obtain better dressing percentage from broiler birds while feeding along conventional protein supplements. Literature is not available on this aspect of the study but although researchers found that protein sources does not adversely affects on antibody titer against ND, however it boost up the immune system of birds.

Taheri *et al*. (2005) used different level of oil extracted propolis as a source of protein in the diet of broiler birds and found significantly higher (P<0.05) antibody titer against ND. Our study supported by Skewes and Monroe (1991) they attempted to compare performance of broiler chickens in commercial grow out houses with different population densities of darkling beetle adults and larvae; have no adverse relationships between eating of darkling beetle on chick mortality. Khatun *et al*. (2003) also supported the findings of this research.

They also did not come across any mortality in all the experimental groups while feeding them different percentages of fish and silkworm pupae meal. Dutta *et al*. (2012) also favors our results. They did not find any mortality case in their research work as our findings revealed. 5% mortality is normal. These findings indicated that worm meal has no toxic affect on birds.

Organoleptic properties

No literature is available regarding organoleptic parameters while feeding the birds on meal worm in ration. Similar study was conducted by Eyo (2006) and Aniebo *et al*. (2011) in fish and reported that maggot meal supplementation in the diet of fish did not affect flavor, juiciness or texture of the fish products.

Similar findings were also reported by Okubanjo *et al.* (2014) who stated that organoleptic study of broiler birds fed with maggot meal did not change taste, tenderness, juiciness, color and flavor of meat.

Economics of meal worm supplementation

Economics was calculated in terms of feed cost, meal worm cost, operational cost, total expenses, gross return and net profit. Statistical analysis showed that gross return and net profit Gross return and net profit was significantly higher ($P<0.05$) for group C (43.55±0.40) followed by group A (41.95±0.49), B (38.66±0.83) and lowest return (35.71±0.33) was D control group. The findings of Dutta *et al.,* (2012) are line to our study who observed that the cost of total feed offered was lowest in where silkworm pupae meal replaced 100% protein of fish meal. This shows that increase of incorporation of silkworm pupae meal in the poultry feed there is corresponding decrease in cost per unit of feed. These finding also agree with the results of some other researchers (Chaudhary *et al.,* 1998; Rahman *et al.,* 1996; Habib and Hasan, 1995; Khatun *et al.,* 2003 and Khatun *et al.,* 2005).

Conclusion

It was concluded from present findings that mealworm could be effectively produced locally and nutrient profile is highly comparable to that of soybean and fish meal. Mealworm supplementation in poultry diet could lead to improved growth performance and efficiently utilization of poultry feed. There was no negative impact of mealworm supplementation on chicken meal quality and antibody titer. Further research studies are however warranted to explore its benefits by replacing soybean meal and examining it beneficial implication including reduction of feed cost.

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