THE EFFECT OF USING *VESPA ORIENTALIS LINNAEUS MEAL* INSTEAD OF SOYBEAN MEAL ON THE GROWTH AND FEED UTILIZATION OF V-LINE MALE RABBITS

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SUMMARY

The current study aims to determine the effect of partial substitution of soybean meal (SBM) with *Vespa Oriental* meal (VOM) [(0%, VOM_0), 25% (VOM_{25}), and 50% (VOM_{50})] in the diets of thirty 12-week-old V-line male rabbits with an average body weight of 1.060±0.01kg on growth performance, digestion, and some blood biochemical changes. The experiment lasted for 90 days. The results revealed that the crude protein (CP) contents of VOM and SBM used in the present study were 76.84 and 43.76 %, respectively, Furthermore, the digestibility of CP (74.65 % & 76.07 %,) and nitrogen free extract (NFE) (68.390 & 70.123 %,) was considerably higher in rabbits fed VOM_{25} and VOM_{50}, respectively than in rabbits fed VOM_0 (72.033 % & 65.44 %). The daily body gain in rabbits fed the VOM_{50} diet was 9.18 %, higher than in rabbits on the VOM_0 diet. Also, the VOM_{25} and VOM_{50} diet-fed rabbits had considerably larger carcass weight, liver, kidney, and cecum length than the control group. Total volatile fatty acids were significantly higher in the caecal contents of VOM_{25} and VOM_{50} rabbits, despite lower caecal Ammonia-N concentration compared to the control diet. Hematological parameters, live and renal functions of rabbits fed the VOM_{50} diet were considerably improved compared to those fed the control diet. The VOM_{25} and VOM_{50} groups exhibited better TDN and DCP values ($P < 0.05$) than the control group in terms of nutritional value. It is concluded that Vespa Orientalis wasp meal can be used as an effective alternative high-quality protein source to soybean meal, up to 50%, with no adverse impacts on rabbit's performance.

Keywords: *Insect meal, rabbits, growth, digestibility and carcass characteristics.*

INTRODUCTION

Agriculture is being confronted with several complicated problems, including decreasing agricultural land availability, climate change, and the threat of low water resources. So the challenge is to meet rising demand with fewer resources. Meat and milk demand are expected to be 58% and 70% higher in 2050, respectively, than in 2010, with developing countries accounting for the majority of this increase (FAO, 2011). Food security is a critical concern for all nations around the world, especially those in developing nations fighting hunger and malnutrition. Furthermore, the rising expense of conventional feed ingredients for animal farming has encouraged feed researchers and producers to find other sources of protein and energy to ensure long-term animal nutrition supplies (Bikker et al., 2016). Thus, more research is needed to explore alternative and cheaper sources of nutrients.

One technique to improve food and feed security is to rear insects (Van Huis et al., 2013). Insects are easy to breed and grow, have high feed conversion efficiency, and can be raised on bio-waste (Makkar et al., 2014). The FAO strongly advises including insect protein in poultry diets to reduce feed costs while improving growth and production parameters (FAO, 2014). According to the FAO report (FAO, 2013), the cost of insect breeding is significantly reduced by saving agricultural land, feed, and drinking water, whereas an average of two kilograms of feed biomass can be used to produce one kilogram of insect biomass (Collavo et al., 2005). In contrast to conventional animal farming, such insect production has no detrimental environmental impact. It requires minimal carbon dioxide emissions into the atmosphere as well as decreases greenhouse gas and ammonia emissions (Oonincx et al., 2010).

Insects are a novel alternative protein that will certainly become more important in the future. Edible insects have been identified as prospective dietary protein sources due to their higher protein content than traditional protein sources such as meat, dairy, and nuts (Cerritos, 2009). Whereas, insect protein has a digestibility similar to chicken eggs, and it is considered a complete protein on par with milk and cow proteins (Shockley and Dossey, 2013).

The majority of experiments on giving insect meals to farm animals were carried out on aquaculture (Belghit et al., 2018), chickens (Józefiak et al., 2016), and dogs (Lei et al., 2019).

According to Pretorius, (2011), broiler chicken feed can contain up to 25% housefly larvae without impacting weight increase, feed intake, or conversion rate. Park et al. (2017) found that laying hens given a compound diet including Hermetia illucens larvae produced more eggs and gained weight.

Vespa Orientalis L. is a hazardous insect that attacks honeybee colonies in many regions of the world and is considered a major beekeeping problem (Abou-Shaara, 2017). So, harvesting this Vespa spp. can be a kind of biocontrol, but it also has the potential to lead to their utilization as human food or animal feed (Ghosh et al., 2021). The population of wasps peaked in October, then declined until it vanished at the end of December (Omran et al. 2011).

Indeed, there has been little research into the use of Vespa Oriental meal in livestock feed (Józefiak et al., 2016). So, it's important to figure out the nutrient value of Vespa Oriental (Van Huis et al., 2013). Although there is a scarcity of literature on the use of insects in rabbit feeding, it is encouraging to observe that interest in this area has grown in the last 10 years. As a result, this study aimed to see how giving rabbit's diets with dried Vespa Oriental meal affected their performance, nutrient digestibility, blood parameters, and meat quality.

MATERIALS AND METHODS

Study area:

This experimental investigation was conducted in Sids Research Station, Beni-Suef Governorate, Animal Production Institute (APRI), Agriculture Research Center (ARC), Ministry of Agriculture, Egypt. The laboratory research was carried out at the Agricultural Research Center's By-products Utilization Research Department, Animal Production Research Institute. The purpose of the study was to detect how rabbit performance would be affected by using insect meal as a cheap protein source.

Vespa Orientalis harvesting and preparation

In two places near Baraka Apiaries, Kfer Shibin in Shibin Al Qanater, Qalyubia Governorate, Egypt. Fifty triangular traps were employed to obtain oriental wasps. In the wasp traps, there was attractive bait that didn't contain any chemicals. The attractive bait cake, which was placed in the trap's drawer, had Sugar, sugar fermented syrup, honeybee, and supplement Baraka organic.

Four baits (100g per treatment weekly) and four traps for every bait used (25g for every trap) were used in this experiment. Sugar, sugar fermented syrup, honeybee, and supplement Baraka organic were used to make the baits. This trap is placed near the wasps, which are counted and collected once a month by inserting a new cake bait into the traps every week. and the temperature and relative humidity were measured (Table 1).

The trap prototype has three funnels (Fig 1) and is made from locally sourced materials (wire gauze, wooden bars, and a stainless steel cone with Moshtohor feeder and baits).

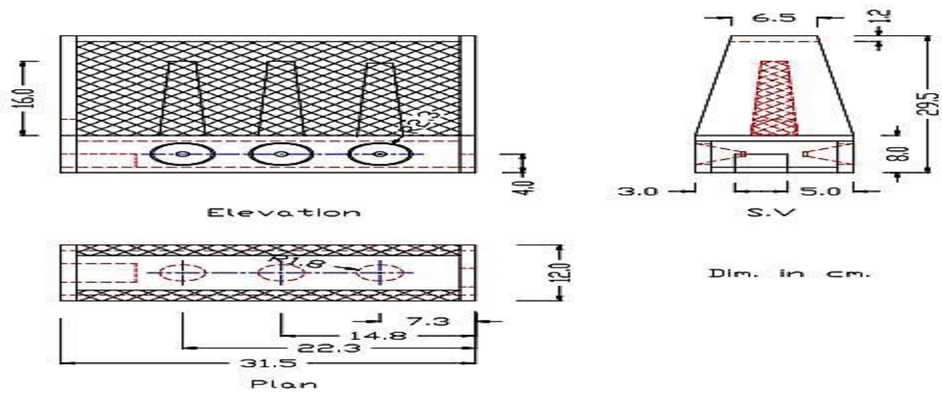

Figure (1): The traps have three funnels each**.**

The design of the experiment:

In this study, thirty V-line male rabbits of 12-week-old and live body weight 1.06±0.03 kg were monitored for nearly ten days before the trial began to rule out any underlying infections. Three equal groups of rabbits (10 males each) were randomly split individually and fed three different diets. As a control, VOM_0 was given (100 % soybean meal as the main protein source). In the other two diets, 25 and 50 % of the soybean protein in the meal was substituted with insect meal (VOM_{25} and VOM_{50}, respectively). The rabbits were kept in galvanized metal rabbit battery cages (60×50×40) with separate feeds. All the animals were kept in the same sanitary and management settings. Rabbits were grown in 24 m length and 12 m width semi-closed rabbitries with wire-netted windows on the sides allowing natural ventilation. During the experiment (90 days), all diets were offered ad libitum, and clean water was provided via automated nipple drinkers.

Table (2) provides the approximate chemical analysis of the basal diet, and they were implemented as indicated (Al-Sagheer et al. 2017). Weekly records of feed consumption and body weight were obtained. Both feed conversion ratio and body weight gain were computed as previously stated (Berger and Halver, 1987). All animal operations were done in accordance with the Animal Ethics Committee of APRI, ARC, Egypt's recommendations for the care and use of experimental animals.

Digestibility trail and analytical methods:

At the end of the experiment (90 days), four rabbits from each group were individually used in a digestibility experiment. Feces were collected daily, weighed, and dried for 48 hours at 60-70º C before being finely powdered and preserved for chemical analysis. The nutrients' digestion coefficients and the nutritive values of the dietary treatments were determined according to AOAC (2000).

Carcass measurements:

The slaughter technique was carried out in the slaughterhouse of the Department of Agricultural By-Products Utilization Research, APRI, ARC, Egypt. The slaughtering of the animals was done humanely. All rabbits were fasted and weighed at the end of the study. Carcasses were weighed (without the head and internal organs) (empty carcass). The values of the dressing, edible giblets, and non-edible components were determined.

Cecum activity:

Cecum contents were sampled from the same slaughtered rabbits for each treatment and immediately used to estimate cecum pH, cecum microflora (bacteria), aerobic total count, Fecal coliforms, Escherichia coli count, Bacillus cereus, Enterobacter, Clostridium sp., Enterococcus, yeasts, Salmonella, and Shigella. Another cecum content sample was strained through four folds of gauze and separated into two halves. The first half was employed right away to calculate the ammonia nitrogen concentration. To determine total volatile fatty acids, the second portion was maintained by adding 1 ml of N/10 HCL and 2 ml of orthophosphoric acid to each 2 ml of cecum content juice. A digital pH meter was used to determine the pH of the cecum contents.

Postage (1969) for aerobic total bacterial counts and Difco (1989) for fecal coliforms and E. coli, respectively, examined the microbial contents in their selective mediums. For Enterococcus and Bacillus cereus, the procedures provided by Baired Parker (1962) and Kim and Goepfert (1971) were employed, also Difco (1989) for Enterobacter and Clostridium Spp, as well as the method published by Lodder (1952) for yeast determination. Salmonella and Shigella were counted using the AOAC's recommended techniques (1998). The colony forming units (CFU) methodology was used. For 2-7 days, the samples were incubated at 30 degrees Celsius. Conway's technique (1958) was used to determine the ammonia nitrogen concentration. According to Eadie et al., (1967) total volatile fatty acids were measured by steam distillation of the distillate.

Specimens of blood:

Following the euthanasia of rabbits, 5 mL of blood was taken in a sterile vacutainer tube. For the haematological analysis, 1 mL of blood was placed in a bottle with ethylene diamine tetra acetic acid (EDTA) as an anticoagulant. The remaining 4 mL of blood was allowed to coagulate for serum preparation by centrifugation at 1.370 × *g* for 15 min. and then transferred into sterilized tubes and stored at - 20 °C until use. An automated approach was used to determine the haematological test (automatic cell counter). After placing the samples on an electric mixer, they were analyzed using a veterinary haematology analyzer (Abacus junior, Radim, Italy). Each sample was evaluated twice to ensure accuracy (the mean of each duplicate was introduced to the statistical analysis).

The levels of alanine aminotransferase (ALT), aspartate aminotransferase (AST), Gamma-glutamyl transferase (GGT), total bilirubin (TB), creatinine, and urea were measured using Biosystems automated reagent kits obtained from Costa Brava 30, Chemical Company, Barcelona (Spain), according to the Young et al. (2000) method.

Chitin determination:

As reported by Porter and Jaworski (1965), the chitin content of VOM samples was detected. According to Waterhouse et al., (1961) the dried residue was solubilized in water and hexosamines were detected. Chitin values were adjusted using a factor derived from pure chitin in known quantities.

Animal ethics statement

The research was carried out in conformity with the European Union's guidelines for the protection of animals used for scientific purposes, No. 2010/63/EU of the European Parliament and the Council on the protection of animals used for scientific purposes, approved on September 22, 2010.

Efficient economics:

The ratio between income (weight gain price) and the cost of feed consumption, determined according to Egyptian market prices of 2021, was used to determine the economic effectiveness of the experimental diets.

Analytical statistics:

Using SAS (2002) software version 9.1.3, a one-way analysis of variance was undertaken using the General Linear Model (GLM) procedure with the dietary treatment as a fixed effect. Duncan's Multiple Range Test was performed to detect variations between the Means (Duncan, 1955), and ANOVA was used to test the impact of treatment

RESULTS AND DISCUSSION

A comparison of four wasp trapping baits:

The results listed in Table (1) showed that the most effective bait for catching wasps was cake supplement (351.50 wasps), followed by sugar fermented syrup (230.25 wasps) and honeybee (226.25 wasps) ($P < 0.05$) compared to sugar (158.75 wasps), noting that the most influential months were October and November. These results agree with Abou El-Enain *et al.* (1999) and Ghania (2007).

Table (1): Comparative between four baits for trapping wasps.

Item	Bait type				±SEM	*P*. value	RH (%)	AT (°C)
	SR	SRF	HNB	CKS				
September	135[c]	184[b]	170[b]	215[a]	6.18	0.0001	58-90	36
October	174[c]	239[b]	251[b]	378[a]	7.60	0.0001	60-70	31
November	180[c]	313[b]	295[b]	564[a]	16.25	0.0001	40-80	26
December	146[c]	185[b]	189[b]	249[a]	6.01	0.0001	60-70	21
Total	635	921	905	1406				
Overall mean	158.75	230.25	226.25	351.50				

[a, b and c.] *Mean within each row with different superscripts are significantly different (P < 0.05).*
Air temperature (AT), Relative humidity (RH), Sugar (SR), Sugar fermented syrup (SRF), honeybee (HNB) and cake supplement (CKS).

Chemical Composition of the experimental diets:

The proportions of all components of the formed diets and the proximal composition of the experimental diets are presented in Table (2). The three diets examined are chemically compatible in terms of crude protein content (ranging from 18.77 to 19.43 %), and gross energy content (4.18- 4.19 Kcal/Kg DM) as they all fell within the recommended range for optimum rabbit growth and performance (NRC, 2011). The crude fiber content of the experimental diets was within the recommended dietary fiber ranges of 10–12 % for rabbit growth by Trocino et al. (2012).

Table (2): Composition and calculated chemical composition of growing experimental diets fed to V-line rabbits.

Item	SBM	VOM	Experimental diet		
			VOM_0	VOM_{25}	VOM_{50}
Clover hay			30.00	30.00	30.00
Vespa Oriental meal (VOM)	---	---	0.00	2.85	5.69
Soybean meal (SBM)	---	---	20.00	15.00	10.00
Yellow corn	---	---	20.00	20.00	20.00
Wheat bran	---	---	24.20	26.35	28.51
Vitamins & Minerals mixture*	---	---	0.50	0.50	0.50
Di-Calcium. phosphate	---	---	1.00	1.00	1.00
Molasses	---	---	3.00	3.00	3.00
Salt	---	---	0.30	0.30	0.30
Limestone	---	---	1.00	1.00	1.00
Total			100	100	100
Calculated nutrients analysis: [1]					
Dry matter %	88.51	96.76	86.77	87.01	87.24
GE (Kcal/Kg DM)	4.662	5.210	4.183	4.189	4.195
Crude protein %	43.76	76.84	18.77	19.10	19.43
Ether extract %	2.67	2.84	2.11	2.08	2.05
Crude fiber %	7.64	0.44	12.11	11.96	11.80
NDF% [2]	33.94	29.21	36.88	36.78	36.68
ADF% [3]	16.40	9.83	20.48	20.34	20.19
Hemicellulose % [4]	17.54	19.38	16.40	16.44	16.48
Nitrogen free extract %	39.08	14.05	61.16	61.07	60.99
Ash %	6.85	5.83	5.86	5.79	5.73
Chitin content (%)	-	34.53	-	0.853	1.695

** Each 1.5Kg. of Vita. Mix contained: 50,000,000 IU Vit.A; 1,000,000 IU D3; 10,000 mg Vit. E; 1170 mg Vit. K3;735 mg Vit.B1; mg Vit.B2; 15000 mg vit B6;15 mg vit; B12; 500 mg Vit.B5 Panathonic acid; 30,000 g Nicotinic acid; 84 mg Biotin; 500g Folic acid; 300g choline cholride. Each 1.5 Kg Min. mix contained 25 g Zn(oxid); 33.4g Mn; 26.7g Fe ; 2.67g Cu; 67mg cobalt; 1mg Se and.0.334g I*

[1] *Calculated according to Cheeke (1987).* [2] *% NDF = 28.924 + 0.657 (% CF)*

[3] *% ADF = 9.432 + 0.912 (% CF).* [4] *Hemicellulose = %NDF - % ADF*

The fat levels inside these examined diets (2.05–2.11%) were near the minimal level of 3% to supply essential fatty acids and keep the hair shiny and silky (Cheeke et al., 1986). More notably, the CP contents of VOM and SBM used in the present study were 76.84 and 43.76%, respectively, which led to a slight increase in the CP content in the experimental diets with the higher inclusion of VOM. It's worth noting that the conversion factor used to convert the N content into CP content is 6.25, but, this factor ranges from approximately 4.43 to 5.75 in different insect species (Finke, 2007; Yi et al., 2013). This might lead to an overestimation of the insect's protein content (Finke, 2015). This finding is comparable to Yang et al. (2009) and Ramos-Elorduy et al. (1997), who determined the protein content of dry matter in nearly a hundred insect species to be between 13 and 77 % and 15 to 81 %, respectively. On the other hand, Rumpold and Schluter (2013) showed that whole edible insects range from 30 to 60% CP, depending on the species of investigated materials and life cycle stage (Finke, 2013). Interestingly, the chitin content of VOM on a DM basis was 34.53 % (Table 1). Huet et al. (2020) declared 45% chitin in the dry matter of Bombyx eri, which is close to the chitin findings in this study. In addition, Sajomsang and Gonil (2010) found 36.6% chitin in Periostracum Cicadae (cicada sloughs) in their investigation. The chitin content in the present study (34.53%), however, is higher than previously observed by Kaya et al. (2015b), who reported that chitin content of Vespa Orientalis, Vespa Crabro, and Vespula Germanica was 6.4, 8.3, and 11.9 percent, respectively. Also, Hahn et al. (2018), found the average insect chitin content was 5–25 %. The chitin content of insects has disclosed great interspecific variation, which is strongly affected by differences in extraction methods used, species, stage of development (Kaya et al. 2015a), and the quantity of wasp wings collected, as established by Kaya et al. (2015b), who noticed that the wings of butterfly species (Argynnis pandora) contain a higher amount of chitin (22 %) than in other parts of the body (8 %).

Apparent nutrient digestibility:

The dry matter (DM), organic matter (OM), and ether extract (EE) digestibility of rabbits fed the control diet (VOM_0) was significantly lower ($P < 0.05$) than rabbits fed the VOM_{25} and VOM_{50}) diets (Table 3). Furthermore, in rabbits fed diets with insect meal (VOM_{25} and VOM_{50}), the digestibility of crude protein (CP, 74.648% & 76.068%, respectively) and nitrogen free extract (NFE, 68.390 & 70.123%, respectively) were significantly ($P < 0.05$) greater than in rabbits fed VOM_0 (72.033 % & 65.443 %, respectively). Hardly, crude fiber (CF) digestibility in the control group was significantly ($P < 0.05$) better than it was in the VOM_{25} diet (56.820 % *vs.* 55.945%, respectively). It is of interest to notice that the VOM_{25} and VOM_{50} groups exhibited better TDN and DCP values ($P < 0.05$) than the control group in terms of nutritional value.

Only a few studies have focused on how insect meal replacement affects digestibility in rabbit diets. Similarly, Narang and Lal (1985) found that nitrogen digestibility increased significantly when Alphitobius diaperinus substituted soybean meal protein. It is worth mentioning that the present findings of CP digestibility were near the range of 76.4 to 93.3 % for the *in vitro* protein digestibility of 11 freeze-dried insect species (Bosch et al., 2014 & 2016). Likewise, the protein digestibility coefficient in rats fed diets supplemented with dried *Tenebrio Molitor* larvae was 75.1% (Goulet et al., 1978). Additionally, Gariglio et al. (2019) showed that the EE apparent digestibility was better in defatted black soldier fly larva meal groups of ducks than in the control group, which agrees with the current findings. Furthermore, Ahmed et al. (2021) found that using edible insects at 25% of SBM enhanced nutrient degradability significantly.

Table (3): Digestion coefficient and nutritive value of V-line rabbits fed the experimental diets.

Item	Experimental diet			±SEM	P. value
	VOM_o	VOM_{25}	VOM_{50}		
Digestion coefficient (%)					
DM	70.410^b	71.585^a	71.745^a	0.262	0.0179
OM	58.250^b	61.315^a	61.225^a	0.512	0.0032
CP	72.033^c	74.648^b	76.068^a	0.207	0.0001
CF	56.820^a	55.945^b	56.020^{ab}	0.212	0.0311
EE	76.323^b	79.575^a	79.830^a	0.730	0.0137
NFE	65.443^c	68.390^b	70.123^a	0.415	0.0001
Nutritive value					
TDN	64.050^c	66.438^b	67.840^a	0.288	0.0001
DCP	13.520^c	14.258^b	14.778^a	0.039	0.0001

[a, b and c.] *Mean within each row with different superscripts are significantly different (P < 0.05).*

On the other hand, the digestibility of nutrients in laying hens declined when fed diets containing 14.6 % of Hermetia illucens (HI) larva meal (Laudadio *et al.*, 2012) or 17 % of HI larva meal (INRA, 2004), which was explained by the chitin content, contrary to the findings of our study. According to the results of these studies, there is a variation in insect protein digestion, which is influenced by many factors, such as the proportion of protein linked to chitin, as well as the kind and maturity of the insect entering ration (Finke.2007).

There are three possible causes for the increased nutrient digestion in rabbit diets with VOM protein compared to the control diet (VOM_0). The first reason could be due to amino acid integration, mainly since all of the insects studied were high in other essential amino acids, especially lysine, tryptophan, and threonine, all of which are relatively low in many cereal proteins, making them a good source of amino acids (Rumpold and Schluter, 2013). In addition, it has a low anti-nutrient content (Inje et al., 2018).

The second argument is that rabbits have the phenomenon of eating their droppings at dawn, which could be one of the reasons for the increase in digestion coefficients for many nutrients (Al-Mamary et al., 2001), except fiber. Although this is an untested truth and may require further examination, it may aid in the digestion of re-ingested chitin-complexes found throughout the gastrointestinal tract.

The third explanation for the high coefficients of digestion associated with the inclusion of insect protein in rabbit diets, aside from fiber, is that the partial substitution of soybean meal protein by VOM protein, which was suitable up to 50% (VOM_{50}), resulted in a low chitin content in the diet (Longvah et al., 2011). Because chitin is regarded as an indigestible fiber of the diet, and because rabbits are unable to secrete the chitinase enzymes (Finke, 2015; Tabata et al., 2018), the digestion of fiber in the VOM groups was lower than in the control group (table 3), as chitin digestion in rabbits is dependent on microorganisms found only in the cecum, which have limited enzymatic activity (Tabata et al., 2018).

Growth, feed and economic efficiency:

There are no significant differences in initial weights for rabbits in the different groups (Table 4). The final body weight (FBW) in all groups had more than tripled by the end of the study. In compared to the control group, the VOM_{50} group had the greatest FBW, total weight gain (TWG), and daily weight gain (DWG) values ($P < 0.05$) at the end of the growth period. The daily body gain in rabbits fed the VOM_{50} diet was 2 g/day, or 9.18 %, higher ($P < 0.05$) than in rabbits on the VOM_0 diet. The VOM groups demonstrated nonsignificant increase in growth rate (GR).

Many researchers have discovered that replacing fishmeal with silkworm pupae meal enhances broiler performance and profitability (Dutta and Dutta, 2012). Nandeesha et al. (1990) found that feeding worms up to 30% in common carp boosted the growth potential. Kowalska et al. (2021) found that partially substituting soybean meal with silkworm pupae and mealworm larvae meals in rabbit diets boosted body weight gains without affecting FCR. In addition, recent research by Schiavone *et al.* (2017) suggested that using Hermetia illucens larval meal as an alternate protein source to soybean meal in broiler chicken diets enhanced productive performance in terms of body weight gain, feed intake, and feed conversion ratio. Furthermore, when insect meal was used as a complete replacement for soybean meal in the diets of Japanese quail chicks, the weight gain was comparable to the control group (Hatab et al. 2020). Additional experiments by Strychalski et al. (2021) demonstrated that replacing soybean meal with silkworm pupae meal (SPM) or mealworm larvae meal (MLM) up to a 50% level can benefit a good result in rabbit production performance in terms of final body weight and daily body weight gains. Alternatively, Cullere et al (2016) found that introducing defatted black solider fly meal to the diets of growing broiler quails to replace 10 - 15% soybean meal had no negative impact on productive performance and mortality.

This positive response to the introduction of insect protein into rabbit diets could be attributed to the high feed intake (Inje et al. 2018) as well as the nutritional content of the insect meal for high biological value protein, which supports the optimal supply of essential amino acids (Khan et al. 2016), as well as the content of the insect protein for biologically active compounds as antioxidant agents, insulin regulators, and anti-inflammatory peptides (Acosta-Estrada et al.,2021).

During the whole growth time, no mortality was detected. These findings are consistent with those of Hatab et al. (2020) who, reported no mortality in Japanese quail diets when insect meal was completely replaced with meat and bone meal.

The dietary treatment had no impact on the amount of dry matter consumed, which indicates that the diets examined had the same palatability. Incorporating insect protein into rabbit diets improved the feed conversion (FC) rate significantly (P < 0.05) when compared to the control group. These FC values were comparable to those described (5.17 -11.32g) by Fakolade and Adetomiwa (2018), who fed weaner rabbits a graded amount of soybean seed meal.

Moreover, economic efficiency ranged from 1.787 in the control group to 2.274 in the VOM_{50} group. However, differences in this feature are statistically significant (P<0.05). Thus, replacing soybean meal in rabbit diets with the tested percentages (25 and 50%) of VOM meal increased the economic benefit by 12.87 and 27.25 %, respectively, compared to the control group. The findings of this study agree with those of Adeniji (2007), who noticed that insect meal diets were less expensive than meat and bone meal. Hatab et al (2020) identified that replacing 100% of meat and bone as the main source of animal protein in Japanese quail diets with insect meal made it more economically profitable than the control diet.

In this regard, it can be concluded that partial substitution of insects up to 50% of soybean in rabbit diets improved performance and economic return, while according to Kroeckel et al. (2012), high inclusion levels of Black Solider Fly lowered the palatability of the diet, protein digestibility, and growth performance of young turbot when compared to a control diet. However, it should be noted that some insects contain allergens that may pose a risk when consumed and should therefore be tested before consumption.

Table (4): Growth performance, feed efficiency, and economic efficiency of V-line rabbits fed the experimental diets.

Item	Experimental diet			±SEM	*P*. value
	Control	VOM_{25}	VOM_{50}		
Growth performance					
Initial weight (IW, g)	1.060	1.062	1.062	0.030	0.9989
Final weight (FW, kg)	3.021^{b}	3.117^{ab}	3.203^{a}	0.037	0.0060
Total weight gain (TWG, kg)	1.961^{c}	2.055^{b}	2.141^{a}	0.026	0.0001
Daily weight gain (DWG, g)	21.788^{c}	22.833^{b}	23.788^{a}	0.284	0.0001
Growth rate (%)	185.000	193.503	201.601	6.206	0.1594
Survival rate (%)	100	100	100	---	---
Feed intake					
DMI / h / d (g)	138.208	139.184	140.776	2.252	0.7208
TDN / h / d (g)	88.522^{b}	92.471^{ab}	95.502^{a}	1.503	0.0105
DCP / h / d (g)	18.686^{b}	19.845^{a}	20.804^{a}	0.324	0.0004
Feed conversion (FC)					
FC (DMI/ DWG)	6.346^{a}	6.096^{ab}	5.918^{b}	0.131	0.0423
FC (TDN/ DWG)	4.065	4.050	4.015	0.086	0.8905
FC (DCP/ DWG)	0.858	0.869	0.875	0.018	0.8433
Economic efficiency					
Price (LE) / kg diet[1]	4.432	4.426	4.420	---	---
Total feed cost / head	55.128	55.443	56.001	0.897	0.7857
Feed cost / kg WG	28.127^{a}	26.979^{ab}	26.156^{b}	0.581	0.0402
Total revenue / head [2]	78.400^{c}	82.200^{b}	85.640^{a}	1.023	0.0001
Net return / head [3]	50.273^{c}	55.221^{b}	59.484^{a}	1.474	0.0006
Economic efficiency[4]	1.787^{b}	2.047^{ab}	2.274^{a}	0.093	0.0036

[a and b]. Mean within each row with different superscripts are significantly differ (P < 0.05).
[1] Based on prices in the Egyptian market during the experimental period (2021).
[2] Total revenue (LE) /rabbit = Total weight gain × 40, assuming that the selling price of each kg of rabbit was LE 40.
[3] Net revenue /rabbit (LE) = Total revenue - feed cost per kg gain.
[4] Economic efficiencies = Net revenue / feed cost per kg weight gain.

Carcass Characteristics:

Results in Table (5) show the carcass characteristics and relative organ weight of different rabbit groups. The pre-slaughter weight of the VOM_{50} rabbit group was 256.25 g higher (P < 0.001) than that of the control rabbit group. The increase in live body weights at the end of the experimental period was due to increasing VOM levels, which led to a similar increase in carcass weights (Kowalska et al., 2020). At the same time, the levels of VOM used in the tested meals had no significant effect on carcass dressing or total edible giblets and heart weight for the entire trial. Additionally, the group of rabbits fed the VOM_{25} and VOM_{50} diets had significantly (P < 0.05) higher carcass weight, liver, kidney, and cecum length than the control group.

The higher protein and amino acid content of insect meal compared to soybean meal might lead to a rise in the relative weight of the carcass, liver, and kidney in groups fed VOM (Hatab et al, 2020). Similar results were reached by Kowalska et al. (2020). They revealed that feeding rabbits dried silkworm pupae and mealworm larvae meals at 4% inclusion level increased their final body weight and carcass meat content. In terms of carcass and organ weight gain, the present results match those of Bovera, *et al.* (2018), who fed broilers *Tenebrio molitor* larvae meal as a protein source, and Hatab et al, (2020), who reported the carcass features of growing Japanese quail chicks are unaffected by using insect meal protein as a replacement for MBM up to 100 %. However, Gasco et al., (2019) discovered that adding insect fat to rabbits' diets had no effect on carcass traits.

Table (5): Carcass traits and relative organs weight of V-line rabbits fed the experimental diets.

Item	Experimental diet			±SEM	*P*. value
	VOM_0	VOM_{25}	VOM_{50}		
Pre-slaughter weight, (g)	3047.500^c	3167.500^b	3303.750^a	13.490	0.0001
Carcass weight, (g)	1650.500^c	1713.250^b	1763.750^a	12.274	0.0001
Carcass dressing, (%)[1]	54.159	54.088	53.386	0.4167	0.0001
Edible giblets, (%)[2]	2.772^b	2.889^{ab}	2.837^a	0.024	0.0151
Total edible giblets, (%)[3]	56.931	56.977	56.223	0.4042	0.0001
Liver, (g)	62.500^b	68.750^a	70.250^a	0.689	0.0001
Kidney, (g)	14.472^c	15.190^b	15.936^a	0.157	0.0001
Heart, (g)	7.498	7.562	7.538	0.126	0.9363
Cecum length, (cm)	32.876^c	34.562^b	36.250^a	0.452	0.0007

[a and b]. Mean within each row with different superscripts are significantly different (P < 0.05).
[1] Carcass dressing (%) = Ratio between hot carcass weight (without head) to live weight.
*[2] Edible Giblets %= (liver+ kidney + heart) / Pre-slaughter weight (g)*100*
*[3] Total edible parts (%) = (carcass wt. + Edible Giblets)/ Pre-slaughter weight (g)*100*

Caecal fermentative characteristics and microbiota:

In rabbits as herbivores, the large intestine environment is the primary site of bacterial fermentation in the digestive system (Jurgoński et al., 2014). In the caecal contents of VOM_{25} and VOM_{50} rabbits, total volatile fatty acids (VFA) were found to be significantly (P < 0.05) higher. However, caecal Ammonia-N concentration and pH were lower (*P* < 0.05) when compared to the control diet (Table 6). These values are within the normal range in healthy rabbits (Garcia et al. 2002). These results can be attributed to the fact that the control diet has higher fiber content (12.11 %) than the other two diets (11.96 and 11.80 %, respectively), in which the fiber content of the diet affects the concentration of total VFA acids (Garcia et al., 2002). The increase in total VFA concentrations could be due to microbial population modulation caused by the insect-based diet (Borrelli et al., 2017). The pH, total VFA, and Ammonia-N concentration values measured in rabbits in the present investigation (table 6) are similar to those found by Chrastinová et al. (2016) and Dabbou et al. (2020). Both caecal pH and VFA content are important factors in determining the degree and pattern of caecal fermentation, and thus serve as an indirect measure of caecal microbial activity (Polansky et al 2016). As it appeared in this study, the aerobic total count, E. coli, enterobacter and Clostridium spp (as a $\log10^{-1}$ CFU/ml) were significantly (*P* < 0.05) lower in rabbits fed VOM_{25} and VOM_{50} diets when compared to rabbits in the control group. However, in comparison with the control group, the *bacillus cereus* and *enterococcus* counts in rabbits fed the VOM diets appeared to be higher, with no significant differences. The present results agree with Józefiak et al. (2020). In comparison to the control group, dietary inclusion of VOM at a level of merely 50% of SBM protein induced a considerable reduction (P < 0.05) in yeast cell count. On the other hand, *Salmonella* and *Shigella* were not detected in any of the treatments. This finding prove that, a high concentration of total caecal VFA in rabbits exhibited a protective effect against enteropathogenic *Escherichia coli* infection (Peeters et al., 1995).

It was indicated that Lactobacilli (a probiotic bacteria) had been shown to enhance intestinal health, nutrient digestion, and animal growth by reducing pathogen infection levels. In addition, dietary insect meal could have the ability to operate as a prebiotic, and chitin is such a vital component of this activity.

However, the chitin content in insect meal could act as a substrate for the intestinal microbiota, therefore altering the fermentation processes (Borrelli et al., 2017). Accordingly, the current study implies that *Vespa Oriental* meal administration to rabbits in a limited amount may have a beneficial antimicrobial effect against infection (Yoon et al., 2018) by reducing harmful pathogen counts (Gasco et al, 2019). Therefore, the antimicrobial activity of VOM may be attributed to the presence of some bioactive compounds that may act on microbiota by inhibiting the growth of microbes (Yoon et al., 2018).

Table (6): Fermentation activity and microbiota counts (log^{-1} CFU/ml) in the caecum of V-line rabbits fed the experimental diets.

Parameter	Experimental diet			±SEM	P. value
	VOM_0	VOM_{25}	VOM_{50}		
Caecum activity					
pH Value	6.662^a	6.288^b	6.168^b	0.044	0.0001
NH_3-N (mg / 100 ml)	8.798^a	8.530^b	8.378^b	0.053	0.0004
TVFAs (ml Eq. / 100 ml)	9.212^c	9.520^b	10.080^a	0.041	0.0001
Microbial counts (log^{-1} CFU/ml)					
Aerobic total count	6.882^a	6.120^b	5.116^c	0.063	0.0001
Bacillus cereus	4.558	4.622	4.716	0.094	0.5082
Enterobacter	5.900^a	4.800^b	4.486^b	0.131	0.0001
Enterococcus	4.026	3.936	3.872	0.109	0.6184
E. Coli	7.218^a	4.548^b	3.962^c	0.090	0.0001
Clostridium spp.	2.508^a	1.960^b	1.672^c	0.055	0.0001
Yeasts	6.882^a	6.120^a	5.116^b	0.094	0.0067
Salmonella and Shigella	ND	ND	ND	-	-

[a and b]. Mean within each row with different superscripts are significantly differ (P < 0.05).
Each value is an average of 3 observations.
TVFAs= Total volatile fatty acids, Number of bacterial cells per gram of cecum content ($log10^{-1}$ CFU/ml), CFU (Colony forming unite); ND =Not detected

Hematological parameters, liver and renal function:

The hematological parameters, liver and renal function of rabbits fed VOM compared to those fed SBM are illustrated in table (7). Hematology testing is well-known for its ability to detect changes in the nutritional, physiological, and pathological status of farm animals (Togun and Oseni, 2005) caused by diet and other variables (Afolabi et al., 2010). In the blood samples from rabbits fed a control diet, the concentration of haemoglobin (Hb), red blood cell count (RBC), mean cell volume (MCV) and mean cell haemoglobin (MCH) were significantly lower ($P < 0.05$) than those placed on the VOM50 diet. The concentration of MCHC and white blood cell count (WBC) were not considerably ($P > 0.05$) different, indicating that introducing insect meal to rabbit diets had no deleterious effect. These findings are consistent with those of Hatab et al. (2020), who discovered that using insect meal protein as a partial replacement for soy bean meal has no effect on the haematological and serum biochemical indices of growing Japanese quail chicks. Similarly, Ekpo (2011) observed that insect enrichment diets had no significant influence on blood parameters in mice. Although the white blood cell count in rabbits administered VOM was not significantly higher, this indicates that these rabbits were more resistant to infection. It is widely known that animals with a sufficient number of white blood cells can produce antibodies and have a high level of immunity (Soetan et al., 2013), whereas those with a low number of white blood cells are susceptible to infection. Liver enzymes were not adversely ($P > 0.05$) affected, while renal function (creatinine and urea concentrations) was increased ($P < 0.05$) by VOM diets.

All determined enzymes values were within the normal range of values established by earlier studies for these parameters (Jenkins, 2008). This indicates that the rabbit liver cells are healthy, however when the liver cells are destroyed, the release of these enzymes are increased (Murray et al., 2012). In terms of renal function, rabbits fed the VOM_{50} diet had substantially higher levels ($P < 0.05$) of creatinine and urea than rabbits fed the control diet. The increased of blood urea and creatinine concentrations in VOM_{50} rabbits may thus represent higher protein intake than in rabbits fed control diets. Similar results were found in broiler chickens with partial or entire substitution of soy bean meal lipid by Hermetia illucens with no significant variations in blood biochemical parameters (Schiavone et al., 2017; Schiavone et al., 2018). Li et al. (2016) observed the same results at varied levels of soybean meal replacement by Hermetia illucens larval meal in juvenile carp feed.

Table (7): Hematological parameters, liver and renal function of V-line rabbits fed the experimental diets.

Item	Experimental diet			±SEM	*P*. value
	VOM_0	VOM_{25}	VOM_{50}		
Hematological parameters					
Haemoglobin (Hb, g/dL)	11.558^b	12.060^b	12.650^a	0.168	0.0043
Red Blood Cell Count (RBC, , $\times 10^6$ /µL))	5.050^b	5.130^b	5.503^a	0.010	0.0236
Mean Cell Volume (MCV, fL)	69.088^b	70.940^b	74.203^a	1.091	0.0259
Mean Cell Hemoglobin (MCH, pg)	22.400^b	22.580^{ab}	23.570^a	0.212	0.0076
Mean Cell Hemoglobin Concentration (MCHC, g/dL)	30.900	30.480	31.080	0.499	0.6940
White Blood Cell Count (WBC, $x10^3$/ µL)	5.700	5.728	5.800	0.089	0.7251
Liver function					
Alanine Aminotransferase (ALT, IU/L)	42.333	42.668	44.333	0.913	0.3008
Aspartate Aminotransferase (AST, IU/L)	82.000	81.290	84.000	1.756	0.5497
Gamma-glutamyl transferase (GGT, IU/L)	5.708	5.773	5.893	0.192	0.7919
Total bilirubin (mg/dl)	0.973^b	0.978^b	1.080^a	0.021	0.0078
Renal function					
Creatinine (mg/dL)	0.690^b	0.730^b	0.888^a	0.690	0.0014
Urea (mg/dL)	27.668^b	32.333^a	34.668^a	1.434	0.0205

[a and b]. Mean within each row with different superscripts are significantly different ($P < 0.05$).

These data could point to *Vespa Oriental* meals positively impacting rabbit metabolism and immunity. This could also be related to the higher bioavailability of essential amino acids in VOM, required for protein synthesis.

CONCLUSION

The findings of this study support the use of *Vespa Orientalis* wasp as a high-quality protein source for partial substitution of soybean meal in rabbit feed up to a 50% without adversely affecting growth performance, digestion parameters, or carcass organ characteristics.

Conflict of interest statement:

We declare that we have no conflict of interest.

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تأثير إستخدام مسحوق حشرة دبور البلح محل كسب فول الصويا على النمو والاستفادة من الغذاء فى ذكورالأرانب

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أجريت الدراسة الحالية بهدف تحديد تأثير الإحلال الجزئى لكسب فول الصويا بمسحوق دبور البلح على اداء النمو والهضم وبعض التغيرات فى قياسات الدم باستخدام ثلاث مستويات إحلال وهم صفر و 25 و50% (**VOM_0** و **VOM_{25}** و **VOM_{50}**) فى العلائق حيث تم توزيع عدد 30 ذكر من الأرانب بعمر 12 إسبوع وبمتوسط وزن بداية 1.06 كجم بالتساوى بين ثلاث مجموعات واستمرت التجربة لمدة 90 يوم. تشير النتائج إلى أن محتوى البروتين الخام فى مسحوق دبور البلح وكسب فول الصويا كان 76.84 و 43.76% على الترتيب. بالاضافة الى أن معاملات الهضم للبروتين كانت 74.65% و76.07% وللمستخلص الخالى من الازوت 68.39 و 70.123% للعلائق ذات الاحلال 25% و 50% على الترتيب والتى كانت أعلى من مجموعة المقارنة (72.033 و 65.44%، على الترتيب) . الزيادة اليومية فى وزن الجسم للارانب التى تغذت على المجموعة **VOM_{50}** كانت أعلى بمقدار 9.18% عن تلك الارانب التى تغذت على مجموعة المقارنة (**VOM_0**). ايضا الارانب بالمجاميع المختبرة **VOM_{25}** و **VOM_{50}** كانت أعلى فى وزن الذبيحة والكبد والكلى وطول الأعور مقارنة بمجموعة **VOM_0**. الاحماض الدهنية الطيارة كانت أعلى بصورة معنوية فى مكونات الاعور بمجموعة **VOM_{25}** و **VOM_{50}** بينما كان هناك إنخفاض فى قيم تلك المجموعتين من تركيز الأمونيا عند المقارنة بمجموعة **VOM_0**. أظهرت المجموعة **VOM_{50}** تحسنا معنويا فى قياسات الدم ووظاف الكبد والكلى مقارنة بمجموعة المقارنة **VOM_0**.

وبناء على نتائج هذة الدراسة يمكن ان نستخلص إمكانية إستخدام مسحوق دبور البلح كمصدر بروتين بديل عالى الجودة محل كسب فول الصويا حتى مستوى إحلال 50% بدون وجود أى اثار سلبية على أداء الارانب. واظهرت المجموعتين **VOM_{25}** و **VOM_{50}** قيم غذائية أعلى فى صورة مجموع المركبات الغذائية المهضومة (**TDN**) والبروتين المهضوم (**DCP**) مقارنة بمجموعة التحكم.