Global J. Environ. Sci. Manage. 9(1): 31-42, Winter 2023, Serial #33

Global Journal of Environmental Science and Management
(GJESM)

Homepage: https://www.gjesm.net/

ORIGINAL RESEARCH ARTICLE

Bioprocessing of organic wastes from poultry and bovine slaughterhouses as food substrate for *Hermetia illucens* larval development

A.P. Luperdi[1], S.S. Flores-Calla[1,*], X.J. Barriga[1], V. Rivera[1], I. Salazar[1], P.L. Manrique[1,2], J.E. Reátegui[1]

[1]*Universidad Católica de Santa María, Postal address 04013, Perú*

[2]*Instituto de Investigación y Desarrollo para el Sur, Postal address 04018, Perú*

ARTICLE INFO

Article History:
Received 19 March 2022
Revised 30 May 2022
Accepted 09 July 2022

Keywords:
Black soldier fly (BSF)
Cattle slaughterhouses
Organic residues
Protein
Poultry slaughterhouses
Sustainability

DOI: 10.22034/gjesm.2023.01.03

ABSTRACT

BACKGROUND AND OBJECTIVES: In the meat industry, inefficient management of organic waste exists, therefore the study aims to evaluate different bovine and poultry organic residues as food substrates during larval development of the black soldier fly, such as a sustainable alternative to obtain high protein meal.

METHODS: The research evaluates the use of organic waste from cattle and poultry slaughterhouses, as food substrate for black soldier fly larvae, including raw beef blood T1, raw beef viscera T2, cooked beef blood T3, cooked beef viscera T4, raw chicken viscera T6 and cooked chicken viscera T7; further, as a control measure balanced feed (7 treatments and 5 replicates). Larvae were fed for 5 days and processed to make meal by drying and grinding; evaluating mortality, weight, size, proximal chemical composition, and apparent digestibility to determine the most viable substrate, analyzing effects and significance by multifactorial ANOVA and Kruskal-Wallis.

FINDINGS: The results show Mortality (F = 917,81, p < 0,0001): T1 y T3 with 76,40 ± 2,86 (%) (F = 917,81, p < 0,0001), following T6 with 69,67 ± 4,55%, T7 with 24,00 ± 3,48%, T2 with 4,60 ± 1,92 %, T5 y T4, both with 4,20 ± 2,00 %. Weight (F = 825,62, p < 0,0001): T2 with 1,78 ± 0,22 gram outperformed the control T5 (1,76 ± 0,50 gram), T4 with 1,45 ± 0,06 g and T7 with 1,66 ± 0,07 gram. Size (F = 248,95, p < 0,0001): T5 with 16,03 ± 0,34 mm, T2 with 15,86 ± 0,22 mm, T4 with 14,72 ± 0,35 mm and finally, 14,51 ± 0,14 millimeter in T7. Proximal chemical analysis of crude protein and fat: T2 resulted in the following results 50,81 % and 21,88 %, T4 with 53,90% y 15,04%, T7 with 42,63 % and 32,03%, and T5 con 41,1 % and 19.55%, respectively. Digestibility: T5 with 20,39%, T2 with 12,66%, T4 with 10,61% and T7 with 5,97%. T2 raw beef viscera were determined to be the most viable substrate, followed by T4 cooked beef viscera and T7 cooked chicken viscera.

CONCLUSION: Testing the effectiveness of cattle viscera as substrate, the experimental data presented may help design a process for an effective treatment method for slaughterhouse waste, which might benefit developing nations in managing their waste effectively, generating high protein meal, with the potential for a circular bioeconomy.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
61	3	5

*Corresponding Author:
Email: *sfloresc@ucsm.edu.pe*
Phone: +51 949 127 680
ORCID: 0000-0003-1257-2711

Note: Discussion period for this manuscript open until April 1, 2023 on GJESM website at the “Show Article”.

INTRODUCTION

Globally, waste generation is expected to reach 3.4 billion tonnes by 2050, currently, 44% of total accumulated waste comprises biodegradable materials, with a higher proportion in low to middle-income countries; most of these are disposed of in landfills (37%) or open dumps (33%) (Lopes *et al.*, 2022). These forms of biodegradable waste disposal are considered important threats to the environment, due to the greenhouse gases (GHG) released into the atmosphere and the contamination of soil and water with toxic compounds, among other factors (Koda *et al.*, 2017). A promising method for treating biodegradable waste that could contribute to the current challenge; black soldier fly (BSF) larvae treatment represents an efficient and economical option for recycling biological matter (Gold *et al.*, 2018; Salam *et al.*, 2022). BSF, *Hermetia illucens* (Diptera: Stratiomyidae), is a generalist saprophytic detritivorous species that colonize a wide variety of matter (Guo *et al.*, 2021; Morais, 2020). Its potential is related to the biological characteristics of its larval stage (Giannetto *et al.,* 2020), capable of reducing 60 to 90 percent (%) of the organic matter volume of substrates (Morales Quintana, 2021). *Hermetia illucens* presents a bioconversion rate of 140 %, with larvae consuming their own weight in food every 12 h (Makkar *et al.,* 2014; Oonincx *et al.,* 2015), accumulating around 40% or more as protein (Ebeneezar *et al.*, 2021). This high protein concentration and the content of other nutrients such as fatty acids, pigments, vitamins, and minerals, allow its inclusion in poultry, livestock, and aquaculture diets (El-Hack *et al.*, 2020; Giraldo J., 2019; Liland *et al.*, 2017). It is important to note that in the adult stage, its jaw is atrophied and it does not need feed to produce viable offspring, being easy to control (Giraldo J., 2019). In addition, BSF is not a vector for the spread of diseases (Singh and Kumari, 2019) compared to other insects, favoring safe breeding and its application in biotechnologies. Like other animal species used for feeding, the nutrient content of biowaste is assumed to have the greatest influence on yield (Gold *et al.*, 2020; Tinder *et al.*, 2017). Biowaste nutritional quality is determined by factors including the density (humidity), proportion, and type of nutrients they contain, as the sum of macronutrients, organic matter, protein, non-fibrous carbohydrates (NFC), fiber, and lipids (Barragán-Fonseca *et al.*, 2018; Gold *et al.*, 2018). Biowaste nutritional quality like the sum of macronutrients, organic matter, protein, non-fibrous carbohydrates (NFC), fiber quantity (cellulose, lignin, hemicellulose), and lipids, is important to determine the level of nourishment provided (Barragán-Fonseca *et al.*, 2018; Gold *et al.*, 2018; Gold *et al.*, 2020; Tinder *et al.*, 2017). BSF feeding experiments suggest that proteins, NFC, and lipids are highly digestible and therefore their supply improves performance (Barragán-Fonseca *et al.*, 2018; Beniers and Graham, 2019). Fiber, on the contrary, is less digestible and tends to decrease larval growth rates (Liu et al., 2018). Faced with these different nutritional conditions, fly larvae adjust their growth rate and nutrient accumulation, with the primary goal of amassing sufficient reserves to complete the non-feeding life stages of metamorphosis and adulthood (Danielsen *et al.*, 2013). In this insect-based treatment, biodegradable waste is converted into products like larval biomass rich in lipids and proteins (Lalander *et al.*, 2019) that can be used in animal feed; and in residues like exoskeleton with chitin processing (Siddiqui et al., 2022), frass considered fertilizer (Beesigamukama *et al.*, 2020; Siddiqui et al., 2022; Xiao *et al.*, 2018), as valuable products are generated, this technology fulfills with the principles of a circular bioeconomy, in which the waste from one process becomes the resource in another (Slorach *et al.*, 2019). There are different organic wastes of high environmental impact that have the ability to be used as food substrate for *Hermetia illucens*; this is the case of waste from the meat industry, which generates liquid effluents from the washing of livestock and poultry, bleeding area, removal of hides, fur, feathers, viscera and cleaning operations, resulting from the processing of meat. Blood and viscera represent approximately 25% of the total weight of a 1000 kg carcass, generating effluents with raised amount of organic compounds High biochemical oxygen demand BOD 520 milligram per liter (mg/L)), as well as suspended solids 1728 mg/L, and a high concentration of phosphorus 63 mg/L, a parameter related with matter putrefaction (Ruiz Sánchez, 2019), exceeding by far MPL (250 mg/L, 300 mg/L, 40 mg/L, respectively) (Salas and Condorhuamán, 2008). Therefore, the objective of this study, is the conversion of cattle and poultry slaughterhouse wastes into high protein meal, taking advantage of *Hermetia illucens* larval development, which reduces organic matter and treatment costs. The overall findings of this study could be very helpful to the scientific society, and animal and meat industries, providing baseline knowledge and guidance on how BSF treatment facilities may systematically operate using biowastes of varying types, eventually, low-cost protein food will be produced by giving added value and making the production sustainable. This study has been carried out at the Catholic University of Santa Maria, Arequipa, Peru in 2019.

MATERIALS AND METHODS

For the experimental tests, aseptic conditions, sterilized materials, and supplies were used, applied an autoclave (Ecoshel CVQ-B100L, Mexico).

Obtaining Black soldier fly

Oviposition units were obtained from adult black soldier fly BSF, *Hermetia illucens*, reared under a controlled environment from the pilot plant of the Catholic University of Saint Mary, located at Fundo "La Católica", district of Pedregal, Province of Caylloma, Arequipa region, Peru. Geographically located at South Latitude 16° 20´ 08.35´´, West Longitude 72 ° 09´ 08,56´´ at an altitude of 1498 meters above sea level (m.a.s.l.), (MAP, 805. Pampa de Majes, Ubigeo Code 040520).

Larval growth on different substrates and meal production

Blood and beef viscera were collected as organic waste from "Santa María de la Colina" metropolitan animal slaughterhouse, likewise, chicken viscera from "Gamboa" poultry processing center, both located in Majes city; the biomass was packaged at 4 °C for 24 h and brought to the experimental temperature prior to each feeding experiment, to avoid external conditions that could affect the feeding. All viscera were processed in a mincer (Thomas TH-9010 400 w, Germany) to get a uniform puree and facilitate the *Hermetia illucens* larvae consumption. Half wastes were cooked for 5 minutes on a hot plate electric stove (Star JX – 6121B, Spain). Thereby 6 food substrates for the larvae were obtained: raw beef blood T1, raw beef viscera T2, cooked beef blood T3, cooked beef viscera T4, raw chicken viscera T6, and cooked chicken viscera T7; also a standard balanced feed (50 % bran, 20% corn meal and 30% alfalfa mixture) T5; moisture content at 60% was monitored, adding solid standard feed or water (purified using Reverse Osmosis Water Purifier PREC PRO7/D1 – 100, Peru). A growth system was established in a controlled environment at 28°C; with a minimum development temperature of 19°C (Holmes *et al.*, 2016) and 60 % humidity (Purkayastha and Sarkar, 2022), insects are ectothermic organisms that regulate their physiological functions according to environmental conditions (Abram *et al*., 2017); applying 7 treatments and 5 replications for each one, 35 experimental units in total. In the oviposition unit, hatched BSF eggs at larval stage 1 were carefully collected in porous cardboard structures called eggies, approximately 10,000 to 15,000 eggs were sown in moist balanced feed; 5 days later, once the secondary larvae had reached stages 2 to 3, 500 g of larvae were randomly transferred to individual trays containing 3 kg of each feed substrate (T1 – T7). Then, after 5 days of treatment, larvae were in larval 5 and prepupal stage, the optimal point for food processing (Lalander *et al*., 2018), characterized by whitish color and soft exoskeleton. Larvae were sifted and several parameters were registered as weight using a digital electronic balance (ABranddeals SF-400, Mexico) and size measured using an electronic vernier (Uberman RM813, Chile). Moreover, humidity (H), mortality (M), total dry matter (TDM), crude protein (CP), ethereal extract (EE), ash (A), crude fiber (CF), nitrogen-free extract (NFE), volatile organic matter (VOM) and apparent digestibility (AD) were evaluated in the percentage of dry matter (%DM), according to The Association of Official Analytical Chemists (AOAC) International protocols, before and after growth, to control the organic residues degradation. At the end of the larval growth period, larvae were manually separated, dried in a hot air dehydrator (Own manufacturing, Peru) at 70 °C for 5 h, and pulverized in an electric mill (Own manufacturing, Peru) to obtain larvae meal, which was characterized according to the AOAC protocol (Feldsine *et al*., 2002).

Statistical analysis

Treatment effects were analyzed by multifactorial ANOVA, using substrate type and time as main variables. Means and standard deviations were calculated from the data obtained. The Kruskal-Wallis test was applied to determine the significance (α = 0.05) between treatments.

RESULTS AND DISCUSSION

All the experimental treatments were performed with 5 repetitions, considering statistical analysis.

Waste degradation

Table 1 shows the quality parameters of each waste substrate at the beginning and end, being the most outstanding, CP levels of T3 with 89.35%, while the control T5 only contains 12.83 %, explained by its high fiber composition. T6 and T7 raw and cooked chicken viscera respectively have 26.23 % and 25.79 % but a low level of EE indicating a low level of CF. The content of dry matter, protein, lipids, ash, and fiber also varied among the wastes. Wastes have an amount of highly digestible lipids and protein and will have a greater impact on development up to prepupae (Barragán-Fonseca *et al*., 2018; Beniers and Graham, 2019).

Larval growth on different substrates

Weight and size analyses showed a significant difference ($P < 0.0001$) over 5 days and between treatments. Fig. 1 shows the weight through 5 days, it was observed that T2 (1.78 ± 0.02 g) and T5 (1.76 ± 0.05 g) are practically equal, demonstrating their effectiveness, followed by T4 (1.45 ± 0.06 g) and

Table 1: Comparison of initial and final nutritional parameters for each of the seven different treatments

Treatments nutritional parameters	T1		T2		T3		T4		T5		T6		T7	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
TDM (%)	35.73	20.56	33.17	43.55	21.90	45.75	29.13	38.15	31.30	27.75	38.73	27.79	43.50	72.46
H (%)	64.27	79.44	66.83	56.45	78.10	54.25	70.87	61.85	68.70	72.25	61.27	72.21	56.50	47.54
CP (%DM)	54.57	48.60	65.17	51.88	89.35	36.07	57.44	59.59	12.83	14.69	26.23	26.88	25.79	24.25
EE (%DM)	0.09	2.01	6.38	5.22	0.53	0.50	2.89	2.27	1.06	1.59	31.55	25.76	25.93	22.59
A (%DM)	3.85	8.54	7.46	6.81	3.65	5.11	6.11	8.34	9.27	6.18	3.95	4.38	4.40	5.12
CF (%DM)	4.57	18.81	2.03	3.66	0.06	7.72	0.42	2.44	22.52	8.56	4.64	4.74	6.03	8.33
NFE (%DM)	36.92	2.04	18.95	32.44	6.41	50.61	33.14	27.37	54.33	68.98	33.63	38.24	37.84	39.70
VOM (%DM)	96.15	91.46	92.54	93.19	96.36	94.46	93.89	91.66	90.73	93.82	96.05	95.62	95.60	96.05

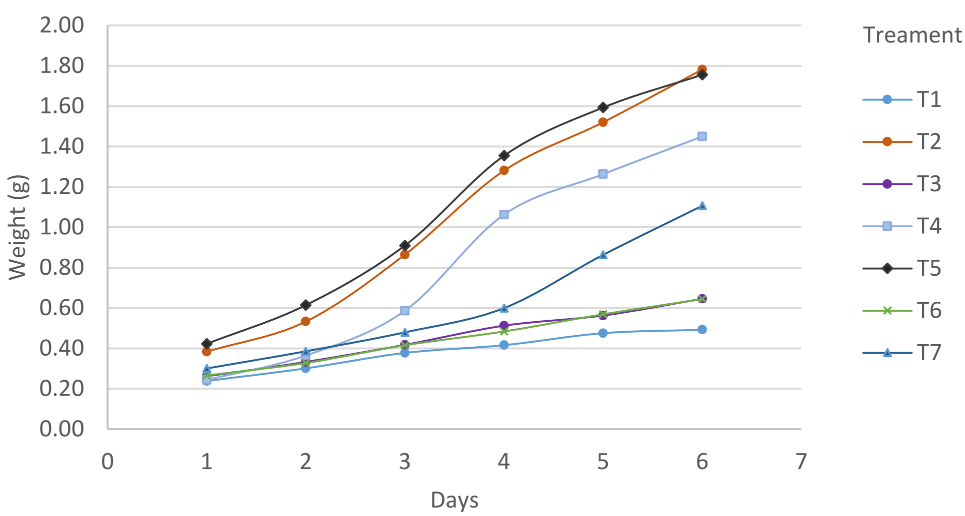

Fig. 1: Weight of *Hermetia illucens* larvae for each treatment over time. Larval growth system (T1: raw beef blood, T2: raw beef viscera, T3: cooked beef blood, T4: cooked beef viscera, T5: control (balanced feed), T6: raw chicken viscera, and T7: cooked chicken viscera)

Table 2: ANOVA *Hermetia illucens* larvae weight at day 5

Source	Sum of Squares	Gl	Half-square	F	P
Substrate	21.7665	1	21.7665	825.62	0.0000
Cooking	0.071286	1	0.071286	2.70	0.1021
Interaction	5.28469	1	5.28469	200.45	0.0000
Residue	4.11277	156	0.0263639		
Total (correct)	31.265	159			

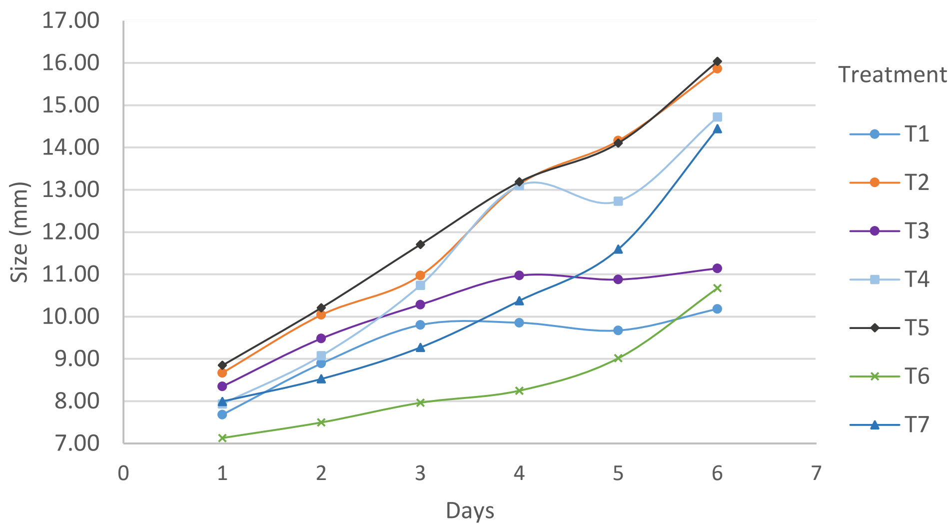

Fig. 2: Size of *Hermetia illucens* larvae for each treatment over time. Larval growth system (T1: raw beef blood, T2: raw beef viscera, T3: cooked beef blood, T4: cooked beef viscera, T5: control (balanced feed), T6: raw chicken viscera, and T7: cooked chicken viscera).

Table 3: ANOVA *Hermetia illucens* larvae size at day 5

Source	Sum of Squares	Gl	Half-square	F	P
Substrate	273.49	1	273.49	248.95	0.0000
Cooking	68.037	1	68.037	61.93	0.0000
Interaction	232.012	1	232.012	211.19	0.0000
Residue	171.377	156	1.09857		
Total (correct)	697.911	159			

T7 (1.06 ± 0.07 g), and finally T1 (0.49 ± 0.04 g), T3 (0.65 ± 0.05g), T6 (0.64 ± 0.05 g). Gold *et al*. (2020) presented data about low-weight larvae in the same stage fed with substrates like Mill by-products (0.17 g), Cow manure (0.06 g), Human feces (0.24 g), and Poultry slaughterhouse waste (0.16 g). Similar results, Zhou *et al*. (2013) tried with Poultry manure (0.15 – 0.26 g), Cow manure (0.07 – 0.15 g) and Human faeces (0.07 - 0.30 g). In addition, Tinder *et al*. (2017) studied millings and brewery side streams (0.08 – 0.29 g).

In Table 2 can be observed the type of substrate used having an influence on weight ($F = 825.62$, $P < 0.0001$), but not on whether the substrate was raw or cooked ($F = 2.70$, $P > 0.0001$). On the other hand, there was an interaction between the type of substrate and the cooking process ($F = 200.45$, $P < 0.0001$).

Fig. 2 shows evolution profiles of BSF size, T2 (15.86 ± 0.22 mm) remains very close to T5 (16.03 ± 0.34 mm) with little difference, the next profile is

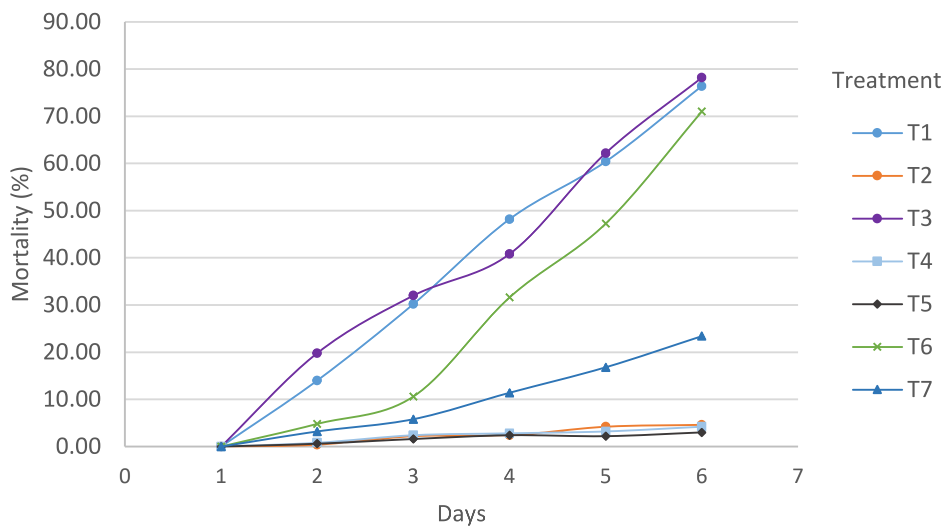

Fig. 3: Mortality of *Hermetia illucens* larvae for each treatment over time. Larval growth system (T1: raw beef blood, T2: raw beef viscera, T3: cooked beef blood, T4: cooked beef viscera, T5: control (balanced feed), T6: raw chicken viscera, and T7: cooked chicken viscera)

Table 4: ANOVA *Hermetia illucens* larvae mortality at day 5

Source	Sum of squares	Gl	Half-square	F	P
Substrate	67522.0	1	67522.0	917.81	0.0000
Cooking	19895.0	1	19895.0	270.43	0.0000
Interaction	19210.0	1	19210.0	261.12	0.0000
Residue	11476.7	156	73.5684	-	-
Total (correct)	110284.0	159	-	-	-

T4 (14.72 ± 0.35 mm) with small stagnation due to the digestibility of the larvae. T7 (14.51 ± 0.40 mm) has a very slow growth below the rest in the first 4 days. Finally, T1 (9.98 ± 0.12 mm), T3 (11.14 ± 0.35 mm) and T6 (10.67 ± 0.40 mm). In addition, it was shown in Table 3 that substrate type ($F = 248.95$, $P < 0.0001$), cooking ($F = 61.93$, $P < 0.0001$) and the interaction between the two ($F = 211.19$, $P < 0.0001$) did influence BSF size and growth.

As shown in Fig. 3, T1 and T3 have the highest mortality, reaching 76.40 ± 2.86%, followed by T6 with 69.67 ± 4.55 %. Likewise, T7 with 24.00 ± 3.48%. T2 with 4.60 ± 1.92%, T4, and T5 with 4.20 ± 2.00%. Some authors indicate this result in % survival units (% complementary to mortality), Gold *et al.* (2020) use as biomass mill by-products, human feces, cow manure, and poultry slaughterhouse waste, with results from 1% to 10% and were not significantly different between the types of biowaste. Similar found by Rehman *et al.* (2017) with M% less than 20%. Lalander *et al.* (2018) reported a range of 0 - 19%, except for wastewater. In Table 4, it was possible to identify the type of substrate used for larval production ($F = 917.81$, $P < 0.0001$), cooking ($F = 270.43$, $P < 0.0001$) and the interaction between both ($F = 261.12$, $P < 0.0001$) significantly influenced the %BSF mortality. The apparent digestibility analysis was carried out for the treatments with the lowest % mortality, obtaining 20.39% in T5, 12.66% in T2, 10.61 % in T4, and 5.97% in T7.

In treatments T1 and T3, which had cooked and raw cattle blood respectively, as they were liquid in consistency, they were thickened by adding dry feed; the cooked blood being more digestible and assimilable by the soldier fly larvae than the raw blood. These two treatments, together with T6, presented the highest mortality % over time since they initiated a decomposition natural process which

Table 5: Comparison of meal nutritional parameters according to four viable treatments

Meal nutritional parameters	T2	T4	T5	T7
TDM (%)	26.82	91.93	93.65	97.89
H (%)	73.18	8.07	6.35	2.11
CP (%DM)	50.81	53.90	41.11	42.63
EE (%DM)	21.88	15.04	19.55	32.03
A (%DM)	5.04	5.75	8.09	6.08
CF (%DM)	5.47	4.87	5.91	5.00
NFE (%DM)	16.79	20.44	25.34	14.27
VOM (%DM)	94.96	93.92	91.91	93.92

makes the humidity and temperature not ideal for larval survival, as indicated by Tomberlin (Tomberlin and Sheppard, 2002), while T3, being cooked, its decomposition is slower, here, dry and hard complexes are formed. These three substrates have the lowest growth and weight, and the highest mortality, confirming that blood is not a viable substrate for BSF larval development. In raw chicken viscera substrate, the pH is acidified, which is not suitable for larval development, several studies indicate that a pH above 6 to 10 is more appropriate (Meneguz *et al*., 2018), since BSF is capable of regulating the pH of liquid alkaline substrate but not strongly acidic medium (Singh and Kumari, 2019). Factors like organic matter, protein, non-fibrous carbohydrates (NFC), and lipids are important to determine quality nutrition (Barragán-Fonseca *et al*., 2018, Gold *et al*., 2018, Gold *et al*., 2020, Tinder *et al*., 2017); thus viscera wastes are rich in organic matter, protein (50–63%) and lipids (Kazemi-Bonchenari *et al*., 2017), it had almost no NFC (Gold *et al*., 2020), with controlled density (humidity), proportion-based in balanced feed, instead, blood wastes do not have necessary nutritional requirements (liquid consistency, low protein, and fat). Considering the previous results, treatments T2, T4, and T7 were selected as the most viable, discarding T1, T3, and T6 due to their mortality percent higher than 50%. Table 5 shows the comparison of the 3 meals and the control, where T4 has the highest level of crude protein of 53.90 % and low fat of 15.04%, the T2 treatment with 50.81% crude protein and fat of 21.88 %, both T2 and T4 have a notably higher percentage than the control treatment T5 of 41.11% protein, which indicates that the residual substrates have been assimilated.

The T4 treatment of cooked beef viscera was the substrate with maximum protein amount obtained, but not the most viable due to the weight, size, and mortality of larvae. Being T2 treatment of raw beef víscera was the optimum for obtaining high protein content *Hermetia Illucens* meal, with a crude protein value of 50.81 %, being above the range reported by other authors that goes from 42.00% to 45.00% CP (Hopkins *et al*., 2021); exceeding by more than 10.00% the content of soybeans, 41.10%, Beetles, 42.20%, *Eristalis tenax*, 40.90%, *Tenebrio molitor*, 38.30% to Crickets, 32.60%, fruits and vegetables, 12.90% to 18.40% (Adámková *et al*., 2017; Barbi *et al*., 2020; Cashion *et al*., 2017; Hu et al., 2020; Kuntadi *et al*., 2018; Nesic and Zagon, 2019; Nyakeri *et al.,* 2017; Sogari *et al*., 2019; Zielińska *et al.,* 2015). Compared to other organic wastes, such as fruit and vegetable wastes, 48.00%, distillers' grains and cellulose wastes, 47.00 %, being lower values; wheat and barley grain wastes, 41.00 % to 54.00 % (Barragán-Fonseca *et al*., 2018; Bava *et al.,* 2019; Chia *et al*., 2020; Salomone *et al.,* 2017), with values like the one obtained. The highest protein content was found in BSF fed with *S. aurita* fish waste, 77.40% a 78.80 % (Barroso *et al.,* 2019). Likewise, the ethereal extract of T2, with 21.88%, is within the range reported between 18.10% and 35.00% (Nyakeri *et al.,* 2017; Weththasinghe *et al.,* 2021), this parameter varies depending on the substrate on which the crop is grown (Nyakeri *et al.,* 2017). Soldier fly meal exhibits a good amino acid and fatty acid profile suitable for inclusion in feed, with high levels of monounsaturated and polyunsaturated fatty acids such as lauric acid (59%), linoleic acid (98%), α-linolenic acid (0.79%) (Renna *et al.,* 2017), palmitic acid (15,23 %) and myristic acid (14,34%) (Abduh *et al*., 2022). In recent years, insect species have received increasing attention as ingredients for animal feed production .Makkar *et al.,* 2014; Nesic and Zagon, 2019); such as *Tenebrio molitor*, which is being studied in the feeding of *Hyplus* rabbits, proving its additional efficiency in digestibility and nitrogen parameters (Kowalska *et al*., 2021); and *Hermetia illucens*, in guinea pig feed at 16.00% improving feed conversion to 2.50 ± 0.04 and with no detrimental effects (Reátegui *et al.,* 2020), and in aquaculture feeds, using zebrafish as an animal model, replacing 100.00% of its protein source and tripling its body weight (Fronte *et al.,* 2021), replacing fish meal in *Totoaba macdonaldi* (Villanueva-Gutiérrez *et al*., 2022), also several studies that support BSFL meal can improve the disease resistance of aquatic animals against pathogens (Mohan *et al*., 2022). Although the mass production of insects is still under review (Sogari *et al*., 2019), the production of BSF larval meal is increasing, due to its high protein content, its form of consumption and sustainability must be optimized (Addeo *et al.*, 2021; Weththasinghe *et al.*, 2021). Hence, waste management with insect larvae is considered one of the most efficient techniques for resource recovery.

CONCLUSIONS

The increase in the human population has generated a massive demand for animal protein and has created the need to seek protein alternatives in a climate emergency context. Currently, insects are cultivated to produce protein-rich foods and replace more polluting productions. Hermetia illucens is a saprophytic species, which colonizes and bioprocesses poultry and cattle slaughterhouse waste to convert it into its body mass; raw beef viscera was the most viable substrate generating more crude protein (50,81% - 53,90%) than the standard balanced feed (41,11%), being a valuable experimental data to scale and use this residual to finally obtain high protein meal as food substrate. The treatments with BSF meal represent a valid alternative; due to its low carbon footprint in production and its high nutritional value, it is a promising sustainable innovation, which can be applied as a supplement or added to animal feed. BSF meal is being recognized as a feed ingredient in animals for its protein-rich content. An additional factor is that this process represents a complete management of residues; frass can be recovered and used as fertilizers for its multiple plant nutrients, larval fats can be extracted to obtain biodiesel, and chitin from adulthood. The BSF rearing system can be implemented at all levels of society and technology, this approach, which also incorporates cost considerations, is applied for feed formulation in commercial livestock production. Future research should investigate whether these results are transferable to treatment plants with higher larval densities and feeding temperatures. Various balanced formulations of biowaste should be investigated with additional analytical resources and new technologies.

AUTHORS' CONTRIBUTIONS

A. Luperdi Puente de la Vega conceived the study and processed data, S. Flores Calla analyzed data and wrote the manuscript, X. Barriga processed and analyzed data, V. Rivera Valdez wrote and translated the manuscript, P. Manrique conducted experiments and statistical analyses, I. Salazar Churata conducted experiments, J. Reátegui Ordoñez conducted experiments. All authors read and approved the final manuscript.

ACKNOWLEDGEMENTS

The authors would like to thank the Research Vice-Rectorate of the Catholic University of Santa Maria. This work was financed by the Banco Mundial (BM), Banco Interamericano de Desarrollo (BID), Programa Nacional de Innovación Agropecuaria (PNIA) Contract [No. 0292016-INIA-PNIA/UPMSI/IE] and the Catholic University of Santa Maria (UCSM) Resolution [No. 24305-R-2017].

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

OPEN ACCESS

PUBLISHER'S NOTE

GJESM Publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

ABBREVIATIONS

°C	Degrees Celsius
° ′ ″	Degrees, latitude, altitude
%	Percent
%DM	Percentage of dry matter
%M	Percentage of mortality
A	Ash
AD	Apparent digestibility
AOAC	Association of official analytical chemists
ANOVA	Analysis of variance
BID	Banco Interamericano de Desarrollo
BM	Banco mundial
BOD	Biochemical oxygen demand
BSF	Black soldier fly
CF	Crude fiber
CP	Crude protein
EE	Ethereal extract
F	Statistical value F
g	Gram
GHG	Greenhouse gases
GI	???
h	Hours
H	Humidity
INIA	Instituto Nacional de Innovación Agraria
kg	Kilograms
MPL	Maximum permissible limit
m.a.s.l.	Meters above sea level
mg/L	Milligram per liter
mm	Milimeters
M	Moisture
NFE	Nitrogen free extract
NFC	Non-fibrous carbohydrates
P	Probability value
PNIA	Programa Nacional de Innovación Agropecuaria
T1	Treatment 1, raw beef blood
T2	Treatment 2, raw beef viscera
T3	Treatment 3, cooked beef blood
T4	Treatment 4, cooked beef viscera
T5	Treatment 5, standard balanced feed
T6	Treatment 6, raw chicken viscera
T7	Treatment 7, cooked chicken viscera

REFERENCES

Abduh, M.Y.; Perdana, M.P.; Bara, M.A., Anggraeni, L.W.; Putra, R.E., (2022). Effects of aeration rate and feed on growth, productivity and nutrient composition of black soldier fly (Hermetia illucens L.) larvae. J. Asia-Pacific Entomology. 25(2): 101902.

Abram, P.K.; Boivin, G.; Moiroux, J.; Brodeur, J., (2017). Behavioural effects of temperature on ectothermic animals: unifying thermal physiology and behavioural plasticity. Biol. Rev., 92(4): 1859-1876 **(8 pages).**

Adámková, A.; Mlček, J.; Kouřimská, L.: Borkovcová, M.; Bušina, T.; Adámek, M.; Bednářová, M.; Krajsa, J., (2017). Nutritional potential of selected insect species reared on the island of Sumatra. Int. J. Environ. Res. Public Health. 14(5): 521.

Addeo, N.; Li, C.; Rusch, T.; Dickerson, A.; Tarone, A.; Bovera, F.; Tomberlin, J., (2021). Impact of age, size, and sex on adult black soldier fly [Hermetia illucens L.(Diptera: Stratiomyidae)] thermal preference. J. Insects Food Feed., 1-12 **(12 pages).**

Barbi, S.; Macavei, L.I.; Fuso, A.; Luparelli, A.V.; Caligiani, A.; Ferrari, A.M.; Maistrello, L.; Montorsi, M., (2020). Valorization of seasonal agri-food leftovers through insects. Sci. Total Environ., 709: 136209.

Barragán-Fonseca, K.; Pineda-Mejia, J.; Dicke, M.; Van Loon, J.J., (2018). Performance of the black soldier fly (Diptera: Stratiomyidae) on vegetable residue-based diets formulated based on protein and carbohydrate contents. J. Econ. Entomol., 111(6): 2676-2683 **(8 pages)**.

Barroso, F.G.; Sánchez-Muros, M.J.; Rincón, M.Á.; Rodriguez-Rodriguez, M.; Fabrikov, D.; Morote, E.; Guil-Guerrero, J.L., (2019). Production of n-3-rich insects by bioaccumulation of fishery waste. J. Food Compos. Anal., 82: 103237.

Bava, L.; Jucker, C.; Gislon, G.; Lupi, D.; Savoldelli, S.; Zucali, M.; Colombini, S., (2019). Rearing of Hermetia illucens on different organic by-products: Influence on growth, waste reduction, and environmental impact. Animals. 9(6): 289.

Beesigamukama, D.; Mochoge, B.; Korir, N.K.; Fiaboe, K.K.; Nakimbugwe, D.; Khamis, F.M.; Tanga, C.M., (2021). Low-cost technology for recycling agro-industrial waste into nutrient-rich organic fertilizer using black soldier fly. Waste Manage., 119: 183-194 **(12 pages).**

Beniers, J.J.A.; Graham, R.I., (2019). Effect of protein and carbohydrate feed concentrations on the growth and composition of black soldier fly (Hermetia illucens) larvae. J. Insects Food Feed, 5(3): 193-199 **(7 pages).**

Cashion, T.; Tyedmers, P.; Parker, R.W., (2017). Global reduction fisheries and their products in the context of sustainable limits. Fish Fish., 18(6): 1026-1037 **(12 pages).**

Chia, S.Y.; Tanga, C.M.; Osuga, I.M.; Cheseto, X.; Ekesi, S.; Dicke, M.; Van Loon, J.J., (2020). Nutritional composition of black soldier fly larvae feeding on agro-industrial by-products.

Entomologia Exp. Appl., 168(6-7): 472-481 **(10 pages).**

Danielsen, E.T.; Moeller, M.E.; Rewitz, K.F., (2013). Nutrient signaling and developmental timing of maturation. Current Topics Develop. Biology, 105: 37-67 **(31 pages).**

Ebeneezar, S.; Tejpal, C.; Jeena, N.; Summaya, R.; Chandrasekar, S.; Sayooj, P.; Vijayagopal, P., (2021). Nutritional evaluation, bioconversion performance and phylogenetic assessment of black soldier fly (Hermetia illucens, Linn. 1758) larvae valorized from food waste. Environ. Technol. Innovation. 23: 101783.

El-Hack, A.; Mohamed, E.; Shafi, M.E.; Alghamdi, W.Y.; Abdelnour, S.A.; Shehata, A. M.; Noreldin, A.E.; Ashour, E.A.; Swelum, A.A.; Al-Sagan, A.A., (2020). Black soldier fly (Hermetia illucens) Meal as a promising feed ingredient for poultry: A comprehensive review. Agriculture. 10(8): 339.

Feldsine, P.; Abeyta, C.; Wallace, H.A., (2002). AOAC International methods committee guidelines for validation of qualitative and quantitative food microbiological official methods of analysis. J. Assoc. Official Anal. Chem., 85(5): 1187–1200 **(14 pages).**

Lopes, I.G.; Yong, J.W.; Lalander, C., (2022). Frass derived from black soldier fly treatment of biodegradable wastes. A critical review and future perspectives. Waste Manage., 142: 65-76 **(12 pages).**

Fronte, B.; Licitra, R.; Bibbiani, C.; Casini, L.; De Zoysa, M.; Miragliotta, V.; Sagona, S.; Coppola, F.; Brogi, L.; Abramo, F., (2021). Fishes. Fishmeal Replacement with Hermetia illucens Meal in Aquafeeds: Effects on Zebrafish Growth Performances, Intestinal. Morphometry Enzymol., 6(3): 28.

Giannetto, A.; Oliva, S.; Lanes, C.F.C.; de Araújo Pedron, F.; Savastano, D.; Baviera, C.; Parrino, V.; Paro, G.L.; Spanò, N.C.; Cappello, T., (2020). Hermetia illucens (Diptera: Stratiomydae) larvae and prepupae: Biomass production, fatty acid profile and expression of key genes involved in lipid metabolism. J. Biotechnol., 307: 44-54 **(11 pages).**

Giraldo J., M.R.V.; N. Benavides M.P., (2019). Uso potencial de Hermetia illucens (Linnaeus) (Diptera: Stratyiomidae) para transformación de pulpa de café: Aspectos biológicos. Revista Cenicafé, 70(2): 81-90 **(10 pages).**

Gold, M.; Tomberlin, J.K.; Diener, S.; Zurbrügg, C.; Mathys, A., (2018). Decomposition of biowaste macronutrients, microbes, and chemicals in black soldier fly larval treatment: A review. Waste Manage., 82: 302-318 **(17 pages).**

Gold, M.; Cassar, C.M.; Zurbrügg, C.; Kreuzer, M.; Boulos, S.; Diener, S.; Mathys, A., (2020). Biowaste treatment with black soldier fly larvae: Increasing performance through the formulation of biowastes based on protein and carbohydrates. Waste Manage., 102: 319-329 **(11 pages).**

Guo, H.; Jiang, C.; Zhang, Z.; Lu, W.; Wang, H., (2021). Material flow analysis and life cycle assessment of food waste bioconversion by black soldier fly larvae (Hermetia illucens L.). Sci. Total Environ. 750: 141656.

Henry, M.; Gasco, L.; Piccolo, G.; Fountoulaki, E., (2015). Review on the use of insects in the diet of farmed fish: past and future. Animal Feed Sci. Technol., 203: 1-22 **(22 pages).**

Holmes, L.; VanLaerhoven, S.; Tomberlin, J., (2016). Lower temperature threshold of black soldier fly (Diptera: Stratiomyidae) development. J. Insects Food Feed., 2(4): 255-262 **(8 pages).**

Hopkins, I.; Newman, L.P.; Gill, H.; Danaher, J., (2021). The Influence of Food Waste Rearing Substrates on Black Soldier Fly Larvae Protein Composition: A Systematic Review. Insects. 12(7): 608.

Hu, Y.; Huang, Y.; Tang, T.; Zhong, L.; Chu, W.; Dai, Z.; Chen, K.; Hu, Y., (2020). Effect of partial black soldier fly (Hermetia illucens L.) larvae meal replacement of fish meal in practical diets on the growth, digestive enzyme and related gene expression for rice field eel (Monopterus albus). Aquacult. Reports. 17: 100345.

Kazemi-Bonchenari, M.; Alizadeh, A.; Javadi, L.; Zohrevand, M.; Odongo, N.E.; Salem, A.Z., (2017). Use of poultry pre-cooked slaughterhouse waste as ruminant feed to prevent environmental pollution. J. Clean. Product., 145: 151-156 **(6 pages).**

Koda, E.; Miszkowska, A.; Sieczka, A., (2017). Levels of organic pollution indicators in groundwater at the old landfill and waste management site. Appl. Sci., 7(6): 638.

Kowalska, D.; Strychalski, J.; Gugołek, A., (2021). The effect of silkworm pupae and mealworm larvae meals as dietary protein components on performance indicators in rabbits. Revista Mexicana de Ciencias Pecuarias, 12(1): 151-162 **(12 pages).**

Kuntadi, K.; Adalina, Y.; Maharani, K.E., (2018). Nutritional compositions of six edible insects in Java. Indonesian J. For. Res., 5(1): 57-68 **(12 pages).**

Lalander, C.; Diener, S.; Zurbrügg, C.; Vinnerås, B., (2019). Effects of feedstock on larval development and process efficiency in waste treatment with black soldier fly (Hermetia illucens). J. Clean. Product., 208: 211-219 **(9 pages).**

Liland, N.S.; Biancarosa, I.; Araujo, P.; Biemans, D.; Bruckner, C.G.; Waagbø, R.; Torstensen, B.E.; Lock, E.J., (2017). Modulation of nutrient composition of black soldier fly (Hermetia illucens) larvae by feeding seaweed-enriched media. PloS One. 12(8): e0183188.

Liu, Z.; Minor, M.; Morel, P.C.; Najar-Rodriguez, A.J., (2018). Bioconversion of three organic wastes by black soldier fly (Diptera: Stratiomyidae) larvae. Environ. Entomol., 47(6): 1609-1617 **(9 pages).**

Makkar, H.; Tran, G.; Heuzé, V.; Ankers, P., (2014). State of the art on use of insects as animal feed. Animal Feed Sci. Technol., 197: 1-33 **(33 pages).**

Meneguz, M.; Gasco, L.; Tomberlin, J.K., (2018). Impact of pH and feeding system on black soldier fly (Hermetia illucens, L; Diptera: Stratiomyidae) larval development. PloS One. 13(8): e0202591.

Mohan, K.; Rajan, D.K.; Muralisankar, T.; Ganesan, A.R.; Sathishkumar, P.; Revathi, N., (2022). Use of black soldier fly (Hermetia illucens L.) larvae meal in aquafeeds for a sustainable aquaculture industry: A review of past and future needs. Aquaculture. 738095.

Morais, A.T.S., (2020). Efeito de diferentes compostos no desenvolvimento larval da mosca soldado negra (Hermetia sp.) e eficiência no processo de decomposição desses resíduos.

Morales Quintana, J.F., (2021). Biotransformación de residuos orgánicos a partir del manejo ex situ de Hermetia illucens (L., 1758)(Diptera: Stratiomyidae) como una alternativa para la gestión sostenible de los desechos sólidos en el Distrito Metropolitano de Quito: UCE.

Nesic, K.; Zagon, J., (2019). Insects–a promising feed and food protein source. Sci. J. Meat Technol., 60(1): 56-67 **(12 pages).**

Nyakeri, E.; Ogola, H.; Ayieko, M.; Amimo, F., (2017). Valorisation of organic waste material: growth performance of wild black soldier fly larvae (Hermetia illucens) reared on different organic wastes. J. Insects Food Feed., 3(3): 193-202 **(10 pages).**

Oonincx, D.; Van Huis, A.; Van Loon, J., (2015). Nutrient utilisation by black soldier flies fed with chicken, pig, or cow manure. J. Insects Food Feed., 1(2): 131-139 **(9 pages).**

Purkayastha, D.; Sarkar, S., (2022). Black soldier fly larvae for treatment and segregation of commingled municipal solid waste at different environmental conditions. J. Environ. Manage., 302: 114060.

Reátegui, J.; Barriga, X.; Obando, A.; Moscoso, G.; Manrique, P.; Salazar, I., (2020). Harina de larva de Hermetia illucens (Diptera: Stratiomyidae) como ingrediente proteico de reemplazo parcial de harina de soja en la alimentación de Cavia porcellus (Cuy): efecto en el consumo, ganancia de peso y conversión alimenticia. Sci. Agropecuaria. 11(4): 513-519 **(7 pages).**

Renna, M.; Schiavone, A.; Gai, F.; Dabbou, S.; Lussiana, C.; Malfatto, V.; Prearo, M.; Capucchio, M.T.; Biasato, I.; Biasibetti, E., (2017). Evaluation of the suitability of a partially defatted black soldier fly (Hermetia illucens L.) larvae meal as ingredient for rainbow trout (Oncorhynchus mykiss Walbaum) diets. J. Animal Sci. Biotechnol., 8(1): 1-13 **(13 pages).**

Ruiz Sánchez, P., (2019). Impacto en la salud pública y el ambiente que producen las actividades de sacrificio de animales para consumo humano en el Camal Municipal de la ciudad de Moyobamba.

Salam, M.; Shahzadi, A.; Alam, F.; Nabi, G.; Dezhi, S.; Ullah, W.; Bilal, M., (2022). Effect of different environmental conditions on the growth and development of black soldier fly larvae and its utilization in solid waste management and pollution mitigation. Environ. Technol. Innovation. 102649.

Salas, G., Condorhuamán, C., (2008). Tratamiento de las aguas residuales de un centro de beneficio o matadero de ganado. Revista Peruana de Química e Ingeniería Química, 11(1): 29-35 **(7 pages).**

Salomone, R.; Saija, G.; Mondello, G.; Giannetto, A.; Fasulo, S.; Savastano, D., (2017). Environmental impact of food waste bioconversion by insects: application of life cycle assessment to process using Hermetia illucens. J. Clean. Product., 140: 890-905 **(16 pages).**

Siddiqui, S.A.; Ristow, B.; Rahayu, T.; Putra, N.S.; Yuwono, N.W.; Mategeko, B.; Nagdalian, A., (2022). Black soldier fly larvae (BSFL) and their affinity for organic waste processing. Waste Manage., 140: 1-13 **(13 pages).**

Singh, A.; Kumari, K., (2019). An inclusive approach for organic waste treatment and valorisation using Black Soldier Fly larvae: A review. J. Environ. Manage., 251: 109569.

Slorach, P.C.; Jeswani, H.K.; Cuéllar-Franca, R.; Azapagic, A., (2019). Environmental and economic implications of recovering resources from food waste in a circular economy. Sci. Total Environ., 693: 133516.

Sogari, G.; Amato, M.; Biasato, I.; Chiesa, S.; Gasco, L., (2019). The potential role of insects as feed: A multi-perspective review. Animals. 9(4): 119.

Tinder, A.C.; Puckett, R.T.; Turner, N.D.; Cammack, J.A.; Tomberlin, J.K., (2017). Bioconversion of sorghum and cowpea by black soldier fly (Hermetia illucens (L.)) larvae for alternative protein production. J. Insects Food Feed, 3(2): 121-130 **(10 pages).**

Tomberlin, J.K.; Sheppard, D.C., (2002). Factors influencing mating and oviposition of black soldier flies (Diptera: Stratiomyidae) in a colony. J. Entomol. Sci., 37(4): 345-352 **(8 pages).**

Villanueva-Gutiérrez, E.; Rodriguez-Armenta, C.; González-Félix, M.L.; Perez-Velazquez, M., (2022). Incorporating hydrolyzed soy protein or black soldier fly (Hermetia illucens) larvae meal into feeds for Totoaba macdonaldi. Aquaculture. 554: 738152.

Weththasinghe, P.; Hansen, J.; Nøkland, D.; Lagos, L.; Rawski, M.; Overland, M., (2021). Full-fat black soldier fly larvae (Hermetia illucens) meal and paste in extruded diets for Atlantic salmon (Salmo salar): Effect on physical pellet quality, nutrient digestibility, nutrient utilization and growth performances. Aquaculture. 530: 735785.

Xiao, X.; Mazza, L.; Yu, Y.; Cai, M.; Zheng, L.; Tomberlin, J.K.; Zhang, J., (2018). Efficient co-conversion process of chicken manure into protein feed and organic fertilizer by Hermetia illucens L.(Diptera: Stratiomyidae) larvae and functional bacteria. J. environ. Manage., 217: 668-676 **(9 pages).**

Zhou, F.; Tomberlin, J.K.; Zheng, L.; Yu, Z.; Zhang, J., (2013). Developmental and waste reduction plasticity of three black soldier fly strains (Diptera: Stratiomyidae) raised on different livestock manures. J. Medical Entomol., 50(6): 1224-1230 **(7 pages).**

Zielińska, E.; Baraniak, B.; Karaś, M.; Rybczyńska, K.; Jakubczyk, A. (2015). Selected species of edible insects as a source of nutrient composition. Food Res. Int., 77: 460-466 **(7 pages).**

AUTHOR (S) BIOSKETCHES

Luperdi, A.P., B.Sc., Research Assistant, Universidad Católica de Santa María, Postal address 04013, Perú.

- Email: *alexandra.luperdi@ucsm.edu.pe*
- ORCID: 0000-0001-5708-4979
- Web of Science ResearcherID: NA
- Scopus Author ID: NA
- Homepage: https://www.ucsm.edu.pe/

Flores, S.S., Ph.D. Candidate, Professor, Universidad Católica de Santa María, Postal address 04013, Perú.

- Email: *sfloresc@ucsm.edu.pe*
- ORCID: 0000-0003-1257-2711
- Web of Science ResearcherID: NA
- Scopus Author ID: NA
- Homepage: https://www.ucsm.edu.pe/

Barriga, X.J., M.Sc., Research Assistant, Universidad Católica de Santa María, Postal address 04013, Perú.
Email: *alexandra.luperdi@ucsm.edu.pe*

- ORCID: 0000-0001-5708-4979
- Web of Science ResearcherID: NA
- Scopus Author ID: NA
- Homepage: https://www.ucsm.edu.pe/

Rivera, V., B.Sc., Research Assistant, Universidad Católica de Santa María, Postal address 04013, Perú.

- Email: *valeria.riverav@ucsm.edu.pe*
- ORCID: 0000-0002-9223-1871
- Web of Science ResearcherID: NA
- Scopus Author ID: NA
- Homepage: https://www.ucsm.edu.pe/

Salazar, I., Ph.D., Professor, Universidad Católica de Santa María, Postal address 04013, Perú.

- Email: *isalazar@ucsm.edu.pe*
- ORCID: 0000-0001-7057-2897
- Web of Science ResearcherID: NA
- Scopus Author ID: NA
- Homepage: https://www.ucsm.edu.pe/

Manrique, P.L., M.Sc., Professor, Universidad Católica de Santa María, Postal address 04013, Perú,
Chief, Instituto de Investigación y Desarrollo para el Sur, Postal address 04018, Perú.

- Email: *plmanrique@ucsm.edu.pe*
- ORCID: 0000-0002-5889-2748
- Web of Science ResearcherID: NA
- Scopus Author ID: NA
- Homepage: https://www.ucsm.edu.pe/

Reategui, J.E., Ph.D., Professor, Universidad Católica de Santa María, Postal address 04013, Perú.

- Email: *jreategui@ucsm.edu.pe*
- ORCID: 0000-0001-6359-3999
- Web of Science ResearcherID: J-3173-2018
- Scopus Author ID: 57201032915
- Homepage: https://www.ucsm.edu.pe/

HOW TO CITE THIS ARTICLE

Luperdi, A.; Flores-Calla, S.S.; Barriga, X.; Rivera, V.; Salazar, I.; Manrique, P.; Reátegui, J., (2023). Bioprocessing of organic wastes from poultry and bovine slaughterhouses as food substrate for Hermetia illucens larval development. Global J. Environ. Sci Manage., 9(1): 31-42.

DOI: https://dx.doi.org/10.22034/gjesm.2023.01.03

url: https://www.gjesm.net/article_253253.html