Colegio de Postgraduados

Potential use of *Tenebrio molitor* L. to promote sustainable livestock farming

López-Vásquez, Isamar J.[1]; Martínez-Puc, Jesús F.[1]; Ramírez-Bautista, Marco A.[1]; López-Hernández, Mónica B.[1]; Candelaria-Martínez, Bernardino[1*]

[1] Tecnológico Nacional de México campus Instituto Tecnológico de Chiná. Calle 11 entre 22 y 28, Chiná, Campeche. C.P. 24520.
* Correspondence: bernardino.cm@china.tecnm.mx

ABSTRACT
Objective: to analyze the available information about the potential of *Tenebrio molitor* for feeding livestock species.
Design/Methodology/Approach: we searched for scientific information available in national and international databases with the search criteria "sustainable livestock", "climate change", "animal nutrition alternatives", "*Tenebrio molitor*", "nutritional properties of *Tenebrio molitor*", "*Tenebrio molitor* meal", "consumption of *Tenebrio molitor*", "weight gain of cattle fed with *Tenebrio molitor*", "weight gain of poultry fed with *Tenebrio molitor*" and "use of *Tenebrio molitor* in livestock" both in English and Spanish.
Results: *Tenebrio molitor* larvae meal has a high content of crude protein and essential amino acids, which makes it an ideal supplement for monogastric livestock species; especially, broiler chickens.
Limitations/Implications of the study: studies reported on monogastric livestock species in tropical conditions are scarce, unlike it occurs with similar studies in ruminants.
Findings/Conclusions: the species *Tenebrio molitor* presents an option for protein supplementation of livestock. It stimulates consumption and feed conversion in broiler chickens. It is advisable to promote research with this supplement in cattle and other ruminants.

Keywords: alternative livestock, edible insects, animal nutrition.

Citation: López-Vásquez, I. J., Martínez-Puc, J. F., Ramírez-Bautista, M. A., López-Hernández, M. B., & Candelaria-Martínez, B. (2025). Potential use of *Tenebrio molitor* L. to promote sustainable livestock farming. *Agro Productividad*. https://doi.org/10.32854/82fjbx62

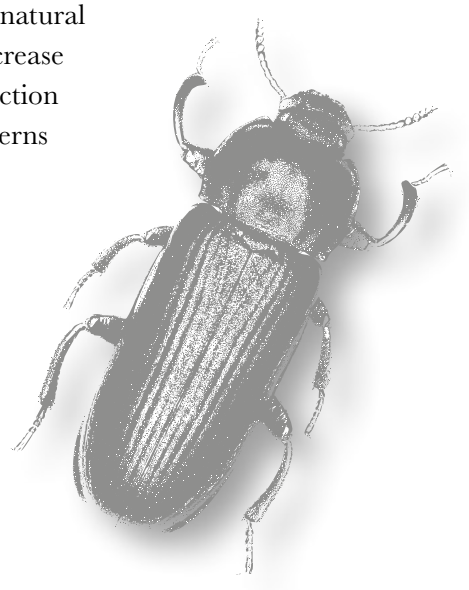
Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: November 15, 2024.
Accepted: April 18, 2025.
Published on-line: June XX, 2025.

Agro Productividad, 18(5). May. 2025. pp: 173-180.

INTRODUCTION

The accelerated population growth of recent decades (FAO, 2009), and the high demand for food inherent to this growth, have exceeded the capacity of soils to maintain constant productivity, which leads to environmental degradation and risks to the productive stability of agricultural systems (Cisneros, 2019). In addition, humanity is facing a scarcity of natural resources such as land, water, and energy, with an increase in greenhouse gases (GHG) emission due to production models that generate changes in climate and rainfall patterns (González, 2023). Livestock farming is responsible for the largest amount of protein consumed by the population and is vital for maintaining people's health. Faced with the aforementioned scenarios, the scientific and technical community is focused on the global search for alternative responses that allow increasing production levels without affecting natural resources.



It has been established that conventional livestock farming is the main source of GHG emissions in

agriculture land use. Oonincx *et al.* (2010) showed that *Tenebrio molitor* had a higher rate of organic feed utilization and lower CO_2, N_2O and NH_3 emissions than any conventional livestock species. Therefore it may constitute an important option for the production of protein for human consumption or livestock feed. The use of *T. molitor* beetle larvae is increasingly accepted in human food, which can become a sustainable option for obtaining food. In addition, organic waste is used to feed this insect (van Broekhoven *et al.*, 2015).

The objective of this documentary research was to compile, analyze and systematize the scientific and technical information available in the specialized literature on the properties and potential uses of the species *Tenebrio molitor* in livestock farming.

MATERIALS AND METHODS

The bibliographic review was implemented from January 2023 to February 2024, through the search for scientific publications in several certified databases on the web and electronic journals available on the internet such as CSIRO Publishing, Scielo, CONAHCYT Science journals, NCBI, Scientific Research, Dialnet, DIGITAL.CSIC, Redalyc, Plos/One, Science Direct, National Agricultural Library, Cambridge Core, Springer, and Elsevier.

The search included scientific articles, bibliographic reviews, and book chapters, which were made visible with the use of search terms and keywords such as "sustainable livestock farming", "climate change", "animal nutrition alternatives", "*Tenebrio molitor*", "nutritional properties of *Tenebrio molitor*", "*Tenebrio molitor* meal", "consumption of *Tenebrio molitor*", "weight gain of cattle fed with *Tenebrio molitor*", "weight gain of poultry fed with *Tenebrio molitor*" and "use of *Tenebrio molitor* in livestock farming", both in English and Spanish.

The search was done without restriction of publication date, but most of the material published in the last five years was chosen. Then, the study and synthesis of the bibliographic issues consulted was elaborated to identify the central theme of the document. In total, 145 documents that met the search criteria were located and reviewed, of which 35 were selected for greater affinity with the objective of this documentary research.

Main limitations of Nutrition in Livestock systems

Currently, breeds of livestock species with high genetic potential are used in livestock systems worldwide to obtain good quality products in a shorter period of time (Grossi *et al.*, 2009). However, for the productive parameters to be expressed, it is necessary to cover the nutrient requirements of livestock, mainly in terms of energy and protein. In this sense, it has been established that in the expression of productive value of a livestock species, approximately 30% corresponds to genetics, and 70% to the environment, where nutrition is a key factor (Pomar *et al.*, 2019).

In the case of ruminant farming, feeding is based on the use of improved native and introduced grasses. However, these resources present problems in the availability and quality of biomass, especially in the tropics. Agricultural drought limits plant growth due to water deficit. This situation generates a deficient production, especially when the deficiency is protein. Different alternatives are studied to access protein sources, including bone meal (Pomar *et al.*, 2019), fish meal, and blood meal (Vignesh and Srinivasan, 2012).

These supplements result in high costs and have long-term negative alterations in ruminant nutrition. Other options for providing protein to ruminants include the foliage of some trees and shrub species. However, the use of foliage is affected by the presence of secondary metabolites, in particular tannins that decrease voluntary consumption.

Use of Insect Meal for Animal Feed

Among the recent options to promote sustainable meat production, the use of insects as feed ingredient for some animal species is proposed (Cullere *et al.*, 2022). Specifically, insect meal as an alternative protein ingredient; which has opened a debate on the possibility of increasing the sustainability of production systems combined with an improvement in the quality of livestock products (Reis and Días, 2020); with the added environmental benefit that insects are grown on waste substrates and organic by-products (Veldkamp *et al.*, 2012). Insect farming is considered a low-cost production, requires small spaces, little infrastructure, and does not generate a carbon footprint, all of which are important characteristics in a sustainable alternative. Insects have a lower environmental impact compared to other protein sources such as egg protein, fishmeal or whey (Smetana *et al.*, 2019). In the poultry industry, insect meals are especially important for their high content of crude protein and ether extract, as well as an essential amino acid profile suitable for feed (Novodworski *et al.*, 2023). This meal has an amino acid profile and essential amino acid indices similar to those present in soybean meal, commonly used in this industry (Veldkamp *et al.*, 2012).

As an example, the inclusion of housefly meal (*Musca domestica*) in the diet of broilers as a substitute for plant-based protein sources provides an increase in the digestibility coefficient of dry matter, crude protein, crude fibre and ether extract (Khan *et al.*, 2018). Several trials have been implemented on the digestibility by different species of aquaculture fish and shellfish fed with diets based on insect meals such as *Tenebrio molitor* and *Hermetia illucens*; positive results have been obtained in that sector.

Among the most studied species for the industrial production of meals and pelleted feeds are silkworm (*Bombyx mori*) pupae and adults, housefly larvae (*Musca domestica*), Mealworm beetle larvae (*Tenebrio molitor*), Black soldier fly larvae (*Hermetia illucens*) and Californian red worm (*Eisenia fetida*). However, in some of these species the presence of chitin is found, that could cause a decrease in the digestibility of nutrients, which is a negative effect on animal yield (Gasco *et al.*, 2019). In livestock farming, the use of insect proteins gains significant attention in research, and currently also in practices (Poveda, 2021). An example is the substitution of fishmeal in the trout diet with meal from worms larvae (Thévenot *et al.*, 2018).

Biological characteristics of *Tenebrio molitor*

Tenebrio molitor is a beetle (Coleoptera) in the Tenebrionidae family. The larvae measure around 2.5 cm or a little more, while the adults can measure up to 2 cm long. They are considered as a pest, that can be found on stones, trunks, and in the production and storage of different grains. They also serve as decomposers because they feed on dead insects, feces, plants, seeds, and fallen leaves. Originally, *T. molitor* is an insect native to Europe, but today it is distributed throughout the world (Ramos-Elorduy, 2008).

The anatomy in adults consists of the head being of the tenebrionid type with prognathous mouthparts hidden dorsally by an enlarged epistoma. The metathorax is of the typical beetle type, but is partially declerotized, indicating the lack of flight (Doyen, 1966). This beetle has a holometabolous development, which means that it has four phases: egg, larva, pupa and imago. The eggs are white and less than 1.5 mm long, hatching between 8 and 10 weeks. The pupae measure from 1.5 mm to 1.8 mm and this phase lasts from 8 to 10 weeks where the insect remains immobile. The larva has a size of 1.6 mm to 3.5 cm, its life in this state is from 1 to 6 months; this time will depend on factors such as humidity, temperature and light exposure. Adults measure from 1.5 cm to 1.8 cm and have a lifespan from 8 to 62 days.

Nutritional characteristics of Tenebrio molitor

T. molitor larvae are used as a source of protein and fatty acids (Paul *et al.*, 2017). The production of *T. molitor* larvae requires little space, basic care management, and no special equipment is required. Larvae are used for the manufacture of meals and feed for livestock, because the adults of this species have a high concentration of chitin, while in the larvae the concentration of this structural carbohydrate is low (Novodworski *et al.*, 2023).

T. molitor flour contains approximately 54.19% crude protein on a dry basis, with a maximum of 63.67% and a minimum of 45.83%; while for the ether extract the average concentration is 27.97%, with a maximum of 34.20% and a minimum of 21.57% (Pietras *et al.*, 2021). The nutritional content of *T. molitor* larvae is 38% dry matter, of which approximately 20% corresponds to crude protein and 20% to fat. When they are processed into flour the content changes to 53% protein, 28% fat, 6% fiber and 5% moisture (Secci *et al.*, 2018).

Likewise, Dalle-Zotte *et al.* (2024) reported a high presence of essential and non-essential amino acids in *T. molitor* larvae. Among the essential amino acids, these composition and proportions include arginine (0.64), histidine (0.53), isoleucine (0.41), leucine (0.92), lysine (0.83), methionine (0.02), phenylalanine (0.45), threonine (0.50) and valine (0.61). Whereas, the non-essential amino acids proportions are alanine (1.06), aspartic acid (1.22), cysteine (0.06), glutamic acid (1.80), glycine (0.80), proline (1.05), serine (0.69), tryptophan (0.17) and tyrosine (0.78).

Environmental impact of using *Tenebrio molitor*

The water, energy, land, and food resource requirements for larvae production are significantly lower compared to traditional livestock faming; this includes the production of protein sources for animal feed (Gravel and Doyen, 2020). In addition, these insects are capable of consuming a wide variety of organic materials, such as complex polysaccharides, and transforming these substrates into biomass that can be used for the production of biofuels (Cemil, 2024). This not only reduces waste volumes, but also mitigates GHG emissions from the decomposition of organic waste.

Therefore, it contributes to the principles of a circular economy, since the waste of this insect becomes a valuable resource (Wang *et al.*, 2017). Its dung has properties that make it useful as an organic fertilizer, with a C:N ratio (13:8) and NPK contents (29%, 34%

and 22%) similar to those of poultry waste (Thévenot *et al.*, 2018). It should be noted that in addition to taking advantage of the excretes of these worms and their flour, the lipids they contain are also used. These insects produce an oil that can be used to generate feed, cosmetics or bioenergy, even competing directly with vegetable oils.

Effect of the use of Tenebrio molitor on the production parameters of livestock

Insects as a protein base promise potential increases in food security and environmental sustainability of food production. If the efficient use of land in their production is also considered (Alexander *et al.*, 2017), insect proteins are positioned as products that generate lower levels of environmental impact, due to a relatively lower carbon footprint (Sánchez-Muros *et al.*, 2014) compared to the carbon footprint generated by ruminant animals.

In the poultry industry, it has been proposed that low doses of insect meal can act as intestinal prebiotics; this becomes an alternative to traditional antibiotics (Colombino *et al.*, 2021). On the other hand, live larvae improve feeding stimulus; in quail, the average feed intake of live larvae of *T. molitor* was 4.84 g per day (Dalle-Zotte *et al.*, 2024). However, larvae were less digestible than the control diet, due to chitin that can act as an anti-nutritional factor and reduce the digestibility of the protein fraction (Kroeckel *et al.*, 2012). The effect will depend on the dose and the species of the poultry, as some species have enzymes that can hydrolyze glycoside bonds, allowing them to be digested.

The use of *T. molitor* meal has been tested on broilers of different breeds and in different presentations. In the implemented studies, the behavior has varied. This may be due to the genetics of the poultry and the particular conditions of the experiments. Some results are sumarized in Table1.

Table 1. Relevant aspects in the research of *Tenebrio molitor* as a supplement in livestock production and documentary sources.

Breed	Sex	Supplementation (%)	Findings	Source
Ross 308	Males	0, 2, 4 y 8	Differences in daily weight gain and feed conversion ratio from 0 to 21 days, with the highest levels of inclusion. No differences in the weight of carcass, organs, thighs or breasts.	Elahi *et al.* (2020)
Shaver Brown	Males	0, 29 y 65	No difference was observed in daily weight gain or carcass yield. Decreased feed conversion was observed.	Bovera *et al.* (2015)
Ross 308	Females	0, 0.2 y 0.3	Increase in daily weight gain and voluntary intake. There were no differences in total albumin in the blood or protein. Decrease in non-esterified fatty acids in the blood.	Hong *et al.* (2020)
Arbor Acres	Females and males	0, 2.5 y 5	Increase in daily weight gain at 0–10 days. There was no difference in voluntary intake, feed conversion, carcass yield, and organs proportion.	Sedgh-Gooya *et al.* (2021)
Hubbard	Females	0, 7 y 5	No difference was observed in weight gain, carcass yield, or intestinal morphology.	Biasato *et al.* (2016)
Ross 708	Males	0, 5, 10 y 15	Increase in crude protein content between 12 and 15 days. Increased voluntary intake and feed conversion. There was no difference in carcass yield.	Biasato *et al.* (2018)

CONCLUSIONS

The meal of *Tenebrio molitor* larvae is presented as a sustainable source of high-quality protein and fatty acids, which is important for the livestock industry. Due to a high content of essential amino acids, its use in monogastric livestock species, especially broilers, has been prioritized as the results are encouraging. Therefore, in scientific terms, we considered necessary to extend this research onto minor and major ruminant species. Also, in practical terms, it is advisable to promote commercial farms of yellow meal worm, *T. molitor*.

ACKNOWLEDGEMENTS

To Mexico's National Council of Humanities, Sciences and Technologies (CONAHCYT) for the postgraduate scholarship granted to Isamar J. López-Vásquez to implement this research.

REFERENCES

Alexander, P., Brown, C., Arneth, A., Dias, C., Finnigan, J., Moran, D. & Rounsevell, M.D.A. (2017). Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use? *Global Food Security*, 15:22-32. https://doi.org/10.1016/j.gfs.2017.04.001

Biasato, I., De Marco, M., Rotolo, L., Renna, M., Lussiana, C., Dabbou, S., Capucchio, M.T., Biasibetti, E., Costa, P., Gai, F., Pozzo, L., Dezzutto, D., Bergagna, S., Martínez, S., Tarantola, M., Gasco, L. & Schiavone, A. (2016). Effects of dietary *Tenebrio molitor* meal inclusion in free-range chickens. *Journal of Animal Physiology and Animal Nutrition, 100*(6):1104-1112. https://doi.org/10.1111/jpn.12487

Biasato, I., Gasco, L., de Marco, M., Renna, M., Rotolo, L., Dabbou, S., Capucchio, M.T., Biasibetti, E., Tarantola, M., Sterpone, L., Cavallarin, L., Gai, F., Pozzo, L., Bergagna, S., Dezzutto, D., Zoccarato, I. & Schiavone, A. (2018). Inclusión de larvas del gusano amarillo de la harina (*Tenebrio molitor*) en dietas para pollos de engorde machos: efectos sobre el crecimiento, la morfología intestinal y los hallazgos histológicos. *Poultry Science, 97*(2):540-548. https://doi.org/10.3382/ps/pex308

Bovera, F., Piccolo, G., Gasco, L., Marono, S., Loponte, R., Vassalotti, G., Mastellone, V., Lombardi, P., Attia, Y.A. & Nizza, A. (2015). Yellow mealworm larvae (*Tenebrio molitor* L.) as a possible alternative to soybean meal in broiler diets. *British Poultry Science, 56*(5):569-575. https://doi.org/10.1080/00071668.2015.1080815

Cemil, K. (2024). Biofuel production utilizing *Tenebrio molitor*: A sustainable approach for organic waste management. *International Journal of Thermofluids*, 22:100603. https://doi.org/10.1016/j.ijft.2024.100603

Cisneros, S.P. (2019). Sistemas silvopastoriles: estrategia pertinente para la ganadería bovina ante el cambio climático. *Revista Vinculando, 17*(1). https://vinculando.org/productores/sistemas-silvopastoriles-estrategia-pertinente-para-la-ganaderia-bovina-ante-el-cambio-climatico.html

Colombino, E., Biasato, I., Ferrocino, I., Bellezza Oddon, S., Caimi, C., Gariglio, M., Dabbou, S., Caramori, M., Battisti, E., Zanet, S., Ferroglio, E., Cocolin, L., Gasco, L., Schiavone, A. & Capucchio, M.T. (2021). Effect of insect live larvae as environmental enrichment on poultry gut health: gut mucin composition, microbiota and local immune response evaluation. *Animals, 11*(10):2819. https://doi.org/10.3390/ani11102819

Cullere, M., Singh, Y., Gerencsér, Z., Matics, Z., Cappellozza, S. & Zotte, A.D. (2022). Silkworm (*Bombyx mori* L.) oil in growing rabbit nutrition: effects on meat physicochemical traits, sensory profile and shelf-life. *Journal of Insects as Food and Feed, 8*(7):733-741. https://doi.org/10.3920/JIFF2021.0084

Dalle-Zotte, A., Singh, Y., Palumbo, B., Contiero, B. & Cullere, M. (2024). Larvas vivas del gusano amarillo de la harina (*Tenebrio molitor*): un enriquecimiento nutricional prometedor para las codornices ponedoras. *Poultry Science, 103*(7):103759. https://doi.org/10.1016/j.psj.2024.103759

Elahi, U., Wang, J., Ma, Y., Wu, S., Wu, J., Qi, G. & Zhang, H. (2020). Evaluation of Yellow Mealworm Meal as a Protein Feedstuff in the Diet of Broiler Chicks. *Animals, 10*(2):224. https://doi.org/10.3390/ani10020224

FAO (Organización de las Naciones Unidas para la Agricultura y la Alimentación). (2009). ¿Cómo alimentar al mundo 2050? Foro de Expertos de Alto Nivel. https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/Issues_papers_SP/La_agricultura_mundial.pdf

Gasco, L., Biasato, I., Dabbou, S., Schiavone, A. & Gai, F. (2019). Animals Fed Insect-Based Diets: State-of-the-Art on Digestibility, Performance and Product Quality. *Animals, 9*(4):170. https://doi.org/10.3390/ani9040170

González, S.C.A. (2023). Emergencia climática y alimentación. *Formación Médica Continuada en Atención Primaria, 30*(6):306-311. https://doi.org/10.1016/j.fmc.2023.02.006

Gravel, A. & Doyen, A. (2020). The use of edible insect proteins in food: Challenges and issues related to their functional properties. *Innovative Food Science & Emerging Technologies*, 59:102272. https://doi.org/10.1016/j.ifset.2019.102272

Grossi, D.A., Venturini, G.C., Paz, C.C.P., Bezerra, L.A.F., Lôbo, R.B., Oliveira, J.A. & Munari, D.P. (2009). Genetic associations between age at first calving and heifer body weight and scrotal circumference in Nelore cattle. *Journal of Animal Breeding and Genetics, 126*(5):387-393. https://doi.org/10.1111/j.1439-0388.2008.00791.x

Hong, J., Han, T. & Kim, Y.Y. (2020). Mealworm (*Tenebrio molitor* Larvae) as an alternative protein source for monogastric animal: a review. *Animals, 10*(11):2068. https://doi.org/10.3390/ani10112068

Khan, M., Chand, N., Khan, S., Khan, R.U. & Sultan, A. (2018). Utilizing the house fly (*Musca domestica*) larvae as an alternative to soybean meal in broiler ration during the starter phase. *Brazilian Journal of Poultry Science*, 20:09-14. https://doi.org/10.1590/1806-9061-2017-0529

Kroeckel, S., Harjes, A.G.E., Roth, I., Katz, H., Wuertz, S., Susenbeth, A. & Schulz, C. (2012). Cuando un rodaballo atrapa una mosca: Evaluación de una comida previa a la pupa de la mosca soldado negra (*Hermetia illucens*) como sustituto de la harina de pescado rendimiento del crecimiento y degradación de la quitina en rodaballo juvenil (*Psetta maxima*). *Aquaculture, 5*(364-365):345-352. https://doi.org/10.1016/j.aquaculture.2012.08.041

Novodworski, J., Castilha, L.D. & Silva, A.A. (2023). Insect meal in poultry feed: a potential protein source. *Acta Scientiarum. Animal Sciences*, 45 p. e60317. https://doi.org/10.4025/actascianimsci.v45i1.60317

Oonincx, G.A.B.D., van Itterbeeck, J., Heetkamp, J.W.M., van den Brand, H., Loon, J.A.J. & van Huis, A. (2010). An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PlosOne, 5*(12):1-7. https://doi.org/10.1371/journal.pone.0014445

Paul, A., Frederich, M., Megido, R.C., Alabi, T., Malik, P., Uyttenbroeck, R., Francis, F., Blecker, C., Haubruge, E., Lognay, G. & Danthine, S. (2017). Insect fatty acids: A comparison of lipids from three Orthopterans and *Tenebrio molitor* L. larvae. *Journal of Asia-Pacific Entomology, 20*(2):337-340. https://doi.org/10.1016/j.aspen.2017.02.001

Pietras, M., Orczewska-Dudek, S., Szczurek, W. & Pieszka, M. (2021). Effect of dietary lupine seeds (*Lupinus luteus* L.) and different insect larvae meals as protein sources in broiler chicken diet on growth performance, carcass, and meat quality. *Livestock Science*, 250:104537. https://doi.org/10.1016/j.livsci.2021.104537

Pomar, C., van Milgen, J. & Remus, A. (2019). 18: Precision livestock feeding, principle and practice. In: Poultry and pig nutrition. Wageningen Academic. pp. 397-418. https://doi.org/10.3920/978-90-8686-884-1_18

Poveda, J., 2021. Insect frass in the development of sustainable agriculture. A review. *Agronomy for Sustainable Development, 41*(1):5. https://doi.org/10.1007/s13593-020-00656-x

Ramos-Elorduy, J. (2008). Energy supplied by edible insects from Mexico and their nutritional and ecological importance. *Ecology of Food and Nutrition, 47*(3). https://www.tandfonline.com/doi/abs/10.1080/03670240701805074

Reis, T.L. & Dias, A.C.C. (2020). Farinha de insetos na alimentação de não ruminantes, uma alternativa alimentar. *Veterinária e Zootecnia*, 27:1-16. https://doi.org/10.35172/rvz.2020.v27.428

Sánchez-Muros, M.J., Barroso, F.G. & Manzano-Agugliaro, F. (2014). Insect meal as renewable source of food for animal feeding: a review. *Journal of Cleaner Production*, 65:16-27. https://doi.org/10.1016/j.jclepro.2013.11.068

Secci, G., Bovera, F., Nizza, S., Baronti, N., Gasco, L., Conte, G., Serra, A., Bonelli, A. & Parisi, G. (2018). Quality of eggs from Lohmann Brown Classic laying hens fed black soldier fly meal as substitute for soya bean. *Animal, 12*(10), pp.2191-2197. https://doi.org/10.1017/S1751731117003603

Sedgh-Gooya, S., Torki, M., Darbemamieh, M., Khamisabadi, H., Karimi Torshizi, M.A. & Abdolmohamadi, A. (2021). Yellow mealworm, *Tenebrio molitor* (Col: Tenebrionidae), larvae powder as dietary protein sources for broiler chickens: Effects on growth performance, carcass traits, selected intestinal microbiota and blood parameters. *Journal of Animal Physiology and Animal Nutrition, 105*(1):119-128. https://doi.org/10.1111/jpn.13434

Smetana, S., Schmitt, E. & Mathys, A. (2019). Sustainable use of *Hermetia illucens* insect biomass for feed and food: Attributional and consequential life cycle assessment. *Resources, Conservation and Recycling,* 144:285-296. https://doi.org/10.1016/j.resconrec.2019.01.042

Thévenot, A., Rivera, J.L., Wilfart, A., Maillard, F., Hassouna, M., Senga-Kiesse, T., Le Féon, S. & Aubin, J. (2018). Mealworm meal for animal feed: Environmental assessment and sensitivity analysis

to guide future prospects. *Journal of Cleaner Production*, 170:1260-1267. https://doi.org/10.1016/j.jclepro.2017.09.054

van Broekhoven, S., Oonincx, G.A.B.D., van Huis, A. & van Loon, J.A.J. (2015). Growth performance and feed conversion efficiency of three edible mealworm species (Coleoptera:Tenebrionidae) on diets composed of organic by-products. *Journal of Insect Physiology, 73*(February):1-10. https://doi.org/10.1016/j.jinsphys.2014.12.005

Veldkamp, T., Van Duinkerken, G., Van Huis, A., Lakemond, C.M.M., Ottevanger, E., Bosch, G., & Van Boekel, M.A.J.S. (2012). Insects as a sustainable feed ingredient in pig and poultry diets - a feasibility study. In: Wageningen UR Livestock Research. www.wur.nl/upload_mm/2/8/0/f26765b9-98b2-49a7-ae43-5251c5b694f6_234247%5B1%5D

Vignesh, R. & Srinivasan, M. (2012). Nutritional quality of processed head and bone flours of Tilapia (*Oreochromis mossambicus*, Peters 1852) from Parangipettai estuary, South East Coast of India. *Asian Pacific Journal of Tropical Biomedicine, 2*(1, Supplement):368-372. https://doi.org/10.1016/S2221-1691(12)60189-0

Wang, H., Rehman, K.u., Liu, X., Yang, Q., Zheng, L., Li, W., Cai, M., Li, Q., Zhang, J. & Yu, Z. (2017). Insect biorefinery: a green approach for conversion of crop residues into biodiesel and protein. *Biotechnology for Biofuels, 10*(1):304. https://doi.org/10.1186/s13068-017-0986-7