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Circular economy approach for mealworm industrial production for human consumption

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Abstract. United Nations has settled that in 2050 world population could reach 9.8 billion people so the food and protein requirements will increase, on the basis of this, the actual paper presents a proposal for a circular economy approach of the industrial production process of the edible insect *Tenebrio molitor* (*T. molitor*) as food. Edible insects are a great solution because of their source of protein, omegas and minerals they are considered as an alternative to ensure food security in a sustainable way. The process of breeding and harvesting *T. molitor* has been designed from the perspective of maximum use of all the resources involved, reducing waste production, minimizing greenhouse gas emissions and the use of all by-products derived from the process, with the aim to be used in agriculture, pharmacy, food and feed. Throughout the course of the *T. molitor*'s breeding needs to be supplied by organic food and a minimal use of water obtained by fruits and vegetables; all the waste generated by it: frass and exoskeletons (chitin), can be reuse with agricultural organic fertilizer purposes (flowering) and it is a great value supply in the food, pharmaceutical and cosmetic industries, that is why the importance of recovering of the larva's exoskeleton from the process. The processes of breeding and harvesting of the *T. molitor* from its beetle stage to the larval stage are described in the 'know how' to obtain an edible organic product as a powder or simply as a dehydrated product.

Keywords: mealworm's circular economy, *Tenebrio molitor* as micro-livestock, edible insects for food.

1. Introduction

Since the early years of the Industrial Revolution 1.0, the linear economy based on “produce, use and waste” has prevailed, causing a great ecological imbalance and resulting in today's climate change [1]. Nowadays, circular economy is a must for environmental sustainability due the pollution caused by the Industrial Revolution for the last 260 years. Therefore, circular economy poses “restoration” and “regeneration” [2]. Circular economy is defined as a restorative industrial system that replaces the



concept of “expiration” with “restoration”, because it tends towards renewable energy as well as the recovery and reuse of products and their components [3].

Entomophagy is the human's ancestral consumption of insects that persists until today [4], in more economically developed countries people ingest insects as an exotic culinary alternative, while in less developed regions these are consumed as a complement of protein necessary for their nutrition [5] as some rural communities in Mexico, where people eat insects because of their contribution of vitamins, the low economy of the country also plays an important factor. Table 1 shows the relationship between circular economy and entomophagy.

Table 1. Reasons why micro livestock farming is the solution to preserve the planet.

Circular economy key principles [6]	Entomophagy [7]
Lower inputs and natural resources.	Less water and greenhouse gases than conventional cattle.
Share energy and renewable and recyclable resources.	Insects feeds on human's food waste, compost and manure (only for feed) or even on vegetables, in this way they convert all waste into a biomass with high quality proteins
Emissions reduction.	The breeding of insects fits excellent because in this way farmers could recover nutrients from mealworm's waste and bring them back into the food chain, and do not leave any trace of pollution by the process.
Reduction of material resource losses, and waste.	They do not need great land spaces such as pasture land for livestock herds.
Maintain component's quality and the use of inexpensive materials.	Two strategies to promote circular economy by recycling organic food waste are proposed [8], one of them is the use of insects to consume organic waste and the final purpose of the insect production is targeted on feed.

Nevertheless, their customs and social habits [9] have an important role in insect consumption. Mexican people use wild harvested insects for most of their consumption [4], however, the natural availability of edible insects as a raw material to produce products for human consumption, is compromised because edible insects are available at a certain season, they cannot meet the demand of the food industry, becoming an expensive delicacy in some cases. In the specific case of the chapulín (*Sphenarium purpurascens* Charpentier (1845)), its price has raised from \$180 MXN per kilo to \$500 MXN per kilo (from 2014 to 2019), with the chichatanas (*Atta mexicana*) and chinicuiles (*Comadia redtenbacheri*), the most expensive insect per kilo in the Mexican market, up to \$2,000 MXN [10].

2. Background

Cockroaches farms consume garbage generated by some big cities of China, these cockroaches are used as livestock feed due to the source of protein. Pigs and other kinds of livestock eat them, likewise, in a more sophisticated process, cockroaches are used in the pharmaceutical and cosmetic industry [11].

Black soldier flies are used since the 20th century to reduce the amount of manure on chicken farms and actually are pretended to be used to process the municipal biowaste [12], and use them to feed fishes, chickens, etc. In Spain there is a company that promotes circular economy by artificially farming various kinds of insects, such as the black soldier fly [13], to generate biomass from the larval state of insects [12]. Its foundations are the following: 1) Sustainability, natural protein enriched animal feed; 2) Recycling, all organic waste and byproducts by converting them into full-organic fertilizers; 3) Organic product, from flour biomass, a flour with high protein value is produced.

Another advantage is that if larvae breeds in captivity, under pre-established conditions, convert organic matter into biomass of high nutritional value [12], such as proteins or calories up to 10 times more efficient than conventional cattle; in other words, conventional cattle consume 10 kg of grass to provide 1 kg of meat, while some insects, such as crickets, with 10 kg of organic matter, produce 9 kg of food [14]; that is, they considered insects the greatest organic matter converters.

3. *Tenebrio molitor*'s life cycle

According to the literature review [14-18], the life cycle of the following is shown graphically. (Fig. 1)

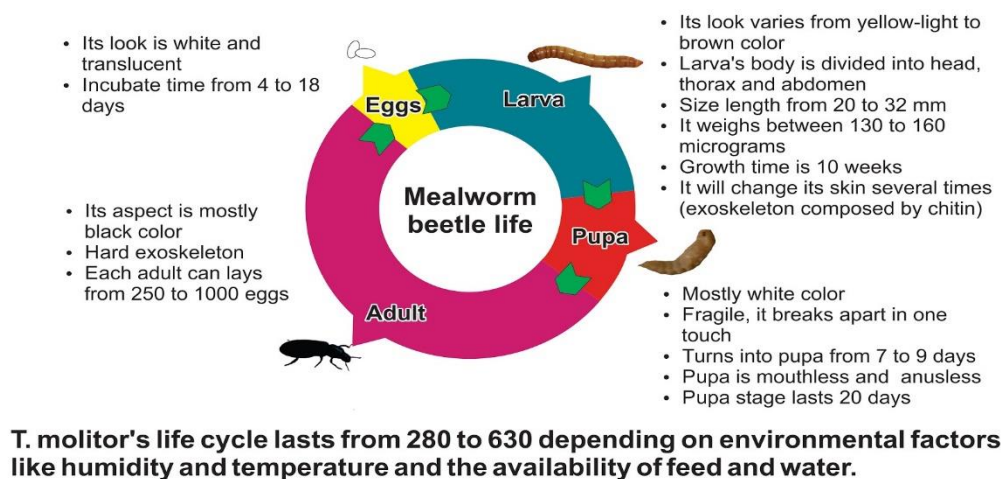


Fig 1. *Tenebrio molitor*'s life cycle.

4. Methodology

The proposal described below (Fig 2) is constructed from the existing literature on the breeding and harvesting of *T. molitor* [19-24]. The industrial harvesting process of *T. molitor* has a set of core operations: the basic operations related to insect growth and a complementary set is related to improve food safety and how the product is formulated: wettable powder or natural [24]. The process begins with the oviposition over the substratum, later it is sifted and all the eggs are laid over another substratum, thus the larvae could hatch to grow up fast and in better conditions. The larvae then start to grow over a cereal bed and fed with vegetables high in water content over the course of several weeks (Morelos, a province of Mexico, is a producer of jicama, tomatoes and other vegetables suitable for feeding larvae). As they grow and according to its size, they are separated into a different insect hutch. During all stages (except the egg stage), *T. molitor* transforms vegetal biomass into organic fertilizer enriched with chitin. It is important to consider that it could take up to two years to obtain the first batch of larvae production [25], according to Constantino L. M.

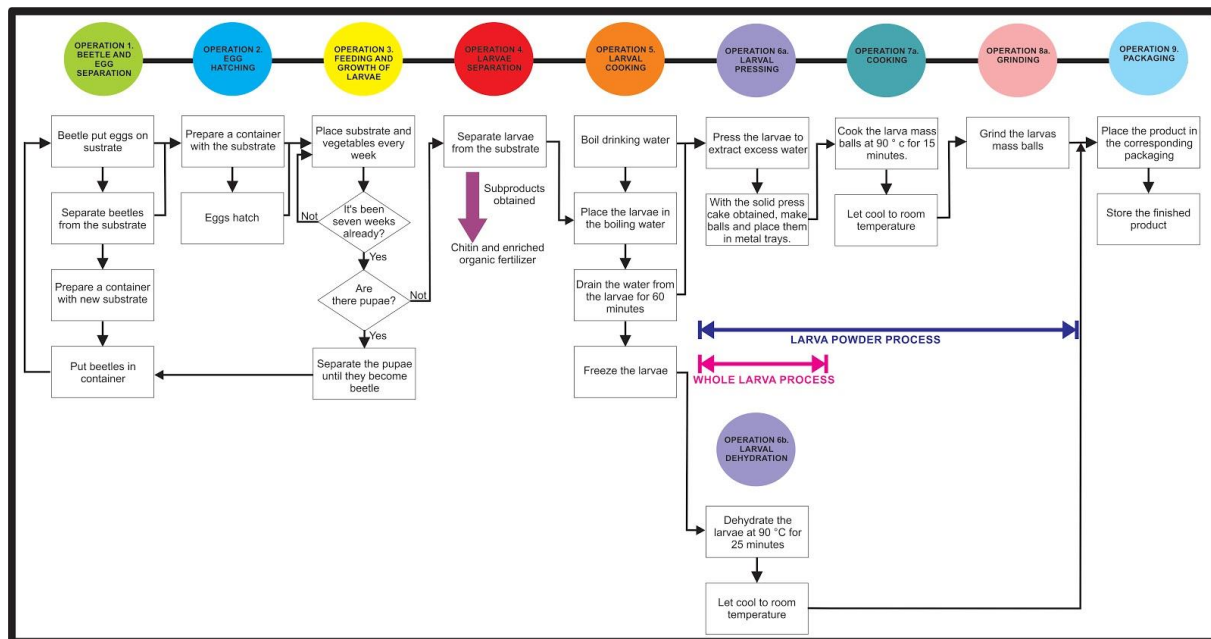


Fig 2. Proposed industrial process.

The following operations (see Fig. 2) are intended to make a final formulation for the sales according to the safety recommendations issued in NOM-251-SSA1-2009 [20]. Larvae are boiled in water at 100 °C for over 10 min and dried for at least 60 min at room temperature in order to expel the greatest amount of water. If the final product will be in the powder form, larvae will be squeezed, cooked and milled. Otherwise, if the product is natural dehydrated larvae, they are frozen a day before the boiling step for over 90 °C for 25 minutes, the next step is to let them chill at room temperature. Finally, they are packed up using an adequate envelope in compliance with the norm NOM-051-SCFI / SSA1-2010 [26], after that, packages will be refrigerated to preserve the food safety and wait for its sale to the customer.

5. Conclusions

In this paper, a proposal for the process of breeding and harvesting of *T. molitor* larva (mealworm) at the industrial production level has been presented. Additionally, a description of the production process of different presentations for sale, namely: whole larvae, larvae powder and larvae paste. All of the above, from a circular economy perspective through taking advantage of the waste in the form of feasible byproducts for commercialization in the agricultural, pharmaceutical and cosmetic sectors of the area. Strengthening the above, it is noted that the breeding and harvesting of insects, in this case *T. molitor*, does not require large amounts of water, since that is provided by the vegetables that feed them, which are typical of the region and without being of poor quality, those vegetables that don't meet the standards of size and cosmetic for sale to the public. In terms of space use, adequate infrastructure design enhances the vertical operation of the process. All the aforementioned actions are summarized in a concept known as mini-cattle, which prevents endangering species that live wildy.

The designed process of breeding and harvesting insects as a source of protein for human consumption, from a circular economy approach, is the main contribution of this article. Given the advances in the legislation of Novel Foods in the European Union, will trigger in the coming years the creation of companies and value chains to incorporate insect-based protein into a greater variety of products, which will invariably rescue the entomophage's ancestral culture of some towns and will create new customs, more friendly with the environment.

This paper describes the early development of a new production process in an agroindustrial complex at the Morelos state south rural region in Mexico, which includes the design of a building with automated temperature and humidity control systems, as well as machinery and / or equipment, applying the industry 4.0 concept, energy sustainability and circular economy principles, simultaneously generating new products with ingredients based on edible insects for the generation of new value-added chains.

References

- [1] Hidalgo M 2017 *Un nuevo impulso hacia la economía circular* Instituto Español de Estudios Estratégicos.
- [2] Espaliat M 2017 *Economía Circular y Sostenibilidad, nuevos enfoques para la creación de valor* Create Space.
- [3] McArthur E and McKinsey 2014 *Hacia una economía circular* Ellen McArthur Foundation.
- [4] Dossey A Morales-Ramos J & Rojas M 2016 *Insects as sustainable food ingredients: production, processing and food applications* Academic Press.
- [5] Lara P 2013 *Etnobiología de escamoles (Liometopum apiculatum) en el altiplano potosino* Repositorio Nacional Conacyt
- [6] Cerdá E and Khalilova A 2016 *Economía Circular* Econ Ind vol. 401, p. 11-20.
- [7] Afton H and Paul V 2013 The contribution of insects to food security, livelihoods and the environment *Food and Agriculture Organization of the United Nations* (Preprint I3264E/1/04.13)
- [8] Borrello M et al 2017 *Consumers' Perspective on Circular Economy Strategy for Reducing Food Waste Sustainability* vol. 9, no 1, p. 141.
- [9] Ramos-Elorduy, J., Pino, M., & José M. (2001) *Contenido de vitaminas de algunos insectos comestibles de México*. Revista de la Sociedad Química de México 45(2), 66-76.
- [10] Castillo M 2019 *Insectos al plato: Retos y posibilidades* El Universal.
- [11] Woo R and Seun T 2018 *Billions of cockroaches are being farmed in China to tackle food waste* World Economic Forum.
- [12] 2018 *Economía circular, proyecto de éxito: BioFlyTech* Eco-Circular.
- [13] Van H Van I Klunder H Mertens E Halloran A Muir G and Vantomme P 2013 *Edible insects: future prospects for food and feed security* (No. 171). Food and Agriculture Organization of the United Nations.
- [14] Soto H 2003 *Gusanos de la harina (Larvas Tenebrio Molitor)* El Canario Uruguayo Época II. No. 2. Uruguay. Págs. 39-40.
- [15] Sarmiento A 2018 *Establecimiento e implementación de un protocolo de cría de Gusano de harina Tenebrio Molitor (Coleoptera:Tenebrionidae), como apoyo al programa de conservación de la rana venenosa dorada Phyllobates terribilis (Anura:Dendrobatidae) en el Bioparque Wakatá, Parque Jaime Duque* Universidad Nacional Abierta y a Distancia "UNAD". Escuela de Ciencias Agrícolas, pecuarias y del medio ambiente ECAPMA. Zipaquirá Bogotá Colombia.
- [16] Moreno J 2018 *Gusano de la harina- Tenebrio Molitor-* Paradaís Sphynx: Animales e información sobre mascotas ISSN 2529-895X.
- [17] Díaz G 2014 *Uso de la larva de Tenebrio (Tenebrio Molitor) como aditivo proteico, en la alimentación de codornices (Coturnix coturnix japónica)* Universidad San Carlos de Guatemala, Facultad de Medicina y Zootecnia, Escuela de Zootecnia Guatemala.
- [18] Ramírez M et al 2010 *La quitina y sus derivados, biopolímeros con potencialidades de aplicación agrícola* Biotecnología aplicada vol. 27, no 4, p. 270-276.
- [19] 2018 *Informe del Comité Científico de la Agencia Española de Consumo, Seguridad Alimentaria y Nutrición (AECOSAN) en relación a los riesgos microbiológicos y alérgicos asociados al consumo de insectos* Revista del Comité Científico de la aecosan p. 11-40.

- [20] 2009 *Norma Oficial Mexicana NOM-251-SSA1-2009, Prácticas de higiene para el proceso de alimentos, bebidas o suplementos alimenticios* Secretaría de Salud del Gobierno Federal Mexicano
- [21] Gahukar R T 2016 *Edible insects farming: efficiency and impact on family livelihood, food security, and environment compared with livestock and crops* Insects as Sustainable Food Ingredients. Academic Press p. 85-111.
- [22] Finke M 2002 *Complete nutrient composition of commercially raised invertebrates used as food for insectivores* Zoo Biology: Published in affiliation with the American Zoo and Aquarium Association vol. 21, no 3, p. 269-285.
- [23] Durst P et al 2010 *Forest insects as food: humans bite back* RAP publication.
- [24] Vázquez R 2014 *Plan de negocio: creación de una empresa productora de harina de insectos para consumo animal* Tesis doctoral <http://hdl.handle.net/10251/38960>.
- [25] Constantino L M 2006 *Biocomercio sostenible de insectos: estado actual, perspectivas y dificultades del mercado en Colombia con especial referencia en Coleóptera y Lepidóptera*. En socolen. Memorias. XXXiii Congreso sociedad Colombiana de entomología–socolen. 2006. p. 26-28.
- [26] 2010 *Norma Oficial Mexicana NOM-051-SCFI/SSA1-2010, Especificaciones generales de etiquetado para alimentos y bebidas no alcohólicas preenvasados-Información comercial y sanitaria* Secretaría de la Contraloría General de Federación/Secretaría de Salud del Gobierno Federal Mexicano.