



Olfactory response and food preference of *Gromphadorhina portentosa* (Blattodea: blaberidae) to agro-industrial waste for biomass production

Resposta olfativa e preferência alimentar de *Gromphadorhina portentosa* (Blattodea: blaberidae) a resíduos agroindustriais para produção de biomassa

Respuesta olfativa y preferencia alimentaria de *Gromphadorhina portentosa* (Blattodea: blaberidae) a residuos agroindustriales para producción de biomasa

DOI: 10.55905/oelv22n11-136

Receipt of originals: 10/11/2024

Acceptance for publication: 11/01/2024

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ABSTRACT

The Madagascar cockroach (*Gromphadorhina portentosa*) is a species widely used in insect farming, including in animal and human diets. Because of these potential applications, we are looking for effective ways to breed them in captivity, through alternatives that reduce production costs. One solution to this problem would be to use agro-industrial waste to feed these insects. Therefore, this study aimed to evaluate the olfactory behavior of the Madagascar cockroach when exposed to different agro-industrial residues. The experiments were conducted at the Entomoculture Laboratory of the Federal Rural University of Pernambuco (UFRPE) using agro-industrial waste from sugarcane bagasse (*Saccharum spp.*), forage palm (*Opuntia ficus*), moringa (*Moringa oleifera* L.), and wheat bran (*Triticum vulgare*). The waste was distributed randomly in the evaluation arena. There were 20 repetitions of both sexes with an evaluation period of 20 min each. The bioassays were carried out in sequence: response time of the cockroaches, first olfactory choice, and food preference. Males and females had the highest average consumption in the 20-min evaluation period, and the first olfactory choice was for moringa; however, food preference was concentrated on wheat bran, where females had an average consumption of 1.3g of wheat bran and males 0.85g. Therefore, using wheat bran could make large-scale production of Madagascar cockroaches feasible and potentially make it possible to reuse and sustainably use this waste.

Keywords: Insect Farming, Diet, Cockroach, Mass Production.

RESUMO

A barata de Madagascar (*Gromphadorhina portentosa*) é uma espécie amplamente utilizada na criação de insetos, inclusive na dieta animal e humana. Devido a essas potenciais aplicações, buscamos formas eficazes de criá-las em cativeiro, por meio de

alternativas que reduzam os custos de produção. Uma solução para esse problema seria utilizar resíduos agroindustriais para alimentação desses insetos. Portanto, este estudo teve como objetivo avaliar o comportamento olfativo da barata de Madagascar quando exposta a diferentes resíduos agroindustriais. Os experimentos foram conduzidos no Laboratório de Entomocultura da Universidade Federal Rural de Pernambuco (UFRPE) utilizando resíduos agroindustriais de bagaço de cana-de-açúcar (*Saccharum spp.*), palma forrageira (*Opuntia ficus*), moringa (*Moringa oleifera L.*) e farelo de trigo (*Triticum vulgare*). Os resíduos foram distribuídos aleatoriamente na arena de avaliação. Foram 20 repetições de ambos os sexos com período de avaliação de 20 min cada. Os bioensaios foram realizados em sequência: tempo de resposta das baratas, primeira escolha olfativa e preferência alimentar. Machos e fêmeas tiveram o maior consumo médio no período de avaliação de 20 min, e a primeira escolha olfativa foi por moringa; no entanto, a preferência alimentar concentrou-se no farelo de trigo, onde as fêmeas tiveram um consumo médio de 1,3 g de farelo de trigo e os machos 0,85 g. Portanto, o uso do farelo de trigo pode tornar viável a produção em larga escala de baratas de Madagascar e potencialmente tornar possível a reutilização e o uso sustentável desses resíduos.

Palavras-chave: Criação de Insetos, Dieta, Barata, Produção em Massa.

RESUMEN

La cucaracha de Madagascar (*Gromphadorhina portentosa*) es una especie ampliamente utilizada en la cría de insectos, incluso en la dieta animal y humana. Debido a estas potenciales aplicaciones, estamos buscando formas efectivas de criarlas en cautiverio, a través de alternativas que reduzcan los costos de producción. Una solución a este problema sería utilizar residuos agroindustriales para alimentar a estos insectos. Por lo tanto, este estudio tuvo como objetivo evaluar el comportamiento olfativo de la cucaracha de Madagascar cuando se expone a diferentes residuos agroindustriales. Los experimentos se realizaron en el Laboratorio de Entomocultura de la Universidad Federal Rural de Pernambuco (UFRPE) utilizando residuos agroindustriales de bagazo de caña de azúcar (*Saccharum spp.*), palma forrajera (*Opuntia ficus*), moringa (*Moringa oleifera L.*) y salvado de trigo (*Triticum vulgare*). Los residuos se distribuyeron aleatoriamente en el área de evaluación. Hubo 20 repeticiones de ambos sexos con un período de evaluación de 20 min cada uno. Los bioensayos se realizaron en secuencia: tiempo de respuesta de las cucarachas, primera elección olfativa y preferencia alimentaria. Los machos y las hembras presentaron el mayor consumo promedio en el período de evaluación de 20 min, y la primera elección olfativa fue la moringa; sin embargo, la preferencia alimentaria se concentró en el salvado de trigo, donde las hembras tuvieron un consumo promedio de 1,3 g de salvado de trigo y los machos 0,85 g. Por lo tanto, el uso de salvado de trigo podría hacer viable la producción a gran escala de cucarachas de Madagascar y potencialmente hacer posible la reutilización y el uso sostenible de este residuo.

Palabras clave: Cría de Insectos, Dieta, Cucaracha, Producción en Masa.



1 INTRODUCTION

Insects are potential protein sources and can be used as an alternative to animal feed. They require little energy and water to produce, are rich in amino acids, lipids, vitamins, and minerals, and require few resources to multiply (Oonincx *et al.*, 2010; Yen, 2009). The Madagascar cockroach (*Gromphadorhina portentosa*), belonging to the order (Blattodea, blaberidae) is considered to be the largest species of cockroach in the world, reaching between 5 and 7.5 cm in length and weighing around 23 g. It has a life cycle of approximately 3.5 years. With a life cycle of approximately 3 years, they are in the egg, larva, pupa, and adult stages; they have nocturnal habits and a sex ratio of 1/1 (Chua J. *et al.*, 2017).

The Madagascar cockroach, which is based on dry matter, offers approximately 63% crude protein, 20% ether extract, and 2.5 g/Kg calcium in its composition, as well as having an amino acid profile suitable for broilers (Oonincx; Dierenfeld, 2012). In Africa, the consumption of insects is part of the population's eating habits, and insects are considered important sources of protein, as well as often being seen as delicacies (Van Huis *et al.*, 2013). By analyzing the nutritional composition of 236 edible insects based on dry matter, we found that insects have energy as well as protein in satisfactory quantities (average protein content of 40.60%) to complement their diets, as well as amino acids, mono- and polyunsaturated fats, micronutrients such as copper, iron, magnesium, zinc, and biotin, which are essential for human development (Rumpold; Schlüter, 2013). Nutritional values can vary within the same group of insects, depending on origin, life stage, and diet (Finke, 2014).

The inclusion of insects in animal diets has been studied to replace animal feed ingredients, especially protein, which is the most commercially valuable macronutrient (Khusro, 2012). Replacing traditional ingredients with alternative foods in animal production can bring greater sustainability and economic benefits to human food production. Researchers have sought to highlight the real benefits of using insects in different forms in animal diets to establish a standard of indication that adequately meets the needs of animals without harming their development (Ramos-Elorduy *et al.*, 2012).



The Brazilian agro-industry produces a lot of waste in its activities that has great potential for use, but this waste is often lost due to a lack of knowledge about its nutritional value and the correct way to use it. Using this waste helps to optimize production and reduce waste. They can also act as an enriching source of nutrients for various products, such as insect feed and food ingredients (Feng *et al.*, 2018).

Some studies have shown similar and even better poultry performance when traditional protein sources are replaced with insect meal (Féon *et al.*, 2019). The Madagascar cockroach is an important feed alternative with high biological value, similar to soybean meal for broilers. The crude protein present in this insect ranges from 43% to 55% (Hopley, 2006). The use of insect meal as a protein ingredient opens new perspectives on animal feed and sparks debates about sustainability and the quality of unconventional products. Among non-ruminant animals, the use of insect meal in poultry and fish production systems stands out, with the potential to cover other species. In general, it does not have a detrimental effect on the digestibility of nutrients in poultry, fish, rabbits, pigs, dogs, and cats, and can be replaced at various levels depending on the composition of the meal (Reis *et al.*, 2020).

The chemosensory system, which includes the antennae, bristles, tarsus, and mouth apparatus, is essential for receiving chemical signals and olfactory responses and cooperates with information from other sensory organs (Ricklefs, 2010; Wyatt, 2014; Leonhardt *et al.*, 2016). This is possible because of a set of structures, cells, and proteins in the nervous system that interpret various odors through olfactory or gustatory detection (Ziegler *et al.*, 2013).

This work seeks to present recent results on the olfactory behavior of the Madagascar cockroach; researching and using different agro-industrial residues that can be used as potential alternatives for feeding the cockroaches, reducing costs, and enabling biomass production for use in animal feed.

2 MATERIALS AND METHODS

2.1 BREEDING *G. portentosa*

The experiments were conducted in the Insect Farming Laboratory of the Zootechnics Department of the Federal Rural University of Pernambuco-UFRPE. Under controlled environmental conditions ($25\pm 2^{\circ}\text{C}$, 60 ± 10 , 12h). The cockroaches were kept in captivity inside plastic containers with a volume of 10 L, with a lid with an open hole, and covered with veil fabric to maintain the aeration of the breeding box. Each box had a variable number of individuals who were fed a diet consisting of wheat bran and offered water using hydrophobic absorbent cotton, as well as having a refuge using cardboard trays used to sell birds' eggs.

Four types of agro-industrial waste were evaluated: wheat bran (*Triticum vulgare*), moringa (*Oleifera L.*), forage palm (*Opuntia ficus*), and sugarcane bran (*Saccharum spp.*). They were offered in 50×25 cm Petri dishes containing 10g of each diet and distributed randomly in the container holding the cockroaches. A plastic container measuring 35 cm×10 cm was used as the evaluation arena, containing a sheet of A4 office paper inside. Circular marks were made at the locations where the diets were placed, just to mark the places where the diets were deposited.

2.2 RESPONSE TIME OF *G. PORTENTOSA*

Using cockroaches from the Entomoculture Laboratory - UFRPE, which were subjected to 72 hours of food shortage, 10 individuals of both sexes were evaluated at four different times: 5, 10, 15, and 20 min. With a food offer of 10g for each of the four diets studied, the initial and final consumption of each cockroach was recorded after the pre-defined evaluation time and the average consumption value was calculated.



2.3 FIRST CHOICE OF *G. PORTENTOSA*

Twenty replicates of both sexes were performed using cockroaches from the Entomoculture Laboratory - UFRPE, which had previously been subjected to a 72-hour scarcity period, using the evaluation time stipulated in the previous experiment. After being released into the center of the arena, the first choice of each cockroach was recorded, i.e., which of the four diets offered the cockroach went first when it was released into the evaluation arena. The Petri dishes containing the diets were arranged randomly in each repetition, and the A4 paper was changed in each repetition, thus preventing contamination by the footprints of the previous individual and avoiding the occurrence of behaviors influenced by external agents.

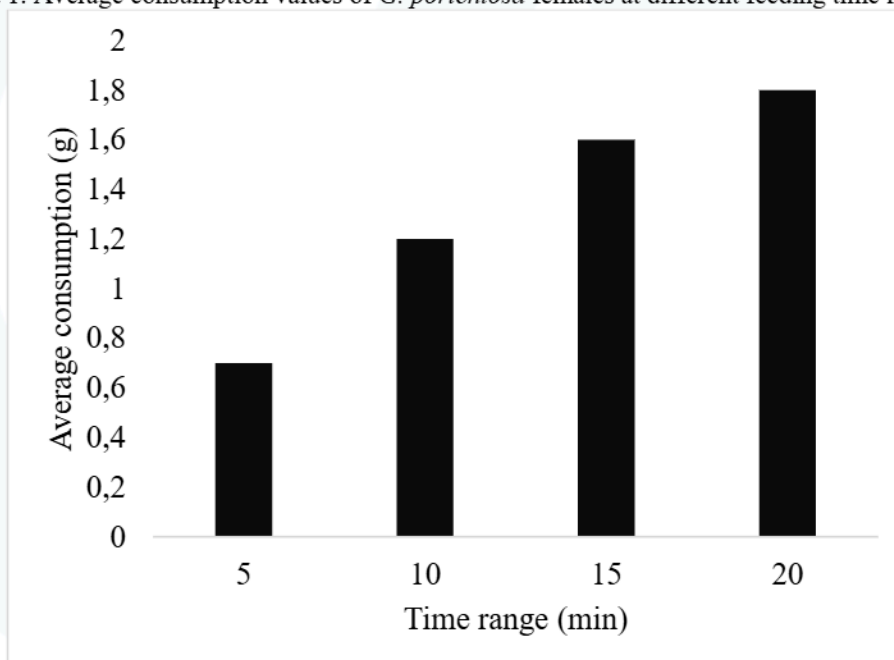
2.4 FOOD PREFERENCES OF *G. portentosa* FOR DIFFERENT AGRO-INDUSTRIAL RESIDUES

Using an arena with the same dimensions as the previous bioassay, the food preferences of the Madagascar cockroaches were assessed. The container had 4 Petri dishes distributed equidistantly, each containing 10g of an alternative diet and agro-industrial waste (moringa, wheat bran, sugar cane bran, and palm). Twenty adult cockroaches (previously subjected to 72 h of food shortage) of both sexes were evaluated for 20 minutes each. Each individual was released from the center of the arena and observed chronometrically. The initial weight of the diet was recorded on each plate (10g), and at the end of the evaluation time a new weighing was carried out on an analytical balance, making it possible to check the consumption of each diet offered to each cockroach evaluated; using the formula: initial weight - final weight; the result of this difference determined the consumption of each cockroach observed.

3 RESULTS AND DISCUSSIONS

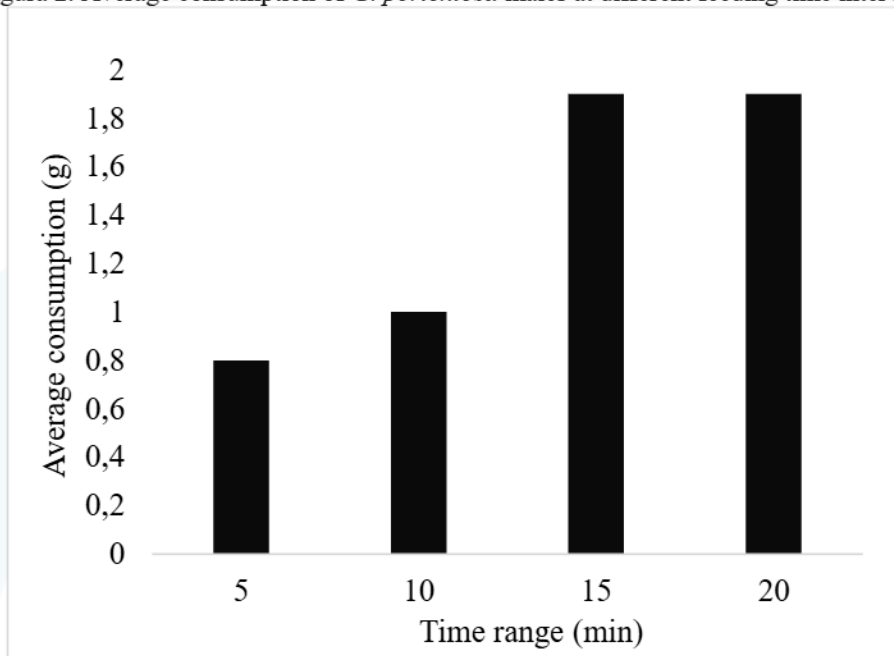
The bioassay for determining the average evaluation time of cockroaches obtained consumption values of: 0.7; 1.2; 1.6 and 1.8 for females at 5, 10, 15, and 20 minutes respectively (Figure 1). For males, the values were: 0.8; 1.0; 1.9 and 1.9 for the evaluation times (Figure 2). This shows that the 20-min evaluation time is the one with the best response for both sexes since it allowed for greater food consumption for both sexes of cockroaches, which is why it was used for the subsequent tests.

Figura 1. Average consumption values of *G. portentosa* females at different feeding time intervals.



Fonte: Autores, 2024.

Figura 2. Average consumption of *G. portentosa* males at different feeding time intervals.

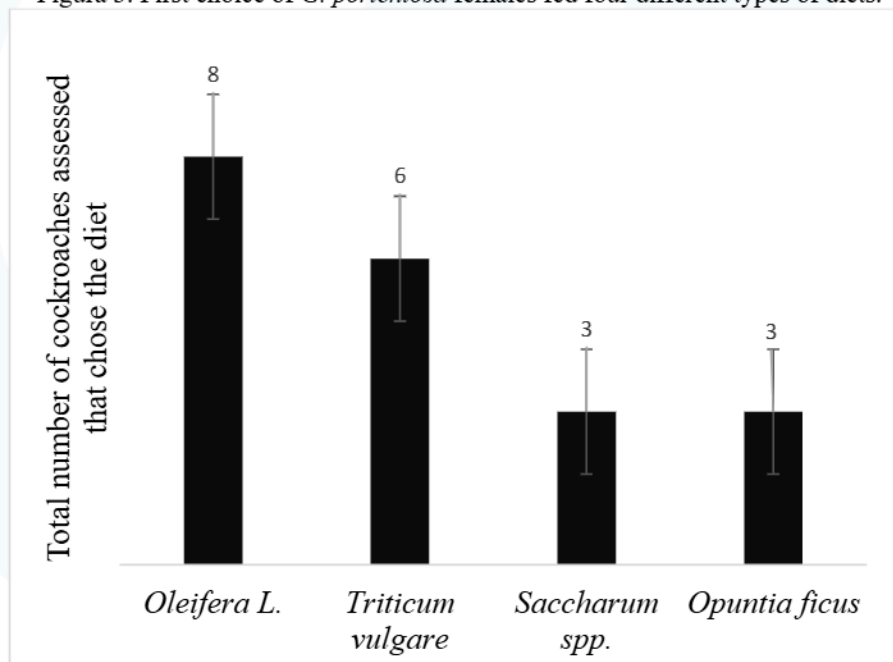


Fonte: Autores, 2024.

The first choice of Madagascar cockroaches (females and males) was the moringa diet. Of the 20 females evaluated, 8 chose moringa as their first choice, 6 wheat bran, 3 sugarcane bran, and 3 forage palm (Figure 3). Of the 20 males evaluated, moringa was their first choice: 9 of them, 6 had cane bran, 4 had fodder palm and 1 had wheat bran (Figure 4). These results show that moringa is an agro-industrial waste that attracts cockroaches, regardless of gender, probably because of its intense odor that is easily perceived by the insect's olfactory system (Bennett; Owens, 2011). Studies have shown the benefits of including moringa in the diet of insects used for entomoculture, such as the inclusion of moringa leaves in the diet of crickets (*Gryllus bimaculatus*) resulting in a higher growth rate and better feed conversion; showing that moringa provides essential amino acids for this growth (Lestari *et al.*, 2020); *Tenebrio molitor* (mealworm) larvae fed moringa can increase their body weight and survival rate, as well as improving their feed efficiency (Liland *et al.*, 2017); according to Kamarudin *et al.* (2021) *Helicoverpa armigera*, fed moringa increases its growth and improves digestibility and feed conversion in captivity.

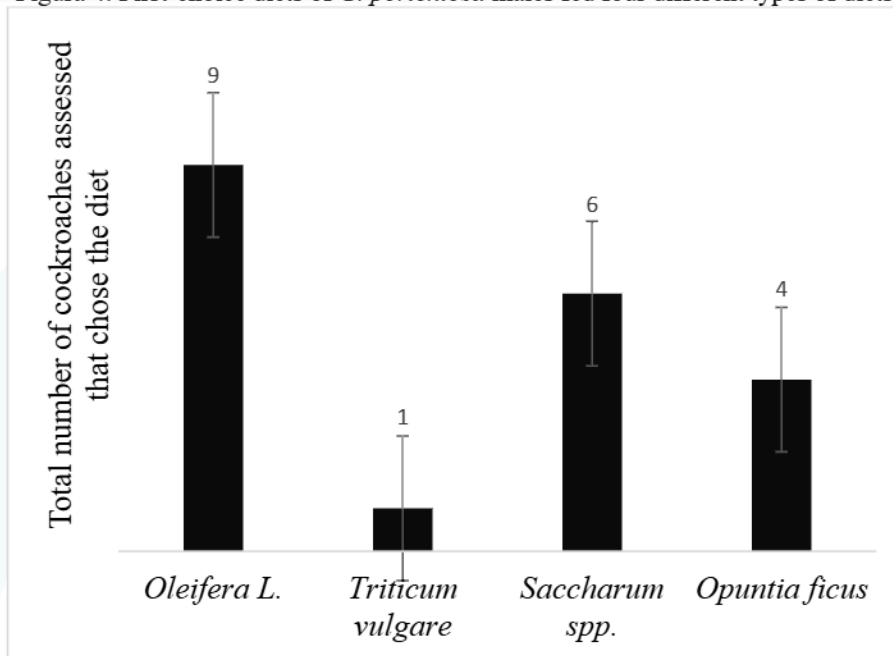
However, it was observed that the males evaluated in the experiment were more heterogeneously attracted to the other diets offered, in addition to moringa, which can be explained by their more mobile behavior; females have more sessile characteristics. This more mobile response by males has already been observed in other behavioral studies (Ritz; Schmitt, 2009; Gonzalez *et al.*, 2005; Sato *et al.*, 2008); this is generally due to factors such as mate searching and courtship behaviors. Males often exhibit greater activity and mobility to find females and compete with other males. In addition to having less reserve tissue than females, they suffer more from the period of food scarcity preceding the start of the tests.

Figura 3. First choice of *G. portentosa* females fed four different types of diets.



Fonte: Autores, 2024.

Figura 4. First-choice diets of *G. portentosa* males fed four different types of diets.

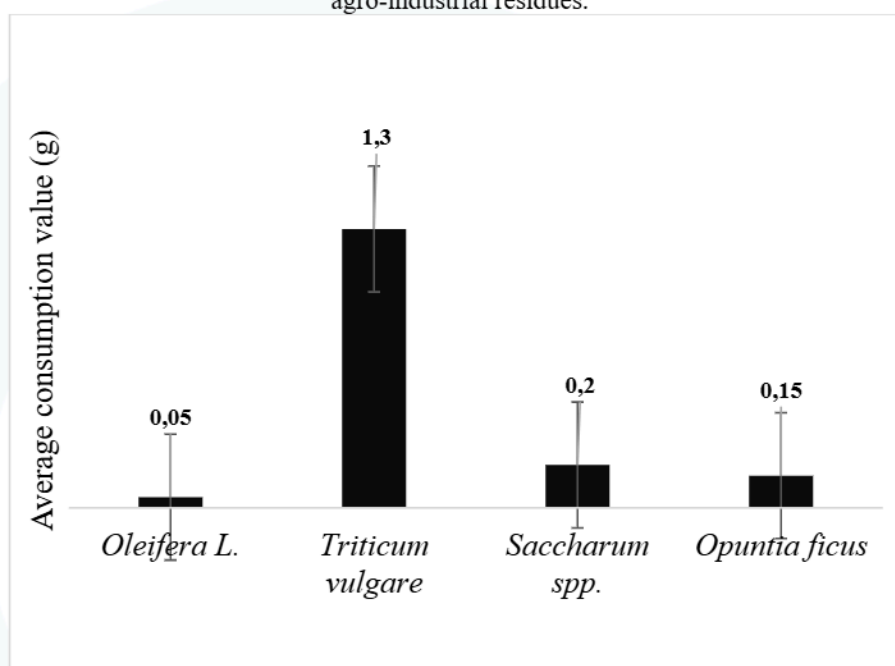


Fonte: Autores, 2024.

In the bioassay to assess the food preference of *G. portentosa*, both sexes preferred the wheat bran diet. The females consumed an average of 0.05g of moringa, 1.3g of wheat bran, 0.2g of sugarcane bran, and 0.15g of forage palm (Figure 5). The males had average consumption values of 0.6g moringa, 0.85g of wheat bran, 0g of sugarcane bran, and 0.15g of fodder palm (Figure 6); Tukey's test ($P < 0.05$) was carried out for both sexes. This reaffirms that moringa was preferred as the species' first olfactory choice (as shown in the first-choice bioassay), but that it was not the Madagascar cockroach's food preference. Wheat bran provides insoluble fiber, B vitamins, and minerals and has a high protein value, similar to moringa (Gallão *et al.*, 2006; Moyo *et al.*, 2011; Sogari, *et al.*, 2020; Bello *et al.*, 2022). In addition, wheat bran is often more accessible in most Brazilian regions, whereas moringa is difficult to obtain in large quantities. It was also observed that the consumption of palm and sugar cane bran was not significant, which may be explained by the lower protein content of these agro-industrial residues, which are not of much nutritional interest to insects compared with the carbohydrate and protein content of the most consumed diet (wheat bran). They were also not olfactorically attractive to the insects evaluated, showing low attractiveness and low palatability to

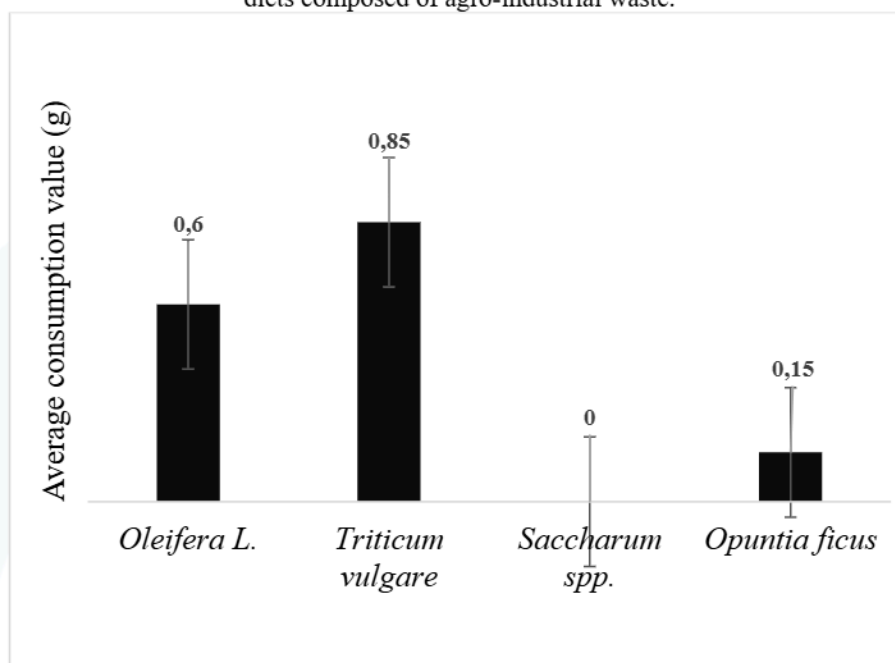
cockroaches. Similar responses were also obtained in other studies (Chakraborty; Bhadra, 2021; Wang; Zhang, 2022; Prakash; Prabhu, 2023).

Figura 5. Mean consumption values (g) of female Madagascar cockroaches (*G. portentosa*) fed different agro-industrial residues.



Fonte: Autores, 2024.

Figura 6. Mean consumption values (g) of male Madagascar cockroaches (*G. portentosa*) fed different diets composed of agro-industrial waste.



Fonte: Autores, 2024.

4 CONCLUSION

Moringa is the most attractive agro-industrial waste for the Madagascar cockroach, but it is not the most palatable for the species to consume in captivity. On the other hand, wheat bran is a cheap, nutritious agro-industrial waste that is preferred by the cockroaches evaluated, which could make large-scale production of Madagascar cockroaches viable and potentially profitable. This could expand the use of this species as an economic activity and enable the sustainable use of agro-industrial waste.

ACKNOWLEDGEMENTS

The Federal Rural University of Pernambuco (UFRPE) for supporting the development of this research on its premises. We thank the anonymous reviewers for their contributions to improving this manuscript.

REFERENCES

BENNETT, G. W., & OWENS, J. M. Advances in urban pest management. New York, Van Nostrand Reinhold Co, 399p.1986.

BUKKENS, S. G. F. Insects in the human diet: Nutritional aspects. In M. G. Paoletti (Ed.). Ecological implications of mini livestock, role of rodents, frogs, snails, and Insects for sustainable development. New Hampshire: Science Publishers, p. 545-577, 2005.

CHAKRABORTY, R., & BHADRA, S. Nutritional evaluation of alternative feed ingredients for the production of edible insects. *Insects*, 12(3), 210. 2021.

CHUA, J.; FISHER, N. A.; FALCINELLI, S. D.; DESHAZER, D.; FRIEDLANDER, A. M. The Madagascar Hissing Cockroach as an Alternative Non-mammalian Animal Model to Investigate Virulence, Pathogenesis, and Drug Efficacy. *Journal of Visualized Experiments*, n. 129, 2017.

FÉON, S. L.; THÉVENOT, A.; MAILLARD, F.; MACOMBE, C.; FORTEAU, L.; AUBIN, J. Life Cycle Assessment of fish fed with insect meal: Case study of mealworm inclusion in trout feed, in France. *Aquaculture*, v. 500, p. 82-91, 2019.

FINKE, M. D. Insects as food for insectivores. In J. Morales Ramos, G. Rojas, & D. I. Shapiro-Ilan (Eds.). *Mass production of beneficial organisms: Invertebrates and entomopathogens*, p. 583-616, 2014. New York: Elsevier.

GONZALEZ, R. et al. Behavioral ecology of cockroaches: a comparison of male and female movement patterns. *Entomological Society of America*. 2005.

KAMARUDIN, M.S. et al. Effects of Moringa Leaf Powder on the Growth Performance and Nutritional Value of *Helicoverpa armigera*. *Pest Management Science*, 77(6): 2603-2610. 2021. DOI: 10.1002/ps.6057.

KATIA, K., BORSRA, K., M. Z. S., GANESAN, D., KUPPUSAMY, G., HERRIMAN, M. & ALI, S. A. 2017. Efficacy of insect larval meal to replace fish meal in juvenile barramundi, *Lates calcarifer* reared in freshwater. *International Aquatic Research* 9:303-312.

KHUSRO, M., ANDREW, N. R. & NICOLAS, A. Insects as poultry feed: a scoping study for poultry production systems in Australia. *World's Poultry Science Journal*, 68:435-446. 2012.

LEONHARDT, SARA DIANA et al. Ecology and evolution of communication in social insects. *Cell*, [s.l.], v. 164, n. 6, p.1277-1287, mar. 2016.

LESTARI, R. et al. The Effect of Moringa (*Moringa oleifera*) Leaf Meal Supplementation on Growth Performance and Nutrient Utilization of Cricket (*Gryllus bimaculatus*). *Journal of Insect Science*, 20(1): 7-14. 2020. DOI: 10.1093/jisesa/ieaa026.

LILAND, K.H. et al. Nutritional Value of Moringa Leaf Powder as Feed Ingredient for Mealworms (*Tenebrio molitor*). *Journal of Insects as Food and Feed*, 3(4): 237-246. 2017. DOI: 10.3920/JIFF2016.0057.

NOWAK, V. et al. Review of food composition data for edible insects. *Food Chemistry*, v. 193, p. 39-46, 2016.

OONINCX, D. G. et al. Na exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *Plos One*, v. 5, n. 12, p. 1-7, 2010.

OONINCX, D. & DIERENFELD, E. An investigation into the chemical composition of alternative invertebrate prey. 2012.

PRAKASH, P., & PRABHU, P. Assessing the use of various feed ingredients for the growth of cockroaches in a sustainable way. *Journal of Insects as Food and Feed*, 9(4), 679-687. 2023.

RAMOS-ELORDUY, J., GONZÁLEZ, E. A., HERNÁNDEZ, A. R., & PINO, J. M. Use of *Tenebrio molitor* (Coleoptera: Tenebrionidae) to recycle organic wastes and as feed for broiler chickens. *Journal of Economic Entomology* 95 (1): 214-220. 2002.

RICKLEFS, ROBERT E. A. *Economics of Nature*. 6. ed. Editora Guanabara Koogan. 2010.

RITZ, M. S., & SCHMITT, T. The role of pheromones in the mating behavior of cockroaches. *Journal of Insect Behavior*, 22(2), 115-127. 2009.

RUMPOLD, B A.; SCHLÜTER, O. K. Nutritional composition and safety aspects of edible insects. *Molecular Nutrition & Food Research*, v. 57, n. 5, p. 802-823, 2013.

SATO, M., et al. Sexual dimorphism in locomotor activity of the German cockroach, *Blattella germanica*. *Physiological Entomology*, 33(1), 20-25. 2008.

VAN HUIS, A. et al. *Edible insects: Future perspectives for food and food security*. Food and Agriculture Organization of the United Nations Rome. 2013.

VARGAS-ABÚNDEZ, A. J., RANDAZZO, B., FODDAIA, M., SANCHINIA, L., TRUZZIA, C., GIORGINI, E., GASCOB, L., AND OLIVOTTO, L. Insect meal based



diets for clownfish: Biometric, histological; spectroscopic, biochemical and molecular implications. *Aquaculture* 498: 1-11. 2019.

WANG, C., & ZHANG, Y. Effects of dietary fiber on growth performance and gut microbiota in cockroaches. *Insects*, 13(2), 123. 2022.

WYATT, T. D. *Pheromones and Animal Behavior: Chemical Signals and Signatures*. Cambridge: Cambridge University Press. 406 p. 2014.

ZIEGLER, A. B.; BERTHELOT-GROSJEAN, M. & GROSJEAN, Y. The smell of love in *Drosophila*. *Frontiers in Physiology*, [s.l.], v. 4, p.1-5. 2013.