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Research Article

Housefly as a bioconvertor: The effects of different wastes on *Musca domestica* (Dip: Muscidae) development, weight gain and adult longevity

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Abstract. Alongside traditional waste management strategies, recent studies have highlighted the potential role of insects in the biodegradation and recycling of organic wastes. One of the most widely recognized candidate species for waste recycling is the housefly, *Musca domestica* Linnaeus, 1758 (Dip: Muscidae). Due to its high nutritional value, housefly larvae can also be used in poultry and fish feeding as an edible insect. The current study aimed to find the optimal substrate for rearing and compare the effects of five types of waste substrates on developmental time, as well as the weight of larvae and pupae, the sex ratio and adult longevity of housefly under controlled laboratory conditions (25 ± 2°C, 50 ± 10% R.H., and 12:12 L:D photoperiod). The wastes used included brewery waste, slaughterhouse waste, bean canning factory waste, kitchen waste, and wheat bran as a control. The results demonstrated a significant difference in larval duration, larval and pupal weight and adult longevity. Significant differences were found in larval duration, larval and pupal weights, and adult lifespan, whereas pupal period and sex ratio were not significantly affected. The shortest development time and highest biomass were observed in the canned bean waste treatment. Adults reared on canned bean and kitchen waste exhibited the longest lifespans, while the shortest was on slaughterhouse waste. Given the absence of significant differences in all parameters between the control (wheat bran) and brewery waste, it can be concluded that, instead of wheat bran, which is often expensive, brewery waste could be used cost-effectively.

Keywords: edible insects, housefly, developmental time, bioconversion, waste management

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Introduction

In recent years, the world population has been increasing, and it is expected to reach almost 10 billion by 2050 (Abd El-Hack *et al.*, 2020; Hong *et al.*, 2020). To fulfil the food demand of such a large population will require nearly doubling current production, yet the expansion of agricultural land is limited. Water shortage and climate change further intensify this challenge, pushing researchers to explore alternative and sustainable food sources (van Huis, 2013). Another direct consequence of rapid population growth is the sharp rise in waste production. Currently, global households produce about 2.01 billion tons of solid waste annually, and it is estimated that this could reach 3.40 billion tons by 2050 (Kaza *et al.*, 2018). Such waste can pollute soil and water, produce greenhouse gases, and spread harmful substances (Leyo *et al.*, 2021). For these reasons, waste management has become a key priority in sustainable development (Tian *et al.*, 2012). Several insect taxa have been investigated for their bioconversion potential due to their efficiency, adaptability, and ecological benefits. Examples include crickets (*Acheta domesticus* Orth.: Gryllidae) (Tang *et al.*, 2019), mealworms (*Tenebrio molitor* Linnaeus, 1758(Col.: Tenebrionidae)) (Muñoz-Seijas *et al.*, 2024), superworms (*Zophobas morio* (Fabricius, 1775) (Col.: Tenebrionidae)) (Nascimento *et al.*, 2022), black soldier flies (*Hermetia illucens* (Linnaeus, 1758) (Dip.:

Stratiomyidae)) (Smetana *et al.*, 2019), flesh flies (*Sarcophaga dux* (Thomson, 1869)(Dip.: Sarcophagidae)) (Siddiqui *et al.*, 2024), houseflies (*Musca domestica* Linnaeus, 1758 (Dip.: Muscidae)) (Yang, 2014), and blowflies (*Lucilia sericata* (Meigen, 1826) (Dip.: Calliphoridae)) (Moore *et al.*, 2024). Among these, the common housefly stands out as one of the most practical and frequently used species in waste recycling.

The housefly, *M. domestica*, is cosmopolitan and well adapted to a variety of climatic zones. Its larvae can be reared inexpensively on many waste-derived substrates and have advantages such as a short life cycle, rapid development, self-cleansing behavior before pupation, and natural migration from the rearing medium at the prepupal stage making it an attractive species for large-scale production (Hall *et al.*, 2018). Nutritionally, the larvae are rich in protein, essential fatty acids (including omega-3), and minerals such as calcium and phosphorus, making them suitable for inclusion in livestock and aquaculture feed (Hussein *et al.*, 2017). In many cases, their nutritional value is comparable to conventional protein sources such as fish meal, bran, or blood meal. However, the nutrient profile can vary depending on factors such as diet composition, larval age, and post-harvest processing (Shah *et al.*, 2022). Understanding the influence of diet on the biological traits of *M. domestica*—including growth rate, weight, and adult longevity—is essential for optimizing mass-rearing systems (Cammack & Tomberlin, 2017). Adult lifespan, in particular, is an informative measure of overall physiological fitness. As noted by Pastor *et al.* (2015), larger pupae often yield adults with greater reproductive potential, suggesting that nutritional advantages gained in the larval stage may carry over into adulthood.

In this study, the growth of *M. domestica* was tested on five different waste materials; i.e. brewery waste, slaughterhouse waste, canned bean waste, kitchen waste, and wheat bran (control). The goal was to find affordable and effective diets that reduce production costs while supporting sustainable waste recycling. While previous research has mostly examined conventional organic substrates such as manure, wheat bran, or food scraps, this work focuses on underused industrial by-products—particularly canned bean and brewery waste. Comparing these with a standard control diet provides new insights into their biological performance and commercial potential. This approach not only contributes to the sustainable valorization of food industry waste but also offers practical alternatives for reducing the cost of insect mass rearing.

Materials and methods

This research was carried out between October 2023 to June 2024 at the Faculty of Agriculture, Bu-Ali Sina University, Hamedan, Iran.

Colony culture and egg collection

The initial housefly (*M. domestica*) colony was established using pupae obtained from the Abbas Abad Poultry Research Facility, Bu-Ali Sina University. Pupae were transferred to the laboratory and placed in well-ventilated wooden cages (30 × 30 cm) until adult emergence. Each cage contained approximately 500 adults. They were fed with a 1:1 mixture of powdered milk and sugar placed in shallow plastic dishes (11 × 6 cm) for easy access. Cotton pads soaked in fresh water provided moisture and were replaced daily. All cages were maintained at 25 ± 2 °C, 50–60% relative humidity, and a 12:12 h light: dark photoperiod. The colony was maintained for at least seven generations prior to the experiments started. Four days after adult emergence, oviposition media were introduced into the cages. These consisted of plastic containers (9 × 12 cm) filled with a mixture of wheat bran, fish meal, yeast, powdered milk, and water (5:2:1:1:10 w/w). Females were allowed to oviposit for eight hours (10:00 AM–18:00 PM), based on preliminary trials to maximize egg yield

Experiments

Five types of organic waste substrates were tested in the experiment: Brewery waste: Obtained from Behnoush Iran Company (Tehran Province), consisting mainly of spent grain from non-alcoholic malt beverage production (no brewer's yeast). Composition included 20–25% crude protein, 5–10% fat, 15–25% crude fiber, and 75–80% moisture. Kitchen waste collected from the Bu-Ali Sina University restaurant, containing ~40% protein-rich components (mainly cooked chicken or meat), 40% carbohydrates (as rice or bread), and 20% vegetables. The mixture was rinsed to reduce salinity, then ground and mixed with water to a paste-like texture, and stored at 4 °C. Canned bean waste collected from Sahar Food Industries Co. (Hamedan), consisting of cooked bean residues mixed with tomato-based sauce. Estimated composition were 6–8% protein (fresh weight; 20–22% dry matter), 4–6% fat, 15–20% fiber, and 25–30% carbohydrates. Slaughterhouse waste prepared from the Central Industrial Slaughterhouse (Hamedan Province), containing offal, fat trimmings, blood, and connective tissues. Estimated composition were 45–55% protein, 25–35% fat, 5–10% ash, and negligible carbohydrates. Wheat bran were used as control and commercial dry bran mixed with water to a paste-like texture. To ensure uniformity, all substrates were homogenized and adjusted with water to achieve similar moisture levels and textures. Potassium sorbate (1 gr per 100 gr substrate, w/w) was added to prevent fungal or microbial spoilage.

For each treatment, 60 housefly eggs were placed individually in ventilated plastic containers (4 × 5 × 6 cm) with 5 g of substrate. Larval survival was monitored daily. Before pupation, last instar larval weight was measured using an electronic precision scale (BEL Engineering Co., M-MW Series, Italy). Pupal weight was also recorded. Upon adult emergence, flies were kept in separate containers and monitored daily until death to record their lifespan. Moreover, to assess sex ratio, 40 pupae per treatment were randomly selected from each treatment group and placed in cylindrical plastic cups (7 × 5 cm). After emergence, adult sex was determined based on abdominal markings and the interocular distance (Cammack & Tomberlin, 2017).

Statistical analysis

normality of residual effect distribution for all measured parameters (larval period, pupal period, larval weight, pupal weight, and adult longevity) was tested using the Kolmogorov–Smirnov test. When the data met the assumptions of normality and homogeneity of variances (verified by Levene's test), one-way ANOVA was conducted, followed by Tukey's HSD post hoc test for pairwise comparisons. This approach was used for larval weight, pupal weight, and adult longevity. Variables not meeting normality assumptions (larval and pupal development times), the Kruskal–Wallis non-parametric test was applied, with adjusted significance levels for pairwise comparisons. Analyses were performed using SAS software (SAS Institute Inc., 2013).

Results

The developmental time of *M. domestica* showed clear variations depending on the organic waste diet provided (Fig. 1). Larvae reared on canned bean waste completed their development in the shortest time, averaging 5.37 ± 0.55 days. This duration was significantly lower than that of all other treatments ($P < 0.05$), highlighting the high nutritional quality of this substrate for larval growth. In contrast, larvae fed on kitchen waste required the longest period to reach pupation (7.84 ± 0.75 days), suggesting that its nutrient balance or composition may be less favorable, or that it demands more metabolic effort for digestion (Table 1). No statistically significant differences were observed in pupal period among most treatments (Table 1; Fig.2), although the canned bean waste group exhibited a slightly shorter duration (5.071 ± 0.259 days).

Regarding larval and pupal weights, flies reared on canned bean waste showed significantly higher biomass accumulation, with the highest larval (0.0312 ± 0.003 g) and pupal weights (0.0209 ± 0.002 g), reflecting high nutrient availability and assimilation efficiency. Conversely, larvae fed on kitchen waste exhibited the lowest weights at both stages, indicating poor conversion of diet to biomass (Table 1). Overall, the canned bean waste treatment provided optimal conditions for faster development and higher larval and pupal weights, whereas kitchen waste yielded inferior outcomes in all measured parameters.

According to the Kruskal–Wallis test, all pairwise comparisons between the different waste-based diets showed statistically significant differences in the larval development time of *M. domestica*, except for the comparison between brewery waste and the control (wheat bran) diet, where the difference was not statistically significant ($P = 0.068$) (Tables 1 & 2). These findings indicate that the substrate type has a considerable effect on the developmental time of housefly larvae. In particular, diets such as kitchen waste and slaughterhouse waste significantly prolonged larval duration compared to others, whereas canned bean waste promoted faster development.

According to the Kruskal–Wallis test results presented in Table 3, no statistically significant differences were found in the pupal period of *M. domestica* among most waste-based diets ($P > 0.05$), except for the comparison between slaughterhouse waste and canned bean waste, which showed a significant difference ($P = 0.008$). Specifically, all other pairwise comparisons—including control vs. slaughterhouse, brewery vs. control, and kitchen waste vs. control—yielded non-significant results, suggesting that the type of substrate had only a minor effect on the pupal development time.

The average pupal weight of *M. domestica* was significantly influenced by different waste diets (ANOVA; F = 23.91, df = 4, P < 0.0001) (Table 1). However, no statistically significant differences were found between the canned bean and control, slaughterhouse waste and control, brewery waste and control, or slaughterhouse waste and brewery waste treatments. Statistical analysis indicated that adult longevity did not differ significantly across different substrate treatments (Tukey's HSD, p > 0.05), despite observed variation in group means (Table 4). The effect of different diets on *M. domestica* sex ratio showed there was no significant effect (Table 5).

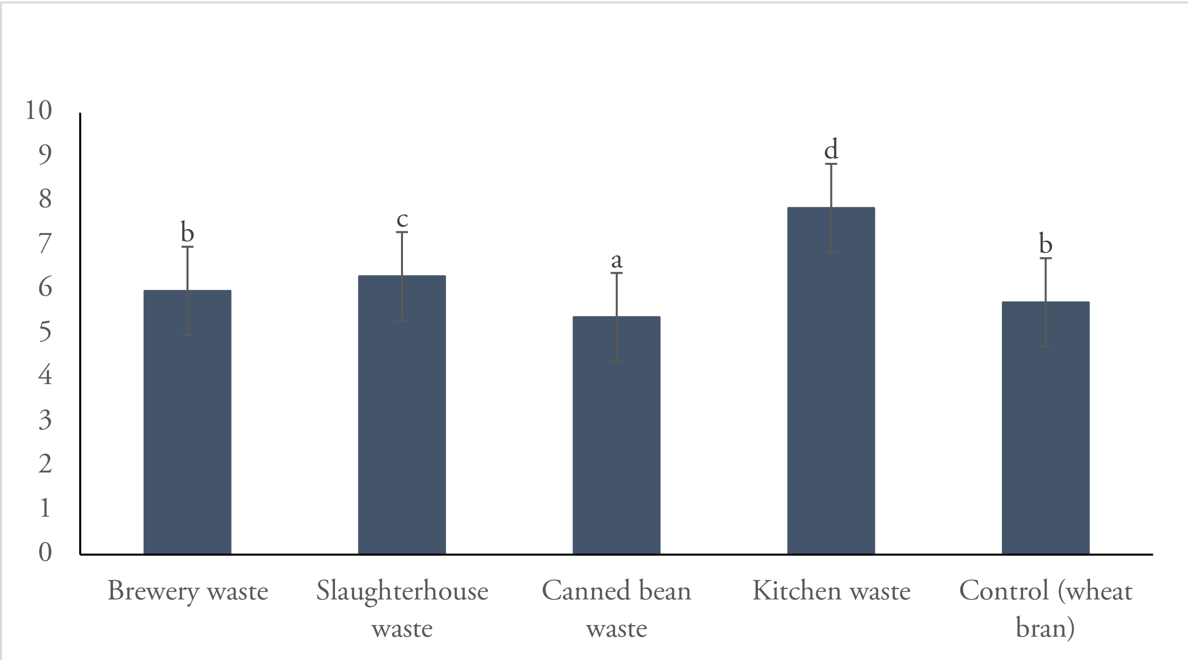

Fig. 1. Mean ± SE of larval period of *M. domestica* reared on different waste substrates

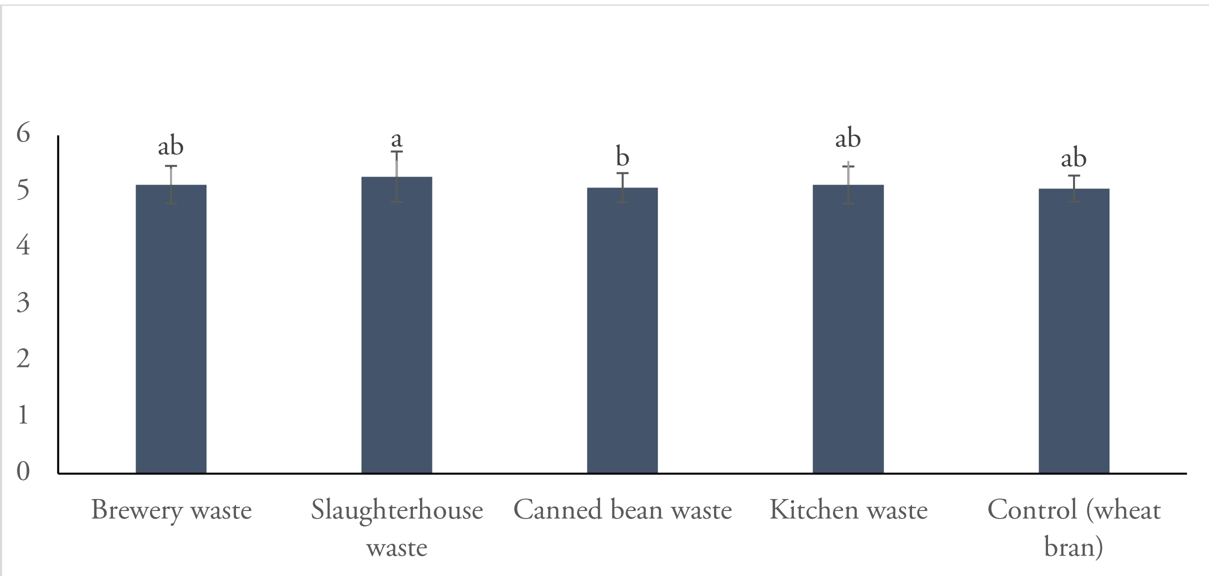

Fig. 2. Mean ± SE of pupal period of *M. domestica* reared on different waste substrate

Table 1. Combined effects of different organic waste diets on larval period, pupal period, larval weight, and pupal weight of *Musca domestica* (Mean ± SE).

(Diet)	Larval period (days)	Pupal period (days)	Larval weight (g)	Pupal weight (g)
Brewery waste	5.966±0.787 b	5.125±0.333 ab	0.0307±0.003 b	0.0181±0.003 b
Slaughterhouse waste	6.298±0.906 c	5.266±0.447 a	0.0281±0.002 c	0.0192±0.002 ab
Canned bean waste	5.373±0.554 a	5.071±0.259 b	0.0312±0.003 a	0.0209±0.002 a
Kitchen waste	7.842±0.751 d	5.120±0.328 ab	0.0232±0.003 d	0.0155±0.001 c
Control (wheat bran)	5.707±0.795 b	5.055±0.231 ab	0.0285±0.003 b	0.020±0.003 ab

Means followed by the same letters are not significantly different at the 5% level

Table 2. Comparison of larval duration (days) of *Musca domestica* reared on different organic waste substrates

Treatment comparison	Kruskal-Wallis test results	Treatment comparison	Kruskal-Wallis test results
Brewery & Slaughterhouse	(Chi-sq. test, df=1, Ch=5.877, P=0.015)	Brewery & Canned bean	(Chi-sq. test, df=1, Ch=19.742, P<0.0001)
Brewery & Control	(Chi-sq. test, df=1, Ch=3.324, P=0.068)	Brewery & Kitchen waste	(Chi-sq. test, df=1, Ch=70.227, P<0.0001)
Canned bean & Control	(Chi-sq. test, df=1, Ch=5.149, P= 0.023)	Canned bean & Kitchen waste	(Chi-sq. test, df=1, Ch=85.436, P<0.0001)
Slaughterhouse & Control	(Chi-sq. test, df=1, Ch=13.58, P= 0.0002)	Canned bean & Slaughterhouse	(Chi-sq. test, df=1, Ch=36.995, P<0.0001)
Kitchen waste & Control	(Chi-sq. test, df=1, Ch=78.116, P<0.0001)	Kitchen waste & Slaughterhouse	(Chi-sq. test, df=1, Ch=60.098, P<0.0001)

The sex ratios (proportion of males) across the brewery waste, slaughterhouse waste, canned bean waste, kitchen waste, and wheat bran (control) diets were 0.60, 0.57, 0.70, 0.55, and 0.55, respectively. According to the Chi-square test (χ^2 = 2.57, df = 4, P = 0.632), no statistically significant differences were observed, indicating that the diet type did not influence the sex distribution of *M. domestica* adults.

Discussion

This study showed that the type of organic waste used as feed obviously influences on housefly larvae growth speed. The difference is not only because of the nutrients in each type of waste, but also because of how the food looks and feels — for example, its moisture and texture (soft or coarse) directly influences on housefly feeding. Among all the diets tested, larvae grew the fastest when fed on canned bean waste. Even though this waste only had a moderate amount of protein (about 6–8% fresh weight), its soft texture, good balance of carbohydrates, and ability to hold moisture made it easy for the larvae to eat and digest. Conversely, housefly larvae reared on kitchen waste had the slowest growth. It did has both protein and carbohydrates, but it seemd watery and often released too much liquid when stored, which could make the food too wet and reduce air flow. This may have made it harder for the larvae to breathe and feed properly. Slaughterhouse waste, rich in protein (45–55%), dried quickly and formed a hard crust on the surface, making it difficult for larvae to reach the food inside. These results suggest that a good rearing diet for houseflies needs the right nutrients, but also the right texture and moisture level so the larvae can feed easily.

Table 3. Comparing the length of the pupal period (days) of *Musca domestica*

Treatment comparison	Kruskal-Wallis test results	Treatment comparison	Kruskal-Wallis test results
Slaughterhouse & Control	(Chi-sq. test, df=1, Ch=0.115, P=0.734)	Brewery & Canned bean	(Chi-sq. test, df=1, Chi=0.899, P=0.343)
Slaughterhouse& Kitchen waste	(Chi-sq. test, df=1, Ch=3.282, P=0.070)	Brewery & Control	(Chi-sq. test, df=1, Chi=1.589 P=0.207)
Canned bean & Control	(Chi-sq. test, df=1, Ch=0.115, P= 0.073)	Brewery & Slaughterhouse	(Chi-sq. test, df=1, Chi=3.246 P=0.071)
Kitchen waste & Control	(Chi-sq. test, df=1, Ch=1.350, P= 0.245)	Brewery & Kitchen waste	(Chi-sq. test, df=1, Chi=0.006, P=0.093)
Slaughterhouse & Canned bean	(Chi-sq. test, df=1, Ch=7.063, P=0.008)	Canned bean & Kitchen waste	(Chi-sq. test, df=1, Ch=0.722, P=0.395)

Table 4. Mean (± SE) adult longevity of housefly reared on different substrates in terms of sex

Diet	Sex	Mean_Longevity	N
Brewery Waste	FEMALE	21.690 ±0.973a	29
Brewery Waste	MALE	18.379±0.0908a	29
Control	FEMALE	24.182±1.490a	33
Control	MALE	21.190±1.388a	21
Canned bean waste	FEMALE	23.833±1.029a	36
Canned bean waste	MALE	18.700^{a}±1.031a	20
Kitchen waste	FEMALE	24.655±1.372a	29
Kitchen waste	MALE	20.952±0.0957a	21
Slaughterhouse waste	FEMALE	23.348±1.351a	23
Slaughterhouse waste	MALE	21.368±1.624a	19

Table 5. Sex ratio of *Musca domestica* on different diets

Diet	Number of males	Number of females	N
Brewery waste	16	24	40
Slaughterhouse waste	17	23	40
Canned bean waste	12	28	40
Kitchen waste	18	22	40
Control (wheat bran)	18	22	40

The results are in line with some earlier researches. For example, Khan *et al.* (2012) reported faster growth on nutrient-rich manures such as poultry and calf, and slower growth on high-fiber, low-nitrogen ones like horse manure. Larraín & Salas (2008) also found that chicken, swine, and calf manure supported quicker larval development than cow, horse, and goat manure, mostly because of higher nutrient levels and a better carbon-to-nitrogen ratio. Kökdener & Kiper (2021) showed that even a protein-rich diet can slow growth if carbohydrates are too low, while more balanced diets like wheat bran can speed it up. In our case, canned bean waste likely had a better nutrient balance, while kitchen waste may have been inconsistent and contained fats, salts, or other factors that contributes to slow growth.

Pupal development times were more similar across diets than larval times, and the differences were not statistically significant in most cases. The shortest pupal period was with wheat bran, and the longest with slaughterhouse waste. This suggests that the pupal stage may be less affected by diet than the larval stage, though other studies (Ali *et al.*, 2024; Kökdener & Kiper, 2021) have shown that extreme nutrient imbalances can still make a difference. Larval and pupal weights in our study reflected the quality of the diet. Canned bean waste consistently produced the heaviest larvae and pupae, demonstarting the larvae were able to use the food more efficiently. Kitchen waste produced the lightest ones, probably for the same reasons it reduced growth. Brewery waste performed almost the same as wheat bran, which means it could be a cheaper replacement in large-scale rearing. Other studies (Leyo *et al.*, 2023; Cheng *et al.*, 2021) have also stressed on both nutrient balance and texture of the food matter for good weight gain.

From a practical point of view, canned bean waste works well for growth but needs grinding before use, which can be increased labour in large-scale production. Brewery waste does not need special preparation, which makes it cheaper and easier to use. Since its results were similar to wheat bran, it could recommend to replace wheat bran in commercial rearing, especially now that wheat bran has become more expensive. It is important to remember that these results come from controlled laboratory tests. In real farm conditions, things like larval crowding, changes in temperature, and differences in humidity could affect the outcome. More tests under commercial conditions would help confirm these results. Overall, the choice of food for housefly rearing should consider both the nutrients and the physical form of the substrate. Canned bean waste gave the best results in this study, but brewery waste offers a good, low-cost alternative with less processing needed, making it a strong option for sustainable insect farming and waste recycling.

Conclusion

In this study, we found that the type of organic waste used as food has a big effect on the growth of *Musca domestica*. Canned bean waste gave the best results, with faster growth and heavier larvae and pupae. This is probably because it had a good balance of protein and carbohydrates, kept enough moisture, and was easy for larvae to eat. Kitchen waste gave the most inferior results, even though it had protein. This may be because of too much salt, fat, or oil, or because the nutrients were not in the right balance. Slaughterhouse waste also did not work well, maybe because it dried fast and became hard on the surface. Brewery waste gave results similar to wheat bran but is cheaper and needs less preparation, so it can be a good option for large-scale rearing. These results show that having a high protein content is not enough; the quality of nutrients, the texture, and the absence of harmful substances are also important.

In the future, it will be useful to test these waste types in bigger production systems and check for harmful microbes. We did not test for bacteria like Salmonella or *E. coli* in this study, but it is important to make sure the insects and their waste are safe before use in feed or food. Good hygiene and processing methods, such as heating or drying, can help make the products safe.

Author's Contributions

Pegah Tarlak: Conceptualization, methodology, formal analysis, investigation, draft preparation, final review and edit; visualization. **Hossein Madadi:**Conceptualization, methodology, formal analysis, final review and edit, visualization, supervision, project administration and funding acquisition. **Mehdi Zarrabi:** final review and edit; supervision, project administration.

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Data Availability Statement

All data supporting the findings of this study are available within the paper.

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Ethics Approval

This article does not contain any studies with human participants performed by the author.

Conflict of Interest

The autores declare that there is no conflict of interest regarding the publication of this paper.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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Research Article

مگس خانگی به عنوان مبدل زیستی؛ اثر پسماندهای مختلف روی رشد و نمو، وزن و طول عمر حشرات کامل مگس خانگی *Musca domestica* (Dip.: Muscidae)

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چکیده: در کنار روش‌های سنتی مدیریت پسماند، مطالعات اخیر بر نقش بالقوه حشرات در تجزیه زیستی و بازیافت پسماندهای آلی تأکید داشته‌اند. مگس خانگی *Musca domestica* L. (Dip.: Muscidae) به‌عنوان یکی از شناخته‌شده‌ترین گونه‌ها در این حوزه مطرح است که به دلیل ارزش غذایی بالای لاروهای آن، می‌تواند به‌عنوان منبع پروتئین در خوراک طیور و آبزیان مورد استفاده قرار گیرد. هدف پژوهش حاضر، یافتن بستر بهینه پرورش و مقایسه تأثیر پنج نوع بستر ضایعاتی بر زمان رشد، وزن لارو و شفیره، نسبت جنسیت و طول عمر بالغین مگس خانگی در شرایط کنترل‌شده آزمایشگاهی (۲۵ ± ۲ درجه سانتی‌گراد، رطوبت نسبی ۵۰ ± ۱۰ درصد و چرخه نوری ۱۲:۱۲) بود. بسترهای آزمایشی شامل ضایعات کارخانه ماءالشعیر، ضایعات کشتارگاه، ضایعات کارخانه کنسرو لوبیا، ضایعات آشپزخانه و سبوس گندم (شاهد) بودند. نتایج نشان داد که بین تیمارها از نظر طول دوره لاروی، وزن لارو و شفیره و طول عمر بالغ اختلاف معنی‌داری وجود دارد، در حالی‌که طول دوره شفیرگی و نسبت جنسیت تفاوت معنی‌داری نداشتند. کوتاه‌ترین دوره رشد و بیشترین زیست‌توده در تیمار ضایعات کنسرو لوبیا به‌دست آمد. بیشترین طول عمر بالغین در تیمارهای ضایعات کنسرو لوبیا و ضایعات آشپزخانه و کمترین در ضایعات کشتارگاه مشاهده شد. با توجه به عدم وجود تفاوت معنی‌دار بین تیمار سبوس گندم و ضایعات ماءالشعیر در تمامی صفات، می‌توان نتیجه گرفت که به جای سبوس گندم که هزینه بالایی دارد، استفاده از ضایعات ماءالشعیر به‌عنوان گزینه‌ای مقرون‌به‌صرفه امکان‌پذیر است.

کلمات کلیدی: مگس خانگی، بازیافت زیستی، ضایعات آلی، حشرات خوراکی

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