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Article

Design and Construction of a Portable Maggot House Using a Design Thinking Approach

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ABSTRACT

Organic waste dominates household waste streams in Indonesia, yet most households lack a practical, space-efficient way to process it. This study aimed to design and construct a portable maggot house for organic-waste management at household and micro, small and medium enterprise (UMKM) scale. A Research and Development design was applied using the five Design Thinking stages: empathize, define, ideate, prototype, and test. User needs were collected through interviews with ten households and UMKM in Bangkinang Kota and analyzed using descriptive qualitative analysis. Nine of the ten respondents discarded organic waste without processing; odour, flies, limited space, and lack of know-how were the main obstacles, and all ten preferred a portable device. The resulting prototype has a welded hollow-steel frame (39 × 55 cm footprint, 75 cm frame height, 15 cm legs), stacked biopond trays with an inclined side and perforated pipe for self-harvesting of prepupae, an egg-laying chamber, and a sloped roof. In a preliminary test on moist rice bran and household organic waste, the prototype supported the development of Black Soldier Fly (BSF) larvae over a cycle of about 16 days larval inoculation to prepupal harvest which does not represent the full egg-to-adult life cycle, without a strong putrid odour this is a subjective observation, as no defined odour assessment was used. The design offers a practical basis for decentralized organic-waste processing; quantitative performance testing remains for future work.

1. Introduction

Waste management is a persistent problem in developing countries because rising consumption and population growth continually increase waste generation. In Indonesia, waste is still handled mainly by dumping and landfilling at final disposal sites (Yuwita et al., 2022). World Bank estimates cited by Yuwita et al. (2022) put average waste generation in Indonesia at about 85,000 tonnes per day, of which roughly 60% is organic, while the capacity to recycle organic waste remains limited. Unmanaged organic waste contributes to greenhouse gas emissions and, in aquatic environments, to eutrophication and declining water quality (Yuwita et al., 2022).

The problem is also visible locally. Data from the Kampar Regency environmental agency for 2020 place Bangkinang among the sub-districts with the highest waste generation in the regency (Ayu et al., 2021). High waste volumes, combined with inadequate facilities, limited regulation, and budget constraints, leave much of this waste unmanaged.

Using organic waste as feed for maggots, the larvae of the Black Soldier Fly (BSF, *Hermetia illucens*), is one alternative. Maggots decompose organic waste, reduce its volume, and help reduce the odour it produces (Kasya et al., 2023). Their cultivation also has economic potential, because maggots can replace part of the costly commercial feed used for fish, poultry, and other livestock (Adnyaswari et al., 2025). Household-level cultivation, however, still faces limited space and limited public understanding. A portable maggot house is an appropriate-technology response that lets households and small enterprises process waste on their own while producing livestock feed (Mutia et al., 2025).

Existing studies on maggot-cultivation equipment have concentrated on IoT-based monitoring of temperature, humidity, and light (Nur & Pradana, 2021), feed fermentation to speed up larval growth (Rahmawati et al., 2020), and automatic separation of larvae from the rearing medium at harvest (Prasetyo et al., 2019). Few studies appear to address the physical design of the maggot house itself, particularly its portability and space efficiency for users with limited land (Section 2.3).

This study therefore aims to design and construct an efficient and user-friendly portable maggot house for organic-waste management at

household and UMKM scale, using the Design Thinking approach, and to evaluate its function in a preliminary rearing test. The scope is limited to design, function, and environmental benefit; production-cost and marketing analyses are excluded. By turning waste into a resource, the device also supports circular-economy principles.

2. Literature Review

2.1 Organic Waste and BSF Bioconversion

Organic waste originates from the remains of living organisms, such as vegetables, rotting fruit, leftover rice, and leaves, and decays quickly (Wahyuningsih et al., 2023; Imelda et al., 2020). Composting is one common treatment that reduces waste and converts it into a useful product (Worotitjan et al., 2022). BSF maggots offer another route, as they consume food waste, fish waste, and animal manure (Manurung et al., 2023). Maggots are the larval stage between the egg and the pupa (Hasanah et al., 2023). BSF occurs between about 45° N and 40° S, and larvae develop into pupae best at 25–30 °C (Siswanto et al., 2022). Maggots contain 40–50% protein and 29–32% dry fat and show high amylase, lipase, and protease activity (Sulistya & Wijayanti, 2021).

The BSF life cycle comprises the egg, larva, prepupa, pupa, and adult stages and lasts roughly 40 days; a female lays 500–900 eggs at a time (Masir et al., 2020). Growth depends on temperature, relative humidity, oxygen, pH, light, and rearing density, as well as the condition of the substrate (Witono, 2023). Through rapid conversion of waste, BSF larvae reduce the volume that reaches landfills, yield organic fertilizer and protein for feed, and can lower the greenhouse gas emissions of waste decomposition (Widiyanto et al., 2024).

2.2 Design Thinking and Design and Construction

Design Thinking is a user-centred, iterative problem-solving approach that emphasizes empathy, collaboration, and creativity. It proceeds through five stages (Priyono et al., 2023). *Empathize* identifies user characteristics and needs through observation, interviews, or surveys. *Define* formulates the problem users face. *Ideate* generates as many creative ideas as possible. *Prototype* builds a physical representation of the proposed solution. Testing

was limited to initial technical feasibility; comprehensive operational user validation remains subject to future work, design and construction (*rancang bangun*) means planning and drawing a design from an analysis of needs and then building it as a functional product.

2.3 Related Studies and Research Gap

Nur and Pradana (2021) designed an IoT-based smart maggot farm that uses DHT11 and LDR sensors, an ESP8266 NodeMCU microcontroller, and the Blynk platform to monitor temperature, humidity, and light intensity in real time, and reported accurate monitoring data on mobile devices. Rahmawati et al. (2020) built a simple fermentation reactor for maggot feed and found that fermentation raised the nutrient content of the feed and accelerated maggot growth. Prasetyo et al. (2019) developed a rearing device from PVC and wire mesh that uses the tilt of the container to separate larvae from the medium automatically, which improved harvest efficiency.

These studies address environmental monitoring, feed quality, and harvest efficiency, respectively. As described by their authors, none of them examines the structural design of the maggot house or its mobility and space efficiency for users with limited land. This gap motivates the present study.

3. Research Methodology

This study followed a Research and Development (R&D) design, which produces a specific product and tests its effectiveness (Okpatrioka, 2023). R&D was chosen because the aim was not only to understand a phenomenon but also to deliver a practical device for the community. The user-centred and iterative Design Thinking approach guided the work through five stages (Figure 1). The device was built at the Manufacturing Laboratory of the Industrial Engineering Study Program, Universitas Pahlawan Tuanku Tambusai, and testing was planned at representative sites such as small households, communities, and UMKM with limited land. The work was scheduled over about 13 weeks: literature study and needs survey (3 weeks), concept and initial design in AutoCAD (3 weeks), prototype fabrication (2 weeks), testing and evaluation (1 week), and data analysis and reporting (4 weeks). Ten households and UMKM actors in Bangkinang Kota served as informants.

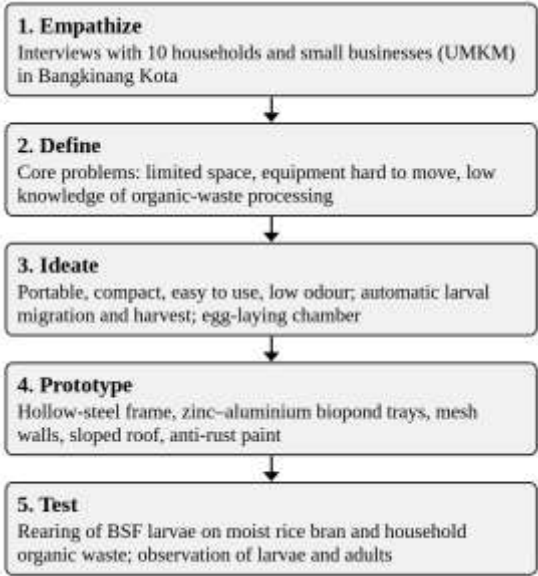


Figure 1. Design Thinking stages as applied in this study.

3.1 Instruments and Materials

Three instruments supported data collection: observation, interviews, and documentation. The interview guide contained ten questions on current organic-waste handling, main obstacles, willingness to process waste independently, previous experience with maggots, preferred ease of use, portable versus permanent installation, tiered versus single-compartment layout, ideal size, preferred harvesting method, and willingness to try the finished device. Drawings were produced with AutoCAD on a laptop. Table 1 lists the tools and materials used in fabrication and testing.

Table 1. Tools and materials used in this study.

Category	Items
Design	Laptop; AutoCAD (2D and 3D drawings)
Fabrication tools	Grinder, hacksaw, welding machine, measuring tools, rivet pliers, drill and drill bits
Fabrication materials	Hollow steel, galvanized zinc sheet, zinc roofing sheet, iron wire mesh, rivets, metal paint (anti-rust)
Test materials	Moist rice bran, BSF eggs, household organic waste (food leftovers and vegetables)

3.2 Data Collection and Analysis

Primary data were gathered through interviews and field observation. Secondary data came from journals, books, online articles, and earlier research reports on organic-waste treatment, maggot-cultivation systems, BSF

biology, and portable design, and formed the theoretical basis of the design. Photographs and video documented the design, material selection, assembly, and field testing.

Interview and observation data were analyzed using descriptive qualitative analysis, in which data in the form of words or images are described rather than expressed numerically, to understand users' perceptions, needs, obstacles, and expectations. Responses were grouped by question and theme, and the number of respondents per theme is reported. The findings were used to refine the design so that it would be functional, easy to use, and suited to field conditions.

In the test stage, the prototype was operated for a planned 7–16 days to assess its effectiveness of use. Moist rice bran served as the initial medium; once larvae were active, household organic waste (food leftovers and vegetables) was added. Larval activity and the degree of waste decomposition were observed as indicators of success. No quantitative measurements are reported in this study.

4. Results and Discussion

4.1 Presentation of Results

4.1.1 User Needs from Interviews

Table 2 summarizes the interviews with ten households and UMKM in Bangkinang Kota. Nine respondents discarded organic waste without processing it, typically into bins, the temporary disposal site (TPS), or behind the house; only one occasionally buried it or made compost. None had ever used maggots, although some had seen them or heard of them. The most frequent obstacle was fear of odour, flies, and dirtiness (five respondents), followed by lack of space (two), not knowing how to process waste (two), and lack of time (one). Seven respondents said that people would be willing to process waste themselves if an example, instruction, or an affordable and practical device were available; three doubted it because of perceived difficulty, laziness, or disgust.

All ten respondents wanted a portable device and a simple routine of putting in waste and harvesting. Opinions on layout were divided: six favoured tiered racks and four a single large compartment. Respondents who gave dimensions suggested heights of 60–100 cm, and others asked for a small or medium size that fits in a kitchen or resembles an ordinary trash bin. Six preferred automatic

harvesting, three manual, and one either. One respondent asked for a roof so that the device could be placed outdoors. All ten were willing to try the finished device.

Table 2. Summary of interview responses (n = 10); figures in parentheses are numbers of respondents.

Topic	Responses
Current handling	Discarded without processing (9); buried or composted occasionally (1)
Main obstacle	Odour, flies, dirtiness (5); lack of space (2); not knowing how (2); lack of time (1)
Maggot experience	Never used maggots (10)
Perceived community willingness	Conditional on example, instruction, or practical device (7); doubtful (3)
Preferred operation	Simple: put in waste, then harvest (10)
Installation	Portable (10)
Layout	Tiered rack (6); single compartment (4)
Size	Small to medium; stated heights 60–100 cm (4)
Harvest method	Automatic (6); manual (3); either (1)
Willing to try device	Yes (10)

4.1.2 Design Requirements and Specification

The Design Thinking synthesis (Figure 1) translated these findings into design requirements. At the empathize stage, most residents were found to discard organic waste because of limited knowledge, equipment, and socialization, and to regard processing as complicated. The define stage stated the core problem as the lack of practical and efficient means, and of the know-how, to process organic waste at home. The ideate stage concluded that the solution should be a portable maggot house that is compact, space-saving, easy to maintain, low in odour, and equipped with automatic migration and harvesting and a breeding place for BSF. Table 3 links the main user needs to the design features adopted.

Table 3. User needs and the corresponding design features.

User need	Design feature
Portable, easy to move (10/10)	Compact welded frame, 39 × 55 cm footprint, on 15 cm legs
Small to medium size; space-saving	Vertical arrangement: 75 cm frame, shelf tiers about 16 cm high

User need	Design feature
Tiered rack (6/10)	Stacked shelves holding the biopond trays
Automatic harvest (6/10)	Biopond with 45° inclined side and perforated collection pipe
Odour and flies (5/10)	Mesh walls and ventilation space for air circulation
Outdoor placement (2 respondents)	Sloped roof against rain and sunlight
Easy cleaning and maintenance	Biopond shape eases handling of the culture medium
Source of larvae	Egg-laying chamber for adult BSF

The design was drawn in AutoCAD in 2D (side, rear, front, top, and bottom views) and in 3D before fabrication to guide assembly and reduce errors. As shown in Figure 2, the frame is 75 cm high and stands on 15 cm legs, with a footprint of 39 cm (width) by 55 cm (length). The shelf tiers are about 16 cm high each and hold the biopond trays. A sloped roof, 5 cm high on the low side and 10 cm on the high side, covers the top and leaves a ventilation space. The frame uses 2 mm hollow-steel sections joined by welding. The biopond is trapezoidal in side view, with a 40 cm base, a 47.07 cm total length, and 7.07 cm side height (Figure 2c). One side is inclined so that larvae entering the prepupal phase can migrate naturally toward the harvest point, which also eases maintenance and cleaning of the culture medium.

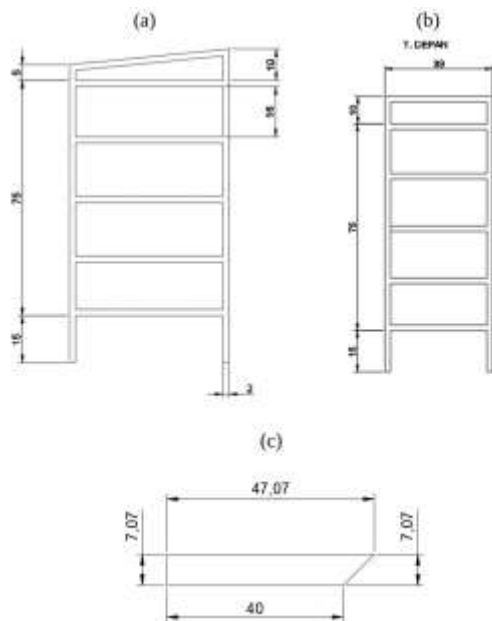


Figure 2. Dimensioned AutoCAD drawings (cm): (a) side view, (b) front view, and (c) side view of the biopond.

4.1.3 Construction of the Prototype

Fabrication followed four steps. First, the frame was assembled from 2 mm hollow steel by welding (Figure 3a); it was kept compact so that it can be moved and used where space is limited. Second, the biopond was made from a modified zinc aluminium sheet container whose front side was inclined at 45° to ease prepupal migration, with a perforated pipe beneath it serving as the collector and migration path for prepupae (Figure 3b). Third, the egg-laying chamber for adult BSF was built from hollow steel integrated with the main structure, fitted with mesh and a light floor of wood or plastic, and holding the egg-laying medium; it sits in a sheltered position with good air circulation. Fourth, during finishing the whole structure was checked for strength and stability, sharp corners were sanded or reshaped, and all frame surfaces were coated with anti-rust paint.



Figure 3. Fabrication: (a) welded hollow-steel frame and (b) zinc galvanized biopond.

The completed prototype (Figure 4) integrates a roof that protects against rain and sunlight, a chamber for egg-laying by adult flies, biopond trays in which larvae decompose the waste, and collection areas with migration channels.



Figure 4. Components of the completed portable maggot house.

4.1.4 Preliminary Test

Testing began with moist rice bran as the initial medium, left for three days until BSF eggs hatched and larvae developed. Once the larvae were active, household organic waste such as food leftovers and vegetables was fed into the biopond. Table 4 lists the test stages, from preparation on day 1 to harvest on days 11–16.

Table 4. Stages of the prototype test.

Stage	Day	Activity
Preparation of device and medium	1	Clean the maggot house; prepare moist rice bran
Egg stocking	1	Spread BSF eggs onto the bran
Early hatching	2–5	Eggs hatch; larvae feed on the bran
Organic-waste feeding	5–10	Add household organic waste as feed
Routine maintenance	5–10	Stir the medium gently; add waste as needed; check ventilation
Harvest	11–16	Collect large, brownish larvae
Cleaning	16+	Remove residue; dry the device

The larvae showed the characteristic appearance of BSF: cream-coloured at early growth and turning brown toward the pupal phase. They were active in the organic medium without a strong putrid odour (Figure 5a). As additional validation, some larvae were allowed to mature; the adults had black bodies and dark wings and were not aggressive (Figure 5b). The prototype thus supported larval development on rice bran and household organic waste within a cycle of about 16 days.

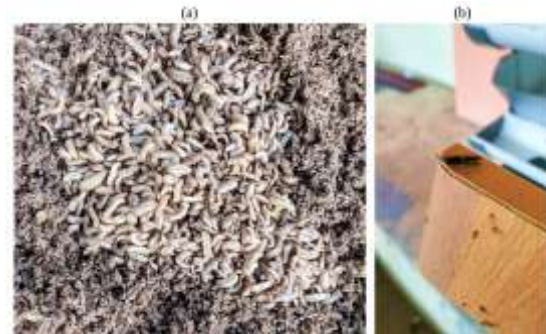


Figure 5. Test results: (a) BSF larvae in the organic medium and (b) adult BSF.

4.2 Discussion of Results

The interviews indicate that the barriers to organic-waste processing in Bangkinang Kota are practical and perceptual: odour, flies, space, time, and know-how. This pattern matches the limited space and limited public understanding noted in the Introduction, and the unanimous willingness to try a finished device suggests that a suitable tool can lower the threshold for participation. The design was therefore built around the needs voiced most consistently, namely portability (10 of 10 respondents), tiered racks (6), and automatic harvest (6). The explicit link between needs and features in Table 3 is an advantage of the Design Thinking process applied here.

Earlier work addressed environmental monitoring (Nur & Pradana, 2021), feed fermentation (Rahmawati et al., 2020), and harvest separation (Prasetyo et al., 2019). This study contributes a user-derived physical design focused on portability and space efficiency. Its inclined biopond with a perforated collection pipe is similar in principle to the tilt-based separation of Prasetyo et al. (2019), but is integrated here into a stackable, movable structure that could later be combined with sensor-based monitoring of the kind reported by Nur and Pradana (2021).

The preliminary trial demonstrated that larvae displaying the expected morphological features of BSF successfully developed within the unit using a substrate of rice bran and household organic waste, reaching a harvestable stage in approximately 16 days without the generation of strong putrid odours. However, because BSF larval growth is strongly governed by environmental parameters such as temperature, humidity, substrate composition, and larval density (Witono, 2023), which were

not systematically monitored in this study the observed harvest window of days 11–16 must be interpreted as indicative rather than definitive.

Furthermore, the absence of strong odour represents an informal observation rather than a standardized olfactory assessment. Because quantitative data on waste reduction rates and larval yields were not collected, claims regarding the unit's effectiveness are strictly limited to its basic functional feasibility, while full operational efficiency remains subject to future verified testing

If adopted at household and UMKM scale, the device could convert kitchen waste into protein-rich larvae for animal feed and organic residue (Widiyanto et al., 2024; Adnyaswari et al., 2025), contributing to circular-economy practice and reducing the load on landfills. The study has several limitations: a small sample of ten informants from one sub-district, qualitative observations from a single test cycle, no quantitative performance data, no evaluation of the device by users after operation, and no cost analysis, which was excluded by scope. Future work should measure waste-reduction rate, larval biomass, temperature, and humidity, and should include user-acceptance trials.

5. Conclusion

This study developed a portable Black Soldier Fly (BSF) rearing unit for household and small-business organic waste management using a Design Thinking approach. Interviews with ten respondents in Bangkinang Kota showed that organic waste is rarely processed, mainly because of limited knowledge, concerns about odor and flies, and limited space. These findings were translated into a design specification for a compact, portable unit measuring 39 × 55 cm with a height of 75 cm, built from welded hollow steel. The unit comprises tiered biopond racks, trapezoidal biopond trays inclined at 45° with perforated pipes intended for larval migration and self-harvesting, an egg-laying chamber, and a sloped roof. In a trial cycle of approximately 16 days, the prototype supported BSF larval development on moist bran and household organic waste, and the larvae and adult flies showed morphological characteristics consistent with BSF.

The main contribution of this study is therefore a user-derived design specification that can be reproduced and refined. However, the prototype was evaluated only through

qualitative observation, and the user requirements were drawn from a small sample in a single area. Verification of the current design should therefore take priority over modular expansion or IoT additions. This includes structural load and relocation testing, direct user task testing, performance verification of the self-harvesting collection path, and replicated measurements of waste reduction efficiency and larval yield. Industrial-scale deployment should be treated as a separate engineering question, not as a capacity extension already supported by this prototype. IoT-based temperature and humidity monitoring, together with user training and community mentoring programs, should be pursued only after the core functional reliability and performance of the base prototype have been established.

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