

Analysing stingless bee garden design for urban farming in Kelantan, Malaysia

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Abstract. The benefits of stingless bee honey for health found in various studies increase the demand for these apiculture activities to grow. However, the production of stingless bee honey requires specific garden design considerations according to the species' nature and behaviour. Therefore, this study aims to analyse the design of a stingless bee garden by three stingless bee honey entrepreneurs in Kelantan, Malaysia for urban farming consideration. Three stingless bee gardens were selected based on their establishment in producing stingless bee honey for business, namely, (i) RTF Kelulut Garden, (ii) Meloris Kelulut Garden, and (iii) Husna Kelulut Garden. This research employed the mapping method, image capture to collect information on spatial arrangement, hive design, and plant identification for the commercial stingless bee garden. Data were analyzed using comparative analysis to define the significant considerations as well as the recommendation for better garden design. The finding suggests that there are three design layouts for the stingless bee garden which are a covered setting, a natural setting, and a mixed setting. Mix setting becomes the recommended setting suitable in tropical countries because of rainy and hot seasons. This study implies that an understanding of stingless bee garden design assists entrepreneurs in increasing the productivity and quality of stingless bee honey.

1 Introduction

Stingless bees contribute significantly as the superior therapeutic properties of their honey production to health. The studies on food sciences indicate the differences between stingless bees' honey compared to others by containing higher levels of bioactive compounds like phenolic acids and flavonoids that contribute to antioxidant, anti-inflammatory, and antibacterial attributes [1-3]. Besides, their potential to address global issues such as obesity, with studies indicating weight-reducing effects in obese-induced rats [4] as well as contributing to the environment as pollination, supporting native plant reproduction and ecosystem conservation [5] shows the trends and demands to be developed further. Hence,

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the studies on stingless bees should not focus on the quality of honey itself but require an understanding of how to make them live in a better environment for better production.

Literature on stingless bees showed significant relevance across various disciplines. In agriculture, particularly in meliponiculture, the knowledge of stingless bees is utilized for honey, pollen, propolis, and wax production [6, 7]. Meanwhile, in pharmaceutical and cosmetic industries, the components contained in stingless bee products such as honey and propolis significantly important and traditionally used due to their biologically active compounds, such as polyphenols and carotenoids [8]. Besides, in natural ecosystem studies, research on stingless bees discussed their foraging behaviour, which includes flower morphology and nectar concentration of preferred food sources, which implies to the beekeepers and promoting ecosystem sustainability [9, 10]. Accordingly, the diverse views on stingless bees' nature map the directions to understand the benefits of their honey and underscore their significance to protecting, preserving and stimulating meliponiculture activities from agriculture, health care and ecological to environmental design studies.

In Malaysia, three prominent species of stingless bee are used for honey production, propolis extraction, and pollination support which are *Geniotrigona thoracica*, *Heterotrigona itama*, and *Tetragonula laeviceps* [1, 5, 11-13]. The locals commonly used these stingless bee species because of ease of cultivation and honey production capabilities, as well as living in an ideal environment for survival and high-quality propolis. Thus, providing a conducive environment for those species indicates better production and quality in the activity of apiculture for stingless bees.

As recorded in temperate regions, the phenomenon leads to a decrease in native stingless bee populations due to exposure to viruses [14]. In addition, Correa-Mosquera, Quicazán, and Zuluaga-Domínguez (2022) indicates that the poor hygienic practices conducted in Colombia in handling the cleaning and harvesting the honey contribute to the rapid growth of harmful microorganisms, affecting the quality of the honey profile [7]. Understanding the effects of agricultural management practices on stingless bee colonies is crucial for protecting ecosystem function and traditional cultural practices, especially in tropical regions where stingless bees are essential pollinators [15]. Moreover, identifying the preferred food sources of stingless bees, such as flowers with high nectar concentrations and specific morphologies, is essential for improving beekeeping activities and promoting the sustainability of flora and fauna in ecosystems [13]. Thus, this study aims to analyse the design of a stingless bee garden by three stingless bee honey entrepreneurs in Kelantan, Malaysia for urban farming consideration for a better understanding of agriculture management practices in stingless bee gardens.

2 Design component of stingless bee garden

The domain of design components for the stingless bee garden consists of (i) plant materials, (ii) hive structure, and (iii) spatial layout of the stingless bee garden.

2.1 Plant materials

Plants contribute to the resinous materials necessary for propolis formation, which influences the honey's composition and quality [12, 16]. The geographical location of stingless bee habitats, rich in resin-secreting trees like those from the *dipterocarpaceae* family, and the humid tropical climate in Southeast Asia contribute to the abundance of stingless bees and

the availability of resin sources for propolis production [12]. The resin collected from specific plants by stingless bees varies in chemical composition based on seasonal fluctuations, environmental factors, and geographical locations, ultimately affecting the properties of the propolis and honey produced [12]. This intricate relationship between stingless bees and plants highlights the importance of a diverse and healthy vegetative environment for sustainable honey production and biodiversity conservation. Therefore, this study indicates that the understanding of plants is an important domain in planning the design of a stingless bee garden.

2.2 Hive structure

The hive indicates a suitable environment for storing honey and facilitating the fermentation process. Stingless bees, such as those in Malaysia and Ethiopia, construct their hives using a mixture of beeswax and tree resins, creating unique pots for honey storage [3, 12, 17]. The use of plant resins in hive building is a common practice among stingless bees, contributing to the antimicrobial properties of their honey [18]. Additionally, the hive structure which reflects the transformation through enzymatic activity and evaporation, influences the flavour, aroma, and quality of the honey produced by stingless bees, making it highly valued in comparison to honey produced by *Apis mellifera* [12, 17]. The hive also serves as a hub for microbial interactions, including bacteria and yeasts, which play a role in honey maturation and the production of bioactive compounds in the honey [3, 18]. Accordingly, this study investigates the hive structure used by local meliponiculture practices in Kelantan, Malaysia to understand the advantages or disadvantages of each structure.

2.3 Spatial layout

The spatial layout of a stingless bee garden plays a crucial role in honey production due to its impact on the availability of nectar sources, which directly influences the quality and quantity of honey produced. Stingless bee species like *Geniotrigona thoracica* store honey in tiny pots made of beeswax and tree resins, resulting in unique flavours and aromas influenced by the diverse colours and physicochemical characteristics of the honey [3]. Stingless bees obtain beeswax through glandular secretions, which they manipulate and shape for hive construction. Factors such as the geographical origin, plant types providing nectar, and climate conditions significantly affect honey quality and production in stingless bees [19]. Additionally, the moisture content in stingless bee honey is a critical parameter, with high moisture levels leading to undesirable fermentation and degradation of honey quality, emphasizing the importance of maintaining moisture levels below 20% for optimal honey storage stability and quality [11]. Hence, this study measures the mapping of a local stingless bee garden to comprehend the arrangement as well as the composition of plants and hive locations for better production.

3 Methods

3.1 Site study

The total number of sixteen stingless bee honey entrepreneurs identified in Kelantan, Malaysia. The business of stingless bees focuses on the commercial cultivation of *Heterotrigona itama* for honey production. Kelantan is one of the states where stingless bee

honey is sourced, with samples like KnA (specific type of honey produced by *Heterotrigona itama*) being used for various studies [12, 20]. The honey produced by *Heterotrigona itama* is known for its unique characteristics, including a less sweet taste, acidic flavour, and higher flavonoid and polyphenol content compared to honey from *Apis mellifera* bees, leading to a higher market value [12]. However, challenges such as limited production, lack of awareness in practicing the standard (Malaysian Standard MS2683:2017), and shorter shelf life due to higher water content hinder the commercialization of stingless bee honey in Kelantan and other regions [12, 21].



Fig. 1. Location of the three selected site which are RTF Kelulut Garden, Meloris Kelulut Garden, and Husna Kelulut Garden.

As shown in Figure 1, the study focuses on three stingless bee gardens namely, (i) RTF Kelulut Garden, (ii) Meloris Kelulut Garden, and (iii) Husna Kelulut Garden. The selection is due to the business which consists of the original cultivation process conducted in a garden, the different design setting, and established more than five years. Accordingly, the criteria are to highlight the importance of ensuring the authenticity and quality of these products in the market.

3.2 Data collections

The study employed mapping data collection which refers to the collecting quantitative information including the quantity and plant materials species as well as qualitative information such as the orientations, positions, and locations of the plants and hives identified in the site selected. The maps of the stingless bee garden were used to identify the quality of plant materials and the location of hives to generate spatial configurations for the garden design. The three selected sites were measured accordingly on-site with permission from the owner. Then, the information gathered in AutoCAD version 2023 in three different maps as shown in Figure 2.

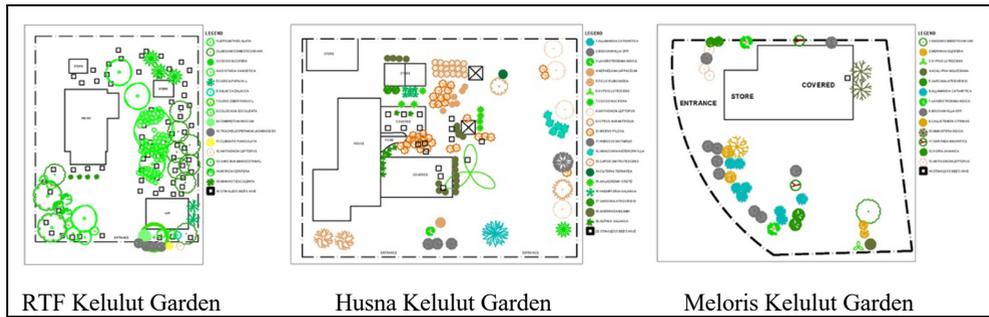


Fig. 2. Maps of RTF Kelulut Garden, Husna Kelulut Garden, dan Meloris Kelulut Garden.

Besides mapping, this study also employed observation data collection to understand the hive structure as the design component to store honey and facilitate the fermentation process. The process of observation involved snapping the photos of hives identified on site and organizing them according to the garden with the permission of the owner.

3.3 Data analysis

Data of plant materials, hive structure, and spatial layouts gathered from maps and observation were analysed according to descriptive analysis using mean rank and percentages, thematic analysis, and spatial analysis. In measuring plant materials for stingless bee gardens, the study employed mean rank and percentages to define the significant plants suitable to be implemented in the garden. To understand the structure of beehives for meliponiculture activities, this study used thematic analysis to measure the structure used to construct a hive for stingless bees. Lastly, in designing the overall stingless bee garden, this study analysed the spatial layout of the stingless bee garden to define the advantages and disadvantages of the orientations, positions, and locations of the plants and hive for the selected site. The spatial analysis of this study was conducted using QGIS version 3.38 to assess the spatial composition of plants and the spatial arrangement of hives. Accordingly, the comparative strategies were used for descriptive analysis, thematic analysis, and spatial analysis in defining the findings for this study.

4 Findings and discussion

4.1 Plant material for stingless bee garden

Table 1 shows the plants that were significantly used by three selected sites to stimulate stingless bee honey productivity. The result indicates that three species of plants significantly used by the locals for their stingless bee garden are *Asystasia gangetica* with 17% (mean rank: 10), *Citrus aurantifolia* with 16% (mean rank: 9), and *Antigonon leptopus* with 11% (mean rank: 6.3). Moreover, *Antigonon leptopus* is the only plant species significantly used by all stingless gardens. Stingless bees depend on plants as the source of food. This means that the productivity, as well as the quality of stingless bee honey, is influenced by the plant species identified near the hive. Hence, the intentional or unintentional of the planted plants by the owners indicates that the availability of species such as *Asystasia gangetica*, *Citrus aurantifolia*, and *Antigonon leptopus* potentially impacts the quality or production of stingless bee honey, especially for commercial purposes.

Table 1. Result of descriptive analysis for plant materials

Plant species (scientific name)	No. of Species (NOS)			Total	Percentage	Mean Rank
	RTF Kelulut Garden	Meloris Kelulut Garden	Husna Kelulut Garden			
<i>Asystasia gangetica</i>			30	30	17%	10.0
<i>Citrus aurantifolia</i>	27			27	16%	9.0
<i>Antigonon leptopus</i>	16	2	1	19	11%	6.3
<i>Allamanda cathartica</i>	3	8		11	6%	3.7
<i>Bougainvillea spp.</i>	1	9		10	6%	3.3
<i>Aglaonema 'crete'</i>	10			10	6%	3.3
<i>Lagestroemia indica</i>	8	1		9	5%	3.0
<i>Lansium domesticum var.</i>			9	9	5%	3.0
<i>Garcinia atroviridis</i>	8			8	5%	2.7
<i>Cocos nucifera</i>	4		3	7	4%	2.3
<i>Lepisanthes alata</i>			7	7	4%	2.3
<i>Bidens pilosa</i>	6			6	3%	2.0
<i>Capsicum frutescens</i>	6			6	3%	2.0
<i>Colocasia esculenta</i>			5	5	3%	1.7
<i>Trachelospermum jasminoides</i>			4	4	2%	1.3
<i>Manihot esculenta</i>			4	4	2%	1.3

As mentioned by the owners, *Antigonon leptopus* are commonly used for stingless bee production due to their significance in providing essential resources for the bees. Stingless bees are crucial pollinators, and the cultivation of these plant species supports their foraging activities, ultimately enhancing honey production [12]. Furthermore, the traditional medicinal use of stingless bee products, such as honey, for treating various ailments like respiratory disorders, constipation, and wound healing, underscores the cultural and therapeutic importance of these bee species and their associated plant resources [22, 23]. Therefore, this study suggests that planted plants near to the beehive are potentially influence the productivity of honey. However, the plants identified requires further experimental methods in testing the significant of plants to be considered as plant materials for the development of stingless bee gardens.

4.2 Hive structure for stingless bee garden

Besides plants as the source of food for stingless bees, the hive is significantly considered the main element of the stingless bee garden which works in various crucial functions, including storing honey, bee bread production, and protecting their colonies from predators and environmental threats. As shown in Table 2 of the thematic analysis of the stingless beehive structure identified at the selected site, the result suggests that a stingless beehive for commercial comes with seven specifications namely, overall height, base, column, hive or log, bitumen, topping, and cover. Accordingly, the study indicates that the three differences in constructing a hive of stingless bees which represent different purposes, specifically hive with or without a log, the column to set up the suitable height of the hive, and the range of overall height with 80cm to 120cm. The significant difference identifies the component of the hive or log in holding the colony. The hive structure with a log is designated to the colony with a queen bee.

Table 2. Result of thematic analysis from the observation for hive structure

Specifications	RTF Kelulut Garden	Meloris Kelulut Garden	Husna Kelulut Garden
Cover (Prevent water flow to the hive)	Wood and Rubber Mat	Wood and Rubber Mat	Wood and Rubber Mat
Topping (Honey storage)	Wood	Wood	Wood
Batumen (Access and gate to the hive)	Resin, Propolis, wax	Resin, Propolis, wax	Resin, Propolis, wax
Hive (Colony area)/ Log (Area for queen)	Wood Hive	Rotten Wood Log	Rotten Wood Log
Column	Wood Column	-	Concrete Column
Base (Foundation of the hive)	Wood/ Concrete	Concrete	Concrete
Overall Height	112cm	84 cm	120 cm

In the natural habitat of stingless bees, the queen lives in the log with its colony including workers, and male bees, with the queen playing a vital role in maintaining colony cohesion and ensuring its development and survivorship. The log is cut from the part of the tree and then placed in the garden according to the specifications. Hence, the log becomes an asset for the beekeeper as it contributes to the breeding of stingless bees in hives and propagating them for colony multiplication. From the process of breeding and propagating, the hive without log constructs according to the specifications such as the suitable height, and the material used to support the hive. Similarly to this study, a hive without a log indicates a more environment-friendly method for the process of forming a bee colony rather than a hive with a log [24]. However, a hive with a log also plays an important role in maintaining and sustaining the colony as the log becomes the main source for breeding and propagating of stingless bee colonies. Consequently, the understanding and knowledge of colony multiplication assist apiculture entrepreneurs in establishing better hives for a stingless bee garden and contributing to the better productivity of stingless bee honey.

4.3 Spatial layout of stingless bee garden

The design of a stingless bee garden consists of the plant's compositions and hive arrangement to stimulate honey productivity. This study analyses the spatial quality of plants composed in the selected site which impacts the stingless beehive. Figure 3 indicates the result of spatial analysis for the selected site. Consequently, Figure 4 shows the result of spatial quality according to the hive location at the respective site. Figure 4 indicates that hives identified at Husna Kelulut Garden show the highest spatial value with an average of 15.64. Whereas the spatial value of hives in RTF Kelulut Garden and Meloris Kelulut Garden shows a similar average value which is 11.70 respectively.

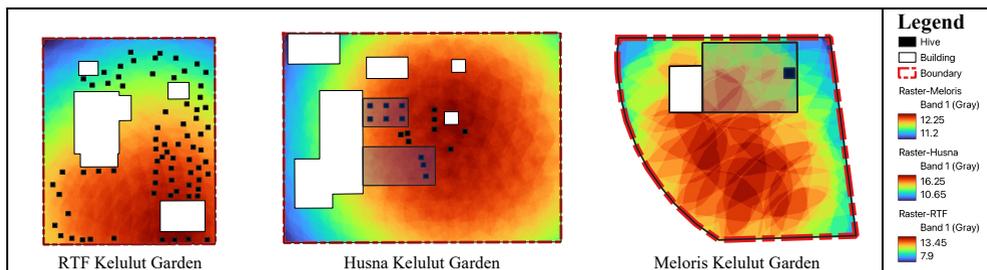
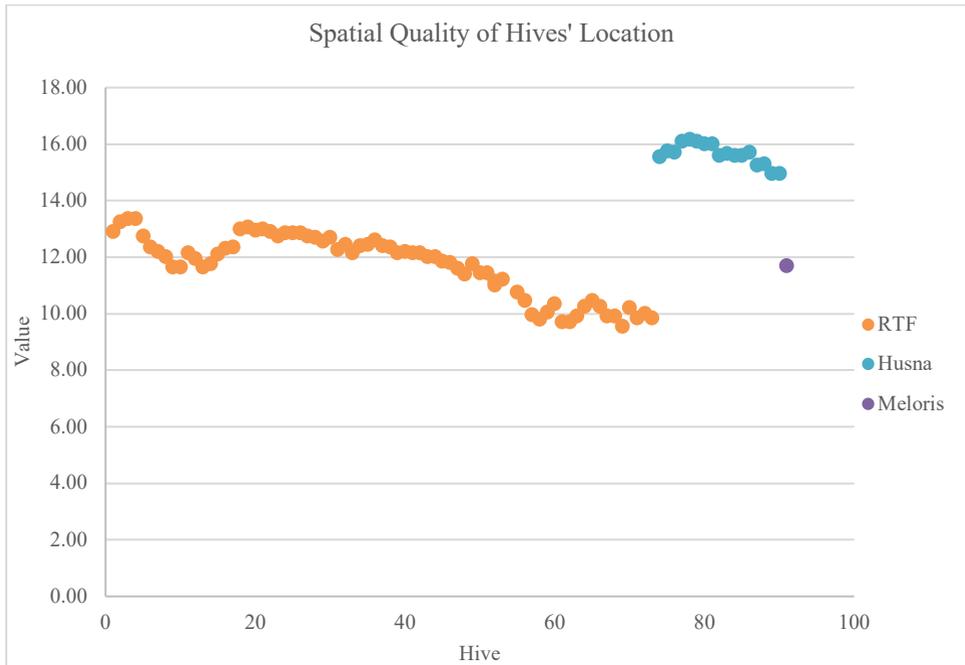


Fig. 3. Result for spatial analysis of RTF Kelulut Garden, Husna Kelulut Garden, dan Meloris Kelulut Garden.



and (iii) the composition and arrangement of planting design and hive location in stimulating the honey productivity.

Antigonon leptopus identified as popular plants practised by the local entrepreneur. In providing the hive structure, a hive without log specifications is recommended as an ecofriendly method as the hive multiples as many as possible through breeding and propagating from the main hive. The garden is also recommended with the appropriate quantity of hives with log as the log becomes the main source for breeding and propagating the colony to sustain the species. Then, the plant are suggested to be composed of dense and diverse with various recommended species in incorporate the hive with plants to increase honey productivity. Accordingly, the garden design consideration is suggested as the deliberation factor to encourage stingless bee business productivity.

As practised by local stingless bee entrepreneurs, the study indicates the trends of building a garden. However, the study recommends conducting further scientific investigation to prove the plant species that increase honey productivity, the relation of hive and plants' location, and hive environments. Moreover, a model is required as the framework and guidelines for the entrepreneur or built environment practice in developing a stingless bee garden for commercial or for conservation, preservation and restoration agenda.

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References

1. A.C. Dos Santos, F.C. Biluca, P. Brugnerotto, L.V. Gonzaga, A.C.O. Costa, and R. Fett, *Food Res Int* **158**, (2022)
2. M.F. Abu Bakar, *Trends Food Sci Technol* **147**, (2024)
3. V.F. Alves, L.T. Chaul, G.C.A. Bueno, I. Reinecke, T.C.G. Silva, P.V.A. Brito, and E.C.P. De Martinis, *Curr Opin Food Sci* **55**, (2024)
4. C.A. Mduda, M.H. Muruke, C.O. Joseph, and J.M. Hussein, *Food and Humanity* **2**, (2024)
5. S.N. Ramli, S.A. Hamid, and N. Basari, *J Asia Pac Entomol* **26**, 4 (2023)
6. J.R. Silva, F.C. Henrique-Bana, J.K. Villas-Boas, T. Colombo Pimentel, W.A. Spinosa, and S.H. Prudencio, *Food Chem (Oxf)* **6**, (2023)
7. A.R. Correa-Mosquera, M.C. Quicazán, and C.M. Zuluaga-Domínguez, *Food Control* **142**, (2022)
8. N.H. Hassan, G. Manickavasagam, J.T. Althakafy, M. Saaid, R. Adnan, B. Saad, and Y.F. Wong, *J Food Compost Anal* **121**, (2023)
9. N.A. Abdullah, N. Zullkiflee, S.N.Z. Zaini, H. Taha, F. Hashim, and A. Usman, *Saudi J Biol Sci* **27**, 11 (2020)
10. N. Ramlee, Z. Zahari, N.H. Abdul Hamid, W.S.N. Wan Mohamad, S.A. Mohamed, R. Hasan, N.I. Othmani, and M.F. Ramlee, *BIO Web Conf* **73**, (2023)
11. N.S. Mohamad Ghazali, Y.A. Yusof, H. Mohd Ghazali, N.L. Chin, S.H. Othman, Y.N. Manaf, L.S. Chang, and S.A.H. Mohd Baroyi, *Food Bioscience* **40**, (2021)
12. A. Mahmad, L.S. Chua, T.U. Noh, C.K. Siew, and L.J. Seow, *Biocatalysis and Agricultural Biotechnology* **54**, (2023)

13. N. Basari, S.N. Ramli, N.A. Abdul-Mutalid, N.F.M. Shaipulah, and N.A. Hashim, *J Asia Pac Entomol* **24**, 2 (2021)
14. F.A. Fleites-Ayil, L.A. Medina-Medina, J.J.G. Quezada Euán, E. Stolle, P. Theodorou, S. Tragust, and R.J. Paxton, *Biol Conserv* **284**, (2023)
15. C. Vaidya, G. Fitch, G.H.D. Martinez, A.M. Oana, and J. Vandermeer, *Agric Ecosyst Environ* **353**, (2023)
16. W.S.N. Wan Mohamad, K. Hassan, A. Awang, M.R. Mohd Nasir, N.H. Ramle, N. Ramlee, and H. Pulli, *Serangga* **25**, 2 (2020)
17. A. Assefa and M. Lemma, *Sci Afr* **15**, (2022)
18. G.T. de Paula, C. Menezes, M.T. Pupo, and C.A. Rosa, *Curr Opin Insect Sci* **44**, (2021)
19. Agussalim, N. Umami, Nurliyani, and A. Agus, *Saudi J Biol Sci* **29**, 10 (2022)
20. C.H. Yong, S.A. Muhammad, F.A. Aziz, F.I. Nasir, M.Z. Mustafa, B. Ibrahim, S.D. Kelly, A. Cannavan, and E.K. Seow, *Food Chem* **368**, (2022)
21. N. Ramlee, I. Said, W.S.N.W. Mohamad, K. Hassan, and R. Hasan, *AIP Conf Proc* **2347**, (2021)
22. N. Zawawi, J. Zhang, N.L. Hungerford, H.S.A. Yates, D.C. Webber, M. Farrell, U. Tinggi, B. Bhandari, and M.T. Fletcher, *Food Chem* **373**, Pt B (2022)
23. S.J. Kiprono, G. Mengich, J. Kosgei, C. Mutai, and S. Kimoloi, *Sci Afr* **17**, (2022)
24. F.G.B. Bueno, C.F. dos Santos, A. Otesbelgue, C. Menezes, J. van Veen, B. Blochtein, R. Gloag, T. Heard, V.L. Imperatriz-Fonseca, and D.A. Alves, *Insectes Soc* **70**, 1 (2023)
25. C.A. Mduda, J.M. Hussein, and M.H. Muruke, *Journal of Agriculture and Food Research* **14**, (2023)
26. M.Y. Abduh, A. Adam, M. Fadhlullah, R.E. Putra, and R. Manurung, *Heliyon* **6**, 11 (2020)