

## Feeding Behavior and Preferences of *Hemiplecta humphreysiana* and *Lissachatina fulica* (Gastropoda) to Support Heliciculture in Indonesia

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**Abstract.** The trend of Heliciculture for human consumption, animal feed, medicine, and nutraceuticals is rising globally. To gain a better knowledge on the Heliciculture of Indonesian land snails, we studied the daily activity with a focus on feeding behavior and the feed preference of two land snail species *Hemiplecta humphreysiana* (HH) and *Lissachatina fulica* (LF). The two species were selected because of their abundance in nature, as well as to compare behavior and preference between native (HH) and invasive (LF) species. Three days of daily activity observation was conducted by using a scan animal sampling method with 5 minutes intervals towards three individuals of HH and LF. The experiment on feeding preference was conducted towards ten individuals per species in 28 days of observation (14 days each for vegetables and fruits). Each individual was placed in different rearing boxes. A multiple-choice test method was applied and consisted of two treatments i.e. vegetable treatment (pakcoy, chicory, lettuce, cabbage) and fruit treatments (mango, cucumber, melon, papaya). The nutritional value from the observed feed was also analyzed. Based on the total of 51,840 minutes of observation records, both species were generally active from 21.00-03.00. HH was more active in moving when given vegetable treatment. The species preferred to feed on cucumber, melon, lettuce, and pakcoy. LF was more active in moving and feeding when treated with fruits. The species is more adaptive when given new feed and likes all four fruits, but preferred lettuce in the vegetable treatment. Both species prefer to feed with relatively high protein, high fiber, and moderate total carbohydrate content. Providing the right feed and at the right time can support the effectiveness of Heliciculture.

**Keywords:** behavior, feed, land snail, native and invasive species, snail farming

### Citation

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### INTRODUCTION

Since prehistoric times, snails have been consumed by humans and remain a delicacy-classy food in some countries, such as

Escargot (commonly refers as *Helix aspersa* or *Helix pomatia*) (Pissia et al., 2021; Conte, 2015; Massari & Pastore, 2014). Although the production and consumption of Escargot are increasing worldwide, the demand is met

only by 60-70% (Zubar & Onyshchuk, 2021). Another food product derived from snails is “snail caviar” which has been produced by some countries such as Poland, Bulgaria, Turkey, North Africa, and Chile (Massari & Pastore, 2014). The mucus of land snails contains active compounds beneficial for wound healing as well as for skin health and beauty which are now a new trend in the cosmetic industry (Rosanto et al., 2021; Ferdian, 2020; Laneri et al., 2019; Pitt et al., 2015; Ehara et al., 2002). The demand of all these snail products is growing and becoming a promising commodity in the future.

In 2015, the export value for snail meat reached US\$ 967,000 (Nurhayat, 2015). In 2018, Indonesia enters the second largest exporter in the world of snail meat which reached 1900 tons or 7.3% worldwide (Zubar & Onyshchuk, 2021). The capacity of Indonesia to export snails could be increased if the concept of Heliciculture is applied. Heliciculture or snail farming aims to optimize the production of snail so that the activity becomes more profitable, including harvesting snail meat, producing snail caviar, and secreting snail mucus (Conte, 2015; Massari & Pastore, 2014).

The concept of Heliciculture in Indonesia needs to be initiated because snail harvesting in Indonesia majorly depends on the season, they harvest directly from nature. This is not sustainable both for the business and the land snail population in the wild. Snail farming or heliciculture is a global trend that is more sustainable and more effective for the snail business. Heliciculture is also more profitable because it can generate a double and even triple profit from the initial investment (Morei, 2012). One of the important aspects of Heliciculture is feeding. The type of feed preferred and needed by the snail can affect the fitness of livestock (Douglas et al., 2005

According to Conte (2015), there are four known commercialized land snail species i.e. *Helix aspersa* which dominates the market (40%), *Helix pomatia* (28%), *Helix lucorum* (22%), and *Eobania vermiculata* (8.5%). *Helix aspersa* is the most economically profitable species because the species is large, easy to breed, and easy to be found in agricultural area (as pests). However, these species do not occur in Indonesia. The utilization of land snail in Indonesia is currently only focused on a single species *Lissachatina fulica* (Asian Escargot). This invasive species is cosmopolite species, produced much mucus, and has a high reproductivity rate (Pawson & Chase, 1984; Cobbinah et al., 2008). There are approximately more than 1800 land snail species in Indonesia (Hausdorf, 2019) and 263 species in Java alone (Nurinsiyah, 2021). Many large snails also potential to be utilized in a sustainable way for example *Hemiplecta humphreysiana*. The native species is widely distributed in Java and large in size (van Benthem Jutting, 1950), thus secretes quite much mucus.

Several important aspects in snail farming to prevent snail dormancy (inactive behavior) are selecting most favorable site for the snail farm, providing good housing for the snails (considering the air temperature, day length, and air humidity), providing good feed and ensuring good snail farm management (Cobbinah et al., 2008). Studies on land snail behavior and heliciculture in Indonesia are lacking. Therefore, to gain a better knowledge on this aspect, we studied the daily activity of two land snail species *L. fulica* and *H. humphreysiana*. The observation focused on feeding behavior and feed preference. In addition, we also analysed the nutritional value from the observed feed to summarize the nutrition needed by the land snails. The study provided basic information on the feeding behavior and

feed preference of *L. fulica* and *H. humphreysiana* to support the Heliciculture in Indonesia in particular and Malacology in general.

## MATERIALS AND METHODS

The research was conducted in January - April 2021 at the Research Center for Applied Zoology, National Research and Innovation Agency / BRIN (formerly Indonesian Institute of Sciences / LIPI), Cibinong, West Java. Two land snail species were used for observation: *Hemiplecta humphreysiana* (later abbreviated as HH), and *Lissachatina fulica* (later abbreviated as LF). Samples of HH were collected from Menoreh, Yogyakarta while LF were collected from Tangerang, Banten. Each individual samples were placed in a box with a size of 36 x 28 x 13 cm. Several holes were created on the lid of the boxes for air circulation. The selected samples were all in the adult stage to minimize the weight gap between samples. Every morning and evening, the cages were sprayed with water to maintain the humidity inside the cage. The cages were placed in a room with a maintained temperature between 26-27°C and air humidity of 70-80%. Temperature and air humidity are two important factors for the survival and growth rate of land snails (Pawson & Chase, 1984; Panha, 1988).

### Daily Activity Observation with Focus on Feeding Behavior

Three individuals each from HH and LF were observed for their daily activity using the scan sampling method for 3×24 hours with 5-minute intervals. Three main activities were recorded such as moving, resting, and feeding. More detailed behavior for instance resting place, feeding direction, etc were also recorded qualitatively. Each sample was placed in a different rearing box filled with selected

feed. There were two period of treatments: vegetable period and fruit period. Data obtained from each treatment period were analyzed using the following formula (modified from Martin and Bateson *in* Withaningsih et al., 2020):

$$\% \text{ Daily activity} = \frac{\text{Time allocation of main activity (minutes)}}{\text{Total observation time (minutes)}} \times 100\%$$

### Feed Preference Observation

Ten individuals each of HH and LF were treated with a feed preference experiment for 14 days with a multiple choice test approach. There were two periods of treatment i.e 14 days of vegetable treatment (vt) and 14 days of fruit treatment (ft). In between the treatment period, there was a break of 3 days with mixed feeding. The vegetable observation included cabbage (*Brassica oleracea* / bo), lettuce (*Lactuca sativa* / ls), pakcoy (*Brassica rapa subsp. chinensis* / brc) and chicory (*Brassica rapa subsp. pekinensis* / brp). Meanwhile, fruit observation includes papaya (*Carica papaya* / cp), melon (*Cucumis melo* / cm), cucumber (*Cucumis sativus* / cs), and mango (*Mangifera indica* / mi). Although the treatment period was 14 days, the feed was changed daily at 8-9 am.

There were two observations conducted in each treatment i.e. palatability and organoleptic observations. The palatability observation was based on the difference in the daily feed weight (Ferdian et al., 2020; Dos Santos et al., 2018; Ogbu et al., 2014). Fresh feed was weighed before given to the snails (before observation) and after 24 hours, the feed was weighed again (after observation). The difference of weight was calculated daily for every feed. The daily weight differences for each feed treatments were then analyzed towards the control treatment to determine whether they were statistically different from each other. This is to prevent bias whether the difference in feed weight was caused by feed-

ing activity or by natural events i.e., evaporation, decay, respiration, etc (Ferdian et al., 2020). Afterwards, we conducted ANOVA test to assess whether the difference in weight between feeds were significantly different. Furthermore, a post hoc test using TukeyHSD was conducted to determine the position of the differences and to identify the preferences of the snail towards the feed (Ferdian et al., 2020). All statistical analyses were performed using statistical software R (R Core Team, 2012).

Meanwhile, the organoleptic observation was based on the measurement from the number of bites on the leftover feed. The relative proportion of snail bites to the feed was illustrated in Figure 1 indicating (+) for bite response of 0-20%; (++) for bite response of 20-40%; (+++) for bite response of 40-60%; (+++++) for bite response of 60-80%; and (+++++) for bite response of 80-100% (Ferdian et al., 2020). The results of palatability and organoleptic analysis were scored 0-5 based on the Tukey test value for palatability observation and the number of bites for organoleptic observation. Finally, the preference of feed was calculated based on the addition of the palatability and organoleptic scores.

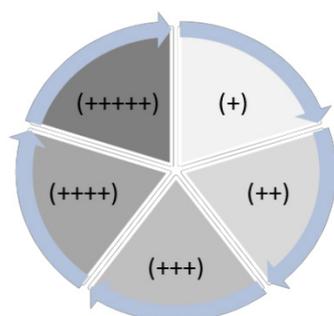


Figure 1. Illustration of bite response assessment (organoleptic) on leftover feed (Ferdian *et al.*, 2020)

### Proximate Analysis

Proximate analysis was conducted to obtain the nutrition data of the feed samples. All feed samples (cabbage, lettuce, pakcoy, chicory, papaya, melon, cucumber, and mango) were cut into small pieces and dried in an oven at a temperature of 60°C for 3 days or until dry (water content less than 10%). Afterward, the samples were removed from the oven and mashed with a blender. The mashed samples were filtered through a 60-mesh sieve (Ferdian et al., 2020). Data obtained from the proximate test in the laboratory was calculated using the AOAC method (2005). Protein, fat, carbohydrate, water content, and minerals were calculated for proximate analysis. Carbohydrate content was calculated using different method (Winarmo, 2004).

### RESULTS AND DISCUSSION

Three individuals from each *Hemiplecta humphreysiana* and *Lissachatina fulica* were observed for 3x24 hours. Total of 51,840 minutes activities was recorded and categorized into moving, resting, and feeding. The moving activity consisted of walking and observing the feed and its surroundings. The resting activity is defined as a non-active behavior. Both snails showed interesting resting behavior for instance hanging on the lid or wall of the box, retracting their body inside the shell and resting on the ground or between leaf litters, and burrowing. Meanwhile, recorded behavior for feeding activity was the length of feeding time and how they fed. Both species were recorded to have similar feeding strategies which were (1) approaching the new feed, (2) identifying the feed, (3) feeding or avoiding the feed, (4) observing/trying new feed, (5) returning to the most preferred feed and spend more time on feeding the most favourite feed. Both species showed different

behavior towards different feed, and they tend to have preferences in feeding.

### **Daily Activity of *Hemiplecta humphreysi-ana***

The daily activity of three HHs was observed when fed with vegetables (vt) and fruits (ft). In general, the species spends most of their time resting (63% vt; 72% ft) compared to moving (32% vt; 21% ft) and feeding (5% vt; 7% ft) (Figure 2). However, HH spends more time moving when given vegetables, and slightly spends more time feeding when given fruit. The activity also corresponds to the type of feed provided in the experiment. The species was most active in moving and feeding at night time. The result is congruent with observation towards the activity of *Hemiplecta distincta* in Thailand where it showed that the species is nocturnal (Panha, 1988). The cooler temperature (but not too low for tropical snails) stimulates the snail's activity including feeding (Cobbinah et al., 2008).

During the vegetable treatment, HH showed moving activity between 22.00-05.00. After resting for hours, HH was seen active again between 8.00-9.00. This was a response to the replaced vegetables in the rearing cage. HH mainly moves to observe the feed and its surroundings. Based on the observation of the feeding activity, HH favors pakcoy and lettuce compared to cabbage and chicory. The species took approximately 15 minutes to approach and taste lettuce before eating it. The chemoreceptors will touch the food and the radula will bite the vegetables. The tentacles will continue to move as the radula bites the feed. This process enables HH and snails in general to reject or approve the potential feed (Barker, 2001). Meanwhile, it took 20-30 minutes for HH to approach and taste pakcoy. HH was seen to approach other

vegetables and taste them for some minutes. Afterward, it would return to feed on pakcoy again. Throughout the day, HH spend most of the time resting. The typical non-active behavior of this species was hiding among the litter and on the ground or sometimes hanging on the side of the box or the lid. The longest record for HH to rest was 20 hours in a day. This happened at the beginning of the experiment which may be assumed that HH was still adapting to the new feed. In its habitat, HH can be found among the litter under weathered logs and at a maximum height of 2 m on artificial structures (Foon et al., 2014).

Meanwhile, in the fruit treatment, HH showed moving activity between 17.00-06.00 and peaked at the night. The feeding activity of HH in the fruit treatment was slightly higher compared to the vegetable treatment. Based on the observation of feeding activity, HH was able to taste and eat all provided fruits. However, the species favors cucumber the most compared to other fruits. The species could spend 30-45 minutes approaching, tasting, and eating cucumber. Afterward, the species would walk around the cucumber and feed on it again. The species were recorded to feed on papaya, mango, and melon, but it will come back to feed on cucumber. HH feeds on the softest part of the fruit first, for instance, the middle part of the fruit, before eating the whole fruit. After feeding, HH will rest near the fruit either on the ground or by hanging on the wall of the box. Similar to the beginning of the vegetable experiment, the longest record for HH to rest in the fruit experiment was during this period. The species was recorded to rest for 11 hours.

### **Daily Activity of *Lissachatina fulica***

The daily activities of three LFs were observed when fed with vegetables (vt) and fruits (ft). Similar to HH, LF spends most of

their time resting (80% vt; 69% ft) compared to moving (18% vt; 22% ft) and feeding (2% vt; 9% ft) (Figure 2). LF spends more time in moving and feeding when given fruit than vegetables. Although LF and most of land snails were nocturnal, thus more active at night, LF was also active in feeding around 08.00-09.00 in the morning and until 13.00. This was the time of fresh feed replacement.

During the vegetable treatment, LF showed moving activity between 20.00-06.00. Same with HH, LH mainly moves to observe the feed and its surroundings. Based on the observation of the feeding activity, LF feed all four vegetables but favors lettuce and pakcoy. The species fed all parts of the vegetables including the leaves and leaf veins. Although chicory and cabbage have thicker leaf veins, LF were recorded to feed on the vegetables with their radulae. Throughout the day, LF spend most of the time resting. The typical non-active behavior (resting) of this species were stayed on the ground, under litter or burying themselves in the ground. In nature, LF can be found buried underground to hide from predators and to keep their eggs (Vogler et al., 2013). The longest record for LF to rest was 20 hours in a day.

LF showed more moving activity when fed by fruit compared to vegetables which were between 19.00 at night and 12.00 at noon. The feeding activity of LF in the fruit treatment was also higher compared to the vegetable treatment. Based on the observation of feeding activity, LF was able to taste and eat all provided fruits. However, the species favors cucumber the most compared to other fruit. Unlike HH, LF only needed approximately 5 minutes to approach and taste new feed. Afterward, LF will observe, approach,

and taste other feed and then return to their favorite feed. After approximately 20 minutes, LF will rest near the feed. Although LF have fed a lot (seen from the number of minutes required to eat on one feed), the species was able to taste and feed other fruits and then come back to its favorite feed. LF did not have a patterned bites like HH which preferred to eat the softest part of the feed. LF could eat the hardest part of the feed. Usually, LF would eat the most reachable part of the feed from its position. From observing feeding activities with different types of feed, LF prefers fresh, soft, or soft textured feed and is able to accept new feed. In the fruit experiment, LF mainly rests during the day starting from 11.00 to 20.00. The longest record for LF to rest was during this period which was 14 hours.

The species of *Lissachatina fulica* and *Hemiplecta humphreysiana* are both most active during the night, thus they are both nocturnal species. Both species showed pre-feeding behavior. In this process, *H. humphreysiana* and *L. fulica* use their sense to smell the odor of the given food. It showed a learning process to adapt with new feed. Both species also showed preferences in the feeding behavior by returning to the most preferred food after tasting all the given food and resting or idling around the preferred food. In addition to the preferences, this also showed that the species have memories towards their preferred feed. There are several confounding factors in feeding strategy of land snails for instance physiology, learning ability, level of hunger, and new feed (Barker, 2001). In addition, the snail behavior was also influenced by temperature as seen in the species *Hemiplecta distincta* (Panha, 1988).

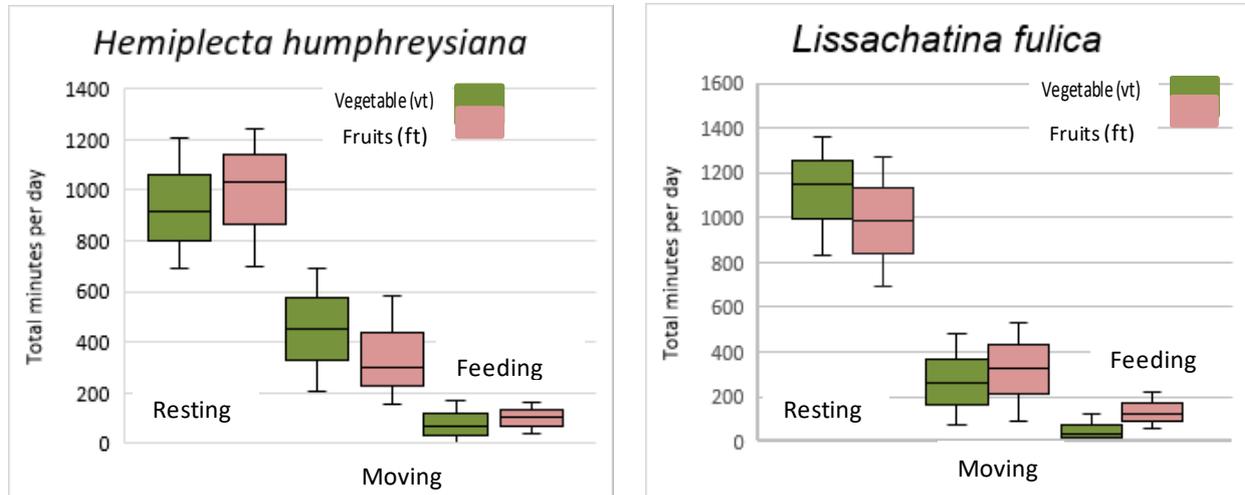


Figure 2. Comparison daily activity of *Hemiplecta humphreysiana* (left) and *Lissachatina fulica* (right) between vegetable and fruit treatments.

## Food Preference

### Palatability Observation

Two observations were conducted in the food preference treatment i.e. palatability and organoleptic observations. In the palatability observation, all eight types of feed were weighed daily before and after observation. The results of the weight difference were compared with the control and analyzed using two sample t.test to determine whether the difference occurred because it was eaten by the snails, or it was due to natural degradation (decay or evaporation). Results showed that the weight difference in all given fruits and vegetables were not due to natural degradation (table 1).

Based on the analysis of variance, the weight differences on fruits eaten by LF and HH showed a significant difference with  $F=3.66$  and  $pvalue=0.018$  for LF and  $F=49.02$  and  $pvalue=0.000$  for HH. The analysis also showed that the difference in weight of vegetables eaten by the two species showed significant difference with  $F=23.96$  and  $pvalue=0.000$  for LF and  $F=11.705$  and  $pvalue=0.000$  for HH. The results from both fruit and vegetable treatments showed that

the weight differences of these feeds were not equal. Thus, LF and HH did not feed on these fruits and vegetables in the same amount. They may have preferences towards a certain type of fruits and vegetables.

The results of multiple group comparisons from the post hoc analysis were shown in Figure 3. Based on the tukeyHSD test (Fig 3), there were groups of treatment which showed statistically significant differences and there were groups that did not show differences. The result of the post hoc test from fruit treatment in LF (Fig. 3i) showed all six intervals contained zero, except for a slight difference in mi-cs (mango-cucumber). In addition, the range of all intervals was too wide. Thus, we cannot justify the clear differences among the four fruits, perhaps only slightly in mango. Therefore, for the palatability observation on fruit treatment in LF, we can conclude that the species prefer all four fruits but slightly less on mango. Meanwhile, in the vegetable treatment, three groups showed significant differences (Fig. 3ii). The weight difference in lettuce showed statistically significant compared to the other three vegetables, and there was no significant difference between pakcoy,

cabbage, and chicory. This indicates that LF feeds more on lettuce compared to the others.

The result of Tukey HSD test from fruit treatment in HH (Fig. 3iii) showed only two groups that were not statistically significant i.e cs-cm (cucumber-melon) and mi-cp (mango and papaya). The result indicates that the species feed more on cucumber and melon

compared to mango and papaya. Meanwhile, in the vegetable treatment (Fig. 3iv), there were two groups that were not statistically significant i.e. brp-bo (pakcoy-cabbage) and ls-brc (lettuce-chicory). Based on the test, it indicates that HH feeds more on tender leaves on lettuce and pakcoy compared to cabbage and chicory.

Table 1. T.test Analysis for each feed treatment towards control treatment

Species	Chicory			pakcoy			Cabbage			Lettuce		
	t	df	pvalue	T	df	pvalue	t	df	pvalue	t	df	pvalue
<i>H. humphreysiana</i>	4.83	49.73	0.0000	5.84	151.74	0.0000	4.12	51.28	0.0001	4.63	60.42	0.0000
<i>L. fulica</i>	4.23	95.16	0.0001	7.42	151.52	0.0000	3.25	150.83	0.0014	7.81	140.58	0.0000

Species	Papaya			Melon			Cucumber			Mango		
	t	df	pvalue	T	df	pvalue	t	df	pvalue	t	df	pvalue
<i>H. humphreysiana</i>	7.24	104.59	0.0000	6.92	40.60	0.0000	15.19	151.60	0.0000	2.60	34.16	0.0137
<i>L. fulica</i>	5.97	152.00	0.0000	3.03	30.01	0.0050	12.53	137.52	0.0000	3.50	68.66	0.0008

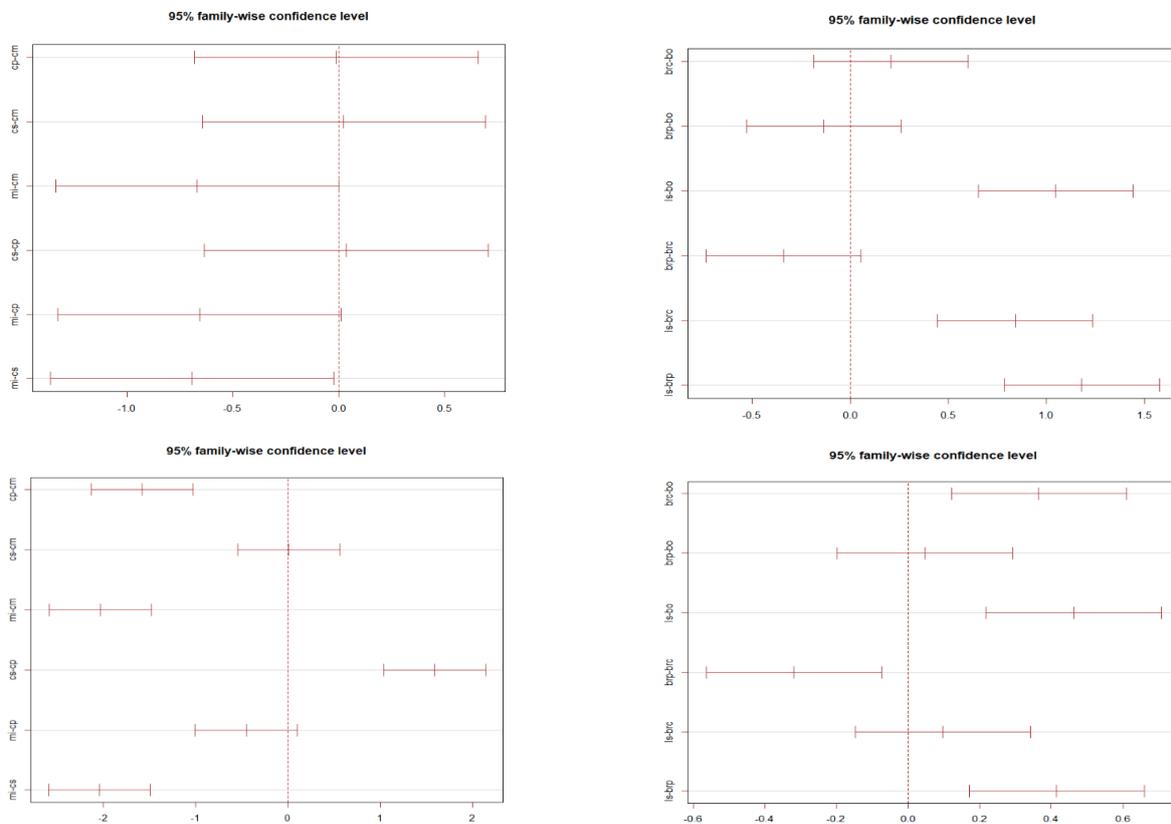


Figure 3. Results for Post Hoc Test. (i) fruit treatment on *L. fulica*; (ii) vegetable treatment on *L. fulica*; (iii) fruit treatment on *H. humphreysiana*; (iv) vegetable treatment on *H. humphreysiana*. bo: cabbage, brc: pakcoy, brp: chicory, cm: melon, cp: papaya, cs: cucumber, ls: lettuce, mi: mango.

*Organoleptic Observation*

The results of organoleptic observations were calculated based on the maximum bite found on the leftover of feed (Table 2). There were many bites found on all of the leftover fruits and vegetables from LF. However, on the latter treatment, LF has the least bites on chicory. The results of bite responses from HH were clearer in both treatments. The species bites more on papaya and cucumber compared to melon and mango. Meanwhile, the species had moderate bites on all given vegetables except on cabbage.

The scoring results, combining palatability and organoleptic observation results, showed the most preferred type of feed for LF and HH (Table 3). LF prefers all given fruits: papaya, cucumber, melon, and mango. However, based on the scoring result the species preferred the two former fruits compared to the latter. The scoring result for vegetable treatment showed that LF preferred lettuce compared to chicory, pakcoy, and cabbage. Meanwhile, HH preferred cucumber compared to the other three given fruits and pakcoy compared to the other three given vegetables.

Feeding preference is a crucial aspect of farming including Heliciculture. Based on the research, *H. humphreysiana* has more specific preferences in fruits and vegetables which were cucumber and pakcoy. A previous study conducted by Ferdian et al. (2020) using a non-choice test feeding experiment, also con-

cluded that HH preferred to feed cucumber, as well as tomato, oyster mushroom and papaya. Both cucumber and pakcoy are all seasons commodity which can be found throughout the year. In addition, cucumber and pakcoy are both available at relatively low prices. These are beneficial factors for Heliciculture.

Meanwhile, *L. fulica* can feed various given food and is very adaptive towards new feed. In the present study, LF behaves edacious towards all given vegetables and fruits. Similar to the present study, Albuquerque et al. (2008), also reported that LF preferred all given feed including *Hibiscus syriacus*, *Ricinus communis*, *Carica papaya*, *Galinsonga coccinea*, *Lippia alba*, *Ixora coccinea*, *Musa paradisiaca*, *Mentha spicata* and *Cymbopogon citratus*.

Land snails primarily eat fruits and leaves (Cobbinah et al., 2008). LF has a wider range of feed selection compared to HH. The Achatinids snail, including *Lissachatina*, feeds on organic detritus as hatchlings and continues to feed on plant materials as adults. The snails then feed more on detritus as they aged (Cobbinah et al., 2008). In some areas, the species were recorded feeding on horse and bull feces (Albuquerque et al., 2008). The Ariophantiniids, including *Hemiplecta*, is also herbivore. In addition, both groups feed on soil particles (Panha, 1987). All types of feed have phago-stimulant which attract the snails from its chemoreceptor (Croll & Chase, 1980; Gelperin, 1974).

Table 2. Result of organoleptic observation based on bite response

Feed Treatment		LF	HH
Fruits	Papaya ( <i>Carica papaya</i> )	(+++++)	(++++)
	Melon ( <i>Cucumis melo</i> )	(++++)	(++)
	Cucumber ( <i>Cucumis sativus</i> )	(+++++)	(+++++)
	Mango ( <i>Mangifera indica</i> )	(+++++)	(++)
Vegetables	Chicory ( <i>Brassica rapa subsp. pekinensis</i> )	(+++)	(+++)
	Pakcoy ( <i>Brassica rapa subsp. chinensis</i> )	(+++++)	(+++)
	Cabbage ( <i>Brassica oleracea</i> )	(+++++)	(+)
	Lettuce ( <i>Lactuca sativa</i> )	(+++++)	(+++)

Table 3. Scoring result from palatability and organoleptic observations

Feed Treatment	LF			HH		
	P	O	Total	P	O	Total
Fruits						
Papaya ( <i>Carica papaya</i> )	5	5	10	4	4	8
Melon ( <i>Cucumis melo</i> )	5	4	9	5	2	7
Cucumber ( <i>Cucumis sativus</i> )	5	5	10	5	5	10
Mango ( <i>Mangifera indica</i> )	4	5	9	4	2	6
Vegetables						
Chicory ( <i>Brassica rapa subsp. pekinensis</i> )	4	3	7	4	3	7
Pakcoy ( <i>Brassica rapa subsp. chinensis</i> )	4	5	9	5	3	8
Cabbage ( <i>Brassica oleracea</i> )	4	5	9	4	1	5
Lettuce ( <i>Lactuca sativa</i> )	5	5	10	5	3	7

### Proximate Analysis

The nutritional content of the feed was analyzed by proximate analysis. The patterns of the nutritional content of given vegetables and fruits were shown in table 4. Based on the scoring, HH prefers to eat cucumber than other fruits, and pakcoy than other vegetables. The nutrition content on both preferred feeds of HH showed they have high protein, high fiber, and moderate total carbohydrate compared to others. Based on the scoring LF likes to eat all given fruits but prefers papaya and cucumber. LF also preferred to eat lettuce on vegetable treatment. The nutritional pattern of these preferred feeds was having high protein, high fiber, and moderate total carbohydrate. Thus, LF tends to have similar nutritional pattern to HH.

Nutrition derived from food such as carbohydrates, cellulose, amino acids, fatty acids, mineral salt, and vitamins are essential for land snail development (Barker, 2001). These nutrients are essential for metabolism and biochemical activity inside the body. Animals, including snails, eat the food for gaining the

nutrients so that they can perform the biological process. The food preference in animals distinguishes appetite from non-appetite (Dos Santos et al. 2018). The appetite of animals is physiologically complicated, but mostly might be affected by their instinct to choose any food that is sufficient for their nutrition need. They need to complete the nutrition requirement to reach their fitness, both for daily activity and reproductivity. Carbohydrates and protein are needed for land snails respectively for energy supply and growth. They also need calcium for shell development as well as minerals and vitamins (Cobbinah et al., 2008). The difference in feeding preference between HH and LF might not be caused by the nutrition content inside the preferred food, but by the texture, smell, or taste. The nutrition pattern inside the preferred food is useful information as a consideration for providing feed in Helicicultureis. Feeding behavior, feeding preferences as well as nutritional requirements are important information for sustainable heliciculture.

Table 4. Results of proximate analysis from fruits and vegetables treatments.

Sample	Dry Weight %	Ash	Protein	Fat	Fiber	Carbohydrate
		Content	Content	Content	Content	Content
-----100% Dry Weight -----						
Chicory ( <i>Brassica rapa subsp. Pekinensis</i> )	81.24	9.24	31.24	1.2	13.88	39.56
Cabbage ( <i>Brassica oleracea</i> )	87.2	7.89	19.39	1.05	12.05	58.87
Lettuce ( <i>Lactuca sativa</i> )	88.83	15.27	26.5	2.86	16.54	44.2
Pakcoy ( <i>Brassica rapa subsp. Chinensis</i> )	86.28	14.53	32.12	3.08	10.87	36.55
Cucumber ( <i>Cucumis sativus</i> )	77.71	8.49	22.09	0.78	15.47	46.35
Papaya ( <i>Carica papaya</i> )	84.92	3.17	4.09	0.66	4.39	77
Melon ( <i>Cucumis melo</i> )	82.09	9.58	8.04	0.17	8.77	64.3
Mangga ( <i>Magnifera indica</i> )	82.22	3.01	4.78	1.94	5.28	72.49

## CONCLUSION

Based on the current research, two land snail species *Lissachatina fulica* and *Hemiplecta humphreysiana* were both active at nighttime (nocturnal). *L. fulica* in general was more active when fed with fruits. It would approach and taste new feed, and in the end, spend a long time feeding on the most favorite fruits. This strategy is also seen in *H. humphreysiana* even though the species needs more time in approaching new feed compared to *L. fulica*. Between mango, melon, papaya, and cucumber, *L. fulica* preferred to feed papaya and cucumber while *H. humphreysiana* preferred cucumber more. Meanwhile, in the vegetable treatment, *L. fulica* preferred lettuce and *H. humphreysiana* preferred pakcoy among the four given vegetables which are chicory, pakcoy, cabbage, and lettuce. Both *H. humphreysiana* and *L. Fulica* prefer to feed with relatively high protein, high fiber, and moderate total carbohydrate content.

## AUTHOR CONTRIBUTION

The authors in the manuscripts have contributed equally in the research.

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## CONFLICT OF INTEREST

This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue. Authors certify that we have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; member-

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## REFERENCES

- AOAC. (2005). Official Methodes of Analysis of The Association Of Official Analytical Chemists (Fifteenth, Vol. 1, Issue Volume 1). Virginia, United States of America: Association of Official Analytical Chemists.
- Albuquerque, F. S., Peso-Aguiar, M. C. & Assunção-Albuquerque, M. J. T. (2008). Distribution, Feeding Behaviour and Control Strategies of The Exotic *Achatina fulica* (Gastropoda: Pulmonata) in the northeast of Brazil. *Brazilian Journal of Biology*, 68(4), 837-842. DOI: 10.1590/S1519-69842008000400020.
- Barker, G. (2001). *The Biology of Terrestrial Molluscs*. New York: CAB International.
- Cobbinah, J. R., Vink, A. & Onwuka, B. (2008). Snail farming: production, processing and marketing. *Agrodok-series* 47.
- Conte, R. (2015). Heliciculture : Purpose and Economic Perspectives in The European Community. The Official Journal of the Institute of Science and Techonology. Retrived from [https://www.researchgate.net/publication/275030005\\_Heliciculture\\_purpose\\_and\\_economic\\_perspectives\\_in\\_the\\_European\\_community](https://www.researchgate.net/publication/275030005_Heliciculture_purpose_and_economic_perspectives_in_the_European_community).
- Croll, R. P. & Chase, R. (1980). Plasticity of Olfactory Orientation to Foods in The Snail *Achatina fulica*. *Journal of Comparative Physiology*, 136, 267–277.
- Douglas, S. J., Dawson-Scully, K. & Sokolowski, M. B. (2005). The Neurogenetics and Evolution of Food-Related Behaviour. *Neurosciences*, 28(12), 644–652. DOI: 10.1016/j.tins.2005.09.006
- Dos Santos, L., Barbosa-Negrisoni, C. R. d. C., dos Santos, M. B. & Junior, A. S. N. (2018). Population Fluctuation and Food Preference of African Snail by Horticulture Crops. *Arquivos do Instituto Biológico*, 85, 1-8. DOI: 10.1590/1808-1657000402017
- Ehara, T., Kitajima, S., Kanzawa, N., Tamiya, T. & Suchiya, T. T. (2002). Antimicrobial Action of Achacin is Mediated by L-amino Acid Oxidase Activity. *FEBS letters*, 531(3), 509-512. DOI: 10.1016/S0014-5793(02)03608-6.
- Ferdian, P. R. (2020). Minireview : Lendir Keong Darat Indonesia Sebagai Sediaan Nutricosmeceutical : Peluang dan Tantangan. Prosiding Seminar Nasional Biologi Di Era Pandemi COVID-19. UIN Aladuddin Makassar, 6(1), 350–354.
- Ferdian, P. R., Handayani, T. H., Amalia, R. L. R. & Nurinsiyah, A. S. (2020). Studi Pendahuluan Penentuan Jenis Pakan Alternatif Keong Darat Asal Monereh, Yogyakarta: *Amphidromus palaceus*, *Dyakia rumphii*, dan *Hemiplecta humphreysiana*. *Zoo Indonesia*, 29(2), 151–165.
- Foon, J. K., Tan, S. K., Chan, S. Y., Nguang, L. H. S. & Low, M. E. Y. (2014). Tree-Climbing Behavior of The Land Snail *Hemiplecta humphreysiana*. Singapore *Biodiversity Records*, 52–53.
- Gelperin, A. & Tank, D. W. (1994). Odour-Modulated Collective Network Oscillations of Olfactory Interneurons in A Terrestrial Mollusc. *Nature*, 345, 437–440. DOI: 10.1038/345437a0.

- Hausdorf, B. (2019). Beyond Wallace's line – dispersal of Oriental and Australo-Papuan Land-Snails across the Indo-Australian Archipelago. *Zoological Journal of the Linnean Society*, 185(1), 66-76. DOI: 10.1093/zoolinnea/zly03.
- Laneri, S., Di Lorenzo, R., Sacchi, A. & Dini, I. (2019). Dosage of Bioactive Molecules in The Nutricosmeceutical Helix Aspersa Muller Mucus and Formulation of New Cosmetic Cream With Moisturizing Effect. *Natural Product Communications*, 14(8), 1–7. DOI: 10.1177/1934578X19868606.
- Martin, P. & Bateson, P. (1988). *Measuring Behavior an Introduction Guide*. Cambridge: Cambridge University Press.
- Massari, S. & Pastore, S. (2014). *Heliciculture and Snail Caviar: New Trends in The Food Sector*. In: M. Miśniakiewicz, S. Popek (eds.) *Commodity Science in Research and Practice – Future trends and challenges in the food sector*, Polish Society of Commodity Science, Cracow, pp. 79-90. ISBN 978- 83-940189-0-0.
- Morei, V. (2012). Heliciculture, Perspective Business in The Context of Sustainable Development of Rural Areas. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, 12(3), 113-118.
- Nurhayat, W. (2015). Bekicot dan ubur-ubur RI Laku di Jepang Hingga ke AS. Retrieved from <https://finance.detik.com/berita-ekonomi-bisnis/d-2942992/bekicot-dan-ubur-ubur-ri-laku-di-jepang-hingga-ke-as> [18/11/2021].
- Nurinsiyah, A. S. (2021). List of Land Snails in Java and Several Adjacent Islands. *Treubia*, 48(2), 153-170. DOI: 10.14203/treubia.v48i2.4270
- Ogbu, C. C., Ani, A. O. & Emeh, M. (2014). Feed Preferences and Feeding Behavior of Two Species of African Giant Land Snails. *Archivos de Zootecnia*, 63(242), 337-347. DOI: 10.4321/S0004-05922014000200012.
- Panha, S. (1987). The Breeding Data of Thai edible Land Snail *Hemiplecta distincta* (Pfeiffer) (Pulmonata: Ariophantidae). *Venus*, 46(1), 25-34. DOI: 10.18941/venusjmm.46.1\_25.
- Panha, S. (1988). Effect of Temperature of The Growth and Behavior of A Tropical Land Snail *Hemiplecta distincta* (Pfeiffer) (Gastropoda: Ariophantidae). *Venus*, 47(3), 197-206.
- Pawson, P. A. & Chase, R. (1984). The Life-Cycle and Reproductive Activity of *Achatina fulica* (Bowdich) in Laboratory Culture. *Journal of Molluscan Studies* 50, 85-91. DOI: 10.1093/oxfordjournals.mollus.a065855.
- Pissia, A. M., Matsakidou, A. & Kiosseoglou, V. (2021). Raw Materials from Snails for Food Preparation. *Future Foods* 3, 1-10. DOI: 10.1016/j.fufo.2021.100034.
- Pitt, S. J., Graham, M. A., Dedi, C. G., Taylor-Harris, P. M. & Gunn, A. (2015). Antimicrobial Properties of Mucus From The Brown Garden Snail *Helix aspersa*. *British Journal of Biomedical Science*, 72(4), 174-181. DOI: 10.1080/09674845.2015.11665749.
- R Core Team. (2012). *A language and Environment for Statistical Computing*, Version 2.15.2. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from <http://CRAN.R-project.org/>.
- Rosanto, Y. B., Hasan, C. Y., Rahardjo, R. & Pangestingsih, T. W. (2021). Effect of Snail Mucus on Angiogenesis During Wound Healing (Version 2; Peer Review: 1 Approved with Reservation). *F1000Research* 2021, 10, 181. DOI:

- 10.12688/f1000research.51297.1
- Van Benthem Jutting, W. S. S. (1950). Systematic Studies on the Non-Marine Mollusca of the IndoAustralian Archipelago. II. Critical Revision of the Javanese Pulmonate Land-shells of the Families Helicarionidae, Pleurodontidae, Fruticolidae and Streptaxidae. *Treubia*, 20, 381–505.
- Vogler, R. E., Beltramino, A. A., Sede, M. M., Gregoric, D. E. G., Núñez, V. & Rumi, A. (2013). The Giant African Snail, *Achatina fulica* (Gastropoda: Achatinidae): Using Bioclimatic Models To Identify South American Areas Susceptible To Invasion. *American Malacological Bulletin*, 31(1), 39–50. DOI: 10.4003/006.031.0115.
- Winarmo. (2004). *Kimia pangan dan Gizi*. Jakarta: Gramedia Pustaka Utama.
- Withaningsih, S., Parikesit & Fazriani, Y. N. 2020. Pola aktivitas harian rusa (*Cervus timorensis*, Blainville, 1822) di penangkaran rusa Cagar Alam Pananjung Pangandaran. *Biotika*, 18 (1), 17-24.
- Zubar, I. & Onyshchuk, Y. (2021). Prospects of Heliciculture Development as An Innovative Industry of Agriculture in Ukraine. *The Scientific Heritage*, 60, 18-27. DOI: 10.24412/9215-0365-2021-60-3-18-27.