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Distribution, density and nutritional value of *Pomacea canaliculata* Snail at several locations in Bali, Indonesia

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ABSTRACT

Rice fields are one of the habitats for the golden apple snails (*Pomacea canaliculata*). The snails also spread in several rice fields in Bali. This research aimed to determine the density, distribution pattern, presence frequency and the nutritional value of golden apple snails from several locations in Bali. Golden apple snails were collected at an altitude of <100m and >500m above sea level in three districts in Bali. In each district, golden apple snail was taken in two locations at each altitude and in three rice fields at each location. The collections of golden apple snail were carried out in a 1x1m quadrate plot. The snails was taken to the laboratory and counted, the morphological characters were observed including the morphometry. The body of the golden apple snail is made into flour and its nutritional value was analyzed. The results showed that the density of the golden apple snail at an altitude of <100m tends to be higher than at an altitude of >500m. The highest density was 10.42 ind/m^2 and the lowest was 1.5 ind/m^2. The presence frequency was absolute with a value of 75-100%. Group distribution patterns were found at nine locations and regular patterns at three locations. Crude protein in locations with an altitude <100m tends to be higher (48.14-51.88%) than an altitude >500m (41.07-43.38%). Amino acid content is 0.17-1.32%, calcium 5.66 - 9.32% and phosphorus 0.18 - 0.40%.

1. Introduction

The golden apple snails (*Pomacea canaliculata*) is a freshwater snails, belonging to the genus Pomacea, family Ampullariidae, phylum Mollusc (Sugianti et al. 2014; Baoanan and Pagulayan 2006). The snails were widely introduced from their natural habitat (South America) through the aquarium trade (Sugianti et al. 2014) and then introduced to Asia, the first time was in Taiwan around 1980s. These snails are important invasive snail because their presence is a pest in America, the Caribbean and South Asia (Baoanan and Pagulayan 2006). Currently, golden apple snails are still a threat to farmers, especially in their distribution areas, including: Java, Sumatra, Kalimantan, West Nusa Tenggara (NTB), and Bali. According to Budiyono (2006), damage to rice plants caused by golden apple snails is about 10-40%.

Golden apple snails have high adaptability in various types of inland water habitats. This causes its spread very widely (Isnaningsih and Marwoto, 2011) and can spread rapidly in agricultural areas to wetlands and other natural freshwater system (Sugianti et al. 2014). Adnyana et al. (2018) found the largest number of egg and small snail populations in all phases of the rice plant in the Jembrana district, Bali province with group distribution pattern in all age snails. There are no many data for golden apple snails in other districts.

Environmental factors influence the growth of golden apple snails. These environmental factor various at different altitudes. Temperature is a factor that greatly influences the growth and feeding rate of golden apple snails (Memon et al. 2011). Temperature, age, sexual maturity, food, and habitat affect the variability of the nutritional content of golden apple snails (Periyasamy et al. 2011).

The distribution of golden apple snails and their ability to damage rice crops has become a problem. These snails are a major pest because of their very high growth and reproductive capacity, which can have a drastic impact on crop yields (Salleh et al. 2012). An alternative to reducing the impact of the golden apple snail population is to use it for economic value, including as a mixture of animal feed because golden apple snails have good nutritional value. This fact encourages this research to be carried out to determine the distribution pattern, density, presence frequency of golden apple snails in several locations in Bali, including their nutritional value.

2. Materials And Methods

Study area

Golden apple snails were collected in the districts of Badung, Gianyar and Karangasem, Bali province from June to August 2020. In each district, snails were collected at an altitude of <100m above sea level (lowland) and >500m (highland). Snails were taken at two locations at each altitude (Figure. 1). Sampling at an altitude of <100m is in Badung districts (Pererenan, at coordinates 08°37’773"S, 115°07’775"E and Cemagi, at coordinates 08°38’40"S, 115°06’648"E), Gianyar districts (Tulikup, at coordinates 08°34’352"S, 115°21’758"E and Ketewel, at coordinates 08°38’363"S, 115°16’961"E) and Karangasem districts (Bugbug, at coordinates 08°29’549"S, 115°35’341"E and Tumbu, at coordinates 08°37’923"S, 115°37’923"E). Sampling at an altitude of >500m is in Badung districts (Pangsan, at coordinates 08°24’499"S, 115°12’867"E and Petang, at coordinates 08°23’943"S, 115°13’047"E), Gianyar districts (Sebatu, at coordinates 08°322’110"S, 115°18’466"E and Taro, at coordinates 08°21’561"S, 115°18’291"E) and Karangasem districts (Duda, at coordinates 08°26’985"S, 115°29’112"E and at coordinates 08°29’150"S, 115°29’150"E).

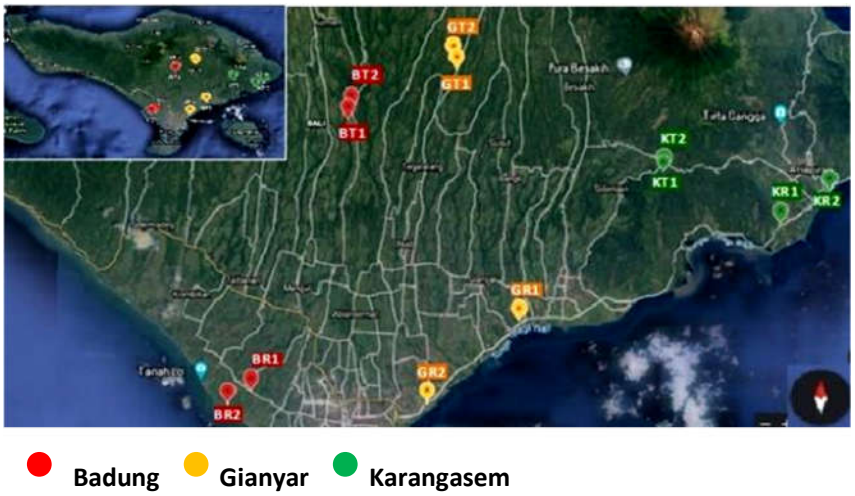

Figure 1. The location for sampling snails
Note: BR1 (Pererenan), BR2 (Cemagi), GR1 (Tulikup), GR2 (Ketewel), KR1 (Bugbug), KR2 (Tumbu), BT1 (Pangsan), BT2 (Petang), GT1 (Sebatu), GT2 (Taro), KT1 dan KT2 (Duda)

Sampling technique

Golden apple snails were taken in three paddy fields in each location with less than one month old of rice plants. In each rice field, snails were taken on four quadrate plots with a size of 1x1m. Snails in each quadrate were collected and stored in a container and brought to the laboratory. In addition, environmental factors were measured at each location to understand their influence on the distribution of snails.

In the laboratory, the golden apple snails from each location were counted and their morphological and morphometry characters were observed. After this step, the snails from each location are boiled for 15 minutes and then separated between the shell and the body. The body of the snail were sliced into small sizes and dried in the sun to dry, then grounded into flour. The nutrient content of the snail flour was analyzed, including amino acids at Laboratory of Animal Food Nutrition, Faculty of Animal Husbandry, Udayana University and at the Laboratory of Feed Science and Technology, Division of Feed Science and Technology, Department of Animal Nutrition and Feed Technology, Faculty of Animal Science, Bogor Agricultural Institute.

Data analysis

The density of golden apple snails at each location were calculated and converted into ind/m^2 using the Brower and Zar (1990) formula:

$D = Ni/A$

Where, D: number of individuals per unit area (ind/m^2); Ni: number of individuals in the quadrate; A: area quadrate (m^2).

The presence frequency is a value that states the number of presence of a species in a habitat and is calculated using the formula:

Presence frequency = the number of quadrate plots where the species were found/ the total number of quadrate plot.
Where, value 0-25%: presence frequency very rare; 25-50%: rare; 50-75%: moderate; 75-100%: absolute.

Distribution pattern of golden apple snails at each location was calculated using the Morisita index, with the formula:

$$Id = n\,[\sum xi^2 - \sum xi\,/\,(\sum xi)^2 - \sum xi]$$

Where, Id: Morisita index; n: sum of all quadrate; xi: number of individuals. Index value terms; Id = 1: random; Id>1: group; Id<1 regular distribution of species.

3. Results and Discussion

Results

The density, presence frequency and distribution pattern

Golden apple snail density is different in each location. The density of the snails in the lowlands tends to be higher than in the highlands. The highest density was found at BR2 (Cemagi) with an average density of 10.42 ind/m^2 while the lowest density was found at KT2 (Duda) with an average density of 1.5 ind /m^2.

The presence frequency of golden apple snails is between 75% and 100%. The lowest presence frequency was at KT2 with a value of 75%. The highest was 100% found in BR1, BR2, GR1, GR2, KR1, KR2, BT1, BT2 and GT2. While the other two locations had presence frequency values of 83.33% (GT1) and 91.67% (KT1). Based on this value, the presence of snails in all locations is absolute because the value is in the range of 75-100%. Range 50-75% (moderate), 25-50% (rare) and 0-25% very rare.

Table 1. Density and presence frequency of golden apple snails

Variable	Location											
	BR1	BR2	GR1	GR2	KR1	KR2	BT1	BT2	GT1	GT2	KT1	KT2
Density (ind/m^2)	5.33	10.42	5.50	8.92	7.92	6.42	6.92	3.67	3.08	4.08	2.50	1.50
Presence frequency (%)	100	100	100	100	100	100	100	100	83.33	100	91.67	75

Note: BR1 (Pererenan), BR2 (Cemagi), GR1 (Tulikup), GR2 (Ketewel), KR1 (Bugbug), KR2 (Tumbu), BT1 (Pangsan), BT2 (Petang), GT1 (Sebatu), GT2 (Taro), KT1 dan KT2 (Duda)

The Morisita index (Id) of all locations is <1 and >1. Based on the Id value, there are two distribution patterns, namely regular and group. The regular distribution pattern is for the Id<1 and the group distribution pattern for the Id>1. The group distribution pattern is the most common found. The pattern was found in nine locations (BR1, BR2, GR1, GR2, KR1, BT1, BT2, GT1 and KT2), while the regular distribution pattern was found in three locations (KR2, GT2 and KT1).

Table 2. The distribution pattern of golden apple snails

Location	Morisita Indexs (Id)	Distribution pattern
BR1	1.20	Group
BR2	1.23	Group
GR1	1.14	Group
GR2	1.57	Group
KR1	1.07	Group
KR2	0.99	Regular
BT1	1.20	Group
BT2	1.13	Group
GT1	1.05	Group
GT2	0.90	Regular
KT1	0.99	Regular
KT2	1.10	Group

Note: BR1 (Pererenan), BR2 (Cemagi), GR1 (Tulikup), GR2 (Ketewel), KR1 (Bugbug), KR2 (Tumbu), BT1 (Pangsan), BT2 (Petang), GT1 (Sebatu), GT2 (Taro), KT1 dan KT2 (Duda),

Golden apple snails from each location were grouped into two groups with reference to Wada *et al.* (2004). Snails with a shell height <25 mm are classified as juvenile and 25 mm or more are classified as adult. The percentage of juvenile and adult snails at KT1 (Duda) showed a fairly large difference (10% juvenile and 90% adults).

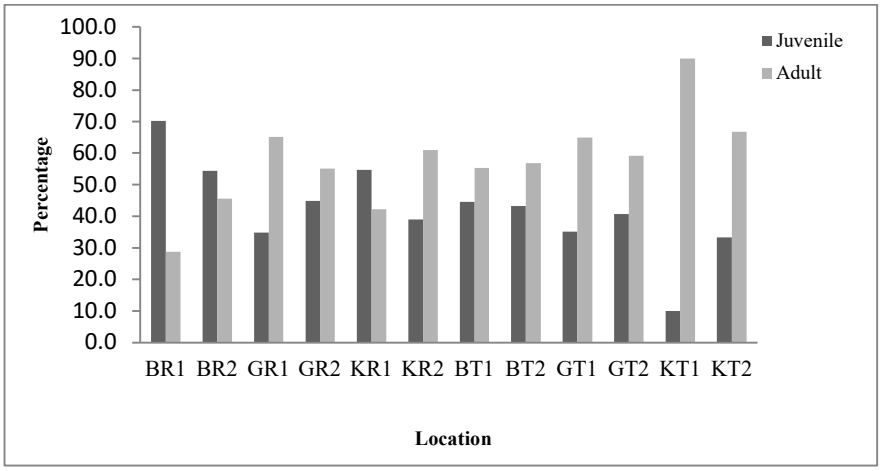

Figure 2. Percentage of juvenile and adult snails found at each location
Note: BR1 (Pererenan), BR2 (Cemagi), GR1 (Tulikup), GR2 (Ketewel), KR1 (Bugbug), KR2 (Tumbu), BT1 (Pangsan), BT2 (Petang), GT1 (Sebatu), GT2 (Taro), KT1 dan KT2 (Duda),

Environmental factors at each location were measured at the time of taking the golden apple snail. The results show differences in environmental factors between locations including lowlands and highlands. Dissolved oxygen (DO) in the lowlands tends to be lower than the highlands. The lowest DO was measured at the KR2 (4.0 mg/L) and the highest at the BT2 (9.4 mg/L). Water temperature and air temperature in the lowlands tend to be higher than those in the highlands. The water pH is not much different at each altitude, while the water depth in some highland locations is higher than in the lowlands.

Table 3. Environmental factors at each location.

Environmental factor	Location											
	BR1	BR2	GR1	GR2	KR1	KR2	BT1	BT2	GT1	GT2	KT1	KT2
Dissolved Oxygen (mg/L)	6.1	5.8	7.4	7.6	4.9	4.0	8.7	9.4	7.1	8.3	8.7	8.4
Water pH	7.2	6.7	6.7	7.0	7.0	7.0	6.7	6.7	6.7	6.5	6.7	6.8
Water temperature (°C)	25.7	25.0	25.2	25.0	25.3	26.7	24.7	22.2	20.2	21.0	22.3	22.5
Water depth (cm)	6.8	7.2	6.4	7.8	7.7	4.3	8.3	9.2	7.0	9.3	10.5	6.8
Air temperature (°C)	25.0	26.0	25.0	27.0	26.0	26.8	19.0	21.0	19.0	19.0	22.0	24.3
Humidity (%)	88.0	88.0	84.0	88.3	84.0	79.2	82.2	89.0	94.5	93.5	88.0	84.3

Note: BR1 (Pererenan), BR2 (Cemagi), GR1 (Tulikup), GR2 (Ketewel), KR1 (Bugbug), KR2 (Tumbu), BT1 (Pangsan), BT2 (Petang), GT1 (Sebatu), GT2 (Taro), KT1 dan KT2 (Duda),

Nutritional value

The nutritional value based on proximate analysis showed that the crude protein of golden apple snails in all locations ranged from 41.07 to 51.88%. The crude protein of the snails in lowland tends to be higher (48.14-51.88%) compared to the crude protein in highland (41.07-43.38%). Crude fiber content at all locations was 0.39-12.6%. Crude fiber in the lowlands tends to be lower (0.39-1.98%) compared to the highlands (7.69-12.6%). Meanwhile, crude fat content did not show a large variation between the lowlands and the highlands where the range of crude fat was 16.50-19.88%.

Table 4. Nutritional value of golden apple snails

Variable	Location											
	BR1	BR2	GR1	GR2	KR1	KR2	BT1	BT2	GT1	GT2	KT1	KT2
Dry weight (%)	18.77	14.44	16.2	18.31	14.64	16.25	12.79	12.56	18.84	17.11	14.85	18.14
Dry matter (%)	87.33	86.39	87.06	88.02	84.74	83.62	87.76	87.34	88.89	89.14	87.12	88.06
Ash (%)	10.78	10.33	11.81	12.19	11.16	11.97	12.55	12.77	12.82	12.62	13.2	12.76
Organic ingredient (%)	89.22	89.67	88.19	87.82	88.84	88.03	87.45	87.23	87.18	87.38	86.8	87.24
Crude protein (%)	51.88	51.24	48.14	51.56	52.47	48.45	43.38	43.02	41.62	41.21	41.07	43.37
Crude fiber (%)	0.39	0.62	1.96	1.98	1.73	1.85	11.76	11.09	8.83	7.69	12.6	9.56
Cr ude fat (%)	19.46	19.88	18.75	17.93	18.81	19.81	18.69	18.29	16.5	17.79	18.18	18.21

Nitrogen-free extract (NFE) (%)	4.83	4.33	6.39	4.35	0.57	1.53	1.38	2.17	9.12	9.83	2.07	4.15
Total digestible nutrient (%)	97.72	97.69	93.48	92.52	94.07	94.92	71.86	72.9	75.85	79.79	69.44	76.16
Gross Energy (K.cal/g)	3.71	3.79	3.99	3.39	3.93	3.64	3.67	3.54	3.61	3.25	3.59	3.34

Note: BR1 (Pererenan), BR2 (Cemagi), GR1 (Tulikup), GR2 (Ketewel), KR1 (Bugbug), KR2 (Tumbu), BT1 (Pangsan), BT2 (Petang), GT1 (Sebatu), GT2 (Taro), KT1 dan KT2 (Duda),

The result of amino acid analysis of golden apple snails showed that the content of glutamic acid was the highest, which was above 1% (1.03-1.32%). Percentage of other amino acids is below 1% (0.17-0.87%). Lysine is higher (0.63-0.87%) than methionine (0.24-0.44%). The calcium content is higher (5.66-9.32%) than phosphorus (0.18-0.40%).

Table 5. Amino acids, calcium and phosphorus of golden apple snails (%)

Variable	Location											
	BR1	BR2	GR1	GR2	KR1	KR2	BT1	BT2	GT1	GT2	KT1	KT2
Amino acid												
Aspartat acid	0.46	0.50	0.68	0.72	0.53	0.47	0.77	0.68	0.52	0.50	0.62	0.59
Glutamic acid	1.13	1.06	1.29	1.29	1.23	1.27	1.24	1.14	1.13	1.03	1.32	1.29
Serin	0.18	0.23	0.39	0.35	0.27	0.30	0.51	0.48	0.36	0.28	0.42	0.42
Glysin	0.27	0.28	0.37	0.36	0.39	0.36	0.62	0.58	0.30	0.22	0.34	0.38
Histidine	0.33	0.30	0.40	0.37	0.42	0.39	0.43	0.38	0.37	0.32	0.46	0.43
Arginine	0.24	0.28	0.32	0.29	0.26	0.29	0.34	0.28	0.27	0.21	0.32	0.28
Threonine	0.28	0.24	0.37	0.40	0.50	0.47	0.28	0.31	0.32	0.29	0.42	0.49
Alanine	0.19	0.28	0.27	0.22	0.37	0.27	0.34	0.42	0.17	0.21	0.27	0.31
Proline	0.37	0.40	0.42	0.39	0.51	0.44	0.41	0.46	0.37	0.31	0.41	0.47
Tyrocine	0.25	0.27	0.27	0.31	0.24	0.19	0.39	0.41	0.19	0.24	0.27	0.29
Valine	0.29	0.26	0.39	0.32	0.37	0.29	0.30	0.37	0.34	0.29	0.34	0.38
Methionine	0.32	0.37	0.44	0.38	0.24	0.28	0.30	0.39	0.37	0.27	0.31	0.31
Cysteine	0.24	0.24	0.27	0.31	0.52	0.44	0.31	0.28	0.26	0.22	0.39	0.47
Isoleucine	0.27	0.19	0.37	0.30	0.34	0.27	0.43	0.39	0.25	0.32	0.25	0.32
Leucine	0.68	0.70	0.78	0.78	0.77	0.69	0.78	0.74	0.62	0.59	0.73	0.74
Phenilalanin	0.31	0.29	0.47	0.41	0.32	0.39	0.35	0.29	0.22	0.34	0.29	0.38
Lysine	0.78	0.67	0.86	0.85	0.63	0.70	0.83	0.77	0.77	0.82	0.87	0.84
Mineral												
Calsium	8.94	8.42	8.95	9.27	6.87	6.18	5.66	7.48	7.43	6.21	8.40	9.32
Phosphor	0.18	0.40	0.18	0.22	0.21	0.19	0.20	0.19	0.19	0.21	0.21	0.20

Note: BR1 (Pererenan), BR2 (Cemagi), GR1 (Tulikup), GR2 (Ketewel), KR1 (Bugbug), KR2 (Tumbu), BT1 (Pangsan), BT2 (Petang), GT1 (Sebatu), GT2 (Taro), KT1 dan KT2 (Duda),

Discussion

The density, presence frequency and distribution pattern

Golden apple snails were found in all locations with various densities. The presence and density of snails in a habitat is influenced by environmental factors. Environmental factors at each location (Table 3) are in the range of environmental factors needed for the life of the golden apple snail. Water temperatures of all locations were 20.2-26.7°C and pH 6.5-7.2. Riyanto (2003) stated that the water temperature ranges for golden apple snails were 23-32°C and pH 5-8.

The density of golden apple snails (Table 1) at lowland location (BR1, BR2, GR1, GR2, KR1 and KR2) tends to be higher than highland location (BT1, BT2, GT1, GT2, KT1 and KT2). The water temperature in lowland locations also tends to be higher (25.0-26.7°C). Water temperature affects the activity and hatchability of golden apple snail eggs. Ismail et al. (2019), stated that the hatchability time of golden apple snail eggs depends on temperature. The increase in temperature stimulates the eggs to hatch earlier and vice versa if there is a decrease in temperature. The higher temperature in the lowlands causes the golden apple snail eggs to hatch faster so that the density at that location is higher than in the highlands.

Water temperature also affects the growth of golden apple snails. At water temperatures of 25°C, 30°C and 35°C the growth is faster than those of 15°C and 20°C (Seuffert and Martín 2013). It can be assumed that the water temperature measured during the study supports the finding of higher density in the lowlands than in the highlands. The water temperature of 25,0-26,7°C in lowland locations causes the growth of snails to be faster. This is also similar to the results of study by Kasidiasa et al. (2018) who found that the density of snails from all age groups at an altitude <500 m was higher than those at an altitude > 500 m.

Other environmental factors, including the processing of rice fields and predators, also affect the golden apple snail. In terms of processing of rice fields, farmers practice different habits to reduce the snail population. One of them is using a molluscicide. In addition, farmers in all locations routinely collect the snails and then destroy them. This was observed at the time of sampling, many of the snail were kept in the dry place and had been distroyed. In some locations, other people (not the farmers who own the rice fields) collect snails which are used as alternative protein or animal feed. Sawangproh and Poonswad (2010) state that, the population dynamics of golden apple snails in rice fields are also controlled by the harvest process, land preparation, and possibly the application of molluscicide.

The value of the presence frequency of snails in all locations (Table 1) is in the range of 75-100% so that it includes the absolute. The presence frequency is a value that states the number of presence of a species in habitat. This describes how often these species can be found. Based on the results, most of the snails were found in 12 quadrate made during sampling except at GT1 (at 10 squared), KT1 (at 11 squared) and KT2 (at 10 quadrate). The high presence frequency of the of golden snails shows the great potential of golden apple snails, both as potential pests, animal feed or alternative protein sources for humans.

The distribution pattern of golden apple snails based on the Morisita index (Table 2) is mostly a group pattern. Most of the snails found near the edge of the rice fields. They are in the shade of grass so that their existence is more protected from predators, including humans. According to Riyanto (2004), the distribution pattern of golden apple snails is related to shelter, attraction to food sources, and also the reproductive process in adult golden applesnails.

Most of the percentages of golden apple snail found were adult (Figure. 2). This is thought to be related to the process of preparing rice fields for rice cultivation and the handling of existing golden snails. Rice field preparation using a tractor engine makes it easier for adult golden snails to be killed. Besides that, the cultivation of the land is also followed by collecting snails that are seen by farmers. Thus, some golden snails that survived during land cultivation will develop into adults along with the rice planting process so that they are more common than young snails

Nutritional value

Golden apple snail crude protein in all locations was 41.07-51.88% (Table 4). The high protein content causes the snails to be widely used as an alternative source of protein for humans and for animal feed so that their existence can provide benefits even though cause damage, especially in agriculture. Crude protein in the lowlands tends to be higher than in the highlands. Crude protein above 50% was found at four locations in lowland (BR1, BR2, GR2 and KR1). Syamsunarno and Sunarno (2016) states that the protein content of golden apple snail were more than 50%. Ghosh et al. (2017) stated that the protein content was 48.5% and Suryadi et al. (2019) stated it was 47.92%. Thus the protein content of golden apple snails in lowlands locations is almost the same as that stated in the two sources. Crude protein in the lowlands was 48.14 - 51.88%.

Crude fiber content from all locations was 0.39-12.6%, lower than the results of Suryadi et al. (2019) which were 13.21% but higher than the results of Adebayo-Tayo et al. (2011) which were 0.10-0.17%. The crude fat content of all location does not show too large variation between lowland and highland. The range of crude fat at all locations was 16.50-19.88%. According to other references, the crude fat of golden apple snails is 5.75% (Suryadi *et al*. 2019) and 3.26-3.44% (Adebayo-Tayo et al. 2011).

Amino acids, calcium and phosphorus showed small variations for all locations (Table 5), but the results of amino acid analysis from all locations showed that glutamic acid was the highest (1.03-1.32%) compared to other amino acids. Lysine (0.63-0.87%) is higher than methionine (0.24-0.44%). Calcium is higher (5.66-9.32%) than phosphorus (0.18-0.40%). Glutamic acid, lysine, methionine and phosphorus were lower while calcium were higher when compared to Joshi et al. (2017) which states that the glutamic acid content of golden snails is 12.2-13.6%, lysine 2.9-9.7%, methionine 11.9-2.4 2%, calcium 3-4% and phosphorus 0.4-1.2%. The high calcium content in golden apple snails, especially in their shells, causes golden apple snails to be used as additional feed sources of calcium. The calcium content in golden apple snails is related to the calcium content of the environment. This calcium is required for shell formation.

The results of the proximate analysis, amino acids and minerals of golden apple snails in all locations after being compared with the results of other studies showed variations. This variation is thought to be due to environmental influences where

each sampling location for the golden snails analyzed has different environmental factors, including the available food factor. Debnath et al. (2016) stated that variations in the proximate and mineral compositions of snail can be caused by environmental, food and biological factors.

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