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Nutritional values of *Avicennia marina* leaves and its application as fodder for Kacang goat (*Capra aegagrus*)

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Abstract. *Basyuni M, Rizaldi MR, Amelia R, Bimantara Y, Sulistiyono N, Slamet B, Al Mustaniroh SS. 2023. Nutritional values of* Avicennia marina *leaves and its application as fodder for Kacang goat* (Capra aegagrus). *Biodiversitas 24: 1039-1048.* Mangrove forests provide a variety of ecosystem services including provisioning and cultural services in which coastal communities traditionally utilize mangrove plants to support their daily life. There are several practices on the uses of mangrove foliage for animal feed by coastal communities, although it is not clear the nutritional value of such feed source and its effect on livestock growth. This study aimed to determine the potential use of *Avicennia marina* leaves as fodder for Kacang goat (*Capra aegagrus*) by investigating the nutritional values in terms of proximate contents and macro- and micro-elements of *A. marina* leaves and the effects of the feeding *A. marina* leaves on the dimensional growth of *C. aegagrus* in term of chest circumference, body length and body weight. We employed two treatments (i.e. fodder of *A. marina* leaves and field grass for the comparison) with three replicates for each treatment. The results showed that the leaves of *A. marina* had a higher content of crude fat, carbohydrates, EWN (extract without nitrogen) and vitamin C, and lower content of water, ash, crude protein, and crude fiber compared to field grass. In terms of macro and microelements, *A. marina* leaves had a higher level of Ca and Na, but lower in terms of P, K, S, Fe, Zn, Cu and Mn. Nonetheless, feeding *C. aegagrus* with *A. marina* leaves resulted in a significantly lower daily body weight gain (16.08 g/goat/day) compared to feeding with field grass (74.46 g/goat/day). During the observation period of 92 days, feeding with field grass increased body weight by 6.85 kg, higher than feeding with *A. marina* leaves, which caused a weight gain of 2.22 kg. Furthermore, the average feed conversion for field grass treatment was 5.24 (g consumption/g daily body weight gain/DWG) while feed of *A. marina* leaves was 4.42 (g consumption/g DWG), indicating inefficient use of feed. The dry weight content of FG feed (149.39%) was slightly higher than that of *A. marina* leaves (149.24%). This study provides evidence of the possibility of the application of *A. marina* leaves as the fodder for *C. aegagrus*.

Keywords: *Avicennia marina*, daily weight gain, field grass, mineral contents, proximate analysis

INTRODUCTION

Mangroves supply a variety of ecosystem services in terms of provisioning, regulating, and supporting as well as cultural services (Kusmana 2018; Basyuni et al. 2022). In terms of provisioning and cultural services, mangroves provide various resources for the local community living around coastal areas (Barbier et al. 2011). They serve as important resources for a wide range of non-wood products, such as foliage for fodder, honey, tannin, and medicinal substances (Dahdouh-Guebas et al. 2006; Pattanaik et al. 2008; Huxham et al. 2017). Indonesia has the largest mangrove forest area in the world with about 2.7 million ha or equivalent to 22.6% of the total global mangrove forest in 2020 (Basyuni et al. 2022), of which about 57,010 ha occured in North Sumatra Province (Basyuni et al. 2022).

Despite the large extent of mangrove forests in Indonesia, these forests have been pressured by timber exploitation in the past (1970-1990) and conversion to shrimp ponds since the 1980s and oil palm plantation since 2000, resulting in mangrove loss of about 193,367 ha during 2000-2020 (Basyuni et al. 2022). The ecological stability of mangrove forests can be maintained by utilizing its elements for various purposes in a sustainable way. The elements being utilized can be in the form of food, medicine and animal fodder. The sustainable utilization of the elements of mangrove forests will reduce the pressures on mangrove forests to be deforested and degraded (Baba et al. 2013).

The availability of forage, especially fresh forage, is sometimes an obstacle in raising ruminants (Dahdouh-Guebas et al. 2006; Pattanaik et al. 2008). The supply of forage for livestock is a major problem in developing countries due to scarcity, with the supply fluctuating throughout the year in terms of both quality and quantity (Pattanaik et al. 2009). In the context of raising ruminants in coastal areas, such problems might be resolved by utilizing foliage extracted from mangrove vegetation. In the context of the utilization of mangrove leaves for livestock fodder, it is argued as a sustainable way of mangrove utilization since this practice does not entail growing crops or even disturbing the forest (Sukardjo et al. 2000).

There are several examples of the uses of mangrove foliage for animal feed, including the leaves of *Rhizophora* spp, *Sonneratia* spp, and *Avicennia* spp (Lubis 2016; Ali

2020). In the Middle East, India and Pakistan, the leaves of *Avicennia marina* are used for feeding camels (Baba et al. 2013). In Indonesia's coastal areas, people have used *Avicennia* leaves for goat feed (Kusmana 2018) although it is not clear the nutritional value of such feed. In the Cimanuk delta, West Java, *Rhizophora* leaves are particularly loved by goats, even the old leaves are delectable (Sukardjo et al. 2000). In East Nusa Tenggara, Indonesia, the leaves of *A. marina* and *Sonneratia alba* are used as animal feed (Rupidara et al. 2020).

The chemical content and rumen fermentation profile of *A. marina* leaves indicate them to be potential sources of forage for animals, especially goat (Jamarun et al. 2020). Such usage calls for a clear indication of the roles of ecosystem services provided by mangrove forests. Goats are the local ruminants often raised by the community because they are easy to maintain, economical, and require relatively little capital investment. There are two dominant goats (*Capra* spp.) varieties commonly raised group in Indonesia, namely the Kacang goat (*Capra aegagrus*) and Etawah goat (*Capra hircus*) (Lestari et al. 2017). *C. aegagrus* is indigenous to Indonesia with several advantages including drought resistance characteristics, feed efficiency, quick to breed and adaptability to various environments (Soeharsono et al. 2020; Budisatria et al. (2021).

This study aimed to determine the potential of *A. marina* leaves as fodder for *C. aegagrus*. In doing so, we conducted a proximate analysis of macro- and micro-elements of *A. marina* leaves compared to field grass (FG), with further assessment of the effects of its application on chest circumference, body length, and body weight. This research is useful in terms of providing information to the community, especially the local coastal community, about the benefits of mangrove forests as animal feed-enriching ruminant feed sources and reducing the rate of deforestation due to the nature of community dependence on mangrove forests by exploring its renewable resources.

MATERIALS AND METHODS

Study area

This research was conducted in Lubuk Kertang Village, West Brandan Sub-district, Langkat Regency, North Sumatra Province, Indonesia, for 3 months and 21 days, June-September 2019 (Figure 1). The research period was divided into 21 days for the preparation stage and 3 months for the feeding of *A. marina* leaves and field grass (FG) to *C. aegagrus*. Nutritional analysis was performed separately at the Food Science and Technology Laboratory, Faculty of Agriculture, Universitas Sumatera Utara, Indonesia for proximate analysis and Socfin Indonesia Laboratory for macronutrient and micronutrient elements, respectively.

Materials

Six individuals of *C. aegagrus* were used for feeding trials using *A. marina* leaves and field grass. The *C. aegagrus* had an average age of 15 months. The mangrove of *A. marina* had an age of five-year-old and was collected from the mangrove forest close to the three Silvofishery ponds, whereas FG feed was taken from the fields and shrubs near the *A. marina* population (FG I-FG III) (Figures 1 and 2). The ingredients of the field grass used for goat feed comprised duck grass (*Echinochloa colona*), skeletal grass (*Eluisine indica*), lorodan grass (*Centotheca lappacea*), bobontengan grass (*Leptochloa chinensis*), and needle grass (*Chrisopogon ariculatus*), as depicted in Figure 2. Of the six individuals used as the samples, three individuals (U1-U3) were fed with FG and the other three (U1-U3) with *A. marina* leaves. However, the U3 goat with *A. marina* feeding died after 38 days of feedings. We did not have evidence for the cause of its death. We assumed that it might be the lack of preference/appetite for *A. marina* leaves.

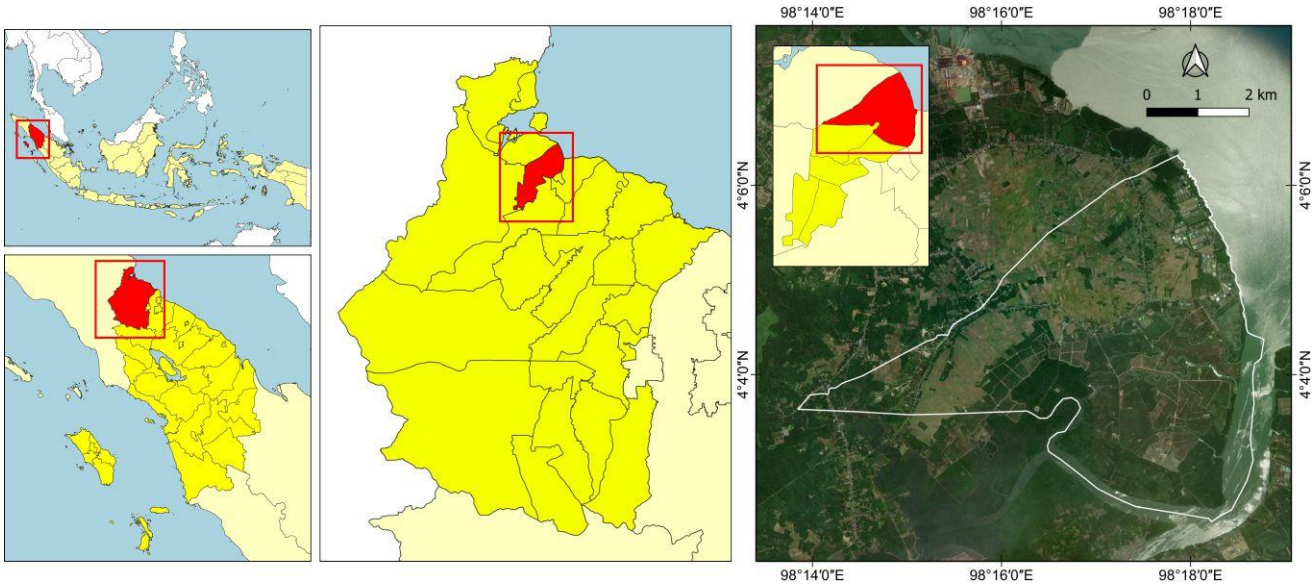

Figure 1. Study site in Lubuk Kertang, North Sumatra, Indonesia, from where field grass (FG) and *Avicennia marina* leaves were collected

Figure 2. The leaves of *Avicennia marina* (*left*) and field grass (*right*)

Nutritional analysis

Proximate analysis

Proximate analysis was conducted at the Food Technology Science Laboratory of the Universitas Sumatera Utara to determine the crude nutritional content of *A. marina* leaves and field grass as described by Basyuni et al. (2019). This analysis measured water content, ash content, crude protein, crude fat, crude fiber, dry weight, carbohydrates, vitamin C, and extract ingredients without nitrogen (EWN).

Macronutrient content

The macronutrients of *A. marina* leaves and field grass such as potassium (K), sodium (Na), and calcium (Ca), were examined following Basyuni et al. (2021). About 0.5 g finely powdered sample of *A. marina* leaves and field grass was wet digested using 30% H_2O_2 and concentrated HNO_3. The macronutrients (K, Na, and Ca) of the digested samples were measured using Flame Photometer PFP7 (Jenway, Staffordshire, UK). Each sample was measured in three independent experiments.

Micronutrient content

The micronutrients were extracted from *A. marina* leaves and field grass as described by Basyuni et al. (2021). Finely ground leaves and grass weighing 0.5 g were wet digested using 30% H_2O_2 and HNO_3 by an AA-700 flame atomic absorption spectrophotometer (Shimadzu). Micronutrients including manganese (Mn), iron (Fe), zinc (Zn), and copper (Cu) were estimated from the digested samples. To prepare new solutions, the distilled water was processed following Basyuni et al. (2021). Each sample was measured in three separate experiments.

Estimated body weight of goat samples

Before feeding, the body length and chest circumference of the sampled goats were measured to determine the initial weight. Data on animal feed consumption/day, measurements of chest circumference and body length per month were used for estimating body weight. The body weight of the sampled goats was calculated by estimating the vital size of the goat's body, considering the chest circumference and body length, following Depison et al. (2021) (Figure 3). The estimation of the goats' body weight using the Winter Indonesia formula combines chest circumference and body length, with a resulting bias of ≤0.2 kg (Soeharsono et al. 2020).

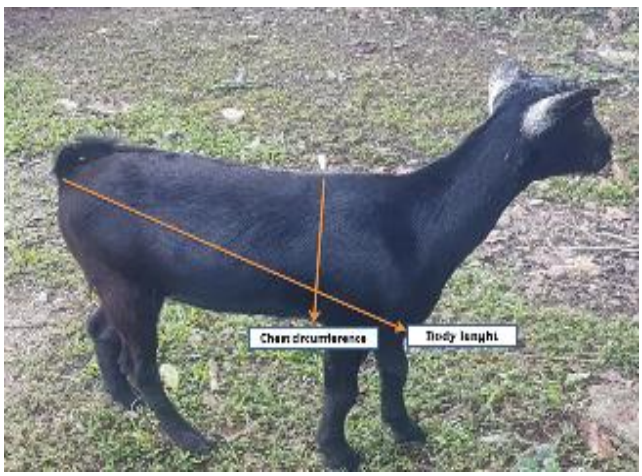

Figure 2. Body vital measurement of *Capra aegagrus*

The Winter Indonesia formula used in this study is as follows (Villandasari et al. 2019; Soeharsono et al. 2020):

$$\text{Body Weight (kg)} = \frac{\text{Chest circumference (cm)}^2 \text{x Body length (cm)}}{10000}$$

The observed variables followed Prasetiadi et al. (2017), namely:

Feed consumption

Calculation of feed consumption was done by subtracting the weight of the feed given (initial weight) from the residual weight.

Feed consumption (gram/individual/day) = initial feed weight - residual feed weight

Increase in body weight

The live weight gain (LWG) of the *C. aegagrus* was measured using the formula:

LWG (kg) = final body weight - initial body weight

While the daily body weight gain (DWG) was calculated using the formula

$$\text{DWG (g/individual/day)} = \frac{\text{final body weight} - \text{initial body weight}}{\text{observing duration}}$$

Feed conversion

Feed conversion is the ratio between the amount of feed consumed by livestock and the products produced by the livestock, as per the formula.

$$\text{Feed conversion} = \frac{\text{feed consumption (gram/individual/day)}}{\text{DWG (gram/individual/day)}}$$

Percentage of live weight

$$\text{Percentage of live weight} = \frac{\text{feed consumption (gram/individual/day)}}{\text{DWG (gram/individual/day)}} x\ 100\%$$

Average live weight

$$\text{Average live weight} = \frac{\text{Number of weighing results during observation}}{\text{Weighing frequency}}$$

Data analysis

Data are presented as mean ± standard deviation (SD) with n = 3 for the number of observations, feed nutrient content, feed consumption, mineral content, chest circumference, body length, body weight, and DWG. Data were tested using a non-parametric Mann Whitney U test. The *p*-value < 0.05 was employed as a limit of statistical significance (IBM SPSS Statistics ver. 20).

RESULTS AND DISCUSSION

Nutritional analysis

The nutritional content of a feed affects feed consumption, body weight, and livestock productivity. Livestock needs adequate nutrition for growth and development. The nutritional quality of feed ingredients includes nutritional value, fiber, energy, and its application to the value of palatability and digestibility.

Proximate content

The average proximate content of *A. marina* mangrove leaves and field grass is presented in Table 1. Among the nine variables observed, the field grass (FG) had higher content on four proximate constituents, while the mangrove leaves of *A. marina* had higher content on four constituents, namely, crude fat, carbohydrates, EWN (extract without nitrogen), and vitamin C. The three components in the form of carbohydrates, fats, and proteins function as energy for livestock to carry out activities.

The average carbohydrate value of *A. marina* leaves (28.48%) was higher than that of field grass (19.35%). Likewise, the fat content of *A. marina* leaves was 4.26%, while that of the FG was 2.50%. Almost 50% of carbohydrates from plants are cellulose. While humans cannot digest cellulose, ruminant animals can, because there are digestive bacteria in their stomachs. Goat may not depend too much on hepatic gluconeogenesis, when they are fed high carbohydrate-based diets (Bernard et al. 2012). The crude protein content of field grass, at 14.21%, was better than *A. marina* leaves (6.08%). The value of the crude protein content of *A. marina* leaves was not much different from *A. alba* (5.09%) (Cruz et al. 2019).

Table 1. Results of proximate analyses of *Avicennia marina* leaves and field grass (FG)

Nutrient	Fodder		p-value
	Field grass	*A. marina* leaves	
Water (%)	57.54 ± 7.90	55.08 ± 3.99	3.00
Ash (%)	6.40 ± 0.19	6.09 ± 0.10	0.00
Crude protein (%)	14.21 ± 0.55	6.08 ± 0.24	0.00
Crude fat (%)	2.50 ± 1.18	4.26 ± 1.28	1.00
Carbohydrate (%)	19.35 ± 9.05	28.48 ± 5.15	1.00
Crude fiber (%)	31.44 ± 0.13	15.15 ± 0.35	0.00
Nitrogen-free extract material (%)	45.45 ± 1.13	68.41 ± 1.39	0.00
Dry weight (%)	149.39 ± 0.98	149.24 ± 0.99	4.00
Vitamin C levels (mg/100 g)	7.50 ± 0.99	11.58 ± 1.06	0.00

Notes: data are expressed as mean ± SD (n = 3); data shows a significant difference for *p*-value <0.05 using Mann Whitney U test

The difference between field grass and *A. marina* leaves may be due to more than one type of grass being used as feed, resulting in higher protein values. The best protein content for animal feed is 13.2-26% (National Research Council 2011) and 14-27% (National Research Council 2012). The protein supplementation contained in the feed must be balanced with the energy level (Akhsan et al. 2015). The water content of field grass was 57.54%, higher than that of *A. marina* leaves at 55.08%. The moisture content is an indication of the water content in the feed. The water content is closely related to storage. Too high water content can reduce feed quality due to the growth of micro-organisms; so, good handling of the feed given is needed to maintain the feed quality (Zheng et al. 2021). Present results on water contents of both field grass and *A. marina* leaves were in the range of water content of Cauliflower leaves (54-62%) as feed for goat bucks (Wadhwa et al. 2006). Determination of the water content is used to analyze the weight/dry matter of feed. Brendel (2021) stated that the older the plant, the less water it contains.

The ash content of field grass (6.40%) was not too different from the leaves of *A. marina* (6.09%). As the ash content is related to the mineral content in feed ingredients, it is one of the determining factors in calculating EWN levels. A decrease in ash content indicates an increase in substrate organic matter (Kholif et al. 2018). The value of EWN in field grass and *A. marina* leaves was 45.45% and 68.41% respectively. The decrease in EWN levels is less favorable from the nutritional aspect because less EWN means fewer components of organic matter that can be digested, so that less energy can be produced (Sari et al. 2015). Based on Ayu (2019), the best treatment was a mixture of 75% mangrove leaves and 25% rice straw for the digestibility of crude fiber, crude fat and EWN.

Vitamin C contained in *A. marina* leaves, at 11.58 mg/100 g, was better than that in the field grass (7.50 mg/100 g), indicating that *A. marina* leaves are suitable for use as animal feed, based on the nutritional vitamin C content. The crude fiber content of FG was much higher at 31.44% than that of *A. marina* leaves (15.15%). Brask et al. (2013) reported that the crude fiber of feed affects milk production positively by 7.6% and provides a fat content of 3% in dairy cows. Consumption of crude fiber also serves as an increase in total solids and milk fat, i.e., higher fiber consumption will increase these components (Habeeb 2017). According to Yakin et al. (2021), the crude fiber content in the ration given affects feed consumption because crude fiber is bulky.

Macro- and micronutrients

The field grass had higher mineral content in terms of P, K, Fe, Zn, Cu, S, and Mn while *A. marina* had higher elements of Ca and Na (Table 2). The main macro mineral content of FG feed was 2.24 K-total, 0.21 P-total, and 0.28% S, while *A. marina* leaves had two macronutrients of Ca and Na with 0.58 and 1.53%, respectively. The percentage of the best phosphorus requirement in recommended animal feed is 0.4-0.7% (NRC 2012) and 0.5-0.8% (NRC 2012).

Higher feed quality results in higher productivity (Restitrisnani et al. 2013). According to Lall (2022), the supply of copper (Cu) minerals has an important role in animal survival, as any excess or deficiency will cause disease. Maranatha et al. (2021) showed that mineral administration has a very significant effect on increasing the chest circumference of male Bali cattle. Suttle (2022) confirmed the treatment with the addition of Ca + P + S minerals. Santoso et al. (2013) found that the addition of Ca and P in the feed causes changes in the relative weight growth, feed efficiency, body composition, body mineral content, and proximate. The mineral content in the forage is influenced by the content of water, soil, and air in the environment where the forage grows (Fathul and Widodo 2012). The result of this study showed that *A. marina* leaves had enough components of macro (S, Na, P) and micro elements (Zn and Cu) as feed for ruminant animals.

Feed consumption

Feed consumption is an important factor for livestock growth and productivity. Consumption determines the amount of feed in the ration consumed by livestock/day. Increasing the amount of feed consumed by livestock maximizes rumen microbial activity in producing the nutrients and energy needed (Knapp et al. 2014). The average consumption of *A. marina* leaves and field grass are presented in Table 3. It is interesting to note that field grass treatment had a higher consumption value than *A. marina* leaves. For field grass treatment, the highest feed consumption occurred on U3 with an average value of 384.67 g/head/day while that of the *A. marina* leaves treatment occurred on U1 with 160.22 g/head/day. Such difference is likely caused by the higher level of preference and adaptation mass of *C. aegagrus* to FG feed than to *A. marina* leaves. In addition, it is suspected that *A. marina* leaves have tannin levels that cause an astringent taste and unpleasant odor because they contain lipoxygenase enzymes (Sánchez-Rodríguez et al. 2019; Jamarun et al. 2021). Tannins are positive for the body of livestock if the content in the feed ingredients does not exceed 4%. In providing animal feed, attention must be paid to its content of nutritional content and toxic compounds so that it can increase the efficiency value of the feed given. Neave et al. (2018) reported that goats had better palatability when being fed with superior grass. In addition, the habit of ruminants consuming forage is a supporting factor.

Table 2. Macro and micro elements of *A. marina* leaves and field grass

Mineral elements	Fodder		p-value
	FG	*A. marina*	
Macro element			
P-Total	0.21 ± 0.04	0.16 ± 0.03	1.00
K-Total	2.24 ± 1.20	0.86 ± 0.04	2.00
Ca-Total	0.45 ± 0.10	0.58 ± 0.02	1.00
S (%)	0.28 ± 0.05	0.23 ± 0.01[a]	2.00
Na (%)	0.63 ± 0.82	1.53 ± 0.05	2.00
Micro element			
Fe-Total	556.41 ± 260.03	291.06 ± 30.77	2.00
Zn-Total	33.89 ± 11.63	19.28 ± 2.20	1.00
Cu-Total	10.26 ± 0.43	9.59 ± 0.19	0.00
Mn-Total	232.21 ± 169.40	41.67 ± 4.01	3.00

Note: data are expressed as mean ± SD (n = 3); data show significant difference for p-value <0.05 using Mann Whitney U test

Table 3. Feed consumption of *Avicennia marina* leaves and field grass by *Capra aegagrus*

Replicate	Feed treatment (g/head/day)						p-value
	Field grass			*A. marina leaves*			
	Amount	Time (days)	Mean ± SD	Amount	Time (day)	Mean ± SD	
U1	35001	92	380.45 ± 63.36	14740	92	160.22 ± 73.71	0.00
U2	35179	92	382.38 ± 65.07	13808	92	150.09 ±73.66	0.00
U3	35390	92	384.67 ± 67.46	595	38	15.66 ± 7.73	0.00

Notes: data are expressed as mean ± SD (n = 3) and show a significant difference for p-value <0.05 using the Mann-Whitney U test. U1-U3 = goat samples representing replicates. After 38 days of treatment, goat number 3 (U3) with *A. marina* feed die

Table 4. Chest circumference, body length and body weight of *Capra aegagrus*

Parameter	Feed treatment						p-value
	Field grass			*A. marina leaves*			
	U1	U2	U3	U1	U2	U3	
Body length (cm)	42.00±2.55	44.00±3.39	46.00±3.39	42.60±1.26	41.30±1.09	20.55±0.14	1.00
Chest size (cm)	53.00±2.91	55.25±3.27	57.25±2.59	54.50±1.12	53.25±1.04	26.58±0.21	2.00
Body weight (kg)	11.91±2.03	13.60±2.67	15.45±2.89	12.67±0.89	11.72±0.77	5.8±0.14	1.00

Note: Data are expressed as mean ± SD (n = 3) and show a significant difference in p-value <0.05 using the Mann Whitney U test. U1-U3 = goat samples representing replicates

The lowest field grass feed consumption was at U1, with an average value of feed consumption of 380.45 g/head/day, while *A. marina* leaves feed was at U3 (15.66 g/head/day). Observation of animal feed consumption was for 92 days, except for U3 goats where it was for 38 days due to death. Factors that affect feed consumption are feed quality, temperature conditions, and the body condition of livestock. The treatment of *A. marina* leaves feed based on nutritional content is suitable for use as animal feed because it contains good carbohydrates, vitamin C, fat, and minerals. However, the goat's preference for *A. marina* feed is not as high as for field grass because the grass is the main forage in the area. The response of ruminants to the feed given can vary, because the ability of livestock to consume rations is influenced by climate, temperature, nutritional balance, ration quality, livestock breed, growth rate, body weight, production level, and ration factors given, such as the delicacy of the ration, its energy level shape and nature (Su and Chen 2020).

The level of feed consumption is also influenced by the material content per unit of the dry weight of the feed. The dry weight content indicates the availability of nutrients that can be utilized by livestock. The dry weight content of field grass feed (149.39 %) was slightly higher than that of *A. marina* leaves (149.24%). These results indicate that the leaf feed of *A. marina* has the potential to be developed as feed for ruminants. A decrease in the dry matter content in a feed ingredient will result in losses because the supply of nutrients provided by it falls and interferes with the growth and development of livestock (Su and Chen 2020).

Body weight

The body weight of livestock can be determined by weighing and estimation. The mean values of chest circumference, body length, and weight are summarized in Table 4. The highest average body length, chest circumference, and body weight values in the field grass feed were found in U3 goat (46.00 cm, 57.25 cm, and 15.45 kg, respectively), followed by U2 goat (44.00 cm, 55.25 cm, and 13.60 kg), and U1 goat (42.00 cm, 53.00 cm, and 11.91 kg). The bust parameter is the best-estimated measure according to Trisnawanto et al. (2012). Chest circumference has the highest correlation value among all the body size parameters. The estimation of the body weight of *C. aegagrus* has previously been done by Permatasari et al. (2013) with a coefficient of determination from 81.4% to 97.8%.

The highest average body length, chest circumference, and body weight values in *A. marina* leaves feed were found in goat U1 (42.60 cm, 54.50 cm, and 12.67 kg, respectively) followed by goat U2 (41.30 cm, 53.25 cm, and 11.72 kg respectively), while the U3 goat died on the third observation and could only be observed twice (20.55 cm, 26.58 cm, 5.8 (kg).

Goat death is thought to be due to bloating. Rumen bloat (bloat) is caused by erectile dysfunction and the rate of gas production exceeding the animal's ability to excrete; this symptom is characterized by a loss of appetite (Yanuartono et al. 2018). Bloating is also caused by eating. The provision of young or wet forage and cold weather are the main causes of bloating (McAllister et al. 2020).

Live weight gain

Live weight gain (LWG) is an important parameter in raising livestock. The increase in body weight indicates the number of units of live weight given to the feed and is related to the economic value produced. The results of the average LWG of *C. aegagrus* are presented in Table 5 and Figure 3. The effect of feeding FG and *A. marina* leaves on the LWG of the *C. aegagrus* was significant ($P < 0.05$) but varied significantly across treatments. Based on the 5% SRD test (Table 5), the best treatment was the field grass

feed with an average of 74.46 g/head/day. In contrast, the goat that died was fed with *A. marina* leaves on the 38th day with an average of 16.08 g/head/day. The increase in feed efficiency indicates that more nutrients can be used for livestock productivity and growth. Live weight is influenced by the amount of feed consumed and the rate of nutrient absorption, which affect the growth and development of livestock (Nuraini and Hafid 2006; Restitrisnani et al. 2013). In addition, it is also influenced by the body weight of livestock. The initial weight of goat fed with field grass for each replicate was 9.36, 10.4, and 12.24 kg, while that for *A. marina* leaves was 11.5 kg, 10.8 kg, and 9.87 kg. Overall, the data showed that *A. marina* leaves still had a high potential for goat fodder.

The field grass feed increased LWG and DWG significantly than the feed of *A. marina* leaves (Figure 3). The average LWG value of field grass feed was 6.85 kg, while that of *A. marina* leaves feed was 2.22 kg. However, *A. marina* leaves can be used as a source of forage for animals based on the nutrients it contains, with a longer adaptation period and new treatments such as a mixture of grass and *A. marina* leaves to improve the palatability of livestock. Both young and adult *C. aegagrus* with high feed consumption and feed digestibility experienced better weight growth. This was due to more nutrients absorbed by the livestock body (Luthfi et al. 2014). According to Rostini and Zakir (2017), higher-feed protein is absorbed in goats due to the protein being a food substance that functions for the conversion of protein into meat.

Feed conversion

The feed conversion value was calculated based on the average goat for each treatment. The average feed conversion value for field grass treatment was 5.24 (g consumption/g DWG) while that of *A. marina* leaves was 4.42 (g consumption/g DWG) (Figure 4). A high feed conversion value indicates an inefficient use of feed. The conversion rate is influenced by the strain and environmental factors, including dietary factors, especially low nutritional value (Budiansyah et al. 2020).

A study by Widiyanto et al. (2011) showed that giving field grass in the form of pellets to rams with the combination of 85% fresh field grass and 15% fine bran increased DWG. Feed conversion, especially for small ruminants, is influenced by feed quality, digestibility value, and efficiency of nutrient utilization in metabolic processes in animal tissues (Santoso et al. 2013). High crude fiber content will make it difficult to be degraded by rumen microbes, with a consequent impact on digestibility (Rusli et al. 2021). Substitution of grass and leaves of *A. marina* can be used as feed to increase the conversion value of feed so that it increases the palatability value of the feed.

To extend our knowledge, we compared the utilization of mangroves as animal fodder across some parts of the world as summarized in Table 6. The genus *Avicennia* and *Sonneratia* comprise three species: *A. alba, A. marina, A. officinalis, S. alba, S. apetala,* and *S. caseolaris* which show potential as fodder. *Rhizophora* consists of two species: *R. apiculata* and *R. mucronata.* Other species such as *Bruguiera gymnorrhiza, Ceriops decandra, Derris terifolia, Excoecaria agallocha, Lumnitzera racemosa*, and *Pometia pinnata* have been reported to have fodder properties (Table 6). The present study strengthens the previous studies on the potential use of mangrove foliage as fodder for goats, camels, and cattle, especially in India, Indonesia, Pakistan, and the Middle East (Dahdouh-Guebas et al. 2006; Pattanaik et al. 2008; Baba et al. 2013; Ghosh et al. 2015; Kusmana 2018; Jamarun et al. 2020).

Table 5. Daily weight gain (DWG in g/head/day) of *Capra aegagrus* fed with field grass and *Avicennia marina* leaves

Replicate	Feed treatment		P value
	Field grass	*A. marina* leaves	
U1	60.65 ± 25.46	26.30 ± 11.27	0.00
U2	78.70 ± 33.60	21.96 ± 9.67	0.00
U3	84.02 ± 36.39	5.80 ± 6.70	0.00
Mean	74.46 ± 12.25	16.08[a] ± 14.10	

Notes: data are expressed as mean ± SD (n = 3) and show a significant difference for p-value <0.05 using the Mann Whitney U test. U1-U3 = goat samples representing replicates

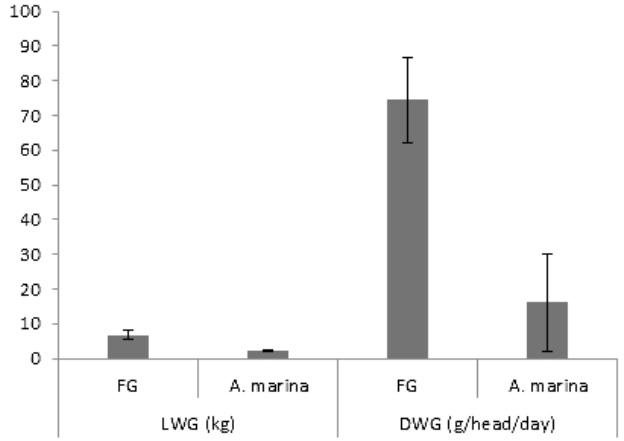

Figure 3. Live weight gain (LWG) and Daily weight gain (DWG) of *Capra aegagrus* fed by field grass and *Avicennia marina* leaves. Data are mean±SD (n= 3) using the Mann Whitney U test, with p-value= 6.00 (LWG), 0.00 (DWG)

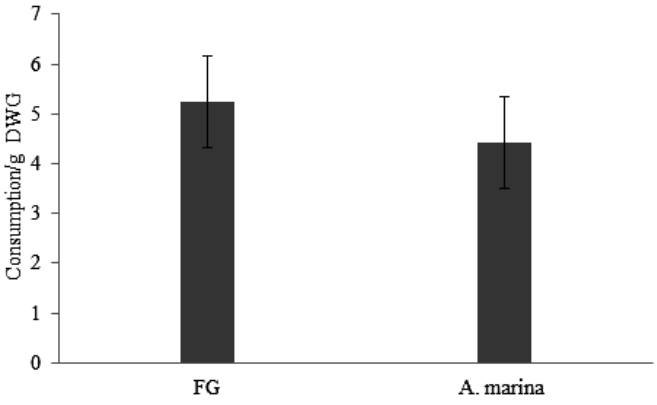

Figure 4. Feed conversion of *Capra aegagrus* fed with field grass and *Avicennia marina* leaves. Data are mean±SD (n= 3) using the Mann Whitney U test, with p-value= 4.00

Table 6. Comparison of mangrove plants utilized as animal fodder in different regions of the world

Species	Plant part/ organ	Countries/region	References
Avicennia alba	Foliage	India (Bhitarkanika wildlife sanctuary, Orissa)	Pattanaik et al. (2008)
		Indonesia	Kusmana (2018)
Avicennia marina	Foliage/leaves	India (Godavari mangrove wetlands)	Dahdouh-Guebas et al. (2006)
		India (Bhitarkanika wildlife sanctuary, Orissa)	Pattanaik et al. (2008)
		Indonesia (Lubuk Kertang, Langkat)	*This study*
		India (Gujarat)	Baba et al. (2013)
		Egypt	Baba et al. (2013)
		Pakistan (Indus Delta)	Baba et al. (2013)
		New Zealand (Waikato)	Maxwell and Lai (2012)
		Indonesia (Borneo)	Bandaranayake (1998)
		India (Sundarban)	Ghosh et al. (2015)
		Indonesia	Kusmana (2018)
		Indonesia (South Coast mangrove forest, West Sumatra)	Jamarun et al. (2020)
Avicennia officinalis	Leaves	India (Godavari mangrove wetlands)	Dahdouh-Guebas et al. (2006)
		India (Gujarat)	Shukla and Shukla (1986)
		Indonesia	Kusmana (2018)
Bruguiera gymnorrhiza	Hypocotyls	India (Bhitarkanika wildlife sanctuary, Orissa)	Pattanaik et al. (2008)
		India (Sundarban)	Ghosh et al. (2015)
Ceriops decandra	Leaves	India (Godavari mangrove wetlands)	Dahdouh-Guebas et al. (2006)
			Hamilton and Snedaker (1984)
Derris terifolia	Leaves	India (Sundarban)	Ghosh et al. (2015)
Excoecaria. agallocha	Leaves	India (Godavari mangrove wetlands)	Dahdouh-Guebas et al. (2006)
Kandelia. candel	Leaves	India (Bhitarkanika wildlife sanctuary, Orissa)	Pattanaik et al. (2008)
Lumnitzera racemosa	Leaves	India (Godavari mangrove wetlands)	Dahdouh-Guebas et al. (2006)
		India (Bhitarkanika wildlife sanctuary, Orissa)	Pattanaik et al. (2008)
Pometia pinnata	Leaves	India (Bhitarkanika wildlife sanctuary, Orissa)	Pattanaik et al. (2008)
Rhizophora apiculata	Leaves	India (Bhitarkanika wildlife sanctuary, Orissa)	Pattanaik et al. (2008)
Rhizophora mucronata	Leaves	Indonesia	Sukardjo (2000, Kusmana (2018)
Sonneratia alba	Leaves	India (Bhitarkanika wildlife sanctuary, Orissa)	Pattanaik et al. (2008)
		India (Godavari mangrove wetlands)	Dahdouh-Guebas et al. (2006)
		Indonesia	Kusmana (2018)
Sonneratia apetala	Leaves	India (Godavari mangrove wetlands)	Dahdouh-Guebas et al. (2006)
Sonneratia caseolaris	Leaves	India (Godavari mangrove wetlands)	Dahdouh-Guebas et al. (2006)
		India (Bhitarkanika wildlife sanctuary, Orissa)	Pattanaik et al. (2008)
		Indonesia	Kusmana (2018)

Mangrove forests play a vital role in many aspects of animal and plant life and the livelihood of local people (Dahdouh-Guebas et al. 2006). There is a close correlation between the livelihood of forest fringe dwelling people and the mangrove forest. Mangroves are also an important resource for a wide range of non-wood forest products, such as honey, bark for tannin as a dye, foliage for fodder for camels and cattle, edible products, sugar, alcohol and vinegar, and many medicinal products (Pattanaik et al. 2008). The results of this study showed the nutritional values of *A. marina* leaves are comparable with those in field grass, especially in terms of water, ash, dry weight, Cu-total. The leaves of *A. marina* even had higher values in terms of crude fat, carbohydrate, EWN, vitamin C, Na, and Ca-total. In this circumstance, the present study supports previous studies on the possibility of *A. marina* foliage for goats feeding. In conclusion, our work has confirmed that *A. marina* leaves could be used as fodder for *C. aegagrus* based on proximate and macro- and micro-nutrient analysis, and verified the effect of *A. marina* leaves to feed on the dimensional growth of *C. aegagrus* in terms of chest circumference, body length, and body weight.

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