Research Article

Production and Nutritional Values of Herbaceous Legumes in Tropical Climates of Indonesia

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Abstract | The high diversity of herbaceous legumes in Indonesia has the potential to be developed as a source of animal feed. This research aims to identify eight herbaceous legumes' productivity and nutritional value. The material used in this research was herbaceous legumes consisting of *Clitoria ternatea, Calopogonium mucunoides, Centrosema pubescent, Dolichos lablab, Pueraria javanica, Macroptilium bracteatum, Vigna* and *Stylosanthes guainensis*. The proximate test was used to obtain chemical component values from herbaceous legumes. The results showed that the highest and lowest potential biomass production is *C. ternatea* and *Vigna*, respectively. Furthermore, *M. bracteatum* had a higher DM percentage (29.12%) value than other herbaceous legumes. *C. ternatea* had the highest CP (21.96 %DM) and TDN (59.81 %DM). In conclusion, the legumes studied have high nutritional content and have the potential to be developed as animal feed, especially in tropical areas.

Keywords | Herbaceous legume, Proximate analysis, Biomass production, Nutritional value, Animal feed

Received | November 14, 2023; **Accepted** | December 22, 2023; **Published** | January 29, 2024
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Citation | Leondro H, Prihandini PW, Tribudi YA, Krisnaningsih ATN, Hadiani DPP, Wijaya AK, Ramsiati DT, Chanafi M, Wulansari WI (2024). Production and nutritional values of herbaceous legumes in tropical climates of Indonesia. Adv. Anim. Vet. Sci., 12(2):381-386.
DOI | https://dx.doi.org/10.17582/journal.aavs/2024/12.2.381.386
ISSN (Online) | 2307-8316

INTRODUCTION

Feed availability, mainly forage, for livestock has been affected by climate changes (increasing heat and higher CO^2 concentrations within the atmosphere). Bamualim (2011) stated that consistent feed availability is a fundamental step for the success of the livestock business. Hence, there is a recommendation to explore the C4 plant, which has a higher photosynthesis rate in high light intensity and hot areas such as Indonesia (Syafruddin *et al*., 2014), to be used as animal feed. The C4 plant could bind CO^2 through its PEP (phosphoenol pyruvate) enzyme and transform it into oxaloacetic acid. One of the C4 forage is legumes (Indriani *et al*., 2020).

Many tropical legumes have been cultivated primarily as a source of protein for ruminants. Legumes are divided into two types: tree and herbaceous legumes. Legumes are known for their adaptability to tropical climates (Suherman and Herdiawan, 2015), are not dependent on seasonal availability, and could be used as a cover crop (Ratnawaty *et al*., 2013). To be used as animal feed, some requirements are needed: good quality, high digestibility, high palatability, and sufficient availability (Castro-Montoya and Dickhoefer, 2020). However, studies and reports on herbaceous legumes were limited for their nutritional value and in vitro parameters as the basis for animal feed quality.

Production and nutritional values evaluation of each herbaceous legume must be carried out as a first step in selecting legumes as animal feed in Indonesia. This study aimed to evaluate the production and nutrient content of eight herbaceous legumes: *Clitoria ternatea*, *Calopogonium mucunoides*, *Centrosema pubescent*, *Dolichos lablab*, *Pueraria javanica*, *Macroptilium bracteatum*, *Vigna* and *Stylosanthes guainensis*.

MATERIALS AND METHODS

This research was carried out for three months, from July to September 2023. The legumes were planted in Kanjuruhan University Experimental Garden, Malang Regency, East Java. The proximate analysis was conducted in the Laboratory of Animal Feed Nutrition, Faculty of Animal Science, Brawijaya University. Eight types of herbaceous legumes were used as treatments: *Clitoria ternatea*, *Calopogonium mucunoides*, *Centrosema pubescent*, *Dolichos lablab*, *Pueraria javanica*, *Macroptilium bracteatum*, *Vigna* and *Stylosanthes guainensis*. All these legumes's seeds were obtained from the Agricultural Instrument Standardization Agency (BSIP) of Nusa Tenggara Timur.

Land preparation and planting

At first, the weeds and other vegetation were removed from the land to prevent nutrient deficiencies in the soil. The land was plowed to provide aeration space for oxygen availability and help the roots to spread. Each type of legume was planted in an area of 500 m^2, with a planting distance of 50 x 50 cm. Each ground was filled with one legume's seed. During the legume's growth, the land was fertilized with chemical fertilizer (phosphor) in doses of 50 $kg^{-1}ha$ and watered thrice weekly.

Procedure of data collection and statistical analysis

The material samples were collected at 60 days by randomly placing a 1 x 1 m metal frame (three times repetition) inside each experimental unit (Ratnawaty *et al*., 2013). The aerial biomass within the quadrant was cut and weighed fresh. For the proximate analysis, 500 gr of each legume was separated and stored in marked paper bags. All samples were oven-dried at 80 °C for 48 hr and weighed. The dried samples were then ground until passing through the 1-mm mesh. The chemical composition consists of dry matter (DM), organic matter (OM), crude fiber (CF), crude protein (CP), and non-nitrogen free extract (NFE), was obtained by proximate analysis following the protocol from the Association of Official Analytical Chemists (AOAC, 2005). The total digestible nutrient (TDN) value was calculated using the formula from Hartadi *et al*. (2005).

$$TDN = (25.6 + 0.53\ CP + 1.7\ Crude\ Fat - 0.474\ CF + 0.732\ NFE)$$

The measured parameter record was tabulated in an Excel program. An analysis of variance (ANOVA) was used to test the effect of different legume types in the SPPS program. Mean values among treatments were compared using Duncan's multiple range tests (DMRT) when the model detected a significant effect of treatment ($p < 0.05$).

RESULTS AND DISCUSSION

Biomass productivity of herbaceous legumes

The biomass production of herbaceous legumes harvested at 60 days are presented in Table 1. The statistical result showed that different legume types significantly affected the DM, OM, and CP contents ($p < 0.05$). The DM, OM, and CP production yield during the study period was highest in *C. ternatea* and lowest in *Vigna*. The DM yield, OM, and CP for the other six legumes ranged from 906.6–2001 kg DM/ha, 904.7–1780.5 kg OM/ha, and 201.4–676.5 kg CP/ha, respectively. The high DM yield of *C. ternatea* indicated its high tolerance to sunlight and dry environments compared to other legumes. *C. ternatea* efficiently uses sunlight for photosynthesis, transforming it into energy for growth and development (Kirschbaum, 2011; Ort *et al*., 2011; Sajimin *et al*., 2021).

Table 1: Biomass production potencies of herbaceous legume at 60 days.

Legume's type	Production yield		
	kg DM/ha	kg OM/ha	kg CP/ha
Clitoria ternatea	4083.7±253.3^{e}	3570±230.9^{c}	813.6±53.4^{d}
Calopogonium mucunoides	1205.4±113.2^{b}	904.7±117.2^{a}	312.4±76.3^{b}
Centrosema pubescent	1083.4±133.4^{a}	1006.4±118.4^{a}	201.4±93.4^{a}
Dolichos lablab	1794±201.5^{c}	1674.9± 206.9^{b}	458.6±66.1^{c}
Pueraria javanica	1601±278.4^{c}	1570.3±246.5^{b}	560.2±40.4^{c}
Macroptilium bracteatum	2001±118.3^{d}	1780.5±125.2^{b}	363.5±74.4^{b}
Vigna	860.5±102.4^{a}	820.6± 89.1^{a}	164.1±20.2^{a}
Stylosanthes guainensis	906.6±121.7^{a}	908.8±120.4^{a}	676.5±43.2^{c}

a, b, c Different superscripts within the same column indicate significant effect (p<0.05).

Table 2: Nutrient composition of herbaceous legumes.

Legume's type	DM (%)	Nutrient content (% DM)					
		OM	CP	CF	Crude Fat	NFE	TDN
Clitoria ternatea	26.42[b]	91.80	21.96	33.78	3,21	32.85	59.81
Calopogonium mucunoides	22.28[a]	90,99	16.82	40.77	3,86	29.54	55.55
Centrosema pubescent	26.36[a]	90.67	18.02	36.24	2,16	34.25	54.72
Dolichos lablab	23.62[a]	88.90	19.54	36.18	2,80	30.38	54.88
Pueraria javanica	27.02[b]	87.14	19.83	36.77	3,20	27.34	53.94
Macroptilium bracteatum	29.12[c]	89.71	18.57	34.12	2,18	31.10	54.98
Vigna	22.55[a]	91.81	18.40	38.32	3.99	29.87	57.99
Stylosanthes guainensis	24.64[a]	89.90	19.56	39.13	1.34	29.87	52.20

a, b, c Different superscripts within the same column indicate significant effect (p<0.05).

It was reported from several previous studies that there are variations in biomass production among herbaceous legumes (Abayomi *et al*., 2001; Cox *et al*., 2017; Hosang *et al*., 2016; Larbi *et al*., 2010; Oppong *et al*., 2002; Whitbread *et al*., 2005). This difference was due to variances in the morphology and physiology of herbaceous legumes, such as plant weight, rooting, soil conditions that are less suitable for growth, and water use efficiency. In this study, the biomass production of herbaceous legumes, especially *C. ternatea*, was similar to the findings reported by Ratnawaty and Fernandes (2009) in *C. pascuorum*, *C. ternate*, and M. *brateatum* (1300 kg DM/ha, 2200 kg DM/ha, and 1100 kg DM/ha, respectively) planted on dry land. Under optimum conditions, Gomez and Kalamani (2003) revealed that the biomass production of *C. ternatea* could reach 2400 kg DM/h, while Nulik (2009) stated 2600 kg DM/ha.

Nutrient composition of herbaceous legumes

The nutrient composition of several herbaceous legumes is presented in Table 2. The effect of different legume types was significant ($p < 0.05$) for DM content but contrary to the OM, CP, CF, crude fat, non-nitrogen free extract (NFE), and total digestible nutrient (TDN) ($p > 0.05$). The data showed that the DM percentage of legumes ranged from 22.28% (*C. mucunoides*) to 29.12% (*M. bracteatum*). Hutasoit (2018) reported that the DM of herbaceous legumes (*A. glabrata*, *S. guianensis*, *C. ternatea*, and *C. rotundifolia*) ranged from 33.75 to 35.75%. His study's DM percentage was higher than this research's findings. The differences in dry matter content in herbaceous legumes are due to differences in species and the same age at which they were cut in each treatment. This reason is supported by the opinion of Tillman *et al*. (1991), who stated that species and age influence the dry matter content of forage. Therefore, the high and low production of dry matter of herbaceous legumes for each type is only influenced by the high and low levels of fresh production.

The OM percentage of eight legume types was similar to the result Indah *et al*. (2020) reported, ranging from 88.28% to 95.20%. Differences in species and ash content can cause these differences. *P. javanica* produces the highest ash content. High ash content can reduce the nutritional value of feed ingredients. The high ash content can be interpreted as two contradictory things: (1) the high mineral content of herbaceous legumes needed by livestock, or (2) the high content of contaminants in herbaceous legumes in the form of soil, sand, and adhering clay (Kilic and Gulecyuz, 2017; Mburu *et al*., 2018).

The feed formulation ratio was calculated based on the crude protein and total digestible nutrient (TDN) since they enormously influence livestock productivity (Nugroho *et al*., 2017; Rosendo *et al*., 2013). *C. ternatea* was found to be a good source of protein (CP = 21.96%) and had the highest TDN (59.81%). The CP of *C. ternatea* in this study was higher than the CP reported by Hutasoit (2018) in similar legumes (13.85%). Differences in CP content in the same species are influenced by plant age, soil (physical, chemical, and biological properties), and climatic conditions. Crude protein content between legumes varied depending on species and age (Ginting and Tarigan, 2005). Solati *et al*. (2018) explained that most crude protein found in fresh legumes is true protein, and around 10-15% is categorized as non-protein nitrogen (NPN; peptides, free amino acids, and nitrates). In proximate analysis, the amount of NPN indicated increased crude protein value.

The TDN values of herbaceous legumes in this study were within the range Indah *et al*. (2020) reported, which were 39.67-72.88%. The TDN value increases following the escalation of ash, crude protein, and crude fat but will decrease with the rise of crude fiber. Crude protein, crude fat, and crude fiber have a relationship with TDN because TDN is an energy system developed based on nutrient content obtained from proximate analysis without considering the energy lost when metabolized or to produce products due to the limited equipment available in the laboratory. TDN is a description of the total energy originating from feed consumed by livestock, where the size of the value depends on the digestibility of the feed's organic ingredients, namely CP, CF, crude fat, and NFE (Mastopan and Hanafi, 2014; Nakano *et al*., 2018). The limitation of TDN is it does not consider detailed energy regarding the loss of nutrients burned during metabolism and the heat energy that arises when consuming feed (Ferrell and Oltjen, 2008; Jayanegara *et al*., 2017).

The crude fat content of herbaceous legumes ranged from 1.34-3.99%. Ratnawaty *et al*. (2018) reported that the crude fat content of herbaceous legumes in tropical areas ranges from 1.35-2.83%. The crude fat content of *Vigna* legumes is the highest compared to seven other herbaceous legume species at 3.99%. This result can be caused by the broader *Vigna* leaves than other herbaceous legumes, affecting the fat content. The crude fat content in herbaceous legumes is mainly found in the leaves and seeds (Mburu *et al*., 2018), whereas the fat content in herbaceous legumes is primarily found in the wax layer on the leaves. This layer is found in several legume plants in tropical areas to minimize evapotranspiration. Umami *et al*. (2017) explained that the wax layer on the leaf surface prevents water loss due to the transpiration process. It is proven that legume plants are plants that are resistant to drought. Ali *et al*. (2021) stated that the fat content in the feed is influenced by water content, storage temperature and humidity, type, age of harvest, and treatment given.

Carbohydrates consist of crude fiber and NFE. NFE is a carbohydrate fraction rich in sugar and starch, making it easier to digest. NFE can be described as the levels of easy-digestible carbohydrates in forages that can be used as the energy source for livestock. Even though it has the lowest DM and CP percentage, it turns out that the crude fiber content in *C. mucunoides* is not much different from other legumes. This result was in line with the statement from Kulivand and Kafilzadeh (2015) that the crude protein had a negative correlation with crude fiber.

Amrullah *et al*. (2015) stated that the higher crude fiber (CF) levels in feed ingredients will reduce the NFE levels. However, that statement was not proven in this study. Table 2 showed that *C. mucunoides* had the highest CF percentage (40.77%), but its NFE value was not the lowest. The lowest NFE value was achieved by *P. javanica* (27.34%). Overall, the NFE levels of herbaceous legumes from this study were slightly different from Akpensuen *et al*. (2019), Koten *et al*. (2014), and Ali *et al*. (2021). The NFE levels of legumes are influenced by the type, climate, and land where they grow. Despite differences in the characteristics analyzed, the legumes studied exhibited high nutritional value, are viable alternative animal feed sources, and are suitable for supplements for ruminants with poor nutritional quality diets.

Providing herbaceous legumes as animal feed should be limited to 30-40% of the total fresh forage given. If given in excess, it will not be utilized optimally, and the effect will not be significant. Antinutrients from feed ingredients will have adverse effects if they exceed the optimum limit that the animal's body can tolerate. Herbaceous legumes contain anti-nutritional substances like tannins with a relatively high concentration of 10-21 (Ratnawaty *et al*., 2013). Tannin is a natural compound consisting of many phenolic hydroxy groups. Tannin in ruminant livestock will affect methane gas production in the rumen and reduce digestibility.

Guerrero *et al*. (2002) give 100% *C. ternatea* hay as feed to dairy cattle, where milk production provides a corrected fat content of 3.5% and a higher fat and solids content than a lower percentage. Muinga *et al*. (2000) stated that herbaceous legumes from *Lablab purpureus*, *C. ternatea*, and *Mucuna pruriens* provide the same lactation performance as using *G. sepium* in Jersey dairy cows.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the results of the proximate tests revealed considerable differences in biomass production and chemical composition across herbaceous legumes, with *C. ternatea* and *Vigna* representing the opposite ends of the spectrum. *C. ternatea* had the highest crude protein and total digestible nutrition values, whereas *M. bracteatum* had the highest dry matter percentage. These findings support the possibility of these legumes as valuable alternatives for improving ruminant diet nutritional quality and replenishing animal feed supplies.

ACKNOWLEDGMENT

The authors are grateful to The Director General of Higher Education, Research, and Technology of The Ministry of Education, Culture, Research, and Technology (MOECRT) for the research funding support, with contract agreement No. 014/C2/I.3/DPPM-UK/VI.2023.

NOVELTY STATEMENT

Many tropical legumes have been grown primarily to provide protein to ruminants. However, investigations and reports on herbaceous legumes for nutritional value and *in vitro* parameters as the basis for animal feed quality were limited. As a preliminary step in selecting legumes for animal feed in Indonesia, each herbaceous legume's production and nutritional value must be evaluated.

AUTHOR'S CONTRIBUTION

HL and YAT: Conceptualization, writing original draft, and statistical analyses. PWP and ATN: Methodology and supervision. DPPH and AKW: Review and manuscript editing. All authors accepted for the final version of the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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