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Effect of Different Energy Sources on Silage of Dwarf Elephant Grass (Pennisetum Purpureum Cv. Mott) on Digestibility and Rumen Fluid Fermentation Parameters

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Abstract: The development of mini elephant grass is an alternative in providing forage because this grass is a superior type of grass. This paper informs about the morphological characteristics and their advantages as a source of feed and their processing to meet the needs of ruminant feed from mini elephant grass. Mini elephant grass (Pennisetum purpureum cv. Mott) is easily distinguished from elephant grass (P. purpureum) in terms of its morphology. Mini elephant grass has several advantages compared to elephant grass in terms of fast growth and regrowth, ratio of leaves to stems, protein content and high production of dry matter. This grass can be used in grazing and cut and carry systems. In addition, this grass can be given in the form of silage or dry (hay). Processing mini elephant grass through fermentation technology is recommended when production is abundant, so that it can be utilized during the dry season when forage availability is limited. The use of energy sources of 5% such as rice bran, cassava and sago pulp in odot grass silage results in a better quality of the chemical composition of odot grass silage and can increase KcBK, KcBO, VFA, and rumen fluid pH. While the use of rice bran as an energy source can increase the parameters of NH_3 fermentation.

Keywords: Digestibility and Rumen Fluid Fermentation Parameters; Energy; Pennisetum Purpureum Cv. Mott

Introduction

Mini elephant grass (Pennisetum purpureum cv. Mott) is native to tropical Africa and is one of the most widespread evergreens in Brazil (Campos et al., 2019; Daher et al., 2002). Moreover, it is traditionally used for its high biomass production potential (da Cunha et al., 2011) and provide high nutritional value for sheep feed (de Almeida Souza et al., 2021; da Silva et al., 2021). There are several genotypes of elephant grass available in Brazil, some of which are high (Elephant B and IRI-381) and short (Taiwan A-146 2.37 and Mott) (de Souza et al., 2017; P. H. F. da Silva et al., 2021). According to Lemos et al. (2021), Silage produced with short genotypes has a higher nutritional value, compared to tall ones.

In Indonesia, pygmy elephant grass and goats are very popular because the leaves are soft without trichomes, and they adapt well to the soil. Dwarf elephant grass has many benefits such as high productivity, 10-15% protein, low crude fiber, soft textured leaves and stems, and the percentage of leaves (76%) (Tudsri et al., 2002; Urribarrí et al., 2005). Dwarf elephant grass contains 13.55% dry matter, 14.45% ash, 13.94% crude protein and 71.43% digestibility (Sarwanto et al., 2019). The development of mini elephant grass is an alternative in providing forage, because this grass is a superior type of grass (Negawo et al., 2017). High production accompanied by a high leaf-stem ratio makes this grass suitable for processing into silage, especially when forage production is abundant so as to extend its shelf life. Provision of mini elephant grass in a fresh state for ruminants is quite practical because with its mini size it can be directly given to livestock without being chopped first (Ajayi, 2011; Gao et al., 2022).

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Mini elephant grass has good palatability and nutritional value so it is very promising as a source of sustainable forage for ruminants. Mini elephant grass is still preferred by livestock when given fresh or dry form in the form of hay (Morais et al., 2007; Negawo et al., 2017). Seen from the aspect of production and crude protein content, mini elephant grass is superior to Brachiaria decumbens, Brachiaria ruziziensis and Paspalum notatum, while from the palatability and digestibility side of mini elephant grass it is comparable to B. ruziziensis grass and still superior to B. grass. decumbens and P. notatum (Sirait, 2018).

Forage is the main source of feed for ruminants. Ruminants require a ration of 60-70% forage in fresh or dry form. Various efforts to increase livestock production in order to meet the needs of animal protein sources will be very difficult to achieve if the availability of forage is not proportional to the needs and the existing livestock population (Riswandi, 2014; Mbambalala et al., 2023). The availability of forage is strongly influenced by the season. During the dry season, the availability of forage is not able to meet the needs of livestock, but on the contrary, during the rainy season, forage is abundant, so it is necessary to preserve it into silage (Sofyan et al., 2017; Wróbel et al., 2023).

Silage is a fermented forage product, a by-product of agriculture and agro-industry with a high water content which is preserved by using acids, either intentionally added or naturally produced during storage under anaerobic conditions (Kung et al., 2018). One of the efforts to maintain the quality of tropical forage silage is the use of inoculum, rice bran and lactic acid bacteria (LAB) during ensilage which can stimulate fermentation (Astutik et al., 2019). The basic principle of making silage is forage fermentation by microbes which produce a lot of lactic acid (Ávila & Carvalho, 2020; Han et al., 2022).

The strategy needed to achieve maximum forage production at the desired level, it is necessary to make efforts to improve the nutrients contained in the soil through the use of fertilizers for soil fertility, it is estimated that 60% of agricultural land has nutrient deficiencies (Cakmak, 2002), therefore the nitrogen content in urea fertilizer is a nutrient that is used in large quantities for forage crops. Fertilization residues from previous crops can also last for a long time and can be used efficiently for regrowth of odot grass.

Method

The materials used in this study were odot grass (Pennisetum purpureum cv. Mott) from the UNPATTI animal husbandry department and several energy source feed ingredients such as sago dregs (Sago Ihur) from Tulehu village, onggok (White Cassava) from Liliboi village and rice bran (Padi Magongga) from Kelapa Dua village. Proximate analysis and nutritional quality of silage were carried out at the Laboratory of Nutrition and Animal Feed and analysis of dry matter digestibility, organic matter digestibility and rumen fermentation parameters (VFA, NH_3 and pH) was carried out at the IPB Dairy Livestock Nutrition Laboratory, Bogor Agricultural University.

The equipment used in this study were machetes, 3 kg PE plastic, tarpaulin, digital scales, thermometer, pH meter, vacuum pump, raffia rope, label paper, large baking sheet, camera and silage sampling (1 kg clear plastic, grinding machine, large baking sheet, label paper, stationery). In Vitro analysis equipment such as balances, centrifuges, fermenter tubes, porcelain cups, Conway cups, Erlenmeyer flasks, 105ºC electric ovens, 600ºC electric furnaces, water shaker baths, CO_2 gas cylinders, vacuum pumps, distillation apparatus, Whatman No. filter paper. 41, and tools for titration, pH meter.

This study was designed using a completely randomized design (CRD) consisting of 4 treatments and 5 replications. That is:

P1	:	Odot grass (Without Energy Source Feed Ingredients)
P2	:	Odot grass 95% + sago dregs 5%
P3	:	Mutton grass 95% + hemp 5%
P4	:	Mutton grass 95% + rice bran 5%

In Vitro analysis using McDougall solution, fresh rumen fluid, pepsin HCl 0.2% solution, aquadest, saturated HgCl2 solution, saturated NaCO3 solution, 0.005 N H2SO4 solution, boric acid indicator, 0.5 N HCl solution, 15% H_2SO_4 solution, 0.5N NaOH solution , PP indicator solution (Phenol Phtalein 0.1%).

The research variables were crude fiber, crude protein, crude fat, and dry matter (BK), silage pH, dry matter digestibility (KcBK), organic matter digestibility (KcBO) and rumen fermentation parameters namely VFA, NH3 and rumen pH. Data were processed by analysis of variance (Anova) based on a Randomized Block Design (RBD) with 4 treatments and 5 replications. If there is a treatment effect, a further test will be carried out with the honest significant difference test (BNJ) according to Gazpersz's instructions (1991). The mathematical model is as follows (Formula 1):

$$Yij = \mu + \tau i + \beta j + \varepsilon ij \quad (1)$$

Information:

Yij	:	observed value of the i-th treatment and the j-th group
μ	:	general average
τi	:	effect of the i-th treatment
βj	:	effect of the jth group

εij : effect of error in the ith treatment and the jth group

Result and Discussion

Nutrient Content of Silage

The results of the analysis of the nutritional content of odot grass silage with the addition of several energy sources can be seen in Table 1 below and the changes of dry matter, crude fat, crude protein, crude fiber and pH in odot grass silage with the addition of several energy sources are shown in Figure 1. Table 1. Analysis of the nutritional content of odot grass silage with the addition of several energy sources.

Table 1. Analysis of the Nutritional Content of Odot Grass Silage adding several energy sources.

Treatment	BK (%)	Crude fat* (%)	Crude protein* (%)	Crude fiber* (%)	pH (%)
P1	23.15c –	1.217b –	6.192 a	24,566 a	4,6 a
P2	25.25 ab	1.013b –	4,509c –	22,001b –	4,2 a
P3	24.57 b	1.171b –	4,156c –	23.187 ab	3,9a –
P4	25.06a –	1,880a –	5,533b –	24.122 ab	4,1 a

*) Results of ITB nutrition and fodder laboratory analysis for 2021.

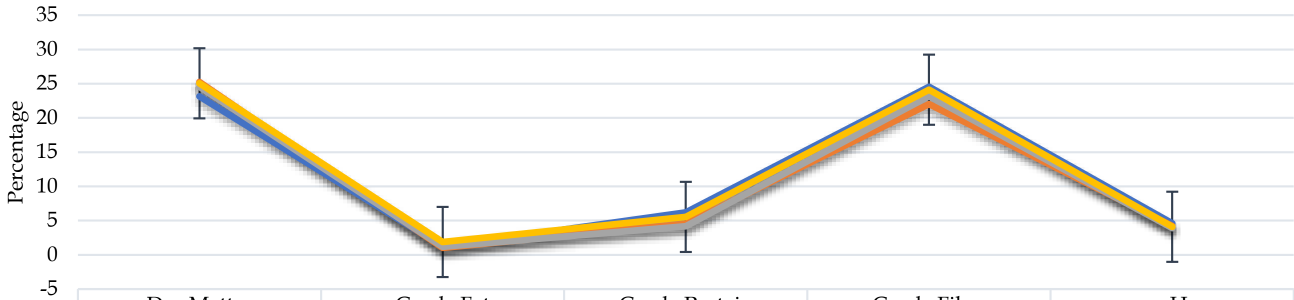
This study shows that the silage treatment of odot grass with the addition of sago pulp had a high DM of 25.25% when compared to other treatments. The high content of dry matter in odot grass silage with the addition of sago pulp is due to the addition of dry matter in the material. The low content of dry matter in treatment P1 (control) without additional energy sources was due to the low content of energy sources for lactic acid bacteria, causing the aerobic phase to last a long time, resulting in heat, CO2, and H2O. The source of energy used by microbes only comes from forage. Microbes will break down the components of food ingredients from forages, causing the dry matter content to be low.

Cassava flour has the lowest dry matter for the three agricultural wastes used as an energy source in making odot grass silage (P3). This is because cassava flour contains dissolved carbohydrates which can increase fermentation resulting in low dry matter. The more sources of soluble carbohydrates, the lower the dry matter content of the silage.

The high content of crude fat in odot grass silage with the addition of rice bran is due to the ensilage process. The low reduction in crude fat content was found in the silage treatment of odot grass with the addition of sago pulp due to microbial activity which degrades glycerol and fatty acids as a source of energy resulting in a decrease in crude fat (Yılmaz Tuncel, 2023).\When compared to other treatments, the high protein content in P1 (control) without the addition of an energy source was due to some protein from plants being degraded by protease enzymes originating from the plants themselves and by microbes during the ensilage. Table 1 above shows that the crude protein content in the silage treatment of odot grass with the addition of sago pulp was lower than the treatment of odot grass with cassava and the treatment of odot grass with the addition of rice bran. In silage given an additional energy source, this is due to the low supply of nutrients for lactic acid bacteria resulting in slow anaerobic conditions being reached and causing the growth of clostrides which can degrade proteins into NH3, H2O and CO2. In addition, the decrease in crude protein content is also suspected by a reduction of microbial activity due to a decrease in the amount of nutrients available for microbial growth and proliferation.

Of the three agricultural wastes used as an energy source in making odot grass silage, the one with a high crude protein content was the odot grass silage treatment with the addition of rice bran. The high crude protein content of odot grass with the addition of rice bran is due to the presence of additional protein-containing microorganisms and substrates in rice straw silage. In addition, during the fermentation process, lignocellulosic silage and lignohemicellulose will stretch so that the protein bound to lignin is released (Kucharska et al., 2018; Manyi-Loh & Lues, 2023).

The high crude fiber content in odot grass silage is due to the P1 (control) treatment without additional energy sources, thus there will be an increase in the mushroom population due to the low availability of energy sources for lactic acid (LAB) so that the fermentation process in the silage does not run optimally. An increase in protozoa or fungi can cause the increase in crude fiber because the heat in the silage increases. Chitin in protozoa or fungi is included in the crude fiber group on proximate analysis. In addition, the high crude fiber is due to the high pH value of silage. At a high pH will cause microbes that are not resistant to high pH will die so that it will cause low degradation of crude fiber.



	Dry Matter	Crude Fat	Crude Protein	Crude Fiber	pH
P1	23.15	1.217	6.192	24.566	4.6
P2	25.25	1.013	4.509	22.001	4.2
P3	24.57	1.171	4.156	23.187	3.9
P4	25.06	1.88	5.533	24.122	4.1

Variable

P1 P2 P3 P4

Figure 1. The changes in dry matter, crude fat, crude protein, crude fiber and pH in odot grass silage with the addition of several energy sources

The low content of crude fiber in odot grass silage with the addition of sago pulp is caused by cellulotic microbial activity during fermentation. Crude fiber in silage is a source of reserve sugar which will be used when the easy-to-use carbohydrate source has run out. Fiber contains cellulose, lignin and other polysaccharides. This compound has a complex bond that is very difficult to break down by microorganisms so microorganisms cannot use crude fiber at the beginning of the fermentation process.

The decrease in crude fiber during the fermentation process in silage is due to the decomposition carried out by microbes during the fermentation process. Microbes that synergize with each other accelerate the loosening of lignocellulosic bonds due to increased activity of enzymes produced during the fermentation process.

Of the three agricultural wastes used as an energy source in making odot grass silage, the one with the highest crude fiber content was the treatment of odot grass with the addition of rice bran. This is because rice bran contains a crude fiber value of 11.62%. This has implications for increasing the crude fiber content in silage. This is reinforced by Anjum et al. (2007) who states that the crude fiber content in rice bran ranges from 6% -30%. In addition, Fahey et al., (2019) stated that the increase in crude fiber was caused by the content of NDF and ADF which are components of crude fiber.

The high pH value in the P1 (control) treatment without additional energy sources was influenced by the dissolved carbohydrate content in the feed ingredients used by lactic acid bacteria to produce organic acids and the protein content which affected the silage capacity. This can happen because odot grass is a feed ingredient with a protein source that contains high nitrogen elements, which will be used as a source of ammonia that can affect the silage's pH value.

In addition to P1 (control) without the addition of an energy source, it has the highest pH (acidity) value, but if it is related to the physical appearance of silage, judging from the texture, there is fungus on the surface of the silage. This is because the microbes are not able to develop properly so that the microbial activity goes well during the fermentation process (Yafetto, 2022).

At the beginning of the ensilage process, respiration occurs momentarily by plant cells after the material is put into the silos, namely by utilizing the remaining oxygen (O2) in the silos until the oxygen runs out. With the end of respiration activity, lactic acid bacteria begin to develop by utilizing easily soluble carbohydrates found in P3, namely odot grass with the addition of cassava to produce lactic acid which will suppress the growth of spoilage bacteria and help lower pH so as to create acidic conditions. The addition of cassava flour lowers the average pH of odot grass. This shows that the addition of cassava flour in the ensiling process of odot grass can provide proper conditions for developing lactic acid-forming bacteria so that the pH decreases quickly. Carbohydrates can accelerate the decrease in silage pH because carbohydrates are energy for lactic acid-forming bacteria.

In addition, the magnitude of this pH value is influenced by the dissolved carbohydrate content (WSC) in the feed ingredients used by lactic acid bacteria to produce organic acids and is influenced by the protein content which affects the silage capacity. This microbial activity will also produce lactic acid to lower the fermented straw's pH level during the curing process. The low pH level will cause the microbial that can't stand the low pH to die so that only the remaining microbial can survive at the fermentation pH (low pH).

Digestibility of Dry Matter (KcBK), Organic Matter (KcBO), Volatile Fatty Acids (VFA), NH_3 Concentration, and Ph Rumen

Dry matter digestibility (KcBK) is a measure of digestibility to determine the amount of feed nutrients absorbed in the gastrointestinal tract by releasing nutrients so that they can be absorbed and excreted in the feces. Measurement of dry matter and organic matter digestibility, VFA, NH_3 and pH rumen in each treatment can be seen in Figure 2. Dry matter digestibility (KcBK) is a measure of digestibility to determine the amount of feed nutrients absorbed in the gastrointestinal tract by releasing nutrients so that they can be absorbed and excreted in the feces.

The results of the analysis of variance showed that between the treatments there was a very significant difference in the digestibility of the dry matter (P<0.01). The BNJ test results showed that the P1 treatment was very significantly different from the treatment P2, P3 and P4 (P<0.01). This is presumably because the crude fiber bonds that form complex compounds in the feed are stretched into simpler compounds due to the feed fermentation process. Loosened crude fiber bonds result in increased microbial degradation/reshuffle activity in the rumen, resulting in increased dry matter digestibility.

The results of the BNJ test showed that treatment P1 was significantly different from treatments P2, P3 and P4 (P<0.01), P2 was not significantly different from treatment P3, but was highly different from treatments P1 and P4 (P<0.01), and likewise the P3 treatment was not significantly different from the P2 treatment, but very significantly different from the P1 and P4 treatments (P<0.01).

The highest organic matter digestibility in this study was found in the P3 treatment, i.e. in odot grass silage plus cassava 5% (figure 2). The advantage of cassava is that it is rich in soluble carbohydrates, namely BETN. The high digestibility of organic matter was due to the high BETN (31.646%) in the feed compared to treatments P1, P2 and P4 (Table 2). BETN is a group of easily soluble carbohydrates. Carbohydrates in the rumen will undergo degradation into simple sugars. Simple sugars then undergo the process of glycolysis into pyruvic acid through anaerobic oxidation of glucose .

Based on the results of analysis of variance, it was shown that the treatments were significantly different from ammonia production (P<0.01). The BNJ test results showed that the P1 treatment was not significantly different from the P2 and P4 treatments, but very significantly different from the P3 treatment (P<0.01), the P2 treatment was not significantly different from the P1 and P3 treatments, but very significantly different from the P4 treatment (P<0.01), and treatment P3 was not significantly different from treatment P2, but very significantly different from treatment P1 and P4 (P<0.01).

The highest concentration of NH_3 in this study was in the P4 treatment, i.e. in odot grass silage plus 5% rice bran (Figure 4). The high concentration of NH_3 was due to the high protein silage content of 5.533% compared to treatments P2 and P3, but almost the same as treatment P1 (Table 2). The advantage of rice bran is that it has a fairly high nutritional content such as crude protein ranging from 12-14%, crude fiber 8-13%. Where the protein content in feed will affect the concentration of NH_3. This is because ammonia in the rumen comes from protein degradation in feed and is degraded by rumen microbes into proteolytic activity (breakdown of protein into organic acids, ammonia and CO_2).

The results of the analysis of variance showed that the treatments were significantly different from the rumen fluid pH (P<0.01). The results of the BNJ test showed that the P1 treatment was very significantly different from the P2, P3 and P4 treatments (P<0.01), the P2 treatment was not significantly different from the P3 treatment, but very significantly different from the P1 and P4 treatments (P<0.01) and likewise treatment P3 was not significantly different from treatment P2, but significantly different from treatment P1 and P4 (P<0.01).

The highest rumen fluid pH in this study was in treatment P1, i.e. odot grass silage without an energy source. The high pH is due to the high crude fiber content in the feed, which is 24.566% (Table 2).

Table 2. Analysis of the Nutritional Content of Odot Grass Silage with Different Energy Sources (%).

Treatment	Water*	Ash *	Crude Fat*	Crude protein*	Crude fiber*	BETN**
P1	23.15	16.331	1.217	6.192	24,566	28.544
P2	25.06	16.101	1.013	4.509	22.001	31.316
P3	24.58	15.260	1.171	4.156	23.187	31.646
P4	24.25	15.570	1.880	5.533	24.122	28.645

*) Results of laboratory analysis nutrition and Animal Feed IP B in 2021.

**) Calculation results according to AOAC, (1990).

Table 3. Average Digestibility of Dry Matter and Organic Matter in Odot Grass Silage with Different Energy Sources

Treatment	KcBK (%)	KcBO (%)
P1	49,141[d]	49,560[c]
P2	55,151[b]	56,086[a]
P3	56,892[a]	57,946[a]
P4	51.605[c]	51,905[b]

[c],[d] *Different supers of scripts* in the same column show a very significant difference (P<0.01). Note: P1: odot grass without feed as an energy source; P2: odot grass + 5% Sago Dregs; P3: odot grass + 5% pile; P4: odot grass + 5% rice bran.

Table 4. Average concentrations of Odot Grass Silage Fermentation Parameters with Different Energy Sources.

Treatment	VGA(mM)	NH_3 (mM)	pH
P1	108,208[b]	7,215[ab]	7,201[a]
P2	115,595[ab]	6,347[bc]	6,965[c]
P3	127,396[a]	5,972[c]	6,894[c]
P4	98,687[b]	7,854[a]	7,075[b]

[b],[c] *Different script supers* in the same column showed a very significant difference (P<0.01) . Note: P1: odot grass without feed as an energy source; P2: odot grass + 5% Sago Dregs; P3: odot grass + 5% pile; P4: odot grass + 5% rice bran.

Conclusion

The use of energy sources of 5% such as rice bran, cassava and sago pulp in odot grass silage results in a better quality of the chemical composition of odot grass silage and can increase KcBK, KcBO, VFA, and rumen fluid pH. While the use of rice bran as an energy source can increase the parameters of NH_3 fermentation.

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Author Contributions
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Conflicts of Interest
The authors declare no competing interests.

References

Ajayi, F. T. (2011). Effects of feeding ensiled mixtures of elephant grass (Pennisetum purpureum) with three grain legume plants on digestibility and nitrogen balance of West African Dwarf goats. *Livestock Science*, *142*(1–3), 80–84. https://doi.org/10.1016/j.livsci.2011.06.020

Anjum, F., Pasha, I., Bugti, M., & Butt, M. (2007). Mineral composition of different rice varieties and their milling fractions. *Pakistan J. Agric. Sci*, *44*(2), 332–336. http://pakjas.com.pk/papers/336.pdf

Astutik, A. S., Irsyammawati, A., & Ndaru, P. H. (2019). Pengaruh Silase Rumput Odot (Pennisetum purpureum cv. Mott) dengan Penambahan Bakteri Lactobacillus plantarum Terhadap Produksi Gas dan Kecernaan Secara In Vitro. *Jurnal Nutrisi Ternak Tropis*, *2*(1), 10–18. https://doi.org/10.21776/ub.jnt.2019.002.01.2

Ávila, C. L. S., & Carvalho, B. F. (2020). Silage fermentation—updates focusing on the performance of micro-organisms. *Journal of Applied Microbiology*, *128*(4), 966–984. https://doi.org/10.1111/jam.14450

Cakmak, I. (2002). Plant nutrition research: Priorities to meet human needs for food in sustainable ways BT - Progress in Plant Nutrition: Plenary Lectures of the XIV International Plant Nutrition Colloquium: Food security and sustainability of agro-ecosystems through basi. *Plant and Soi*, *247*(1), 3–24. https://doi.org/10.1007/978-94-017-2789-1_1

Campos, B. B., Diniz, R. H. S., Da Silveira, F. A., Ribeiro Júnior, J. I., Fietto, L. G., MacHado, J. C., & Da Silveira, W. B. (2019). Elephant grass (pennisetum purpureum schumach) is a promising feedstock for ethanol production by the thermotolerant yeast kluyveromyces marxianus CCT 7735. *Brazilian Journal of Chemical Engineering*, *36*(1), 43–49. https://doi.org/10.1590/0104-6632.20190361s20170263

da Cunha, M. V., Lira, M. de A., dos Santos, M. V. F., de Freitas, E. V., Dubeux Junior, J. C. B., de Mello, A. C. L., & Martins, K. G. R. (2011). Associação entre características morfológicas e produtivas na seleção de clones de capim-elefante. *Revista Brasileira de Zootecnia*, *40*(3), 482–488. https://doi.org/10.1590/S1516-35982011000300004

da Silva, J. K. B., da Cunha, M. V., dos Santos, M. V. F., Magalhães, A. L. R., de Mello, A. C. L., da Silva, J. R. C., da Rocha Souza, C. I., de Carvalho, A. L., & de Souza, E. J. O. (2021). Dwarf versus tall elephant grass in sheep feed: which one is the most recommended for cut-and-carry? *Tropical Animal Health and Production*, *53*(1), 1–14. https://doi.org/10.1007/s11250-020-02508-y

da Silva, P. H. F., Sales, T. B., Lemos, M. F., Silva, M. da C., Ribeiro, R. E. P., Dos Santos, M. V. F., de Mello, A. C. L., & da Cunha, M. V. (2021). Tall and short-sized elephant grass genotypes:

Morphophysiological aspects cut-and-carry, and grazing management. *Ciencia Rural*, *51*(9), 1–9. https://doi.org/10.1590/0103-8478cr20200848

Daher, R. F., Pereira, M. G., Pereira, A. Vander, & Amaral Jr., A. T. do. (2002). Genetic divergence among elephantgrass cultivars assessed by RAPD markers in composit samples. *Scientia Agricola*, *59*(4), 623–627. https://doi.org/10.1590/s0103-90162002000400001

de Almeida Souza, R. T., Dos Santos, M. V. F., da Cunha, M. V., Gonçalves, G. D., da Silva, V. J., de Mello, A. C. L., Muir, J. P., Ribeiro, R. E. P., & Dubeux, J. C. B. (2021). Dwarf and tall elephantgrass genotypes under irrigation as forage sources for ruminants: Herbage accumulation and nutritive value. *Animals*, *11*(8), 1–17. https://doi.org/10.3390/ani11082392

de Souza, P. H., Faturi, C., Rodrigues, L. F. de S., Filho, E. da S., do Rêgo, A. C., & Filho, J. A. R. (2017). Nutritional value of elephant grass genotypes. *Pesquisa Agropecuaria Brasileira*, *52*(10), 951–955. https://doi.org/10.1590/S0100-204X2017001000016

Fahey, G. C., Novotny, L., Layton, B., & Mertens, D. R. (2019). Critical factors in determining fiber content of feeds and foods and their ingredients. *Journal of AOAC International*, *102*(1), 52–62. https://doi.org/10.5740/jaoacint.18-0067

Gao, L., Yan, Q., Li, J., Pang, T., Lu, L., Yi, X., Jones, C. S., & Zhang, J. (2022). Elephant grass supplementation in the feed of fattening pigs affects growth performance, carcass characteristics, blood profiles and intestinal microorganisms. *Frontiers in Animal Science*, *3*, 1–12. https://doi.org/10.3389/fanim.2022.911692

Gaspersz, V. 1991. Metoda perancangan percobaan untuk ilmu-ilmu pertanian, ilmu-ilmu teknik dan biologi. CV. Armico. Bandung. 472 p

Han, H., Wang, C., Huang, Z., Zhang, Y., Sun, L., Xue, Y., & Guo, X. (2022). Effects of Lactic Acid Bacteria-Inoculated Corn Silage on Bacterial Communities and Metabolites of Digestive Tract of Sheep. *Fermentation*, *8*(7), 1–14. https://doi.org/10.3390/fermentation8070320

Kucharska, K., Rybarczyk, P., Hołowacz, I., Łukajtis, R., Glinka, M., & Kamiński, M. (2018). Pretreatment of lignocellulosic materials as substrates for fermentation processes. *Molecules*, *23*(11), 1–32. https://doi.org/10.3390/molecules23112937

Kung, L., Shaver, R. D., Grant, R. J., & Schmidt, R. J. (2018). Silage review: Interpretation of chemical, microbial, and organoleptic components of silages. *Journal of Dairy Science*, *101*(5), 4020–4033. https://doi.org/10.3168/jds.2017-13909

Lemos, M. F., de Mello, A. C. L., Guim, A., da Cunha, M. V., da Silva, P. H. F., Atroch, T. M. A., Neto, D. E. S., Neto, P. M. D. O., Medeiros, A. S., & Clemente, J. V. F. (2021). Grass size and butterfly pea inclusion modify the nutritional value of elephant grass silage. *Pesquisa Agropecuaria Brasileira*, *56*, 1–10. https://doi.org/10.1590/S1678-3921.pab2021.v56.02409

Manyi-Loh, C. E., & Lues, R. (2023). Anaerobic Digestion of Lignocellulosic Biomass: Substrate Characteristics (Challenge) and Innovation. In *Fermentation* (Vol. 9, Issue 8). https://doi.org/10.3390/fermentation9080755

Mbambalala, L., Rani, Z. T., Mpanza, T. D. E., Mthana, M. S., Ncisana, L., & Mkhize, N. R. (2023). Fodder Radish as a Potential Alternative Feed Source for Livestock in South Africa. *Agriculture (Switzerland)*, *13*(8), 1–11. https://doi.org/10.3390/agriculture13081625

Morais, J. A. D. S., Sanchez, L. M. B., Kozloski, G. V., De Lima, L. D., Trevisan, L. M., Reffatti, M. V., & Cadorin, R. L. (2007). Dwarf elephant grass hay (Pennisetum purpureum Schum. cv. Mott) digestion by sheep at different levels of intake. *Ciencia Rural*, *37*(2), 482–487. https://doi.org/10.1590/s0103-84782007000200029

Negawo, A. T., Teshome, A., Kumar, A., Hanson, J., & Jones, C. S. (2017). Opportunities for napier grass (Pennisetum purpureum) improvement using molecular genetics. *Agronomy*, *7*(2), 1–21. https://doi.org/10.3390/agronomy7020028

Riswandi. (2014). Evaluasi Kecernaan Silase Rumput Kumpai (Hymenachne acutigluma) dengan Penambahan Legum Turi Mini (Sesbania rostrata). *Jurnal Peternakan Sriwijaya*, *3*(2), 43–52.

Sarwanto, D., Tuswati, S. E., & Sulistyaningtyas, S. (2019). The Level of Dwarf Elephant Grass (Pennisetum Purpureum cv. mott) to Substitute Indigenous Forage for Goat Feed in Limestone Mountain. *IOP Conference Series: Earth and Environmental Science*, *372*(1), 1–6. https://doi.org/10.1088/1755-1315/372/1/012039

Sirait, J. (2018). Dwarf Elephant Grass (Pennisetum purpureum cv. Mott) as Forage for Ruminant. *Indonesian Bulletin of Animal and Veterinary Sciences*, *27*(4), 167. https://doi.org/10.14334/wartazoa.v27i4.1569

Sofyan, A., Widyastuti, Y., Utomo, R., & Yusiati, L. M. (2017). Improving physico-chemical characteristic and palatability of king grass (Pennisetum hybrid) silage by inoculation of lactobacillus plantarum - saccharomyces cerevisiae consortia and addition of rice bran. *Buletin Peternakan*, *41*(1), 61. https://doi.org/10.21059/buletinpeternak.v41i1.12980

Tudsri, S., Jorgensen, S. T., Riddach, P., & Pookpakdi, A. (2002). Effect of cutting height and dry season closing date on yield and quality of five napier grass cultivars in Thailand. *Tropical Grasslands*, *36*(4), 248–252.

Urribarrí, L., Ferrer, A., & Colina, A. (2005). Leaf protein from ammonia-treated dwarf elephant grass (Pennisetum purpureum Schum cv. Mott). *Applied Biochemistry and Biotechnology - Part A Enzyme Engineering and Biotechnology*, *122*(1–3), 721–730. https://doi.org/10.1007/978-1-59259-991-2_60

Wróbel, B., Nowak, J., Fabiszewska, A., Paszkiewicz-Jasińska, A., & Przystupa, W. (2023). Dry matter losses in silages resulting from epiphytic microbiota activity—a comprehensive study. *Agronomy*, *13*(2), 1–24. https://doi.org/10.3390/agronomy13020450

Yafetto, L. (2022). Application of solid-state fermentation by microbial biotechnology for bioprocessing of agro-industrial wastes from 1970 to 2020: A review and bibliometric analysis. *Heliyon*, *8*(3), 1–17. https://doi.org/10.1016/j.heliyon.2022.e09173

Yılmaz Tuncel, N. (2023). Stabilization of Rice Bran: A Review. *Foods*, *12*(9), 1–21. https://doi.org/10.3390/foods12091924