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Research article

PELLETED FORAGE CONSERVATION AND ITS EFFECTS ON NUTRITIONAL VALUE, FEEDING BEHAVIOR, AND FEED INTAKE IN DAIRY CATTLE

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ABSTRACT

The development of a simple and economical forage conservation method suitable for local dairy farmers is essential due to the seasonal availability of forages. This study aimed to evaluate the feasibility of conserving forages in pelleted form and to assess the acceptability, palatability, and quality of pelleted forages. Hybrid Napier Grass (CO3), Panicum maximum (Guinea grass), Leucaena leucocephala (Ipil ipil) and Gliricidia sepium were harvested and sun-dried for 3 h (short-dried (Sd)), 4 h (medium-dried (Md)), and 5 h (long-dried (Ld)) to determine the optimal drying duration for pelleting. Pelletability, moisture content, bulk density, unit density, keeping quality, and nutrient composition of the pellets were analyzed. Supplemented pellets were prepared from each forage type by mixing 75% dried forage with either 25% rice polish (T1) or 75% dried forage with 12.5 % rice polish and 12.5% coconut poonac (T2). The pellets were evaluated for keeping quality, acceptability, and palatability in dairy cows. The biomass from short-dried (Sd) Leucaena, medium-dried (Md) Giricidia, long-dried (Ld) CO3, and Guinea grass showed the best pelleting properties, producing stable pellets with the highest bulk and unit densities and the longest shelf life. High-quality pellets were storable at room temperature for over two months without fungal or mold growth, off-odors, or discoloration. The T2 pellets exhibited higher acceptability and palatability than T1 across all the forage types. The palatability differed significantly between the treatments (T1 and T2) and among the forage varieties (P = 0.05). Forage pelleting proved to be a cost-effective conservation method for grasses and legumes, producing pellets with improved keeping quality, palatability, and acceptability for dairy cattle. Therefore, forage pelleting represents a sustainable, economical, and practical conservation strategy for small- to medium-scale dairy farmers.

Key words:
forage conservation, pelleting ability

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INTRODUCTION

The dairy industry is regarded as the most important sub-sector within the livestock sector due to its substantial potential to contribute to Sri Lanka's economic growth. Moreover, milk is a vital component in addressing nutritional deficiencies across all age groups (Ranaweera, 2015). However, to meet the current milk demand resulting from the growing population, Sri Lanka annually imports approximately 70,000–75,000 metric tons of milk powder, incurring an expenditure of nearly Rs. 30 billion. According to the National Livestock Development Board, achieving national self-sufficiency in milk production would require an additional 482 million liters of milk per year. Consequently, the present government has prioritized the development of the dairy industry, implementing several dairy development projects (Lam and Sokhansanj, 2014). Despite the importation of high-yielding dairy breeds and modern milking equipment under these initiatives, milk productivity remains low, primarily due to the shortage of high-quality animal feed required for the optimal management of genetically improved cows (St. Joseph, 2007).

One of the major challenges faced by dairy farmers in the Coconut Triangle is the significant decline in cattle body condition during prolonged droughts due to feed scarcity (Ibrahim and Jayatileka, 2000). Forage plays a crucial role in the diet of dairy cattle, supporting rumen health and, importantly, helping to reduce the costs associated with commercial feed. As indicated by several studies, the nutritive value of forages declines with decreases with advancing maturity (Blaser, 1964). As emphasized by Thomas and van der Poel (1995), the availability of high-quality fodder in adequate quantities is the most critical foundation for any efficient milk production system. The higher the potential milk yields of dairy cattle, the greater the requirement for high-quality roughage. When low-quality roughage is fed, it must be supplemented with nutrient-rich concentrate feeds to sustain optimal milk production and to stimulate forage intake, particularly when the forage quality is poor (Premaratne and Premalal, 2005).

In order to ensure a steady supply of quality livestock feed even during the dry season, excess forages could be preserved as silage, hay and leaf meal blocks (Somasiri et al., 2010). However, forage conservation in the form of silage or hay remains unsatisfactory among Sri Lankan dairy farmers, primarily due to high labor requirement. Poor-quality silage often results from inadequate planning, insufficient equipment and silo facilities, and inappropriate harvesting practices. Similarly, haymaking presents several challenges, including the need for skilled operators to produce weather-resistant bales, specialized equipment for handling and feeding, and additional storage space, as hay packages are typically non-stackable. Therefore, there is a growing need for an effective forage conservation technique that requires less labor and time. Pelleted grass meal represents a promising alternative method of forage preservation, as it reduces bulkiness, improves handling and transportation efficiency, and potentially enhances feed utilization. Moreover, several studies have demonstrated that animals achieve better growth performance when fed pelleted diets compared with meal-based rations (Tumuluru et al., 2015).

Tumuluru (2013) reported that optimizing moisture content, preheating temperature, and die speed significantly improves the density and durability of pellets produced from high-moisture corn stover, contributing to more energy-efficient biomass pellet production with lower drying requirements. In another study, Krogstad et al. (2021) investigated the effects of feeding pelleted dried distillers grains with solubles (DDGS) at varying forage concentrations to lactating Jersey cows and found that pelleting influenced feeding behavior, rumen fermentation, and milk production. Specifically, cows fed pelleted DDGS exhibited altered chewing activity and rumen parameters compared to those receiving meal-form DDGS, underscoring the importance of feed physical form in dairy cow performance. In like fashion, Miron et al. (2004) observed that pelleted soy hulls and corn gluten feed increased eating time, dry matter intake, and milk fat yield in dairy cows. Bonfante et al. (2016) found that Holstein heifers fed pelleted diets exhibited greater feed intake and reduced rumination time without any decline in weight gain. Conversely, Suarez (2014) demonstrated that calves fed finer feed particles showed impaired rumen development, while coarser particles improved digestion efficiency. Furthermore, Borreani et al. (2018) reported that ensiled forages had lower true protein content and higher non-protein nitrogen levels, resulting in reduced feed quality.

The present study was designed to evaluate the feasibility of conserving forages in pelleted form and to develop supplemented pellets to assess their acceptability and palatability for dairy cattle. Additionally, the study aimed to determine the nutritional value, keeping quality, and cost-effectiveness of pelleted forages as a sustainable feeding strategy for small- to medium-scale dairy farmers.

MATERIAL AND METHODS

Selection of forages

The experiment was conducted using four commonly available forage species: Hybrid Napier Grass (CO3), Guinea grass *(Panicum maximum*), *Gliricidia sepium* and *Leucaena leucocephala* (Ipil ipil).

Hybrid Napier grass (variety CO-3):

Premaratne ans Premalal (2005) state that this grass falls under the elephant grass category due to its high tillering capacity, with a single clump capable of producing over 50 tillers under favorable soil and climatic conditions. Additionally, it has a high green forage yield, averaging 5–8 kg of green fodder per plant per cut or 250–350 tons per hectare per year, with a harvesting cycle of every 30–45 days. The cultivation of CO-3 grass is an effective solution for land-limited dairy farmers due to its high nutritive value and resistance to drought, pest and diseases.

Panicum maximum (Guinea grass):
Panicum maximum is a robust, perennial bunchgrass that grows naturally in open grasslands. Its leaf blades are long, narrow, and finely tipped, while stems may be branched and range from hairless to densely hairy. It is widely cultivated throughout the tropics as forage for various classes of grazing livestock. Young, leafy growth exhibits high palatability and favorable nutritional value, contributing to improved animal performance.

*Leucaena leucocephala (*Ipil Ipil):
Leucaena leucocephala is a long-lived perennial leguminous shrub with considerable potential for integration into tropical and subtropical dairy production systems. It provides high-quality forage, particularly valuable during dry periods. Feeding dairy cows with *Leucaena* foliage under cut-and-carry systems has been shown to increase milk yield as well as milk fat and protein content.

Gliricidia sepium:
Gliricidia forage has a relatively high rumen digestibility of approximately 62.8%, which enhances weight gain and milk production in both large and small ruminants when used as a supplement. When included at 20–40% of the diet alongside low-quality basal feeds such as grass, straw, and crop residues, it significantly improves the overall animal performance.

Cocos nucifera (Coconut poonac):
Coconut poonac, or coconut meal, is a by-product of coconut oil extraction from copra. It serves as a valuable source of both energy and protein and is widely used as a supplementary feed ingredient in coconut-producing regions for dairy cattle (Silva, 1980). The recommended safe inclusion level for dairy cows is 1.5–2.0 kg per day; higher amounts may result in undesirable fat consistency in butter.

Oryza sativa (Rice polish):
Rice polish is a by-product obtained during the rice milling process, produced by brushing the grain to polish the kernel. It is a good source of proteins, energy, vitamins and minerals, and provides a balanced amino acid profile (particularly rich in lysine and methionine) compared with other cereal grains such as maize and wheat.

Experimental area
This study was conducted from March to July in 2017 at the Department of Livestock and Avian Sciences, Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka. The experimental site is situated in the low-country intermediate agro-ecological zone (IL2) at coordinates 7°19'25.0" N and 79°59'17.9" E.

Drying, pelleting, pellet quality determination, and nutrient analysis
The forages were cut into pieces using a grass chopping machine and sun-dried from 9.00 a.m. to 3.00 p.m. The material was turned and mixed three to four times during drying to ensure uniform moisture reduction. The ambient temperature during the drying process ranged from 35.7°C to 38.6°C, with relative humidity between 65% and 68%.
The selected forages were subjected to three sun-drying durations: 3 h (short-dried, Sd), 4 h (medium-dried, Md), and 5 h (long-dried, Ld). The dried samples were ground to a particle size of 4–5 mm and pelletized using a dry pelleting machine. The resulting pellets were evaluated for physical quality parameters, including moisture content**,** bulk density, and unit density, as well as organoleptic properties such as color, aroma, and shelf life.

Determination of pellet quality and analysis of the nutrient value of forage pellets
The proximate composition of the pelleted forages—crude protein, crude fiber, ether extract (fat), and ash content—was determined following the standard methods of the Association of Official Analytical Chemists (AOAC, 2000). The samples that exhibited the best pelleting ability, favorable physical quality, and longest shelf life were selected for further evaluation.
Supplemented pellets were made with each forage variety either by mixing 75% dried forages with 25% rice polish (the T1 diet) or 75% dried forages with 12.5 % rice polish and 12.5% coconut poonac (the T2 diet). Palatability and acceptability tests were conducted using six untrained early-lactation Friesian × Sahiwal crossbred dairy cows of similar body weight. For acceptability assessment, equal quantities of T1 and T2 pellets from each forage type were

simultaneously offered, and the cows' preference was observed. Palatability was evaluated by offering 1 kg of each pelleted diet and recording the quantity of feed remaining after 10 minutes of consumption.

Statistical analysis

Physical quality parameters of the pelleted forages were analyzed using a factorial completely randomized design (CRD). Proximate composition data and palatability test results were subjected to the analysis of variance (ANOVA) using the SPSS version 16.0. Differences between the treatment means were considered statistically significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Pelleting ability of forages

The fastest drying rates were observed in *Leucaena leucocephala* and *Gliricidia sepium*, respectively. Both species possess broad leaves compared to grasses, which facilitates faster moisture evaporation. A reduction in initial moisture content from 72.03% to 17.46% in *Leucaena* (short-dried, Sd) and from 76.43% to 15.83% in *Gliricidia* (medium-dried, Md) resulted in superior pelleting ability compared with the long-dried (Ld) legumes (Figure 1). The prolonged drying of *Leucaena* and *Gliricidia* proved challenging due to substantial biomass losses caused by leaf shedding and dispersal by wind. In contrast, Hybrid Napier grass (CO3) and Guinea grass (*Panicum maximum*) required prolonged drying (Ld) to achieve the optimal pelleting conditions. The initial moisture content of CO3 declined from 82.42% to 15.28%, while that of Guinea grass decreased from 80.65% to 14.92%. The slower drying rate of these grasses may be attributed to their thicker, softer stems and the slightly hairy texture of their leaf blades, which hinder rapid moisture loss.

Figure 1. Significant differences in the average moisture reduction among the forages subjected to varying sun-drying durations

Moisture content plays a critical role in determining pelleting efficiency, physical quality characteristics, and the storage stability of forage pellets. Elevated moisture content in raw material leads to increased pellet moisture, reduced durability, and shorter shelf life. Conversely, excessive drying decreases the binding capacity of the material, as water acts as a natural binder during pelletization. Insufficient moisture may result in pellets with surface cracks, brittleness, and a higher tendency to disintegrate. Therefore, optimizing the moisture content of forage biomass is essential to ensure the production of high-quality, durable pellets with extended storage stability.

Determination of physical properties of forage pellets

There was a significant interaction ($P < 0.05$) between the drying duration (Sd, Md, and Ld) and forage type (F_1, F_2, F_3, and F_4) on the mean moisture content, bulk density, and unit density of the pellets (Table 1). The results revealed that *Leucaena* and *Gliricidia* pellets prepared from Sd and Md biomass, respectively, exhibited superior pelleting ability, producing high-density pellets with good strength and extended shelf life. The best-quality legume pellets were obtained from the Ld biomass, characterized by a diameter of 8–10 mm and a length of 13–15 mm.

In contrast, the grasses (CO3 and *Guinea*) required prolonged drying (Ld) to achieve the optimal pellet quality, with high density, stability, and long shelf life. These pellets typically ranged from 8–9 mm in diameter and 12–15 mm in length. The grasses pelleted at higher moisture levels (Sd and Md) produced poor-quality pellets with lower bulk and unit densities, visible surface cracks, and structural breakage. These pellets were smaller, averaging 5–7 mm in diameter and 8–10 mm in length.

Overall, a decrease in pellet moisture content was associated with increased bulk and unit densities, resulting in more compact pellets that required less storage and packaging space and exhibited improved storability.

Table 1. Effect of sun-drying hours and forage type on moisture content, bulk density, and unit density of forage pellets

Sun-drying hours	**Pelleted forage type**	**Moisture (%)**	**Bulk density (kg/m^3)**	**Unit density (kg/m^3)**
Three hrs (Sd)	CO3(F1)	34.14 ± 0.35^a	478.00 ± 9.17^b	773.13 ± 10.77^c
	Guinea(F2)	31.13 ± 0.64^b	452.67 ± 2.57^c	699.40 ± 14.06^d
	Leucaena(F3)	13.42 ± 0.29^d	680.00 ± 2.65^a	1082.65 ± 5.65^b
	Gliricidia(F4)	26.23 ± 0.43^c	542.33 ± 3.22^b	1046.89 ± 10.5^b
Four hrs (Md)	CO3	22.26 ± 0.41^a	578.33 ± 3.51^b	979.11 ± 6.10^c
	Guinea	16.35 ± 0.54^b	559.67 ± 1.53^c	943.25 ± 8.58^d
	Leucaena	10.51 ± 0.14^d	724.33 ± 5.13^a	1148.35 ± 3.89^b
	Gliricidia	13.63 ± 0.14^c	768.33 ± 4.73^b	1158.62 ± 8.85^b
Five hrs (Ld)	CO3	12.31 ± 0.13^a	662.67 ± 5.03^b	1032.11 ± 5.49^c
	Guinea	12.25 ± 0.47^b	668.33 ± 2.08^c	1067.86 ± 6.82^d
	Leucaena	9.40 ± 0.42^d	871.67 ± 2.08^a	1235.31 ± 13.0^b
	Gliricidia	10.06 ± 0.26^c	868.33 ± 4.72^b	1277.50 ± 10.5^d

Legend: Sd- short drying; Md- medium drying; Ld- prolonged drying; F_1- CO3; F_2– Guinea; F_3- *Leucaena*; F_4 - *Gliricidia*

Organoleptic properties of pelleted forages

The pelleted forages differed in color and aroma according to species. The *Leucaena* pellets displayed a greenish-brown color with a mild leguminous aroma, whereas the *Gliricidia* pellets appeared dark green with a distinct, strong sunny aroma. The CO3 pellets were light green and emitted a sweet, sunny aroma, while the *Guinea grass* pellets were bright green with a characteristic fresh, sunny aroma. These visual and olfactory traits may contribute to the overall acceptability of the pellets by ruminants.

Keeping quality of pelleted forages

The shelf life of the pellets was evaluated by storing them in airtight polythene bags. The pellets made from Ld-dried biomass grass, *Leucaena* Sd pellets, and *Gliricidia* Md pellets remained stable for up to two months, showing no signs of fungal or mold growth, caking, off-color development, or smutty odor. In contrast, the pellets made from Md-dried biomass grass began to clump and cake after four weeks, with fungal and mold growth observed after five weeks. The pellets produced from Sd-dried grasses exhibited a wet powder-like texture within seven days and started to cake, with fungal growth appearing after approximately ten days.

Nutrient value of supplemented pellet forages

There were significant differences ($P < 0.05$) in the mean crude protein, crude fiber, and ash contents between the forage types (Table 2).

Table 2. Nutritional composition of raw pelleted forages and supplemented diets

Feed ingredients	**Average**					
	DM%	**CP%**	**CF%**	**EE%**	**Ash%**	**TDN%**
CO3 (F1, Ld)	87.69	14.78^a	34.64^a	2.05	11.39^c	55.39
Guinea pellet (F2, Ld)	87.75	15.41^b	37.13^b	1.37	11.96^c	54.41
Leucaena pellet (F3, Sd)	86.50	19.70^d	19.52^c	9.44	9.44^a	65.50
Gliricidia pellet (F4, Md)	86.47	18.67^c	18.74^c	10.50	10.59^b	62.80
Coconut poonac	91.50	20.00	12.30	7.50	14.30	73.99
Rice polish	90.80	12.00	9.00	16.20	7.20	81.99

Legend: DM – dry matter; CP – crude protein; CF – crude fiber; EE – ether extract; TDN – total digestible nutrient; values with different superscripts indicate significant differences

The average crude fiber content was higher in the pelleted grass than in the pelleted legumes, indicating the fibrous and bulky nature of grasses. Moreover, the average crude protein content was higher in the leguminous pellets compared to the pelleted grasses, indicating high availability of fermentable nitrogen required by the rumen bacteria for microbial protein synthesis (Figure 2). During the dry season, the natural pasture and crop residues available for animals are usually fibrous and devoid of most essential nutrients including proteins, energy, minerals and vitamins (Simbaya, 2002).

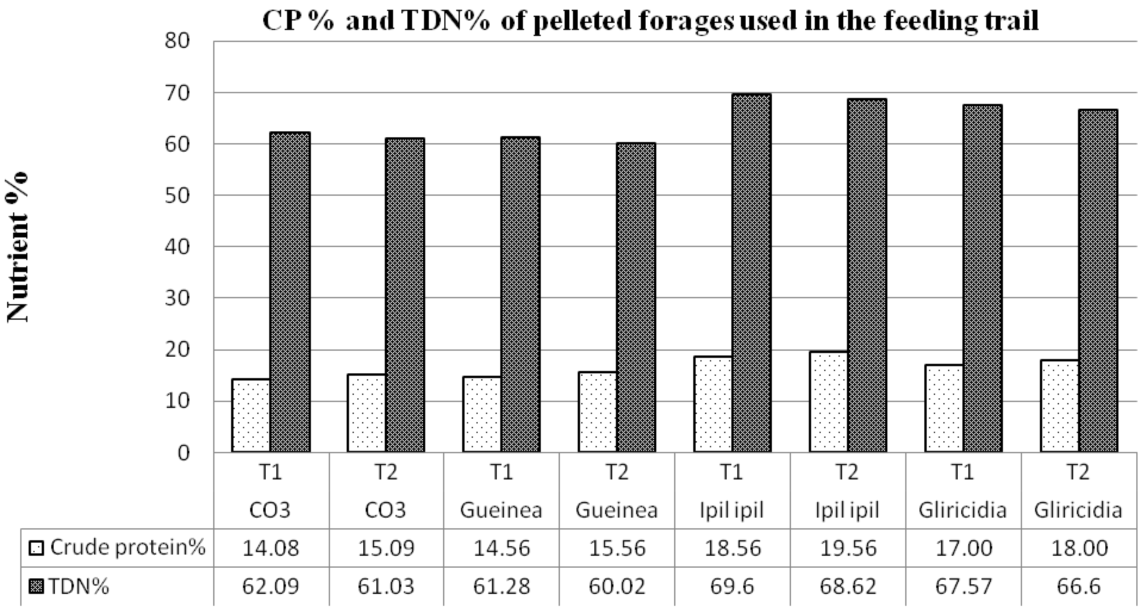

Figure 2. Crude protein (CP %) and total digestible nutrients (TDN %) of the T1 and T2 pelleted forage types
T1= 75% forages + 25% rice polish; T2 = 75% forages + 12.5% rice polish +12.5% coconut poonac

According to Ranawana (2008), forage diets must be supplemented with additional energy or protein sources (concentrates) and minerals to meet the cows' nutritional needs. According to Reynolds and Cobbina (1992), supplementing roughage with concentrates improves feed digestibility and intake in animals, while enhancing pelleting ability. Somasiri et al. (2010) reported that Gliricidia leaf meal blocks can be improved nutritionally by mixing leaf meal with other feed ingredients such as coconut poonac and rice bran, and could be stored up to three months without quality deterioration if properly packed.

Acceptability and palatability of supplemented pelleted forage diets

Acceptability and intake of T1 diet were higher than the T2 diet in all forage varieties showing first reaching and quick finishing. This shows significant difference on mean intake of pellets between the tested T1 and T2 diet types and forage varieties with ($p < 0.05$) (Table 3).

Table 3. Palatability of supplemented pelleted forage diets during a ten-minute feeding period

Pelleted forages	Diet type	Average intake (g)	SD	Significant value
CO3 (F1,Ld)	T1	536.2^{a}	±10.62	
	T2	699.6^{b}	±12.62	
Guinea(F2,Ld)	T1	450.8^{a}	±5.36	
	T2	565.6^{b}	±7.64	0.000
Leucaenea (F3,Sd)	T1	707.6^{a}	±7.40	
	T2	764.6^{b}	±7.20	
Gliricidia (F4,Md)	T1	822.4^{a}	±8.50	
	T2	989.4^{b}	±4.22	

Legend: Values with different superscripts indicate significant differences

The highest palatability was observed for the *Gliricidia* pellets compared with other forage types. Overall, dairy cows showed greater preference for legume-based pelleted diets than grass-based pellets, likely due to the higher nitrogen content of legumes. Somasiri et al. (2010) reported that grasses and straw are generally high in fiber, which increases rumen retention time and reduces voluntary feed intake, explaining the lower palatability of grass pellets.

Cost analysis

On average, one worker can harvest and handle 300 kg of fresh forage per day. The combined cost of cutting, drying, and pelleting forage was estimated at Rs. 6.00/kg on a fresh-weight basis. The current market prices for supplements were Rs. 35/kg for rice polish and Rs. 45/kg for coconut poonac. The average requirement of fresh forage to produce 1 kg of pellets was 5.37 kg for grasses and 3.9 kg for legumes. Consequently, the cost of producing raw pelleted forage was Rs. 20.14/kg for grasses and Rs. 15.70/kg for legumes. The supplemented T1 diet cost Rs. 24.83/kg for grass pellets and Rs. 21.52/kg for legume pellets, whereas the T2 diet cost Rs. 22.77/kg for grass pellets and Rs. 26.08/kg for legume pellets.

CONCLUSION

The prolonged-dried grasses, medium-dried *Gliricidia*, and short-dried *Leucaena* exhibited optimal pelleting ability, producing high-quality and durable pellets with extended shelf life. Dairy cows demonstrated higher acceptability and palatability for supplemented pelleted forage diets, particularly legume-based pellets. Therefore, forage pelleting represents a sustainable and cost-effective conservation method for small- to medium-scale dairy farmers, providing economically viable, nutritionally balanced, and readily consumable feed.

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REFERENCES

AOAC. 2000. Official Methods of Analysis. 17th Edition, The Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Bonfante, E., Palmonari, A., Mammi, L., Canestrari, G., Fustini, M. & Formigoni, A. 2016. Effects of a completely pelleted diet on growth performance in Holstein heifers. *Journal of Dairy Science,* 99(12): 9724-9731. https://doi.org/10.3168/jds.2016-11033

Blaser, R.E. 1964. Effects of fertility levels and stage of maturity on forage nutritive value. *Journal of Animal Science*, 23: 246-253.

Borreani, G., Tabacco, E., Schmidt, R.J., Holmes, B.J. & Muck, R.E. 2018. Silage review: Factors affecting dry matter and quality losses in silages. *Journal of Dairy Science*, 101(5): 3952-3979. https://doi.org/10.3168/jds.2017-13837

Ibrahim, M.N. & Jayatileka, T.N. 2000. Livestock production under coconut plantations in Sri Lanka: Cattle and buffalo production systems. *Asian-Australasian Journal of Animal Sciences*, 13(1): 60-67. https://doi.org/10.5713/ajas.2000.60

Krogstad, K.C., Herrick, K.J., Morris, D.L., Hanford, K.J. & Kononoff, P.J. 2021. The effects of pelleted dried distillers grains and solubles fed with different forage concentrations on rumen fermentation, feeding behavior, and milk production of lactating dairy cows. *Journal of Dairy Science*, 104(6): 6633-6645. https://doi.org/10.3168/jds.2020-19592

Lam, P.S. & Sokhansanj, S. 2014. Engineering properties of biomass. Biomass and Bioenergy Research Group, Clean Energy Research Center, Department of Chemical and Biological Engineering, The University of British Columbia, 2360 East Mall, Vancouver, BC V6T 1Z3, Canada.

Miron, J., Yosef, E., Nikbachat, M., Zenou, A., Maltz, E., Halachmi, I. & Ben-Ghedalia, D. 2004. Feeding behavior and performance of dairy cows fed pelleted nonroughage fiber byproducts. *Journal of Dairy Science*, 87(5): 1372–1379, https://doi.org/10.3168/jds.S0022-0302(04)73286-5

Premaratne, S. & Premalal, G.G.C. 2005. Country Pasture/Forage Resource Profiles, Sri Lanka. http://www.fao.org/ag/agp/agpc/doc/Counprof/srilanka/srilanka.htm

Ranawana, S. 2008. Dairy industry in Sri Lanka: Problems and prospects. *Agricultural and Food Sciences.* https://www.semanticscholar.org/paper/Dairy-industry-in-Sri-Lanka.-problems-and-prospects-Ranawana/ffefee989b2e219799d5f1c6c0e8b12eb047cba2

Ranaweera, N.F. 2015. Sri Lanka: Opportunities for dairy sector growth. Smallholder Dairy Development: Lessons Learned in Asia, Bangkok: APHCA/FAO, 93-109.

Reynolds, L. & Cobbina, J. 1992. The integration of livestock production in alley farming. The AFNETA Alley Farming Training Manual – Source Book for Alley Farming Research, 2, Unit 4.

Silva, N.T.M.H. de. 1980. Rejuvenating senile coconut plantations: An economic analysis. *Journal of Plantation Crops*, 8(1): 29-35.

Simbaya, J. 2002. Potential of fodder tree/shrub legumes as a feed resource for dry season supplementation of smallholder ruminant animals. *Agricultural and Food Sciences*, 69-76.

Somasiri, S.C., Premaratne, S., Gunathilake, H.A.J., Abeysoma, H.A., Dematawewa, C.M.B. & Satsara, J.H.M.N. 2010. Effect of Gliricidia (*Gliricidia sepium*) leaf meal blocks on intake, live weight gain and milk yield of dairy cows. *Tropical Agricultural Research*, 22(1): 76-83. https://doi.org/10.4038/tar.v22i1.2672

St. Joseph, 2007. *Cubes, pellets, and crumbles: Definitions and methods for determining density, durability, and moisture content.* American Society of Agricultural and Biological Engineers (ASABE Standards S269.4).

Suarez, F.X. 2014. Particle size of calf starter: Effects on digestive system development and rumen fermentation. Ph.D dissertation, The Pennsylvania State University.

Thomas, M. & van der Poel, A.F.B. 1995. *Physical quality of pelleted animal feed: Criteria for pellet quality*. Wageningen Agricultural University, WIAS, Department of Animal Nutrition, Wageningen, Netherlands.

Tumuluru, J.S. 2013. *Effect of process variables on the density and durability of the pellets made from high moisture corn stover.* Biofuels and Renewable Energy Technologies Department, Energy Systems & Technologies Division, Idaho National Laboratory, Idaho Falls, USA.

Tumuluru, J.S., Tabil, L.G., Song, Y. & Iroba, K.L. 2015. Impact of process conditions on the density and durability of wheat, oat, canola, and barley straw briquettes. *BioEnergy Research*, 8, 388–401. https://doi.org/10.1007/s12155-014-9527-4