

Comparison of Nutritive Value in Fodder Species and Industrial By-products Available in Anuradhapura

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Abstract : This experiment intended to figure out the nutritive value of fodder species and industrial by-products for feeding ruminants in Anuradhapura. Fodder species; maize (*Zea mays*), sorghum (*Sorghum bicolour*), CO-3 (*Pennisetum purpureum* x *P. americanum*), gliricidia (*Gliricidia sepium*), and guinea grass (*Panicum maximum*) and agro-industrial by-products; rice (*Oryza sativa*) bran, coconut (*Cocos nucifera*) poonac, maize (*Zea mays*) meal and soya bean (*Glycine max*) meal (SBM) were analyzed for proximate composition, acid detergent fiber (ADF), neutral detergent fiber (NDF) and gross energy (GE). Nitrogen free extract (NFE), total digestible nutrients (TDN) and metabolizable energy (ME) were calculated. The data were analyzed using the one-way ANOVA procedure in SAS. The observed TDN, ME and GE of fodder species differed significantly ($p < 0.05$). The highest ($p < 0.05$) values of dry matter (DM), crude fat (EE), crude protein (CP), TDN, GE and ME were obtained for gliricidia. Guinea grass contained the highest ($p < 0.05$) ADF and NDF contents compared to other fodder species. Sorghum and CO3 showed the highest ($p < 0.05$) ash and crude fiber (CF) while the lowest ($p < 0.05$) ash and CF were recorded in maize and gliricidia. The DM was not significantly differed ($p > 0.05$) in agro-industrial by-products. The highest ($p < 0.05$) total ash, CP, TDN and ME were reported in SBM while NFE was highest in maize meal. The highest ($p < 0.05$) values of EE and GE contents were obtained for rice bran. The nutrient content observed in the feed ingredients in the present study, is in par with other references. According to the nutrient composition, these feed ingredients can be used for feeding ruminants and in the formulation of total mixed rations for dairy cows in Anuradhapura.

Keywords: Agro-industrial by-products, Fodder species, Gross energy, Nutrient comparison

Introduction

The livestock sector plays a major role in the Sri Lankan economy and it contributes around 0.7% to the National Gross Domestic Product (GDP) of the country (Central Bank Report, 2019). The national livestock population has been estimated as 1.08 million cattle, 0.30 million buffaloes, and 0.32 million goat/ sheep in 2019 (Department of Census and Statistics, 2019). Under the livestock sector, cattle and buffaloes play a key role in the dairy industry in Sri Lanka. The current annual milk production has been estimated as 447.58 million liters in Sri Lanka and the number of milking cattle and buffaloes were estimated at 0.3 million and 0.09 million, respectively in 2019 (Department of Census and Statistics, 2019). As the climatic conditions in Sri Lanka vary widely, the breed of cattle to be reared varies depending on the agro-climatic zone. The agro-climatic zones in Sri Lanka are broadly classified into dry zone, coconut triangle, mid-country, and hill country (FAO, 1977). Anuradhapura district is located in North Central Province and it is classified under the dry zone. The livestock sector is also considered as a supplementary income source in the Anuradhapura district.

The fodder species play a vital role and it is the cheapest source of feed available for feeding ruminants in Sri Lanka (Premarathne and Samarasinghe, 2020). The most indispensable and basic input for efficient dairy production is the good quality fodder. The dairy industry in Sri Lanka primarily depends on natural pasture and fodder found on ravines, tank banks, uncultivated paddy fields, roadsides,

and uncultivated public and private lands. Due to the abundance of natural grazing lands, the majority of dairy cattle is found in the dry zone of Sri Lanka (Houwens *et al.*, 2015). They are mostly indigenous species and crossbred animals (Premarathne and Samarasinghe, 2020). However, the availability of the forage is seasonal, the yield depends on the climate, cropping pattern, and soil conditions. Further, the quality of the forage is poor and it is not available in the required quantity thus resulting in low production of ruminants in the dry zone (Premarathne and Samarasinghe, 2020). The climatic condition and the irrigation facilities in the dry zone are favourable for cultivating forages like maize (*Zea mays*), sorghum (*Sorghum bicolor*), CO-3 (*Pennisetum purpureum* x *P. americanum*), gliricidia (*Gliricidia sepium*), and guinea grass (*Panicum maximum*) throughout the year. Maize is one of the major cereal crops; which has a higher-yielding potential and wider adaptability under fluctuating agro-climatic conditions (Sarmini and Premaratne, 2017). Maize is grown as a food and feed source in the dry and intermediate zones during the *Maha* season. It is considered as an ideal forage, because, it is rich in nutrients, highly palatable and high yielding and it helps to increase the body weight and milk quality in dairy cattle (Sattar *et al.*, 1994).

Sorghum plays a vital role as a forage crop under drought conditions as it uses water efficiently and provides a high yield (Sarmini and Premaratne, 2017). Further, sorghum has the ability to tiller and regrow after cutting, defoliation, and/or

browsing. CO-3 has special characters like high tillering ability, high yielding potential, high crude protein content, quick re-growth capacity, high palatability, free from other adverse factors, and resistance to pest and disease attacks (Premaratne and Premala 2006). Hence, CO-3 has been recommended for the small scale dairy farmers in Sri Lanka, due to its favourable characters (Premaratne and Premalal, 2006). Gliricidia is one of the major legume forage trees grown in tropical areas and it consists of high nutritive value, fast-growing ability and it can adapt to the different adversary climatic conditions. Gliricidia is widely used as a plant protein source for ruminants (Premarathne & Samarasinghe, 2020). However, it contains a high concentration of tannin and it affects negatively on rumen digestion (Ash, 1990). Therefore, it is not recommended to feed more than 20% of the animal's daily feed requirement. Guinea grass is a bush forming perennial grass that grows in warm areas and it can withstand continuous heavy grazing. It is a fast-growing leafy grass, palatable to dairy cattle with good nutritional value (Aganga and Tshwenyane, 2004).

Similarly, in Sri Lanka, rice (*Oryza sativa*) bran and coconut (*Cocos nucifera*) poonac are mostly used as agro-industrial by-products. According to the requirement, maize meal and soya bean (*Glycine max*) meal (SBM) can be fed as other agro-industrial by-products (Premarathne and Samarasinghe, 2020). Rice bran is a major industrial by-product, which is widely used as a cattle feed supplement in Sri Lanka. Rice bran refers to the mixture of aleurone and other layers removed

from rice during the milling process (Shi *et al.*, 2015). It is a good source of vitamin B-group, less expensive, contains a substantial amount of fat, protein, and metabolizable energy content (Rezaei, 2006). Coconut poonac is a by-product of the coconut oil manufacturing process and it is a residue left after the removal of oil from copra. In Sri Lanka, a high amount of coconut poonac has been used for livestock feeding (Silva, 1980). Maize is a primary source of energy supplement for ruminants (Premarathne and Samarasinghe, 2020). Maize meal contains less protein. Therefore, most farmers mix maize meal with high-quality forages and other ingredients such as soybean meal (www.feedipedia.org). Soybean meal is the by-product of the extraction of soya bean oil and is widely used as a plant-based protein source in animal feeds in Sri Lanka (Premarathne and Samarasinghe, 2020). Hence, there is a potential to increase milk production by using a ration formulated with above-stated forages and agro-industrial by-products that are abundantly available in the dry zone of Sri Lanka. However, the nutritive value of the selected forages and industrial by-products should be known to determine the suitability for feeding and ration formulation for ruminants. Therefore, this experiment was aimed to figure out the nutritive value of fodder species and industrial by-products for feeding ruminants in Anuradhapura, Sri Lanka.

Materials and Methods

Sample Collection

Different feed ingredients available in the Anuradhapura district (8.3114° N and

80.4037° E) were collected and the laboratory analysis was conducted at the Animal Science laboratory in the Faculty of Agriculture, Rajarata University of Sri Lanka, Puliyankulama, Anuradhapura from September 2019 to August 2020. The collected fodder species were maize, sorghum, CO-3, guinea grass, gliricidia,

at 60 °C and ground to a powder. Sub-samples of each chopped fodder species and by-products were dried to a constant weight at 60°C in an oven (YCO-010, Taiwan) for dry matter (DM) determination. Dried samples were ground to pass through a 1 mm screen and stored in sample bottles at room temperature for nutrient analysis.

$$NFE (\%) = 100 - Ash (\%) - CF(\%) - EE(\%) - CP(\%) \text{ (Kearl, 1982)}$$

$$ME (Mcal/kg) = ((1.01 \times (TDN\% \times 0.04409)) - 0.45) \text{ (NRC, 2001)}$$

$$\begin{aligned} TDN (\%) (\text{Dry forage and roughages}) \\ = -17.26 + 1.212(CP) + 0.8352(NFE) + 2.464(EF) \\ + 0.4475(CF) \end{aligned}$$

$$\begin{aligned} TDN (\%) (\text{Energy feeds}) \\ = 40.26 + 0.1969(CP) + 0.4228(NFE) + 1.190(EF) \\ - 0.1379(CF) \end{aligned}$$

$$\begin{aligned} TDN (\%) (\text{Protein supplements}) \\ = 40.32 + 0.5398(CP) + 0.4448(NFE) + 1.422(EF) \\ - 0.7007(CF) \end{aligned}$$

(Kearl, 1982)

and agro-industrial by-products; rice bran, maize meal, coconut poonac, and SBM. The agro-industrial by-products were purchased from milling centers in Anuradhapura. The whole plant of maize was harvested before the cob initiation and the guinea grass was harvested at the pre-blooming stage. The whole plant of sorghum without seeds and CO-3 grass at the pre-blooming stage were collected. The leaves and twigs from the mature gliricidia trees were collected for analysis.

Sample Preparation

Harvested fodder species were chopped by using a grass chopper and dried under shade. Industrial by-products were dried

Nutrient Analysis

The samples were then analyzed for total nitrogen (N), crude fiber (CF), ether extract (EE) and ash by using Kjeldahl unit (DK 20, Italy), fiber analyzer (FIWE3, Italy), soxhlet extractor (MIC ROSIL, India), and a muffle furnace (DMF-05, Korea), respectively according to protocols described by AOAC (2019). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were analyzed according to Van Soest (1991). The values were derived on a dry matter basis. Gross energy content was analyzed using a bomb calorimeter (C200 Auto, Germany).

Calculation of Crude Protein, Nitrogen-free extract and Energy Values

Crude protein (CP) was calculated as N% into 6.25. Nitrogen free extract (NFE), total digestible nutrients (TDN), and metabolizable energy (ME) values were calculated using the following equations.

Where, NFE- Nitrogen free extract, CF- Crude fiber, EE- Ether extract, CP- Crude protein, ME- Metabolizable energy and TDN- Total digestible nutrients.

Statistical Analysis

Five replicates were analysed from each sample. The nutrient data were statistically analyzed using one way ANOVA procedure using Statistical Software for Data Analysis (SAS), Ver 9.0 (SAS, 2002).

Result and Discussion

Chemical Composition of Fodder Species

The proximate composition of fodder species is presented in Table 1. The highest ($p < 0.05$) values of DM, EE, and the lowest ($p < 0.05$) CF, ADF percentages were obtained for gliricidia in the present study. The DM percentage of fodder species was ranging between $18.15 \pm 1.01\%$ and $25.10 \pm 0.78\%$. The findings of DM percentages for sorghum and CO-3 of the present study were higher than the reported values by Sarmini and Premaratne, (2017); $15.55 \pm 0.02\%$ for sorghum and $17.00 \pm 0.01\%$ for CO-3, respectively in the north region of Sri Lanka. According to Sarmini and Premaratne (2017), DM

percentage of maize (Pacific 984) was $32.73 \pm 0.01\%$ in the northern region of Sri Lanka and it was higher than the reported values of the present study. Heuze *et al.*, (2017) observed CP, CF, EE, and ash content as 3.0 - 12.8%, 19.1 - 36.6%, 0.7 - 3.1%, and 2.5 - 11.8%, respectively for maize and present study results agree with these values. National Dairy Development Board (NDDB) in India reported that sorghum hay and maize hay contained CP, EE, CF, Ash, NDF, ADF, ME, NFE as 7.0%, 1.2%, 38.9%, 8.5%, 56.5%, 40.3%, 1900 kcal/g, 47.1% and 3.6%, 0.8%, 33.2%, 10.5%, 62.2%, 37.4%, 2100 kcal/g, 51.9%, respectively (NDDB, 2012). The slight variation in the contents of nutrients could depend on the variety, season, soil nutrient composition, and maturity stage. Further, Bandara *et al.*, (2016) reported that DM, CP, and CF content of sorghum in the 1st harvest were 22.1%, 11.63%, and 36.8%, respectively, and in 2nd harvest as 16.9%, 9.60%, and 35.8%, respectively. Therefore, the nutrient composition of sorghum varied with the harvesting interval.

Premaratne and Premalal (2006) reported a CP content of 15 – 16% for CO-3 in the mid-country of Sri Lanka. The highest ($p < 0.05$) and lowest ($p < 0.05$) total ash contents were reported in CO-3 and Maize, respectively in the present study. According to Sampath *et al.* (2009), the ash content of gliricidia was 7.84%. However, Sarmini and Premaratne (2017) reported that the total ash contents of Maize, Sorghum,

Table 1: Chemical composition of fodder crops; gliricidia, guinea grass, CO3, sorghum, and maize (mean $\pm$ SE)

Component*	Fodder				
	Gliricidia	Guinea grass	CO3	Sorghum	Maize
DM (%)	25.10 $\pm$ 0.78 ^a	21.29 $\pm$ 0.64 ^c	18.15 $\pm$ 1.01 ^d	23.87 $\pm$ 0.98 ^b	23.33 $\pm$ 0.77 ^b
Ash (%)	8.51 $\pm$ 1.15 ^{bc}	9.64 $\pm$ 0.61 ^{ab}	10.21 $\pm$ 1.77 ^a	10.01 $\pm$ 1.24 ^{ab}	7.77 $\pm$ 0.44 ^c
EE (%)	3.96 $\pm$ 0.62 ^a	2.05 $\pm$ 0.48 ^c	2.95 $\pm$ 0.82 ^b	1.76 $\pm$ 0.53 ^c	1.90 $\pm$ 0.33 ^c
CP (%)	23.79 $\pm$ 0.41 ^a	5.76 $\pm$ 0.21 ^d	11.23 $\pm$ 1.04 ^b	8.83 $\pm$ 0.30 ^c	9.25 $\pm$ 1.19 ^c
CF (%)	26.37 $\pm$ 5.48 ^d	35.41 $\pm$ 2.86 ^{ab}	32.00 $\pm$ 1.74 ^{bc}	36.70 $\pm$ 2.94 ^a	30.27 $\pm$ 1.41 ^{cd}
NFE%	37.36 $\pm$ 5.31 ^d	47.13 $\pm$ 2.47 ^{ab}	43.50 $\pm$ 2.78 ^{bc}	42.70 $\pm$ 3.30 ^c	51.03 $\pm$ 1.05 ^a
ADF (%)	27.08 $\pm$ 0.95 ^c	46.78 $\pm$ 3.25 ^a	39.73 $\pm$ 0.92 ^b	36.70 $\pm$ 2.94	39.19 $\pm$ 1.48 ^b
NDF (%)	30.76 $\pm$ 1.52 ^d	71.15 $\pm$ 1.96 ^a	60.02 $\pm$ 1.05 ^c	59.95 $\pm$ 2.25 ^c	63.07 $\pm$ 2.88 ^b
TDN%	64.34 $\pm$ 1.40 ^a	49.99 $\pm$ 1.32 ^c	54.36 $\pm$ 2.26 ^b	49.86 $\pm$ 2.28 ^c	54.53 $\pm$ 0.64 ^b
GE (kcal/g)	4060 $\pm$ 5.54 ^a	3630.6 $\pm$ 35.63 ^c	3228 $\pm$ 20.80 ^c	3879 $\pm$ 25.80 ^b	3575.6 $\pm$ 90 ^d
ME (kcal/g)	2420 $\pm$ 0.26 ^a	1780 $\pm$ 0.25 ^c	1980 $\pm$ 0.42 ^b	1780 $\pm$ 0.43 ^c	1990 $\pm$ 0.12 ^b

Differing superscripts within a row indicate means that were significantly different ($p < 0.05$).

*DM-dry matter; EE-ether extract; CP-crude protein; CF-crude fibre; ADF-acid detergent fibre; NDF-neutral detergent fibre; TDN-total digestible nutrients; NFE; nitrogen free extract; ME- metabolizable energy

and CO-3 were 10.70 $\pm$ 0.18%, 11.76 $\pm$ 0.02%, and 16.06 $\pm$ 0.01%, respectively and maize contained 7.35 $\pm$ 0.09% of CP. In support of the present findings, Somasiri *et al.*, (2010) reported 26% of CF content for gliricidia cultivated in the intermediate zone of Sri Lanka. In contrast, Sarmini and Premaratne (2017) observed 35.15 $\pm$ 0.60%, 38.28 $\pm$ 0.14%, and 33.35 $\pm$ 0.57% of CF contents for Maize, sorghum, and CO-3, respectively in the northern area. Aganga and Tshwenyane (2004) reported that the CF content of early bloom guinea grass in Tanzania was 39.6% and these findings were higher than the values observed in the present study. The NDF and ADF contents reported by Premaratne and Premalal,

(2006) were 74 – 78% and 42-47%, respectively for CO-3. Musco *et al.*, (2016) found that the NDF and ADF contents of guinea grass were 50.80% and 38.85%, respectively. The findings of NFE percentages for CO-3 and sorghum of the present study were higher than the reported values by Pavithra *et al.* (2019); 37.4 $\pm$ 0.04% for CO-3 and 37.7 $\pm$ 0.06% for sorghum. According to the present study, gliricidia had significantly higher ($p < 0.05$) gross energy content (4060 $\pm$ 5.54 kcal/g) compared to the other fodder species and the lowest gross energy content (3228 $\pm$ 20.80 kcal/g) was recorded in CO-3. Sampath *et al.* (2009), found that the gross energy contents of gliricidia and maize were 4330 and 3880 kcal/g,

respectively. Pavithra *et al.*, (2019) reported the gross energy content of CO-3 and sorghum, as 3580±0.00 and 3850±0.02 (kcal /g DM), respectively. Gliricidia had the highest (p<0.05) ME content compared to CO3 and Maize which in turn were higher (p<0.05) than guinea grass and sorghum.

Chemical Composition of Industrial By-products

The chemical composition of different industrial by-products is summarized in Table 2. The DM content of industrial by-products did not show any significant difference (p>0.05). The significantly higher total ash and CP contents were reported in SBM. Ravindran (1992),

reviewed that the DM, ash, EE, CP, CF, and gross energy content of the SBM were 92.0%, 5.6%, 6.0%, 42.4%, 8.0%, and 4180 kcal/g, respectively. However, the variation of the nutrient content of SBM in the present study might be due to the genotypic variations, processing method, and environmental condition. According to the Somasiri *et al.*, (2010), the DM, CF, EE, CP, and ash content of coconut poonac were 92%, 10%, 9%, 21%, and 6%, respectively.

Rice bran had significantly higher (p<0.05) EE and gross energy contents compared to other industrial by-products in the present study. However, Sampath *et al.*, (2009) reported ash, CP, ADF, and

Table 2: Chemical composition of industrial by-products; coconut poonac, maize meal, rice bran, and SBM (mean ± SE)

Component*	Industrial by-products			
	Coconut poonac	Maize meal	Rice bran	SBM
DM%	90.32±1.78 ^a	90.31±0.50 ^a	89.94±0.60 ^a	89.94±0.28 ^a
Ash%	3.97±0.35 ^c	0.64±0.22 ^d	5.72±0.78 ^b	8.52±0.79 ^a
EE%	7.31±0.56 ^b	3.36±0.63 ^c	10.96±1.04 ^a	2.38±0.68 ^c
CP%	19.40±0.44 ^b	9.36±0.14 ^d	11.99±0.19 ^c	50.99±0.43 ^a
CF%	10.45±1.82 ^a	3.56±0.74 ^b	9.93±0.59 ^a	4.08±1.11 ^b
NFE%	58.87±1.57 ^c	83.08±1.22 ^a	61.40±1.95 ^b	34.03±1.62 ^d
ADF (%)	31.08±4.52 ^a	3.94±0.99 ^c	8.75±0.82 ^b	8.10±0.32 ^b
NDF (%)	56.58±3.90 ^a	19.86±2.15 ^b	19.58±1.05 ^b	13.07±0.76 ^c
TDN%	80.05±2.26 ^b	80.74±0.38 ^b	80.25±0.64 ^b	83.50±2.09 ^a
GE (kcal/g)	3948.6±73.44 ^b	3469.6±19.00 ^d	4258.8±61.62 ^a	3739.6±39.10 ^c
ME (kcal/g)	3130±0.42 ^b	3160±0.07 ^b	3140±0.12 ^b	3280±0.39 ^a

Differing superscripts within a row indicate means that were significantly different (p< 0.05).

*DM-dry matter; EE-ether extract; CP-crude protein; CF-crude fibre; ADF-acid detergent fibre; NDF-neutral detergent fibre; TDN-total digestible nutrients; NFE; nitrogen free extract; ME- metabolizable energy

NDF contents of rice bran as 4.58%, 16.68%, 16.77%, and 23.35%, respectively. The NDDDB, (2012) has reported that rice bran contain CP, EE, CF, Ash, NDF, ADF, ME and NFE 14.0%, 14.0%, 12.0%, 11.8%, 19.4%, 15.0%, 2700 kcal/g, 49.2%, respectively. Different soil types and climatic conditions also affected the chemical composition of the rice bran (Shi *et al.*, 2015). According to the NDDDB, (2012) maize grain contained CP, EE, CF, Ash, NDF, ADF, ME and NFE as 9.0%, 4.2%, 2.0%, 2.0%, 15.6%, 3.5%, 3100 kcal/g and 81.6%, respectively. However, the reported values of ME and NFE for maize meal and rice bran by the NDDDB (2012) were higher than the values observed in the present study. Ravindran (1992) observed 92.0%, 1.5%, 4.0%, 9.2% and 2.3%, of DM, ash, EE, CP and CF contents, respectively for maize grain. According to Abiose and Ikujenlola (2014), the chemical composition of maize meals differed due to the variety of maize and maturation stage. Coconut poonac contained significantly higher ($p < 0.05$) CF and ADF contents compared to other industrial by-products in the present study. Rice bran had higher gross energy (4258.8 ± 61.62 kcal/g) contents compared to the other feed sources and the lowest gross energy content was recorded in (3469.6 ± 19.00 kcal/g) maize meal. However, the result of the present study did not agree with the finding of Ravindran (1992), who reviewed that the gross energy content of rice bran, coconut poonac, and SBM as

3710, 4220, and 4180 kcal/g, respectively. Sampath *et al.* (2009), reported the gross energy contents of maize and rice bran as 3880 and 3760 kcal/g, respectively. According to the Pavithra *et al.* (2019), the gross energy and NFE contents of coconut poonac, were 4300 ± 0.01 kcal/g and $53.1 \pm 0.54\%$ respectively. Soya bean meal had the highest ($p < 0.05$) ME content compared to other ingredients in the present study. According to ME contents of maize grain, rice bran, SBM and Coconut poonac were 3100 kcal/g, 2700 kcal/g, 2500 kcal/g and 2300 kcal/g, respectively. The TDN contents reported by NDDDB, (2012) was 85 – 90% for maize grain and 70 – 90% for rice bran. According to the NDDDB (2012), the TDN content was ranged from 75% to 84% for SBM and it was depending upon the de-hulling and processing method.

Conclusion

The nutrient contents observed in the feed ingredients in the present study are in par with other references. According to the available nutrient composition, these feed ingredients can be used for feeding ruminants and in the formulation of total mixed rations (TMR) for dairy cows in Anuradhapura.

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References

Abiose, S. H. and Ikujenlola, A. V. 2014. Comparison of chemical composition, functional properties and amino acids composition of quality protein maize and common maize (*Zea mays* L.). *African Journal of Food Science and Technology*, 5:81-89.

Aganga, A. A. and Tshwenyane, S. 2004. Potentials of guinea grass (*Panicum maximum*) as forage crop in livestock production, *Pakistan Journal of Nutrition*, 3: 1-4.

AOAC International. 2019. Official methods of analysis of AOAC international, 21st edition, Gaithersburg, MD, USA. 1-75.

Ash, A .J. 1990. The effect of supplementation with leaves from the leguminous trees *Sesbania grandiflora*, *Albizia chinensis* and *Gliricidia sepium* on the intake and digestibility of guinea, *Journal of Animal Feed Science and Technology*, 28:225-232.

Bandara, P. G. G., Premalal, G. G. C. and Nayananjali, W.A. D. 2016. Assessment of nutritive value of sorghum [*Sorghum bicolor* (L.) Moench] fodder in Sri Lanka,

International Journal of Livestock Research, 6: 44-49.

Central bank report. 2019. Economic and social statistics of Sri Lanka. Janadhipathi mawatha, Colombo 01, Sri Lanka, 56.

Department of census and statistics. 2019. Annual report. Department of Animal Production and Health. Retrieved on April 05, 2020, from www.daph.gov.lk/web

FAO. 1977. Animal breeding selected articles from the world animal review. FAO, Rome, Italy, 139.

Feedipedia. 2020. Oil plant and by-products. Retrieved on March 19, 2020, from <http://www.feedipedia.org>.

Heuze, V., Tran, G., Edouard, N. and Lebas, F. 2017. Maize green forage. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO, Retrieved on April 05, 2020, from <http://www.feedipedia.org>.

Houwers, W., Wouters, B. and Vernooij, A. 2015. Sri Lanka fodder study; an overview of potential, bottlenecks and improvements to meet the rising demand for quality fodder in Sri Lanka. Lelystad, Wageningen University & Research center, Livestock Research, Livestock Research Report. 924.

Kearl, L. C. 1982. Nutrient requirements of ruminants in developing countries. International Feedstuff Institute, Agriculture

- Export State., Utah State University, Logan, Utah, USA, 381.
- Musco, N., Koural, I. B., Tudisco, R., Awadjihè, G., Adjolohoun, S., Cutrignelli, M. I., Mollica, M. P., Houinato, M., Infascelli, F. and Calabrò, S. 2016. Nutritional Characteristics of forage grown in south of benin. *Asian Australas Journal of Animal Sciences*, 29:51-61.
- NDDB (National Dairy Development Board). 2012. Nutritive value of commonly available feeds and fodders in India. National Dairy Development Board, Animal Nutrition Group, Anand, India, 1-112.
- NRC (National Research Council) 2001. Nutrient requirements of dairy cattle, National Academy of Sciences, Washington, USA, 13.
- Pavithra, S., Vidanarachchi, J. K., Sarmini, M. and Premaratne, S. 2019. Chemical composition and gross energy content of commonly available animal feedstuff in Sri Lanka. *Journal of Nutrient Sciences*, 47: 79-87.
- Premaratne, S., and Premalal, G. G. C. 2006. Hybrid Napier (*Pennisetum perpureum* X *Pennisetum americanum*) Var. CO-3: A resourceful fodder grass for dairy development in Sri Lanka. *The Journal of Agricultural Sciences*, 2:22–33.
- Premarathne, S. and Samarasinghe, K. 2020. Animal feed production in Sri Lanka: past present and future. *Agricultural Research for Sustainable Food Systems in Sri Lanka*, 12: 277-301.
- Ravindran, V. 1992. Chemical composition and energy utilization values of common Sri Lankan feedstuff for growing pigs. *Journal of the National Science Council of Sri Lanka*, 20:91-98.
- Rezaei, M. 2006. Utilization of mixed rice bran in laying hen diets. *Pakistan Journal of Biological Sciences*, 9: 1420–1423.
- Sampath, W. A. K., Perera, A. N. F. and Prathapasinghe, G. A. 2009. Evaluation of an economical total mix ration for dairy cattle with locally available feed resources. *Wayamba Journal of Animal Science*, 578: 14-17.
- Sarmini, M. and Premaratne, S. 2017. Yield and nutritional quality potential of three fodder grasses in the northern region of Sri Lanka. *Tropical Agricultural Research*. 28: 175 – 182.
- SAS. 2002. Statistical Analyses System. Users Guide Statistics. SAS Institute Inc. Cary, North Carolina, USA, 59-67.
- Sattar, M. A, Haque, M. F. and Rahman, M. M. 1994. Intercropping maize with broadcast rice at different row spacing. *Bangladesh Journal of Agriculture Research*. 19: 159-164.

Shi, C. X., Liu, Z. Y., Shi, M., Li, P., Zeng, Z. K., Liu, L., Huang, C. F., Zhu, Z. P. and Li, D. F. 2015. Prediction of digestible and metabolizable energy content of rice bran fed to growing Pigs. *Asian Australian Journal of Animal Sciences*, 28: 654-661.

Silva, E. C. D. 1980. Suggested strategies for reducing the dependence of livestock industries on coconut poonac as a feed concentrate, *Journal of Ceylon Coconut Plantations*, 7: 36-43.

Somasiri, S. C., Premaratne, S., Gunathilake, H. A. J., and Abeysoma, H. A. 2010. Effect of gliricidia (*Gliricidia sepium*) leaf meal blocks on intake, live weight gain and milk yield of dairy cows. *Journal of Tropical Agricultural Research*, 22:76–83.

Van Soest, P. J., Robertson, J. B., and Lewis, B. A. 1991. Method of dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Sciences*, 74:3583-3597.