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RESEARCH ARTICLE

Chemical composition and gross energy content of commonly available animal feedstuff in Sri Lanka

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Abstract: The aim of the present study was to evaluate the chemical composition and gross energy content of currently available feedstuff used for animal feeding in Sri Lanka. A total of 35 feedstuff including 10 energy supplements, 11 plant protein supplements, 3 animal protein supplements, 2 mineral supplements, 3 grasses, and leaves of 6 tree species was evaluated. Proximate composition, van Soest fiber content, *in vitro* dry matter digestibility, gross energy (GE) and mineral content of the feedstuff were measured using standard protocols. Values were expressed as percentage dry matter (DM) for proximate constituents and van Soest constituents, and kcalg^{-1} DM for gross energy content. The crude protein (CP) content of plant protein supplements varied from 24.4 % DM [black gram (*Vigna mungo*) husk] to 61.3 % DM (corn gluten meal); however animal protein supplements had less variation in CP content [varied from 50.3 % DM (meat & bone meal) to 69.2 % DM (fish meal)]. Portia (*Thespesia populnea*) leaves had more CP (15.9 % DM) and ether extract (EE) content (9.9 % DM) than all other roughages except manilkara leaves (*Manilkara hexandra*), which had 15.4 % DM EE. Cocoa (*Theobroma cacao*) husk contained the highest crude fibre content (38.3 % DM) when compared to all the other evaluated ingredients. GE content was highest in brewery waste (4.78 kcalg^{-1} DM) and lowest in coconut distillery waste (2.97 kcalg^{-1} DM). Mineral content of animal protein supplements was higher than in the other concentrates and roughages. *In vitro* dry matter digestibility of the concentrates was higher than that of roughages. The same trend was observed in organic matter digestibility. The data collected from the current study will be useful for balanced ration formulation for animals living under farm conditions in Sri Lanka.

Keywords: Animal and plant protein supplements, energy supplements, grasses and tree species, minerals, Sri Lanka.

INTRODUCTION

Livestock industry is an important and integral part of the agriculture sector in Sri Lanka. Development of livestock industry is hindered mainly by the unavailability of quantity and the quality feed resources (Houwers *et al*., 2015). Livestock is mainly fed on low-quality roughages, which are poor in energy, protein, minerals and vitamin contents (Ibrahim *et al*., 1999).

Ruminants can efficiently use crop residues, other non-conventional feed sources and mill by-products. The use of agricultural by-products and conventional feedstuff for feeding livestock is a common practice in developing countries (Uddin *et al*., 2015). Approximately 80–95 % of locally available feedstuff is used for the livestock and poultry industries in Sri Lanka, India, Pakistan, Bangladesh and Nepal (Winugroho, 1999). In Sri Lanka, the principal crop residues available to smallholder dairy farmers from natural grazing and browse include rice straw, maize stover, and other straws such as black gram, cowpea, millet and soybean depending on their seasonality (Ranawana, 1991). In addition, imported oilseed meals such as cottonseed meal, soya bean hulls from soya bean industry and spent liquor from alcohol distillers and brewers are also available as concentrate feeds (Ibrahim *et al*., 1999).

Numerous varieties of plant based feedstuff are available in Sri Lanka for feeding livestock (Ibrahim *et al*., 1999). Evaluating the nutritive value of these

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available feed resources is essential as this could make an important contribution to ruminant nutrition mainly in ration formulation (Taphizadeh *et al*., 2008). When formulating a ration to meet the nutritional requirements of the animals, it is necessary to know the nutritive value, availability of nutrients, palatability of feeds, the nutritional requirements of the animals and the cost (Kearl, 1982). Access to a database of nutritive values, and use of such information, will have a significant impact on improved animal performance and productivity (Devendra & Leng, 2011). Therefore, the present study was undertaken to evaluate the nutritional quality of commonly available feed resources for feeding livestock and poultry in Sri Lanka.

METHODOLOGY

Feed materials

The following types of feedstuff used for ruminant feeding were studied: energy supplements such as corn (*Zea mays*), wheat (*Triticum aestivum*) bran, broken-rice (*Oryza sativa*), rice (*Oryza sativa*) polish [S-Sinhapitiya Farm, Gampola and CIC- Chemical Industries Colombo (Pvt.) Ltd., Ekala, Ja-Ela], bakery by-product, biscuit powder (S-Sinhapitiya Farm, Gampola), biscuit powder [N- New Bernard (Pvt.) Ltd., Kuliyapitiya], soybean (*Glycine max*) husk and cocoa (*Theobroma cacao*) husk; plant protein supplements such as United States (US) soybean (*Glycine max*) meal, textured vegetable protein (TVP) powder, coconut (*Cocos nucifera*) poonac, gingelly (*Sesamum indicum*) poonac, coconut (*Cocos nucifera*) distillery waste, brewery waste, corn gluten meal (CGM), distillers dried grains with solubles (DDGS), black gram (*Vigna mungo*) husk, dhal (*Lens culinaris*) husk only and dhal (*Lens culinaris*) seeds with husk; animal protein supplements such as fish meal, meat & bone meal and poultry offal meal; grass species such as CO-4 (*Pennisetum americanum* × *Pennisetum purpureum*), CO-3 (*Pennisetum americanum* × *Pennisetum purpureum*) and sorghum (*Sorghum bicolor*); tree leaves like banyan leaves (*Ficus benghalensis*), portia leaves (*Thespesia populnea*), manilkara leaves (*Manilkara hexandra*), midnapore creeper leaves (*Rivea hypocrateriformis*), jackal jujube leaves (*Ziziphus jujube*) and white fig leaves (*Ficus virensaiton*); and mineral supplements such as $CaCO_3$ (lime stone) and dicalcium phosphate (DCP).

Sample collection

Rice polish (S), biscuit powder (S), dhal husk, and black gram husk were collected from the Sinhapitiya Farm (Gampola). Corn, broken-rice, biscuit powder (N), coconut poonac and gingelly poonac were obtained from New Bernard (Pvt.) Ltd. (Kuliyapitiya). Except the above, all the other concentrates were collected from CIC (Pvt.) Ltd. (Ja-Ela). Subsamples of grasses were collected from the research field of the Veterinary Research Institute, Gannoruwa. Leaves of tree species were harvested from mature trees found in the fields of livestock farmers in Killinochchi District. All samples were collected from a single visit in September 2016. All collected samples (about 1 kg of each sample) were dried in an oven (Yamato Scientific Co., Ltd., Japan) at 60 °C until a constant weight was obtained. The samples were then ground using a laboratory grinder and passed through a 1 mm mesh screen. Ground samples were stored in sampling bottles until used for chemical analyses.

Chemical analyses

Moisture [Association of Official Analytical Chemists (AOAC) method 950.46B], ash (AOAC method 938.08), ether extract (EE; AOAC method 945.16) and crude fibre (CF; AOAC method 962.09) were determined by the methods of AOAC (2005). Nitrogen-free extract (NFE) was calculated by the difference (i.e., 100 - % moisture - % ash - % crude protein - % EE - % CF). Crude protein (CP) content was determined by the micro-Kjeldahl procedure, AOAC method 920.87; the factor N × 6.25 was used to convert nitrogen into crude protein (AOAC, 2005). The EE (crude lipid) was extracted using a Soxhlet apparatus and the quantity of EE was determined gravimetrically. CF content was determined by the suction system with repeated treatment of dilute H_2SO_4, followed by dilute NaOH and washing with water. Accuracy of each estimation was evaluated by running a standard casein sample with a known proximate composition. Acid detergent fibre (ADF), neutral detergent fibre (NDF) and hemicellulose (HC) contents were analysed according to Goering and van Soest (1970) and van Soest and Robertson (1980). *In vitro* dry matter digestibility (IVDMD) and organic matter digestibility (OMD) (Tilley & Terry, 1963) were also determined using rumen liquor. The energy value of feed was measured using a bomb calorimeter (IKA-C-7000; Germany).

Statistical analyses

Three replicates of each sample were used for all the analyses. The data obtained were subjected to descriptive analysis using the Statistical Package for Social Sciences (SPSS). Values expressed as percentage dry matter (DM) for proximate constituents and van Soest constituents, and $kcalg^{-1}$ DM for gross energy contents were presented as mean ± standard deviation.

Table 1: Proximate composition of feedstuff (% DM)

Feedstuff	DM	Ash	CP	EE	CF	NFE
CONCENTRATES						
Energy supplements						
Corn (*Zea mays*)	89.2 ± 0.11	1.00 ± 2.17	10.7 ± 0.28	4.04 ± 0.01	2.95 ± 0.15	81.2 ± 0.33
Wheat (*Triticum aestivum*) bran	90.9 ± 0.06	2.76 ± 2.24	18.7 ± 0.06	4.18 ± 0.05	12.0 ± 0.01	62.2 ± 0.19
Broken rice (*Oryza sativa*)	86.8 ± 0.03	6.88 ± 2.86	10.1 ± 0.23	1.44 ± 0.00	4.82 ± 0.16	76.6 ± 0.58
Rice (*Oryza sativa*) polish (S)	87.4 ± 0.02	5.83 ± 0.33	17.2 ± 0.29	17.43 ± 0.17	10.6 ± 0.10	48.9 ± 0.05
Rice (*Oryza sativa*) polish (CIC)	89.5 ± 0.08	6.39 ± 2.48	16.7 ± 0.23	16.8 ± 0.03	10.0 ± 0.04	49.9 ± 0.23
Bakery by-product	84.3 ± 0.12	2.09 ± 0.82	11.5 ± 0.31	10.7 ± 0.17	0.91 ± 0.00	74.7 ± 0.52
Biscuit powder (S)	86.6 ± 0.14	1.67 ± 0.78	11.7 ± 0.07	7.33 ± 0.35	0.76 ± 0.00	78.4 ± 0.09
Biscuit powder (N)	85.1 ± 0.04	2.01 ± 1.16	12.4 ± 0.23	9.80 ± 0.03	1.51 ± 0.00	74.2 ± 0.07
Soybean (*Glycine max*) husk	91.9 ± 0.02	5.04 ± 0.26	14.8 ± 0.19	1.84 ± 0.00	36.5 ± 0.20	41.8 ± 0.35
Cocoa (*Theobroma cacao*) husk	93.9 ± 0.07	8.59 ± 0.07	11.9 ± 0.06	6.77 ± 0.04	38.3 ± 0.03	34.3 ± 0.30
Plant protein supplements						
United State (US) soybean (*Glycine max*) meal	88.6 ± 0.14	7.44 ± 0.33	54.4 ± 0.56	7.37 ± 0.02	2.90 ± 0.01	27.8 ± 0.02
Textured vegetable protein (TVP) powder	87.8 ± 0.21	8.01 ± 1.28	49.2 ± 0.14	6.03 ± 0.01	1.64 ± 0.07	35.1 ± 0.19
Coconut (*Cocos nucifera*) poonac	91.2 ± 0.06	5.79 ± 4.74	25.6 ± 0.12	4.30 ± 0.01	11.1 ± 0.09	53.1 ± 0.54
Gingelly (*Sesamum indicum*) poonac	92.0 ± 0.05	14.0 ± 18.02	44.7 ± 0.08	3.30 ± 0.01	9.50 ± 0.02	28.4 ± 0.00
Coconut (*Cocos nucifera*) distillery waste	40.6 ± 0.15	15.2 ± 23.67	26.1 ± 0.00	2.97 ± 0.00	3.62 ± 0.12	52.0 ± 0.16
Brewery waste	32.5 ± 0.02	4.20 ± 0.94	26.0 ± 0.19	9.78 ± 0.01	11.7 ± 0.07	48.2 ± 0.00
Corn gluten meal (CGM)	85.3 ± 0.08	5.82 ± 0.34	61.3 ± 0.26	3.81 ± 0.05	4.32 ± 0.36	24.7 ± 0.29
Distillers dried grains with solubles (DDGS)	89.7 ± 0.00	6.41 ± 1.72	32.5 ± 0.03	8.60 ± 0.01	6.75 ± 0.13	45.6 ± 0.36
Black gram (*Vigna mungo*) husk	85.9 ± 0.09	3.42 ± 0.59	24.3 ± 0.11	3.84 ± 0.00	17.7 ± 0.27	50.5 ± 0.12
Dhal (*Lens culinaris*) husk only	87.3 ± 0.25	2.40 ± 0.19	24.6 ± 0.32	4.21 ± 0.01	15.0 ± 0.07	53.6 ± 0.11
Dhal (*Lens culinaris*) seeds with husk	87.9 ± 0.34	2.72 ± 0.03	45.6 ± 0.27	4.33 ± 0.01	12.1 ± 0.14	35.0 ± 0.10
Animal protein supplements						
Fish meal	90.7 ± 0.02	18.3 ± 0.73	69.2 ± 0.23	3.18 ± 0.00	1.83 ± 0.34	7.40 ± 0.00
Meat and bone meal	91.5 ± 0.05	29.9 ± 1.08	50.3 ± 0.22	4.07 ± 0.01	1.80 ± 0.14	13.8 ± 0.09
Poultry offal meal	90.2 ± 0.22	14.5 ± 0.07	64.9 ± 0.13	9.22 ± 0.25	3.14 ± 0.27	8.08 ± 0.00
ROUGHAGES						
Grass						
CO-4 (*Pennisetum americanum* × *Pennisetum purpureum*)	19.7 ± 0.09	14.8 ± 0.26	14.0 ± 0.01	3.84 ± 0.05	30.8 ± 0.19	36.4 ± 0.08
CO-3 (*Pennisetum americanum* × *Pennisetum purpureum*)	17.2 ± 0.10	14.4 ± 2.99	10.3 ± 0.01	2.93 ± 0.01	34.9 ± 0.16	37.3 ± 0.04
Sorghum (*Sorghum bicolor*)	15.7 ± 0.19	9.83 ± 0.14	13.5 ± 0.24	2.80 ± 0.35	36.1 ± 0.10	37.7 ± 0.06
Tree leaves						
Banyan leaves (*Ficus benghalensis*)	46.6 ± 0.05	8.25 ± 3.90	9.07 ± 0.45	9.61 ± 0.02	31.1 ± 0.14	41.9 ± 0.30
Portia leaves (*Thespesia populnea*)	38.2 ± 0.28	15.0 ± 3.92	15.9 ± 1.05	9.92 ± 0.04	20.1 ± 0.03	38.9 ± 0.86
Manilkara leaves (*Manilkara hexandra*)	36.5 ± 0.02	8.21 ± 3.78	10.2 ± 0.28	15.4 ± 0.00	35.6 ± 0.01	30.4 ± 0.34
Midnapore creeper leaves (*Rivea hypocrateriformis*)	42.8 ± 0.02	14.7 ± 1.31	13.4 ± 0.21	8.12 ± 0.01	19.6 ± 0.20	44.0 ± 0.05
Jackal jujube leaves (*Ziziphus jujube*)	39.6 ± 0.02	12.4 ± 3.22	15.3 ± 0.18	2.89 ± 0.01	23.8 ± 0.22	45.4 ± 0.34
White fig leaves (*Ficus virensaiton*)	38.2 ± 0.01	18.0 ± 0.03	11.8 ± 0.31	4.53 ± 0.01	24.1 ± 0.23	41.4 ± 0.51
MINERAL SUPPLEMENTS						
$CaCO_3$ (lime stone)	98.7 ± 0.08	96.98 ± 1.16	-	-	-	-
Dicalcium phosphate (DCP)	98.3 ± 0.05	99.00 ± 0.02	-	-	-	-

Values are expressed as averages ± SD (standard deviation); S: Sinhapitiya Farm; CIC: Chemical Industries Colombo (Pvt.) Ltd.; N: New Bernard (Pvt.) Ltd.

DM: dry matter; CP: crude protein; CF: crude fibre; EE: ether extract; NFE: nitrogen-free extract

RESULTS AND DISCUSSION

Proximate composition of the feedstuff

The proximate composition of feedstuff is given in Table 1. The results indicate that the nutritional composition of feedstuff varies widely with the origin of ingredients. The dry matter (DM) content of tested materials ranged from 15.7 % to 98.7 %. Excluding the coconut distillery waste and brewery waste, the DM content of all concentrates were higher (above 85 %) than that of roughages (below 50 %).

With the exception of mineral supplements, meat and bone meal had the highest total ash content (29.9 % DM), followed by fish meal (18.3 % DM) and white fig leaves (18.1 % DM). The ash content of other samples measured were below 16 % DM and corn (1 % DM) had the lowest content. According to Jayawardena and Perera (1991), the ash content of fodder leaves between 5 and 10 % DM, is considered as a satisfactory source of minerals. The ash content of all the tree leaves analysed in this study was greater than 8 % DM and could be considered as satisfactory mineral sources. Gingelly poonac and coconut distillery waste were found to contain relatively higher ash contents (14.0 and 15.2 % DM, respectively) when compared to that of other plant protein supplements. Perhaps this could be due to impurities such as sand present in those samples. A previous study reported that gingelly poonac contains 10.8 % (DM basis) of ash (Ravindran, 1992).

The CP content of samples ranged from 9.07 % DM (banyan leaves) to 69.7 % DM (fish meal). Of all the plant protein supplement samples evaluated, CGM had the highest CP content (61.4 % DM). Concerning the roughages, portia leaves had the highest CP content (15.9 % DM) followed by jackal jujube leaves (15.4 % DM) and CO-4 (14.1 % DM). The results of the study revealed that fish meal and poultry offal meal are the best sources of CP supplements among the feedstuff tested. In addition, CGM, US SBM and TVP powder can be considered as good sources of plant protein supplements. CP levels below 8.0 % DM would negatively affect the microbial activity in the rumen (Ibrahim, 1988). All analysed feed samples recorded medium values for CP in terms of feeding ruminants (above 8 % DM).

The tested materials such as rice polish, bakery by-products and manilkara leaves had appreciable EE contents of 17.4 %, 16.9 % and 15.5 % DM, respectively while the others were below 10 % DM. The CF content was high in the roughages and ranged from 19.7 % DM (midnapore creeper leaves) to 36.2 % DM (jackal jujube leaves), while that of biscuit powder (S) and bakery by-product was the lowest (0.76 % and 0.90 % DM, respectively). With respect to NFE, animal protein supplements had the lowest values, whereas the other ingredients contained a relatively high percentage of NFE ranging from 24.7 % DM (CGM) to 81.25 % DM (corn).

Proximate composition of concentrates, particularly corn, wheat bran husk and soybean husk were similar to those reported by NRC (1998). However, the CP content given by Samarasinghe (2007) for broken rice (7.44 % DM), rice polish (13.15 % DM), coconut poonac (21.5 % DM), gingelly poonac (41.36 % DM), and poultry offal meal (63.29 % DM) were lower than those reported in the current study. These variations could be a result of differences in field practices such as processing, drying and storage. Further, this may partly be explained not only by geographical and seasonal variation, but also by methodological differences.

Proximate composition of CO-3 and sorghum in this study were comparable to those obtained by Sarmini and Premaratne (2017). However, the CP content (15 % DM) of CO-3 obtained by Premaratne and Premalal (2006) was higher than that of this study. Moreover, the CP content of CO-4 (11 % DM) obtained was quite high but the ash (8.2 % DM), EE (5.8 % DM) and CF (27 % DM) remain below the values reported by Lahiru and Jayaweera (2016). The variation may be due to differences in the climatic condition and maturity level at harvest.

van Soest fibre content of the feedstuff

van Soest fibre contents of the feedstuff showed a high variation in ADF, NDF and HC as given in Table 2. The value for ADF in feedstuff ranged between 2.34 % DM (fish meal) to 49.07 % DM (CO-3). Neutral detergent content of the samples varied from 5.37 % DM (poultry offal meal) to 83.13% DM (CO-4). Meanwhile, the HC content varied from 1.47 % DM (poultry offal meal) to 35.89 % DM (wheat bran). Among energy supplements, cocoa husk contained the highest NDF and ADF.

The ADF and NDF contents reported for soybean husk and DDGS by NRC (1998) and for banyan leaves by Ibrahim (1988) were similar to the present results. However, the ADF content reported for cocoa husk by Donkoh *et al.* (1991) (68.64 % DM), for portia leaves by Jayawardena and Perera (1991) (31.65 % DM), for

Table 2: van Soest fibre contents of the feedstuff (% DM)

Feedstuff	ADF %	NDF %	HC %
CONCENTRATES			
Energy supplements			
Corn (*Zea mays*)	6.67 ± 0.22	15.3 ± 0.03	8.72 ± 0.12
Wheat (*Triticum aestivum*) bran	13.7 ± 0.15	49.5 ± 0.03	35.8 ± 0.12
Broken rice (*Oryza sativa*)	6.83 ± 0.22	20.0 ± 0.16	13.2 ± 0.45
Rice (*Oryza sativa*) polish (S)	30.9 ± 0.21	40.1 ± 0.19	9.18 ± 0.15
Rice (*Oryza sativa*) polish (CIC)	27.6 ± 0.36	35.6 ± 0.44	7.97 ± 0.01
Bakery by-product	5.12 ± 0.14	16.4 ± 0.14	10.3 ± 0.03
Biscuit powder (S)	6.05 ± 0.07	18.0 ± 0.71	12.0 ± 0.16
Biscuit powder (N)	6.87 ± 0.07	20.3 ± 0.22	13.4 ± 0.19
Soybean (*Glycine max*) husk	44.6 ± 0.07	60.7 ± 0.10	16.0 ± 0.44
Cocoa (*Theobroma cacao*) husk	48.4 ± 0.07	78.4 ± 0.11	30.0 ± 0.14
Plant protein supplements			
United State (US) soybean (*Glycine max*) meal	15.8 ± 0.15	26.9 ± 0.30	11.0 ± 0.15
Textured vegetable protein (TVP) powder	6.31 ± 0.07	21.7 ± 0.04	15.4 ± 0.07
Coconut (*Cocos nucifera*) poonac	27.4 ± 0.43	52.5 ± 0.01	25.1 ± 0.43
Gingelly (*Sesamum indicum*) poonac	19.2 ± 0.07	31.1 ± 0.06	11.8 ± 0.07
Coconut (*Cocos nucifera*) distillery waste	43.5 ± 0.15	55.2 ± 6.35	11.7 ± 0.15
Brewery waste	30.2 ± 0.22	53.1 ± 0.17	22.8 ± 0.22
Corn gluten meal (CGM)	9.52 ± 0.43	11.4 ± 0.12	1.93 ± 0.33
Distillers dried grains with solubles (DDGS)	20.4 ± 0.43	38.8 ± 0.12	18.4 ± 0.19
Black gram (*Vigna mungo*) husk	30.4 ± 0.07	48.9 ± 0.45	18.5 ± 0.58
Dhal (*Lens culinaris*) husk only	33.1 ± 0.14	48.1 ± 0.15	15.0 ± 0.05
Dhal (*Lens culinaris*) seeds with husk	8.64 ± 0.15	30.4 ± 0.01	21.7 ± 0.23
Animal protein supplements			
Fish meal	2.34 ± 0.00	5.87 ± 0.24	3.53 ± 0.04
Meat & bone meal	7.66 ± 0.36	14.2 ± 0.31	6.54 ± 0.27
Poultry offal meal	3.90 ± 0.07	5.37 ± 0.29	1.47 ± 0.18
ROUGHAGES			
Grass			
CO-4 (*Pennisetum americanum*×*Pennisetum purpureum*)	48.2 ± 0.37	83.1 ± 0.18	34.9 ± 0.07
CO-3 (*Pennisetum americanum*×*Pennisetum purpureum*)	49.0 ± 0.07	80.2 ± 0.91	31.1 ± 0.15
Sorghum (*Sorghum bicolor*)	45.0 ± 0.08	68.3 ± 0.03	23.3 ± 0.22
Tree leaves			
Banyan leaves (*Ficus benghalensis*)	41.3 ± 0.14	53.9 ± 0.45	12.5 ± 0.24
Portia leaves (*Thespesia populnea*)	28.5 ± 0.15	54.2 ± 0.02	25.7 ± 0.31
Manilkara leaves (*Manilkara hexandra*)	39.6 ± 0.14	49.6 ± 0.01	10.0 ± 0.29
Midnapore creeper leaves (*Rivea hypocrateriformis*)	29.7 ± 0.14	48.8 ± 0.02	19.0 ± 0.15
Jackal jujube leaves (*Ziziphus jujube*)	43.8 ± 0.25	58.2 ± 0.01	14.3 ± 0.22
White fig leaves (*Ficus virensaiton*)	44.2 ± 0.00	53.0 ± 0.01	8.80 ± 0.33

Values are expressed as averages ± SD (standard deviation); S: Sinhapitiya Farm; CIC: Chemical Industries Colombo (Pvt.) Ltd.; N: New Bernard (Pvt.) Ltd.

ADF: acid detergent fibre; NDF: neutral detergent fibre; HC: hemicellulose

manilkara leaves by Ibrahim (1988) (45.8 % DM) and for CO-4 by Lahiru and Jayaweera (2016) (60 % DM) were higher than the value obtained in the present study. The variation may be due to differences in the maturity level at the time of harvesting.

In vitro **dry matter digestibility content of feedstuff**

This study suggested a very high variation in DMD (27.84 – 88.95 % DM) and OMD (22.38 – 85.15 % DM) of feedstuff as illustrated in Table 3. The concentrate

Table 3: *In vitro* digestibility values of feedstuff (% DM)

Feedstuff	DMD %	OMD %
CONCENTRATES		
Energy supplements		
Corn (*Zea mays*)	83.0 ± 0.62	79.7 ± 0.60
Wheat (*Triticum aestivum*) bran	74.9 ± 0.73	68.9 ± 0.72
Broken rice (*Oryza sativa*)	88.9 ± 0.36	85.1 ± 0.35
Rice (*Oryza sativa*) polish (S)	51.8 ± 0.52	48.5 ± 0.55
Rice (*Oryza sativa*) polish (CIC)	72.3 ± 0.05	68.4 ± 0.05
Bakery by-product	73.0 ± 0.19	71.2 ± 0.19
Biscuit powder (S)	82.3 ± 0.57	81.9 ± 0.57
Biscuit powder (N)	78.2 ± 0.05	75.5 ± 0.05
Soybean (*Glycine max*) husk	73.3 ± 3.12	60.7 ± 3.28
Cocoa (*Theobroma cacao*) husk	27.8 ± 1.29	22.3 ± 1.31
Plant protein supplements		
United State (US) soybean (*Glycine max*) meal	70.6 ± 1.89	65.7 ± 1.98
Textured vegetable protein (TVP) powder	84.3 ± 0.68	81.9 ± 0.73
Coconut (*Cocos nucifera*) poonac	63.2 ± 0.12	60.5 ± 0.13
Gingelly (*Sesamum indicum*) poonac	72.1 ± 0.13	66.0 ± 0.15
Coconut (*Cocos nucifera*) distillery waste	59.4 ± 0.68	22.3 ± 1.20
Brewery waste	45.3 ± 0.44	41.3 ± 0.44
Corn gluten meal (CGM)	38.0 ± 0.16	33.4 ± 0.17
Distillers dried grains with solubles (DDGS)	36.9 ± 0.95	31.7 ± 0.99
Black gram (*Vigna mungo*) husk	66.2 ± 0.36	64.4 ± 0.37
Dhal (*Lens culinaris*) husk only	62.2 ± 0.27	60.9 ± 0.28
Dhal (*Lens culinaris*) seeds with husk	75.0 ± 0.11	71.1 ± 0.10
Animal protein supplements		
Fish meal	83.4 ± 1.61	69.3 ± 2.61
Meat & bone meal	88.8 ± 0.82	80.9 ± 1.15
Poultry offal meal	68.1 ± 0.89	64.9 ± 0.93
ROUGHAGES		
Grass		
CO-4 (*Pennisetum americanum*×*Pennisetum purpureum*)	50.2 ± 0.51	47.9 ± 0.58
CO-3 (*Pennisetum americanum*×*Pennisetum purpureum*)	48.9 ± 1.35	44.9 ± 1.48
Sorghum (*Sorghum bicolor*)	63.6 ± 0.15	54.1 ± 0.16
Tree leaves		
Banyan leaves (*Ficus benghalensis*)	37.0 ± 0.87	31.2 ± 0.94
Portia leaves (*Thespesia populnea*)	63.2 ± 0.60	54.6 ± 0.68
Manilkara leaves (*Manilkara hexandra*)	39.2 ± 0.33	33.5 ± 0.36
Midnapore creeper leaves (*Rivea hypocrateriformis*)	57.7 ± 0.92	49.6 ± 1.07
Jackal jujube leaves (*Ziziphus jujube*)	47.1 ± 0.30	39.4 ± 0.34
White fig leaves (*Ficus virensaiton*)	42.3 ± 0.08	28.7 ± 0.09

Values are expressed as averages ± SD (standard deviation); S: Sinhapitiya Farm; CIC: Chemical Industries Colombo (Pvt.) Ltd.; N: New Bernard (Pvt.) Ltd.
DMD: dry matter digestibility; OMD: organic matter digestibility

feeds were found to have the highest digestibility values compared to roughages. The average DMD and OMD of cocoa husk and rice polish were less than 55 % DM, while in other energy supplements it was more than 55% DM. Among the grasses, sorghum had an OMD of 54.2 % DM, while the lowest value was observed in CO-3 grass (45 % DM). Except portia leaves, the other tree leaves had an OMD value below 50 % DM. The

OMD values are closely related to the lignin content of the feeds (Ibrahim, 1988). The low digestibility of most of the analysed roughages can be considered a limiting factor for feeding ruminants.

Table 4: Mineral and gross energy contents of the feedstuff

Feedstuff	Ca ($g\ kg^{-1}$ DM)	P ($g\ kg^{-1}$ DM)	Energy ($kcal\ g^{-1}$ DM)
CONCENTRATES			
Energy supplements			
Corn (*Zea mays*)	0.39 ± 0.04	2.70 ± 0.28	4.13 ± 0.00
Wheat (*Triticum aestivum*) bran	1.95 ± 0.07	10.8 ± 0.78	4.15 ± 0.00
Broken rice (*Oryza sativa*)	2.55 ± 0.49	2.80 ± 0.42	4.34 ± 0.46
Rice (*Oryza sativa*) polish (S)	2.85 ± 0.21	4.20 ± 0.42	4.55 ± 0.09
Rice (*Oryza sativa*) polish (CIC)	2.05 ± 0.35	6.55 ± 0.92	4.31 ± 0.34
Bakery by-product	0.25 ± 0.08	2.55 ± 0.49	4.62 ± 0.16
Biscuit powder (S)	0.41 ± 0.16	2.55 ± 0.92	4.49 ± 0.26
Biscuit powder (N)	0.52 ± 0.10	2.75 ± 0.92	4.33 ± 0.17
Soybean (*Glycine max*) husk	3.05 ± 1.34	1.25 ± 0.78	3.93 ± 0.01
Cocoa (*Theobroma cacao*) husk	1.60 ± 0.57	4.25 ± 1.20	3.46 ± 0.51
Plant protein supplements			
United State (US) soybean (*Glycine max*) meal	2.40 ± 0.42	6.75 ± 0.35	4.10 ± 0.02
Textured vegetable protein (TVP) powder	0.32 ± 0.12	0.20 ± 0.03	4.03 ± 0.01
Coconut (*Cocos nucifera*) poonac	1.30 ± 0.57	6.00 ± 0.71	4.30 ± 0.01
Gingelly (*Sesamum indicum*) poonac	19.2 ± 3.11	13.5 ± 1.13	4.30 ± 0.01
Coconut (*Cocos nucifera*) distillery waste	0.65 ± 0.35	0.55 ± 0.07	2.97 ± 0.01
Brewery waste	0.61 ± 0.16	10.1 ± 3.18	4.78 ± 0.01
Corn gluten meal (CGM)	0.85 ± 0.49	7.65 ± 2.47	3.81 ± 0.05
Distillers dried grains with solubles (DDGS)	2.70 ± 1.13	10.1 ± 1.63	4.60 ± 0.01
Black gram (*Vigna mungo*) husk	5.15 ± 0.64	2.20 ± 0.42	3.84 ± 0.00
Dhal (*Lens culinaris*) husk only	4.60 ± 0.42	2.50 ± 0.28	4.21 ± 0.01
Dhal (*Lens culinaris*) seeds with husk	0.07 ± 0.04	0.02 ± 0.01	4.33 ± 0.01
Animal protein supplements			
Fish meal	37.3 ± 5.16	22.7 ± 2.62	3.18 ± 0.00
Meat & bone meal	91.1 ± 18.5	31.0 ± 5.66	4.07 ± 0.01
Poultry offal meal	29.3 ± 8.27	15.9 ± 6.08	4.22 ± 0.25
ROUGHAGES			
Grass			
CO-4 (*Pennisetum americanum*×*Pennisetum purpureum*)	2.00 ± 0.42	2.95 ± 0.21	3.92 ± 0.01
CO-3 (*Pennisetum americanum* × *Pennisetum purpureum*)	1.05 ± 0.21	2.20 ± 0.42	3.58 ± 0.00
Sorghum (*Sorghum bicolor*)	0.85 ± 0.21	3.05 ± 0.21	3.85 ± 0.02
Tree leaves			
Banyan leaves (*Ficus benghalensis*)	10.7 ± 2.40	7.75 ± 3.89	4.29 ± 0.01
Portia leaves (*Thespesia populnea*)	4.75 ± 1.20	0.22 ± 0.04	4.20 ± 0.02
Manilkara leaves (*Manilkara hexandra*)	3.60 ± 0.57	0.17 ± 0.05	3.99 ± 0.01
Midnapore creeper leaves (*Rivea hypocrateriformis*)	0.32 ± 0.16	0.09 ± 0.02	3.73 ± 0.16
Jackal jujube leaves (*Ziziphus jujube*)	0.38 ± 0.13	0.34 ± 0.08	4.04 ± 0.04
White fig leaves (*Ficus virensaiton*)	0.14 ± 0.07	0.23 ± 0.09	3.85 ± 0.26
Mineral supplements			
$CaCO_3$ (*Limestone*)	329 ± 1.77	0.00	-
Dicalcium Phosphate (DCP)	226 ± 10.5	182 ± 3.68	-

Values are expressed as averages ± SD (standard deviation); S: Sinhapitiya Farm; CIC: Chemical Industries Colombo (Pvt.) Ltd.; N: New Bernard (Pvt.) Ltd.

Mineral and gross energy content of the feedstuff

The minerals and gross energy (GE) content of feedstuff summarised in Table 4 shows that animal protein supplements appear to be better sources of calcium and phosphorus for animal nutrition than plant protein supplements. Banyan leaves had the highest amount of calcium (10.7 % DM) and phosphorous (7.75 % DM) among roughages. The calcium and phosphorus content of concentrates reported by Samarasinghe (2007) and NRC (1998) were similar to the results reported in the current study. Calcium and phosphorous are metallic elements present in various forms and amounts in many animal tissues. Their functions in various livestock species are widespread, from bone mineralisation, blood pressure regulation to nerve conduction, muscle contraction, blood clotting and immune system activation. Phosphorus is also important in energy utilisation and transfer, acid-base and osmotic balance. In ruminants it is required by ruminal microbes for growth and cellular metabolism (Suttle, 2010). Meat and bone meal (91.1 % and 31.0 % DM), fish meal (37.3 % and 22.7 % DM), and poultry offal meal (29.3 % and 15.9 % DM), which contain comparatively high amounts of calcium and phosphorus, respectively could be considered as good sources of mineral supplements when formulating feeds for livestock species. No single roughage source is optimal for calcium and phosphorus; nevertheless a mixed diet should provide sufficient amounts of those minerals for ruminants especially with banyan leaves (*Ficus benghalensis*).

The GE content was the highest for brewery waste (4.78 kcal g^{-1}DM), followed closely by bakery by-product (4.62 kcalg^{-1} DM) and DDGS (4.6 kcal g^{-1} DM). Coconut distillery waste recorded the lowest GE content of 2.97 kcal/g DM. According to the analysis, bakery by-products and rice by-products (rice polish and broken rice) contained more energy (4.3–4.7 kcal g^{-1} DM) compared to other energy supplements.

From the generated data, a nutritional index could be established, which would be helpful in ration formulation for enhancing animal productivity in Sri Lanka.

CONCLUSION

Data on the nutritional value of leaves of tree species of tropical origin and industrial by-products are scanty. Considering the crude protein composition, DMD and OMD, portia (*Thespesia populnea*) tree leaves make it the best candidate for utilising as a good roughage source for ruminants. However, the level of anti-nutritional factors may complicate the utilisation of such tree leaves in large quantities in ruminant feeding. Furthermore, the results of the current study show high variation in the nutritional composition of the feedstuff. Thus, it is concluded that the evaluation of various feedstuff and applying the nutrient value variations is helpful in balanced ration formulation for ruminants in Sri Lanka.

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