

Macronutrient-based assessment of fibre source quality in lowland and highland smallholder dairy cattle farms

Tri Wahyu Apriliana, Idat Galih Permana*, Despal, and Annisa Rosmalia

Department of Animal Nutrition and Feed Technology, Faculty of Animal Science, IPB University, 16680 Bogor, Indonesia

Abstract. Dairy cattle require high-quality fibre sources to support their milk production. Macronutrients, including ash, crude protein, ether extract, crude fibre (neutral detergent fibre, acid detergent fibre, and hemicellulose), nitrogen-free extract, and total digestible nutrients can be used to evaluate the quality of fibre sources. Altitude may influence the macronutrient composition of fibre sources due to microclimatic differences between lowland and highland areas. This study aimed to analyze the differences in fibre source quality used by dairy farmers in lowland and highland regions. Fibre source samples were collected from lowland farms (Bogor) and highland farms (Pangalengan). Fibre source samples were analyzed for proximate composition and fibre fraction (% DM) using NIRS. Group means were compared using an independent t-test. The results showed that crude protein levels in highland fibre sources were significantly higher ($p < 0.05$), whereas crude fibre levels were significantly lower ($p < 0.05$) compared with those in lowland areas. The NDF, ADF, and hemicellulose fractions in highland fibre sources were also significantly lower ($p < 0.05$) than those in the lowland fibre sources. Based on their macronutrient composition, highland fibre sources exhibit better nutritional quality. These findings underscore the need to account for altitude-driven variation in fibre source nutritional quality in precision ration formulation.

1 Introduction

Fibre sources are essential feed components required by ruminant animals, including dairy cows, to support various physiological functions such as growth, reproduction, and milk production. Dairy cows require high-quality fibre sources to support their various needs, especially for supporting milk production (milk yield and quality). Nutrient composition is one of the key indicators for assessing fibre source quality, as fibre sources contain ash, crude protein (CP), ether extract (EE), crude fibre (CF), total digestible nutrients (TDN), and nitrogen-free extract (NFE). At a deeper level, the crude fibre fraction includes Acid Detergent Fibre (ADF), Neutral Detergent Fibre (NDF), and hemicellulose, all of which play important roles in determining the overall quality of a fibre source.

* Corresponding author: permana@apps.ipb.ac.id

Each nutrient plays a specific role in supporting the productivity of dairy cows. Ash contains various minerals required to support a wide range of biological functions. Crude protein provides essential amino acids necessary for milk synthesis and the formation of milk components. Fatty acids can serve as precursors for important milk properties such as conjugated linoleic acid (CLA) [1]. Crude fibre (NDF and ADF) plays an essential role in the digestive physiology of ruminants by influencing feed intake, rumen fermentation, and overall nutrient utilization [2]. Nitrogen-free extract (NFE) is easily digested and is particularly important for synchronizing with ammonia to support microbial protein synthesis, which serves as a precursor for milk production [3]. Total digestible nutrients (TDN) reflect the energy available to dairy cattle, which is closely associated with increased milk lactose synthesis and overall milk production [4]. Hemicellulose, a component of NDF, serves as a carbohydrate source used to produce volatile fatty acid (VFAs), which are essential for dairy animals [5].

Differences in environmental conditions between lowland and highland regions, particularly temperature, may influence the macronutrient composition of fibre sources. For example, NDF concentration is influenced by temperature, with higher ambient temperatures leading to higher NDF values [6]. Crude protein content is also affected by temperature, as increasing temperatures generally reduce protein concentration in fibre sources [6]. In Indonesia, temperature conditions differ widely across regions, particularly between areas located at different altitudes. Highland areas generally have lower temperatures compared to lowland areas. These temperature variations are expected to influence the macronutrient content of fibre sources, especially those commonly used by dairy farmers at different altitudes. Therefore, this study was conducted to assess variations in the nutritional quality of fibre sources utilized by dairy farmers across lowland and highland areas.

2 Materials and methods

2.1 Materials

The analysis utilized several pieces of equipment, including an oven maintained at 60°C, a laboratory milling machine, a digital scale, a petri dish, and an FT-NIR Spectro Solid Cell (NIRFlex N-500, BUCHI, Switzerland).

The materials used consisted of fibre sources collected from 30 dairy farms in Bogor (Kunak and Kebon Pedes) representing lowland areas (222.2m a.s.l and 175.68m a.s.l), and 35 farms in Pangalengan at three milk collecting points (MCP Cipanas, MCP Citere, and MCP Gunung Cupu) representing highland areas (1410m a.s.l.). The fibre sources collected from the lowland area consisted of Napier grass, native grass, rice straw, pakchong grass, corn grass, and corn husk, whereas those from the highland area consisted of Napier grass, field grass, corn pericarp, carrot leaves, and silage.

2.2 Methods

2.2.1 Exploration

The exploration aimed to identify the types of fibre sources commonly used by dairy farmers. It also aimed to collect representative fibre source samples from the farms. The exploration was conducted at smallholder dairy farms located in Bogor and Pangalengan. Data were obtained through interviews with farmers regarding the types of fibre sources typically used as feed. The amount of fibre source given to the dairy cows was directly weighed using a digital scale, after which the identified fibre sources were collected as representative samples.

2.2.2 Sample preparation

The fibre source samples were air-dried under sunlight for 2–3 days, followed by oven drying at 60°C until a constant dry weight was achieved. The dried materials were then milled into a fine powder using a laboratory milling machine.

2.2.3 Proximate and fibre fraction analysis

The ground fibre sources were analyzed for their proximate and fibre fraction content using Near-Infrared Spectroscopy (NIRS). The proximate components obtained from the NIRS analysis included ash, CP, EE, and CF. DM was determined by oven-drying the samples at 105°C until a constant weight was achieved. NFE was calculated using the following equation:

$$\text{NFE (\%)} = 100 - (\text{Ash} + \text{Crude Protein} + \text{Ether Extract} + \text{Crude Fibre}) \quad (1)$$

TDN was calculated using the equation from Wardeh (1981) [7] :

$$\text{TDN} = -14.8356 + 1.3310 (\%CP) + 0.7923 (\%NFE) + 0.9787 (\%EE) + 0.5133 (\%CF)$$

Hemicellulose was estimated using the equation from Campos *et al.* (2013) [8]

$$\% \text{Hemicellulose} = \% \text{NDF} - \% \text{ADF} \quad (2)$$

2.3 Data analysis

The proximate data were presented descriptively, and for comparison, the data were grouped into two categories representing lowland and highland areas and analyzed using an independent samples t-test to determine differences in nutrient parameters between the two locations. The analysis was conducted using SPSS version 26.

3 Results and discussion

Several types of fibre sources and their proximate values used by dairy farmers in both lowland and highland areas are presented in Table 1.

Table 1. Fibre source types and their proximate composition in lowland and highland dairy farms

Types of fibre sources	n	Proximate value (%DM)						TDN	NDF	ADF
		DM	Ash	CP	EE	CF	NFE			
Lowland										
Napier grass	26	14.62	13.88	10.49	4.58	30.09	40.96	51.50	63.20	37.43
Rice straw	13	91.14	16.49	8.87	3.38	32.76	38.50	49.45	66.51	36.38
Pakchong grass	1	19.76	12.64	9.00	4.53	33.74	40.09	50.65	67.75	39.30
Corn grass	1	21.17	7.27	8.25	4.44	29.07	50.97	55.78	65.38	35.84

Table 1. Fibre source types and their proximate composition in lowland and highland dairy farms (continue)

Types of fibre sources	n	Proximate value (%DM)						TDN	NDF	ADF
		DM	Ash	CP	EE	CF	NFE			
Lowland										
Native grass	2	27.75	10.16	11.87	4.30	28.03	45.65	55.71	62.95	36.22
Corn husk	1	19.14	6.89	7.23	3.68	29.93	53.92	56.59	72.73	35.32
Highland										
Napier grass	31	12.98	15.25	11.65	4.26	27.18	41.66	51.79	59.15	32.84
Field grass	1	14.51	12.09	12.07	4.45	27.17	44.23	54.56	57.46	34.22
Silage	1	18.25	9.22	12.24	2.36	23.05	37.85	57.68	65.59	40.62
Corn pericarp	1	48.65	5.60	12.19	1.59	18.63	61.99	59.42	59.05	40.71
Carrot leaves	2	10.13	14.70	18.30	4.93	24.23	53.13	56.76	46.72	29.00

Note: DM= Dry matter; CP= Crude protein; EE= Ether extract; CF= Crude fibre; NFE= Nitrogen-free extract (100 – (ash + crude protein + ether extract + crude fibre)); n= the number of farmers using the respective fibre source

Several types of fibre sources are used by dairy farmers in both lowland and highland areas. The most commonly used fibre source in both regions is Napier grass, while other fibre source types vary according to the characteristics of each production area. The proximate analysis of fibre sources from both lowland and highland regions shows clear differences, even when the fibre sources are of the same type. A comparison of their macronutrient composition between the two altitudinal zones is shown in Table 2 to provide a clearer assessment of fibre source quality.

Table 2. Comparison of macronutrients of fibre sources across altitude

Nutrient parameters	Altitude		p-value
	Lowland	Highland	
Ash	14.10±3.32 ^a	14.70±3.45 ^a	0.435
CP	9.92±1.31 ^b	12.06±2.09 ^a	0.000
EE	4.19±0.68 ^a	4.17±0.83 ^a	0.939
CF	30.84±1.70 ^a	26.66±2.51 ^b	0.000
NFE	40.95±4.04 ^a	42.40±5.10 ^a	0.160
TDN	51.28±2.56 ^a	52.52±3.46 ^a	0.080

Note: CP= Crude protein; EE= Ether extract; CF= Crude fibre; NFE= Nitrogen-free extract (100 – (ash + crude protein + ether extract + crude fibre)); Values (mean±SD) with different superscript letters in a column indicate significant differences (p<0.05).

The results revealed significant differences (p<0.05) in the CP and CF parameters between the two altitudes. Crude protein was significantly higher in the highland fibre sources (p<0.05), whereas crude fibre was significantly lower compared with the fibre sources from the lowland areas (p<0.05). Meanwhile, the other macronutrient parameters did not differ significantly between altitudes. These results are supported by Moyo and Nsahlai (2021) [6], who reported a positive association between crude fibre and ambient temperature, alongside a negative association between crude protein and temperature. In Indonesia, highland areas experience lower temperatures than lowland regions, which slows the lignification process and contributes to the lower CF values observed in highland fibre sources, as lignin is a structural component of crude fibre [9]. The decrease in CP is associated with increased lignification, which expands the structural fibre fraction of the cell

wall and reduces the relative proportion of protein, resulting in lower CP content [6]. An increase in crude fibre accompanied by a decrease in crude protein leads to a reduction in fibre source quality. Based on the proximate results, the nutritional quality of fibre sources in the lowland was therefore lower than that in the highland.

One of the proximate components commonly used as an indicator to evaluate feed quality, particularly for fibre sources, is crude fibre content. Variations in crude fibre among these samples provide insight into differences in nutritional value and digestibility between fibre sources grown at different altitudes. Crude fibre can be divided into two major fractions, namely NDF and ADF. In general, NDF includes cellulose, hemicellulose, and lignin, while ADF contains only cellulose and lignin. The mean values of these fibre fractions for all fibre sources collected from both lowland and highland regions are presented in Table 3.

Table 3. Fibre fraction content of fibre sources used by dairy cattle farmers across altitude

Fibre fraction	Altitude		p-value
	Lowland	Highland	
NDF	64.52 ± 2.95 ^a	58.59 ± 5.15 ^b	0.000
ADF	37.02 ± 2.25 ^a	33.10 ± 3.12 ^b	0.000
Hemicellulose	27.50 ± 3.46 ^a	25.49 ± 4.40 ^b	0.025

Note: NDF= Neutral detergent fibre; ADF= Acid detergent fibre; Hemicellulose = NDF – ADF; Values (mean±SD) with different superscript letters in a column indicate significant differences (p<0.05).

The findings indicated that fibre sources from lowland areas had significantly higher (p<0.05) contents of NDF, ADF, and hemicellulose. Variations in these fibre fractions reflect the influence of environmental conditions on cell wall composition. The pattern observed for NDF aligns with previous findings [6], which found a positive linear relationship between ambient temperature and NDF content in feed. The study indicated that the NDF value increases with rising temperature, where each 1°C increase in temperature leads to approximately a 4% increase in NDF content [6]. In Indonesia, lowland areas generally experience higher temperatures compared to highland regions. This temperature difference likely explains the higher NDF concentration observed in fibre sources collected from lowland dairy farms. Low temperatures can reduce lignin biosynthesis during plant growth, resulting in lower ADF concentrations in forage produced in highland areas [9]. This result is further supported by the ADF findings, which show that ADF values in the lowland region were statistically greater (p<0.05) compared with those in the highland area, as lignin is likewise a constituent of the ADF fraction.

Higher dietary NDF levels have been reported to reduce milk yield, milk protein concentration, and nitrogen utilization efficiency, while increasing milk fat content and milk urea nitrogen (MUN) [2]. Additionally, dry matter intake declines, whereas eating and rumination times increase [2]. A reduction in dry matter intake (DMI) can lead to a reduction in milk production and milk protein yield because DMI reflects the total amount of nutrients consumed by the animal. Previous studies have also mentioned that a decline in DMI leads to lower milk yield and milk protein yield [10].

ADF is a fibre fraction that is highly indigestible. Its low degradability limits the extent to which animals can utilize the feed. Digestibility is a crucial factor in feed because it determines how much of the nutrients consumed can be digested and utilized by the animal. Feed that is not digested will be excreted directly through feces, thus providing no nutritional contribution. Greater feed digestibility increases its potential contribution as a precursor for milk synthesis, ultimately enhancing both milk yield and quality. Previous studies have also reported that improving organic matter digestibility is positively associated with increased milk production, milk fat yield, and feed conversion efficiency [11]. Previous study has reported that increases in both NDF and ADF concentrations are associated with reductions in fibre source quality [12].

Hemicellulose is broken down and fermented by anaerobic microbes in the rumen, generating volatile fatty acids that serve as the primary energy source for dairy cattle [5]. Hemicellulose content in fibre sources from lowland areas was significantly higher. These findings support the explanation that high NDF and ADF levels are influenced by cellulose and hemicellulose bound to lignin, forming a resistant matrix [13]. The higher hemicellulose content observed in the lowland samples is consistent with this mechanism, as greater structural fibre components contribute to the increased NDF and ADF values in that region.

Considering that the NDF and ADF values have been shown to influence both milk production and quality, it is important to pay close attention to these parameters in order to maximize milk yield. This is particularly relevant given that national milk production and quality, especially milk protein content, remain relatively low [14, 15].

4 Conclusion

Differences in altitude significantly influenced the nutritional quality of fibre sources used by dairy farmers. Fibre sources from highland areas exhibited better nutritional quality than those from lowland regions. Highland fibre sources contained higher crude protein levels, along with lower crude fibre, NDF, ADF, and hemicellulose values.

The authors gratefully acknowledge the Indonesian Ministry of Research and Technology–National Research and Innovation Agency for financial support provided through the PMDSU research scheme, under contract No. 006/C3/DT.05.00/PL/2025 and subcontract No. 23183/IT3.D10/PT.01.03/P/B/2025.

References

1. L.U. Riestanti, Despal, R. Yuli, Supplementation of prill fat derived from palm oil on nutrient digestibility and dairy cow performanc. *Am. J. Anim. Vet. Sci.* **16**, 172-184 (2021). <https://doi.org/10.3844/ajavsp.2021.172.184>
2. R. Shi, S. Dong, J. Mao, J. Wang, Z.Cao, Y. Wang, L. Shengli, G. Zhao, Dietary Neutral detergent fibre levels impacting dairy cows' feeding behavior, rumen fermentation, and production performance during the period of peak-lactation. *Animals.* **13**, 2876 (2023). <https://doi.org/10.3390/ani13182876>
3. J. Zhang, N. Zheng, W. Shen, S. Zhao, J. Wang, Synchrony degree of dietary energy and nitrogen release influences microbial community, fermentation, and protein synthesis in a rumen simulation system. *Microorganisms.* **8**, 231(2020). <https://doi.org/10.3390/microorganisms8020231>
4. A.M. Gabbi, C.M. Mcmanus, L.T. Marques, A.S. Abreu, S.C. Machado, M.B. Zanela, R.S. Barbosa, V. Fisher, Different levels of supplied energy for lactating cows affect physicochemical attributes of milk. *J. Anim. Feed Sci.* **27**, 11–7 (2018). <https://doi.org/10.22358/jafs/83703/2018>
5. D. Anzhany, T. Toharmat, D. Despal, A. Lozicki, N. Rofiah, Nutrient and fatty acid composition of elephant and king grasses from different altitudes, in Proceedings of The 4th International Conference on Agriculture and Bio-industry, Indonesia, October 10 (2022). <https://doi.org/10.1088/1755-1315/1183/1/012002>
6. M. Moyo, I. Nsahlai, Consequences of increases in ambient temperature and effect of climate type on digestibility of forages by ruminants: A meta-analysis in relation to global warming. *Animals.* **11**, 1–17 (2021). <https://doi.org/10.3390/ANI11010172>
7. M.F. Wardeh, Models for estimating energy and protein utilization for feeds,

- Dissertation, Utah, Utah State University (1981)
8. F.P. Campos, P. Sarmiento, L.G. Nussio, S.M.B. Lugão, C.G. Lima, J.L.P Daniel, Fibre monosaccharides and digestibility of Milenio grass under N fertilization. *Anim. Feed. Sci. Technol.* **183**, 17–21 (2013).<https://doi.org/10.1016/j.anifeedsci.2013.04.014>
 9. W. Gindl, M. Grabner, R. Wimmer, The influence of temperature on latewood lignin content in treeline Norway spruce compared with maximum density and ring width. *Trees - Struct. Funct.* **14**, 409–414 (200).<https://doi.org/10.1007/s004680000057>
 10. F. Giallongo, M.T. Harper, J. Oh, C. Parys, I. Shinzato, A.N. Hristov, Histidine deficiency has a negative effect on lactational performance of dairy cows. *J. Dairy Sci.* **100**, 2784–2800 (2017).<https://doi.org/10.3168/jds.2016-11992>
 11. M. Coppa, D. Pomiès, B. Martin, M. Bouchon, J.P. Renaud, M Aoun, B. Deroche, R. Baumont, Dietary inclusion of hay of greater digestibility and water-soluble carbohydrate content increases performance of dairy cows, irrespective of concentrate type and breed. *Animal.* **19**, 101464 (2025).<https://doi.org/10.1016/j.animal.2025.101464>
 12. T.L.Hansen, L.M Lawrence, Composition factors predicting forage digestibility by horses. *J. Equine. Vet. Sci.* **58**, 97-102 (2017).<https://doi.org/https://doi.org/10.1016/j.jevs.2017.08.015>
 13. S.M. Pratama, S.W. Amirrudin, A. Jayanegara, S. Samadi, Evaluation of some forage as feed for ruminant animal : chemical composition, in vitro rumen fermentation, and methane emissions. *Anim. Prod.* **24**, 150-60 (2022)
 14. Apriliana TW, Permana IG, Despal, Amirroenas DE, Rohaeni ES, Analysis of the best secondary metabolite compound of binahong leaves (*Anredera cordifolia* (Ten.) Steenis) against *Staphylococcus epidermidis*, In Proceeding of the Frontier in Sustainable Agromaritime and Environmental Development Conference, Indonesia, December 9 (2024).<https://doi.org/10.1051/bioconf/202517101003>
 15. D.E. Yolanda, A.F. Alfitra, T.W. Apriliana, D. Evvyernie, E.S. Rohaeni, B. Bakrie, T.P. Priyatno, S.N. Ahmad, U. Affif. Study of binahong leaves (*anredera cordifolia* (ten.) steenis) potency as an herbal feed additive for lactating dairy animals, in Proceedings of the Frontierin Sustainable Agromaritime and Environmental Development Conference, Indonesia, September 30 (2023).<https://doi.org/10.1088/1755-1315/1359/1/012114>