

## **The investigation of the efficacy of horticultural by-product on the feed nutritive values and the performance of Bali cattle in regency of Barru, South Sulawesi**

**Amriana Hifizah<sup>1\*</sup>, Astatu Astatu<sup>1</sup>, Anas Qurniawan<sup>1</sup>, Basir Paly<sup>1</sup>, Sutomo Syawal<sup>2</sup>, Nurlina Saking<sup>3</sup> and Suriani<sup>4</sup>**

<sup>1</sup> *Alauddin Islamic State University, Gowa, South Sulawesi, 92118, Indonesia*

<sup>2</sup> *Hasanuddin University, Makassar, South Sulawesi, 90245, Indonesia*

<sup>3</sup> *Agency for Animal Husbandry and Animal Health, South Sulawesi, 90131, Indonesia*

<sup>4</sup> *Agency for Agriculture and Food Security, Barru Regency, South Sulawesi, 90712, Indonesia*

\*Corresponding author: amriana.hifizah@uin-alauddin.ac.id

### **Abstract**

Hifizah, A., Asati, Qurniawan, A., Paly, B., Sutomo, Saking, N. & Suriani (2026). The investigation of the efficacy of horticultural by-product on the feed nutritive values and the performance of Bali cattle in regency of Barru, South Sulawesi. *Bulg. J. Agric. Sci.*, 32(1), 186–192

The regency of Barru is one of the breeding centers of Bali cattle in the province of South Sulawesi, Indonesia. It is rich of horticultural by-products that are potential. The aim of the study is to investigate the efficacy of the horticultural by-product on the performance of Bali cattle, and the income over feed cost in the regency of Barru, Province of South Sulawesi, Indonesia. The study applied completely randomized design with four treatments and three replicates each. The treatments were T0 (100% Elephant Grass); T1 (70% Elephant Grass+30% By-product); T2 (40% Elephant Grass+60% By-product); T3 (100% By-product). The study showed that there was a significant effect on the content of crude protein, ash, fat, nitrogen free extract, NDF, ADF, cellulose, hemicellulose and undissolved ash, except for lignin. Crude Protein content ranged from 6.68 to 13.86% DM<sup>-1</sup>. The treatment T3 was with the highest value. Crude fat and ash content ranged from 3.30 to 4.08 % DM<sup>-1</sup>, and 12.27 to 14.41 % DM<sup>-1</sup>, respectively, with the least amount on the treatment T2, that contained horticultural by-product. The value of nitrogen free extract tent to increase with the increase amount of the horticultural by-product in the mixture. The highly significant difference in the value of NDF, ADF and hemicellulose was noticeable in T3 to T2 and T1. There was a significant effect ( $P < 0.05$ ) on the daily weight gain with the highest one on T3, then followed by T2. The high value of income over feed cost was on T1 and T2, respectively.

*Keywords:* horticultural by-product; Bali cattle; South Sulawesi

### **Introduction**

The zero-waste farming system pattern provides feed sourced from by-products of food crops, while utilizing animal manure for plant growth, thus leaving no waste behind. The hope is that carbon emissions produced from food crops and livestock will be balanced with the carbon utilization for

the benefit of the animals and plants (Hai et al., 2020). Farmers are expected to maximize the utilization of by-products from food crops in their respective areas, so that in the end, not only sustainability in livestock farming is achieved, but also feed independence, with consideration given to emission mitigation from livestock farms (Eisler et al., 2014). This is in accordance with the commitment already proclaimed by

the Ministry of Agriculture to promote feed self-sufficiency in Indonesia while still prioritizing the principle of animal welfare. In other words, processed feed must be digestible, contain complete nutrients according to the needs of the livestock, and ensure the health of the animals consuming it.

Barru regency is one of the regencies in the South Sulawesi province, which serves as a center for Bali cattle breeding. The total area is 1,174.72 square kilometers, with a population of 185,525 people (Misbahuddin and Harjanti, 2022). The distance from Barru regency to Makassar, which is the capital of South Sulawesi province, is approximately 1.5 hours, while the distance to Pare-pare city, which is a port area, is only 45 minutes. In terms of location, Barru regency is a strategically positioned area for marketing its flagship products, which would significantly support the region's development acceleration. Moreover, Barru regency is a fertile area with abundant natural resources potential.

Bali cattle is the dominant ruminant livestock in Barru regency, with a total population of 61,812 heads in 2021, showing an increase of 0.4%, compared to 2019. In terms of the livestock feed source, Barru regency is potential supplier as it has various agricultural plants and food crops. The most prevalent food commodities in Barru regency are rice, corn, peanuts, rambutan, soursop, oranges, and bananas, with several horticultural crops being available abundantly, based on the season (Misbahuddin and Harjanti, 2022). The by-products from these food crops have great potential to be used as supplementary feed in the diet of Bali cattle, and can even serve as substitutes for conventional green fodder during the dry season. If processed correctly, this local potential can reduce feed costs, and also contribute to efforts to reduce emissions generated from the burning of waste from these food crops.

Mostly, the local farmers in Barru regency have lack of experience and knowledge on how to process the horticultural by-product to be converted to feed for their livestock. Apparently, cattle is just fed by dried forage and dried rice straw, or anything available nearby, and the cattle ends up losing lots of weight, because of this less nutritious feed. This influences the livestock productivity and eventually the farmers income.

This research aimed to investigate the efficacy of the horticultural by-products in the regency of Barru, that have the potential as livestock feed. The efficacy in terms of the nutritional value including crude protein, crude fat, ash and nitrogen free-extract, and the fiber fractions, which are NDF, ADF, cellulose, hemicellulose, tannin and ATL (undissolved ash). The efficacy of the by-products was also continued to the animal trial, to see the effect of the feed to weight gain and the income over feed cost. All of this information is very valuable for the local farmers. The innovative and practical research is

highly necessary, especially in Barru regency, as this is one of the breeding centers for Bali cattle in South Sulawesi province, and is highly potential to support the national GDP. This research can provide a triple benefit impact, not only for the environment and livestock, but also benefits for the farmers.

## Materials and Methods

### *Location, study design, sample collection and preparation*

This research was conducted from June to December, 2023. The samples were collected from the district of Tanete Riaja, Lempang village, Barru regency, province of South Sulawesi, Indonesia. Geographically, it was located on 119.649071 LS/LU. -4.486865 BT/BB. The total area of Lempang village is 17.714,84 Ha with majority hilly area.

A total of 18 samples were collected, consisted of five different types with triplicates each type: banana stem (*Musa paradisiaca* var. Cavendish), corn straw (*Zea mays*), *Gliricidia maculata*, rice bran, Elephant Grass (*Pennisetum purpureum*), Brachiaria Grass (*Brachiaria decumbens*). We collected approximately 1 kg fresh weight of the edible parts (leaf; stems less than 3 mm in diameter). Upon collection, samples were placed in a sealed plastic bag and stored in a cooled insulated container for transfer to the laboratory of Basic Animal Science, Department of Animal Science, Faculty of Science and Technology, UIN Alauddin Makassar. The feed samples were ground through a 1 mm screen and kept in sealed bags. Then, they were stored in a freezer at a temperature of  $-20^{\circ}\text{C}$  until needed for analyses. The control was Elephant grass, because this is the basal diet for cattle in the regency of Barru.

The nutritional content of the individual feed source was analyzed as well as in the mixed ration.

There were four different treatments with three replicates each:

- T0: 100% Elephant grass (control);
- T1: 70% Elephant grass + 30% horticultural by-product mixture;
- T2: 40% Elephant grass + 60% horticultural by-product mixture;
- T3: 100% horticultural by-product mixture.

The formulation of the feed source from horticultural by-products was formulated based on the nutritional content and the nutritional requirement of the experimental animal, weighed 100–120 kg, 12 male, 1.5 years of age (NEm = 2200–2500 Kcal; CP = 14–18.0%DM). The cattle were on treatment for 3 consecutive months, including 1 month as the pre-experimental period.

**Proxymate analysis**

Crude protein (CP), crude fat (CF), ash and nitrogen free extract components of samples were collected, and the ration were analyzed using standard methods, described by the Association of Official Analytical Chemists (AOAC, 1990).

**Fiber fraction analyses**

The content of acid detergent fibre (ADF), neutral detergent fibre (NDF), cellulose, hemicellulose, lignin and undissolved ash (ATL) of the samples were collected, and the ration were analyzed using a modification of the Van Soest procedures (Van Soest, 1993), described by Ankom Technology Corporation.

**Daily weight gain**

The daily weight gain was calculated following Kunda modified method (Kunda et al., 2017):

$$DWG (Kg) = WG_0 - WG_E$$

where: DWG = daily weight gain;

WG<sub>0</sub> = weight at the first day of the experiment;

WGE = weight at the last day of the experiment.

**Feed conversion**

Feed conversion ratio was also calculated based on Johansen (Johansen et al., 2024):

$$FCR = \text{total DMI} / \text{total WG}$$

where FCR Feed Conversion Ratio;

DMI Dry Matter Intake;

WG Weight Gain.

**Income over feed cost**

The calculation of the income over feed cost was following Buza (Buza et al., 2014a):

$$IOFC = AR - AFC$$

where: IOFC Income Over Feed Cost;

AR = average revenue per head of cattle sold;

AFC = average feed cost per head of cattle.

**Statistical analysis**

The treatments as fixed effect was analyzed by using Statistical Tool for Agricultural Research (STAR) Software/

**Table 1. Nutritional values of the single substrate of the feed source for cattle in the regency of Barru, South Sulawesi**

No	Component	<i>Musa paradisiaca</i> (stem)	<i>Zea mays</i> (leaves)	<i>Gliricidia maculata</i> (leaves)	Concentrate (mix rice bran and tofu waste)	<i>Pennisetum purpureum</i>	<i>Brachiaria decumbens</i>
1	Moisture	8.47	6.98	8.99	8.35	6.61	6.85
2	Ash	14.49	19.82	10.76	11.37	14.72	14.17
3	Crude protein	2.49	10.78	21.81	10.38	6.68	11.32
4	Fat	1.77	4.06	5.83	9.50	3.72	2.45
5	NDF	47.04	56.12	23.41	34.25	68.63	63.3
6	ADF	33.0	34.45	15.79	23.46	39.88	32.34
7	Cellulose	28.07	19.69	9.98	12.99	30.66	21.65
8	Hemicellulose	14.05	21.68	7.62	10.79	28.75	30.96
9	Nitrogen free extract	29.09	43.04	52.34	27.56	34.38	33.24
10	Lignin	4.69	4.98	5.21	7.26	5.3	6.81
11	Undissolved ash	0.25	9.78	0.6	3.21	3.93	3.88

Source: Laboratory of Feed Chemistry, Department of Nutrition and Feed, Faculty of Animal Science, Hasanuddin University, 2023.

**Table 2. Nutritional values of the complete experimental feed for cattle in the regency of Barru, South Sulawesi**

Treatment	Nutritional content and fiber fraction (%DM)									
	Ash	CP	Fat	BETN	NDF	ADF	Cellulose	Hemicellulose	Lignin	ATL
T0	12.27±0.06 <sup>d</sup>	6.68±0.05 <sup>d</sup>	3.3±0.08 <sup>c</sup>	45.24±0.06 <sup>c</sup>	68.36±0.65 <sup>a</sup>	38.20±0.49 <sup>a</sup>	31.19±0.18 <sup>a</sup>	30.16±0.50 <sup>a</sup>	5.69±0.17	1.32±0.20 <sup>c</sup>
T1	14.08±0.16 <sup>b</sup>	8.61±0.23 <sup>c</sup>	4.08±0.04 <sup>a</sup>	45.80±0.48 <sup>b</sup>	56.73±0.67 <sup>b</sup>	33.81±0.52 <sup>b</sup>	25.19±0.25 <sup>b</sup>	22.92±0.16 <sup>b</sup>	5.55±0.40	3.08±0.25 <sup>a</sup>
T2	13.68±0.12 <sup>c</sup>	11.08±0.28 <sup>b</sup>	3.86±0.06 <sup>b</sup>	47.62±2.02 <sup>ab</sup>	48.33±0.14 <sup>c</sup>	30.26±0.22 <sup>c</sup>	21.80±0.29 <sup>c</sup>	18.07±0.34 <sup>c</sup>	6.00±0.49	2.46±0.19 <sup>b</sup>
T3	14.41±0.24 <sup>a</sup>	13.86±0.02 <sup>a</sup>	4.02±0.17 <sup>ab</sup>	48.50±0.66 <sup>a</sup>	38.13±0.05 <sup>d</sup>	25.30±0.14 <sup>d</sup>	17.53±0.36 <sup>d</sup>	12.82±0.17 <sup>d</sup>	5.58±0.26	2.19±0.49 <sup>b</sup>
Significance	**	**	**	**	**	**	**	**	ns	**

Source: Laboratory of Feed Chemistry, Department of Nutrition and Feed, Faculty of Animal Science, Hasanuddin University, 2023.

Notes: Means ± Deviation Standard; Means with a similar superscript letter in the same column are not significantly different. Least Significant Difference (LSD) Test level of significance = 1%.\*\* significant at p(α) 0.01; ns non-significant

STAR Vers 2.0.1. If the result was significant, it would be continued to LSD test to observe the difference among the treatments.

## Results and Discussion

### Results

The nutritive values of the experimental feed, both as the single feed source or as a complete experimental feed, are presented in tables 1 and 2.

### Discussions

#### *The nutritive values*

The conventional forage that has been fed to local beef cattle in the district of Tanete Riaja is *Pennisetum purpureum*, which has less protein content that was averagely 6,68%DM. There are various reports of the crude protein content of *Pennisetum purpureum*, ranged from 10-18%DM. The various amount reportedly due to the time of harvesting, the plant's age, the season and the plant's variety (Woli et al., 2023). Sometimes, local farmers fed their cattle with *Brachiaria decumbens*, which naturally grown in the area. Based on our result, the crude protein content is lower than *Pennisetum purpureum*, but the value of the other component is comparable to *Pennisetum purpureum*. *Gliricidia maculata* is the conventional legum, that is highly nutritious, so we include it increase the nutritional value of the total feed, and it is easily accessible in the regency of Barru.

The by-products that we used are all easily accessible and continuously available, eventhough has various pluses and minuses. For example, the stem of *Musa paradisiaca* is a good source of fiber for ruminants (Azar et al., 2022), but the downside is the crude protein content. The leaves of *Zea mays* has much higher crude protein content, compared to the stem of *Musa paradisiaca*, and comparable value to the concentrate, and also a good source of fiber and nitrogen free extract, however it contained high value of ash and undissolved ash, which is an indication of longer stay in the barn (MLA Administration, 2019). It appears that rice bran has been used by the local farmers in the regency of Barru. They has been stored longer time in the barn, showed by the content of high value of ash. Additionally, it was indicated that the concentrate was mixed somehow with husk, showing from the high content of lignin, and lower content of crude protein, compared to the general rice bran that has averagely 12%DM of crude protein (Wu et al., 2024). Ash content reflects the anorganik compound mainly minerals in the substrate, which is not required in high amount for the livestock (MLA Administration, 2019), because it will influ-

ence the nutritional absorpsion of livestock feed (Aliahmadi et al., 2025).

The statistical analysis showed that the complete feed for all the treatment significantly affect the component of crude protein, ash content, fat content, NDF and ADF content, cellulose and hemicellulose content, nitrogen free extract and undissolved ash. The crude protein content ranged from 6.82-13.86%DM, with the highest content on T3 (100% complete feed). The value is 51.8% higher than crude protein content of control, indicated that this formula is potentially fed to the local cattle as the substitution of *Pennisetum purpureum*, when there is not much availabel. The high value of crude protein in the complete feed is because of the portion of the highly nutritious feed source, that contained in the formulation (Henry et al., 2019). Protein is the main source of amino acid that has important roles in the living cells, the function of enzymes and hormones that are important for metabolism in ruminants. Feed protein will be degraded in to ammonia in rumen, and the rumen microbes will utilize N from the compound (Soliva et al., 2008). Crude protein content is also influenced by the type of the forage, the feed processing both at the drying and the grinding (Xia et al., 2018). The quality of the feed is mainly determined by the quality of the feed component.

Fat content in our data ranged from 3.29% – 4.02% with the highest value was on T3, but it still in the safe range based on national standard in Indonesia for feed, which is not exceed 6%DM (Zullaikah et al., 2022). The fluctuation of fat content in feed is due to the presence of moisture, oil, air exposure, catalist and light. Water content, moisture and temperature are the main factors that increase the process of destruction by the microorganism (Getachew et al., 2004).

Fiber content in all the treatments ranged from 18.95–31.98 %DM. T3 has low fiber content compared to the other treatment, might due to the feed components that have less fibre but high crude protein. Fiber is an important component in ruminant feed to ensure the normal function in rumen. Low fibre content in feed will improve the feed quality for ruminant, so the feed will be easily degraded in rumen. On the contrary, if the fibre contet in feed is high (exceed 36%DM of the TMR), then it will reduce the outflow of feed particle leaving the rumen, and will affect the digestion process of the feed (Carro et al., 2005). High fiber in feed will reduce feed intake, the total nutrition of the feed, and the digestibility (Bedford et al., 2023).

#### *The daily weight gain*

The average daily weight gain of Bali cattle treated in this study, and the income over feed cost for the farmers, are presented in table 3.

**Table 3. The average daily weight gain of Bali cattle and the income over feed cost**

Parameters	Treatments			
	T0	T1	T2	T3
Consumption (kg/h/d)	10.00±0.00 <sup>ab</sup>	9.99±0.01 <sup>ab</sup>	9.70±0.31 <sup>bc</sup>	9.02±0.34 <sup>c</sup>
FCR	0.49	1.54	0.84	0.46
DWG ( kg/h/d )	0.19±0.11 <sup>b</sup>	0.06±0.01 <sup>d</sup>	0.11±0.03 <sup>c</sup>	0.20±0.08 <sup>a</sup>
IOFC (IDR/h)	17.222.800,-	21.800.144,-	17.305.900,-	17.819.984,-

Source: Authors' own elaboration

Based on our results, the treatments significantly ( $P < 0.05$ ) affected feed consumption with the highest amount for T1, which might due to the presence of 70% Elephant grass, that the cattle has already used to it, and the mixture of by-product (30%). As reported by another study, that the factors that can affect feed consumption in Bali cattle include the feed provided, temperature and humidity, the cattle themselves, body weight, palatability, physiological status, and rumen capacity, the feed chemical structure, nutritional composition, taste, and texture (Munier, 2008), and the type of the feed component and the feed processing technique (Getachew et al., 2004). Another aspect that probably caused the variation in the feed consumption, is the protein and fiber content that has good tolerance to support rumen activity in degrading the feed. The feed becomes palatable, which in turn affects the weight gain of the cattle. This is in line with the opinion of Soufizadeh (Soufizadeh et al., 2018), who stated that the cattle weight gain is influenced by feed quality, and cattle type the better the feed quality, the more efficient the energy formation used, resulting in higher weight gain. The improvement in the quality and quantity of feed will greatly influence the rate of metabolism and the flow of nutrients in the livestock's body, enabling optimal utilization to promote growth and development. Livestock with high feed consumption and good digestion of nutrients will result in high weight gain (Hasan et al., 2022).

Utilizing by-products can lower the feed costs for farmers, improving profitability, reducing horticultural waste, and promoting circular economy principles (Harkness et al., 2021). However, if the by-product is not properly processed, the animal might experience nutrient deficiencies or excesses, digestion problem and lower palatability, thus affecting feed intake (Skwarek and Karwowska, 2023). Therefore, in this study we started with analyzing the type of the by-product that we were using, to prevent the toxic compound and the excess anti nutrition compound that might be consumed. Another treatment to the by-product that was conducted in this study was the process of drying and grinding, and the mixture with other feed source that call can affect nutrient content and digestibility.

This study covered the initial process of the selection of the feed source until the last process, which was the feed formulation prior to fed it to the experimental animals. When the experimental feed was on trial, the animals were monitored continuously in terms of the animal health, the consumption, feed conversion and the weight gain. This is crucial to prevent all those negative impacts that could have influenced the digestion process. This reflects the green farming in ruminant farm, and is potentially apply to the local farmers in the regency of Barru.

#### *The income over feed cost*

Based on our result, the average income over feed cost was: (T0) Rp. 17,222,800, (T1) Rp. 21,800,144, (T2) Rp. 17,305,900, (T3) Rp. 17,819,984. This refers to the amount of the feed consumption; the more feed consumed, the better the growth and weight gain, impacting the sale value of Bali cattle or generating profit. The profit from Bali cattle maintenance is related to the IOFC value, because the profit is the difference between income and expenditure (Bach, 2023). The IOFC in the T3 trial livestock was lower than in T1, although the average daily weight gain (PBBH) of the T3 trial livestock was significantly higher than the livestock in T1. This is due to the lower initial body weight of the livestock in T3 compared to the livestock in T1. The feed experimental treatment was based on horticultural by-product, which does not require high costs for procurement and processing, thus reducing operational costs. The treatment research results showed a significant difference in the value of income over feed cost, due to the low feed treatment capital, while the selling price of Bali cattle increased, because consumer demand rises during major holidays. Efficient feed usage can reduce feed costs.

The income over feed cost (IOFC) is the difference between the income from the sale of Bali cattle and the expenditure on feed consumption used during maintenance, related to the feed consumption of beef cattle (Buza et al., 2014b). A high value of the income over feed cost will increase the profit from Bali cattle farming. The profit generated from the difference between the income from the sale of each head of cattle, and the average feed consumption cost of each head.

This high value requires good feed efficiency to achieve a high IOFC value.

Perhaps if the acclimatization period is extended to 2 months, all experimental livestock will become more palatable with the new feed formulation, thereby increasing feed consumption and significantly improving FCR.

## Conclusions

The incorporation of horticultural by-products into cattle feed rations demonstrated a positive impact on feed quality, animal performance, and economic returns for farmers in Barru regency, South Sulawesi. It is suggested that the feed formulation is possible to be used from 30% mixed with 70% conventional *Pennisetum purpureum*, or 100% substituted conventional *Pennisetum purpureum*.

## Acknowledgments

We would like to express our gratitude to BRIN under the scheme of RIIM 3 (Year 1 series), with contract number 16/IV/KS/05/2023, for funding this research. Also, we would like to express our gratitude to the Agency for Animal Husbandry and Animal Health, Province of South Sulawesi, and the Agency for Agriculture and Food Security, Barru Regency, Province of South Sulawesi. Our appreciation also goes to the involved team from the Faculty of Animal Science, Hasanuddin University, Makassar.

## Conflict of Interest

We declare that there is no conflict of interest starting from the field research up to the writing process of this manuscript.

## References

- Alihmadi, M., Cao, Y., Sokhansanj, S. (2025). Drying rate of corn silage and the influence of drying temperature on the feedstock quality. *Journal of Sustainable Bioenergy Systems*, 15(3), 139 – 154. <https://doi.org/10.4236/jsbs.2025.153008>.
- AOAC. (1990). Official methods of analysis. Association Official Analytical Chemist.
- Azar, A. S., Rozi, A. F., Falih, A. A. & Reza, A. F. (2022). The use of banana stem as feed. *Jurnal Bakti Kita*, 3(1), 29 – 36. <https://doi.org/10.52166/baktikita.v3i1.3143>.
- Bach, A. (2023). Changes in milk production and estimated income over feed cost of group-housed dairy cows when moved between pens. *Journal of Dairy Science*, 106(6), 4108 – 4120. <https://doi.org/10.3168/JDS.2022-22875>.
- Bedford M. R., Svihus, B. & Cowieson, A. J. (2023). Dietary fibre effects and the interplay with exogenous carbohydrates in poultry nutrition. *Animal Nutrition*, 16, 231 – 240. <https://doi.org/10.1016/j.aninu.2023.09.007>.
- Buza, M. H., Holden, L. A., White, R. A. & Ishler, V. A. (2014a). Evaluating the effect of ration composition on income over feed cost and milk yield. *Journal of Dairy Science*, 97(5), 3073 – 3080. <https://doi.org/10.3168/JDS.2013-7622>.
- Buza, M. H., Holden, L. A., White, R. A. & Ishler, V. A. (2014b). Evaluating the effect of ration composition on income over feed cost and milk yield. *Journal of Dairy Science*, 97(5), 3073 – 3080. <https://doi.org/10.3168/JDS.2013-7622>.
- Carro, M. D., Ranilla, M. J., Martín, A. I. & Alcaide, E. M. (2005). Microbial fermentation of a high forage diet in sheep rumen, semi-continuous (Rusitec) and continuous culture systems. In: E. M. Alcaide, B. H. Salem, K. Biala, & P. Morand-Fehr (Eds.), *Sustainable grazing, nutritional utilization and quality of sheep and goat products*, 383 – 387. Available at: <http://om.ciheam.org/article.php?IDPDF=6600068>.
- Eisler, M. C., Lee, M. R. F., Tarlton, J. F., Martin, G. B., Beddington, J., Dungait, J. A. J., Greathead, H., Liu, J., Mathew, S., Miller, H., Misselbrook, T., Murray, P., Vinod, V. K., Van Saun, R. & Winter, M. (2014). Steps to sustainable livestock. *Nature* (London), 507, 32 – 34. <https://doi.org/10.1038/507032a>.
- Getachew, G., Robinson, P. H., DePeters, E. J. & Taylor, S. J. (2004). Relationships between chemical composition, dry matter degradation and in vitro gas production of several ruminant feeds. *Animal Feed Science and Technology*, 111, 57 – 71. [https://doi.org/10.1016/S0377-8401\(03\)00217-7](https://doi.org/10.1016/S0377-8401(03)00217-7).
- Hai, L. T., Tran, Q. B., Tra, V. T., Nguyen, T. P. T., Le, T. N., Schnitzer, H. & Braunegg, G. (2020). Integrated farming system producing zero emissions and sustainable livelihood for small-scale cattle farms: Case study in the Mekong Delta, Vietnam. *Environmental Pollution*, 265(Part B), 114853. <https://doi.org/10.1016/j.envpol.2020.114853>.
- Harkness, C., Areal, F. J., Semenov, M. A., Senapati, N., Shield, I. F. & Bishop, J. (2021). Stability of farm income: The role of agricultural diversity and agri-environment scheme payments. *Agricultural Systems*, 187, 103009. <https://doi.org/10.1016/J.AGSY.2020.103009>.
- Hasan, S., Nompo, S., Mujnisa, A., Rinduwati., Ardiasnyah, Widiastuti., Sema., Khaerani, P. I., & Syamsuddin, F. A. (2022). Complete feed of corn silage and its effect on male Bali cattle performance, feed consumption, and beef quality. *Livestock and Animal Research*, 22, 131 – 138. ISSN 2721 – 7086. <https://jurnal.uns.ac.id/lar/article/view/75681/46463>.
- Henry, A. G., Hutschenreuther, A., Paine, O. C. C., Leichter, J., Codron, D., Codron, J., Loudon, J., Adolph, S. & Sponheimer, M. (2019). Influences on plant nutritional variation and their potential effects on hominin diet selection. *Review of Palaeobotany and Palynology*, 261, 18 – 30. <https://doi.org/10.1016/J.REVPALBO.2018.11.001>.
- Johansen, K., Vestergaard, M., Spleth, P., Hein, L., Nielsen, H. M. & Kargo, M. (2024). Growth and feed efficiency of Nordic Red Dairy Cattle, Holstein, and their F1 crossbreeds when limiting feed energy concentration in prepubertal heifers. *Journal of Dairy Science*, 107(10), 7973 – 7982. <https://doi.org/10.3168/JDS.2024-24904>.
- Kunda, V., Malik, A. K. & Sinlae, M. (2017). The effect of pump-

- kin flour (*Cucurbita moschata*), moringa leave flour (*Moringa oleifera*) and coconut oil combination as the corn substitution, on the feed intake, daily weight gain and the feed conversion of Broiler. *Jurnal Nukleus Peternakan*, 4(1), 1 – 7. ISSN 2355-9942.
- Misbahuddin & Harjanti, S.** (2022). Barru Regency in Figures 2022. ISSN 2598-1811. <https://barrukab.bps.go.id/en/publication/2022/11/29/13e5f2a7cf9af7464b843e07/region-statistics-of-barru-regency-2022.html>.
- MLA Administration.** (2019). Understand livestock nutritional requirements. <https://Mbfp-Pastoral.Mla.Com.Au/Managing-Your-Feedbase/Understand-Livestock-Nutritional-Requirements/>.
- Munier, F. F.** (2008). The Daily Life Weight Gain of Fat Tail lamb Fed on Leguminous Feed Additive. *Seminar Nasional Teknologi Peternakan Dan Veteriner*. <http://kalteng.litbang.pertanian.go.id/ind/pdf/all-pdf/peternakan/fullteks/semnas/pro08-68.pdf>.
- Skwarek, P. & Karwowska, M.** (2023). Fruit and vegetable processing by-products as functional meat product ingredients - a chance to improve the nutritional value. *LWT*, 189, 115442. <https://doi.org/10.1016/J.LWT.2023.115442>.
- Soliva, C. R., Zeleke, A. B., Clément, C., Hess, H. D., Fievez, V. & Kreuzer, M.** (2008). In vitro screening of various tropical foliage, seeds, fruits and medicinal plants for low methane and high ammonia generating potentials in the rumen. *Animal Feed Science and Technology*, 147(1–3), 53 – 71. <https://doi.org/10.1016/j.anifeedsci.2007.09.009>.
- Soufizadeh, M., Pirmohammadi, R., Alijoo, Y. & Khalilvandi Behroozyar, H.** (2018). Indigestible neutral detergent fibers: Relationship between forage fragility and neutral detergent fibers digestibility in total mixed ration and some feedstuffs in dairy cattle. *Veterinary Research Forum: An International Quarterly Journal*, 9(1), 49 – 57. <https://www.ncbi.nlm.nih.gov/pubmed/29719664>.
- Van Soest, P. J.** (1993). Cell wall matrix interactions and degradation. In: *H. G. Jung, D. R. Buxton, R. D. Hatfield, & J. Ralph (Eds.), Forage cell wall structure and digestibility*, 377 – 396. American Society of Agronomy, Inc.
- Woli, P., Long, C. R., Tedeschi, L. O. & Rouquette, F. M.** (2023). Developing the herbage allowance-nutritive value- based pasture factor for estimating daily herbage intake of stocker cattle grazing Bermudagrass pasture. *Applied Animal Science*, 39(5), 264 – 272. <https://doi.org/10.15232/aas.2023-02407>.
- Wu, X., Zhang, B., Li, H., Zhao, M. & Wu, W.** (2024). The synergistic effects of rice bran rancidity and dephenolization on digestive properties of rice bran protein. *Food Chemistry*, 460, 140617. <https://doi.org/10.1016/J.FOODCHEM.2024.140617>.
- Xia, C., Aziz Ur Rahman, M., Yang, H., Shao, T., Qiu, Q., Su, H. & Cao, B.** (2018). Effect of increased dietary crude protein levels on production performance, nitrogen utilisation, blood metabolites and ruminal fermentation of Holstein bulls. *Asian-Australasian Journal of Animal Sciences*, 31(10), 1643 – 1653. <https://doi.org/10.5713/ajas.18.0125>.
- Zullaikah, S., Pramujati, B., Prasetyo, E. N., Wicaksono, S. T., Nikmah, H., Haryanto, Jannah, A., Wardhana, A. G. S., Prakoso, A., Mujiburrosyid, A., Maulana, A., Gianfranco, E., Ihsan, H., Widagda, I. C., Febrada, M. H., Wilhan Ariawan, M. E., Darajat, M. I., Majid Alifan, M., Rizky Sanjaya, M., Solehuddin, M. & Raja, R.** (2022). Technology of the concentrate production for beef cattle based on Indonesian National Standard on the basis of agricultural by-product. *Sewagati*, 6(5), 626 – 636. <https://doi.org/10.12962/j26139960.v6i5.398>.

Received: July, 29, 2024; Approved: December, 03, 2025; Published: February, 2026