The Utilization of Coconut Coir as Supplementary Feed for Beef Cattle Production

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Abstract

High feed price is a major problem in the production of beef cattle. Therefore, this study aims to determine coconut coir's technical and economic potential for beef cattle feed. This is an in vivo and in vitro study that involved 95 days trial period and 16 male Brahman crossbreed cattle weighing 134±12.1 kg. The coconut coir was fermented using buffalo rumen liquid and was termed fermented coconut coir (FCC). A randomized block design was used in this research, including four feed treatments, namely complete feed D1 using 15% FCC, D2 using 20% FCC, D3 using 25% FCC and D4 using 30% FCC. The parameters observed were technical performance (protein, dry and organic matter intake), ruminal fermentability, purine derivatives and economic performance. The data were analyzed using analysis of variance and Duncan's multiple range test for posthoc multiple comparisons. The results showed that the intake of beef cattle feed D1, D2 and D3 was higher than D4. Furthermore, the digestibility of D1, D2 and D4 was higher than D3. The purine derivatives of D2 were the highest but not significantly different (P > 0.05) from D1 and D4. In addition, the ruminal fermentability was not significantly different (P > 0.05) among treatments. Moreover, the beef cattle feed on D2 had the best economic performance. The performance results showed that ruminal fermentability, purine derivatives and economic performance of D2 (20% FCC) gave the best results but were not statistically different (P > 0.05) from other variables. Conclusively, coconut coir can be used as beef cattle feed without causing health problems.

Keywords: coconut coir; economic performance; purine derivatives; ruminal fermentability; technical performance

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INTRODUCTION

Coconut is a common multifunctional found in Indonesia found on the North Coast of Java, growing from Banten Province to Banyuwangi Regency. Furthermore, it is spread across many Asian countries and is widely used as food, drinks, biodiesel and even cosmetics (Ramesh et al., 2021). Coconuts' production worldwide covers more than 10 million hectares, distributed in 92 countries. Indonesia, India and the Philippines account for nearly 75% of its production worldwide. Indonesia has become the largest coconut producer in the globe. One of its available biomasses is coconut coir, which has a high calorific value in the form of lignin and cellulose and consists of charcoal, pyrolineous acid, tar, gas, potassium and tannin (Zafar, 2021). Generally, coconut coir has a great potential to be used as ruminant feed. Coconut coir is primarily used for direct combustion to generate heat; otherwise, it is just
Coconut coir is a natural fiber often used to manufacture household products; hence, it can be converted into animal feed with the suitable fermentation method that will reduce the cost in the livestock business (Shamim et al., 2016). However, an abundance of coconut coir has not been adequately utilized as feeding materials. This study aimed to determine the potential utilization of coconut coir in beef cattle production, such as technical performance, ruminal fermentability, purine derivatives and economic performance.

**MATERIALS AND METHOD**

**Experiment location**

This research was conducted at the Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, Semarang, Indonesia.

**Animal and treatments**

Sixteen male Brahman crossbred cows aged 8 to 10 months with a bodyweight of 134±12.1 kg were arranged in a randomized block design for 95 days. The study used four feed treatments and four replications, namely complete feed D1 using 15% Fermented Coconut Coir (FCC), D2 using 20% FCC, D3 using 25% FCC and D4 using 30% FCC.

**Feeding trial study**

The study involves 95 day treatments and the feeding trial was used to determine the FCC's potential for beef cattle production. The feed composition used is shown in Table 1. The coconut coir is fermented using buffalo rumen by cutting into 1 to 2 cm sizes to be homogeneous. The cultured microbes of buffalo rumen fluid had the highest enzyme activity inoculated in liquid media for 16 hours before being used as an inoculum in the coconut coir fermentation method. Then, fermentation was carried out by adding 0.1% urea, 3% molasses, distilled water (60% moisture content calculation based on dry coconut coir) and 5% inoculum. The coconut coir was stirred

The development of animal feed is indispensable because it influences the production and productivity of livestock. Utilizing agricultural, plantation and industrial waste is one of the efforts that increase productivity and reduce the price of animal feed. Coconut coir contains 3.13% protein (Kairupan et al., 2021) and can be used as a mixture of ruminant animal feed as a source of fiber (Muzaki et al., 2020). It is a natural fiber often used to manufacture household products; hence, it can be converted into animal feed with the suitable fermentation method that will reduce the cost in the livestock business (Shamim et al., 2016). However, an abundance of coconut coir has not been adequately utilized as feeding materials. This study aimed to determine the potential utilization of coconut coir in beef cattle production, such as technical performance, ruminal fermentability, purine derivatives and economic performance.

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evenly, placed in an airtight room and incubated for four weeks. Before being used as a complete feed, FCC was analyzed for proximate analysis (AOAC, 2012).

Table 1. Ingredients and chemical composition of complete feed containing FCC

| Materials                  | Dietary | %   |
|----------------------------|---------|-----|
|                            | D1      | D2  | D3  | D4  |
| Corn                       | 20.00   | 20.00 | 22.00 | 25.00 |
| Rice bran                  | 14.00   | 7.00  | 5.00  | 4.00  |
| Palm oil                   | 15.00   | 15.00 | 14.00 | 7.00  |
| Coconut oil                | 1.00    | 1.00  | 1.00  | 1.00  |
| Kapok seed meal            | 8.00    | 8.00  | 6.00  | 7.00  |
| Coconut meal               | 10.00   | 12.00 | 13.00 | 17.00 |
| Coffee husk               | 6.00    | 6.00  | 3.00  | 2.00  |
| CaCO₃                      | 0.20    | 0.20  | 0.10  | 0.20  |
| Salt                       | 0.20    | 0.20  | 0.10  | 0.10  |
| Molasses                   | 10      | 10    | 10    | 6     |
| Urea                       | 0.6     | 0.6   | 0.8   | 0.7   |
| FCC                        | 15.00   | 20.00 | 25.00 | 30.00 |

Content of nutrient (%)

| Gross energy (cal g⁻¹) | 3633.51 | 3634.92 | 3739.36 | 3683.83 |
| Dry matter             | 88.53   | 88.39   | 87.15   | 87.20   |
| Nitrogen-free extract matter | 43.19 | 46.39 | 42.09 | 44.75 |
| Crude protein          | 11.14   | 11.62   | 12.29   | 12.41   |
| Organic matter         | 91.37   | 90.85   | 90.10   | 92.72   |
| Crude fiber            | 32.53   | 28.85   | 31.21   | 30.41   |
| Ether extract          | 4.52    | 4.00    | 4.51    | 5.15    |
| Total digestible nutrient | 66.75 | 69.59 | 69.20 | 70.70 |

Source: (Hartadi et al., 1993).

**In vitro experiment**

Experiment 2 was aimed at evaluating the in vitro ration fermentability. The observed fermentability parameters of partial VFA (acetate, propionate, butyrate), acetate/propionate, hexose conversion efficiency and N-NH₃ were measured in vitro based on the method of (Tilley and Terry, 1963) with a modified incubation of 4 hours (Tillman et al., 1998). Furthermore, acetic, propionic and butyric acid concentrations were measured using a gas chromatography technique (AOAC, 2012). The formula used to calculate the VFA concentration of the sample is equation I.

The hexose utilization efficiency was calculated based on the stoichiometry of the carbohydrate fermentation reaction from hexose to VFA (acetate, propionate, butyrate) according to (Owens and Basalan, 2016). The formula used was equation II.

\[
VFA \text{ partial (mM)} = \frac{\text{Sample Area} \times \text{Standard Concentration}}{\text{Standard Area} \times \text{MW}}
\]  
\[
E \% = \left( \frac{0.622 \ pA + 1.091 \ pP + 1.558 \ pB}{pA + pP + pB} \right) \times 100
\]

Where; MW is the molecular weight of acetate, propionate and butyrate, respectively.

Where; pA = proportion of acetate; pP = proportion of propionate; pB = proportion of butyrate.
The measurement of N-NH₃ concentration was based on an endophenol reaction catalyzed to produce a consistent blue compound. Subsequently, the mixture stages of 1 ml of 10% sodium tungstate solution, 2 ml of rumen fluid and 1 ml of H₂SO₄ were centrifuged at 15,000 rpm for 10 minutes. Afterward, a 20 ml supernatant sample was taken and mixed with 2.5 ml phenol and hypochlorite solution. Incubation was carried out for 30 minutes in a water bath at a temperature of 40°C until a blue color was formed. Finally, the cold mixture was read using a spectrophotometer with a wavelength of 630 nm (Cui et al., 2018).

**Parameters measured**

The observed parameters include technical performance (dry matter intake, organic matter intake, crude protein intake), ruminal fermentability, purine derivatives and economic performance. In addition, the data collected included: NH₃ concentration and total rumen VFA concentration in vitro. The determination of NH₃ and VFA concentrations was based on (Satter and Slyter, 1974).

**Sample analysis**

Feed intake, digestibility and economic performances were calculated using the formula of Dolewikou et al. (2016), Santoso et al. (2016), and Tayengwa et al. (2020). The entire analysis was used to prove that FCC is safe to be used for beef cattle production.

**Data analysis**

Data were subjected to a one-way analysis of variance using SPSS Version 24. Means were separated with Duncan’s multiple range test (DMRT) (Santoso et al., 2017).

**RESULTS AND DISCUSSION**

The results of feed intake, nutrient digestibility and rumen fermentability in beef cattle feed on FCC are shown in Tables 2, 3 and 4, respectively. As shown in Table 2, dry matter intake containing FCC showed significantly different (P < 0.05) results between treatments. Dry and organic matter and crude protein intake in beef cattle feed D1, D2 and D4 diets were higher than D3. These results indicate that the beef cattle consume the same amount of dry and organic matter and protein intake when fed a complete feed containing 15%, 20% and 30% FCC. This result is consistent with the report of Xue et al. (2020) that the utilization of natural waste is only around 20% in feed.

Tables 2 and 3 show that the differences in FCC levels on the D1, D2 and D4 rations has no significant effect on the consumption and digestibility of treated cattle rations. However, they were significantly different from the D3 rations. This is due to the higher digestibility possessed by D1, D2 and D4 than the D3 rations, resulting in the digestive tract emptying rate, thereby increasing consumption. The ruminal characteristics value of NH₃ and VFA concentrations were not statistically different and they provide precursors for microbial protein synthesis in the rumen, as shown in Table 4. Furthermore, rumen microbes require nitrogen in the form of NH₃ or oligopeptides for bacteria, peptides for protozoa, carbon framework branch chain, isobutyrate and isovalerate and ATP as an energy source in protein synthesis (Kondo et al., 2014). The products of rumen fermentation in branched-chain fatty acids (isobutyrate and isovalerate) are produced from the degradation of feed protein (Gilliam, 2016; Alnouss et al., 2020). According to Cui et al. (2018), the NH₃ concentration of rumen fluid varies from 1 to 34 mg 100 ml⁻¹ of rumen fluid. The maximum rate of microbial protein synthesis is achieved when NH₃ concentration ranges from 3.0 to 8.0 mg 100 ml⁻¹ of rumen fluid (Alnouss et al., 2020).

According to Alnouss et al. (2020), the concentration of VFA in the rumen varies from 0.2 to 1.5 g 100 ml⁻¹ or 10 to 70 mmol l⁻¹. This condition is determined from the excretion of purine derivatives, which also significantly affected the ratio treatment. This demonstrates the large number of microbes that have undergone a proliferation process and can degrade nutrient rations. Consequently, the greater the number of purine derivatives excreted in the urine, the greater the microbial protein synthesis.

According to Orskov (1982), allantoin is the result of nucleic acid metabolism in rumen microbes used to measure microbial protein production. Singh et al. (2007) reported that the total concentration of purine derivatives is related to organic matter’s digestibility. This is because the digestible organic matter in the rumen is a source of energy for rumen microbes. Furthermore, a higher digestibility of organic matter resulted in a higher rumen
microbial biomass. Liang et al. (1994) stated that allantoin is the main purine catabolism in microbial nucleic acids, which is used as an indicator of microbial digestion in ruminants and contributes to the excretion of endogenous purine derivatives and enzymes involved in purine metabolism. The difference in the excretion of purine derivative in urine is influenced by the contribution of allantoin and uric acid, in which allantoin is the highest concentration in purine catabolism (Liang et al., 1994), the contribution of excretion of endogenous purine derivatives and the types of enzymes involved in the process.

Table 2. Nutrient intake of beef cattle fed on complete feed containing consumption of metabolizable body weight (Intake of metabolizable body weight (MBW))

| No. | Items                        | Dietary                  |
|-----|------------------------------|--------------------------|
| 1   | Dry matter intake (%)        | 136.09<sup>a</sup>      | 132.17<sup>a</sup>      | 102.01<sup>b</sup>      | 111.69<sup>a</sup>      |
| 2   | Organic matter intake (%)    | 124.34<sup>a</sup>      | 120.08<sup>a</sup>      | 91.90<sup>b</sup>       | 103.55<sup>a</sup>      |
| 3   | Crude protein intake (%)     | 15.16<sup>a</sup>       | 15.36<sup>a</sup>       | 12.54<sup>b</sup>       | 13.86<sup>a</sup>       |

Note: Different superscripts on the same line indicate significant differences (P < 0.05)

Table 3. Nutrients digestibility in beef cattle fed on complete feed containing FCC

| No. | Items                        | Dietary                  |
|-----|------------------------------|--------------------------|
| 1   | Dry matter digestibility (%) | 66.75±1.75<sup>a</sup>   | 68.20±0.74<sup>a</sup>   | 50.72±4.07<sup>b</sup>   | 64.80±2.5<sup>a</sup>   |
| 2   | Organic matter digestibility (%) | 71.45±1.62<sup>a</sup>  | 72.42±0.70<sup>a</sup>   | 52.25±3.83<sup>b</sup>   | 68.60±2.3<sup>a</sup>   |
| 3   | Crude protein digestibility (%) | 71.77±3.23<sup>a</sup>  | 73.80±1.44<sup>a</sup>   | 67.75±4.56<sup>b</sup>   | 75.26±3.3<sup>a</sup>   |

Note: Different superscripts on the same line indicate significant differences (P < 0.05)

Table 4. Fermentability of coconut coir in beef cattle fed FCC

| No. | Items                        | Dietary                  |
|-----|------------------------------|--------------------------|
| 1   | NH<sub>3</sub> (mg 100 ml<sup>-1</sup>) | 24.50±1.141             | 26.18±1.47              | 26.34±1.40              | 25.30±0.45              |
| 2   | VFA (mM)                     | 46.39±9.68               | 42.52±8.02              | 42.72±5.86              | 36.76±4.84              |
| 3   | C2 (mM)                      | 27.05±6.40               | 21.76±5.01              | 23.06±3.76              | 19.93±2.97              |
| 4   | C3 (mM)                      | 8.78±1.91                | 7.5±1.68                | 9.1±2.42                | 7.3±1.05                |
| 5   | C4 (mM)                      | 10.55±1.82               | 8.34±1.93               | 10.1±1.38               | 9.45±0.96               |
| 6   | CH4 (mM)                     | 16.61±3.68               | 13.15±2.96              | 14.48±2.17              | 17.85±1.64              |
| 7   | Purine derivatives           | 31.208<sup>a</sup>      | 35.075<sup>a</sup>      | 21.253<sup>b</sup>      | 24.943<sup>ab</sup>    |
| 8   | EMNS (g N day<sup>-1</sup>)  | 21.392<sup>a</sup>      | 23.449<sup>a</sup>      | 13.436<sup>b</sup>      | 15.910<sup>a</sup>      |
| 9   | EMNR (g N BOTR<sup>-1</sup>) | 8.372<sup>a</sup>       | 8.574<sup>a</sup>       | 5.343<sup>b</sup>       | 5.874<sup>b</sup>       |

Note: Different superscripts on the same line indicate significant differences (P < 0.05); EMNS = Efficiency of Microbial N Supply; EMNR = Estimation of Microbial N fermented in the Rumen

As shown in Table 3, there are statistical differences between treatments in dry and organic matter and crude protein digestibility. The results showed that the digestibility of beef cattle fed D1, D2 and D4 was greater than D3. This is consistent with the reports of De Souza et al. (2017) that the optimal use of fiber sources at 20% level results in optimal digestibility levels (dry matter and crude protein). As shown in Table 4, NH<sub>3</sub> concentration, VFA production, C2 production, C3 production, C4 production and CH4 production has no significant difference (P > 0.05). This is consistent with the reports of Kumar et al. (2016) that the fermentation of beef cattle fed with fiber sources was not significantly different between treatments in NH<sub>3</sub>, VFA, C<sub>2</sub>, C<sub>3</sub>, C<sub>4</sub> and CH<sub>4</sub>.
The total VFA concentration is below the optimum range for microbial growth and the rumen system, which accounted for 60 to 120 mM (Alnouss et al., 2020). This low VFA concentration can be influenced by the amount of non-structural and structural carbohydrates arranged in a complete feed. Furthermore, the ingredients of non-fiber carbohydrate (NFC) and neutral detergent fiber (NDF) were used in the complete feed formulation. The total VFA concentration is positively correlated with NFC and NDF. Kondo et al. (2014) reported that the NFC fraction is an important element in supporting adenosine triphosphate (ATP) formation in the rumen to form microbial proteins. Rahayu et al. (2019) reported a complete feed based on ammonia rice straw with 12% crude protein, 60% total digestible nutrient, 18% NFC and 68.71% NDF, resulting in a total VFA of 58.33 mM. Mbiriri et al. (2012) reported that complete feed treatment of concentrate and rice straw 60:40% with 13% CP resulted in a total VFA of 51.65 mM. Nuswantara et al. (2020) reported that the high fiber component in the feed could inhibit the digestibility of other fractions in the feed. This is because the energy needed to digest cellulose, hemicellulose and lignin is large enough to lower the VFA.

According to Kondo et al. (2014) and Cui et al. (2018), NDF content negatively correlates with the formation of VFA in the rumen and the digestibility of organic feed matter. The fermentability of feed ingredients influences the production of level VFA, the number of soluble carbohydrates, rumen pH, digestibility of nutrients, the number and types of bacteria present in the rumen. Miguel et al. (2021) reported complete fermented feed treatment with 41.35% NDF content during 6 and 24 hours incubation, resulting in 67.33 mM and 96.04 mM concentrations. As shown in Figure 1, the efficiency of hexose utilization showed is not much different. These results are in line with Amaryanti et al. (2015) that found the efficiency of hexose utilization insignificantly different in using the combination of soybean meal and hibiscus leaves in goat feed.

As shown in Table 4, microbial protein production showed significant differences between the four treatments. Treatments D1, D2 and D4 were not significantly different but higher than the D3 feed. These results are consistent with the reports of Amaryanti et al. (2015) that microbial protein production was not significantly different (P > 0.05) in the use of a combination of soybean meal and Hibiscus tiliaceus leaves in goat feed. Subsequently, FCC and Hibiscus tiliaceus leaves have the same nutrient contents.

As shown in Table 4, the purine derivatives were not significantly different among the four treatments. Ariyani et al. (2016) found that purine derivatives were not significantly different (P > 0.05) when using bagasse as basal feed. Purine derivatives reflect that the use of FCC does not interfere with the digestive system in cattle.
As shown in Table 5, the feed price decreased when coconut coir in the feed increased, but 20% FCC (D2) in the feed resulted in the highest income over feed cost (IOFC). Furthermore, the utilization of coconut coir waste reduces feed costs and increase income (IOFC). This result is consistent with the reports of Xue et al. (2020) and Santoso et al. (2017) that the use of agricultural waste could increase income.

Table 5. Economic analysis of beef cattle fed FCC

| No | Items                          | Dietary |
|----|--------------------------------|---------|
| 1  | Feed price (IDR kg⁻¹)          | D1 2,500 D2 2,415 D3 2,375 D4 2,280 |
| 2  | Income over feed cost (IDR kg⁻¹) | D1 2,300 D2 2,750 D3 1,050 D4 1,520 |

**CONCLUSIONS**

Based on the research results, coconut coir can be used as a beef cattle feed supplement without harming the health and growth of beef cattle. The abundance of coconut coir production will potentially reduce production costs.

**REFERENCES**

Alnouss, A., Parthasarathy, P., Shahbaz, M., Al-Ansari, T., MacKey, H., & McKay, G. (2020). Techno-economic and sensitivity analysis of coconut coir pith-biomass gasification using ASPEN PLUS. *Applied Energy*, 261, 114350. https://doi.org/10.1016/j.apenergy.2019.114350

Amaryanti, A. K., Naswantara, L. K., & Achmadi, J. (2015). Combination of soybean meal and hibiscus tiliaceus leaf in the goat diet, effect of some parameters of carbohydrates metabolism. *Journal Indonesian Tropical Animal Agriculture*, 40(3), 153–158. https://doi.org/10.14710/jitaa.40.3.153-158

AOAC. (2012). Official methods of analysis of the association of official analytical chemists. *Association of Official Analytical Chemist*. Retrieved from https://scholar.google.co.id/scholar?cites=17848862564178015747&as_sdt=2005&scidt=0,5&hl=en

Ariyani, S. A., Naswantara, L. K., Pangestu, E., Wahyono, F., & Akhmad, J. (2016). Parameters of protein metabolism in goats fed diets with different portion of sugarcane bagasse. *Journal Indonesian Tropical Animal Agriculture*, 39(2), 111–116. https://doi.org/10.14710/jitaa.39.2.111-116

Asadu, C. O., Anthony, E. C., Elijah, O. C., Ike, I. S., Onoghrarite, O. E., & Okwudili, U. E. (2021). Development of an adsorbent for the remediation of crude oil polluted water using stearic acid grafted coconut husk (*Cocos nucifera*) composite. *Applied Surface Science*, 6, 100179. http://dx.doi.org/10.1016/j.apsusc.2020.100179

Bello, O. S., Moshooda, M. A., Ewetumoa, B. A., & Afolabi, I. C. (2020). Ibuprofen removal using coconut husk activated Biomass. *Chemical Data Collections*, 29, 100533. https://doi.org/10.1016/j.cdc.2020.100533

Cui, X., Tang, C., & Zhang, Q. (2018). A Review of Electrocatalytic Reduction of Dinitrogen to Ammonia under Ambient Conditions. *Advance Energy Materials*, 8(22), 1800369. https://doi.org/10.1002/aenm.201800369

Dolewikou, R. L., Sumekar, W., & Setiadi, A. (2016). The profitability analysis of dairy cattle business on the group of dairy farmers in West Ungaran District, Semarang Regency. *Journal Indonesian Tropical Animal Agriculture*, 41(4), 216–223. https://doi.org/10.14710/jitaa.41.4.216-223

Gilliam, F. S. (2016). Forest ecosystems of temperate climatic regions: from ancient use to climate change. *New Phytologist*, 212(4), 871–887. https://doi.org/10.1111/nph.14255

Hartadi, H., Reksohadiprodjo, S., & Tillman, A. D. (1993). *Tabel komposisi pakan untuk Indonesia*. Gadjah Mada University Press. Retrieved from https://scholar.google.co.id/scholar?cites=1296503871049274243&as_sdt=2005&scidt=0,5&hl=id

Kairupan, A. N., Silondae, H., Salamba, H. N., & Mubarak, H. (2021). Support for animal feed innovation technology in the North Sulawesi border area. *IOP Conference Series: Earth
and Environmental Science, 807, 032050. http://dx.doi.org/10.1088/1755-1315/807/3/032050

Kondo, M., Hirano Y., Ikai, N., Kita, K., Jayanegara, A., & Yokota, H. (2014). Assessment of anti-nutritive activity of tannins in tea by-products based on in vitro ruminal fermentation. Anim Biosci., 27 (11), 1571–1576. https://doi.org/10.5713/ajas.2014.14204

Kumar, A., Gautam, A., & Dutt, D. (2016). Biotechnological transformation of lignocellulotic biomass in to industrial products: An overview. Advances in Bioscience and Biotechnology, 7(3), 149–168. http://dx.doi.org/10.4236/abb.2016.73014

Liang, J. B., Matsumoto, M., & Young, B. A. (1994). Purine derivate excretion and ruminal microbial yield in Malaysian cattle and buffalio. Animal Feed Science and Technology, 47, 189–199. https://doi.org/10.1016/0377-8401(94)90123-6

Mariyono, J., Kuntariningih, A., Suswati E., & Kompas, T. (2018). Quantity and monetary value of agrochemical pollution from intensive farming in Indonesia. Management of Environmental Quality, 29(4), 759–779. https://doi.org/10.1108/MEQ-03-2017-0030

Mariyono, J. (2015). Green revolution and wetland-linked technological change of rice agriculture in Indonesia. Management of Environmental Quality, 26(5), 683–700. https://doi.org/10.1108/MEQ-07-2014-0104

Mbiriri, D., Oh, S. J., & Choi, N.-J. (2012). Effect of different silages for TMR on in vitro rumen simulative fermentation. Journal of the Korean Society of Grassland and Forage Science, 32(4), 379–386. http://dx.doi.org/10.5333/KGFS.2012.32.4.379

Miguel, M., Manuad, L., Ramos, S., Ku, M. J., Jeong, C. D., Kim, S. H., Cho, Y. I., & Lee, S. S. (2021). Effects of using different roughages in the total mixed ration inoculated with or without coculture of Lactobacillus acidophilus and Bacillus subtilis on in vitro rumen fermentation and microbial population. Animal Bioscience, 34(4), 642–651. http://dx.doi.org/10.5713/ajas.20.0386

Muzaki, M. D. R., Sunarso, & Agus, S. (2020). Analisis potensi sabut kelapa serta strategi penggunaannya sebagai bahan baku pakan ternak ruminansia. Livestock and Animal Research, 18(3), 274–288. https://doi.org/10.20961/lar.v18i3.46001

Nuswantara, L. K., Sunarso, M. A, & Setiadi, A. (2020). Komponen serat sabut kelapa yang difermentasi menggunakan mikroba pencerna serat dari rumen kerbau. Jurnal Agripet, 20(1), 1–8. https://doi.org/10.17969/agripet.v20i1.15545

Orskov, E. R. (1982). Protein nutrition in ruminant. Academic Press. Retrieved from https://scholar.google.com/scholar?cluster=3983992450355219735&hl=id&as_sdt=2005&scidt=0,5

Owens F. N., & Basalan, M. (2016). Ruminal fermentation. in: millen D., De Beni Arrigoni M., Lauritano Pacheco R. (eds) Rumenology. Springer, Cham. https://doi.org/10.1007/978-3-319-30533-2_3

Rahayu, A. G., Utama, P. S., Nurulita, Y., Miranti, M., & Nugraha, T. T. (2019). Surfactant, nitrogen and carbon media optimization for Trichoderma asperellum LBKURCC1 laccase production by flask solid state fermentation of rice straw. Journal of Physics: Conference Series, 1351, 012030. https://doi.org/10.1088/1742-6596/1351/1/012030

Ramesh, S.V., Krishnan,V., Praveen S., & Hebbar, K. B. (2021). Dietary prospects of coconut oil for the prevention and treatment of alzheimer’s disease (AD): A review of recent evidences. Trends in Food Science and Technology, 112, 201–211. https://doi.org/10.1016/j.tifs.2021.03.046

Santoso, S. I., Suprijatna, E., Setiadi, A., & Susanti, S. (2016). Effect of duck diet supplemented with fermented seaweed wastes on carcass characteristics and production efficiency of indigenous Indonesian ducks. Indian Journal of Animal Research, 50(5), 699–704. http://dx.doi.org/10.18805/ijar.11160

Santoso, S. I., Susanti, S., & Setiadi, A. (2017). Economic analysis of male broiler chickens fed diets supplemented with Salvinia molesta. International Journal of Poultry Science, 16(6), 233–237. https://dx.doi.org/10.3923/ijps.2017.233.237
Satter, L. D., & Slyter, L. (1974). Effect of ammonia concentration on rumen microbial protein production in vitro. *British Journal of Nutrition, 32*(2), 199-208. https://doi.org/10.1079/bjn19740073

Shamim, M., Hussain, M. S., & Mahin, A. A. (2016). Solid-state fermentation of coconut coir by pleurotus sajor-caju increases the anti-oxidant properties and nutritional value. *Biotechnology, 15*(6), 141–147. http://dx.doi.org/10.3923/biotech.2016.141.147

Singh, M., Sharma, K., Dutta, N., Singh, P., Verma, A., & Mehra, U. (2007). Estimation of rumen microbial protein supply using urinary purine derivatives excretion in crossbred calves fed at different levels of feed intake. *Ruminant Nutrition and Forage Utilization, 20*(10), 1567–1574. https://doi.org/10.5713/ajas.2007.1567

Tayengwa, T., Chikwanha, O. C., Dugan, M. E. R., Mutsvangwac, T., & Mapiye, C. (2020). Influence of feeding fruit by-products as alternative dietary fibre sources to wheat bran on beef production and quality of angus steers. *Meat Science, 161*, 107969. https://doi.org/10.1016/j.meatsci.2019.107969

Tilley, J. M. A., & Terry, R. A. (1963). A two-stage technique for the in vitro digestion of forage crops. *Grass and Forage Science, 18*(2), 104–111. http://dx.doi.org/10.1111/j.1365-2494.1963.tb00335.x

Tillman A. D., Hartadi, H., Reksohadiprojo, S., Prawirokusumo, S., & Lebdosoekojo, S. (1998). *Ilmu makanan ternak dasar*. Cetakan ke-6. Gadjah Mada University Press. Retrieved from https://scholar.google.com/scholar?cluster=15497549145472889805&hl=id&as_sdt=2005&sciodt=0,5

Uwineza, C., Sar, T., Mahboubi, A., & Taherzadeh, M. J. (2021). Evaluation of the cultivation of *Aspergillus oryzae* on organic waste-derived vfa effluents and its potential application as alternative sustainable nutrient source for animal feed. *Sustainability, 13*(22), 12489. https://doi.org/10.3390/su132 212489

Verma, R., Maji, P. K., & Sarkar, S. (2021). Comprehensive investigation of the mechanism for Cr(VI) removal from contaminated water using coconut husk as a biosorbent. *Journal of Cleaner Production, 314*, 128117. https://doi.org/10.1016/j.jclepro.2021.128117

Wijaya, A. F., Kuntariningsih,A., Sarwono, S., & Suryono, A. (2021a). Malnutrition mitigation and community empowerment through the sustainable food reserve programme in Indonesia. *Development in Practice, 31*(1), 37–48. https://doi.org/10.1080/09614524.2020.1782845

Wijaya, A. F., Kuntariningsih, A., Sarwono, S., & Suryono, A. (2021b). Role and contribution of vegetables in mitigating malnutrition through a sustainable food reserve program. *International Journal of Vegetable Science, 27*(1), 65–75. https://doi.org/10.1080/19315260.2019.1703872

Xue, Z., Mu, L., Cai, M., Zhang, Y., Wanapat, M., & Huang, B. (2020). Effect of using banana by-products and other agricultural residues for beef cattle in Southern China. *Tropical Animal Health and Production, 52*, 489–496. https://doi.org/10.1007/s11250-019-02031-9

Zafar, S. (2021). Coconut husk: Energy potential of coconut biomass. *BioEnergy Consult*. Retrieved from https://www.bioenergyconsult.com/coconut-biomass/