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Research Article

Improving Feed Quality Through the Addition of Mangrove Fruit (*Sonneratia alba*) on Indigofera (*Indigofera zollingeriana*)

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ABSTRACT

This study investigated the effects of incorporating tannin-rich mangrove fruit (*Sonneratia alba*) into *Indigofera zollingeriana*-based rations on in vitro digestibility and rumen fermentation characteristics. Using a completely randomized design with four treatments (0%, 3%, 6%, and 9% *S. alba*) and four replicates, we evaluated dry matter digestibility (DMD), organic matter digestibility (OMD), crude protein digestibility (CPD), crude fiber digestibility (CFD), crude fat digestibility, nitrogen-free extract (NFE), rumen pH, volatile fatty acids (VFA), and ammonia (NH_3) concentrations. Results revealed that moderate tannin inclusion (6%) improved CPD and nutrient protection without significantly impairing DMD or OMD. However, higher inclusion (9%) significantly reduced CFD, crude fat digestibility, NFE, VFA, and NH_3 concentrations ($P<0.05$ or $P<0.01$), indicating suppressed microbial activity. These findings suggest that while *S. alba* tannins can effectively reduce ruminal protein degradation and modulate fermentation, excessive inclusion negatively impacts overall feed digestibility. The optimal inclusion rate was identified at 6%, balancing protein protection and fermentation efficiency. This study supports the strategic use of plant-based tannins as a feed additive to enhance protein utilization and reduce nitrogen losses in ruminant diets.

Keywords: digestibility, *Indigofera zollingeriana*, rumen fermentation, *Sonneratia alba*, tannins

INTRODUCTION

Feed is essential in supporting the growth and development of livestock, where forage is generally obtained through the cultivation of grass and leguminous plants. Good feed quality is closely related to the quality of livestock produced. About 60-80% of the total cost of cattle is used to meet feed needs, so it is important to improve feed use efficiency, especially in terms of protein utilization in the rumen. Digestive inefficiency in the rumen can reduce livestock productivity while using cheap and quality protein source feed can increase production efficiency and reduce negative environmental impacts (Nascimento et al., 2021).

Leguminous plants have better nutrient content than grasses and can provide stable feedstuffs in the long term, especially during the dry season. One type of legume that contains high protein is *Indigofera zollingeriana*, which has a tolerance to drought and waterlogging and is resistant to various environmental conditions (Hassen et al., 2008). *Indigofera zollingeriana* has a

high crude protein (CP) and energy content, making it a potentially valuable feed for ruminants (Simanuhuruk & Sirait, 2009). This plant contains 26-31% protein, with a protein digestibility of 83-86%; fiber fraction includes ADF at 32-38% and NDF at 49-57%, and it has a high dry matter digestibility of 72-81%, this makes it a promising potential protein source for feed, as its high protein content can enhance the activity of rumen microorganisms (Abdullah, 2010; Abdullah, 2014). Although the crude protein is high, the level of tannins in *Indigofera zollingeriana* is relatively low; thus, livestock digestion will not be disturbed. This is based on the statement of Herdiawan et al. (2014), which states that the tannin content contained in *Indigofera zollingeriana* ranges from 0.16 - 0.22%.

The results of research conducted by Permana et al. (2020) show that as an alternative to concentrate feed, *Indigofera zollingeriana* can maintain the value of total protein in feed in the normal range of up to 15%. The high protein of *Indigofera zollingeriana* also has a high level of degradation in the rumen, or RDP (rumen degradable protein), which is also called a protein that can be degraded in the high rumen. According to Pazla et al. (2023), *Indigofera zollingeriana* has a high degradation rate of over 60%. Rumen microbes need nitrogen obtained from proteins degraded in the rumen. In contrast, ruminants that act as hosts need amino acids from food by-pass proteins and microbial proteins digested into the post-rumen. Increasing *Indigofera zollingeriana* by-pass protein through binding with tannins is necessary to balance these high protein requirements. One source of high tannin is mangrove fruit (*Sonneratia alba*).

Mangrove plants (*Sonneratia alba*) consist of fruit, leaves, stems, and roots, starting from the wood used as a building material, and some people use it as firewood. In contrast, the leaves are used as animal feed (Elihasridas et al., 2023). The abundance of *Sonneratia alba* is high compared to other types of mangroves because it has good adaptability, so it is called a pioneer mangrove that contains many seeds and the ability to grow in new habitats in a short time per year (Primavera & Esteban, 2008). In addition to containing complete nutrition, mangrove plants are also a source of carbohydrates and calories so that they can be used as energy source concentrate feed (Elihasridas et al., 2024). The nutrient content of mangrove fruit is 9.63% moisture content, 5.39% ash content, 8.34% protein, 1.54% fat, and 75.1% carbohydrates (Ardiansyah et al., 2020) and the tannin content in mangrove fruit is 21.2%, so it can be concluded that the tannin content of mangrove fruit is high and can be utilized as a source of tannin (Elihasridas et al., 2023; 2025).

Tannins are polyphenolic compounds found in many plants, which act as antinutrients and can negatively affect livestock nutrition (Popova & Mihaylova, 2019; Verma et al., 2021). Tannins are known to form complexes with proteins, carbohydrates, and lipids, which have an impact on reducing nutrient digestibility, especially if the concentration is too high (Makkar, 2003). According to FAO (2005), tannin levels above 4% can inhibit the growth of ruminants and even cause death. Providing tannins in low concentrations can support rumen microbial activity in degrading feed components. In contrast, providing tannins in high concentrations can reduce ration consumption due to their astringent taste, reduce digestibility, and have a toxic effect on rumen microbes because it can inhibit enzyme activity (Elihasridas et al., 2023).

The protein content of the feed is generally partly used for microbial protein synthesis; with the increase in the number of microbes in the rumen, the digestibility of crude fiber, fat, and energy will be higher. However, the use of tannins to protect protein in feed ingredients is thought to reduce the digestibility of crude fiber, fat, and energy to a certain level due to the reduced supply of nitrogen for microbial synthesis, and in tannins, there are phenol compounds that can kill bacteria in the rumen. The inhibited growth of microorganisms will result in changes in the

microbial population in the rumen (Mushawwir et al., 2010). Changes in rumen microbial population and structure impact the ability of microbes to degrade feed nutrients in the rumen.

Regarding non-fiber carbohydrates or NFE, tannins can inhibit microbial activity that ferments simple sugars and starch, reducing metabolic energy production from NFE (Jamarun et al., 2020). Although tannins at specific concentrations can provide benefits, such as increasing protein utilization efficiency by reducing excess degradation in the rumen, a concentration that is too high can reduce the overall digestibility of the feed. This excessive binding of protein over time will result in the growth of microorganisms in the rumen being inhibited (Cipriano-Salazar et al., 2018). This follows the statement of Jamarun et al. (2020) that tannin levels of more than 3% can cause a decrease in digestibility and feed consumption, while levels of 1%-2% are considered optimal for protecting feed protein from rumen degradation. Previous studies have reported that high concentrations of tannins can inhibit the fermentation of crude fiber, crude fat, and Nitrogen extract and reduce the availability of NH_3 in the rumen (Min et al., 2003).

In rumen fermentation, tannins also affect ammonia (NH_3) production, the primary nitrogen source for rumen microbes. A decrease in NH_3 can impact the activity of rumen microbes involved in crude fiber degradation, resulting in decreased digestibility (Patra & Saxena, 2011). In addition, tannins can also affect lipid metabolism in the rumen. The interaction of tannins with microbes that hydrolyze lipids can lead to a decrease in crude fat digestibility. This effect is further exacerbated by the ability of tannins to interact directly with lipids, which reduces the accessibility of fat for digestion (Frutos et al., 2004).

Tannins contained in mangrove fruit can inhibit rumen microbial activity that reduces RDP and can also reduce the production of NH_3 and VFA, which indicates impaired carbohydrate fermentation; decreased VFA will affect the energy available to ruminants and increase rumen pH caused by decreased VFA production in the rumen, with decreased NH_3 levels which are a source of nitrogen for microbes, to reduce rumen microbial protein in the rumen fluid. Adding tannins to feed can reduce the number of protozoa and bacteria that produce methane gas (Pazla et al., 2024a; Pazla et al., 2025). Ciliated protozoa in the rumen can feed on amylolytic bacteria to fulfill their protein needs, thus reducing the number of amylolytic bacteria and amino acid supply. A decrease in the protozoan population impacts amylolytic and cellulolytic bacteria in the rumen because the more reduced the protozoa, the more the bacterial population will increase (Kim et al., 2015). Therefore, this study aims to explore the potential use of *Sonneratia alba* fruit as a source of tannins in *Indigofera zollingeriana*, as well as its impact on proximate digestibility, fiber fraction digestibility, and rumen fluid characteristics in vitro.

MATERIALS AND METHODS

This study uses materials including Indigofera (*Indigofera zollingeriana*), mangrove fruit (*Sonneratia alba*), and *McDougall's* solution and laboratory analysis materials. The tools used in this study are fermentor tubes, shaker water bath, magnetic stirrer, pH meter, thermometer, thermos, CO_2 tube, filter, syringe, digital scales, vacuum pump, becker glass, oven, desiccator, drop pipette, gauze, centrifuge and a set of laboratory equipment for measuring digestibility in vitro and analyzing rumen fluid characteristics.

Research Design

The method used in this research is a Completely Randomized Design with four treatments and four replicates. Table 1 shows the nutritional value of Indigofera (*Indigofera zollingeriana*)

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and mangrove fruit (*Sonneratia alba*). Table 2 shows the nutrient content of the treatments.

Table 1. Chemical composition of Indigofera (*Indigofera zollingeriana*) and Mangrove Fruit (*Sonneratia alba*)

Nutrient Content (%)	*Indigofera zollingeriana*	*Sonneratia alba*
Dry Matter	91.08	51.8
Organic Matter	94.27	94.6
Crude Protein	29.19	3.56
Crude Fat	4.46	1.00
Crude Fiber	9.25	16.8
NFE	51.37	73.21
Ash	5.73	5.43
TDN	68.73	63.0
NDF	44.87	62.2
ADF	26.90	54.0
Cellulose	18.35	22.6
Hemicellulosa	17.97	8.18
Lignin	10.91	23.5
Silika	7.44	7.85
Tanin	0.22	21.2

Table 2. Chemical composition of treatment

Nutrient content (%)	Treatment			
	P1	P2	P3	P4
Dry Matter	91.08	92.63	94.19	95.74
Organic Matter	94.27	94.28	94.29	94.30
Crude Protein	29.19	28.44	27.74	27.07
Crude Fat	4.46	4.36	4.26	4.17
Crude Fiber	9.25	9.47	9.68	9.87
NFE	51.37	52.01	52.61	53.17
Ash	5.73	5.72	5.71	5.70
TDN	68.73	65.78	63.38	58.03
NDF	44.87	35.53	35.44	35.43
ADF	26.90	21.67	21.98	22.29
Cellulose	18.35	14.45	14.37	14.31
Hemicellulosa	17.97	13.67	13.46	13.13
Lignin	10.91	8.87	8.98	9.14
Silika	7.44	5.83	5.77	5.71
Tanin	0.22	0.29	0.35	0.42

In Vitro Preparation

Material preparation

The raw materials used in this study are mangrove fruit *Sonneratia alba* and *Indigofera zollingeriana*. Mangrove fruit is taken from the Padang Pariaman area in Tiram Beach, and Indigofera is taken at BPTU HPT Padang Mengatas, Payakumbuh, West Sumatera. Mangrove and Indigofera decomposed from the twigs and dried with the help of sunlight and an oven at a temperature of 55^{o}C. The purpose of drying is to facilitate the process of pulverizing the material. After drying, the material was pulverized to a powdery form with a blender.

McDougalls solution

Weigh each required ingredient, and then all ingredients are dissolved gradually with 10 liters of distilled water. This buffer solution was prepared the day before conducting the in vitro assay.

Preparation of rumen fluid

Rumen fluid is taken in the morning when the cattle are slaughtered at the slaughterhouse. Before taking the rumen fluid, prepare a thermos filled with hot water to maintain the temperature of the rumen fluid. Before the rumen fluid is inserted, the hot water in the thermos is discarded first. Ingesta is put into a thermos with a temperature of 39^{o}C and supplied with CO_2 gas. This aims to maintain the temperature and keep the microbial environment anaerobic. The rumen fluid was then filtered with gauze as much as needed to mix with McDougall's solution.

In Vitro Digestibility

Put 2.5 grams of sample into a 250 ml erlenmeyer, then add 50 ml of rumen fluid and 200 ml of buffer. Then, CO_2 gas is flowed into the erlenmeyer for 30 seconds in anaerobic conditions. The tube is closed again with a ventilated rubber cover, placed on a shaker set at 39 ℃, and incubated for 48 hours. After 48 hours, the erlenmeyer tube was immersed in ice cubes to stop fermentation activity by rumen microbes. The liquid and food particles and the incubation results were centrifuged at 4000 rpm for 15 minutes. The centrifugation results in the form of residue and supernatant were separated using Watman® 41 filter paper and bottles.

Measured Parameters

Dry Matter Digestibility (DMD)

$$\frac{(\text{sample weight} \times \%DM \text{ sample}) - (\text{residual weight} \times \%DM \text{ residual})}{(\text{sample weight} \times \%DM \text{ sample})} \times 100\%$$

Organic Matter Digestibility

$$\frac{(\text{sample weight } x\ \%OM \text{ sample}) - (\text{residual weight } x\ \%OM \text{ residual})\ x\ 100\%}{(\text{sample weight } x\ \%OM \text{ sample})}$$

Crude Protein Digestibility

$$\frac{(\text{sample weight} \times \%CP \text{ sample}) - (\text{residual weight} \times \%CP \text{ residual})}{(\text{sample weight} \times \%CP \text{ sample})} \times 100\%$$

Crude Fiber Digestibility

$$\frac{(DM \text{ weight of sample } x \text{ initial } \%DM \ x\ \%CF \text{ sample}) - (DM \text{ weight of residual}) \ \%DM \text{ residual } x\ \%CF \text{ residual}}{DM \text{ weight of sample } x \text{ initial } \%DM \ x\ \%CF \text{ sample}} \text{ x } 100\%$$

Crude Fat Digestibility

$$\frac{(DM \text{ weight of sample } x \text{ initial } \%\ DM \ x\ \%CF \text{ sample}) - (DM \text{ weight of residual}) \ x\ \%DM \text{ residual } x\ \%CF \text{ residual}}{DM \text{ weight of sample } x \text{ initial } \%DM \ x\ \%CF \text{ sample}} \text{ x } 100\%$$

NFE Digestibility

$$\frac{(DM \text{ weight of sample } x \text{ initial } \%\ DM \ x\ \%NFE \text{ sample}) - (DM \text{ weight of residual}) \ x\ \%DM \text{ residual } x\ \%NFE \text{ residual}}{DM \text{ weight of sample } x \text{ initial } \%DM \ x\ \%NFE \text{ sample}} \text{ x } 100\%$$

pH

When the electrode is put into the fermenter tube, the pH value is determined by looking at the number on the monitor screen.

VFA total

VFA content was measured using the Vapor Distillation technique (General Laboratory Procedures, 1966), i.e. Total VFA (mM) = (ml HCl titration blank - ml sample titration) x N HCl x 1000/5).

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NH_3

Measurement of NH_3 content of rumen fluid was done by Conway microdiffusion (General Laboratory Procedures, 1996), i.e. NH_3 (mM) = ml H2SO4 titration x N H2SO4 x 1000.

Data Analysis

All data obtained were processed by variance analysis using ANOVA and then Duncan's Multiple Range Tests (DMRT).

RESULT

Table 3. Digestibility of Dry Matter, Organic Matter, Crude Protein, Crude Fiber, Crude Fat, and NFE (%)

Treatment	DMD	OMD	CPD	CFD	Crude Fat Digestibility	NFE
P1	74.28	77.73	63.78^{a}	62.34^{a}	63.15^{a}	73.63^{a}
P2	73.53	77.03	63.27^{a}	62.21^{a}	62.58^{a}	72.56^{b}
P3	72.79	76.69	62.75^{ab}	61.08^{ab}	61.09^{ab}	71.31^{c}
P4	66.41	70.64	60.83^{c}	59.05^{b}	59.21^{b}	69.89^{d}
SE	2.19	1.91	0.52	0.67	0.84	0.32

Notes: Different superscripts indicate significantly different effects (P<0.05), Different superscripts indicate significantly different effects (P<0.01), SE (Standard Error)

Table 4. pH, VFA and NH_3

Nutrient	pH	VFA (mM)	NH_3 (mM)
P1	7.19	131.25^{a}	8.88^{a}
P2	7.14	128.50^{ab}	8.28^{a}
P3	7.13	123.75^{b}	7.30^{b}
P4	7.08	121.75^{b}	6.49^{c}
SE	0.06	2.23	0.41

Notes: Different superscripts indicate no significant effect (P>0.05), Indicate significantly different effects (P<0.05), Indicate significantly different effects (P<0.01), SE (Standard Error)

Dry Matter Digestibility

It can be seen that dry matter digestibility ranged from 66.41%-74.28%. Based on statistical analysis showed that the addition of mangrove fruit as a source of tannins in Indigofera had no significant effect (P>0.05) on dry matter digestibility in vitro.

Organic Matter Digestibility

Table 3 shows that the treatment gave a significantly different effect (P>0.05) on the digestibility of organic matter (OMD). The digestibility of organic matter obtained in this study ranged from 70.64%-77.73%.

Crude Protein Digestibility

Based on Table 3, the analysis of variance showed that each treatment gave a very significantly different effect (P <0.01) on crude protein digestibility. The average value of crude protein digestibility obtained in this study ranged from 58.60%-71.98%.

Crude Fiber Digestibility

The average value of crude fiber digestibility in this study was 62.34% to 59.05%. The analysis of variance showed that the treatments gave significantly different effects (P <0.05) on crude fiber digestibility.

Crude Fat Digestibility

This study showed that adding mangrove fruit significantly affected crude fat digestibility (P <0.05). It can be seen that the lowest average crude fat digestibility was obtained in treatment P4 with an average crude fat digestibility of 63.15% and the highest average crude fat digestibility was obtained in treatment P1 with an average of 59.21%.

Nitrogen-Free Extract (NFE) Digestibility

The average value of NFE digestibility in this study was 73.63% to 69.89%. Based on the analysis of variance showed that the addition of mangrove fruit had a very significant effect (P <0.01) on NFE digestibility. It can be seen that the lowest NFE treatment average was obtained in treatment P4 with an average of 69.89%, and the highest was obtained in treatment P1 with an average of 73.63%.

Rumen pH

Rumen pH is a balanced interaction between buffer capacity and acidity or the freedom of fermentation products produced in the rumen. The addition of mangrove fruit (*Sonneratia alba*) as a source of tannin in *Indigofera zollingeriana* had no significant effect (P>0.05) on the average pH of rumen fluid.

VFA Concentration

The addition of mangrove fruit (*Sonneratia alba*) as a source of tannin in *Indigofera zollingeriana* has a significantly different effect (P <0.05) on the concentration of rumen fluid VFA. This study obtained the highest VFA concentration in treatment P1 (131.25 mM) without adding mangrove fruit, while the lowest VFA concentration was in treatment P4 (121.75 mM) with 9% mangrove fruit flour.

Ammonia Concentration (NH_3)

The addition of mangrove fruit (*Sonneratia alba*) as a source of tannin in indigofera (*Indigofera zollingeriana*) affects very significantly different (P <0.01) on the average NH_3 concentration. In this study, the highest NH_3 concentration was obtained in treatment P1 (without the addition of tannin), which was 8.88 mM, while the lowest NH_3 was in treatment P4 (9% tannin level), which was 6.49 mM.

DISCUSSION

Dry Matter Digestibility

In the P2, P3, and P4 treatments, the digestibility of dry matter tends to decrease because the tannins in mangrove fruit form tannin-protein bonds that can inhibit digestion in the rumen. This is supported by the study of Gameda dan Hassen (2015), which found that the formation of complex bonds between tannin-protein and tannin-carbohydrate in the rumen causes a decrease in DM and OM digestibility. Ardani et al. (2024) stated that protein digestibility is closely related to dry matter digestibility, where the value of crude protein digestibility is directly proportional to dry matter digestibility or vice versa.

In addition, the addition of mangrove fruit as much as 9% as a source of tannin in indigofera does not give a significantly different effect because the tolerance limit of tannins to ruminants reaches 4%. The limit of tannin used in ruminant rations is 3 - 4% (Makkar, 2003). The addition

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of mangrove fruit containing tannins can bind to proteins to inhibit the digestibility of crude fiber in the rumen, making dry matter digestibility low. The research results by Elihasridas et al. (2023) also stated that feeding concentrates containing condensed tannins caused the degradation of organic matter in the rumen to decrease by increasing the level of condensed tannins up to 30%.

Organic Matter Digestibility

The digestibility of organic matter decreased in line with the value of dry matter digestibility, which also decreased. The opinion of Jamarun et al. (2020) states that the pattern of OMD is in line with DMD because most of the dry matter consists of organic matter, and what distinguishes it is the ash content. Pazla et al. (2023) also stated that digestible dry matter consists mainly of organic matter (protein, fat, and carbohydrates) that can be digested. The addition of mangrove fruit can reduce the digestibility of organic matter. This proves that the tannins in mangrove fruit can bind proteins, so the proteins contained in indigofera escape from degradation in the rumen.

According to Pazla et al. (2021), the average value of organic matter digestibility is directly proportional to the average value of dry matter digestibility. The digestibility of organic matter is closely related to dry matter, where part of the dry matter consists of organic matter. This agrees with Pazla et al. (2023), which states that the digestibility of organic matter and the digestibility of dry matter are interconnected, where dry matter is composed of two chemicals, namely organic matter and inorganic matter, in the organic matter itself contains crude fat, crude protein, crude fiber, and NFE, while inorganic matter consists of ash.

Crude Protein Digestibility

In the P2, P3, and P4 treatments, there was a decrease in crude protein digestibility; the low digestibility of crude protein is due to the influence of antinutrients on mangrove fruit and forming tannin and protein bonds so that they cannot be degraded in the rumen. Mangrove fruit contains high enough tannins, so adding mangrove fruit will reduce the digestibility of crude protein. The provision of tannins will positively impact feed that contains high protein but is soluble (soluble protein). The tannin bond complex with protein can be released at low pH in the abomasum so that the enzyme pepsin can degrade the protein, and the amino acids it contains can be utilized by livestock (Jamarun et al., 2020; Jamarun et al., 2025).

The addition of tannins tends to reduce feedstuff digestibility and total VFA production. The decreasing NH_3 levels can prove the increase in feed protein that escapes rumen microbial degradation. This decrease is because tannins will bind strongly to proteins so that rumen microbes cannot degrade some proteins. This will benefit livestock in optimal tannin conditions, making protein available to the host. Tannins can precipitate proteins with several functional groups that can form powerful complex bonds with protein molecules. These bonds result in proteins that rumen microbes cannot degrade.

This protein protection is very beneficial because it will increase the supply of quality feed protein that can avoid excessive degradation by rumen microbes, thus increasing the amount of feed amino acids absorbed by the host animal. However, if the concentration is not optimally regulated, digestibility and overall nutrient absorption can be impaired because tannins not only interact with the protein but also with fiber and other components such as fiber, vitamins, and minerals.

Crude Fiber Digestibility

The highest crude fiber digestibility was obtained in treatment P1 (62.34%), namely 100% *Indigofera zollingeriana* flour. This is because there is no addition of mangrove fruit flour containing tannins. Tannins can bind to proteins by forming complex compounds resistant to

protease enzymes so that protein degradation in the rumen decreases. The decrease in protein degradation in the rumen disrupts rumen microbial activity, impacting crude fiber digestibility. Supported by the study of Maynard et al. (2005), several factors, including fiber content in the feed, the composition of crude fiber constituents, and the activity of microorganisms, influence the digestibility of crude fiber.

The decrease in crude fiber digestibility occurred when adding 3-9% tannins; the lowest was at the 9% level, 59.05%. These results indicate that adding mangrove fruit can reduce crude fiber digestibility. The decrease in crude fiber digestibility is due to the increasing tannin content in each treatment. Increased tannin content causes proteins that should be degraded in the rumen to produce ammonia, a nitrogen source for microbes. The decrease in crude fiber digestibility is caused by tannins binding strongly to protein, so microbes cannot optimally utilize the high protein content at a 9% tannin level.

Factors that affect significantly different ($P < 0.05$) crude fiber digestibility are also supported by cellulose digestibility, which also shows significantly different results ($P < 0.05$). In the study, crude fiber digestibility decreased from treatment P1 to P4, aligning with the decrease in cellulose digestibility. This is because the increased use of mangrove fruit reduces cellulose degradation, giving a significantly different effect from the P1 treatment as a control. This is supported by the statement of Pazla et al. (2024b) that increasing the use of mangrove fruit can reduce cellulose degradation due to a more complex cellulose structure and unbalanced nutrient distribution.

The lowest crude fiber digestibility was found at the 9% tannin level (P4), with the highest crude fiber content of 9.87%. This indicates that high fiber content does not guarantee high fiber digestibility. However, fiber digestibility is indeed influenced by the chemical composition of feed ingredients, where the chemical composition of feed ingredients affects fermentative digestibility by rumen microbes. The same thing is also stated by Indah et al. (2020), where crude fiber content has a negative relationship with digestibility; the lower the crude fiber, the higher the digestibility of the ratio.

Crude Fat Digestibility

Crude fat digestibility is closely related to crude fiber digestibility because the crude fiber consumed will be broken down into cellulose, which is then fermentatively digested by rumen microbes to produce VFA (volatile fatty acid) so that a decrease in crude fiber digestibility can result in decreased crude fat digestibility and vice versa. A decrease in crude fiber digestibility causes a decrease in crude fat digestibility. Astuti et al. (2009) stated that crude fat digestibility is also influenced by crude fiber digestibility because crude fat is part of the contents of plant cells and is deposited on the cell wall, so crude fat digestibility depends on crude fiber digestibility.

The low digestibility of crude fat in the P2, P3, and P4 treatments was caused by the tannin content contained in each treatment. Because the tannins in mangrove fruit bind to the protein of the protein source feed ingredients from Indigofera, the protein can not be adequately digested. Mangrove tannins spread and dissolve in rumen fluid and bind to the protein of feed ingredients. The formation of tannins and proteins through condensation can not be hydrolyzed or hydrolyzed in the rumen (Rosmalia et al., 2022b).

The low digestibility of crude fat in the P4 treatment is due to the content of TDN as energy and CP as N, which is poorly produced in fermentation by microbes so that it can interfere with microbial growth. The imbalance of the chemical composition of TDN and CP in the P4 treatment disrupts microbial growth and activity, causing a decrease in the digestibility of feed ingredients, one of which is crude fat digestibility. Balanced CP and TDN values in feed will increase feed

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digestibility because if the CP and TDN values of feed are not balanced, it will reduce the rate of microbial proliferation and population so that microbes will find it challenging to digest feed ingredients eaten by livestock (Putri et al., 2021; Santos et al., 1998).

Nitrogen-Free Extract Digestibility

The high average NFE digestibility of treatment P1 obtained is likely due to the high starch content in the treatment. NFE content in the P1 treatment was 73.63%. According to Despal et al. (2021c), the high NFE content illustrates that the fraction of easily digestible carbohydrates such as starch and sugar is also high. NFE contains monosaccharides, trisaccharides, disaccharides, and polysaccharides, especially starch, all of which are soluble in acids and bases and have high digestibility. Microbes naturally more easily digest NFE, so microbes are more likely to utilize NFE first (Ardani et al., 2024).

The decreasing value of NFE digestibility of P2, P3, and P4 treatments was caused by the digestibility of crude fiber and crude fat digestibility decreased and the higher concentration of tannins in each treatment, starting from the treatment of the addition of mangrove flour as a source of tannins which can reduce the digestibility of nutritional components that affect NFE digestibility.

The lowest NFE digestibility in the P4 treatment was 69.89%; besides being influenced by the addition of mangrove fruit flour as a source of tannins, low protein levels were also a factor in the decrease in digestibility. This is the opinion of Sari et al. (2022) that NFE digestibility increases with increasing ration protein levels; this indicates that protein plays a role in the utilization of other food substances. The increase in protein influences the absorption and utilization of feed nutrients, so NFE digestibility tends to increase.

pH

According to Kamlasi et al. (2024), the pH value of the rumen plays an important role in regulating processes in the rumen, such as support for rumen microbes in producing VFA and NH_3. Different pH values obtained in this study indicate that it is still classified as usual for rumen microbial activity. The high pH value without the addition of mangrove fruit (*Sonneratia alba)* as a source of tannin in indigofera (*Indigofera zollingeriana*) due to high NH_3 concentration, NH_3 is alkaline, so the pH of rumen fluid will be high. High NH_3 concentration is due to high Indigofera crude protein degraded in the rumen.

The treatment in this study showed no significant effect on the rumen fluid's pH, so the treatment of various percentage additions did not interfere with the balance of the rumen environment for microorganisms for the feed fermentation process. Each treatment did not have a significant effect on the pH of rumen fluid; this was due to the balance between acidic VFA and alkaline NH_3

Volatile Fatty Acid Concentration

Based on the data, it can be seen that there is a decrease in VFA along with the addition of mangrove fruit (*Sonneratia alba*) as a source of tannins in *Indigofera zollingeriana*. These results show that adding mangrove fruit can reduce the concentration of VFA. The decrease in VFA concentration is caused by increased tannin content in each treatment. The increase in tannin content causes the amount of carbohydrates and proteins that escape degradation to increase so that the amount of glucose fermented by microbes decreases.

VFA are the result of fermentation of organic matter in the rumen. In the rumen, the digestibility of organic matter showed the highest results in the P1 treatment. This result is to the opinion of Yang et al. (2016) and Durango et al. (2021), which explains that the concentration of

VFA and ammonia in the rumen shows the digestibility value of organic matter consumed, the higher the production value of VFA and ammonia in the rumen, the higher the digestibility value of organic matter.

The lowest VFA concentration in the P4 treatment was due to high lignin levels. The crude fiber content of mangrove additions likely causes a decrease in VFA production. The addition of mangroves contributed to the increase in the crude fiber of the treatment feed. Wijayanti et al. (2012) reported that the crude fiber content of the feed influenced decreased VFA production. This study's VFA concentration ranged from 121.75 mM to 131.25 mM. The results can support the growth and activity of microbes in the rumen. Putri et al. (2023) stated that the optimal VFA concentration for microbial growth ranges from 70 to mM-150 mM. The increase in VFA concentration indicates the extent to which the feed can be easily or difficult to degrade by microbes in the rumen.

Ammonia Concentration (NH_3)

The decrease in NH_3 concentration was caused by an increase in the tannin content of mangrove fruit in each treatment. The increase in tannin levels resulted in a decrease in NH_3 concentration from 8.88 mM to 6.49 mM. The higher the tannin, the more protein is protected to reduce the concentration of NH_3. According to D'Mello and Devendra (1995), tannins are compounds that can protect feed protein from excessive degradation in the rumen. Tannins can form complexes with proteins and protect proteins from rumen degradation.

Low NH_3 results in slow growth of microorganisms because microbes need NH_3 to synthesize protein (Zain et al., 2019). The high concentration of NH_3 in the treatment without the addition of tannin is due to the high degradation of crude protein in the rumen. This is based on the statement of Gumilar et al. (2017) that the higher the degradation of crude protein in the rumen, the higher the concentration of NH_3 will be, and vice versa.

NH_3 levels in this study ranged from 8.88 mM to 6.49 mM in rumen fluid. According to McDonald et al. (2002), the optimum amount of NH_3 concentration in the rumen ranges from 85-300 mg/l to 6-21 mM. The NH_3 content is sufficient for the optimal growth needs of microbes. Zain et al. (2020) stated that tannins can reduce the ability of protein degradation and amino acid deamination in the rumen and produce low NH_3 levels. Adding mangrove fruit as a source of tannins in *Indigofera zollingeriana* can increase tannin levels and reduce degradation in the rumen.

CONCLUSION

The study demonstrated that adding mangrove fruit (*Sonneratia alba*) as a tannin source to *Indigofera zollingeriana* feed significantly influenced various digestibility parameters and rumen characteristics. Treatments with higher tannin levels (up to 9%) reduced crude protein digestibility (CPD), crude fiber digestibility (CFD), and nitrogen-free extract (NFE) digestibility, indicating potential inhibitory effects of tannins on rumen microbial activity at elevated concentrations. Conversely, the treatment containing 6% mangrove fruit (P3) achieved a favorable balance, showing improved crude protein protection while maintaining adequate digestibility levels and rumen fluid characteristics such as ammonia (NH_3) and volatile fatty acid (VFA) concentrations. These findings highlight the potential of moderate tannin supplementation to enhance feed efficiency and protein utilization in ruminants, particularly when optimized at appropriate inclusion rates.

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