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CHEMICAL CHARACTERISTICS AND FIBER FRACTION OF RUMINANT COMPLETE FEED BASED ON SEAWEED (*PADINA AUSTRALIS*) WITH DIFFERENT LEVELS OF USE

Irmayanti[1, a], Jisril Palayukan[1], and Suriansyah[1]
[1]*Departement of Animal Science, Faculty of Animal Science and Fisheries, Universitas Sulawesi Barat, Indonesia*
[a]*email:* irmayanti@unsulbar.ac.id

Abstract
The aim of this study was to examine the effect of the level of seaweed (*Padina australis*) as a ruminant feed on the nutritional quality and fiber fraction of complete diets. The variables observed were dry matter, crude protein, crude fiber, extract ether, N-free extract, ash content, acid detergent fiber and neutral detergent fiber. This study was based on a completely randomized design (CRD) with 4 treatments and 4 replications, namely P0 = complete feed (control), P10 = complete feed with 10% *Padina australis* level, P20 = complete feed with 20% *Padina australis* level, and P30 = complete feed with 30% *Padina australis* level. The results showed that using *Padina australis* up to 30% can increase dry matter and crude protein and reduce crude fiber, extract ether and ash content, as well as N-free extract, neutral detergent fiber, and acid detergent fiber content. The use of *Padina australis* at 20% level is the best treatment because it can reduce extract ether at 6.21%, ash content at 16.56%, neutral detergent fiber at 50.88%, and acid detergent fiber at 31.22%.
Keywords: Fiber fraction, Nutritional quality, Padina australis, Complete feed.

KARAKTERISTIK KIMIA DAN FRAKSI SERAT PAKAN KOMPLIT BERBASIS RUMPUT LAUT (PADINA AUSTRALIS) DENGAN LEVEL PENGGUNAAN YANG BERBEDA SEBAGAI PAKAN TERNAK RUMINANSIA

Abstrak
Tujuan penelitian ini untuk menguji pengaruh level rumput laut (Padina australis) sebagai pakan ternak ruminansia terhadap kualitas nutrisi dan fraksi serat pakan komplit. Variabel yang diamati adalah bahan kering, protein kasar, serat kasar, lemak kasar, bahan ekstrak tanpa nitrogen, kadar abu, acid detergen fiber dan neutral detergen fiber. Penelitian ini didesain berdasarkan Rancangan Acak Lengkap (RAL) dengan 4 perlakuan dan 4 ulangan, yaitu: P0 = Pakan komplit (Kontrol), P10 = Pakan komplit dengan level Padina australis 10%, P20 = Pakan komplit dengan level Padina australis 20%, P30 = Pakan komplit dengan level Padina australis 30%. Hasil penelitian menunjukkan bahwa penggunan rumput laut Padina australis sampai 30% dapat meningkatkan bahan kering, protein kasar, dan menurunkan serat kasar, lemak kasar, bahan ekstrak tanpa nitrogen, kadar abu serta kandungan neutral detergent fiber dan acid detergent fiber. Penggunaan Padina australis pada level 20% merupakan perlakuan terbaik karena dapat menurunkan lemak kasar 6,21%, kadar abu 16,56%, neutral detergen fiber 50,88%, dan acid detergen fiber 31,22%
Kata Kunci: Fraksi serat, Kualitas nutrisi, Padina australis, Pakan komplit.

INTRODUCTION

Ruminants play a major role in the food supply and sustainability of agricultural production systems. Increasing ruminant production must be accompanied by good feeding management to increase livestock productivity (Kustantinah et al., 2022). In order to increase livestock production, feed plays a very important role. Feed accounts for the largest cost in the production of livestock, which is up to 70 percent. Therefore, good feed is needed to produce maximum production (Munandar et al., 2020). The supply and feeding of forage as a source of fiber for ruminants is a matter of concern. Fluctuating fodder production produces low quality and quantity during the dry season. Therefore, alternative fiber sources are needed

to support livestock production and ensure fodder availability (Irmayanti and Ningtiyas, 2022).

One of the efforts to overcome the fibrous feed needs of ruminants is to utilize alternative fiber sources, such as seaweed. West Sulawesi is a coastal area with 20,300 ha of seaweed land. Each hectare of seaweed produces approximately 500 tons, and 15 per cent of this is tritip waste, with 20 per cent being damaged seaweed waste (Ambarwati et al., 2023). The use of seaweed as a supplement in ruminant feed is currently of interest to the feed industry. Seaweed has been reported to be very efficient in increasing the productivity of ruminants in several studies conducted in several countries, including Europe, Australia, the United States, New Zealand, Korea, and Africa (Roque et al., 2019).

Seaweed has been identified as a promising marine resource with the potential to be developed as a unique feed ingredient, aimed at enhancing feed value. *Padina australis*, a species of seaweed, is particularly abundant in Indonesian waters, with a notable presence in the province of West Sulawesi. This species of seaweed holds promise for utilization as a feed ingredient due to its absence from the diets of the surrounding community. Besides its abundance, this type of seaweed also has the advantage of good nutritional value as a dietary fibre source with a nutritional composition of 30.59% dry matter, 12.57% crude protein, minerals, and high structural carbohydrates (Hidayah et al., 2022). Furthermore, the plant is high in minerals, offering potential as an organic mineral source for use as an alternative mineral supplement in ruminant feed (Kustantinah et al., 2022). Padina australis also has weaknesses as feed, including high fibre and ash content, so efforts are needed to improve its quality as ruminant feed.

The problem-solving approach undertaken to address the feed supply and availability issue involves the utilization of feed processing technology. A novel innovation that can effectively enhance the quality, quantity, and shelf life of feed, thereby increasing the economic value of seaweed (*Padina australis*). The utilization of seaweed (*Padina australis*) in the production of feed has emerged as a promising local resource, with the potential to enhance the quality and availability of ruminant feed throughout the year. The objective of this study was to assess the nutritional quality and fiber fraction of seaweed-based complete feed (*Padina australis*) with varying usage levels, with the aim of enhancing the productivity of ruminants.

MATERIALS AND METHODS

Materials and Tools

The fabrication of complete feed entails the utilization of various tools and materials, including grinding machines, containers, scales, and buckets. The materials employed in this study encompass seaweed (*Padina australis*), corn bran, coconut meal, rice bran, molasses, ground corn, minerals, urea, salt, labels, plastic ropes, masking tape, polyethylene plastic, masks, hand gloves, and materials utilized for the analysis of feed nutrition and fiber fraction.

Research Procedures

The research procedure commenced with the preparation of tools and feed ingredients, which included seaweed (*Padina australis*) that had undergone a drying and grinding process, as well as corn bran, rice bran, coconut meal, ground corn, minerals, salt, urea, and molasses. The fabrication of seaweed-based complete feed (*Padina australis*) commenced with the cleansing of *Padina australis* from dirt using clean running water. The seaweed was then soaked for 8 hours to reduce its salt content. After this, the seaweed was cut into small pieces and dried in the sun for 3 days. It was then ground using a chopper. Subsequently, the feed ingredients are prepared and weighed based on 15% crude protein (CP) requirements (Table 1) and thoroughly mixed until homogeneity. The feed ingredients are then weighed, with each experimental unit in the treatment being packed in plastic and stored anaerobically at room temperature. The quality test of feed nutrition was calculated based on the AOAC method (AOAC, 2010), and the fiber fraction was calculated based on the van Soest method (Van Soest et al., 1991).

Table 1. Seaweed (*Padina Australis*) Based Complete Feed Formulation

Feed Ingredients	Amount (%)			
	P0	**P10**	**P20**	**P30**
Padina australis	0	10	20	30
Rice bran	18	18	18	18
Corn stalk	45	35	25	15
Ground corn	17	18	18	18
Coconut meal	12	12	12	12
Molases	5	5	5	5
Mineral	1	1	1	1
Salt	1	0	0	0
Urea	1	1	1	1
Total	**100**	**100**	**100**	**100**

Research Design

This research method utilizes an experimental approach with a research design employing a complete randomized design (CRD) with four treatments and four replicates. The treatments consist of the following:

P0 = Complete feed (control)
P10 = Complete feed with 10% *Padina australis* level
P20 = Complete feed with 20% *Padina australis* level
P30 = Complete feed with 30% *Padina australis* level

Research Variable

The variables observed in the study were the quality of feed nutrition, fiber fraction, fermentability, and digestibility of complete feed, including the test of nutritional quality of complete feed: dry matter (DM), crude protein (CP), crude fiber (CF), ether extract (EE), N-free extract (NFE) and ash content. Fiber fractions include Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF).

Data Analysis

Data collection techniques in this study by observing variables on seaweed (*Padina australis*)-based complete feed. Data were analyzed using Analysis of Variance (ANOVA) based on a completely randomized design (CRD) consisting of 4 treatments and 4 replicates. Then the difference in the effect on the existing treatment will be continued with the smallest real difference test.

RESULTS AND DISCUSSION

Nutritional Quality

The data presented in Table 2 offers insights into the nutritional quality of complete feed with varying levels of seaweed (*Padina australis*) utilized as ruminant feed. The results of the analysis of variance demonstrated that the incorporation of seaweed at varying levels did not elicit a significant effect on crude fiber content ($P > 0.05$). However, it exerted a significant effect on the value of dry matter, crude protein, ether extract, N-free extract, and ash content ($P < 0.05$).

Dry Matter

The results of the analysis of variance showed that complete feed with the use of different seaweed (*Padina australis*) showed a significant effect ($P <0.05$) on the dry matter content of complete feed. The results showed that the average dry matter content of the complete feed was 83.22% - 85.22%. Complete feed with the use of seaweed (*Padina australis*) at 20% had the highest dry matter content (85.22%), and the lowest at 0% treatment at 83.22%. The low value of dry matter shown in the P0 and P10 treatments compared to P20 and P30, occurred because the water content in corn stalks was higher than seaweed, so that the higher the level of seaweed use in the complete feed will cause an increase in the dry matter content of the complete feed.

Table 2. Nutritional Quality of a *Padina Australis*-Based Complete Feed

Item	Treatment			
	P0	**P10**	**P20**	**P30**
Dry matter	83.22±0.14[a]	83.32±0.48[a]	85.22±1.05[b]	85.04±0.14[b]
Crude protein	14.91±0.93[a]	15.67±0.60[ab]	16.22±0.17[b]	16.32±0.21[b]
Crude fiber	10.49±3.45	7.75±0.11	8.73±0.36	9.53±0.32
Ether extract	5.34±1.14[a]	6.86±0.05[b]	6.21±0.09[ab]	6.22±0.12[ab]
N free extract	61.59±2.94[d]	56.89±0.39[c]	52.03±0.80[b]	48.50±0.06[a]
Ash	7.73±0.85[a]	12.05±0.14[b]	16.56±0.31[c]	18.48±0.02[d]

Source: Primary Data Research Results, 2024. Notes: Different superscripts in the same column indicate significant differences (P < 0.05). P0 = complete feed (control), P10 = complete feed with 10% *Padina australis* level, P20 = complete feed with 20% *Padina australis* level, P30 = complete feed with 30% *Padina australis* level.

Dry matter content consists of organic matter and inorganic matter where organic matter is broken down into simpler food substances such as crude fiber, crude protein and N-free extract. Dry matter is important to observe because dry matter reflects the nutritional quality of the feed contained, low dry matter can indicate low nutritional quality as well. This can lead to a decrease in the nutritional value of the complete feed and is more susceptible to mold contamination due to increased moisture, leading to low storability (Wijayanti et al., 2024).

Furthermore, Ridla et al. (2023) explained that the ideal moisture content range to inhibit microbial activity is between 12-14%. The elevated moisture levels observed in the P0 and P10 treatments can potentially compromise the integrity of feed during storage, thereby increasing the risk of contamination. The moisture content of a feed ingredient is determined by the composition and properties of the ingredients that constitute the feed. It has been demonstrated that the moisture content of ingredients is directly proportional to that of the resulting feed ingredients (Handayani et al., 2019). Excess moisture content has the potential to encourage microbial growth, which can lead to the proliferation of harmful microorganisms. Therefore, effective management of moisture content is crucial to prevent such growth. Increased moisture content has been shown to lead to increased respiration, which in turn causes higher release of CO_2, water and heat during storage (Ferdian et al., 2019).

Crude Protein

The results of the analysis of variance showed that the complete feed with the incorporation of varying quantities of seaweed (*Padina australis*) exhibited a significant effect (P <0.05) on crude protein content. The study revealed that the mean crude protein content of the complete feed ranged from 14.91% to 16.32%. It was observed that complete feed incorporating seaweed at levels up to 30% exhibited a higher crude protein content in comparison to the 0% treatment. The elevated crude protein content observed in the *Padina australis* treatment is attributable to the incorporation of up to 30% *Padina australis*. It has been established that the main constituent feed ingredients of Padina australis have a crude protein content of 7.54%, resulting in a higher crude protein value when compared to other treatments. Conversely, the crude protein content of the primary constituent material P0 corn stalk has been determined to be 2.99% (Islamiyati & Surahman, 2017), which is lower than the content observed in *Padina australis*. Fitriani & Asyari (2017) posited that the levels of crude protein in feed can be influenced by several factors, including the type of feed ingredients and the level of provision of feed constituents. Furthermore, Kearl (1982) explained that the crude protein requirement for ruminants is 12-14% of dry matter requirements. The significance of crude protein content, particularly in the formulation of ruminant feed based on Total Digestible Nutrients (TDN) and crude protein (Rosendo et al., 2013).

Protein source feed ingredients have a crude protein content of >18%. In general, crude protein refers to the total protein content in an animal feed product. Crude protein does not provide accurate information about the quality of protein or amino acids present in the sample (Kamid et al., 2024). Protein is an important feed nutrient for livestock. In addition to requiring adenosine triphosphate (ATP) as a source of energy in the process of chemical reactions, protein is also beneficial for rumen microbes in the synthesis of body protein (Bediona et al., 2024). Protein is one of the nutrients that can fulfill the productivity level of ruminants. The role of protein is very important in the body of livestock, not only as a determinant of production quality but also for basic living needs, activities, and needs adjusted to the ability of these livestock to consume protein (Sudarmadji et al., 1984).

Crude Fiber

The average crude fiber content of complete feed with the use of different seaweed (*Padina australis*) showed a non-significant effect (P>0.05). This outcome is attributable to the crude fiber content of the complete feed's primary constituents. The analysis of *Padina australis* revealed a 15.68% reduction in crude fiber content compared to corn stalk, suggesting that the incorporation of seaweed could be a means of decreasing the crude fiber content of complete feed derived from corn stalk. This finding aligns with the results of a previous study, which demonstrated that adding *Padina australis* at a rate of 10% resulted in a lower crude fiber content compared to levels added at 20% and 30%.

The percentage decrease in crude fiber content of complete feed with the use of *Padina australis* at varying levels is noteworthy. The average crude fiber content of complete feed ranges from 7.75% to 10.49%, falling below the maximum limit of good crude fiber content standards in feed. Suroso et al. (2023) have delineated a standard of 12-17% as the benchmark for a favorable crude fiber content. The presence of high levels of crude fiber in feed has been demonstrated to result in a decline in digestibility due to the presence of recalcitrant components, such as lignin, which hinders the breakdown of cellulose and hemicellulose (Astutik et al., 2019). Crude fiber, being a carbohydrate, is also known to be indigestible (Sutardi, Adawiah, & Sunaryati, 2003). Crude fiber is typically composed of cellulose, hemicellulose, and lignin, collectively referred to as neutral detergent fiber (NDF) (Irwadim, 1990). Of these components, lignin presents a particular challenge due to its recalcitrant nature, which hinders its digestibility. Consequently, feed ingredients with a high lignin content may compromise their overall nutritional value and efficacy.

Ether Extract (EE)

The results of the analysis of variance demonstrated that the incorporation of seaweed (*Padina australis*) exerted a significant effect ($P < 0.05$) on the ether extract content of complete feed, which ranged from 5.34% to 6.86%. The lowest ether extract content was observed in the 0% treatment, where *Padina australis* was not utilized (5.34%), while the highest content was recorded in the 10% *Padina australis* treatment (6.86%). The highest ether extract content was found in the P20 and P30 treatments. The increase in this value is in line with the increase in dry matter content of the complete feed. The increase in dry matter content of complete feed causes an increase in organic matter such as protein, carbohydrates, and fat (Reski et al., 2021).

Next, the data showed that the ether extract content of the complete feed of all treatments exceeded the maximum limit for ruminant feed. This is due to the ether extract content in other constituent feed ingredients such as coconut meal and ground corn. It is known that the ether extract content of *Padina australis* seaweed is 0.62%. The nutritional content of feed constituents will influence the ether extract content of complete feed. This is in accordance with Wina & Susana (2013), the maximum limit of ether extract content in ruminant feed is approximately 5%. However, a high content of ether extract above 5% in feed has been shown to have a negative effect on crude fiber digestibility in the rumen. Ether extract content that is too high in ruminant feed ingredients can interfere with the fermentation process of feed ingredients in the rumen of livestock.

Ash Content

Ash content is defined as an inorganic substance that remains after burning organic matter at a temperature of 550-600°C (Paga & Suek, 2024). Analysis of variance demonstrated that the incorporation of seaweed (*Padina australis*) exerted a highly significant effect (P<0.05) on the ash content of complete feed. The mean ash content of the complete feed ranged from 7.73% to 18.48%, with the highest mean ash content observed in the treatment that incorporated 30% seaweed (*Padina australis*) (18.48%) and the lowest (7.73%) in treatments devoid of seaweed. This variation can be attributed to the elevated ash content characteristic of *Padina australis*. Seaweed has been found to possess a mineral content that exceeds that of terrestrial plants. Paga et al. (2021) reported that seaweed contains 10-20 times more minerals than land plants.

Padina australis has been shown to have high mineral content, making it a potentially valuable addition as an organic mineral source in ruminant feed. Given that all seaweed generally has a mineral content of more than 20%, it offers significant potential as a source of minerals for ruminants, either as a mineral supplement or as an alternative to tropical grass in ruminant feed (Kustantinah et al., 2022). The data showed that treatments P20 and P30 exceeded the maximum limit of ash content in ruminant feed. Wulandari et al. (2015) explained which stipulates that an ash content of no more than 15% is optimal for animal feed, thereby promoting enhanced growth. This viewpoint is corroborated by (Meity et al., 2023) who contend that the ash content of a feed material directly correlates with its mineral content. Higher ash content in livestock feed has been shown to lead to a decrease in appetite and disrupt the balance and absorption of other minerals (Paga & Suek, 2024). Conversely, insufficient ash content has been found to disrupt the body's metabolic processes, inhibit bone growth, and disrupt muscle work (Fadhilah et al., 2022).

Nitrogen Free Extract (NFE)

The lowest average NFE content was observed in the treatment involving the addition of 30% *Padina australis* (48.50%), while the highest was recorded in the control treatment, which did not include *Padina australis* (61.59%). The results of the analysis of variance revealed a significant effect (P < 0.05) of the treatment on the NFE content. The use of *Padina australis* with different levels showed that as the level of seaweed use increased, the NFE content of the complete feed decreased. This is thought to be influenced by the crude fibre and ash content of the complete feed. These components influence the NFE content. The content of crude fibre and ash in this study increased along with the level of use of *Padina australis* seaweed, so that the NFE content became low. This is in line with the explanation (Fakhri et al., 2015) that NFE will be lower along with the lower quality of feed, high and low NFE content in feed due to differences in crude protein, ether extract, crude fibre, and ash content.

NFE is a simple carbohydrate that is utilised by microbes as an energy source to support their growth. This is in accordance with the opinion of Santi (2018) that microbes utilise NFE as an energy source to maintain their survival. One of the nutrients needed is energy obtained from carbohydrates in the substrate. NFE is a feed material consisting of carbohydrates, sugar, and starch, so that NFE content is determined by reducing 100% dry matter by the percentage of crude protein, ether extract, crude fibre, and ash (Purnomo et al., 2024). High NFE content is needed by livestock to produce energy (Sutardi, 2006). The more NFE means the more organic material components that can be digested, so that the energy produced will also increase.

Fiber Fraction

Research data concerning the fiber fraction of complete feed with varying levels of seaweed (*Padina australis*) as ruminant feed is presented in Table 3. The results of the analysis of variance demonstrated that the incorporation of seaweed at varying levels exerted a significant influence on the content of acid detergent fiber (ADF) and nutrient detergent fiber (NDF) at a significance level of P <0.05. The fiber fraction content of the complete feed is also presented in Table 3.

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Table 3. Fiber Fraction of *Padina Australis*-Based Complete Feed

Component	Treatment			
	P0	P10	P20	P30
ADF	34.96±0.44[a]	31.72±1.84[a]	31.22±1.39[b]	31.23±1.95[b]
NDF	50.88±6.93[a]	45.43±0.50[ab]	46.68±1.48[b]	47.02±1.67[b]

Source: Primary Data Research Results, 2024. Notes: Different superscripts in the same column indicate significant differences (P < 0.05). P0 = complete feed (control), P10 = complete feed with 10% *Padina australis* level, P20 = complete feed with 20% *Padina australis* level, P30 = complete feed with 30% *Padina australis* level.

ADF Content

The ADF content of *Padina australis*-based complete feed had a significant effect (P < 0.05) on the level of *Padina australis* use, with the highest average ADF content observed in the 0% treatment (34.96%) and the lowest in the 20% treatment (31.22%) The data showed that the range of ADF content of complete feed from all treatments was within normal limits for livestock.

This is in accordance with the opinion of Surbakti et al. (2022), which states that the percentage of ADF of normal feed to be given to livestock is in the range of 36.7% to 66.6%%. The low ADF content is influenced by the ADF content of the complete feed raw material, which is low enough to affect the decrease in ADF content of Padina australis-based complete feed. The higher the ADF, the lower the quality or digestibility of the feed. Therefore, the ADF content should be as minimal as possible so that the feed given to ruminants is beneficial (Armin et al., 2019). Feed ingredients with low ADF content have high energy content (Sudirman et al., 2015).

NDF Content

The content of neutral detergent fiber (NDF) in *Padina australis*-based complete feed exhibited a significant effect (P < 0.05) on the utilization of *Padina australis*. According to the observation data, the NDF content in the 0% treatment (50.88%) was observed to be the highest, while the lowest content was recorded in the 10% treatment (45.43%). The data showed that the NDF content of the P0 and P10 treatments was higher than the P20 and P30 treatments. This is due to the higher NDF content in corn stover as the main component of feed compared to Padina australis seaweed. Low NDF and ADF content in feed ingredients provides better benefits for livestock, because it indicates that the crude fibre is low, while in ruminants, crude fibre is needed in the digestive system and serves as a source of energy.

The value of NDF content of all treatments shows the value of NDF content in accordance with the needs of ruminants. Armin et al. (2019) explained that the maximum NDF content, in accordance with the needs of ruminants, especially for cattle, is in the range of 62.36-57.50%; low NDF values indicate good feed quality. Furthermore, Saidil & Fitriani (2019) explained that lower the NDF value, the higher the feed digestibility rate and the better the feed quality. Neutral Detergent Fiber (NDF) is a fast method to determine the total fibre of the cell wall contained in plant fibre. NDF has a high correlation with the amount of forage consumption. The higher the NDF, the lower the quality of feed digestibility (Crampton and Harris, 1969).

CONCLUSIONS

The results of this study indicate that the most optimal utilization of *Padina australis* as a source of fiber in complete feed is at the P20 level, corresponding to a concentration of 20% *Padina australis* in feed. This is due to its ability to enhance the content of dry matter and high crude protein while concomitantly reducing the content of extract ether, crude fiber, and neutral detergent fiber and acid detergent fiber in complete feed, across a range of different levels of *Padina australis*.

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