In vitro digestibility of fermented rice straw combined with different levels of green concentrate

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Abstract. One way to further improving the nutritive value of fermented rice straw (FRS) is by combining it with a high-quality feedstuff such as green concentrate. The purpose of this study was to assess the in vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD) of FRS mixed with different levels of green concentrate prepared from different legume trees. The study was carried out according to a completely randomized design consisting of 10 treatments and three replications. The treatments were C = 100% FRS (control), A1 = 90% FRS + 10% Gamal meal, A2 = 80% FRS + 20% Gamal meal, A3 = 70% FRS + 30% Gamal meal; B1 = 90% FRS + 10% Lamtoro meal, B2 = 80% FRS + 20% Lamtoro meal, B3 = 70% FRS + 30% Lamtoro meal, C1 = 90% FRS + 10% Indigofera meal, C2 = 80% FRS + 20% Indigofera meal, and C3 = 70% FRS + 30% Indigofera meal. Data analysis indicated that IVDMD and IVOM of FRS (control) was much less (P<0.05) than those of FRS combined with green concentrate. Among the green concentrate treatments, the IVDMD and IVOMD of FRS mixed with either Lamtoro or Gamal meal were less (P<0.05) than those of FRS combined with Indigofera meal. Among the legume meal treatments, the IVDMD and IVOMD of FRS + Gamal meal were similar (P>0.05) to those of FRS + Lamtoro meal. Within each legume meal, the IVDMD and IVOMD significantly increased (P<0.05) as the level of legume meal in the mixture increased. In conclusion, the nutritive value of fermented rice straw could be boosted through substituting some of the FRS with green concentrate and among three different legume meals used as a green concentrate, the use of Indigofera meal resulting in the biggest improvement in terms of IVDMD and IVOMD compared with the use either Gamal or Lamtoro meal.

1. Introduction

One important factor determining the productivity of ruminant animals is the availability of feed in terms of quantity, quality, and continuity. Indonesia, as a tropical country, experiences two extreme seasons, dry season and rainy season. The production of forage, the main feedstuff for ruminant, is abundant during the rainy season but decreases significantly during the dry season [1]. One alternative of feeds is unconventional feedstuff. The use of such agricultural by-products as rice straw is...
important in fulfilling the needs of feed for ruminants, especially during the dry season. In Indonesia, South Sulawesi produces a great amount of rice straw as the by-product of producing rice. However, the use of such type feedstuff as rice straw has some inherent problems that need to be overcome before feeding to the animal. The high fiber content and the existence of a link between lignin and cellulose or hemicellulose, as well as a high content of silica, make this stuff having low digestibility, which is, in turn, will limit its function for feed [2,3]. In addition, the crude protein content of rice straw is generally very low and variable, depending on the variety and planting management of the rice [1,4–8]. The use of rice straw as the sole diet failed to meet the nutrient requirements of the animal. Using rice straw as a single feed resulting in a bodyweight loss of buffaloes [9], cattle [10], and sheep [11].

In order to improve the nutrient value of the rice straw, it must be processed prior to giving to the animals. Physical, chemical, biological, or their combination, are usually used for improvement. Many studies have been done to evaluate the effects of different processing methods in increasing the nutrient values of rice straw [2–4,7,8,12–19]. Among those processing methods, fermentation is frequently used. The fermentation of rice straw provides some advantages such as better aroma of feed, improved nutrient quality and palatability of feed [11,20,21]. However, the magnitude of the improvement is still not enough yet to meet the minimum requirements of the ruminants [22]. Therefore supplementation with high-quality feed is still required in order to maximize the production of animals consuming rice straw as the main diet.

The use of concentrate supplementation to low-quality forage such rice straw is commonly practiced. The concentrate contains high protein and readily available carbohydrate which can correct the nutrient content of the rice straw. Even though the use of concentrate has been proven to be an effective way to in maximizing the use of rice straw, the high price of concentrate needs to be considered. An alternative to concentrate is by using legume meals or green concentrate [23]. Some of the legume meals that have high crude protein and readily available carbohydrate contents are *Gamal* [24–26], Lamtoro [27,28], Turi [29,30], *Indigofera* [31]. Supplementation of low quality forages with the N rich content feedstuff has been proved to increase the nutrient utilization of that forages by the animal [4,15,22]. Based on this background, it is necessary to study the combination of fermented rice straw with green concentrate to improve feed digestibility. The purpose of this study was to determine the in vitro dry matter digestibility and in vitro organic matter digestibility of fermented rice straw supplemented by different types and different levels of green concentrate.

2. Research materials and methods

2.1. Experimental design

The experiment was carried out according to completely randomized design consisting of 10 treatments and 3 replications for each giving a total number of the experimental unit was 30. The structure of the treatments was:

K = Fermented rice straw without supplementation (Control)

A1 = Fermented Rice Straw (90%) + *Gamal* 10%

A2 = Fermented Rice Straw (80%) + *Gamal* 20%

A3 = Fermented Rice Straw (70%) + *Gamal* 30%

B1 = Fermented Rice Straw (90%) + Lamtoro 10%

B2 = Fermented Rice Straw (80%) + Lamtoro 20%

B3 = Fermented Rice Straw (70%) + Lamtoro 30%

C1 = Fermented Rice Straw (90%) + *Indigofera* 10%

C2 = Fermented Rice Straw (80%) + *Indigofera* 20%

C3 = Fermented Rice Straw (70%) + *Indigofera* 30%
2.2 Fermentation of rice straw and preparation of legume meals
Rice straw, Ciliwung variety, was obtained from the rice fields in the Districts of West Sinjai, Central Sinjai, and South Sinjai. The straw was stacked into several layers. Each layer was roughly 30 cm high. The rice straw was then sprinkled with 6 kg starbio 6 kg urea fertilizer for every 1 ton of rice straw. The straw was then sprayed with water until the water content of straw was approximately 60%. A similar procedure was carried out for the next layer. The final step is to make the haystack become solid and cover it with plastic. The fermentation process was allowed for three weeks. After 21 days, the rice straw was dismantled and aerated. After aerating, the fermented rice straw can be directly given to the animal or stored it as feedstock. Preparation of legume meals was conducted by procuring *Gamal* leaves and *Lamtoro* leaves from the surrounding farmers. While the *Indigofera* leaves were obtained from the farmer groups of Bulukumba and Pinrang Districts. All legume leaves were dried under the sunshine before grounding it to be legume meals.

2.3. Parameters
Parameters measured in this experiment were *In vitro* dry matter digestibility (IVDMD) and *In vitro* organic matter digestibility (IVOMD) of each treatment. The determination of IVDMD and IVOMD was carried out according to the procedure of Minson and McLeod [32]. The coefficient of IVDMD and IVOMD was calculated as follows:

\[
\text{IVDMD} = \left( \frac{\text{DM weight of the sample (g)} - \text{DM weight of the residue (g)}}{\text{DM weight of the sample (g)}} \right) \times 100\%
\]

\[
\text{IVOMD} = \left( \frac{\text{OM weight of the sample (g)} - \text{OM weight of the residue (g)}}{\text{OM weight of the sample (g)}} \right) \times 100\%
\]

DM = dry matter, OM = organic matter

2.4. Data analysis
Data were analyzed using analysis of variance according to a completely randomized design. Contrast orthogonal analysis was used to separate the significant effects of the treatment groups further, while the effects of level within the group were analyzed using orthogonal curve responses [33]. Analysis of data was carried out using SPSS ver 16 [34].

3. Results and discussion
The data for IVDMD and IVOMD of each treatment were presented in Table 1, while the average data of IVDM and IVOMD for each group of treatment were given in figures 1 and 2, respectively.

Contrast orthogonal analysis indicated that the average value for IVDMD and IVOMD of fermented rice straw supplemented with legumes, either with *Gamal*, *Lamtoro*, or *Indigofera*, were significantly higher (P<0.05) than that of fermented rice straw without supplements. Across the supplemented groups (figure 1 and 2), the contrast orthogonal analysis indicated that the IVDMD and IVOMD of fermented rice straw supplemented with *Indigofera* were higher (P<0.05) than those of fermented rice straw supplemented either with *Gamal* or *Lamtoro*, while the IVDMD and IVOMD of the fermented rice straw supplemented with *Gamal* were similar (P>0.05) than those supplemented with *Lamtoro*. Analysis using polynomial contrast was performed to analyze the effects of increasing levels of each green concentrate on the IVDMD and IVOMD of the whole feed. The result indicated that IVDMD and IVOMD linearly (P<0.05) increased as the level of green concentrate increased.

It has been well documented that using rice straw as a single feed could not meet the requirements of the ruminant animals. Therefore, some kinds of processing are required in order to optimize its use as a feed. The utilization of rice straw can be improved in different ways. It could be done either by
physical treatment, chemical treatment, biological treatment, or their combination of them. In addition, the improvement could be made by the feed management system in terms of supplementing the low-quality forage with rich-N content feedstuff, such as legume meals. In this study, each of three different legume meals was mixed by a binary combination with fermented rice straw and analyzed its effects on in vitro dry matter and in vitro organic matter digestibility. The results of this study indicated that supplementation of fermented rice with either of three legume meals significantly increases the digestibility of the whole feed (a combination of rice straw and fermented rice straw).

Table 1. IVDMD and IVOMD of each treatment.

| Treatments | IVDMD (%) | IVOMD (%) |
|------------|-----------|-----------|
| K          | 32.54±0.394 | 28.63±0.366 |
| A1         | 36.23±0.290 | 32.94±0.080 |
| A2         | 40.69±0.418 | 35.40±3.043 |
| A3         | 43.52±0.487 | 41.15±0.143 |
| B1         | 36.27±0.28   | 32.51±0.390 |
| B2         | 40.29±0.453 | 37.45±0.492 |
| B3         | 43.41±0.343 | 40.93±0.138 |
| C1         | 37.36±0.445 | 35.03±0.075 |
| C2         | 42.36±0.333 | 38.54±0.313 |
| C3         | 46.26±0.335 | 42.52±0.423 |

K = Control: Fermented Rice Straw (FRS); A1: FRS (90%) + Gamal 10%; A2: FRS (80%) + Gamal 20%; A3: FRS (70%) + Gamal 30%; B1: FRS (90%) + Lamtoro 10%; B2: FRS (80%) + Lamtoro 20%; B3: FRS (70%) + Lamtoro 30%; C1: FRS (90%) + Indigofera 10%; C2: FRS (80%) + Indigofera 20%; C3: FRS (70%) + Indigofera 30%

The previous study has indicated that the crude protein content of the rice straw could be increased when it is fermented [3,7,8,35–41]. In this study, the N content of fermented rice straw was roughly 7%. Low digestibility of fermented rice straw without supplements has already been predicted beforehand. The average crude protein content of the green concentrate use in this study was roughly 25% [26,27,31,42–44]. Therefore, when the fermented rice straw was mixed with 10- 30% of either one of the three green concentrates used, the crude protein content of the whole feed will be varied.
between 9.5% and 14.5%. This crude protein is much higher than the minimum crude protein content of feed required by the ruminant animal of 7.5% [22,45,46].

![Figure 2. The mean of IVOMD for each group of treatment.](image)

The main reasons why the in vitro digestibility (dry matter and organic matter) of fermented rice straw significantly increased when supplemented with green concentrates is the occurrence of associative effects between fermented rice straw and the green concentrate. The associative effect was known when the digestibility of a mixture of feed is not similar to the sum of each individual component of that feeds. Associative effects are broadly categorized into negative and positive associative effects. The positive associative effect can occur when low-quality forages are supplemented by high N low fiber feedstuff [47]. Many studies (in vitro and in vivo) has shown the improvement of rice straw digestibility when this feedstuff supplemented with feedstuff rich in nitrogen content [4,47–55]

With regard to the types of green concentrate, it is found that the higher levels of concentrate use, the higher the digestibility of the feed. This phenomenon was related to the chemical components of the feed. As discussed before that the crude protein content of the feed (fermented rice straw + green concentrate) is above the minimum requirements. The green concentrate containing high N and readily available carbohydrates could affect the digestibility of the whole feed. A significant linear effect of green concentrate supplementation is an indicator that the optimum level of supplementation is not reaching yet and it is open a possibility for further study for increasing the level of green concentrate. Among the three legumes, Indigofera has the highest impact on the digestibility, while the effects of using either Gamal or Lamtoro was similar. The possible reason for the phenomenon is maybe related to some of the secondary compounds of the green concentrate. It is known that Gamal contains coumarin and Lamtoro contains mimosine that might be contributing to lower digestibility compared to Indigofera [26,31,42,43,56,57].

4. Conclusions
Based on the results and discussion, it can be concluded that the supplementation of fermented rice straw with green concentrate, i.e., Gamal, Lamtoro, or Indigofera can increase the in vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD) of the feed. Among the legume concentrates, the use of Indigofera shows the highest effects on the IVDMD and IVOMD compared to others. Level of supplementation positively affecting the extent of feed digestibility, in which the higher the level of green concentrate, the higher the value of IVDMD and IVOMD.
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