The use of calcined oyster shell and rock flour to improve the nutritive value of rice straw preserved in airtight wrapping for feeding cattle under a tethered herding system

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Abstract. Rice straws are a cheap source of fodder, but they are underutilized as feed due to their low voluntary intake and susceptibility to physical and microbial damage. The present study aimed to define the beneficial effect of calcined oyster shells and rock flour as preservative agents to maintain the physical appearance, palatable component, moisture, nutrient content, and nutritional value of rice straw preserved in an airtight wrapping method. Rice straws in intact and fresh form were sprayed with 1.2% molasses and 0.15% urea solution and sprinkled with 1% calcined oyster shell (cOS), 1% calcined rock flour (cRF), and a mixture of 0.5% cOS+0.5% cRF. The straws were preserved in airtight wrapping for 60 days. Fresh and preserved straws were assessed for organoleptic values, botanical fractions, and proximate and fiber fraction content. The nutritive values were evaluated through a feeding trial using young Pesisir bulls reared under a tethering herding system. There were four experimental diets: fresh rice straw (FRS), cOS preserved rice straw, cRF preserved rice straw, and cOS+cRF preserved rice straw. Parameters measured included DM intake, weight gain, blood hematology, protein, and mineral profiles. Results found that preserved rice straws had higher moisture and crude protein content than fresh straws. Preserved rice straws supplemented with a mixture of calcined shells and rock flour had significantly better texture and microbial status than that of either calcined shell or rock flour. Feeding preserved rice straw supplemented with a mixture of calcined shells and rock flour improved body weight gain that was not significantly different from the fresh straw. In conclusion, using preservatives as a mixture of calcined shells and rock flours produces the best-preserved rice straw for feeding cattle.

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1 Introduction

Pesisir cattle (Bos indicus) is one of the Indonesian indigenous breed cattle and originally habitat in the South Pesisir regency, West Sumatra, Indonesia. The Pesisir cattle are genetically closely related to Bos indicus and B. javanicus and have a unique physical performance with smaller body weight and size and slender legs than the other Indonesian indigenous breeds of Bali, Madura, and Aceh cattle [1,2,3]. The local breed has good reproductive performance, is disease-resistant, and is well-known and adapted to low-quality diets [3,4]. They are currently widely distributed and raised in the coastal areas of Pesisir Selatan, Padang Pariaman, Agam, and Pasaman regency of West Sumatra, where the forage feed sources are relatively limited.

Feeding of the local cattle relies on native grass and rice straw [5]. The small-scale holder traditionally raises the Pesisir cattle in a tethered herding system. The animals are enclosed in cages at night and restrained to graze on indigenous or wild grasses in diverse non-grazing locations throughout the farm or villages, including roadsides, riverbanks, harvested rice fields, fallow land, and tree crop plantations. The availability of natural grass varies seasonally, being more abundant during the wet season and scarce in the dry season. Rice straw is becoming increasingly important during the dry season due to the inadequate availability of native grass.

Rice straw is popular fodder and is freely obtained by farmers because rice cropping is found in almost all villages. Rice straw is usually collected during harvesting day and offered to the animal in fresh form due to cattle preference for fresh straw. Cattle farmers also stock fresh rice straw by staking in the open air. However, the stocked rice straws by loose staking in an open-air stacking encounter undesirable physical changes and are easily infected by fungi, which causes poor flavor and texture [6,7]. As a result, just a portion of the straw gets eaten. The majority are used as bedding or compost material, discarded as garbage, or underutilized as feed.

Rice straw should be kept intact and fresh in airtight, compacted wrapping to keep its moisture level, palatable component, and desirable texture and aroma because cattle prefer fresh ones [6,7]. Feeding cattle with a rice straw-based diet requires energy, nutrients, and mineral supplementation to maintain voluntary intake and cattle performance. Rice straw needs to be supplemented with locally accessible calcite-based minerals, molasses, and urea as mineral, energy, and protein sources before storage since it has low levels of water-soluble carbohydrates, minerals, and protein for microbial growth. Adding preserved rice straws as a supplement may reduce nutrient loss and physical and microbiological contamination while improving growth performance [7]. Bivalve shells and limestone are abundant mineral feed supplies in the West Sumatra region. Compared to raw meal products, calcined limestone, and bivalve shell meal had superior physical qualities, finer particle size, and greater calcium. Calcination of limestones increased magnesium concentration and specific density but reduced micro minerals copper and manganese. The calcined oyster shell had a higher zinc concentration, specific density, and finer particle portion than the uncalcined products. Calcites have antimicrobial properties [8,9,10], mainly related to the alkaline effect caused by the hydration of CaO [10]. Using the local calcites might potentially prevent fungal outbreaks in the preserved rice straw and supply the essential mineral for cattle.

To retain the physical characteristics, pleasant component, moisture, nutrient content, and nutritional value of rice straw maintained using an airtight wrapping method, the current study sought to determine the advantageous effects of additions and calcined oyster shell and rock flour as preservative agents. The most suitable natural preservative agent to preserve nutrients and maintain the nutritional value of rice straw stored in manual airtight wrapping may be a combination of calcined shell and rock fours. Feeding the basic manual preserved rice straw is anticipated to improve feed intake, passage rate, and fiber degradation, leading to improved cattle performance and feed utilization efficiency comparable to that of fresh straw.

2 Materials and Method

2.1 Rice straw preservation

About 1.5 tons of rice straws were collected in five harvesting days and rice fields. The straws of about 300 kg for each period were divided into three parts of 100 kg each. Each part was manually arranged on three stretched ropes and gradually compacted using a concrete culvert. The straws were gradually sprayed with 1.2% molasses and 0.15% urea solution and sprinkled with different calcites as treatments during the arranging and compacting. There were four treatments: T0: fresh straw as a control, T1: 1% calcined oyster shell (cOS), T2: 1% calcined rock flour (cRF), and T3: 0.5% cOS+0.5% cRF, respectively. Molasses and feed-grade urea were dissolved in 15 l of water before being sprayed on the straw [7]. The straws were then rolled up, manually compacted, and tied to the two ends of the rope. The rolled straws were then wrapped up in a plastic sheet and tied at the ends of the plastic. Wrapping is done using black plastic sheets, 3 x 1.5 meters. The airtight-wrapped straws were stored at room temperature for 60 days.

Before the straws were wrapped and supplied, samples of fresh rice straw were gathered. On day 60, samples of conserved rice straw were collected from the outer, center, and middle sections of three distinct pile placements. 15 experienced panelists evaluated the physical appearances of the typical samples, weighing between 900 and 1000 g, by looking at changes in color, texture, scent, and the prevalence of microbiological spoiling as soon as the wrapped straws were opened. The modified 5-point hedonic scale was used to create the panelists' questionnaire, following the process outlined by Khalil et al. [7].

The botanical fractions of the stem, leaf (including blade and sheath), and panicle were then separated from the straw samples by cutting them [6,7]. To determine the yield rate of the straw components, each component was weighed. The weight of the component was divided by the weight of the entire straw, and the result was multiplied by 100 to determine the straw yield rate in percentage. The components of the straw were chopped to a size of roughly 2-3 cm, combined, and baked for 72 hours to dry them. In order to determine the moisture, nutritional, and fiber fraction content, the dried samples were pulverized in a hammer mill until they passed through a 1-mm screen. In accordance with AOAC guidelines, proximate analysis was used to examine the moisture and crude nutrients [11]. The fiber fractions of cellulose, lignin, neutral detergent fiber (NDF), and acid detergent fiber (ADF) were examined using Goering and Van Soest's methods [12]. The variation in hemicellulose (HC) between NDF and ADF.

2.2 Feeding Trial

The feeding trial lasted for eight weeks, from July to August 2023. Four young male Indonesian- indigenous Pesisir cattle of 7-8 months were used. The cattle had an initial body weight of 78.1±11.4 kg. The animals were housed in separate enclosures with buckets for drinking water and feed troughs, following the Republic Indonesian Law No. 18 of 2009, which serves as the national ethical guideline for animal care. From early in the morning until late in the afternoon, the animals were tied to wild forages that grew freely around the property.

The fresh and preserved rice straws were chopped and fed to the experimental cattle in four treatments: T0: fresh rice straw (FRS) (control), T1: cOS preserved rice straw, T2: cRF preserved rice straw, and T3: cOS+cRF preserved rice straw. The straws were offered to the animals in pens in the late afternoon after the animals were tethered around the farm. The feeding trial was conducted in a 4x4 Latin Square design for a seven-day adaption period. Data gathering thereafter takes place for four days every period [7]. Additionally, self-mixed concentrates were provided to the animals to satisfy their nutritional and energetic needs [13]. Rice bran (17.68%), soybean meal (17.28%), chopped cassava tuber peel (19.18%), and palm kern meal (44.3%) make up the concentrate.

Parameters measured included feed intake (straws and concentrate) and body weight gain, feed intake, blood minerals (Ca, P, Mg), blood haematology (haemoglobin [HGB], total red blood cell [RBC], white blood cell [WBC], lymphocyte [LYM]), and total protein. Determination of the haematological parameters was performed by using a Medonic Veterinary Hematology analyzer (Medonic CA 620, Sweden). The total protein, calcium, phosphorus, and magnesium serum concentration was analyzed using an auto-analyzer (Mindray).

3 Results and Discussion

3.1 Physical appearance and straw component

Tables 1 and 2 show the preserved rice straws' physical appearance and parts compared to the fresh ones. The color of preserved straws turned into light amber brown. The degree of color obtained (yellowish to light-yellow) in the present study was close to the original color of fresh rice straw before storing, which indicates the success and quality of preserved rice straw. The preserved straws had a pleasant alcoholic-fermented aroma and soft, brittle texture. The texture had so significant changes compared to the fresh one.

A few fungal spots were observed on the outer layer of preserved straws (T1, T2, and T3). The most intensive fungal contamination was found in rice straws preserved with calcined rock flour (T2). The microbial contamination was significantly reduced using a preservative agent composed of a calcined shell and rock mixture (P3). The present study revealed that the effectiveness of calcites as a preservative agent increased if the calcined shells were combined with calcined rock. The positive effect is presumably due to the increase in the concentration of calcium and magnesium hydroxides in the calcite products. Calcium and magnesium in CaO and MgO had a more substantial effect on depressing microbial development [9]. There is also a finding on the composition of calcium oxide in seashells, which is higher than that of limestone [14].

As shown in Table 2, the stem was the most significant portion of the straw component, followed by the leaf and panicle. The preserved straws supplemented with calcined shells or rock flour (T1 and T2) had significantly higher leaf portions than the fresh straw (T0).

Rice straw's digestibility and intake were based on the percentage of its constituent parts [15]. The leaves have a poorer dry matter digestibility (50–51%) than the stems (61%) because they contain more acid-insoluble ash and less NDF [15]. There was no significant effect of preservation and addition of preservative agents on the portion of stem and panicle components. The results indicate the possibility of preserving fresh rice straw with an added additive and a mixture of calcined shell and rock flour as a preservative agent to minimize fungal contamination, maintaining preserved straws' color, and texture, and a palatable component of stems equivalent to fresh straw.

Table 1. The organoleptic values of fresh and preserved rice straws.

Parameter	Fresh straw	Preserved straws +calcined:		
		Oyster shell	Rock flour	Oyster shell+ rock flour
	(T0)	(T1)	(T2)	(T3)
Color	9.07^{a}±0.08	6.69^{b}±0.98	6.49^{b}±0.80	8.78^{b}±0.33
Flavor	9.02±0.11	7.89±0.45	7.57±0.97	8.70±0.23
Texture	9.03^{a}±0.10	7.38^{b}±0.61	6.46^{c}±0.94	8.89^{a}±0.17
Fungal contamination	9.10^{a}±0.03	7.45^{b}±0.89	6.43^{c}±1.14	8.57^{a}±0.49

^{a,b,c} values within a row with different superscripts differ significantly ($p < 0.05$)

Table 2. The botanical component of fresh and preserved rice straws.

Parameter	Fresh straw	Preserved straws +calcined:		
		Oyster shell	Rock flour	Oyster shell+ rock flour
	(T0)	(T1)	(T2)	(T3)
Stem	61.66±5.26	50.21±15.47	55.71±10.37	51.38±1.08
Leaf	28.99^{b}±4.87	40.34^{a}±12.21	34.75^{ab}±8.13	38.66^{b}±3.23
Panicle	9.35±3.34	9.45±3.52	9.53±2.99	9.95±3.20
Stem	61.66±5.26	50.21±15.47	55.71±10.37	51.38±1.08

^{A,b} values within a row with different superscripts differ significantly ($p < 0.05$).

3.2 Proximate composition and fiber fraction

Table 3 presents the moisture, DM, crude nutrient, and fiber fraction content. The preserved rice straws (T1, T2, T3) had significantly higher moisture and crude protein content than the fresh straw (T0). Using additive and preservative agents significantly increased the moisture and crude protein but reduced the DM content of the preserved straws. The moisture and crude protein levels were kept at or above those of fresh straw by wrapping, which stopped moisture and nitrogen from evaporating [7]. The moisture and crude protein increased from 57.6 and 6.7% of the fresh straw (T0) to 70.7-74.8% and 9.3-10.1%, respectively. Table 3 shows no statistically significant effect of preservation on crude ash, fiber, and fiber fraction content. The crude nutrient and fiber fraction composition was based on the percentage of straw parts [15]. Table 3 illustrates that adding calcites and preservation had no discernible impact on the portion of stems and panicles. Another study from China found that ensiling broke down the physical structure of rice straw and decreased its hemicellulose and NDF concentration [16].

3.3 Cattle performances

The results of the feeding trial are presented in Table 4. Cattle fed on preserved rice straws (T1, T2, T3) had significantly lower feed intake than fresh rice straw (T0). The differences in the DMI are likely to be related to the differences in the DM content (Table 3). There was no significant difference in DM feed intake among the preserved rice straws. However, feeding preserved rice straws using a calcined shell and rock mixture(T3) had significantly higher body weight gain than the other preserved straws (T1, T2). The Pesisir cattle fed on preserved rice straws supplemented with a mixture of calcined shell and rock (T3) had significantly higher body weight gain than that fed on rice straws supplemented with either calcined shells (T1) or calcined rock flour (T2). The weight gain of cattle fed on preserved rice straw supplemented with a mixture of calcined shells and rock flour (T3) equals fresh straw (T0).

Table 3. Proximate composition and fiber fraction of fresh and preserved rice straws.

Parameter	Fresh straw	Preserved straws +calcined:		
		Oyster shell	Rock flour	Oyster shell+ rock flour
	(T0)	(T1)	(T2)	(T3)
Crude nutrient				
Moisture (% FW)	57.55^{b}±5.02	70.71^{a}±.4.09	71.26^{a}±1.79	74.79^{a}±5.40
Dry matter (% FW)	42.45^{a}±5.02	29.29^{b}±4.09	28.74^{b}±1.79	25.21^{b}±5.40
Crude ash (% DM	18.48±3.15	22.60±2.55	22.92±0.77	20.49±3.88
Crude protein (% DM)	6.74^{b}±1.27	9.26^{a}±0.85	10.00^{a}±0.81	10.11^{a}±1.75
Neutral detergent fibre (NDF)	78.16±1.05	75.29±6.37	75.83±7.55	74.61±4.55
Acid detergent fiber (ADF)	58.18±1.34	56.35±4.39	55.71±3.64	54.48±3.23
Hemicellulose	19.99±1.06	18.94±4.72	20.12±6.39	20.12±3.88
Cellulose	31.47±1.61	33.49±0.93	35.61±2.30	34.60±9.12
Lignin	10.73±1.13	8.06±3.67	9.22±3.95	8.84±2.35
Silica	15.98±3.91	14.83±4.77	10.90±4.47	11.05±1.44

^{A,b} values within a row with different superscripts differ significantly ($p < 0.05$).

As shown in Table 4, there was no significant difference in blood haematology, minerals, and protein. The results indicate no health problems for the animals fed on preserved rice straws. The red blood cell counts (RBC) and haemoglobin concentration (HGB) reported in this study were close to the typical standard values of 5.3-7.9 g/dL and 9-15 g/dL for cattle reported by McDowell [17] and Roland et al. [18], respectively. The haemoglobin concentration (HGB) range in this study fell within the 9-15 g/dL range reported by Roland et al. [18]. White blood cells (WBCs) and lymphocytes (LYM) play an essential role in immune defence [18]. The values of WBC and LYM were within the normal range [17, 18]. There is a tendency for cattle to be fed on preserved rice straws using a mixture of calcined shell and rock flour (T3) to have better blood profiles in terms of white blood cells, lymphocytes, calcium, and protein than other preserved straws (T1, T2) and equivalent to that fed on fresh straw (T0). Considering the normal standard and critical level of the blood for Ca (8.0 mg/dL) [17], the results suggest that blood plasma Ca in the cattle fed on fresh rice straw (T0) was far below the critical limits. The animals were suspected to be deficient in mineral Ca. Fresh rice straw is poor calcium. Rice straw also has a relatively high lignin and oxalate content, affecting calcium digestibility [19, 20]. The present results proved that the supplementation of preserved rice straws with calcites supplied adequate mineral requirements and improved the nutritional value of rice straws.

The result also indicates that using locally available natural preservative agents could improve the quality of rice straws preserved in a wrapping method close to the fresh straw's nutritional values. Adding molasses as a sugar-rich material provides water-soluble carbohydrates for rumen organisms. It stimulates lactic acid bacterial fermentation in anaerobic storage conditions, ensuring good fermentation quality and positively affecting the preserved rice straw's aroma, moisture content, and fiber digestibility [21,22]. Urea is a nitrogen source and a delignifying agent through ammonization [22]. Rice straw, as the major crop by-product and available in large quantities during rice harvesting season in the West Sumatra region, can be effectively utilized for local cattle feeding in fresh and preserved form.

Table 3. Proximate composition and fiber fraction of fresh and preserved rice straws.

Parameter	Fresh straw	Preserved straws +calcined:		
		Oyster shell	Rock flour	Oyster shell+ rock flour
	(T0)	(T1)	(T2)	(T3)
Total DM intake (g/head/period):	1589.3^{a}±339.4	715.3^{b}±1089	755.7^{b}±100.0	886.6^{b}±59.0
(Rice straw, g/head/period)	1383.1^{a}±343.3	470.3^{b}±109.3	526.6^{b}±99.4	670.3^{b}±56.2
− (Concentrate (g/head/period)	206.1^{b}±22.0	245.0^{a}±1.1	209.1^{b}±5.5	216.3^{b}± 8.2
Live body weight gain:				
− Total weight gain (g/head/period)	1200.0^{a}±81.7	875.0^{b}±95.7	825.0^{b} ±50.0	1100.7^{a}±81.7
− Daily weight gain (g/head/day)	300.0^{a}±20.4	218.8^{b}±23.9	206.3^{b}±12.5	275.0^{a}±20.4
Blood haematological profile				
− RBC (x10^{6}/µL)	5.8±1.3	6.6±1.5	6.0±0.7	6.1±0.5
− HGB (g/dL)	8.6±1.1	9.8±1.5	9.0±0.9	8.7±0.6
− WBC (x10^{3}/µL)	8.7±2.3	8.5±2.3	7.5±1.5	8.6±2.5
− LYM (10$_{3}$/µL)	6.0±1.8	5.5±1.7	4.7±1.5	6.2±2.3
Blood mineral (mg/dL):				
− Calcium	5.2±4.5	8.5±2.8	7.2±1.6	8.4±2.4
− Phosphorus	6.4±1.9	5.3±1.4	5.3±1.3	4.4±3.5
− Magnesium	2.7±0.2	2.5±0.3	2.6±0.2	2.5±0.3
Total protein (mg/dL)	12.7±5.0	12.4±4.5	11.1±4.0	12.6±4.7

^{a,b} values within a row with different superscripts differ significantly ($p < 0.05$).

4 Conclusion

Rice straws preserved in airtight wrapping increased moisture and crude protein content and reduced color value compared to fresh straws. Preserved rice straws supplemented with calcined shells and rock flour had better texture and microbial contamination values. Feeding the preserved rice straws supplemented with a calcined shell and rock to the Pesisir cattle increased body weight gain equivalent to fresh straw. In conclusion, using preservatives as a mixture of calcined shells and rock flours produces the best-preserved rice straw for the Pesisir cattle.

Acknowledgement

This article is part of a project entitled "The Use of Local Calcites to Improve Storage Stability and Nutritive Value of Bulk Stored Rice Straw for Feeding Pesisir Cattle under a Tethering Herding Systems". The Andalas University financially supported the project through the Directorate of Research and Community Service (LPPM) (Contract No: T/17/UN16.19/PT.01.03/Pangan-RPB/2023) Fiscal Year 2023).

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