Research Article

Simple Bulk Storage Methods to Maintain the Physical Properties, Botanical Component, Nutrient Content, and Nutritional Values of Rice Straw Supplemented with Calcite-Based Minerals, Molasses, and Urea

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Abstract | Rice straw is underutilized as feed due to low voluntary intake and is susceptible to physical and microbial damage during storage. The present research aimed to find a practical bulk storage method to maintain the palatable component, moisture, nutrient content, and nutritional value of rice straw supplemented with 1% calcite-based mineral mixture, 0.6% molasses, and 0.05% urea. The supplemented straws were stored for 60 days in three bulk treatments: loose stacking, open-tied rolling, and airtight wrapping. The changes in physical appearances, botanical fraction, proximate, and fiber fraction content were determined. The nutritive values of stored rice straws were evaluated by feeding four male Indonesian-indigenous Pesisir cattle in a 4x4 Latin Square design. There were four experimental diets: basal diet + fresh rice straw (FRS), basal diet + stacking-supplemented rice straw (SSRS), basal diet +rolling-supplemented rice straw (RSRS), and basal diet + wrapping-supplemented rice straw (WSRS). The diets were fed. Parameters measured included: live weight gain (LWG), dry matter intake (DMI), feed conversion ratio (FCR), and nutrient digestibility. Storage of the supplemented straw by wrapping minimized the change of color, flavor, texture, microbial contamination, and moisture content but increased the crude protein and reduced the crude fiber content. Feeding the stored rice straw gave no significant effects on cattle performances. The results suggested that wrapping was the most appropriate method to maintain the moisture, and nutrient content of supplemented rice straw during storage.

Keywords | Calcined mineral, Physical appearance, Rice straw storage, Supplemented rice straw, Pesisir cattle

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INTRODUCTION

Beef cattle production in the West Sumatra region, Indonesia, relies on native grass and rice straw. The livestock feeds native grass or wild forages growing in various non-grazing areas around the farm or villages, such as roadside, riverbank, harvested rice fields, idle land, and tree crop estates (Yuherman *et al*., 2017). The availability of native grass fluctuates throughout the year, being more available during the rainy season and scarcity in the dry season. Of the grazing forage inadequacies, the farmer offers additional feed on the farm using locally available crop by-products such as rice straw. However, the voluntary intake of rice straw is lower than native grass due to slow ruminal degradation, low energy and nutrient content, and poor storage stability (Abo-Donia *et al*., 2022; Khalil *et al*., 2023). Consequently, the animal could not satisfy their energy and nutrient requirements to maintain growth and reproduction, and the amount of rice straw used as feed is much lower than their availability.

Rice straw is categorized as a highly fibrous forage with a relatively low available energy, protein, and mineral content. The daily intake of rice straw is limited to less than 2% of animal body weight or 1.0-1.5 kg per 100 kg live weight due to high content and slow degradation of cell wall component in the rumen (Oladosu *et al*., 2016; Aquino *et al*., 2020). The cell wall of rice straw composes of approximately 40% cellulose, 18% hemicellulose, 5-12% lignin, and 5-15% silica (Wyman *et al*., 2005; Van Soest, 2006; Trach and Tuan, 2008; Oladosu *et al*., 2016; Nguyen and Dang, 2020; Otero-Jimenez *et al*., 2021). Several researchers reported that the digestibility, nutritive value, and utilization of rice straw improved by physical and biological treatments (Fadel-Elseed, 2005; Wanapat *et al*., 2009). However, the pre-feeding treatments are not economical and practically feasible for small-scale farmers because rice straw is usually fed to the animal in intact and fresh form.

Moreover, rice straw is abundantly available during the rice harvesting season. Rice straw is usually collected during harvesting day and fed to cattle in intact and fresh form. Due to the seasonality of rice harvesting, the fresh straw is also stocked on the farm in open-air loose stacking or manual tied rolling. Our previous study found that the fresh straw stored by the traditional open-air system significantly decreased moisture content and palatable stem component and encountered undesirable microbial damages and physical changes of rot or toughness, resulting in poor organoleptic values and digestibility (Khalil *et al*., 2023). Consequently, only some part of the straw is consumed by cattle. Most stocked rice straws are disposed of as waste or used as bedding or compost material. It is likely the main factor causing rice straw to be underutilized as feed on the traditional farm. The loss rate of rice straw stocked in the conventional ways reached 30%-50% in China (Li *et al*., 2018) and 20-30% in Bangladesh (Sarker *et al*., 2018).

Rice straw is a potential feed source for small-scale cattle holders due to its low cost and abundant availability. Optimizing the use of rice straw as feed requires supplementation and practical and effective long-term storage strategies to maintain the voluntary intake and the availability of nutrients and energy for efficient utilization of rice straw for the traditional small-scale cattle farm. Due to cattle's preference for a fresh one, the rice straw should be preserved in intact and fresh form by manual compacting and wrapping to produce straw silage which maintains the moisture content, palatable component, and good texture and aroma (Sultana *et al*., 2020). Since the successful ensiling of rice straw is difficult due to insufficient compacting, its hollow stem, low content of water-soluble carbohydrates, mineral and protein for microbial growth (Kim *et al*., 2017), there is a need to supplement the fresh straw with local available calcite-based mineral, molasses, and urea as mineral, energy, and protein sources before storage. The manual wrapping of the supplemented rice straw might also minimize physical and microbial contamination and nutrient loss.

Nutrient supplementation needs to be designed to positively affect the mineral, energy, and protein availability and storage stability. The West Sumatra region is rich in mineral feed sources of limestone and bivalve shells (Khalil and Anwar, 2008; Khalil *et al*., 2018). Calcined limestone and bivalve shell meal contain higher calcium, finer particle size, and better physical properties than raw products (Khalil *et al*., 2021). Calcite also has antifungal properties (Oikawa *et al*., 2000; Li *et al*., 2014; Yao *et al*., 2014; Ha *et al*., 2019). The addition of the calcite-based mineral mixture could inhibit the proliferation of undesirable microorganisms in the manually compacted and wrapped rice straw during storing and supplying the essential mineral for ruminal organisms and the host animal. Minerals such as calcium (Ca), sulphur (S), phosphorus (P), magnesium (Mg), copper (Cu), and zinc (Zn) play an essential role in the synthesis and activity of microorganisms in the rumen (Wanapat *et al*., 1996).

The addition of molasses as sugar sugar-rich material provides water-soluble carbohydrates for rumen organisms. It stimulates the lactic acid bacterial fermentation in anaerobic storage condition, which ensure good fermentation quality and might positively affect the aroma, moisture content, and fiber digestibility of the stored rice straw (Oladosu *et al*., 2016; Sarker *et al*., 2018). Urea is a nitrogen source and a delignifying agent through ammonization (Oladosu *et al*., 2016). It is expected that feeding of the manual compacted wrapping of the nutrient-enriched rice straw will enhance feed intake, rate of passage, and fiber degradation, resulting in better cattle performance and feed utilization efficiency.

The present research aimed to evaluate the effects of manual loose stacking, tied rolling, and airtight wrapping to maintain the organoleptic value, palatable component, moisture, nutrient content, and nutritional value of stored rice straw supplemented with the calcite-based mineral mixture, molasses, and urea for feeding of the local cattle. It is hypothesized that wrapping of supplemented fresh rice straw was considered the most appropriate handling method to preserve nutrients and maintain the nutritional value of intact rice straw during storage due to the optimal beneficial effect of the preservative activity of calcites, readily fermentable molasses, and minimum loss of protein. The product quality of wrapping-supplemented straw is equivalent to that the fresh straw.

MATERIALS AND METHODS

Preparation and packing of rice straw

A total of 1.8 tons of fresh rice straw were directly collected by harvesting day in five different periods and rice fields. The intact straw of about 360 kg for each period was divided into three parts of about 120 kg. Each part was manually packed or arranged in three different bulk treatments: loss stacking (stacking), tie compacted rolling (rolling), and airtight compacted wrapping (wrapping). The stacking of rice straw was done by plugging a wooden pole 1.5 m high on the floor. The straw was gradually piled up and compacted by hand pressure around the bar. The second part was rolled by stretching three ropes on the floor, and then rice straws were arranged and pressed by hand pressure on the rope gradually. After all the straws were placed, they were manually rolled up, compacted by pressing with hands and feet, and tied to the two ends of the rope. Wrapping used a black plastic sheet of 3 x 1.5 meters. The rice straw is manually rolled up, compacted, and tied with string, then airtight wrapped with the black plastic sheet and tied at the ends of the plastic.

Supplementation and storage of rice straw

During the process of stacking, rolling, and wrapping, the straw was gradually sprayed with molasses (0.6%) and urea (0.05%) by using a plant watering sprayer and sprinkled manually with the calcite-based mineral mixture (1%). Molasses and urea were dissolved in 15l of water before being sprayed on a straw. The mineral mixture composed of calcined limestone (20.9%), calcined oyster shell (18%), limestone (20%), dicalcium phosphate (20%), iodized kitchen salt (14%), cobalt ($CoCO_3.6H_2O$) (0.1%), copper sulphate ($CuSO_4.5H_2O$) (1%), zinc sulphate ($ZnSO_4.7H_2O$) (1%), and premix (5%). The mineral concentrations were designed to complement the mineral deficiency of the local rice straw and forages (Yuherman *et al*., 2017) to meet the standard mineral requirement for cattle, according to NRC (1996). The packed straws were stored at room temperature for 60 days on a cattle farm.

Sampling and assessment of physical appearance

Samples of fresh rice straw were collected before straws were supplemented, stacked, rolled, and wrapped. Samples of stored rice straw were collected on day 60 in three different pile positions (surface, middle, and inner part). The representative samples of about 900-1000 g were assessed for physical appearances organoleptically by five trained panelists on the changes of color, aroma, texture, and microbial spoilage prevalence immediately after opening the stacked, rolled and wrapped straws according to the procedure described by Oladosu *et al*. (2016), Manaye *et al*. (2018), and Nguyen and Dang (2020). The panelists questionnaire was prepared using the modified 5- point hedonic scale described by Nguyen and Dang (2020), as shown in Table 1.

Sample preparation and chemical analysis

The straw samples were cut to separate the botanical fractions of the stem, leaf (including blade and sheath), and panicle, according to Nori *et al*. (2006). Each part was weighed to calculate the yield rate of the straw components. The straw yield rate in % was calculated by dividing the weight of the part divided the weight of the whole straw and multiplying it by 100. The straw components were chopped to the size of about 2 cm, mixed, and dried for 72 hours in the oven. The dried samples were ground to pass through a 1- mm sieve in a hammer mill for moisture, nutrients, and fiber fraction content. The moisture and crude nutrients were analyzed using proximate analysis according to AOAC (2016). The fiber fraction of Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), cellulose, and lignin was analyzed according to the procedures of Goering and Van Soest (1970). Hemicellulose (HC) was calculated by the difference between NDF and ADF.

Table 1: Description of organoleptic assessment for physical appearances of the fresh and stored rice straw.

Hedonic scale	Physical appearances, aroma, and microbial spoilage			
	Color	Aroma	Texture	Microbial spoilage
7.1-9.0	Bright greenish yellow, specific to the colour of fresh straw	Normal, specific smell of fresh rice straw	Normal, specific fresh rice straw	Fungal or yeast spot free, specific fresh straw
5.1-7.0	Light amber brown	Pleasant aroma, alcoholic or sweet aroma	Soft, wet, and brittle	Few fungal spots on the straw surface
3.1-5.0	Brown	Bland, tasteless, minimal smell	Clumping, slightly wet and soft	More fungal spots on the surface and in inner pile
1.1-2.9	Dark brown	Ammonia smell	Slightly clumpy, slightly dry and tough	Lots of fungal spots, outside and inside the pile
≤1	Black, like coffee drink colour	Musty and rotten aroma	Dry and clay	Full of fungal spots all over the straw

Preparation of experimental diets

The nutritional value of the stored rice straw was evaluated through a feeding trial. The straws were chopped and mixed with 25% with a basal diet composed of 55% elephant grass and 20% concentrate. There were four experimental diets: T0: basal diet + fresh rice straw (FRS) (control), T1: basal diet + stacking-supplemented rice straw (SSRS), T2: basal diet + rolling-supplemented rice straw (RSRS), and T3: basal diet + wrapping-supplemented rice straw (WSRS). The feed formula and nutrient composition of the experimental diets are presented in Table 2. Self-mixed concentrated feed composed of palm kern meal (49.4%), chopped cassava tuber peel (21.6%), soybean meal (19.3%), rice bran (8.4%), kitchen salt (0.53%), limestone (0.24%), and premix (0.53%) with crude protein and TDN content of about 18 and 69%, respectively.

Table 2: Feed ingredient and nutrient composition of experimental diets.

Feed	Experimental diets mixed with			
	FRS (T0)	SSRS (T1)	RSRS (T2)	WSRS (T3)
Elephant grass	55.0	55.0	55.0	55.0
Concentrate	20.0	20.0	20.0	20.0
Fresh rice straw (FRS)	25.0	-	-	-
Staking-supplemented rice straw (SSRS)	-	25.0	-	-
Rolling- supplemented rice straw (RSRS)	-	-	25.0	-
Wrapping- supplemented rice straw (WSRS)	-	-	-	25.0
	100.0	100.0	100.0	100.0
Nutrient composition (% DM)				
Crude protein	10.53	10.48	10.58	10.98
Crude fiber	27.72	27.85	26.83	26.46
Crude fat	2.81	2.85	2.85	2.85
Crude ash	13.38	14.83	15.62	14.11
TDN	58.67	57.89	57.57	59.12
DM	40.43	46.58	43.91	37.90

Experimental animals

We used four male Indonesian-indigenous Pesisir cattle (10-12 months of age) with an initial body weight of 99.4±6.7 kg. The experimental diets were fed to the animals in a 4×4 Latin Square design for seven days adaptation period and subsequently four days for data collection for each period by following the method described Budiono *et al*. (2000). The animals were kept in individual pens which were equipped with feed troughs and drinking water buckets. Animal care procedures followed the national guideline ethic for animal care based on the Republic Indonesian low number 18 of 2009. There was no treatment or handling that harmed or impeded the animals freedom.

Cattle performance and apparent nutrient digestibility

Parameters measured included: dry matter intake (DMI); live body weight gain (LWG); feed conversion ratio (FCR); apparent digestibility of DM, organic matter (OM), crude nutrients, and fiber fractions. During data collection, the feed intake was recorded daily by weighing the amount of grass, concentrate, and rice straw offered and refused. Fresh feces were collected and weighed three times a day (morning, afternoon, and evening). About 150 g of representative samples of fresh feces was dried under the sun for 48 hours and then in an oven at 60°C for 24 hours. The air-dried samples from each animal were bulked and ground to pass through a 1-mm sieve in a hammer mill for moisture, crude nutrients, and fibre fraction content analysis. Apparent digestibility was measured as the portion of nutrient intake, not retrieval in the feces (Abo-Donia *et al*., 2021).

Statistical analysis

Data on the storage experiment were statistically analyzed in one-way variance analysis. Data on the feeding trial were accounted for in the 4×4 Latin Square design using the SPSS software program version 18. Duncan's Multiple Range (DMRT) was applied to separate means. Differences were considered significant at $P<0.05$.

RESULTS AND DISCUSSION

Physical appearances

Data on the values of organoleptic assessment and the botanical component of the fresh and supplemented rice straw stored for 60 days are presented in Table 3. Compared with the WSRS and FRS, the color, flavor, and texture of SSRS and RSRS changed significantly to pale yellow and light brown, with an undesirable bland flavor and clumping texture. The stem turned to dry and rot in the stacked and rolled straw, resulting in poorer flavor, color, and texture than the WSRS. The leaves and panicles of the SSRS and RSRS were visually found to be spoiled by white fungal spots, resulting in significantly lower microbial values than the WSRS. There was no beneficial effect of adding calcite-based mineral mixture and molasses to control microbial growth and undesirable flavor and texture if the rice straw was stored in the traditional open-air staking and rolling. Adding molasses solution has even induced the proliferation of unwanted aerobic microorganisms in the outer layer and decay in some parts of the inner pile of the open-air storage condition, thus resulting in moldy rice straw.

Table 3: The organoleptic values of fresh and supplemented rice straws stored in different methods.

Parameter	Fresh straw	Storage treatment			P value
		Stacking	Rolling	Wrapping	
	(FRS)	(SSRS)	(RSRS)	(WSRS)	
Color	8.10^{a}±0.38	6.04^{b}±0.72	4.24^{b}±0.69	6.60^{ab}±2.03	0.00
Flavor	8.02^{a}±0.15	5.08^{b}±0.91	4.52^{b}±2.14	6.92^{a}±0.17	0.00
Texture	8.06^{a}±0.38	3.64^{b}±1.88	4.76^{b}±0.82	7.96^{a}±1.48	0.00
Fungal contamination	8.50^{a}±0.50	6.52^{b}±1.24	5.96^{b}±1.45	7.24^{ab}±1.63	0.04

Table 4: The botanical component of fresh and supplemented rice straws stored in different methods (%).

Straw component	Fresh straw	Storage treatment			P value
		Stacking	Rolling	Wrapping	
	(FRS)	(SSRS)	(RSRS)	(WSRS)	
Stem	43.14^{a}±3.31	20.51^{c}±2.69	18.47^{c}±2.25	25.55^{b}±3.04	0.00
Leaf	47.78^{c}±3.48	66.68^{b}±3.89	72.92^{a}±1.91	66.05^{b}±4.11	0.00
Panicle	9.06^{b}±0.89	12.80^{a}±2.03	8.60^{b}±1.36	8.39^{b}±1.94	0.00

On the other hand, airtight wrapping (WSRS) could minimize the undesirable change in organoleptic values and microbial contamination. The WSRS had significantly better flavor, texture, and microbial spoilage values than SSRS and RSRS. Wrapping maintained the desirable physical characteristics of pleasant aroma, light yellow color, soft and brittle texture, and very few microbial contaminations, which are close to the values of the fresh one. It could also be attributed to good fermentation, inhibiting undesirable microorganisms by adding molasses and calcite-based minerals, which might maintain the straw's palatability (smell, texture, and color) (Sultana *et al*., 2020). Storage of the supplemented rice straw in the airtight wrapping was treated anaerobically as a silage process to prevent spoilage by an aerobic microorganism and rapid decline in pH value by lactic acid bacteria (Xu *et al*., 2023). The firm texture and pleasant aroma indicated the success of ensiling rice straw. Sultana *et al*. (2020) reported that adding molasses to the airtight fresh rice straw stored for 90 days during fermentation indicated a successful fermentation, resulting in good ensilage quality, color, smell, and no fungal growth. Abo-Donia *et al*. (2021) reported that using water or molasses plus urea improved the quality of the ensiling rice straw.

Botanical component

Rice straw comprises a stem, leaf blades, sheath, and panicles. As shown in Table 4, storage of supplemented rice straw significantly reduced the stem's percentage but increased the leaf part rate compared to the fresh one. The highest percentage of leaf, panicle and lowest stem parts was recorded in the RSRS and SSRS. However, WSRS has the lowest stem decreasing among the stored rice straw due to minimal moisture loss (Table 4). The stem was the most palatable part and contained the highest moisture content of 79-80%, followed by the leaf (58-67%) and the panicle (50-55%) (Khalil *et al*., 2023). It means that wrapping minimizes the loss of stem as the most palatable and degradable straw component. The proportion of straw parts determined the intake and digestibility of rice straw (Vadiveloo, 2000).

Crude nutrient and fibre fraction content

The moisture, DM, crude nutrient, and fiber fraction composition of the stored rice straw compared to the fresh straw are presented in Table 5. Except for crude fat, storage and supplementation of rice straw significantly affected the moisture, dry matter, and crude nutrient content. Adding a calcite-based mineral mixture and urea significantly increased crude ash and protein content but reduced crude fiber and cellulose in the stored rice straws. The SSRS and RSRS had significantly higher dry matter and crude ash but lower moisture and crude protein than the WSRS. Lower crude ash content in the WSRS might be due to the utilization of ash for microbial growth during the ensiling period (Sarker *et al*., 2018).

The open-air storage method of SSRS and RSRS allowed for freely evaporation of moisture and nitrogen, causing the drying process and nitrogen loss. Besides cellulose, there was no significant effect of storage and nutrient supplementation on NDF, ADF, hemicellulose, and lignin content. The significantly lower crude fiber and cellulose and slightly higher moisture content in the RSRS than the SSRS occurred presumably due to decay processes, mainly on the inside part of the pile of the rolling straw. The study's crude fiber and cellulose decrease may be due to decomposition and fermentation, thereby indicating the utilization of these constituents for the proliferation of microbes during storage (Sarker *et al*., 2018).

Table 5: Nutrient composition of fresh and supplemented rice straws stored in different methods.

Parameter	Fresh straw	Storage treatment			P-value
		Stacking	Rolling	Wrapping	
	(FRS)	(SSRS)	(RSRS)	(WSRS)	
Crude nutrient					
Moisture (% FW)	64.84^{a}±4.92	31.35^{b}±16.01	42.04^{b}±15.30	66.08^{a}±8.85	0.00
Dry matter (% FW)	35.51^{b}±4.92	68.64^{a}±16.01	57.96^{a}±15.30	33.91^{b}±8.85	0.00
Crude ash (% DM	19.36^{c}±0.90	24.88^{ab}±1.54	28.02^{a}±5.47	21.98^{bc}±5.95	0.00
Crude protein (% DM)	5.26^{b}±1.10	6.23^{b}±10.84	6.63^{ab}±0.64	8.03^{a}±1.40	0.02
Crude fat (% DM)	1.50±0.58	1.27±0.47	1.28±0.47	1.28±0.46	0.81
Crude fibre (% DM)	33.58^{a}±5.21	29.68^{ab}±5.27	25.63^{c}±1.91	24.13^{c}±5.29	0.03
Fibre fraction (% DM)					
Neutral detergent fibre (NDF)	79.69±3.99	76.22±5.02	74.21±3.94	78.09±3.63	0.27
Acid detergent fiber (ADF)	58.29±2.04	58.89±3.11	54.44±10.93	57.44±1.98	0.59
Hemicellulose	27.90±7.48	17.32±2.74	19.77±13.32	20.65±2.19	0.29
Cellulose	36^{a}.58±1.61	32.51^{ab}±5.11	28.08^{b}±8.19	33.11^{ab}±4.26	0.08
Lignin	7.50±1.11	7.92±0.93	7.51±2.35	6.46±1.18	0.35

Table 6: Digestibility of crude nutrient and fiber fraction of experimental diets (%).

Parameter	Experimental diets mixed with				P-value
	FRS	SSRS	RSRS	WSRS	
DM and crude nutrient					
Dry matter	72.38±0.58	70.14±8.14	62.17±10.63	70.01±4.15	0.14
Organic matter	76.44^{a}±2.28	71.99^{ab}±5.87	68.29^{b}±7.79	70.99^{b}±4.70	0.04
Crude protein	79.65±3.37	84.24±3.97	80.66±6.15	81.41±3.67	0.48
Crude fibre	84.10±2.66	80.41±13.22	77.87±20.24	71.60±16.04	0.41
Fiber fraction					
NDF	85.60^{a}±0.52	81.44^{ab}±5.70	79.21^{b}±4.87	85.28^{a}±2.47	0.07
ADF	54.94±1.01	52.03±14.04	51.51±18.76	55.47±8.94	0.82
Hemicellulose	83.41±2.84	71.01±23.14	71.52±10.74	65.63±17.16	0.42
Cellulose	65.36^{a}±6.90	45.25^{b}±4.38	48.13^{b}±15.42	70.14^{a}±7.70	0.01
Lignin	32.18^{a}±11.22	22.84^{b}±1.05	23.13^{b}±3.27	36.90^{a}±3.76	0.01

On the other hand, the WSRS had the highest moisture and crude protein but the lowest dry matter content and crude fiber. The reduction of dry matter of the airtight ensilages fresh rice straw was also reported by Sultana *et al*. (2020), presumably due to minimal moisture lost runoff, oxidation, and loss of volatile organic compounds. Wrapping prevented moisture and nitrogen evaporation, maintaining the moisture and crude protein levels equal to and higher than the FRS. The value of moisture content of WSRS was close to the FRS. The high moisture content, coupled with an excellent lactic-acid fermentation process during the storage, might be able to soften and reduce the crude fiber, which was significantly lower than the FRS. This indicates the success and quality of the stored rice straw. Xu *et al*. (2023) reported that ensiling ruptured the physical structure of rice straw, and reduced the content of DM, NDF, and hemicellulose.

Crude nutrient and fibre fraction digestibility

Table 6 shows data on the nutrient and fiber fraction digestibility of diets containing fresh and stored rice straws. Except for OM, there was no significant difference in DM and crude nutrient digestibility amongst treatments. The diet containing stored rice straw had significantly lower OM digestibility than fresh straw. There was no significant difference in OM digestibility among the stored rice straws. Open-air storage of SSRS and RSRS tended to reduce the digestibility of all fiber fractions. Diets mixed with SSRS and RSRS had lower digestibility of NDF, cellulose, and lignin NDF than the WSRS and the FRS. The lowest NDF digestibility was found in the diets containing the RSRS. The lignin had the poorest digestibility of 23-37%.

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The digestibility was related to the straw botanical composition. As shown in Table 4, the stacking (T1) and rolling (T2) supplemented rice straw had a higher portion of leaf and panicle but a lower stem than the wrapping. According to Vadiveloo (2000), the leaves are less degradable than the stems. Leaves of rice straw contain less NDF than the stems, but more ash and acid-insoluble ash, resulting in a lower *in vitro* dry matter digestibility of the leaves (50-51%) compared to the stems (61%) (Vadiveloo, 2000). According to Sadeghi and Karimi (2020), straw fibers form a stabile lignocellulosic compound resistant to breakdown by microbial enzymes.

Moreover, WSRS had better digestibility in NDF, cellulose, and lignin than SSRS and RSRS, and there was no significantly different with those of the fresh straw. Xu *et al.* (2023) reported that ensiling ruptured the physical structure of the rice straw, which increased the surface area and exposed the internal contents. In addition, the surface of the WSRS was rougher and more porous than RS, facilitating the attachment of bacteria, which promoted the colonization of microorganisms and improved digestion, improved rumen degradability of cellulose and hemicellulose (Tuyen *et al.*, 2012). The increase in temperature in the wrapped straw allowed ammonia (NH3) from urea to penetrate the cell walls and breakdown the lignocellulosic bond, thereby free cellulose is available for microbial fermentation in the rumen (Bakshi and Wadhwa, 2017).

Cattle performances

Table 7 shows data on dry matter intake (DMI), live body weight gain (LWG), and feed conversion ratio (FCR) of cattle fed on diets containing fresh and supplemented rice straws stored for 60 days. Cattle feed diets containing FRS and WSRS had significantly lower dry matter intake than the SSRS and RSRS. The differences in the DMI are likely to be related to the differences in the DM content (Kim *et al.*, 2014). As shown in Table 7, FRS and WSRS had significantly lower DMI than SSRS and RSRS.

There was no significant difference in DMI between the FRS and WSRS. Numerically, cattle fed on FRS and WSRS had higher body weight gain and better FCR than the SSRS and RSRS. The live body weight gain (228.1 g/d) and FCR (17.2) of the WSRS are close to that of the FRS (LWG: 234.4 g/d; FCR: 14.7) (T0). However, there was no statistically significant difference in the LWG and FCR presumably due to high data variation. These results showed that feeding of the wrapping of supplemented intact rice straw had not been able to give significant beneficial effects on cattle's growth performance and feed utilization efficiency. On the other hand, Xu *et al.* (2023) reported that the ensiling of rice straw in China effectively improved the feed's nutritional quality and daily LWG of lambs. The different results could be attributed by the different straw form. Xu *et al.* (2023) cut the rice straw into length of 1 cm before storing in sealed plastic bags, while in our study we used intact rice straw.

According to Sarnklong *et al.* (2010), the limiting factor for low voluntary intake and digestibility of rice straw are its high levels of lignification and silicification and its typical contents of nitrogen, vitamin, and minerals. Despite the low nutritional value of rice straw, when supplemented and stored in the wrapping method, rice straw has the potential to be locally available feed to alleviate the shortage of native grass. The present results proved that rice straw fed in fresh form without supplementation had the best effect the body weight gain and provided utilization efficiency due to the preferable nutritional and physical characteristics of the new straw. This is presumably a good explanation for why the local cattle preferred the fresh straw. However, feeding rice straw in fresh form limits their utilization as animal feed. The present study indicated that wrapping is a promising practical method to maintain the feeding value of long-period storage of supplemented rice straw, improving its component and crude nutrient composition without affecting the performance of animals. The result also indicates that the use of additives could improve the storage quality of rice straws in a wrapping method close to the fresh straw's nutritional values. The straw becomes

Table 7: DM intake, body weight gain, and FCR of cattle-fed diets containing fresh and supplemented rice straws stored in different methods.

Parameter	Experimental diets mixed with				P value
	FRS	SSRS	RSRS	WSRS	
DM intake					
Total DM intake (kg/h)	13.09^{c}±0.37	14.45^{a}±0.86	13.92^{ab}±0.67	13.08^{c}±0.51	0.02
Daily DM intake (kg/h/d)	3.27^{c}±0.09	3.61^{a}±0.21	3.48^{ab}±0.16	3.27±^{c}0.13	0.02
Live body weight gain					
Total weight gain (kg/head)	0.93±0.23	0.83±0.23	0.84±0.40	0.91±0.44	0.70
Daily weight gain (g/h/d)	234.37±59.83	209.37±58.07	210.62±102.43	228.12±111.04	0.70
FCR	14.66±3.72	18.21±4.61	19.81±9.30	17.24±8.37	0.33

soft and brittle with a fermented aroma, easy to chop, and palatable for cattle. In addition, storage of intact rice straw with manual wrapping as a feed ingredient will not only reduce the waste disposal and underutilized abundant rice straw but also provide an inexpensive feed source for the traditional small-scale holders who raise the small-body size indigenous breed cattle with low nutrient requirements and low input-low output production systems.

CONCLUSIONS AND RECOMMENDATIONS

Storage of the enrichment rice straw by stacking and rolling reduced the organoleptic acceptance, palatable stem component, moisture content, body weight gain, and feed utilization efficiency. Wrapping of supplemented rice straw had desirable color, soft and brittle texture, pleasant flavor, minimized undesirable fungi growth, increased crude protein, and reduced crude fiber content. However, the use of wrapped rice straw in the cattle diet could not significantly improve the body weight gain and feed utilization efficiency.

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NOVELTY STATEMENT

Rice straw needs to be utilized more as feed mainly due to low voluntary intake, poor digestibility, and storage stability. Supplementation of rice straw with mineral, energy, and protein sources was intended to improve nutrients and energy availability and to maintain the feeding value during storage. The present study indicated that the manual airtight wrapping was the most practical method to keep the feeding value of long-period storage of rice straw supplemented with the calcite-based mineral mixture, molasses, and urea

AUTHOR'S CONTRIBUTION

Khalil: Conceptualization, methodology, writing the original draft.
Dwi Ananta: Resources, investigation, data curation, review, and editing.
Andri: Project administration, data analysis.
Hermon: Methodology, review, and editing.

Abbreviations

FRS, fresh rice straw; SSR, stacking supplemented rice straw; RSRS, rolling supplemented rice straw; WSRS, wrapping supplemented rice straw; DM, dry matter; DMI, dry matter intake; FCR, feed conversion ratio; NDF, neutral detergent fiber; ADF, acid detergent fiber, LWG, live body weight gain; TDN, total digestible nutrient; OM, organic matter.

Conflict of interest

The authors have declared no conflict of interest.

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