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Evaluation of Nutrient and Digestibility of Agricultural Waste Total Mixed Ration Silage as Ruminant Feed

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ABSTRACT

Difficulties in feeding ruminants, which generally use field grass, can be modified by utilizing forage waste from corn, rice and cassava using the total mixed ration (TMR) silage model to obtain feed that is rich in nutrients and long lasting. The study aimed of the study was to determine the nutritional value and digestibility of TMR silage using forage and concentrate waste from corn, rice and cassava. The research design used a completely randomized design with 3 treatments of agricultural waste and 6 replications. The treatment is CWS (corn waste silage); RWS (rice waste silage) and CVWS (cassava waste silage). The parameters tested were crude protein, crude fiber, crude fat, NDF, ADF, WSC, RFV, NH_3, rumen PH, VFA, In *vitro* dry matter digestibility (IVDMD) and In *vitro* organic matter digestibility (IVOMD). The results showed that CVWS (cassava waste silage) increased crude protein, RFV and reduced NDF, while CWS (corn waste silage) reduced crude fiber and ADF, increased NH_3 production, VFA and *in vitro* digestibility ($p<0.05$). The research conclusion is that CWS (corn silage waste) is the best treatment because it increases nutrition, rumen fermentation and digestibility *in vitro*.

Keywords: *C*omplete feed, Waste, Nutrition, Digestibility

Introduction

The provision of ruminant animal feed in rural livestock systems in Indonesia generally comes from green pastures with traditional and extensive rearing patterns so feed provision is never measured in terms of quality or actuality so that production, rumen digestibility, and livestock growth are not achieved optimally. Feed needs can still be met from forage originating from agricultural waste, namely corn, rice and cassava. Production of corn, cassava and rice in Riau Province is very high. BPS data for the 2021 stage reports that production of corn, cassava and rice in Riau Province is 30,870 tons/ha^{-1}, 11.14 tons/ha^{-1} and 37.60 tons/ha^{-1}. This condition creates potential waste, including corn. The production of straw, rice straw, cassava leaves and cassava peel is also very high. Apart from that, various waste materials have different nutrients, including corn straw containing crude fiber (CF) 33.21%, crude protein (CP) 10.90%, neutral detergent fiber (NDF) 69.81%, and acid detergent fiber (ADF) 40.20% (Tulung *et al.,* 2020). Rice straw contains CF 31.99%, CP 8.26%, NDF 77.00% and ADF 57.91% (Amin *et al.,* 2015). Cassava leaves contain CP 8.11%, CF 15.20% and ether extract (EE) 1.29% (Nurlaili *et al.,* 2013). Cassava peel contains 7.2% lignin and 13.8% cellulose (Sandi *et al*., 2013). Rice bran contains CP 5.34%, EE 2.79% and CF 26.43% (Mila and Sudarma. 2021).

The problems that are always faced by feed from agricultural waste are high water and fiber content and low protein so if it is not handled quickly and correctly it will affect environmental health. Therefore it is necessary to process fibrous feed which is capable of converting forage. Agricultural waste into high value feed. in the form of silage. The silage process using the anaerobic compaction method by adjusting the water content during storage (Kung *et al.,* 2018). Furthermore, the silage process the loss of dry matter during the handling process so that it still has high digestibility when given to livestock (Borreani *et al.,* 2018). Complete silage through the input of various forage source materials and concentrates in the form of total mixed ration (TMR). Bueno *et al.* (2020) reported that TMR silage is a complete feed silage consisting of fresh forage, protein concentrate and energy concentrate which is formulated to meet nutrient needs.

The success of the TMR silage process in maintaining nutrition and digestibility also greatly influenced the involvement of lactic acid bacteria (LAB) in utilizing soluble carbohydrates for as long as predicted. LAB can maintain the durability of the feed because in addition to producing lactic acid products it also produces organic acid products, namely propionic acid, acetic acid and other metabolite products (Savadogo *et al.,* 2007, Sadishkumar and Jeevaratnam, 2016) so that silage feed products are protected from clostridia bacteria which cause silage to become moldy and rotten (Smith *et al.,* 2017; Kuipers *et al.,* 2000; Patil *et al.,* 2010). Therefore, to increase the ability of lactic acid bacteria to maintain their durability during the silage process, it is necessary to add some carbohydrates in the form of concentrates from agricultural waste so that the silage product is in a complete feed form.

This study aims to find the best nutritional value and digestibility of TMR silage made from legume forages mixed with various component of agricultural wastes from corn, rice and cassava to obtain good quality ruminant animal feed.

Materials and Methods

Various agricultural-based wastes, namely cassava waste (leaves, peel, cassava), corn waste (straw, peel, cob, corn bran) and rice waste (straw, rice bran) obtained from various villages in Pekanbaru, Riau Province and *Indigofera* legumes obtained from UIN Sultan Syarif Kasim Riau. The study used a completely randomized design with 3 treatments and 6 replications. The treatment was CWS (corn waste silage); RWS (rice waste silage) and CVWS (cassava waste silage) (Table 1). The following are the components of the constituent materials and the chemical composition of the silage of various agricultural wastes in ruminants.

The process of making TMR silage begins with the physical processing of various agricultural wastes and indigofera forage were chopped to a size of 3-5 cm then wilted for 18 hours to reduce water content as well as legume. Then mix all the silage ingredients, after the ingredients are mixed evenly they were put into a silo, compacted and tightly closed (*anaerobic*) and fermented for 21 days.

Table 1. Raw material and chemical components of TMR silage for various agricultural wastes

Raw material components (%)	CWS	RWS	CVWS
Corn bran	24.0	-	-
Corn straw	35.0	-	-
Corn cob	8.0	-	-
Corn husk	8.0	-	-
Rice bran	-	39.0	-
Rice straw	-	34.0	-
Onggok	-	-	16.0
Cassava leaves	-	-	36.0
Cassava peel	-	-	30.0
Indigofera	20.0	22.0	13.0
Molases	5.0	5.0	5.0
Chemical components (%)			
Crude protein	10.14	10.87	12.97
Total digistible nutrient	63.04	52.99	65.70

CWS (corn waste silage); RWS (rice waste silage) and CVWS (cassava waste silage).

The TMR silage samples were dried by drying in the sun for 2-3 days. After drying, it was dried at 60^0C for 48 h to determine the constant dry matter. The sample was then ground into flour with a size of 1 mm and the nutrition was explained. Research parameters namely dry matter (DM), CP, NDF, ADF using Near Infrared Reflectance Spectroscopy (NIRS) analysis. Estimated dry matter digestibility value (DMD), dry matter intake (DMI) and relative feed value (RFV) is determined by calculating: DMD (%) = 88.9 - (%ADF x 0.779); DMI (%) = 120 /% NDF; RFV = (DMD x DMI)/1.29 (Rohweder *et al.,* 1978). RFV parameters are used for determining the quality of forage available in in the Hay Marketing Task Force of the American Forage and Grassland Council. Standard forage value: reject (score<75), poor (75-86), fair (87-102), good (103 - 124), premium (125-151) and prime (>151) (Rohweder *et al.,* 1978). Tests for total NH_3 and volatile fatty acid (VFA) productions as well as *in vitro* dry matter digestibility (IVDMD) and *in vitro* organic matter digestibility (IVOMD) refer to the method of Tilley and Terry (1963). Fermentability and digestibility studies were carried out using a two-stage *in vitro* method. Rumen liquor was collected from fistulated Frisian Holstein bulls were kept in the field laboratory of Dairy Nutrition, Faculty of Animal Science, IPB University. Fermentability tests were conducted in a 100 mL fermentation tube.

The 0.5 g sample was put into the tube with 40 mL pre-warm McDougall buffer and 10 mL rumen liquor. The tube was aerated with CO_2 gas for 30 s to produce an anaerobic condition. The tube was closed using ventilated rubber stopper and put in a 39^0C shaker water bath for 4 h. After fermentation, the tube was centrifuged at 3500 *g* for 15 min, and the supernatant was collected for NH_3, VFA, and protozoa measurement. The NH_3 was measured using Conway, while VFA was measured using the steam distillation method. Digestibility tests were conducted using two steps. The first steps applied a similar procedure as the fermentation test. However, the fermentation lasted for 48 h. After the termination of the fermentation, the tube was centrifuged at 3500 *g* for 15 min. The residue was collected and added with 40 mL HCl-pensin solution. The tube was put in the 39^0C water bath for another 48 h aerobically. After 48 h enzymatic digestion, the residue was filtered, dried, and weight to determine the DM residue. The OM residue was determined after combustion of the residue in a 600^0C muffle oven for 6 h. The data obtained were analyzed using SPSS 20 software and continued by Duncan's further testing, if the means were significantly different.

Results and Discussion

TMR silage chemical composition of various agricultural wastes

The nutritional composition of various TMR silages for agricultural waste can be seen in Table 2. The CVWS and RWS treatments produced higher dry matter ($p<0.05$) than CWS (90.36; 89.97 vs 83.35%). In addition, CVWS also produced the highest crude protein ($p<0.05$) compared to CWS and RWS, namely 13.47%. The increase in crude protein in CVWS was due to the cassava leaf waste material being the largest constituent in the ration formulation, namely 36%, supported by a high nutritional value as well. Cassava leaves contain 29% crude protein (Mulyasari, 2011). The crude

Table 2. The chemical composition of nutrients for various TMR silages

Parameter	Treatment		
	CWS	RWS	CVWS
DM (%)	83.35 ± 0.32[b]	89.97 ± 0.97[a]	90.36 ± 0.28[a]
Crude Protein (% DM)	7.83 ± 0.07[c]	10.79 ± 0.26[b]	13.47 ± 0.32[a]
Crude Fiber (% DM)	12.17 ± 0.55[b]	21.76 ± 1.64[a]	12.52 ± 0.90[b]
EE (% DM)	7.58 ± 0.44[a]	5.05 ± 0.67[c]	6.53 ± 0.92[b]
NDF (% DM)	32.92 ± 1.00[a]	34.37 ± 3.01[a]	26.93 ± 2.71[b]
ADF (% DM)	16.78 ± 0.42[c]	24.79 ± 1.16[a]	19.21 ± 2.25[b]
WSC (%)	2.05 ± 0.10[a]	1.50 ± 0.33[b]	2.10 ± 0.23[a]
pH	3.96 ± 0.13	4.29± 0.33	3.80 ± 0.44
DMI (%)	3.65 ± 0.11[b]	3.52 ± 0.31[b]	4.49 ± 0.44[a]
DMD (%)	75.83 ± 0.32[a]	69.59 ± 0.90[c]	73.93 ± 1.75[b]
RFV	214.32 ± 6.69[b]	189.91 ± 19.18[b]	258.12 ± 31.41[a]

CWS (corn waste silage); RWS (rice waste silage) and CVWS (cassava waste silage); DM (dry matter); NDF (neutral detergen fiber); ADF (acid detergen fiber); WSC (water soluble carbohydrat); DMD (dry matter digestibility); EE (ether extract); DMI (dry matter intake); RFV (relative feed value).
[a,b,c] Different superscripts in the same column and row indicate significant differences ($p<0.05$).

fiber value of the RWS treatment was higher than the CWS treatment, namely 21.76 vs 12.52%. This is because RWS as a constituent of silage waste is dominated by rice straw which has a high fiber content, in contrast to CWS which consists of corn straw which has low crude fiber. Rice straw waste contains 31.99% crude fiber (Amin *et al.,* 2015). The results of other studies report that rice straw waste contains 27.61% crude fiber (Mayasari *et al.,* 2015). Then, based on the crude fat parameter, it showed that the CWS treatment produced the highest crude fat ($p<0.05$) compared to the RWS and CVWS treatments (Table 2). The high crude fat content in CWS is caused by the distribution of corn bran which has a higher fat content than rice and cassava bran.

The CWS and RWS treatments produced an NDF that was not different ($p>0.05$) but different ($p<0.05$) when compared to CVWS with the highest value of 34.37%, similarly the ADF parameter also produced the highest value ($p<0.05$) in the RWS treatment, namely 24.79% (Table 2). The high content of NDF and ADF in CWS and RWS is due to the contribution of waste material from rice straw and corn straw which dominates the composition of silage feed supported by rice straw and corn which have quite high NDF and ADF. In the WSC parameter, it turned out that the CWS treatment produced values that were not different ($p>0.05$) from CVWS but significantly different ($p<0.05$) when compared to the RWS treatment with the highest value of 2.05%. The high WSC in CWS and CVWS is due to corn and cassava bran which tend to have high enough fermentable carbohydrates so they have the ability to maintain the stability of the silage process. The TMR silage pH parameter yielded the same value ($p>0.05$) for all treatments (Table 2), this indicated that the fermentation was all running optimally with indications of lactic acid bacteria using substrates whose overall pH was in the low category. The decrease in pH is influenced by the availability of WSC substrate which is utilized by LAB so that the delay process takes place optimally (Ennahar *et al.,* 2003). The results of this study resulted in a lower pH than Okunlola *et al.* (2019) using silage made from cassava peels plus banana leaves and dried poultry manure resulting in a pH of 4.0 - 4.4. RFV estimation is a measurement method for evaluating feed quality. Table 3 shows that the RFV value in CVWS is higher ($p<0.05$) compared to CWS and RWS. The highest RFV value was in the CVWS treatment, namely 258.12, and the lowest was in the RWS, namely 189.91. The high RFV value on CVWS is caused by the DMI and DMD values which are also high due to the low NDF values produced. There is a correlation between the NDF content and the RFV value. The lower the NDF and ADF content usually increases the RFV content resulting in better quality of the feed (Kilic and Gulecyuz, 2017). In general, the quality of silage feed based on CWS, RWS, and CVWS is the best quality feed because it is included in the prime feed category (>151) (Rohweder *et al*., 1978).

Rumen fermentation and *in vitro* digestibility

Rumen fermentation and *in vitro* digestibility of various TMR silages of agricultural waste can be seen in Table 3. The CWS treatment produced the same value ($p>0.05$) as CVWS but differed ($p<0.05$) when compared to RWS on rumen pH parameters. The rumen pH produced in this study was still relatively normal between 6.0 -7.0 (Sung *et al.,* 2007). Furthermore, the highest NH_3 production value was found in the CWS treatment, which was 10.45% higher ($p<0.05$) compared to RWS and CVWS. NH_3 production is an illustration of protein degradation due to the work of rumen microbes (Table 3). Although CWS which is corn waste silage produces low crude protein compared to others, CWS is a component of silage material having easily digestible carbohydrates with its metabolite product glucose so that sufficient energy availability allows rumen bacteria to use nitrogen effectively resulting in increased production of NH_3. Junior *et al.* (2017) stated that NH_3 production is closely related to the proteolysis produced NH_3, when the fermentation process takes place aerobically the NH_3 production is usually lower. Salam (2009) added that feed containing high energy can help and increase protein synthesis in synchronizing available energy and ammonia so that it affects the increase in nutrient digestibility.

Total VFA also produced the highest value in the CWS treatment with a value of 116.42%. VFA is the main product of carbohydrate fermentation that occurs in the rumen. The high

Table 3. Rumen fermentation and digestibility of various TMR silages (% DM)

Parameter	Treatment		
	CWS	RWS	CVWS
Rumen pH	6.78 ± 0.01[b]	6.94 ± 0.02[a]	6.87 ± 0.02[b]
NH_3 (mM)	10.45 ± 0.37[a]	7.83 ± 0.52[c]	9.54 ± 0.63[b]
VFA (mM)	116.42 ± 9.11[a]	74.12 ± 10.43[c]	95.03 ± 9.13[b]
IVDMD (%)	70.42 ± 1.70[a]	38.28 ± 1.19[c]	64.32 ± 1.32[b]
IVOMD (%)	70.91 ± 1.95[a]	40.22 ± 1.40[c]	63.40 ± 1.66[b]

CWS (corn waste silage); RWS (rice waste silage) and CVWS (cassava waste silage); VFA (*volatile fatty acid*); IVDMD (*In vitro* dry matter digestibility); IVOMD (*In vitro* organic matter digestibility).
[a,b,c] Different superscripts in the same column and row indicate significant differences ($p<0.05$).

VFA in CWS which is silage made from corn waste products because it is composed of various high water soluble carbohydrate components that are easily fermentable and generally form starch making it easier for bacteria in the rumen fluid to utilize carbohydrates into simple sugars in the form of glucose. VFA production in the rumen is dominated by acetic and propionic acids. In contrast to the RWS and CVWS treatments made from rice and cassava, they are generally dominated by structural in the form of amylose and amylopectin so that rumen bacteria do not optimally utilize existing substrates resulting in low VFA.

Likewise the IVDMD and IVOMD parameters yielded the highest value ($p<0.05$) in the CWS treatment compared to other treatments at values of 70.42% and 70.91%. This indicates that CWS, which is silage made from corn waste, has a high non-structural carbohydrate component so that rumen microbes are very free to ferment existing substrates primarily based on the WSC parameter which has a value of 2.05%. In contrast to the RWS and CVWS treatments which had low dry matter and organic digestibility because the two silage materials were composed of components played by high crude fiber materials including lignin rumen microbes had difficulty degrading feed ingredients which could result in lower dry matter and organic digestibility values. Al-Masri (2010) stated that feed reflects good nutritional value and digestibility if lignin substance is negatively correlated with IVDMD and IVOMD (Table 3). Okoruwa *et al.* (2012) added that the level of digestibility in the rumen is very dependent on the fibrous feed used, the higher the fiber feed, the longer it takes rumen microbes to digest the available feed.

Conclusions

CVWS (cassava waste silage) reduces crude fiber and NDF further increases crude protein and RFV while CWS (corn waste silage) increases the production of NH_3, VFA, IVDMD and IVOMD.

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