UTILIZATION OF PROBIOTIC-FERMENTED RICE STRAW AS RUMINANT FEED

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ABSTRACT

Agriculture in Indonesia is dominated by a rice-based farming system where ruminants are kept as saving and to provide draft power. The productivity of ruminants under this farming system is relatively low. The low productivity is mainly due to inadequate supply of feed. As the agriculture is a rice-based farming system, rice straws become potential crop residues existing in almost all areas in Indonesia. Many studies on the utilization of rice straw as ruminant feed have been conducted. Rice straw has very low nutritive values, especially its crude protein content and digestibility. A lot of treatments have been applied to improve the nutritional values particularly the digestibility value, that is, by means of physical, chemical and biological treaments. In recent studies, the efficiency of rice straw utilization for ruminants was improved by supplementation of probiotic. The aim of probiotic addition is to enhance the ability of rumen microbes to digest the rice straw in the rumen by their synergistic effect. The methods of probiotic addition can be introduced into rice straw through fermentation process or mixed with the concentrates. This paper exposes the utilization of probiotic-fermented rice straw for ruminant animals and their storage system.

Key words: Rice straw, fermentation, probiotic, ruminants

ABSTRAK

PEMANFAATAN JERAMI PADI FERMENTASI PROBIOTIK SEBAGAI PAKAN TERNAK RUMINANSIA

Pertanian Indonesia didominasi oleh sistem pertanian berbasis padi dimana ternak ruminansia dipelihara sebagai tabungan dan untuk tenaga kerja. Produktivitas ternak ruminansia pada kondisi sistem pertanian seperti ini relatif rendah. Rendahnya produktivitas ternak ruminansia terutama karena suplai bahan pakan yang tidak mencukupi. Sehubungan dengan sistem pertanian yang berbasis padi, jerami padi merupakan residu yang potensial dan terdapat hampir di semua daerah pertanian di Indonesia. Penelitian mengenai pemanfaatan jerami padi sebagai pakan ternak ruminansia telah banyak dilakukan. Kualitas jerami padi sebagai pakan kurang baik, terutama disebabkan oleh nilai kandungan protein dan kecernaannya yang sangat rendah. Berbagai perlakuan telah banyak diaplikasikan untuk meningkatkan nilai nutrisi jerami padi, khususnya, nilai kecernaannya melalui perlakuan-perlakuan secara fisik, kimiawi atau biologis. Dalam dekade terakhir, telah dilakukan penelitian-penelitian mengenai peningkatan efisiensi penggunaan jerami padi sebagai pakan ternak ruminansia dengan perlakuan intervensi probiotik. Pada prinsipnya, penambahan probiotik bertujuan untuk meningkatkan kemampuan mikroba rumen dalam mendegradasi jerami padi yang dikonsumsi melalui efek sinergistik. Metode penambahan probiotik dapat diintroduksi melalui proses fermentasi atau dengan dicampurkan ke dalam konsentrat. Tulisan ini memaparkan tentang penggunaan jerami padi yang difermentasi dengan probiotik untuk ternak ruminansia dan aspek penyimpanannya.

Kata kunci: Jerami padi, fermentasi, probiotik, ruminansia

INTRODUCTION

Demand for animal protein increases along with the increase of income and human population. Hence, livestock production should be improved by providing the animals with adequate feed.

Indonesia is one of the intensive agriculture countries in South East Asia with rice as the most priority crop. Consequently, available land for growing single purpose of forage plants such as napier grass for animal consumption is very limited, especially in Java island. Beside that, the conversion of land use and ownership including fertile agricultural land for estate and industrial purposes, has been taken place in the last decade. Therefore, alternative feedstuffs for the animals are derived from crop residues and processing by-products where rice straw is the most potential feed especially for Java area. This residue is available on most rice-based farms in Indonesia, especially during dry season.

Despite its high potency for animal feed, rice straw has low contents of essensial nutrients like protein, energy, minerals and vitamins as well as poor palatability and digestibility. These low nutritive values can be improved by undertaking pre-treatments or supplementing with high quality feeds as well as nitrogen and minerals to improve the supply of nutrients to the animal tissues. Many treatment methods involving mechanical, chemical and biological approaches have been reported.

The treatment for rice straw discussed in this paper is the use of probiotic containing live fibrolytic bacteria through fermentation process. The probiotical treatment has changed the chemical and physical characteristics of rice straw. The technique of probiotical fermentation is more complex than urea treatment, but the farmers tend to prefer probiotic to urea treatment. Several feedlotters and a few dairy farmers have utilized the probiotic-fermented rice straw as basal feed for their herds.

POTENCY OF RICE STRAW AS ANIMAL FEED

Rice straw is the most potential agricultural by-product in Indonesia as rice is planted in 11.8 million ha of land to produce staple food for 229 million people (BIRO PUSAT STATISTIK, 2007). The harvested area for rice in 2006 around 66% of the total food crop areas with 61% of the total food crop production (Table 1).

As the human population is concentrated in Java island (ie. 59% of total population) which area is only 7% of the total area of Indonesia, the distribution of the rice crop and the livestock population are also concentrated in Java island (ie. 48% of total harvested area and 42% of total ruminants, Table 2 and 3) (BIRO PUSAT STATISTIK, 2007). The production of rice straw in 2006 and the composition of ruminant are shown in Table 2 and 3, respectively. The total amount of dried rice straw per year obtained here is lower than the one calculated by MARTAWIDJAJA (2003). It is due to the different conversion factor used, where MARTAWIDJAJA (2003) used the conversion factor of 3.86 tonnes dry matter of rice straw per ha. It was estimated 31,755,365 tonnes/year or about 67% of total dry matter forage was consumed by ruminants.

How many cattle can be maintained a year by utilization of rice straw? If about only one third of the rice straw available for the animal feed, and one cattle consumes approximately 6 kg DM of rice straw per day, it means that the total amount of rice straw produced annually would be able to maintain 4.12 millions cattle per year. So, rice straw can support to maintain about 38% of cattle population in Indonesia.

Table 1. Harvested area, production and yield rate of food crops in 2006

Crops	Harvested area (ha)	Production (tonnes)	Yield rate (tonnes/ha)
Paddy	11,780,400	54,402,200	4.62
Maize	3,346,400	11,610,600	3.47
Cassava	1,222,800	19,927,600	16.30
Sweet potatoes	176,200	1,851,800	10.51
Peanuts	706,600	838,000	1.19
Soybeans	581,600	749,000	1.29

Source: BIRO PUSAT STATISTIK (2007)

Table 2. Estimation of rice straw production in 2006

Regions	Harvested area of rice crop[1]	Dry matter of rice straw[2]
Java	5,703,589 ha	13,118,255 tonnes
Outside Java	6,076,811 ha	13,976,665 tonnes
Indonesia	11,780,400 ha	27,094,920 tonnes

Source: [1]BIRO PUSAT STATISTIK, 2007
[2]Dry matter of rice straw was estimated according to the report of DJAJANEGARA and RANGKUTI, 1987 (ie. 2.3 tonnes DM of rice straw per ha)

Table 3. Ruminant population in Java, outside Java and Indonesia in 2006

Ruminant	Population in 2006 (head)		
	Java	Outside Java	Indonesia
Cattle	4,482,609	6,392,516	10,875,125
Dairy	359,596	9,412	369,008
Buffalo	321,738	1,844,868	2,166,606
Goat (approx. equiv. to cattle unit)	701,745	677,250	1.378.995
Sheep (approx. equiv. to cattle unit)	776,393	121,592	897,985
Total	6,642,081	9,045,638	15,687,719

The conversion of sheep and goat populations into the cattle unit is multiplied by 0.1
The total population (ie. 15,687,719) is a number as large ruminant unit

CHEMICAL POTENTIAL OF RICE STRAW AND ITS CONSTRAINT FOR FEED

The main components of rice straw are fibrous cell wall substances consisting of cellulose, hemicellulose, lignin and silica. Detail of the chemical description of rice straw is shown in Table 4.

Table 4. Chemical composition of fibrous materials of rice straw

Fraction	Component	% on dry weight basis
Dry matter	Cellular contents	20.3
	Cell wall	79.7
Organic matter	Organic cellular contents	12.0
	Neutral detergent fiber (NDF)	62.0
Cell wall	Cellulose	35.0
	Xylan	24.5
	Lignin	5.1
	Silica	12.9

Source: WIDYASTUTI *et al*. (1987)

The dominant content of rice straw fibrous is cell wall (ie. 79.7%), therefore the digestion characteristics of these cell wall substances in the rumen affect the nutritional availability of rice straw in the ruminant feeding system. Lignin and silica substances cause the low digestibility of rice straw.

Based on the proximate analysis of the rice straw (Table 5), about 27,094,920 tonnes dry matter of rice straw produced in 2006 contributed the large amount of valuable nutrients (ie. 387,457 Tera Joule Gross Energy; 1,517,316 tonnes of crude protein; and other nutritional substances in tonne unit of weight). The amount of 1.5 millions tonnes of crude protein is able to maintain approximately more than 5 millions of 400 kg weight cattle (with 0.5 kg ADG) in one year, or about more than 8 millions of 400 kg weight cattle with zero ADG. And 380,000 TJ gross energy is able to maintain approximately more than 7 millions of 400 kg weight cattle (with 0.5 kg ADG) or about more than 11 million of 400 kg cattle with zero ADG (KEARL, 1982).

In principle, the chemical energy contained in NDF fraction can be degraded by the cellulase and hemicellulase enzymes produced by the rumen microorganisms resulting in the formation of volatile fatty acids (VFA) and microbial protein for the host animal. However, due to low digestibility, the plant cell

Table 5. Proximate analysis of the rice straw[1] and the estimation of their amount in 27,094,920 tonnes dry matter produced in 2006[2]

Components analysed	Nutrient content based on DM	Amount the nutrient in 27,094,920 tonnes
Gross energy (MJ/kg)	14.30	387,457 Tera Joule
Crude protein (%)	5.60	1,517,316 tonnes
Crude fat (%)	1.70	460,614 tonnes
Ash (%)	20.00	5,418,984 tonnes
NDF (%)	70.50	19,101,919 tonnes
Soluble carbohydrate (%)	29.97	8,120,348 tonnes
In vitro degraded DM in the rumen (%)	27.30	7,396,913 tonnes

[1]THALIB *et al*. (1994); [2]Table 2

wall of the straw restricts intake and minimizes yield of digested nutrients and microbial protein that can be utilized by the animals. The availability of nutrients is determined by interaction of substances contained in cell wall with rumen microorganisms where the degradation rate of cell wall has to be proceeded by attachment stage. Silica, lignin and xylan appeared to be cell wall masking substances (MCMANUS, 1983). Rice straws contain 10 – 15% silica and 4.7 – 8.3% lignin, and xylan is prominent component of hemicellulose (MCMANUS, 1983).

The adhesive force of attachment of microorganism on cell wall is interfered by silica content. Silica is deposited on cellulosic structure in growing phase of the plant and in advanced stage of growth, the deposition rate of hemicellulose is accelerated by mineralization of silica. Both deposits undergo crystallization and mask the cell wall from contact with digestive enzymes. Xylan which is prominent component of hemicellulose, has a high degree of polymerization and its unbranched sections are sufficiently long to allow crystallization, whereas xylan percentage content increases with plant maturity (MCMANUS, 1983). The rate of hydrolysis of xylan by acid seems closely associated with the degree of lignification and it is suggested by VAN SOEST (1967) that lignin is covalently bound to hemicellulose. While WILKIN (1977) *in* MCMANUS (1983) reported that there is a significantly negative correlation between cellulose digestibility and lignin content. Therefore, the principle constraint dealing with low digestibility of rice straw is mainly associated with a polymeric nature between carbohydrate fractions of cell wall and minerals (ie. silica) and lignin. Because of that, rice straw has to be subjected to pre-treatment to improve its efficiency in feed utilization.

THE PROBIOTIC–FERMENTED RICE STRAW AS RUMINANT FEED

IBRAHIM (1983) has summarized the treatment methods for improving the nutritive value of crop residues. These included: physical treatments (grinding and pelleting, gamma irradiation, steam processing), chemical treatments (sodium hydroxide, potassium hydroxide, calcium hydroxide, anhydrous ammonia/ ammonium hydroxide/urea, sodium carbonate, chlorine and chlorinated compounds, sulfur dioxide), physico-chemical treatments (steaming with chemical), and biological treatments (white rot fungi, mushroom, addition of enzymes). Most of these treatments have shown increased in feed intake and digestibility and therefore become interesting and relevant choice for feed evaluation.

The effectiveness of the steam treatment of rice straw was reported by MONIRUZZAMAN (1996) to be influenced by pressure and steaming time. That is, an application of high steam pressure (3.5 MPa) for 2 minutes effectively enhanced subsequent enzymatic saccharification fermentation of rice straw (ie. the saccharification reached 92%). The values of *in vitro* DMD of steam-pretreated rice straw at 2 atm for 20 minutes was 8.3 points higher than untreated rice straw (ie. 44.1 vs. 35.8%) (THALIB *et al*., 1994). The treatment also improved NDF and soluble carbohydrate contents (ie. 53.7 vs. 70.5% and 30 vs. 35% respectively). LIU and ORSKOV (2000) reported that cellulose treatment has further improved the nutritional values of steam-pretreated rice straw at 15 bar for 5 minutes (ie. *in vitro* OMD = 52 – 54.5% for steam-pretreated rice straw vs. 46.8 – 48.7% for untreated rice straw). Fungal treatment increased fibre digestibility of the major component of rice straw (cellulose) compared to untreated rice straw (ie. 61.1 vs. 48.8%) (KARUNANANDAA and VARGA, 1996). Rice straw silage inoculated with buffalo rumen microbes improved microbial digestion of rice straw in rumen of Ongole cattle compared to untreated rice straw (ie. 54 vs. 33%) (THALIB *et al*., 2000).

However, only a few of the treatment methods can be considered applicable in the villages. Urea supplementation of rice straw was reported by YULIASTINI *et al*. (2000) to be simple and practicable, and consistently increased the N content and *in vitro* OMD compared to untreated rice straw (ie. 49.9 vs. 32.5%), but there was no consistent effect of urea supplementation treatment on the chemical components. Another report (YULIASTINI *et al*., 2003), however, indicated that DMI of urea-supplemented rice straw by sheep was lower than that of untreated rice straw (ie. 772 vs. 892 g/head/day).

The use of microorganisms to increase the biological values of several kinds of feedstuffs including forages have been reviewed by WINA (2005). Some researches in Indonesia have found advantages in treating rice straw with simple biofermentation processes using probiotics (HARYANTO *et al*., 1999; AGUS *et al*., 2000). Probiotics have been defined as viable microbes, single or combination of several species, or enzyme specimens which may be directly fed to and improve the health of the animals (FULLER, 1992). The effects of probiotic supplement have been reported to reduce the number of pathogenic microbes in the digestive tract and help in balancing the microbial consortium by optimizing the fermentation process.

The kind of viable microbes commonly used as probiotic for improving the performance of animals were *Aspergillus oryzae*, *Saccharomyces cerevisiae* and *Lactobacillus* spp. (YOON and STERN, 1995). Currently, probiotics containing local fibrolytic microbes have widely been utilized in Indonesia as feed additives for ruminants such as Starbio, BioMikro, Bioplus and Probion. Starbio and BioMikro are commercially available in animal feed shops. The advantage of probiotic in rice straw fermentation is contributing both to pre-treatment and natural digestion in the rumen. The principal process of rice straw fermentation includes two stages, i.e: fermentation and drying stages. The main diagram of preparation of the probiotic-fermented rice straw is shown in Figure 1. One tonne of rice straw containing approx. 65% of moisture were mixed with 6 kg urea and 6 kg probiotic "Starbio" or with 2.5 kg urea and 2.5 kg probiotic "Probion" or 1 kg urea, 2 L molasses and 1 L probiotic "BioMikro", and incubated for about 21 days. Incubation was done under shade (avoid direct sunshine and rain). The fermented rice straw was dried under sunshine, and then kept in an appropriate place. The incubation step of a fermentation process of rice straw is shown in Figure 2.

The technique of this type of fermentation is called "open fermentation" in the way to differentiate it with "ensilage". In the incubation step for ensilage technique, the forage is fermented in a silo anaerobically to reach the pH of silage about ≤ 4.0, and the silage kept in that silo as a storage system; while in the incubation step for open fermentation technique, the forage is fermented in order to degrade its fibrous component and after the optimum fermentation reached (ie. about 21 days), the fermented forage must be dried to stop the degradation. The effect of fermentation on chemical composition of rice straw is shown in Table 6.

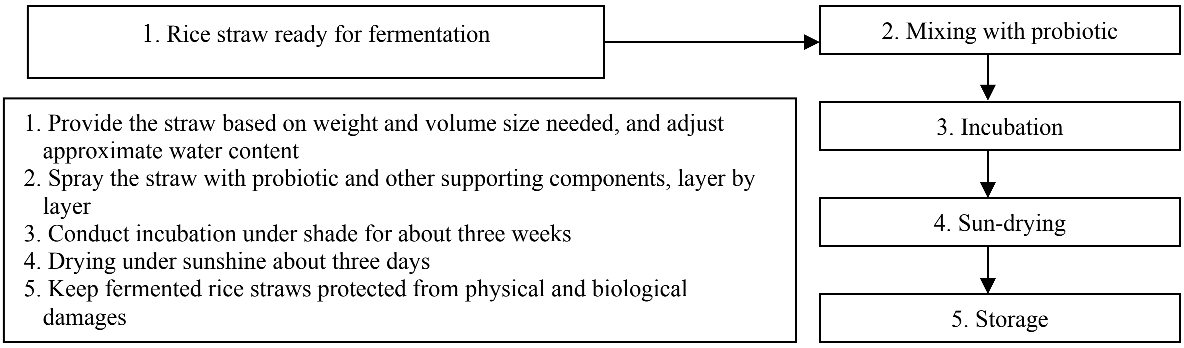

Figure 1. A diagram of preparation of probiotic-fermented rice straw

Figure 2. Incubation step of fermentation process of rice straw

Source: THALIB (koleksi pribadi)

Table 6. Chemical compositions and digestibility values of probiotic-fermented rice straw (PFRS) and untreated rice straw (URS) based on dry matter

Measurements	URS	PFRS	References/probiotic
Crude protein (%)	3.50 – 5.17	5.63 – 9.56	AGUS *et al*., (2000)/Starbio; SARIUBANG *et al.* (2002)/Starbio; SEMBIRING *et al*. (2002)/Starbio; THALIB *et al*. (2007)/Probion
Crude fat (%)	0.88 – 1.24	1.09 – 2.46	AGUS *et al*. (2000)/Starbio; SARIUBANG *et al*. (2002)/Starbio; THALIB *et al*. (2007)/Probion
Crude fibre (%)	26.24 – 31.59	22.36 – 30.28	AGUS *et al*. (2000)/Starbio; AKMAL *et al*. (2004)/EM-4; SARIUBANG *et al*. (2002)/Starbio; THALIB *et al*. (2007)/Probion
NDF (%)	79.78 – 80.0	73.6 – 77.0	AKMAL *et al*.,2004/EM-4; THALIB *et al*. (2007)/Probion
NFE (%)	30.50 – 44.81	34.70 – 48.02	AGUS *et al*. (2000)/Starbio; SARIUBANG *et al*. (2002)/Starbio
Ash (%)	22.54 – 33.50	21.89 – 31.02	AGUS *et al*. (2000)/Starbio; SARIUBANG *et al*. (2002)/Starbio
In vitro DMD (%)	34.77	37.79 – 51.03	HARYANTO *et al*. (2003 ; 2004)/Probion; THALIB (unpublished)/BioMikro; THALIB *et al*., (2007)/Probion
In vitro OMD (%)	38.46	42.57 – 54.46	HARYANTO *et al*. (2003; 2004)/Probion; THALIB (unpublished)/BioMikro
In vitro NDFD (%)	28 – 30	50 – 55	HARYANTO *et al*. (2003)/Probion
In vitro ADFD (%)	-	52.22	HARYANTO *et al*. (2003)/Probion
In sacco DMD (%)	64.93	68.50	AGUS *et al*. (2000)/Starbio
In sacco OMD (%)	64.17	71.71	AGUS *et al*. (2000)/Starbio
In sacco CFD (%)	59.62	63.99	AGUS *et al*. (2000)/Starbio

Starbio is a probiotic that has been widely used as inoculum for fermentation of rice straw. The paragraphs have shown that the probiotic fermentation improved the nutritional values of rice straw. Consistent significant improvements were shown in crude protein content, digestibility and other nutritional values. Increased protein is assumed due to the increased content of urea and probiotic microbes. Fermentation process using all kinds of probiotics as inoculum usually is supplemented with urea as a nitrogen source. The increased digestibility is due to the increased NFE and lowered crude fibre. It is also assumed that probiotic microbes are able to penetrate the fibrolytic structure and cleave the binding of lignified carbohydtrate and in some extent, degrade cellulose and hemicellulose. The probiotic treatment also changes the physical characteristics of rice straw, such as being wilted and slightly silage-like smell.

The effects of probiotic-fermented rice straw on dry matter intake (DMI) and average daily gain (ADG) are shown in Table 7 for cattle and Table 8 for sheep.

Starbio was used as the probiotic to treat rice straw for almost all feeding trials on cattle reported in Table 7, while the probiotic type used in all feeding trials of sheep was Probion (Table 8).

Table 7. Daily consumption and daily gain of cattle fed either URS or PFRS

Parameter	URS	PFRS	References/probiotic
DMI (kg/head/day)	2.10 – 2.33	2.51 – 5.88	HARYANTO *et al*. (1999)/Starbio; KOSTAMAN *et al*. (2000)/Starbio; KUSNADI *et al*. (2001)/BioMikro; UMIYASIH *et al*. (2002)/Starbio
ADG (kg)	0.19 – 0.42	0.29 – 0.75	HARYANTO *et al*. (1999)/Starbio; KOSTAMAN *et al*. (2000)/Starbio; KUSNADI *et al*. (2001)/BioMikro; SARIUBANG *et al*. (2002)/Starbio; SEMBIRING *et al*. (2002)/Starbio; UMIYASIH *et al*. (2002)/Starbio

Table 8. Daily consumption and daily gain of sheep fed probiotic fermented rice straw

Parameter	Value	References/Probiotic
DMI (g/head/day)	550 – 830	BUDIARSANA *et al.* (2005)/Probion; HARYANTO *et al.* (2003;2004;2005)/Probion; SUTAMA *et al*. (2003)/Probion; THALIB *et al*. (2007)/Probion
ADG (g)	46 – 87	BUDIARSANA *et al.* (2005)/Probion; HARYANTO *et al.* (2003; 2004; 2005)/Probion; SUTAMA *et al*. (2003)/Probion; THALIB *et al*. (2007)/Probion

Generally, biological values of the probiotic-fermented rice straw (PFRS) are better than the untreated rice straw (URS). KUSNADI *et al*. (2001) reported that palatability of PFRS was higher than that of URS (DMI: 3.47 vs. 2.22). Improved palatability of fermented rice straw might be due to the changes of physical characteristic (the fermented straw become soft and aromatic). The highest DMI value was reported by SARIUBANG *et al.* (2002) (ie. 5.88 kg/head/day). The use of PFRS as basal feed (in all reports) need to be supplemented with concentrate or with local protein resources such as rice bran and soybean curd waste. The cattle responded positively to PFRS as shown by a significant ADG (Table 7) which could reach about 0.7 kg (KOSTAMAN *et al*., 2000; UMIYASIH *et al*., 2002).

More attention should be paid on farmer's preference to use either URS or PFRS for their ruminant livestock. Up to now, farmer's response to the utilization of PFRS as basal feed for their livestock have been reported by HARYANTO *et al*. (1999) and KURTZ and PANJAITAN (2002). Detailed study reported by HARYANTO *et al.* (1999) involved several groups of farmers in a crop-livestock system (CLS), indicated that more than 80% of the farmers have utilized rice straw for their animal either in fresh or wilted form, but only 5% of them knew about the fermentation technology for rice straw. After following the program, 65% of the farmers adopted the fermentation technology for their farming system. More recently, semi-structured interviews in NTT Province (one of the densely populated livestock areas in eastern Indonesia) have been conducted by KURTZ and PANJAITAN (2002). They found a positive perception from cattle-raising farmers about the suitability of fermentation technique to improve rice straw quality after the farmers practiced the technique mentioned in handouts that was previously distributed to them. Some farmers were happy and experienced no difficulties to prepare PFRS. They believed that PFRS can be used as feedstock, and fermentation could increase the quality and appetite of cattle and maintain body weight of cattle during dry season. Some farmers were initially reluctant to risk their time and money in the new technology, but after they involved in producing PFRS, and feed to cattle, they concluded that PFRS would be a very good option to be used in their farming system.

STORAGE SYSTEM FOR THE PROBIOTIC-FERMENTED RICE STRAW

The last important step of the fermentation of rice straw is the storage system. It is an idea to introduce the wafering method for storage of the fermented rice straw. Wafering method as the storage system for sugar cane top was reported by WARDHANI *et al.* (1989). They developed this technique for sugar cane top as storage system as well as the transportable product. The wafer of sugar cane top was produced in the industrial scale in East Java. The principle process producing the wafer involves the compartments of roll mill, cutter, furnace, rotary dryer, cooller fan and presser.

The idea of the storage system for the fermented rice straw in the form of wafer as shown in Figure 3.

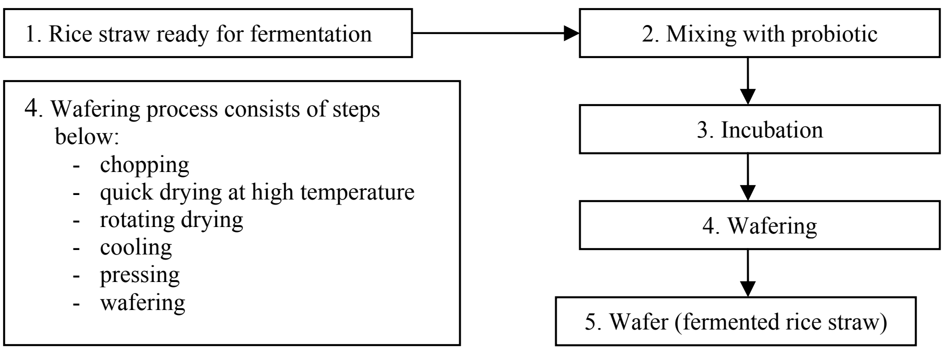

Figure 3. The storage system for the fermented rice straw in the form of wafer

It will be good if molasses is added as adhesive component at the wafering process. The wafer would be more practical supply in transportation system such as interlocations, interprovinces, interislands and so on. The idea of wafering method needs a capital which could be carried out by an enterprise or by farmer's cooperation. However, it will be advantageous in long term to sustainable agricultural system.

CONCLUSION

The estimated quantity of rice straw produced annually would be able to maintain about half of cattle population in Indonesia.

The characteristic plant cell wall of rice straw restricts the intake and minimizes the yield of digested nutrients and microbial protein to be utilized by ruminant animals. This limitation can be improved by pre-treatments or supplemented with high quality concentrate. Probiotic fermentation treatments of rice straw, to some extent, have been adopted by farmers as basal feed for their cattle. The probiotic fermentation improved the nutritional values of rice straw and consistent significant improvements on dry matter intake (DMI), average daily gain (ADG) and feed conversion ratio (FCR) have been reported. The storage of the fermented rice straw in the form of wafer would be a good system for sustainable supply of ruminant feed.

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