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Review Article
The Current Utilisation and Possible Treatments of Rice Straw as Ruminant Feed in Vietnam: A Review

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Abstract
This review provides an overview of the availability, nutritive value and possible strategies to improve the utilisation of rice straw as a ruminant feed. Although, rice straw is the most abundant agricultural by-product and can consider as a sustainable source for ruminant feed in Vietnam, only a small proportion of rice straw is fed to ruminants. Rice straw is rich in polysaccharides and has the high levels of lignin and silica, limiting voluntary intake and reducing degradability by ruminal microorganisms. Some physical treatments are not practical because they require machinery application or are not economically feasible for the farmers. Chemical treatments, such as urea, ammonia or lime, currently seem to be more practical for on-farm use. The application of chemical agents can be hard to handle, harmful to the habitat. The use of white-rot fungi, exogenous enzymes and lactic acid bacteria to enhance the nutritive value and digestibility of rice straw are expected to be a practical and environmental-friendly approach in the future. It is recommended that combinations of these biological treatments with traditional methods are promising for having a synergistic effect on the nutritive improvement of rice straw. Future research should focus on the optimisation of biological and economic effects of different treatments and development in alternative enzyme production and fermentation technologies to obtain the higher nutritive value and digestibility of rice straw.

Key words: Rice straw, ruminant feed, nutritive value, ruminant production, exogenous enzyme, Vietnam

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INTRODUCTION

Rice (*Oryza sativa*) is the staple crop for livelihood in Southeast Asia and more specifically in Vietnam. In 2018, Vietnam produced 44.0 million tonnes of rice[1] and the equivalent amount of dry rice straw was generated. However, a large amount of rice straw is burned in the field hampering sustainable management in intensive rice systems in Vietnam[2]. Meanwhile, ruminant production with approximately 11.2 million heads mainly depends on cut grasses and agricultural by-products since lack of grazing land[3]. Although, in dry or winter season, cut grasses and pastures only meet about 35-57% total forage demand leading to the death of thousands of ruminants, the percentage of rice straw using in ruminant production is really limited compared to its annual yield[4]. In Vietnam, rice straw has not been maximally utilised for ruminant production yet. It is usually fed as part of the forage component in cattle diets during the time when fresh forage is insufficient[5]. For maintaining optimal production levels, feeding only rice straw does not provide enough nutrients to the ruminants[6]. Therefore, increasing the nutritive values of rice straw is very beneficial in the sustainable development of ruminant production.

Low and unbalanced nutritive contents, low voluntary intake and slow rate of digestion are mainly limited the use of rice straw in ruminant production[7,8]. For many years, various extensive research have attempted to improve the nutritional quality of rice straw as a sustainable source of ruminant forage. The possible alternative for better utilisation of rice straw is to improve its nutritive value and digestibility through breaking lignocellulose bonds or at least loosening them to free the major portions of cellulose and hemicellulose to be digested by ruminal microorganisms[9]. In Vietnam, numerous methods of physical (grounding, steaming and pelleting) and chemical (urea, ammonia and lime) treatments have been investigated. Some, however, focus on making rice straw silage by biological treatments (white-rot fungi, enzymes, lactic acid bacteria) or supplementing with other feedstuffs or (and) high soluble carbohydrate sources in order to improve the utilisation of rice straw by ruminants. Although, many methods for improving rice straw utilisation have been developed and recommended, the majority of ruminant farms still feeds untreated rice straw t o their animals[5]. Therefore, the objectives of this paper were to provide an overview of current situation of ruminant production and rice straw utilisation as a source of ruminant feed and highlight some possible techniques used to improve the utilisation of rice straw in ruminant production in Vietnam.

CURRENT RUMINANT PRODUCTION AND RICE STRAW UTILISATION

In 2018, Vietnam had totally about11.2 million ruminants including 5.7 million beef cattle, 0.3 million dairy cattle, 2.5 million buffaloes, 2.5 million goats and 0.2 million sheep[3]. It is widely accepted that each large ruminant daily needs approximately 20-30 kg of forage. Thus, about 62-93 million tonnes of forage are annually needed for raising cattle and buffaloes across the country. The demand of forage, which accounts for around 60-85% total weight of feed, is huge. However, in dry or winter season, natural and grown grasses only provide about 35-57% total forage demand of cattle[5]. In the last decade, the serious deficiency of forage combined with harsh winter have resulted in the death of thousands of cattle and buffaloes per annum in northern mountainous provinces. Especially, in 2008 winter, approximately 200,000 cattle and buffaloes were dead and the amount of dead large ruminants in 2010 winter were about 100,000 heads[10]. Lack of forage also reduces animal productivity capacity and farmers economic profit.

Numerous studies agreed that dry rice straw yield is equal to rice yield[4,11,12]. As a result, Vietnam has about 44.0 million tonnes of dry rice straw per annum. Hung *et al*.[2] reported about 90% of rice production area is harvested by combine harvesters which only cut 1/3 upper top of rice tree. This part of rice straw is collectable and can use as ruminant feed. Therefore, rice production annually generate approximately 13.0 million tonnes of dry collectable rice straw. This is an abundant and sustainable feed source for ruminant feed. Rice straw can be used directly or treated by different preserved methods to store and improve nutritive value of the rice straw for animal feed during forage-shortage periods. However, there is a fact that the proportion of rice straw using in ruminant production is really low. Both Truc *et al*.[13] and Nam *et al*.[4] reported that in southern Vietnam, less than 1% of total rice straw was used as ruminant feed. Furthermore, Nguyen[5] observed that in southern Vietnam, the highest percentage of rice straw using for ruminant feed was 1.4% in dry season, while the percentage of rice straw using for ruminant feed was highest (5.6%) in winter in northern Vietnam. Rice straw are also used for other activities such as cooking fuel, mushroom cultivation, compost, mulching and bio-char with low proportions[5,14]. Currently, the majority of rice straw (54.1-87.0%) has been burned on fields during and soon after harvest seasons in Vietnam[2,5,15]. Most of the farmers stated that burning on fields is the cheapest and fastest mode of rice straw disposal. Burning rice straw causes environmental pollution, accelerates the climate change due to increasing greenhouse gas emissions, traffic accidents thanks to smoke, have detrimental effects on human health. Furthermore, it wastes resource and reduces economic benefit and soil fertility[16]. Small cultivation fields, limited time between crops, lack of labor and consumed market, high transportation cost, use of gas and electric stoves for cooking are main reasons explaining the limited utilisation of rice straw using for ruminant feed and other economic activities[2,14]. The low nutrient value and voluntary intake, slow rate of digestion of rice straw also constrains the use of rice straw in the ruminant production[7,8].

CHEMICAL COMPOSITION AND NUTRITIVE QUALITY OF RICE STRAWIN FEEDING TO RUMINANTS

The chemical composition and nutritive values of rice straw are dependent upon different factors. They are influenced by intrinsic factors such as variety, plant health and maturity status[8,17]. The environmental conditions such as light, temperature, soil moisture, fertiliser and growing season also affect chemical compositions and digestibility of rice straw[6,18]. The height of harvested cutting, morphological fractions (leaves, stems), threshing and post-harvested storage methods and time have considerable effects on the quality and digestibility of rice straw[6]. The chemical and mineral compositions of rice straw, compiled from previous studies in Vietnam, are presented in Table 1.

Silica is a cell wall component in rice, grasses and many other plants. In rice straw, silica can be present in high concentrations ranging from 4.4-13.0% (Table 1), depending on the rice variety[27] and the availability of this mineral in the cultivated soil[28]. The high silica accumulation in rice straw plays a vital role in increasing rice growth, improving plant rigidity and grain quality, reducing lodging and mitigating plant biotic and abiotic stresses, protecting from heavy metal toxicity and pathogens[29]. The role of silica on the quality of rice straw was also reviewed by Van Soest[8]. Song *et al.*[30] concluded that the high silica content of rice straw makes it more poorly digestible to livestock. Silica reduces palatability and the degradability of rice straw in the rumen due to its direct action in preventing colonisation by ruminal microorganisms[28] and negative effects on cellulose enzymes[31].

Apart from silica, the rice straw cell walls predominantly consist of cellulose, hemicellulose and lignin. Enzymes including cellulase, hemicellulase and ligninase are required to break down these components[32]. Cellulase and hemicellulase are not produced by the ruminants themselves but microorganisms in the rumen do produce these enzymes. However, in rice straw, lignin accounts for about 4.3-12.5% (dry matter basis) and it cannot be broken down in the rumen due to lack of ligninase[9]. Theoretically, lignin located between the cellulose micro fibrils is regarded as the most abundant natural aromatic organic polymer. Lignin is primarily composed of three types of monolignols/hydroxycinnamyl alcohols (p-coumaryl, coniferyl and sinapyl alcohols) linked with each other by different types of ether and carbon-carbon bonds like β-O-4, 4-O-5, β-β, β-1 and β-5 to make phenylpropanoid units such as p-hydroxyphenyl, guaiacyl and syringyl. Among these, the β-O-4 linkage is the most predominant ether bond (about 40-60%) in rice straw lignin[18]. Lignin is proposed to be attached to carbohydrates by benzyl esters, benzyl ethers and phenyl glycosides. It is quite difficult to remove lignin in its native form. Even if, lignin could be degraded in the rumen it would not provide much energy for

Table 1: Chemical and major mineral compositions of rice straw in Vietnam

Compositions	Units	Fresh rice straw	Dry rice straw
pH		6.1-6.4	5.9-6.4
Dry matter (DM)	%	26.3-34.4	81.5-92.1
Organic matter	%DM	82.6-89.5	83.7-90.0
Crude protein	%DM	3.2-7.3	2.0-6.6
Crude fat	%DM	0.7-1.6	0.6-1.7
Crude fibre	%DM	27.4-43.2	30.1-42.5
NDF	%DM	63.4-72.5	66.3-73.2
ADF	%DM	34.8-43.5	36.3-42.6
Hemicellulose	%DM	23.0-32.2	26.6-33.5
Cellulose	%DM	30.4-35.8	32.8-47.0
Lignin	%DM	4.3-12.5	4.0-13.2
Silica	%DM	4.4-13.0	5.9-12.8
Total Ash	%DM	10.5-17.5	10.0-16.3
Calcium	g kg^{-1} DM	4.9-5.6	3.7-5.4
Phosphorus	g kg^{-1} DM	1.2-1.9	1.7-2.3

Compiled from Nguyen[19], Tuyen *et al.*[20], Nguyen *et al.*[21], Vinh *et al.*[22], Vu *et al.*[23], Trach *et al.*[24], Dinh *et al.*[25], Nguyen and Dang[26] the animals because rumen microorganisms require a large amount of energy from other sources to break down its chemical linkages and tight physical bonds[9]. In nature, lignin plays a role in resisting compressing forces, providing protection against consumption by insects and mammals. It also inhibits the rate and degree of microbial degradation[33]. Thus, lignin has detrimental effects on livestock production through adversely influencing degradability and feed intake and must be removed to make the carbohydrates available for further hydrolysis processes.

As mentioned before, cellulose and hemicellulose are the digestible parts of rice straw cell walls. Cellulose in the plant is composed of both crystalline and amorphous structures. Satlewal *et al.*[18] stated that the level of crystallinity of cellulose is believed to affect the rate of its decomposition by the cellulolytic bacteria. Moreover, accessibility of the rumen microorganisms to cellulose and hemicellulose can be restricted by direct (covalent) or indirect (ester or ether) linkages between lignin and cellulose, hemicellulose[34]. Van Soest[35] suggested that feed intake is limited by the amount of fibre in diets when cell wall content lies between 50 and 60% of forage dry matter. Voluntary feed intake is also expected to be inversely related to the fibre content of forage because further intake is limited as the slower digesting fraction becomes large in relation to the volume of digestive tract. In the same way, particle passage is expected to decrease with increasing neutral detergent fibre (NDF) intake, particle size, coarseness of forage and decreasing forage digestibility[36].

Besides cell wall polymers, rumen microorganisms and in turn ruminants need other nutrients for growth and metabolism. Rice straw contains only 2.0-7.3% crude protein, while 8.0-10.0% of crude protein in ruminant feed is required for improved consumption and good growth. Furthermore, rice straw has low content in fat, calcium (Ca) and phosphorus (P) compared to other forage sources. Malik *et al.*[6] stated that animals need diets containing about 0.3% of P and 0.4% of Ca for their normal growth and fertility. It is clear in Table 1 that feeding animals with only rice straw may not provide enough P levels. The Ca content in rice straw (0.37-0.56%) appears to be met normal Ca requirement. However, rice straw contains about 0.20-0.66% oxalate[37,38]. In native grass and cereal hays, oxalate might bind 38-44% of calcium to generate calcium-oxalate compound[38]. Rahman *et al.*[39] reported that most of the ingested calcium-oxalate appear to pass intact through the ruminant digestive tract because they cannot be degraded by most rumen or intestinal bacteria. Furthermore, the presence of oxalate and silica in rice straw exacerbate the Ca absorption and utilisation of ruminants[37]. As a consequence, there is in a negative balance in Ca when cattle are fed only untreated rice straw[9].

Generally, anti-nutritional factors such as silica and lignin are the primary limitations to rice straw digestibility in ruminant animals[8]. Rice straw nutritive values are unbalanced with high energy content and poor in protein. A number of studies stated that feeding only rice straw does not provide enough nutrients to the ruminants to maintain high production levels due to the low nutritive value of this highly lignified material[6,8]. Animals fed with unsupplemented rice straw diet only will very often lose weight. In the past, many attempts have been made towards increasing the nutritive value, digestibility and utilisation of rice straw[40-42]. The improvement of this valuable fodder crop is of great importance so as to create economic profits and be friendly with environment rather than the cultural practices of burning.

POSSIBLE TREATMENTS TO IMPROVE RICE STRAW UTILISATION IN RUMINANTS

Rice straw typically is a poor-quality feed in its natural state because of low digestibility and protein content, poor palatability and bulkiness, although it contains enough cellulose and hemicellulose to make it an excellent source of dietary energy for ruminants. The key to improving the use of crop residues for ruminants is to overcome their inherent barriers to rumen microbial fermentation. In the case of rice straw, the important factors that restrict bacterial degradation in the rumen are its high levels of lignification and silicification and its low contents of nitrogen, vitamins and minerals. Numerous treatment processes, including physical, chemical and biological are used to increase the acceptability of rice straw to animals, thus increasing palatability, daily feed intake, nutritive value and maintained the health quality of ruminants as compared to untreated rice straw.

Physical treatment: Globally, the mainly used physical methods are grinding, soaking, pelleting and chopping or steaming, pressured cooking or X-rays. Physical treatments of biomass with the purpose of increasing available surface areas and reducing crystallinity of cellulose, being better degradable by enzymes[9,43,44]. Reducing particle size of rice straw usually decreases dry matter digestibility, which was mainly due to a decreased fermentation rate and decreased total retention time of the feedstuff and resulting in an increased intake[45]. However, at the same time these methods increase the net energy value of the straw somewhat because the nutrients that are digested are utilised more efficiently by the animal[46]. Liu *et al.*[47] reported that the use of steam treatment in a high pressure vessel at different pressures and for a range of different treatment times increased the *in vitro* degradation in rumen fluid after 24 h and the rate of degradation but could not enhance the potential degradability of the fibrous fractions such as NDF, ADF and hemicellulose. Steam and/or pressure treatment of rice straw increases solubilisation of cellulose and hemicellulose and/or by freeing digestible materials from lignin or silica[48]. Various studies agreed that only using physical treatment is not satisfactory to the improvement of rice straw nutritive values. Moreover, almost all physical treatments are not for practical use on small-scale farms, because they require machines or industrial processing. This makes these treatments economically unprofitable for farmers as the benefits may be too low or even negative[32]. The treatments also require the significant amount of high energy making it a cost intensive and difficult to scale up for industrial purposes[49]. However, small machines to grind or chop rice straw in combination with other treatments such as chemical and biological treatment in order to improve the efficiencies may be feasible.

In Vietnam, soaking dry rice straw in water before feeding animals is a traditional method using by many small-scale farmers[5]. They supposed that soaking will make rice straw softer and more desirable for animal eating. Recently, several enterprises have used industrial grinder and pelletiser systems to produce enriched-rice straw pellets supplying to large-scale cattle farms. Rice straw was chopped, ground and then mixed with ground processed cattle feed and/or other feedstuffs at different ratios. The mix was pelletised and packed before transporting to cattle farms. Hieu *et al.*[50] reported that the pelletising technology resulted in reducing transportation costs due to increase in its density and improving rice straw eating desirability for cattle. Although, the method increased the cost of densified product by 40-50%, it may create a new market for rice straw with more alternative options which cause reducing greenhouse gas emission from rice straw burning in the field.

Chemical treatment: Chemical treatments have received an appreciable amount of research and been popular methods of improving the nutritive value of rice straw. Chemicals may be alkaline, acidic or oxidative agents. Among these, alkali agents such as urea, ammonia and lime have been most widely investigated and practically accepted for application on farms. The chemicals are relatively cheap and procedures to use them are relatively simple. However, safety precautions are needed for their use as these chemicals themselves are not harmless[48]. Basically, alkali agents can disrupt cell wall structure by chemically breaking down the ester bonds between digestible carbohydrates and lignin for solubilisation of significant amount of hemicellulose and decrystallising cellulose[49]. Moreover, they physically make structural fibres swollen and thereby increase the amount of accessible surface of particles for microbial attachments to have higher degradability and better feed intake by ruminants[51].

Urea treatment is a conventional method of increasing the nitrogen level of ensiling materials through increasing the nitrogen content and digestibility[24,52]. Since urea is a solid chemical, which releases ammonia after dissolving in water, it is easy to handle and transport. For practical use by farmers, urea is cheaper and safer than using anhydrous or aqueous ammonia. It serves as a delignifying agent through ammonification[49]. In addition, urea treatment results in the removal of silica polymerised cuticle waxes from the surfaces of leaf sheath and blade[53]. Shen *et al.*[54] stated that urea treatment lead to a decrease in hemicellulose contents and an increase in extractable biogenic silica contents of rice straw. It also exposes the underlying tissues of straw to bacterial colonisation[55].

In Vietnam, treating rice straw by urea has received a great attention from both researchers and farmers. Since 1970s, rice straw treated by urea has fed to animals and cattle fed 2.5% urea-treated rice had 23.7% average daily gain higher than animals fed untreated rice straw[56]. Trach *et al.*[24] also concluded that cattle fed urea-treated rice straw improved average daily gain by 55-60% compared to that fed untreated rice straw. Trach[7] and Trach and Tuan[57] recommended that treating rice straw by up to 4% urea is an economic and effective preserved method to improve its nutritive value and digestibility. It in turn increases animal feed intake and performance. Trach *et al.*[58] and Thu and Dong[59] also observed that more rice straw cell wall fibres were solubilised and more rice straw dry matter was degraded in both *in sacco* and *in vitro* conditions when treating the straw by up to 5% urea in comparison with untreated rice straw. Similarly, there was an increase in voluntary feed intake and dry matter, organic matter, crude protein and NDF digestibility in urea treated rice straw when feeding to swamp buffalo bulls[22]. Man and Wiktorsson[52] concluded that the substitution of elephant grass (*Pennisetum purpureun*) by up to 75% fresh rice straw treated with 5% urea in lactating cow diets had no detrimental effect on milk yield and composition. They also suggested that the urea preservation of fresh rice straw for dairy cattle can reduce the cost of buying grass in forage-shortage periods, which is common practice in dairy production in Vietnam. Nguyen[5] observed that urea is the most popularly used treatment of rice straws.

Treating rice straw with anhydrous and aqueous ammonia (NH_3) has been widely investigated to improve degradability[40,60]. The principle of ammonia treatment is supposed to be similar to that of urea treatment. Ammonia treatment not only increases the degradability of rice straw but also adds nitrogen[9]. The urea and ammonia treatments increase the pH of silage above 8[57,61]. With this high pH and ammonia effect on silage, the growth of mould and yeast is inhibited specially in high moisture forage and consequently increases aerobic stability of the silage materials. Addition of ammonia also restrains plant proteases which diminishes the rate of protein degradation during preservation[48]. Besides, improvement in degradability of structural carbohydrates, ammonia treatment is an effective method to reduce the amount of supplemental nitrogen, in turn reduce the costs of purchasing protein-rich feedstuffs and enhance acceptability and voluntary intake of the treated straw by ruminants[62].

In Vietnam, a limited number of research use NH_3 as an alkali agent to treat rice straw and farmers prefer using urea to NH_3 to treat rice straw because of following reasons: (1) As mentioned before, urea is actually an ammonia source because it releases ammonia after dissolving in water, (2) Urea can be obtained easily in both urban and rural areas whereas NH_3 is not popularly sale, (3) Aqueous NH_3 is more technically difficult to handle and may expose the handler to health hazards while urea does not pose such problems. When using urea and ammonia, caution must be taken because excess ammonia may result in poor fermentation (because of a prolonged buffering effect) and low animal performance[63]. Since ammonia is corrosive to zinc, copper and brass, materials made of these substances should be avoided while ensiling ammonia treated forage.

Lime ($CaO/Ca(OH)_2$) is a weak alkali agent with a low solubility in water. It has been suggested that lime can be used to improve the utilisation of straw and also can be used to supplement rations with calcium. Lime is cheap and possible to easily find in many places. Moreover, lime treatments are simple, safe and almost harmless to environment[11]. Soaking and ensiling are two methods of treating straw with lime. In Vietnam, MARD[64] suggested farmers soaking rice straw with lime feeding to cattle during winter when forage is not enough. The straw is soaked in1% $Ca(OH)_2$ solution for three days, then it is either directly fed or dried before feeding[11]. Giang and Trach[65] reported that ensiling rice straw with either 6% CaO or 8% $Ca(OH)_2$ had higher apparent organic matter digestibility and metabolisable energy content compared to those of untreated straw. Trach *et al.*[58] concluded that lime treatments appeared to be more powerful in delignification than urea treatments. However, treating rice straw with lime at high level ($\geq$6%) maybe toxic to microorganism in the rumen and decrease voluntary dry matter intake, due to a reduced acceptability of the treated feed by animals. Furthermore, ensiling rice straw with lime should not be recommended for practical application because it cannot inhibit mould growth[11,65]. Numerous studies suggested that a combination of lime and urea would give better results than urea or lime alone. This combination has the advantage of increased degradability, increased both calcium and nitrogen contents and mould growth prevention.

In the world, other chemical agents such as sodium hydroxide, formic acid, propionic acid and acetic acid have been used to improve the use of crop residues for ruminant feeding[66,67]. The principal advantages of sodium hydroxide treatments are increased degradability and palatability of treated straw, compared to untreated straw[66]. Acids are used during ensiling to initiate rapid drop in pH to inhibit growth of undesirable microbes. They also reduce fermentation losses of carbohydrate and protein[63]. However, such chemicals are not widely available as a resource for small-scale farms and may be too expensive to use[68]. In addition, the application of these agents can be a cause of environmental pollution, resulting in a high content of sodium and inorganic acids in the environment[69,70]. It is difficult to handle these chemicals and they are toxic to human and animals. Therefore, they are limitedly applied and not recommended for use in developing countries[68].

Biological treatment: The biological treatments including lactic acid bacteria (LAB), white-rot fungi and their enzyme extracts have great potential in improving the nutritive value of rice straw[20,71,72]. Recently, perhaps no other area of silage management has received as much attention among both researchers and livestock producers as biological treatments. Table 2 summarises different microorganisms involved in treatment strategies and their effects on the nutritive value and degradation of rice straw.

White-rot fungi, as lignocellulolytic microorganisms, are able to degrade and metabolise plant wall cell constituents (lignin, cellulose and hemicellulose) by their enzymes[91]. Lee *et al.*[92] stated that lignin degradation by white-rot fungi occurs due to the presence of peroxidases and laccases (lignin-degrading enzymes).Numerous species of white-rot fungi have been used to improve the nutritive value of fodder

Table 2: Bacteria, fungi and their enzyme production studied to improve the nutritive value of rice straw for ruminant feed

Species	Determined enzyme	Main results	References
Ceriporiopsis subvermispora, *Lentinula edodes*, *Pleurotus eryngii*, *Pleurotus ostreatus*	Lignocellulolytic enzymes	Improved degradation of cell wall components, especially lignin	Tuyen *et al.*[20];
Pleurotus eryngii	Lignocellulolytic enzymes	Enhanced content of crude protein and reduced ADF, NDF and ADL contents; Increased the *in vivo* digestibility, N retention and microbial protein synthesis	Huyen *et al.*[73]; Huyen *et al.*[74]
Pleurotus ostreatus	Lignocellulolytic enzymes	Enhanced delignification, softness and the contents of protein and free sugar	Khan *et al.*[41]; Khattab *et al.*[75]; Sherief *et al.*[76] Chalamcherla *et al.*[77]
Trichoderma reesei, *Trichoderma viride*	Fibrolytic enzymes	Increased dry matter degradability and protein contents, decreased fiber contents	Eun *et al.*[78]; El-Bordeny *et al.*[79]; Gomaa *et al.*[80]
Phlebia brevispora	Xylanase	Minimised loss in total organic matter, improved crude protein content, lignin degradability and *in vitro* DM digestibility	Sharma and Arora[81]
Aspergillus terreus	Lignocellulolytic enzymes	Improved hemicellulose and lignocellulose degradation	Jahromi *et al.*[82]
Aspergillus niger	Cellulase and xylanase	Improved *in vitro* digestibility of nutrients	Cuong *et al.*[83]
Exogenous enzymes	Cellulase and xylanase	Improved rumen fermentation, dry matter and NDF digestibility, enhanced the rumen bacterial population	Mao *et al.*[84]; Sujani *et al.*[71]
Exogenous enzymes	Cellulase, xylanase, protease and alpha amylase	Improved the dry matter, NDF and ADF degradability	Gado *et al.*[85]
Exogenous enzymes	Fibrolytic enzymes	Improved *in vitro* digestibility of nutrients and rumen fermentation	Sheikh *et al.*[86]; Adesogan *et al.*[87]
Bacillus licheniformis	Proteolytic enzymes	Increased dry matter, NDF degradability	Eun *et al.*[78]
Lactobacillus bulgaricus		Quickly reduced pH to repress the growth of unexpected microorganisms, increased palatability	Wang *et al.*[88]
Lactobacillus fermentum		Quickly reduced pH to improve preservation efficiency	Yanti *et al.*[89]
Lactobacillus buchneri and *Pediococcus pentosaceus*		Significantly improved rumen fermentation and silage quality	Zhang *et al.*[90]
The mix of lactic acid bacteria		Improved lactic acid production and *in vitro* digestibility of dry matter	Liu *et al.*[72]

including rice straw. Tuyen *et al.*[20] treated rice straw with 4 white-rot fungus species and concluded that *Ceriporiopsis subvermispora*, *Lentinula edodes* perform the best and have a significantly high potential to improve the degradation of cell wall components, especially lignin in rice straw. Using oyster mushrooms (*Pleurotus ostreatus*) to increase the degradability of rice straw were employed by many studies (Table 2). White-rot fungi are able to decompose free phenolic monomers and to break the bonds with which lignin is cross-linked to the polysaccharides in rice straw[82], enhance *in vitro* dry matter digestibility[78,80] and minimise loss in total organic matter[79,81].

In the last decade, concerted efforts have been devoted of using exogenous enzymes to improve forage quality and ruminant animal performance. In rice straw, Sujani *et al.*[71] and Mao *et al.*[84] concluded that a combination of cellulase and xylanase effectively improve rumen fermentation, increase rice straw DM and NDF digestibilities and enhance the rumen bacterial numbers. Sheikh *et al.*[86] and Gado *et al.*[85] treating rice straw with fibrolytic enzymes also observed an improvement in *in vitro* rumen fermentation and nutrient digestibility. However, other studies, using fibrolytic enzymes, could not significantly increase the degradability of rice straw[9,93]. Enzyme additives vary in effectiveness (efficiency of fiber-degrading) depending upon forage types, moisture content, temperature, incubation time, its own characteristics[42]. To optimise fibrolytic activity, Adesogan *et al.*[87] suggested the enzymes need to: (1) Contain appropriate amounts of cofactors, co-enzymes and activators, (2) Be resistant to degradation by ruminant proteases, (3) Have a robust composition that does not vary appreciably with the enzyme batch, (4) Be sourced from a readily culturable fungus, (5) Exhibit optimal and steady activity under a wide range of ambient conditions, (6) Be in liquid form or dissolve rapidly and completely in water, (7) Be thermo-stable in cases it will be added during feed manufacturing and (8) Maintain its hydrolytic activity when appropriately stored for long durations.

Recently, bacteria have become one of the main additives to during silage preparation and making. Lactic acid bacteria are commonly investigated and used to improve the fermentation quality of rice straw silage. The LAB associated with silage belonging to the genera of *Lactobacillus*, *Enterococcus*, *Pediococcus* and *Leuconostoc*[94].

The whole base of LAB in silage is centralised on their ability to reduce the pH value which can be reduced to 3.7 and 4.2 and contain high concentration of lactic acid[42]. Anaerobic bacteria fermentation converts sugary compounds in the straw into lactic acid inhibiting normal aerobic bacterial action. If the air is kept out of the silage, it is preserved efficiently and stably. Yanti *et al.*[89] reported that fermenting rice straw with *Lactobacillus fermentum* resulted in better silage quality compared to bacillus and fungi (*Aspergillus niger* and *Saccharomyces cerevisiae*). Other studies also confirmed that ensiling rice straw with LAB is one of the methods for quickly reducing pH to oppress the growth of unexpected microorganisms[88]; improving lactic acid production[72]; achieving a proper rumen fermentation and nutrient preservation[90].

Numerous studies have recommended that combinations biological treatments with other methods are promising for having a synergistic effect on the nutritive improvement of rice straw[9,17,95]. Abdel-Aziz *et al.*[42] concluded that combination microorganisms with actions including chopping, moisture changing and pressing improved the fermentation quality. The similar results were observed by Wang *et al.*[88], who treated wilted rice straw with LAB in combination with chemical additives and by Eun *et al.*[78] who treated rice straw with xylanase or cellulase in combination with ammonia. In theory, these additives complement each other by utilising additional substrate provided by the enzymes during the fermentation process.

In Vietnam, the number of studies using biological additives alone or combining with other methods to treat rice straw for ruminant feed still remain limited and inconsistent. When treating fresh rice straw with LAB (mainly *Lactobacillus plantarum*, *Lactobacillus pentosus* and *Enterococus lactis*) and/or multi-enzymes for 60 days, Hung *et al.*[93] did not observe any improvement in the *in sacco* degradability of dry matter and NDF in the straw. In contrast, Cuong *et al.*[83] concluded that the *in vitro* degradability of nutrients was improved when dried rice straw was treated with the mix of cellulase and xylanase (extracted from *Aspergillus niger*) alone or in combination with microbial additives. Huyen *et al.*[73] and Huyen *et al.*[74] reported that fermenting rice straw with *Pleurotus eryngii* increased the content of crude protein and the *in vivo* digestibility of nutrients in the straw feeding to sheep. As of now, several small-scale farms have treated fresh rice straw with multi-purposed effective microorganisms (containing *Lactobacillus plantarum*) in combination with molasses and salt to produce silage for ruminants[5]. However, no on-farm research on rice straw biological treatments affecting ruminant performance have been recorded.

The biological treatments have great potential and advantages in comparison to other methods. They do not require machine or industrial processing and safer to handle. Biological treatments are low-energy processes, non-corrosive to machinery and regarded as environmentally friendly viable alternatives[6,49]. Nevertheless, there are also a number of serious problems to consider and overcome if these treatments are applied on-farm and industrial scales in developing countries[17,95]. In an on-farm application, it is difficult to control the optimal environmental conditions for fungal growth, such as temperature, pH, pressure, oxygen and carbon dioxide concentration when treating rice straw. Currently, it is also difficult and lack of technology to produce large quantities of fungi or their enzymes to meet the requirements, leading to expensive in price[95]. Furthermore, sterile conditions, time consuming and major portion of dry matter loss in fungal treatments should also be taken into account[70]. With recent developments in alternative enzyme production and fermentation technologies, the costs of these materials are expected to decline and commercial products may become viable in the future[49,95].

Supplemented with other additives: It is necessary to provide the rumen microbes with the nutritive elements which they need for self-multiplication and for degradation of the cell walls of rice straw and to ensure all conditions for maintenance of good cellulolysis. The supplementation of locally available additives should be an effective and inexpensive strategy for better use of rice straw. As aforementioned, rice straw is low in crude protein and difficult to degrade, it is obvious that supplementation of rice straw with a protein source and a more easily accessible energy source will improve the performance of the animals. Supplementation of rice straw with protein, energy and/or minerals may optimise rumen function, also maximise utilisation of the rice straw, increase intake and reduce the time taken to attain desirable market weight[96]. Apart from

Table 3: Feeding rice straw supplemented with other components in Vietnam

Supplements	Animals	Effects	References
Leucaena leaf pellet	Swamp buffaloes	Improved rumen ecology, N-retention and microbial N supply	Hung *et al.*[98]
Urea-molasses cake	Swamp buffaloes	Increase in rumen NH_3-N concentration, microbial population and feed intake	Thu and Udén[99]
Ensiled or pelleted cassava foliage	LaiSind heifers	Improved growth rate	Khang and Wiktorsson[100]
Cottonee seed cake and water hyacinth silage	LaiSind heifers	Improved crude protein intake and digestibility of nutrients	Tham and Udén[101]
Cassava root meal and groundnut cake	LaiSind cattle	Increased dry matter intake and live weight gain	Trung *et al.*[102]
Elephant grass and cassava powder	LaiSind cattle	Increased digestibility of nutrients and live weight gain	Ba *et al.*[96]
Cassava leaf meal and the mixture of molasses and urea	LaiSind cattle	Improved growth performance and feed conversion	Tham *et al.*[103]
Urea-sprayed and wet brewers' grains	LaiSind cattle	Improved feed intake and growth rate	Trach and Thom[104]
The mixture of cassava chips, rice bran, crushed rice grain, fish meal, urea	Crossbred Brahman cattle	Increased digestibility of nutrients, live weight gain	Quang *et al.*[105]
Mulberry leaf meal	Crossbred Brahman cattle	improved dry matter intake, ruminal NH_3-N and rumen ecology	Tan *et al.*[106]
Molasses urea block, beverage residue, soybean meal	Holstein-Friesian crossbred cows	Increased milk yield and fat content, reduce the time of calving interval	Vu *et al.*[107]
Leucaena silage	Dairy steers	Improved microbial population and microbial protein synthesis	Giang *et al.*[108]
Molasses and protein-rich forage	Phan Rang lambs	Increased dry matter intake, nutrient digestibility and feed conversion	Hue *et al.*[109]
Cassava foliage hay, molasses urea block, cassava root	Lactating goats	Increased milk yield and quality, growth rates of kids	Dung *et al.*[110]

commercial concentrate, a huge number of studies on untreated or treated rice straw diets supplementing with locally available by-products have been conducted around the world and recently reviewed elsewhere[6,97].

In Vietnam, a wide range of supplements have been used such as molasses, brewers' grains, cassava chips, green leaves, multi-nutrient blocks and other crop residues in ruminant diets with rice straw as a main forage. It is evident in Table 3 that the growth performance of animals and their product quality were considerably increased. LaiSind beef cattle dramatically increased their feed intake and growth rate when feeding rice straw diet supplemented with cassava roots and/or ground nut cake[96,102]. Protein-rich leaves (leucaena, cassava and mulberry) were commonly used to supplement into rice straw basal diet and had more benefits as indicated by an increased feed intake, live weight gain in beef cattle[100,106]; increased milk yield and quality in lactating goats[110], less consumption of commercial concentrate and other expensive protein sources and therefore an increased income[108,109]. The rice straw supplemented with molasses urea block increased both the nutritive values of the degradability of diets and the production performance of ruminants[99,107].

Although, there have already been numerous laboratory studies, *in sacco* experiments, on-station and on-farm trials in Vietnam, most of the research works have so far been conducted separately. There is still a lack of systematic research into straw treatment and supplementation from laboratory to production. The majority of studies recommended that suitable treatment techniques in combination with nutrient supplementation could result in improved utilisation of rice straw and better feeding value. However, the percentage of rice straw using as ruminant feed is really low and farmers usually feed untreated rice straw without supplements to animals. In this respect, future research should focus on optimisation of biological and economic effects of different treatments and supplement inputs including locally available sources to suggest the best or alternative solutions.

CONCLUSIONS AND FUTURE RECOMMENDATIONS

In Vietnam, ruminant production plays a crucial role but its further development is confronted with major issues related to forage because of the shortage of grazing land and grown grasses and the low quality of crop residues. Rice straw is the most abundant and sustainable source for ruminant feed in terms of volumes annually generated. However, the majority of rice straw has been burned on fields, only a small proportion is fed to ruminants.

Rice straw is typically poor and unbalanced in nutritive values high levels of lignification and silicification and low contents of crude protein and minerals. So feeding only rice straw to ruminants does not provide enough nutrients even for maintenance.

Although, numerous treatments have been employed to improve the utilisation of rice strawin ruminant production by increasing its degradability and voluntary intake. The practical use of single physical or chemical treatment in small-scale farms is still restricted in terms of costs, safety concerns and potentially negative environmental consequences. The question is arisen that what are the strategies which can be technically and socio-economically relevant and acceptable to farmers under local conditions. The use of fungus and exogenous enzyme treatments is expected to be a practical, cost-effective and environmental-friendly approach for enhancing the nutritive value and digestibility of rice straw. In addition, the application of ligninolytic fungi or their enzymes combined with locally available inputs such as urea and/or lime, protein-rich sources, nonstructural carbohydrates may be an alternative ways to shorten the period of the incubation times and/or decrease the amount of chemicals, effecting some synergy. It can be concluded that till date a difficulty in controlling optimal environmental conditions for fungal growth and alack of technology to produce large quantities of fungi or their enzymes are the main obstacles of biological treatments applied in small-scale farms. Further studies are needed on optimisation of biological and economic effects of different treatments and development in alternative enzyme production and fermentation technologies.

REFERENCES

1. GSO., 2018. Socio-economic situation in 2018. General Statistic Office, (In Vietnamese). https://www.gso.gov.vn/default.aspx?tabid=621&ItemID=19037
2. Nguyen, H.V., C.D. Nguyen, T.V. Tran, H.D. Hau, N.T. Nguyen and M. Gummert, 2016. Energy efficiency, greenhouse gas emissions and cost of rice straw collection in the mekong river delta of vietnam. Field Crops Res., 198: 16-22.
3. Huong, H.T.T., 2018. Current situation of ruminant production in Vietnam and development orientation to 2030. In Ruminant Production: Status Quo and Solution, Hanoi, Vietnam, pp: 1-10, (In Vietnamese).
4. Nam, T.S., N.T.H. Nhu, N.H. Chiem, N.V.C. Ngan, L.H. Viet and K. Ingvorsen, 2014. To quantify the seasonal rice straw and its use in different provinces in the Vietnamese Mekong Delta. Can. Tho. Uni. J. Sci., 32: 87-93, (In Vietnamese).
5. Nguyen, D.V., 2018. Current status of ruminant feed production from rice straw in Vietnam. Low Carbon Agricultural Support Project, Ministry of Agriculture and Rural Development, Hanoi, Vietnam.
6. Malik, K., J. Tokkas, R.C. Anand and N. Kumari, 2015. Pretreated rice straw as an improved fodder for ruminants-An overview. J. Applied Nat. Sci., 7: 514-520.
7. Trach, N.X., 1998. The need for improved utilisation of rice straw as feed for ruminants in Vietnam: An overview. Livest. Res. Rural Dev., Vol. 10.
8. Van Soest, P.J., 2006. Rice straw, the role of silica and treatments to improve quality. Anim. Feed Sci. Technol., 130: 137-171.
9. Sarnklong, C., J.W. Cone, W.F. Pellikaan and W.H. Hendriks, 2010. Utilization of rice straw and different treatments to improve its feed value for ruminants: A review. Asian-Aust. J. Anim. Sci., 23: 680-692.
10. Anonymous, 2014. Ministry of Agriculture and Rural Development: Conference on implementing hunger and cold prevention for cattle inwinter-spring crop in 2014. (InVietnamese). http://www.khuyennongvn.gov.vn/vi-VN/hoat-dong-khuyen-nong/thong-tin-huan-luyen/bo-nong-nghiep-va-ptnt-hoi-nghi-trien-khai-cong-tac-phong-chong-doi-ret-cho-gia-suc-vu-dong-xuan-nam-2014_t114c31n10687.
11. Ngoan, L.D., N.X. Ba and N.H. Van, 2007. Feed for Ruminants in Household Central Vietnam. Agriculture Publishing House, Vietnam, (In Vietnamese).
12. Hưng, N.T.Q., L.K. Thong and N.M. Ky, 2017. Ti mnăngsinhkh iph ph mnôngnghi pvàhi uqu ngd ngs nxu t than sinhh c (biochar) quymôh giađình GòCôngTây, t nhTi nGiang [Potential of agricultural by-product biomass and the efficiency of biochar production in household scale in Go Cong Tay, Tien Giang province]. Sci. Technol. Dev., 20: 68-78 (In Vietnamese).
13. Truc, N.T.T., Z.M. Sumalde, M.V.O. Espaldon, E.P. Pacardo, C.L. Rapera and F.G. Palis, 2012. Farmers' awareness and factors affecting adoption of rapid composting in Mekong Delta, Vietnam and Central Luzon, Philippines. J. Environ. Sci. Manage., 15: 59-73.
14. Duong, P.T. and H. Yoshiro, 2015. Current situation and possibilities of rice straw management in Vietnam. http://www.jsrsai.jp/Annual_Meeting/PROG_52/ResumeC/C02-4.pdf.
15. UN-ESCAP., 2018. Status of straw management in Asia-Pacific and options for integrated straw management. http://www.un-csam.org/Publication/Status Of Straw MgrAP_final_31July2018.pdf.
16. Le, T.H., T.N.T. Nguyen, K. Lasko, S. Ilavajhala, K.P. Vadrevu and C. Justice, 2014. Vegetation fires and air pollution in Vietnam. Environ. Pollut., 195: 267-275.

17. Sheikh, G.G., A.M. Ganai, P.A. Reshi, S. Bilal, S. Mir and D. Masood, 2018. Improved paddy straw as ruminant feed: A review. Agric. Rev., 39: 137-143.
18. Satlewal, A., R. Agrawal, S. Bhagia, P. Das and A.J. Ragauskas, 2018. Rice straw as a feedstock for biofuels: Availability, recalcitrance and chemical properties. Biofuels Bioprod. Biorefin., 12: 83-107.
19. Nguyen, D.V., 2018. The chemical compositons of fresh and dry rice straw from different project provinces in Viet Nam. Low Carbon Agricultural Support Project, Ministry of Agriculture and Rural Development, Hanoi, Vietnam.
20. Tuyen, D.V., H.N. Phuong, J.W. Cone, J.J.P. Baars, A.S.M. Sonnenberg and W.H. Hendriks, 2013. Effect of fungal treatments of fibrous agricultural by-products on chemical composition and *in vitro* rumen fermentation and methane production. Bioresour. Technol., 129: 256-263.
21. Nguyen, D.V., S.H. Nguyen, T.T. Luu and C.C. Vu, 2012. Effects of supplementary rich tannin leaf meals on methane production in an *in vitro* incubation using rice straw and rice bran as a basal substrate. J. Anim. Sci. Technol., 36: 65-76.
22. Nguyen, V.T., M. Wanapat, P. Khejornsart and P. Kongmun, 2012. Nutrient digestibility and ruminal fermentation characteristic in swamp buffaloes fed on chemically treated rice straw and urea. Trop. Anim. Health Prod., 44: 629-636.
23. Vu, C.C., M.W.A. Verstegen, W.H. Hendriks and K.C. Pham, 2011. The nutritive value of mulberry leaves (*Morus alba*) and partial replacement of cotton seed in rations on the performance of growing Vietnamese cattle. Asian-Aust. J. Anim. Sci., 24: 1233-1242.
24. Trach, N.X., B.Q. Tuan, M.T. Thom and N.T. Tu, 2006. Treatment and preservation of fresh rice straw for ruminant feeding. Vietnam J. Anim. Prod., 9: 27-32, (In Vietnamese).
25. Dung, D.V., N.X. Ba, N.H. Van, L.D. Phung, L.D. Ngoan, V.C. Cuong and W. Yao, 2013. Practice on improving fattening local cattle production in Vietnam by increasing crude protein level in concentrate and concentrate level. Trop. Anim. Health Prod., 45: 1619-1626.
26. Nguyen, D.V. and L.H. Dang, 2020. Fresh rice straw silage affected by ensiling additives and durations and its utilisation in beef cattle diets. Asian J. Anim. Sci., 14: 16-24.
27. Vadiveloo, J., 1992. Varietal differences in the chemical composition and *in vitro* digestibility of rice straw. J. Agric. Sci., 119: 27-33.
28. Agbagla-Dohnani, A., P. Noziere, B.G. Martinie, M. Puard and M. Doreau, 2003. Effect of silica content on rice straw ruminal degradation. J. Anim. Sci., 140: 183-192.
29. Meharg, C. and A.A. Meharg, 2015. Silicon, the silver bullet for mitigating biotic and abiotic stress and improving grain quality, in rice? Environ. Exp. Bot., 120: 8-17.
30. Song, Z., H. Wang, P.J. Strong and S. Shan, 2014. Increase of available soil silicon by Si-rich manure for sustainable rice production. Agron. Sustainable Dev., 34: 813-819.
31. Agrawal, R., A. Satlewal, B. Sharma, A. Mathur, R. Gupta, D. Tuli and M. Adsul, 2017. Induction of cellulases by disaccharides or their derivatives in *Penicillium janthinellum* EMS-UV-8 mutant. Biofuels, 8: 615-622.
32. Schiere, J.B. and M.N.M. Ibrahim, 1989. Feeding of Urea-Ammonia Treated Rice Straw: A Compilation of Miscellaneous Reports Produced by the Straw Utilization Project (Sri Lanka). Pudoc Publication, Wageningen.
33. Iiyama, K., T.B.T. Lam and B.A. Stone, 1990. Phenolic acid bridges between polysaccharides and lignin in wheat internodes. Phytochemistry, 29: 733-737.
34. Ding, S.Y., Y.S. Liu, Y. Zeng, M.E. Himmel, J.O. Baker and E.A. Bayer, 2012. How does plant cell wall nanoscale architecture correlate with enzymatic digestibility? Science, 338: 1055-1060.
35. Van Soest, P.J., 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants: Voluntary intake in relation to chemical composition and digestibility. J. Anim. Sci., 24: 834-843.
36. Kanjanapruthipong, J. and B. Thaboot, 2006. Effects of neutral detergent fiber from rice straw on blood metabolites and productivity of dairy cows in the tropics center. Asian-Aust. J. Anim. Sci., 19: 356-362.
37. Gowda, N.K.S. and C.S. Prasad, 2005. Macro- and micro-nutrient utilization and milk production in crossbred dairy cows fed finger millet (*Eleucinecoracana*) and rice (*Oryza sativa*) straw as dry roughage source. Anim. Breed. Genet., 18: 48-52.
38. Cymbaluk, N.F., J.D. Millan, D.A. CHristensen, 1986. Oxalate concentration in feeds and its metabolism by ponies. Can. J. Anim. Sci., 66: 1107-1116.
39. Rahman, M.M., R.B. Abdullah and W.E.W. Khadijah, 2013. A review of oxalate poisoning in domestic animals: Tolerance and performance aspects. J. Anim. Physiol. Anim. Nutr., 97: 605-614.
40. Fadel Elseed, A.M.A., J. Sekine, M. Hishinuma and K. Hamana, 2003. Effects of ammonia, urea plus calcium hydroxide and animal urine treatments on chemical composition and *in sacco* degradability of rice straw. Asian-Aust. J. Anim. Sci., 16: 368-373.
41. Khan, N.A., S. Hussain, N. Ahmad, S. Alam and M. Bezabhi *et al*., 2014. Improving the feeding value of straws with *Pleurotusostreatus*. Anim. Prod. Sci., 55: 241-245.
42. Abdel-Aziz, N. A., A.Z.M. Salem, M.M. El-Adawy, L.M. Camacho, A.E. Kholif, M.M.Y. Elghandour and B.E. Borhami, 2015. Biological treatments as a mean to improve feed utilization in agriculture animals-an overview. J. Integr. Agric., 14: 534-543.
43. Agbor, V.B., N. Cicek, R. Sparling, A. Berlin and D.B. Levin, 2011. Biomass pretreatment: Fundamentals toward application. Biotechnol. Adv., 29: 675-685.
44. Nibedita, S., K.G. Sumanta, B. Satarupa and A. Kaustav, 2012. Bioethanol production from agricultural wastes: An overview. Renewable Energy, 37: 19-27.

45. Stensig, T., M.R. Weisbjerg, J. Madsen and T. Hvelplund, 1994. Estimation of voluntary feed intake from in sacco degradation and rate of passage of DM or NDF. Livest. Prod. Sci., 39: 49-52.
46. Selim, A.S.M., J. Pan, T. Takano, T. Suzuki, S. Koike, Y. Kobayashi and K. Tanaka, 2004. Effect of ammonia treatment on physical strength of rice straw, distribution of straw particles and particle-associated bacteria in sheep rumen. Anim. Feed Sci. Technol., 115: 117-128.
47. Lui, J.X., E.R. Orskov and X.B. Chen, 1999. Optimization of steam treatment as a method for upgrading rice straw as feeds. Anim. Feed Sci. Technol., 76: 345-357.
48. Emtenan, M.H., H.H. El Khadrawy, W.M. Ahmed and M.M. Zaabal, 2012. Some observations on rice straw with emphasis on updates of its management. World Applied Sci. J., 16: 354-361.
49. Kumar, A.K. and S. Sharma, 2017. Recent updates on different methods of pretreatment of lignocellulosic feedstocks: A review. Bioresourc. Bioprocess., 4: 1-19.
50. Nguyen, V.H., T.N. Nguyen, Q.V. Le, M.A. Le, V.H. Nguyen and M. Gummert, 2018. Developing densified products to reduce transportation costs and improve the quality of rice straw feedstocks for cattle feeding. J. Vietnamese Environ., 10: 11-15.
51. Wanapat, M., S. Polyorach, K. Boonnop, C. Mapato and A. Cherdthong, 2009. Effects of treating rice straw with urea or urea and calcium hydroxide upon intake, digestibility, rumen fermentation and milk yield of dairy cows. Livest. Sci., 125: 238-243.
52. Man, N.V. and H. Wiktorsson, 2001. The effect of replacing grass with urea treated fresh rice straw in dairy cow diet. Asian Aust. J. Anim. Sci., 14: 1090-1097.
53. Wang, J.K., J.X. Liu, J.Y. Li, Y.M. Wu and J.A. Ye, 2007. Histological and rumen degradation changes of rice straw stem epidermis as influenced by chemical pretreatment. Anim. Feed Sci. Technol., 136: 51-62.
54. Shena, H.S., D.B. Nib and F. Sundstolc, 1998. Studies on untreated and urea-treated rice straw from three cultivation seasons: 1. Physical and chemical measurements in straw and straw fractions. Anim. Feed Sci. Technol., 73: 243-261.
55. De Sousa Santos, F.N., M.S. de Souza Carneiro, R.A. de Araújo, C.D.S. Costa and L.D.N.C. da Silva *et al*., 2017. Ammoniation on the quality of tropical grasses: A review. Rev. Bras. HigieneSanidade Anim., 11: 131-143.
56. Chinh, B.V., L.L. Viet and N.H. Tao, 1995. Study on processing and use of agricultural by-products and available food sources in Rural areas. In Selection of Research Works on Animal Production 1969-1995. Agricultural Publisher, Hanoi, Vietnam, (In Vietnamese).
57. Trach, N.X. and B.Q. Tuan, 2008. Effects of treatment of fresh rice straw on its nutritional characteristics. J. Sci. Dev., 2008: 129-135.
58. Trach, N.X., M. Mo and C.X. Dan, 2001. Effects of treatment of rice straw with lime and/or urea on its chemical composition, *in-vitro* gas production and in-sacco degradation characteristics. Livest. Res. Rural Dev., Vol. 13, No. 4.
59. Thu, N.V. and N.T.K. Dong, 2011. Application of *in vitro* techniques for assessment of nutritive values as ruminant feed. Can. Tho Univ. J. Sci., 17: 124-132, (In Vietnamese).
60. Selim, A.S.M., J. Pan, T. Suzuki, K. Ueda, Y. Kobayashi and K.Tanaka, 2002. Postprandial changes in particle associated ruminal bacteria in sheep fed ammoniated rice straw. Anim. Feed Sci. Technol., 102: 207-215.
61. Lunsin, R., S. Duanyai, R. Pilajun, S. Duanyai and P. Sombatsri, 2018. Effect of urea-and molasses-treated sugarcane bagasse on nutrient composition and *in vitro* rumen fermentation in dairy cows. Agric. Nat. Resourc., 52: 622-627.
62. Thanh, V.T.K., 2012. The effect on intake digestibility and microbial protein production of adding urea to rice straw for cattle and buffalo calves. Livest. Sci., 150: 111-113.
63. Yitbarek, M. and B. Tamir, 2014. Silage additives: Review. Open J. Applied Sci., 4: 258-274.
64. B Nôngnghi pvàPháttri nnôngthôn 2009. Ch bi nrơmlàmth cănchotrâubòtrongv đôngxuân. [Processing straw as food for cattle in the winter-spring crop.] (In Vienamese) https://www.mard.gov.vn/Pages/che-bien-rom-lam-thuc-an-cho-trau-bo-trong-vu-dong-xuan-1014.aspx
65. Giang, V.D. and N.X. Trach, 2002. Effects of treatments with lime and/or urea on ricestraw chemical composition, intake anddegradability. Proceedings of the Workshop on Improved Utilization of By-Products for Animal Feeding in Vietnam, (PAFV'02), The Agricultural Publishing House, Hanoi, Vietnam, pp: 162-175.
66. Ghasemi, E., M. Khorvash, G.R. Ghorbani, M.R. Emami and K. Karimi, 2013. Dry chemical processing and ensiling of rice straw to improve its quality for use as ruminant feed. Trop. Anim. Health Prod., 45: 1215-1221.
67. Koike, S., H. Yabuki and Y. Kobayashi, 2014. Interaction of rumen bacteria as assumed by colonization patterns on untreated and alkali treated rice straw. Anim. Sci. J., 85: 524-531.
68. Ngoan, L.D., N.T.H. Ly and D.T.T. Hang, 2005. Animal Feed. The Agricultural Publishing House, Hanoi, Vietnam, (In Vietnamese)..
69. Dashtban, M., H. Schraft and W. Qin, 2009. Fungal bioconversion of lignocellulosic residues; opportunities and perspectives. Int. J. Biol. Sci., 5: 578-595.
70. Van Kuijk, S.J.A., A.S.M. Sonnenberg, J.J.P. Baars, W.H. Hendriks and J.W. Cone, 2015. Fungal treated lignocellulosic biomass as ruminant feed ingredient: A review. Biotechnol. Adv., 33: 191-202.
71. Sujani, S., T. Piyasena, T. Seresinhe, I. Pathirana and C. Gajaweera, 2017. Supplementation of rice straw (*Oryza sativa*) with exogenous fibrolytic enzymes improves *in vitro* rumen fermentation characteristics. Turk. J. Vet. Anim. Sci., 41: 25-29.

72. Liu, J.J., X.P. Liu, J.W. Ren, H.Y. Zhao and X.F. Yuan *et al*., 2015. The effects of fermentation and adsorption using lactic acid bacteria culture broth on the feed quality of rice straw. J. Integr. Agric., 14: 503-513.
73. Huyen, N.T., N.T.T. Le and B.Q. Tuan, 2019. Fermenting rice straw with the fungus *Pleurotuseryngii* increased the content of crude protein and the digestibility of the straw. Livest. Res. Rural Dev., Vol. 21. No. 2.
74. Huyen, N.T., B.Q. Tuan, N.X. Nghien, N.T.B. Thuy and N.T.T. Le, 2019. Effect of using fungal treated rice straw in sheep diet on nutrients digestibility and microbial protein synthesis. Asian J. Anim. Sci., 13: 1-7.
75. Khattab, H.M., H.M. Gado, A.Z.M. Salem, L.M. Camacho, M.M. El-Sayed, A.M. Kholif and A.E. Kholif, 2013. Chemical composition and *in vitro* digestibility of pleurotusostreatus spent rice straw. Anim. Nutr. Feed Technol., 13: 507-516.
76. Sherief, A.A., A.B. El-Tanash and A.M. Temraz, 2010. Lignocellulolytic enzymes and substrate utilization during growth and fruiting of *Pleurotusostreatus* on some solid wastes. J. Environ. Sci. Technol., 3: 18-34.
77. Chalamcherla, V., A.S. Maringanti, V.L. Muvva, L.N. Mangamoori and M.R. Ramireddy, 2009. Use of lignocellulolytic mutants of *Pleurotusostreatus* in ruminant feed formulations. BioResources, 4: 142-154.
78. Eun, J.S., K.A. Beauchemin, S.H. Hong and M.W. Bauer, 2006. Exogenous enzymes added to untreated or ammoniated rice straw: Effects on *in vitro* fermentation characteristics and degradability. Anim. Feed Sci. Technol., 131: 86-102.
79. El-Bordeny, N.E., H.M. Khattab, A.M. El-Badr and M.A. Madkour, 2015. Using of bio-upgraded rice straw in growing lambs nutrition. Asian J. Anim. Vet. Adv., 10: 62-73.
80. Gomaa, R., H. Gado, H. El-Sayed and S. Abd El Mawla, 2012. Usage of treated rice straw with exogenous anaerobic bacterial enzymes (ZAD) for Ossimi sheep. Ann. Agric. Sci., 57: 183-190.
81. Sharma, R.K. and D.S. Arora, 2010. Changes in biochemical constituents of paddy straw during degradation by white rot fungi and its impact on *in vitro* digestibility. J. Applied Microbiol., 109: 679-685.
82. Jahromi, M.F., J.B. Liang, M. Rosfarizan, Y.M. Goh, P. Shokryazdan and Y.W. Ho, 2011. Efficiency of rice straw lignocelluloses degradability by *Aspergillus terreus* ATCC 74135 in solid state fermentation. Afr. J. Biotechnol., 10: 4428-4435.
83. Cuong, P.K., B.T.T. Hien, L.T. Thi, P.N. Thach, L.V. Hung, L.T.H. Yen and D.V. Hop, 2017. Effects of bio-product supplementation on *in vitro* fermentation of several kinds of roughage used for cattle. J. Anim. Sci. Technol., 81: 57-71, (In Vietnamese).
84. Mao, H.L., C.H. Wu, J.K. Wang and J.X. Liu, 2013. Synergistic effect of cellulase and xylanase on *in vitro* rumen fermentation and microbial population with rice straw as substrate. Anim. Nutr. Feed Technol., 13: 477-487.
85. Gado, H.M., A.Z.M. Salem, L.M. Camacho, L.M. Camacho, M.M.Y. Elghandour and M.C. Salazar, 2013. Influence of exogenous enzymes on *in vitro* ruminal degradation of ensiled rice straw with DDGS. Anim. Nutr. Feed Technol., 13: 569-574.
86. Sheikh, G.G., A.M. Ganai, A. Ishfaq, Y. Afzal and H.A. Ahmad, 2017. *In vitro* effect of probiotic mix and fibrolytic enzyme mixture on digestibility of paddy straw. Adv. Anim. Vet. Sci., 5: 260-266.
87. Adesogan, A.T., Z.X. Ma, J.J. Romero and K.G. Arriola, 2014. Ruminant nutrition symposium: Improving cell wall digestion and animal performance with fibrolytic enzymes. J. Anim. Sci., 92: 1317-1330.
88. Wang, Y.S., W. Shi, L.T. Huang, C.L. Ding and C.C. Dai, 2016. The effect of lactic acid bacterial starter culture and chemical additives on wilted rice straw silage. Anim. Sci. J., 87: 525-535.
89. Yanti, Y., S. Surahmanto, A. Purnomoadi and Y. Kawamoto, 2012. Organic acids production of rice straw fermented with several types of microorganism at different temperatures. J. Indones. Trop. Anim. Agric., 37: 189-194.
90. Zhang, Y.G., H.S. Xin and J.L. Hua, 2010. Effects of treating whole-plant or chopped rice straw silage with different levels of lactic acid bacteria on silage fermentation and nutritive value for lactating Holsteins. Asian-Aust. J. Anim. Sci., 23: 1601-1607.
91. Eriksson, K.E.L., R. Blanchette and P. Ander, 1990. Microbial and Enzymatic Degradation of Wood and Wood Components. 1st Edn., Springer-Verlag, Berlin Heidelberg, Pages: 407.
92. Lee, J.W., K.S. Gwak, J.Y. Park, M.J. Park, D.H. Choi, M. Kwon and I.G. Choi, 2007. Biological pretreatment of softwood *Pinus densiflora* by three white rot fungi. J. Microbiol., 45: 485-491.
93. Hung, L.V., N.S. Manh, C.C. Vu, D.V. Tuyen, T.Q. Viet, L.V. Huyen and B.T.T. Huyen, 2012. Effects of using bacterial inoculant, multi-enzyme supplement to silage on degradability in sacco of some kinds of grass and crop residues as feed for ruminants. J. Agric. Rural Dev., 11: 37-54, (In Vietnamese).
94. McDonald, P., 1981. The Biochemistry of Silage. John Wiley's and Sons Ltd., New York, Pages: 226.
95. Yanti, Y. and M. Yayota, 2017. Agricultural by-products as feed for ruminants in tropical area: Nutritive value and mitigating methane emission. Rev. Agric. Sci., 5: 65-76.
96. Ba, N.X., N.H. Van, L.D. Ngoan, C.M. Leddin and P.T. Doyle, 2008. Amount of cassava powder fed as a supplement affects feed intake and live weight gain in Laisind cattle in Vietnam. Asian-Aust. J. Anim. Sci., 21: 1143-1150.
97. Salami, S.A., G. Luciano, M.N. O'Grady, L. Biondi, C.J. Newbold, J.P. Kerry and A. Priolo, 2019. Sustainability of feeding plant by-products: A review of the implications for ruminant meat production. Anim. Feed Sci. Technol., 251: 37-55.
98. Hung, L.V., M. Wanapat and A. Cherdthong, 2013. Effects of Leucaena leaf pellet on bacterial diversity and microbial protein synthesis in swamp buffalo fed on rice straw. Livest. Sci., 151: 188-197.

99. Van Thu, N. and P. Uden, 2001. Effect of urea-molasses cake supplementation of swamp buffaloes fed rice straw or grasses on rumen environment, feed degradation and intake. Asian-Aust. J. Anim. Sci., 14: 631-639.
100. Khang, D.N. and H. Wiktorsson, 2006. Performance of growing heifers fed urea treated fresh rice straw supplemented with fresh, ensiled or pelleted cassava foliage. Livest. Sci., 102: 130-139.
101. Tham, H.T. and P. Udén, 2013. Effect of water hyacinth (*Eichhorniacrassipes*) silage on intake and nutrient digestibility in cattle fed rice straw and cottonseed cake. Asian-Aust. J. Anim. Sci., 26: 646-653.
102. Trung, N.T., J. Berg, V.C. Cuong and N.P. Kjos, 2014. Influence of varying levels of supplemental cassava root meal without or with groundnut cake on performance of growing laisind cattle. Trop. Anim. Health Prod., 46: 925-930.
103. Tham, H.T., N.V. Man and T.R. Preston, 2008. Performance of young cattle fed rice straw sprayed with mixture of urea and molasses supplemented with different levels of cassava leaf meal. Livest. Res. Rural Dev., Vol. 20.
104. Trach, N.X. and M.T. Thom, 2004. Responses of growing beef cattle to a feeding regime combining road side grazing and rice straw feeding supplemented with urea and brewers grains following an oil drench. Livest. Res. Rural Dev., Vol. 16, No. 7.
105. Quang, D.V., N.X. Ba, P.T. Doyle, D.V. Hai and P.A. Lane *et al*., 2015. Effect of concentrate supplementation on nutrient digestibility and growth of Brahman crossbred cattle fed a basal diet of grass and rice straw. J. Anim. Sci. Technol., Vol. 57, No. 35 10.1186/s40781-015-0068-y
106. Tan, N.D., M. Wanapat, S. Uriyapongson, A. Cherdthong and R. Pilajun, 2012. Enhancing Mulberry leaf meal with urea by pelleting to improve rumen fermentation in cattle. Asian-Aust. J. Anim. Sci., 25: 452-461.
107. Vu, D.D., L.X. Cuong, C.A. Dung and P.H. Hai, 1999. Use of urea-molasses-multinutrient block and urea-treated rice straw for improving dairy cattle productivity in Vietnam. Prev. Vet. Med., 38: 187-193.
108. Giang, N.T.T., M. Wanapat, K. Phesatcha and S. Kang, 2016. Effect of inclusion of different levels of *Leucaena* silage on rumen microbial population and microbial protein synthesis in dairy steers fed on rice straw. Asian-Aust. J. Anim. Sci., 30: 181-186.
109. Hue, T.K., T.T.D. Van and I. Ledin, 2008. Effect of supplementing urea treated rice straw and molasses with different forage species on the performance of lambs. Small Rumin. Res., 78: 134-143.
110. Dung, N.T., D.V. Binh, N.T. Mui and T.R Preston, 2010. Effect of cassava hay supplementation on milk production in lactating goats. Livestock Res. Rural Dev., Vol. 22, No. 3.

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Research Article
Fresh Rice Straw Silage Affected by Ensiling Additives and Durations and its Utilisation in Beef Cattle Diets

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Abstract
Background and Objectives: Rice straw is the most abundant crop by-product in Vietnam, but research on fresh rice straw (FRS) silage is very limited. The objectives of this study were to investigate the effects of ensiling additives and durations on organoleptic characteristics and chemical compositions of FRS silage and to determine the suitable substitution of green grass with FRS silage in growing beef cattle under an intensive production condition. **Materials and Methods:** In Experiment 1, urea, ammonia and lactic acid microbes were employed to mechanically treat FRS bales. The bales were stored indoor up to 16 weeks in separate bags for organoleptic and chemical assessments at different preservation durations. In experiment 2, the best FRS silage from experiment 1 was used to replace VA06 grass in dietary forage with different dry matter levels: No FRS silage (Control), 1/3 FRS silage and 2/3 FRS silage. Fifteen Laid Sind growing cattle were randomly allocated to and individually fed 1 of 3 forage treatments for 12 weeks, after a 2 week adaptation. **Results:** The 2% urea treated FRS (fresh matter basis) (URS) displayed the best quality with stably high pH, yellow color and strong ammoniac odor, highest crude protein content throughout 16 week preservation. The replacement of 2/3 URS reduced daily feed intake, but did not cause significant differences in growth performance. **Conclusion:** These findings suggest that 2% urea is an effective treatment to preserve FRS and URS can replace up to 2/3 green grass in growing beef cattle diets under an intensive production condition.

Key words: Urea treatment, fresh rice straw silage, organoleptic characteristics, feed intake, growth performance, beef cattle

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice (*Oryza sativa*) is the most popular crop in Vietnam. In 2018, Vietnam produced 44.0 million tonnes of rice[1] and the equivalent amount of dry rice straw was generated. A large majority of rice straw has been burned in the field[2]. Meanwhile, ruminant production with approximately 11.2 million heads mainly depends on cut grasses and agricultural by-products since lack of grazing land[3]. During winter in the North or dry season in the South of Vietnam, cut grasses and pastures only meet about 35-57% total forage demand leading to the death of thousands of buffaloes and cattle. Farmers usually feed dry rice straw as a forage source to their cattle during the time when fresh grass is insufficient because of the fact that feeding only dry rice straw does not provide enough nutrients to the ruminants to maintain high production. Animals fed dry rice straw diet only will even lose their weight[4,5]. However, the percentage of rice straw using in ruminant production remains limited compared to its annual yield[6]. Therefore, increasing the nutritive values of rice straw is very beneficial in the sustainable development of ruminant production.

Rice straw is low and unbalanced nutritive contents, high lignin and silica contents and low content of crude protein which contribute to the low voluntary intake and low rate of digestion[4,7]. For many years, various extensive researches have attempted to improve the nutritional quality of rice straw through physical, chemical and microbial treatments[8-10]. However, most studies in Vietnam have used dry rice straw and adjusted the moisture content. Research on alkaline and microbial treatments of fresh rice straw (FRS) silage is very limited. Therefore, the objectives of this study were to investigate the effects of ensiling additives and durations on organoleptic characteristics and chemical compositions of FRS silage and to determine the suitable substitution of green grass with FRS silage in growing beef cattle under an intensive production condition.

MATERIALS AND METHODS

Two experiments were conducted to synthetically assess the feed characteristics of treated fresh rice straw silage. Experiment 1 was carried out from September-December, 2018 at Hung Vuong University, Phu Tho, Vietnam. In this experiment, FRS was treated with 1 of 3 different additives (urea, liquid ammonia and lactic acid microbes). Experiment 2 was a feeding trial conducted from June-October, 2019 at a commercial farm, Nam Dinh, Vietnam. In the trial, the most effective treatment from experiment 1 was chose to produce FRS silage and then partly replace fresh grass in growing cattle diets. The effects of FRS silage substitution on daily feed intake and growth rate were evaluated.

Experiment 1: Effects of additives and preservation durations on FRS silage.

Silage preparation: Rice (cv.Du Huong) was cultivated in paddy fields in Phu Tho, Vietnam. The rice was harvested and threshed at the maturity stage using a combined harvester (DC-70, Kubota, Osaka, Japan). After harvesting, fresh rice straw was spread in 60 cm wide rows on the fields. A round baler (Star 870, Guoan, Shandong, China) pulled by a tractor (L4508, Kubota, Osaka, Japan) attached a spraying device was used to spray silage additive solutions and roll sprayed fresh rice straw into bales (dimension: 50 cm in diameter, 70 cm in height; weight: 27-32 kg). The FRS silage treatments were as follows:

- **Urea treated fresh rice straw silage (URS):** Two liters of solution containing 600 g of urea were added to a bale of fresh rice straw by the spraying device while it was being rolled
- **Ammoniac treated fresh rice straw silage (ARS):** The 600 mL of liquid ammoniac were diluted with clean water in 2 L of solution and then added to a bale of fresh rice straw while it was being rolled using the spraying device
- **Lactic acid microbes treated fresh rice straw silage (LRS):** The 30 mL of the mixture of *Bacillus subtilis, Saccharomyces cerevisae* and *Lactobacillus acidophilus* with 1.0×10^{8} CFU mL^{-1} each species (Soils and Fertilizers Research Institute, Ha Noi, Vietnam) were diluted with 300 g of molasses and 150 g of salt in 2 L of solution, then added in a bale of fresh rice straw by the spraying device while it was being rolled

After spraying and rolling, each treated bale was manually placed a double-layer bag (dimension: 60 cm in diameter, 130 cm in height) and tightly packed separately 2 layer by irreversible-zipped plastic strings. The inner layer of the silage bag was a nylon bag to create the anaerobic condition of the silage and the outer layer was a plastic sackcloth bag to prevent the inner nylon bag from breaking. Fifteen-treated bales were prepared for each silage treatment to sample three bales at 2, 4, 8, 12 and 16 week after ensiling. The bags are then transported to the Laboratory of the Experimental Center, Hung Vuong University (Phu Tho, Vietnam) and stored indoor at room temperature.

Organoleptic characteristics: The color, odor, mold prevalence of the samples were assessed immediately after opening the ensiled bales following the procedure described by Manaye *et al.*[11]. In brief, during the organoleptic evaluation, three assessors assigned the color of silage bales: Yellowish green, pale yellow, light brown, dark or deep brown. The odor of molasses, alcohol, lactic acid, yogurt, vinegar, burnt tobacco and ammoniac were used to assess the offered silage bales. The prevalence of visible mold was taken by having a look to the ensiling bales by walking around in random order with no opportunity to see each other's judgment. The highest frequently scored judgment was taken as the value of the assessment for each organoleptic parameter. The organoleptic assessments were undergone by the same group of panelists throughout the trial to minimize variations.

Chemical composition analysis: The pH of the silage samples was determined using digital pH meter (Go Direct pH Sensor, Vernier S and T, Beaverton, OR, USA). The samples of fresh rice straw silage from different treatments at different ensiling durations were ground through a 1 mm screen. The total nitrogen contents of URS and ARS were determined from freezing samples following the Kjeldahl protocol of AOAC[12]. The samples were dried in a fan-forced oven to a constant weight at 65^0C to determine DM content. Total nitrogen content of LRS was determined from dried samples by the Kjeldahl protocol as described by AOAC[12]. Crude protein (CP) content was calculated by multiplying total nitrogen by 6.25. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the methods of Van Soest *et al.*[13]. The samples were combusted in a furnace at 550°C for 5 h to quantify ash content. Organic matter (OM) was computed as OM = 100-ash.

Statistical analysis: The data were subjected to ANOVA general linear model for a factorial design with 2 fixed factors using the Minitab statistical software[14] version 16.2. In the model, ensiling treatment, duration and their interactions were fitted as fixed effects and pH and chemical compositions were dependent variables. The final statistical model used for the analysis was:

$$Y = \mu + T_i + D_j + (T \times D)_{ij} + E_{ijk}$$

Where:

Y = Dependent variable
μ = Overall mean
T_i = Effect of treatment
D_j = Effect of ensiling duration
$(T \times D)_{ij}$ = Interaction effects of ensiling treatment and duration
E_{ijk} = Residual error

When F-test was significant, mean separations were performed using Tukey's tests for pairwise comparison. Significant effects were declared at $p<0.05$.

Experiment 2: Effects of replacing grass with FRS silage on growing cattle performance.

Silage and grass preparation: From the result of experiment 1, the most effective treatment was chosen to produce 7 t of rice straw silage which was used in a 12 week feeding trial.

The rice (cv. Du Huong) was harvested and threshed at the maturity stage using a combined harvester (DC-70, Kubota, Osaka, Japan). After harvesting, fresh rice straw was treated with the most effective additive with the same procedure as described in experiment 1. The treated bags are then transported to the commercial cattle farm and stored in storage at room temperature. After 2 weeks of ensiling, the silage was started to feed experimental animals. Fresh rice straw samples were collected and stored at -20°C for subsequent analysis.

Varisme 06 (VA06) hybrid grass was intensively cultivated at the farm. It was daily harvested at 45 days cutting intervals. Before supply to the animals both fresh rice straw silage and VA06 grass were chopped into 10-15 cm pieces using a commercial electricity chopper (TTP 150, Aatesco, An Giang, Vietnam).

Animals and experimental design: Fifteen Lai Sind cattle, 12 months of age and 122±3 kg of body weight, were randomly selected and assigned to a completely randomized experimental design. The cattle were vaccinated against foot and mouth disease, de-wormed using Ivermectin and identified by numbered ear tags before commencing the experiment. They were randomly allocated to 1 of 3 forage treatments: 100% VA06 grass (control), the mixture of 67% VA06 grass+33% fresh rice straw silage (DM basis) (1/3 URS) and the mixture of 33% VA06 grass+67% fresh rice straw silage (2/3 URS). The diets were formulated to meet the requirements for maintenance and a desired live weight gain of 400-500 g/day. The forage to concentrate ratio (F:C) of the diets was 75:25 (DM basis). Concentrate was offered as a cooked mixture, separately from the forages. The mixture, which the farm usually feeds to their young cattle, consisted of 90% traditional rice distillers' by-product and 10% corn flour (fresh matter basis). Chopped rice straw silage and VA06 grass were mixed following the above treatments to minimize feed selection. The daily offered amount of concentrate was adjusted based on their body weight at 4 week intervals and fed in 1 time at 6:30 am. Forages were offered daily in 2 equal halves at 7:00 am and 5:00 pm. The daily offered amounts of forage accounted for about 110% of the average daily forage intake measured over the previous 3 days. Each animal was placed in a stall (2×4 m) in the same house and individually fed with unlimited access to clean water and a mineral block (Reva, Konya, Turkey) at all times. The feeding trial lasted for 12 weeks after a 2 week adaptation period.

Feed intake and growth measurements: The offered concentrate and forage were recorded daily. On days 1, 28, 56 and 84 of the experimental period, offered concentrate, VA06 grass and FRS silage samples were collected and stored at -20°C for subsequent analyses. Daily refusals were weighed before morning feeding and sampled for DM determination using a rapid microwave oven technique[15].

During the trial, the cattle were weighed on 2 consecutive days every 4 weeks in the morning before feeding using Ruddweigh 200 walk-over weighing electronic scale (Ruddweigh, Guyra, Australia). Average daily gain was calculated as total body weight gain divided by the number of days on the feeding trial. Feed conversion ratio was computed as the quotient of ADG divided by DMI.

Feed chemical composition analysis: The samples of offered concentrate, VA06 grass, fresh rice straw and fresh rice straw silage were ground through a 1 mm screen. The analysis methods of the chemical compositions of the samples were outlined in detail in experiment 1. The total nitrogen content of URS was also determined from freezing samples.

Statistical analysis: All collected data were analyzed using the Minitab statistical software[14] version 16.2. The ANOVA general linear model analyses were used to fit forage treatments as fixed effects and feed intake and growth performance characteristics as dependent variables. The final statistical model used for the analysis was:

$$Y = \mu + T_i + E_{ij}$$

Where:

- Y = dependent variable
- μ = Overall mean
- T_i = Effect of forage treatment
- E_{ij} = Residual error

When F-test was significant, mean separations were performed using Tukey's tests for pairwise comparison. Significant effects were declared at $p<0.05$.

RESULTS

Experiment 1: The effects of additives and preservation durations on FRS silage.

pH and organoleptic characteristics: The pH of fresh rice straw silage was significantly affected by both ensiling treatment and duration ($p<0.01$, Fig. 1). The pH of URS (9.8) was lower than that of ARS (11.8) at the beginning of ensiling process. However, the pH of URS remained approximately 9.0, while the pH of ARS dropped to 6.0 after 16 weeks of preservation. In contrary, the pH of LRS increased from 3.3-5.2 during the 16 week preservation.

The organoleptic characteristics of FRS silage are illustrated in Table 1. The URS displayed the highest quality with yellow color and strong ammoniac odor throughout 16 week preservation, while dark color and burnt tobacco was observed in LRS. Although, ARS was alkaline treatment, it had yogurt smell after ensiling 8 weeks. During the 16 week preservation, no visible mold was observed in URS bales, whereas LRS and ARS bales appeared visible fungi after ensiling 8 and 12 weeks, respectively. The percentage of visible fungi in ARS and LRS bales increased to 10 and 15%, respectively after 16 week preservation.

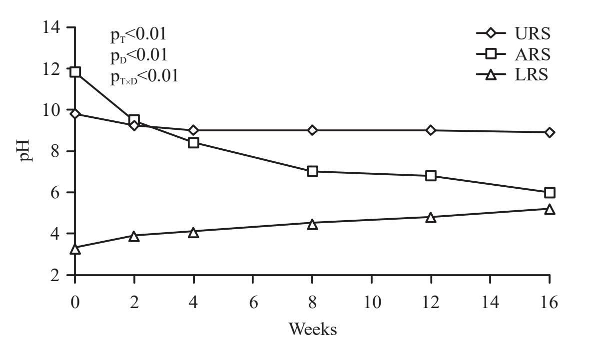

Fig. 1: Changes in pH during 16 week ensilage

URS: Fresh rice straw treated with 2% urea, ARS: Fresh rice straw treated with 2% ammoniac, LRS: Fresh rice straw treated with lactic acid microbes

Table 1: Effects of ensiling treatment and duration on the organoleptic characteristics of ensiled fresh rice straw

		Ensiling duration (week)					
Items	Treatments	0	2	4	8	12	16
Odor	URS	SA	SA	SA	SA	SA	SA
	ARS	SA	SA	SA	Yg	Yg	Yg
	LRS	Mo	Mo	Yg	Vin	Vin	To
Color	URS	YG	YG	Y	Y	Y	Y
	ARS	YG	YG	PY	PY	PY	PY
	LRS	YG	YG	PY	DY	DY	DY
Visible mold (FM (%))	URS	0	0	0	0	0	0
	ARS	0	0	0	0	5	10
	LRS	0	0	0	6	10	15

FM: Fresh matter, URS: Fresh rice straw treated with 2% urea, ARS: Fresh rice straw treated with 2% ammoniac, LRS: Fresh rice straw treated with lactic acid microbes, SA: Strong ammoniac smell, Yg: Like yogurt smell, Mo: Like molasses smell, Vin: Like vinegar smell, To: Like burnt tobacco smell, YG: Yellow green, PY: pale yellow, DY: dark yellow, Y: yellow

Table 2: Effects of ensiling treatment and duration on the chemical compositions of ensiled fresh rice straw

	Treatments			Ensiling duration (week)							p-value		
Items	URS	ARS	LRS	0	2	4	8	12	16	SEM	T	D	T×D
DM (%)	40.6	40.3	39.5	41.1	40.1	39.8	39.3	38.6	42.0	0.05	0.26	0.08	0.11
OM (%DM)	86.3	86.6	85.9	86.4	85.8	86.4	86.3	87.0	85.7	0.02	0.14	0.11	0.35
CP (%DM)	11.3[a]	6.5[b]	3.7[c]	7.6	7.4	7.2	7.1	6.8	6.7	0.06	<0.01	0.99	<0.01
NDF (%DM)	70.6	70.3	69.8	70.4	70.3	69.1	70.7	70.2	70.7	0.03	0.09	0.36	<0.01
ADF (%DM)	38.2	38.7	37.7	37.8	38.8	37.4	38.6	37.8	38.8	0.03	0.10	0.10	<0.01
Ash (%DM)	13.7	13.4	14.1	13.6	14.2	13.6	13.7	13.0	14.3	0.02	0.14	0.11	0.35

DM: Dry matter, OM: Organic matter, CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, URS: Fresh rice straw treated with 2% urea, ARS: Fresh rice straw treated with 2% ammoniac, LRS: Fresh rice straw treated with lactic acid microbes, T: Effects of ensiling treatment, D: Effects of ensiling duration, T×D: Interaction effects of ensiling treatment and ensiling duration, [a,b,c]Means in the same row with different superscripts show significant differences at p<0.05

Table 3: Chemical composition of fresh rice straw and feeds used in the experiment

Items	FRS	URS	VA06 grass	Concentrate mixture
Dry matter (DM) (%)	53.0±3.6	56.3±4.2	15.5±1.5	15.5±0.4
Organic matter (DM) (%)	87.5±0.2	87.6±0.7	91.2±0.5	96.8±0.2
Crude protein (DM) (%)	5.0±0.2[b]	12.7±0.1[a]	8.3±0.3	22.3±0.6
NDF (DM) (%)	71.4±0.5[a]	68.8±0.9[b]	66.0±0.8	27.6±0.6
ADF (DM) (%)	38.1±1,3	38.2±0.8	34.7±1.1	8.4±0.4
Total ash (DM) (%)	12.5±0.2	12.4±0.7	8.9±0.5	3.2±0.2

FRS: Fresh rice straw, URS: Fresh rice straw treated with 2% urea, Means of FRS and URS in the same row with different superscripts differ significantly at p<0.05

Changes in chemical compositions of fresh rice straw silage: Crude protein (CP) was significantly affected by ensiling treatment (p_T< 0.01, Table 2). The CP content was highest in URS (11.3% DM) and lowest in LRS (3.7% DM). However, no differences in other analyzed chemical compositions were observed among the 3 treatments (p_T>0.05). Ensiling duration did not affect the chemical compositions of fresh rice straw silage (p_D>0.05).

Significant interaction effects on CP, NDF and ADF contents were detected ($p_{T\times D}$<0.05, Table 3). The URS at the first 8 weeks recorded the highest CP contents, ranging from 11.4% DM to 12.1% DM), whereas the lowest CP content was observed in LRS at the beginning of preservation (3.0% DM). For NDF contents, the highest (72.8% DM) and lowest (67.5% DM) valued were observed both in ARS at the beginning of preservation and week 4, respectively. The ADF content of URS at week 8 was significantly higher than that of LRS at week 8.

Experiment 2: Effects of replacing grass with FRS silage on growing cattle performance.

Changes in chemical compositions of untreated FRS and URS: The chemical compositions of the untreated fresh rice straw and experimental feed are presented in Table 3. Up to 4 months ensiling, all the URS bags well preserved, with strong ammonia smell, dark brown color and no fungi. With 2% urea treatment, the CP content increased significantly (p<0.05) from 5.0% DM in untreated FRS to 12.7% DM in URS (2.5 folds). In contrast, the NDF content of URS (68.8% DM) was significantly lower (p<0.05) than that of FRS (71.4% DM). Other chemical compositions of fresh rice straw were not affected by urea treatment (p>0.05).

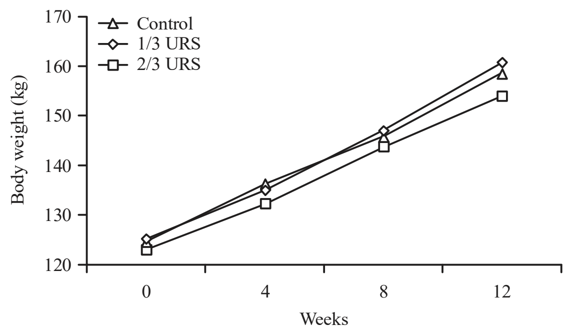

Fig. 2: Changes in body weights during the experimental period
URS: Fresh rice straw treated with 2% urea

Table 4: Feed intake of experimental cattle (kg/day)

Items	Control	1/3 URS	2/3 URS
Fresh matter basis			
Concentrate intake	5.48±0.17	5.60±0.14	5.55±0.15
VA06 grass intake	17.50±0.32	11.47±0.20	5.23±0.10
URS intake	0	1.56±0.03	2.93±0.05
Forage intake	17.50±0.32	13.03±0.22	8.16±0.15
Dry matter basis			
Concentrate DMI	0.85±0.04	0.87±0.03	0.86±0.03
Forage DMI	2.71±0.05[a]	2.65±0.05[a]	2.46±0.05[b]
Total DMI	3.56±0.06[a]	3.52±0.06[ab]	3.32±0.06[b]
OMI	3.31±0.06[a]	3.23±0.05[a]	2.07±0.04[b]
CPI	0.42±0.01[b]	0.45±0.01[a]	0.46±0.01[a]
F:C	3.16±0.04[a]	3.10±0.05[a]	2.87±0.05[b]

URS: Fresh rice straw treated with 2% urea, DMI: Dry matter intake, OMI: Organic matter intake, CPI: Crude protein intake, F:C: Forage to concentrate ratio, means in dry matter basis bearing different superscripts within the same row differ significantly at p<0.05

Table 5: Growth performance of experimental cattle (kg/day)

Items	Control	1/3 URS	2/3 URS
Initial body weight	124.80±6.8	125.20±5.6	123.00±4.5
Final body weight	158.40±5.7	160.60±4.8	153.80±5.9
TWG	33.60±3.9	35.40±2.7	30.80±1.9
ADG	0.40±0.05	0.42±0.03	0.37±0.02
DMI of 100 kg body weight	2.66±0.03[a]	2.62±0.02[ab]	2.52±0.03[b]
FCR	0.11±0.01	0.12±0.01	0.11±0.01
FCE	9.33±0.82	8.58±0.75	9.21±0.63

URS: Fresh rice straw treated with 2% urea, TWG: Total weight gain, ADG: Average daily gain, DMI: Dry matter intake, FCR: Feed conversion ratio, FCE: Feed conversion efficiency, means in the same row bearing different superscripts differ significantly at p<0.05

Feed intakes of experimental animals: The daily feed dry matter intakes were influenced by replacing VA06 grass with URS (p<0.05, Table 4) with the exception of concentrate DMI. The cattle fed forage containing 67% URS had significantly lower forage DMI (2.46 kg/day) than the cattle fed forage containing only VA06 grass and 33% URS (2.71 and 2.65 kg/day, respectively). As a consequence, the forage to concentrate ratio in the control and 1/3 URS treatments were significantly higher than that in the 2/3 URS treatment.

The total DMI in the control treatment (3.56 kg/day) was considerably higher (p<0.05) than that in the 2/3 URS treatment (3.32 kg/day). However, there was no difference in total DMI between the 1/3 URS treatment and the other treatments. The animals in the control treatment had significantly higher organic matter intake (OMI), but lower crude protein intake (CPI) than their counterparts in the 2/3 URS treatment.

Growth performance: Replacing VA06 grass with URS in the cattle diets did not significantly affect their growth performances (p>0.05, Table 5, Fig. 2). No differences in final weight, total weight gain, feed conversion ratio and feed conversion efficiency were observed. Likewise, the ADG are relatively similar among treatments, ranged from 0.37-0.42 kg/day/head. In contrast, there was a significant difference (p<0.05) in the DMI of 100 kg body weight between the control (2.66 kg) and 2/3 URS (2.52 kg) treatments.

DISCUSSION

The primary aim of ensiling forage is to attain acidic (pH<4.5) or alkaline (pH>8) anaerobic condition in silage because the spoiled microbes and fungi in silage are restricted at these pH range[16,17]. As a result, ensiled materials could prolong storage time, decrease nutrient loss and mold appearance[4]. In the present study, the sensory characteristic of URS seemed to be better than the others, due to the stable pH at 9 during 16 weeks of ensilage. The dark yellow color, tobacco burnt smell and the appearance of fungi of the ARS and LRS implied the spoiled silage and poor fermentation. These might be contributed by the weakly acidic pH, which ranged from 4.5-7 after 8 week preservation.

Moreover, the addition of lactic acid microbes conventionally aims to enhance lactic acid production in rice straw silage, resulting in a decrease in pH (below 4.5) and thus increasing silage quality[18,19]. Zhang *et al.*[18] concluded that after 45 day sensiling FRS with higher levels of LAB inoculants containing *Lactobacillus buchneri* and *Pediococcus pentosaceus* (provided by Chr. Hansen Biosystems, Milwaukee, WI, USA), all the silage were well preserved with pH<4.5 and the quality of rice straw silage. In fact, LRS in the present study seems to be in a good condition after 45 days of preservation. Differences in LAB inoculants, addition levels and ensiling time might be the main reason for the difference between the findings of this study and Zhang *et al.*[18] research. Moreover, Ohmomo *et al.*[20] and Li *et al.*[21] stated that the characteristics of LAB inoculants widely vary even within the same species. It is important to note that not all commercial LAB inoculants are always suitable for silage-making in all countries and regions.

In the present study, ensiling treatment considerably influenced the CP content of rice straw silage. Supplementing non protein nitrogen (NPN) such as urea and ammoniac is conventional methods to enhance CP content[4,7]. However, the reduction in pH of ARS during ensiling contributed to the emergence and development of spoiled microbes, which might use NPN for their protein biosynthesis and other metabolic processes[22]. Numerous studies agreed that the inoculation of lactic acid microbes did not improve the CP content of rice straw silage[11,18,19].

In the present study, urea treatment decreased the NDF content of the silage, but the ADF content was not affected, which is consistent with numerous studies[16,19,23]. The decrease in NDF content is due to the reduction in hemicelluloses which was utilized by microorganism for their proliferations during natural fermentation[24]. The effects of urea treatment vary depending on the levels of added urea, the quality of rice straw, the moisture content, loading density and storage method of the silage[19,25,26].

It is obvious that fresh VA06 grass is more palatable than URS because rice straw intrinsically has the high levels of indigestible fiber and anti-nutritional factors such as silica and lignin, limiting voluntary intake[27,28]. Therefore, the replacement of 2/3 fresh grass with URS in this study could reduce forage palatability, resulting in decreases in the voluntary intakes of forage, total feed and organic matter in terms of dry matter. Moreover, the lower OMI in 2/3 URS treatment could partly be attributed to the high total ash content of URS (Table 3). Man and Wiktorsson[26] also stated that the higher levels of urea treated fresh rice straw (>50% DM basic) in the mixed forage treatment resulted in a reduction in palatability and higher indigestible contents in dairy cow diets compared to elephant grass. This would cause low dry matter intakes and forage to concentrate ratio.

The higher CPI in the mixed forage treatments in the present study could be explained by the higher CP content in URS in comparison with that in VA06 grass (Table 3). The outcomes were in accordance with previous studies by Wanapat *et al.*[23] and Gunun *et al.*[29], who fed dairy lactating cows untreated and urea treated rice straw as forage sources. In contrast with these results, Man and Wiktorsson[26] and Sanh *et al.*[25] observed no difference in the CPI of dairy lactating cows when replacing up to 75% fresh grass (DM basic) with urea treated rice straw. The significant differences in their studies were absent because the calculation was based on the CP content after sun-drying urea treated rice straw silage. They also noticed that exposure of urea treated rice straw silage in the atmosphere increased the loss of ammonia and then reduced CPI.

The final body weight, total weight gain and ADG were no significant differences among the treatments clearly indicating that replacing up to 67% fresh grass with URS did not significantly influenced the growth performance of the growing beef cattle. The absence of significant difference in growth performance, although there was a reduction in DMI, in this study could be explained by the higher CPI in the mixed forage treatments (Table 4). The replacement increased the CP content of feed dry matter intake from 11.8% (in control treatment) to 12.7 and 13.8% (in 1/3 and 2/3 URS treatments respectively). This indicates that URS provided additional nitrogen, resulting in higher NH_3-N concentration in the rumen[30]. Obara *et al.*[31] reported that nitrogen supplementation from urea could increase the activity of rumen microorganism in degrading carbohydrates (cellulose, hemicellulose and starch) when the energy level is sufficient. The higher CPI and probably higher ruminal microbial synthesis, fiber digestibility by urea treatment may contribute to the similar growth performance of cattle fed diets containing URS compared to cattle in the control diet.

In the present study, the significant difference in DMI of 100 kg body weight between the control and 67% URS treatments is due to significant difference in total DMI while the body weights of these two treatments were similar. The results were much lower compared to the outcomes of Hossain *et al.*[32], who fed diets containing fresh rice straw treated 3.5% urea and fresh grass to 20 months old female beef cattle. The diversities in breed, age and the level of offered concentrate[26] and dietary nutrient density and expected ADG [33] might explain for these differences.

CONCLUSION

Fresh rice straw can be preserved by common ensilages with different additives. Treating FRS with 2% urea (fresh mater basis) improved the CP content of FRS silage without negative effects on pH, organoleptic characteristics and other chemical compositions during 16 weeks of preservation. The present findings suggested that lactic acid microbes can be added to FRS for up to 2 months of preservation. Substitution of VA06 with URS at up to 67% (DM basis) of the forage in growing beef cattle did not have detrimental effects on growth performance. Urea preservation of FRS for beef cattle can be a sustainable alternative forage source, especially in the winter or dry season in Vietnam.

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SIGNIFICANT STATEMENTS

- Fresh rice straw can be preserved by common ensilages with different additives for cattle as a sustainable alternative forage source
- Treating fresh rice straw with 2% urea (fresh mater basis) improved the crude protein content of silage without negative effects on pH, organoleptic characteristics and other chemical compositions during 4 months of preservation
- Urea treated fresh rice straw silage can be used to replace up to 67% (DM basis) of green grass in growing beef cattle without detrimental effects on growth performance

REFERENCES

1. GSO., 2018. Socio-economic situation in 2018 (in Vietnamese). General Statistic Office. https://www.gso.gov.vn/default.aspx?tabid=621&ItemID=19037.
2. Van Nguyen, H., C.D. Nguyen, T. van Tran, H.D. Hau, N.T. Nguyen and M. Gummert, 2016. Energy efficiency, greenhouse gas emissions and cost of rice straw collection in the mekong river delta of Vietnam. Field Crops Res., 198: 16-22.
3. Huong, H.T.T., 2018. Current situation of ruminant production in Vietnam and development orientation to 2030. In Ruminant Production: Status Quo and Solution, Hanoi, Vietnam, pp: 1-10, (In Vietnamese).
4. Van Soest, P.J., 2006. Rice straw, the role of silica and treatments to improve quality. Anim. Feed Sci. Technol., 130: 137-171.
5. Malik, K., J. Tokkas, R.C. Anand and N. Kumari, 2015. Pretreated rice straw as an improved fodder for ruminants-An overview. J. Applied Nat. Sci., 7: 514-520.
6. Nam, T.S., N.T.H. Nhu, N.H. Chiem, N.V.C. Ngan, L.H. Viet and K. Ingvorsen, 2014. To quantify the seasonal rice straw and its use in different provinces in the Vietnamese Mekong Delta. Can. Tho. Uni. J. Sci., 32: 87-93, (In Vietnamese).
7. Trach, N.X., 1998. The need for improved utilisation of rice straw as feed for ruminants in Vietnam: An overview. Livest. Res. Rural Dev., Vol. 10.
8. Chinh, B.V., L.L. Viet and N.H. Tao, 1995. Study on processing and use of agricultural by-products and available food sources in Rural areas. In Selection of Research Works on Animal Production 1969-1995. Agricultural Publisher, Hanoi, Vietnam, (In Vietnamese).
9. Hue, T.K., T.T.D. Van and I. Ledin, 2008. Effect of supplementing urea treated rice straw and molasses with different forage species on the performance of lambs. Small Rumin. Res., 78: 134-143.
10. Huyen, N.T., B.Q. Tuan, N.X. Nghien, N.T.B. Thuy and N.T.T. Le, 2019. Effect of using fungal treated rice straw in sheep diet on nutrients digestibility and microbial protein synthesis. Asian J. Anim. Sci., 13: 1-7.
11. Manaye, T., A. Mengistu, A. Tolera and G. Geesink, 2018. Evaluation of sensory silage quality, chemical composition and *in vitro* digestibility of tef (*Eragrostis tef*) straw inoculated with Effective Microorganisms (EM) at different application rates and ensiled for different durations. Greener J. Agric. Sci., 8: 286-293.
12. AOAC., 1990. Official Methods of Analysis. 15th Edn., Association of Official Analytical Chemists, Washington, DC., USA., Pages: 684.
13. Van Soest, P.J., J.B. Robertson and B.A. Lewis, 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.
14. Minitab, 2010. Minitab 16 Statistical Software. Minitab Inc., LLC State College, PA, USA.
15. Oetzel, G.R., F.P. Villalba, W.J. Goodger and K.V. Nordlund, 1993. A comparison of on-farm methods for estimating the dry matter content of feed ingredients. J. Dairy Sci., 76: 293-299.
16. Trach, N.X. and B.Q. Tuan, 2008. Effects of treatment of fresh rice straw on its nutritional characteristics. J. Sci. Dev., April 2008: 129-135.
17. Lunsin, R., S. Duanyai, R. Pilajun, S. Duanyai and P. Sombatsri, 2018. Effect of urea-and molasses-treated sugarcane bagasse on nutrient composition and *in vitro* rumen fermentation in dairy cows. Agric. Nat. Resourc., 52: 622-627.
18. Zhang, Y.G., H.S. Xin and J.L. Hua, 2010. Effects of treating whole-plant or chopped rice straw silage with different levels of lactic acid bacteria on silage fermentation and nutritive value for lactating Holsteins. Asian-Aust. J. Anim. Sci., 23: 1601-1607.
19. Fang, J., M. Matsuzaki, H. Suzuki, Y. Cai, K.I. Horiguchi and T. Takahashi, 2012. Effects of lactic acid bacteria and urea treatment on fermentation quality, digestibility and ruminal fermentation of roll bale rice straw silage in wethers. Grassl. Sci., 58: 73-78.
20. Ohmomo, S., O. Tanaka, H.K. Kitamoto and Y. Cai, 2002. Silage and microbial performance, old story but new problems. Jpn. Agric. Res. Q., 36: 59-71.

21. Li, X., W. Xu, J. Yang, H. Zhao, H. Xin and Y. Zhang, 2016. Effect of different levels of corn steep liquor addition on fermentation characteristics and aerobic stability of fresh rice straw silage. Anim. Nutr., 2: 345-350.
22. Liu, Q., J. Zhang, S. Shi and Q. Sun, 2011. The effects of wilting and storage temperatures on the fermentation quality and aerobic stability of stylo silage. Anim. Sci. J., 82: 549-553.
23. Wanapat, M., S. Kang, N. Hankla and K. Phesatcha, 2013. Effect of rice straw treatment on feed intake, rumen fermentation and milk production in lactating dairy cows. Afr. J. Agric. Res., 8: 1677-1687.
24. Wadhwa, M., K. Kaur and M. Bakshi, 2010. Effect of naturally fermented rice straw based diet on the performance of buffalo calves. Indian J. Anim. Sci., 80: 59-62.
25. Sanh, M.V., H. Wiktorsson and L. Ly, 2002. Effect of partial replacement of green grass by urea treated rice straw in winter on milk production of crossbred lactating cows. Asian-Aust. J. Anim. Sci., 15: 543-548.
26. Man, N.V. and H. Wiktorsson, 2001. The effect of replacing grass with urea treated fresh rice straw in dairy cow diet. Asian Aust. J. Anim. Sci., 14: 1090-1097.
27. Sarnklong, C., J.W. Cone, W.F. Pellikaan and W.H. Hendriks, 2010. Utilization of rice straw and different treatments to improve its feed value for ruminants: A review. Asian-Aust. J. Anim. Sci., 23: 680-692.
28. Sheikh, G.G., A.M. Ganai, P.A. Reshi, S. Bilal, S. Mir and D. Masood, 2018. Improved paddy straw as ruminant feed: A review. Agric. Rev., 39: 137-143.
29. Gunun, P., M. Wanapat and N. Anantasook, 2013. Rumen fermentation and performance of lactating dairy cows affected by physical forms and urea treatment of rice straw. Asian-Aust. J. Anim. Sci., 26: 1295-1303.
30. Chanthai, S., M. Wanapat and C. Wachirapakorn, 1987. Rumen ammonia-N and volatile fatty acid concentrations in cattle and buffalo given rice straw based diets. Proceedings of the 3rd AAAP Animal Science Congress, (AAAP'87), Seoul, Korea, pp: 873-875.
31. Obara, Y., K. Shimbayashi and T. Yonemura, 1975. Changes of ruminal properties of sheep during feeding urea diet. Jpn. J. Zootech. Sci., 46: 140-145.
32. Hossain, M., M. Khan and M. Akbar, 2010. Nutrient digestibility and growth of local bull calves as affected by feeding urea and urease enzyme sources treated rice straw. Bangladesh J. Anim. Sci., 39: 97-105.
33. Kearl, L.C., 1982. Nutrient Requirements of Ruminants in Developing Countries. 1st Edn., International Feedstuffs Institute, Utah State University, Logan, Utah, USA., ISBN: 9780874211160, Pages: 381.