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Review Article
A Review on the Availability and Economics of Rice Milling Waste as Animal Feeding Stuff in Nigeria

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Abstract

The need to achieve Sustainable Development Goals (SDGs) numbers 1, 2 and 6, the increase in the world population, the high cost of conventional feeding stuffs and inadequate protein intake in most developing countries have shifted the attention of scientists to find alternative sources of feeding stuff. One of such alternative ways includes the waste associated with the milling of rice. This review was aimed at pulling information on rice milling waste together in order to provide information for researchers and also to bring to the knowledge of researchers that rice milling waste is a cheap and available feeding stuff. Rice milling waste (RMW) is one of the commonest agro-industrial wastes generated in large quantities in most parts of Nigeria, causing environmental pollution if not harnessed. Literature materials from different authors on the availability and use of rice milling waste were pulled together to show that rice milling waste is in abundant supply and it has been used to feed various species of animals such as poultry, rabbit, ram and fish. The review showed that RMW is made up of the husk, bran and broken pieces and it is of very high quantity in Nigeria as documented by several authors. Moreover, it was also revealed that diets formulated with RMW (especially after been treated) at different inclusion levels had no adverse effects on body weight gain, feed intake and feed conversion ratio and carcass quality. Its use results in saving cost, production of meat at a cheaper cost and improved performance. In this way, the large amounts being dumped as waste can be prevented which pose disposal problems and bring about methane emissions. The disposal problems posed by RMW have led to indiscriminate burning of the waste, resulting in environmental pollution and loss of land. Inclusion of different levels of RMW is quite acceptable in the diets of most livestock species. Rice milling waste is in abundant supply and very cheap. It is a by-product of the rice milling industries, which comprises of rice bran, rice husk and broken pieces of rice. Processing of RMW ensures better utilization by animals and it has been fed to several species of animals. The use of RMW is cost effective and without adverse effects to the animals. The use of RMW as an alternative source of feeding is therefore strongly recommended.

Key words: Rice bran, rice milling waste, feeding stuff, sustainable development goals, methane emissions

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INTRODUCTION

The major challenge to livestock production in the tropics is the availability of cheap and quality feedstuffs. About 70-80% cost of livestock production goes to feed and these feeds are not readily available, due to seasonality, scarcity and competition existing between humans and animals for conventional feedstuffs. However, to reduce cost, the use of alternative and inexpensive feed ingredients or non-conventional feed resources (NCFR's) can be a substitute[1]. Examples of NCFR's includes maize offal, brewer's dried grain, Bambara nut waste, rice milling waste (rice bran, husk, broken pieces of rice) etc. Rice milling waste (RMW) is the byproduct which is obtained from small-scale milling industries that processes parboiled rice through a mechanism which combines the removal of husk and polishing into one operation to produce the clean grain and rice offal which contain husk, bran, polishing and small quantities of broken grains[2]. In developed countries, this waste is separated into different components and converted into value-added products. In Nigeria, however, it is mostly used together in feeding animals. The waste makes up about 40% of the parboiled rice. In spite of its abundance, it has been neglected as animal feeds because it contains high level of fibre and low protein and energy[3].

According to the International Rice Research Institute (IRRI)[4], the main by-products of rice milling are rice hulls or husk, rice bran and bravery's rice. Rice husks, the major part of RMW contains about 3.66 Kcal g^{-1} energy, 5.25% crude protein and as high as 33.1% fibre. The use of rice milling waste as an ingredient in animal feeds, especially ruminants and poultry has been well documented[2,5]. Rice bran (also a constituent of RMW) has the potential of being used as an alternative to grains in livestock production. It contains 15-22% oil, 11-17% protein, 6-14% fibre, 10-15% moisture and 8-17% ash[6]. The use of agricultural wastes and by-products as animal feeds in order to reduce cost of production and as an effective means of handling their disposal is encouraged[7-10].

This waste if not properly managed could cause environmental pollution and if burned, could lead to the emission of methane into the atmosphere, thereby causing ozone layer depletion. This review was therefore; aimed at harnessing the available materials, on the availability, processing, utilization and economics of rice milling waste as feedstuff for livestock.

RICE PRODUCTION AND DEMAND

Rice (*Oryza sativa* L.) is the most widely grown and cultivated staple food-crop. It is estimated that 3.5 billion people worldwide are into rice farming[11]. Rice is among the three most important grain crop in the world and it has a major contribution to fulfill the food needs across the globe. The role of rice crop is inevitable in the current and future global food security. Rice is grown in Asia, America, Australia, Europe and Africa following diverse production practices[12]. Rice is an important cereal crop and a staple food for more than half of the world's population[13,14]. Its importance to the world population's dietary requirements is evident from the presence of rice in the diet of a quarter of world's population. The global rice production in year 2010 stood[15] at 696324394 t. It is one of the cereals that has been playing crucial role as major source of food, income and employment in Nigeria. It is widely grown in all agro-ecological zones of the country in various production systems such as swampy lowland, rain-fed upland, irrigated, deep water and mangrove[16]. In Nigeria, rice has assumed a strategic position in the food basket of rural and urban households and is cultivated in virtually all of Nigeria's agro-ecological zones from the mangrove and swampy ecologies of the River Niger delta in the coastal areas to the dry zones of the Sahel in the north. In the past decade, consumption has increased 4.7%, almost four times the global consumption growth and reached 6.4 million t in 2017-accounting for 20% of Africa's consumption. As in 2011, rice accounted for 10% of household food spending and 6.6% of total household spending. Given the importance of rice as a staple food in Nigeria, boosting its production has been accorded high priority by the government in the past 8 years rice provides up to 50% of the dietary caloric supply and a substantial part of the protein intake for about 520 million people living in Asia. In sub-saharan Africa, rice consumption among urban dwellers has steadily grown, with per-capita consumption that has doubled[11] since 1970. Countries in Caribbean and Latin America regions are also reporting a steady rise in rice intake in their populations[11]. Therefore, rice is of unique nutritional importance in Asia Pacific region, parts of Latin America and Caribbean and in sub-saharan Africa (SSA)[17].

It is also the primary source of income and employment for more than 200 million households across countries in the developing world[17-19]. Despite the considerable potential for rice production expansion in all these production ecologies, the rice sector has not been able to satisfy the demand of rice consumers. About 70% of the annual rice demand is met by

Table 1: Nigerian livestock population estimate

Species	Number (millions)
Chicken	82,400.00
Goats	34,500.00
Sheep	22,100.00
Cattle	13,900.00
Horses	0.200
Camels	0.090
*Other poultry	31,900.00
Pigs	3,500.00
Rabbits	1,700.00
Guinea pigs	0.50

*Includes pigeons, ducks, Guinea fowls and Turkeys, Source: Bourn *et al.*[24]

Table 2: Proximate composition of rice milling waste

Nutrient (DM %)	Composition (%)	Composition (%)	Composition (%)
Dry matter	94.42	93.65	91.09
Moisture	-	6.350	-
Crude protein	5.090	5.250	7.320
Crude fibre	30.39	33.18	18.00
Ether extract	3.400	3.9	1.820
N-free extract	46.10	28.17	-
Ash	16.67	23.15	-
Authors	Maikano[25]	Ani *et al.*[26]	Adeyina *et al.*[27]

Source: Maikano[25], Ani *et al.*[26] and Adeyina *et al.*[27]

local rice producers. The deficit has to be imported to the extent that Nigeria has become the largest importer of rice in Africa[20] and second in the world[21]. To bridge the demand-supply gap, milled rice worth 356 billion was imported into the country[22,23].

The progressive increase in the population of Nigerians, lead to the increase in demand for rice as a staple food for the teaming population, which in turn leads to the increase in the production of rice and as a result, thereby increases the quantity of rice milling waste, which causes environmental pollution if left unused or when burned (contributing to the accumulation of gases in the atmosphere that leads to ozone layer depletion). It should be therefore properly harnessed and used as livestock feed (Table 1).

PROXIMATE COMPOSITION OF RICE MILLING WASTE

Different authors have reported different proximate composition of rice milling waste. Scientists have reported the proximate composition of rice offal thus: 94.42% dry matter, 5.09% crude protein, 30.39% crude fibre, 3.40% ether extract, 16.67% ash and 46.10% nitrogen free-extract[25]. Moreover, researchers also reported the proximate composition of rice milling waste as 93.65% dry matter, 6.35% moisture content, 5.25% crude protein, 33.18% crude fibre, 3.9% ether extract, 28.17% nitrogen free extract and 23.15% ash[26] while also reported that[27], Proximate composition of RMW reveals, 91.09% dry matter, 7.32% crude protein, 18.00% crude fibre and 1.82% ether extract among others. Variations in the composition might be due to seasonality, method of processing and the nature or type of treatment the provided to rice milling waste. The variability of the result could also be due to differences in the processing methods of paddy and rice milling machine efficiency. Dafwang and Shwaremen[2], Awesu *et al.*[5] and Abasiekong[28] have reported that the high crude fibre (30-44%), mainly lignin and low protein contents have resulted in reduced voluntary feed intake and low utilization in poultry feeding. This high fibre concentration results in poor nutrient utilization and consequent poor growth performance due to the presence of non-starch-polysaccharides (NSP) and phytate when fed to broiler chickens without any form of treatment and this has necessitated processing and treatment of the rice milling waste before feeding to animals, for optimum performance. Urea treated rice milling waste (UTRMW) increased the protein content of rice milling waste due to non-protein nitrogen contribution from urea[29] (Table 2).

LIMITATIONS TO THE USE OF RMW AS FEEDSTUFF FOR LIVESTOCK

Rice milling waste can be used in the feeding of livestock. However, its use in the feeding of monogastric animals is limited because of its high fibre content, low crude protein, energy and mineral content. In broilers, high fibre tends to limit the amount of intake of the available energy by birds and it also results to the secretion of excessive nutrients[30]. Crude fibre consists of cellulose, hemicelluloses and lignin[31] which are not well utilized by monogastrics[32]. Lignin, which envelopes some nutrients, is highly resistant to chemical and enzymatic degradation and is poorly degraded by rumen microbes[33,34]. Strong chemical bonds exist between lignin and many plant polysaccharides and cell wall proteins, which render these compounds unavailable during digestion. These bonds are however, broken by chemical treatment thereby increasing the digestibility of fibrous feeds[33-35]. Among the chemicals that have been utilized, sodium hydroxide has proven to be the most effective in improving digestibility but lacks nitrogen. It has reported that high fibre and lignin contents of RMW are capable of reducing nutrient utilization and also precipitate metabolic dysfunction when digested by non-ruminants[36]. Considering the fact that poultry cannot fully utilize high fibre diets because of the lack of the digestive framework that can elaborately digest large amount of fibre, it becomes necessary, to incorporate exogenous enzymes into their diets in order to enhance the breakdown of the non-starch polysaccharides (NSPs) present in fibre.

Rice milling waste and its impact on the environment: Rice milling waste is presently considered as waste and which

when disposed constitutes environmental hazard. It is cheap to the extent that it is burnt at rice milling sites to minimize its pollution effect. The burning of rice waste however increases the level of carbon in the atmosphere thereby affecting the ozone layer[27]. The quantity of rice milling by-products generated in Nigeria annually was estimated at about[37] 1,032,993.6 metric t. A large amount of these by-products is dumped as waste thereby posing disposal problems and bringing about methane emissions[38,39]. The disposal problems posed by rice milling waste have led to indiscriminate burning of the waste and subsequent accumulation of ash in rice producing areas resulting in environmental pollution and loss of land. Rice milling waste can also cause respiratory problems due to its characteristics[38,40]. The effective utilization of rice milling waste as animal feed will greatly reduce its disposal problems and contributes towards value addition in the rice sector[41].

ECONOMIC IMPORTANCE OF RICE MILLING WASTE (RMW)

Competition between humans and animals on available grains make it difficult to meet the nutritional requirements of animals at reasonable costs. The high cost and seasonality of feeds have stimulated the search for alternative feed resources that can economically supplement the conventional feed ingredients in rations without adverse effects on health and performance of animals[42,43]. According to Muhammad *et al.*[44], Cost of feed (N kg^{-1}) decreased from N17.35-N11.65 kg^{-1} across the treatments indicating a decrease in cost with increasing levels of rice milling waste in the diets. Total cost of feed consumed showed that there were no significant differences ($p>0.05$) between treatments 1 (0% RMW), 2 (15% RMW) and 3 (30% RMW) while treatment 4 (45% RMW) with the lowest total cost of feed consumed of N1217.95 was significantly different from the other treatments. A study carried out by using RMW reported that, the feed intake did not significantly ($p>0.05$) alter but marginally reduced as levels of RMW was increased[27]. Within the treated groups, 30% RMW produced higher final live weight followed by 20 and 10% and the parameter was deteriorated by 40%. Nevertheless, there was no significant ($p<0.05$) difference between the weight gain of control, 10 and 40%. The feed gain ratio was best in 30% followed by 20 and 10% which were similar. The difference between feed gain ratio of control and 40% was not significant ($p>0.05$). The use of rice milling waste to replace cereal grains in poultry diets have been studied[45,46] and has been successfully fed to broiler chickens at lower levels of inclusion[25,31,47,48] in order to reduce feed costs. Urea treated Rice Milling Waste (UTRMW) gave a better feed cost per kg gain[29]. Carcass characteristics and bio-economics of broiler chickens fed urea treated and untreated rice milling waste showed that feed cost per kg feed and feed cost per kg gain were highly significant ($p<0.01$) while feed conversion ratio was significant ($p<0.05$) affected by the treatment of urea at the starter phase[49]. At the finisher phase, FCR, feed cost/kg gain, feed cost/kg feed and cost benefit ratio (CBR) were highly significantly different ($p<0.01$). Gross margin was significant ($p<0.05$). Wing weight was highly significant ($p<0.01$) while live weight, plucked weight, dressed weight, dressing (%) and the weights of the thigh, back, breast, neck and shank were significantly different ($p<0.05$). About 10% dietary level of inclusion of UTRMW and levels below 10% of UNTRMW is recommended in broilers diet.

Treatment/processing of RMW (methods): Rice milling waste, like other cereal crop residues is a potential source of energy for ruminants especially. However, its potential as an energy source is limited because it is high in dietary fibre (>50%) and low in crude protein (2-7%) and mineral contents (0.02-0.16%)[50]. For efficient utilization by livestock species, there are various treatment/processing methods of rice milling waste. This is done because of the high fibre content of the feedstuff and the inability of some of these livestock species to fully utilize high fibre diets, due to their digestive structure that cannot completely digest large amount of fibre. One way in which, the low nutritive value of rice waste could be improved is through treatment with urea. It was reported that, urea treatment of crop residues is acknowledged to improve nutritional value of crop residues and other fibrous by-products and also reduce feed cost and wastages with practical application at the smallholder level in developing countries[51]. Other studies have also shown that the nutritional value of rice milling waste can be significantly improved by mechanical treatment, ensilage, biological treatment and chemical treatment with alkalis and urea[33,34] since urea treatment increases rice milling waste utilization and fibre fraction degradation. Alkali treatments of various fibrous materials[52] and urea treatment[53,54] have been reported to improve their nutritional qualities. Among the chemicals that have been utilized, sodium hydroxide has proven to be the most effective in improving digestibility but lacks nitrogen. Furthermore, there is increased sodium load in animals fed with diets treated with sodium hydroxide[55]. Another effective chemical that has been used successfully in achieving this is ammonia, which weakens the hard cell walls, allowing better penetration by rumen micro-organisms to produce more effective fermentation and liberation of nutrients[56]. In developing countries like Nigeria, one of the more successful procedures available to improve the digestibility and therefore

nutritional value of fibrous feeds is urea treatment since this requires little equipment or expenses, even subsistence farmers can apply urea treatment. Chemical treatment of rice milling waste with urea can lead to significant improvement in nutritional quality and therefore greater utilization[57]. Urea ammunition has been used to improve the quality and utilization of RMW for broilers[57,58]. Although, one can hardly classify rice milling waste among hazardous wastes, its treatment is very important in view of the great volume of waste materials involved. Waste treatment techniques are normally employed to alter the physical, chemical or biological characteristics of waste and make it safer for disposal[41].

Another treatment method that RMW can undergo for efficient and effective utilization by livestock is by extrusion cooking. Extrusion cooking is a high-temperature and short time thermal/mechanical pre-treatment feed and feedstuffs processing technique, which involves applying heat treatment in the presence of moisture. It is an effective processing method causing physic-chemical and nutritional modifications of the feed constituents, such as permanently denaturing lipases[59]. Extrusion cooking is also effective in stabilizing oxidative rancidity in rice bran[60].

Effect of treated RMW on the performance of livestock species: Researchers, who fed west African dwarf goats some ensiled non-conventional feeding stuff including rice milling waste observed that it had no adverse effect on the goats. They recommended that ensiling of non-convectional feedstuff (like RMW) be encouraged as a way of preserving the nutritive value of feeding stuff to serve as dry season feed to ruminants[61].

The use of 10, 20 and 30% extruded rice bran in broiler diets, compared with raw and roasted rice bran increased weight gain and feed consumption[62]. Similarly, previous research indicated that feeding of extruded rice bran (cooked rice bran) had the ability to protect young pigs against diarrhoea, increase CATTD (coefficient of total tract apparent digestibility) and average daily gain (ADG)[63-65]. Diarrhoea is often experienced by piglets after weaning and it is a multi-factorial condition associated with proliferation of haemolytic strains of *Escherichia coli* in the small and large intestine[66]. Although previous studies reported the beneficial effects of extrusion cooking process of rice bran on the performance of mono-gastric animals[65], the adequate temperature of extrusion of rice bran for optimal performance is yet to be ascertained. It is hypothesized that processing of rice bran and inclusion in pig nutrition could help reduce the public health implications that could arise from indiscriminate disposal of these wastes, improve animal performance as well as reducing the cost of animal production[66].

Scientists observed that 15.0% urea treated rice offal increased feed intake compared with birds fed other diets[67] but disagree with those of Yakubu *et al*.[31] and Ihenkwumere *et al*.[68], who reported lower feed intake with birds fed urea treated rice milling waste when compared to those fed untreated rice milling waste. Urea treated rice offal increase feed intake[67]. Weight gain at 15.0% level of inclusion of urea treated rice offal was highest compared with birds fed diets fed other diets. Broilers fed urea treated rice milling wastes had significantly higher final body weight and daily weight gain than those fed other diets[47,67]. It was reported that 15.0% urea treated rice offal, had better efficient feed utilization than those fed diet containing 7.50% urea treated rice offal[67]. This finding agreed with reports by Ihenkwumere *et al*.[68] in broilers who reported an increase in weight gain and efficiency of feed utilization when birds were placed on diets containing urea treated rice-milling waste. Energy content of diets decreased with increasing levels of urea treated rice milling waste. Since energy intake is a productive function of feed intake, the higher the feed intake of birds fed the urea treated rice milling waste, the higher their weight gain.

The treatment of RMW with urea increased its nitrogen content due to the addition of non-protein nitrogen[69]. This is in agreement with the reports of Abdel Hameed *et al*.[57] and Amaefule *et al*.[58] that urea ammunition increases the crude protein content of feed materials including RMW. Although, there was no complete degradation of fibre fraction of RMW due to urea treatment, the reduction (41.43%) in crude fibre content when compared with the untreated RMW diet could be considered significant. Urea treated RMW diet improved broiler daily weight gain and final body weight more than other diets in contrast to earlier report Amaefule *et al*.[58] which showed that urea treated RMW had no effect on body weight and daily weight gain of broilers. This could be due to the age of the broilers (4 week old) used in the study. The treatment of RMW with poultry droppings did not improve broiler performance[70]. The difference in the performance of broilers fed D2 and D3 diets suggested that the source of urea used in the ammunition of RMW had significant effect on the performance of the broilers. The untreated RMW (D1) diet had the highest intake probably due to high crude fibre content which may have caused the broilers to consume more of the diet to meet their nutrient requirement[71]. The low intake of D3 may have been due to the presence of uric acid in the poultry droppings[58], which had identified as gut irritant that either depresses feed intake[72]. This may have also been

responsible for the poor daily weight gain of broilers fed D3 diet in addition to an earlier observation that there was low utilization of RMW by poultry[73]. The higher dressed carcass weight of broilers fed D2, when compared with others, is considered a direct consequence of the better final body weight and FCR of the broilers fed D2. It suggested that urea treated RMW was not toxic to the broilers especially when there was no significant differences in the weight of internal organs of the broilers fed the various treated and untreated RMW diets. The result of nutrient utilization of the treatment diets by broilers did not actually reflect the observed performance of the broilers and also did not follow any regular pattern. This suggested that the effect of the treatments on RMW needs proper investigation. It was expected that urea and poultry droppings would enhance crude protein and fibre utilization of the diets since according to Abdel Hameed *et al.*[57] urea ammunition increased RMW utilization and fibre fraction degradation. The results of this study showed that rice milling waste (RMW), which is cheap and readily available, when treated with urea could be utilized in finisher broiler diet. Researchers evaluated the effects of urea treated rice milling waste (UTRMW) and untreated Rice Milling Waste (UNTRMW) on the performance and internal organ characteristics of broiler chickens. Five experimental diets T_1, T_2, T_3, T_4 and T_5 containing 0% UNTRMW, 10% UNTRMW, 15% UNTRMW, 10% UTRMW and 15% UTRMW, respectively were formulated. In the starter phase, weekly weight gain was highly significant ($p<0.01$). Final weight, total weight gain, daily weight gain and FCR were significant ($p<0.05$). At the finisher phase, final weights, weekly weight gain, total feed intake, FCR and Feed cost/kg gain were highly significant ($p<0.01$). Daily feed intake was significant ($p<0.05$). As for the internal organs, spleen and intestine weights were highly significant ($p<0.01$) while liver and gizzard weights were significant ($p<0.05$). The T_2 was better in feed cost per kg gain (N) at the starter phase. The T_4 (10% UTRMW) had the best live weight apart from T_1. The T_3 had the highest gizzard weight. About 10% dietary level of inclusion of UTRMW and levels below 10% of UNTRMW is recommended in broilers diet and 15% level of inclusion of UNTRMW is recommended if the sale of gizzard is a priority[29].

CONCLUSION AND RECOMMENDATIONS

This study confirmed the abundant availability of RMW in Nigeria as a result of high production of rice. It was also clear that to prevent this waste from constituting environmental pollution, it should be properly processed and used as an alternative source of feeding stuffs. This will reduce the competition for conventional feeding stuffs existing between humans and animals since it has been established that most animals, including: Poultry, rabbits, fish, pigs, ruminants, etc, can be fed levels of RMW without adverse effect on them. For better utilization of RMW by animals, several treatments can be given to RMW. Therefore, the inclusion of rice milling waste (RMW) as feeding stuff in the diet of livestock feed should be encouraged.

SIGNIFICANCE STATEMENT

This study discovered that rice milling waste is in abundant supply and that it can be beneficial for the feeding of most domestic animals since it contains some useful nutrients needed by these animals. This study will help the researchers to uncover the critical areas of the use of RMW. This area has not been explored by many researchers. Thus a new theory on the use of RMW and different treatments to improve the utilization of RMW as a feeding stuff may be arrived at.

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