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Underutilized Tropical Legumes as Feed Resources: *A Review*

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Abstract

The application of underutilized legumes as a good protein source makes them to be attracted to the poultry and livestock industry in general for the same purpose. The utilization of underutilized legumes as animal feeds will help to balance the competition between humans and animals who commonly share the same feed resources. Literature search reveals that there are several species and varieties of under-utilized legumes with relatively comparable amount of protein with that of the commonly consumed legumes by humans. However, their utilization as animal feed faces challenges in terms of presence of antinutritional factors and limited literature documentation. There is need for conducting and reporting more studies so as to get economically viable and alternative sources of livestock feeds. The tropical climates are abundant in many underutilised legumes with seeds and foliage that are rich in proteins and antinutritional factors. However these underutised legumes have potentials as feed resources when adequate processing techniques are applied to reduce or eliminate the potency of the antinutritional factors. This review is therefore presented to elucidate the different underutilized legumes utilized as sources of animal feeds and create awareness among livestock farmers and researchers.

Keywords: Underutilised legumes, antinutritional factors, processing techniques, proteins, malnutrition

Description of Problem

Nutrition is the most important factor in livestock production (1). Animals on good plane of nutrition regardless of the strains and species are likely to dress out in a better way [2]. High cost of conventional feed ingredients has led to high cost of animal production [3]. The over-reliance on soyabean and groundnut cakes as the major conventional plant protein concentrates for farm animals in many developing countries, including Nigeria, has resulted in increases in prices of livestock feeds and its products [4]. There is a need to research into alternative feedstuffs for livestock so as to avoid the over dependence on the limited conventional feeds as the key protein and energy feedstuffs for livestock [5]. The risk of protein deficiency diseases in farm

animals is another cause for concern. There is therefore the need to look for viable alternative sources of feed raw material such as underutilized legumes. Tropical legumes have been reported to be important and potential sources of protein and energy for farm animals [6]. The unavailability of protein of animal origin for farm animals and humans in adequate quantities makes the use of comparatively rich underutilized legumes as essential nutrients in nutrition. Legumes are found globally, although the largest varieties grow in the tropics and subtropics where they substantially contribute to dietary protein consumption for humans [7].

The feed industry is faced with several challenges, not only on the availability of feed ingredients but also on the ability to supply high quality products in a cost-effective manner [8]. There is an alarming competition between humans, animals and industries for the conventional feed resources as a result of increasing human population in the developing countries [9] [10]. Due to constant threat of hunger in developing countries, there is an urgent need to source for alternatives and viable feedstuffs which are readily available, for incorporation into the diets of farm animals [10]. Such feedstuffs should have low human preference as food, readily available and should be easily adaptable to changing climatic conditions.

There is a need to exploit some under-utilized legumes which could serve as possible replacers for the expensive energy and protein sources for livestock, in order to decrease feed competition between human and animals [7]. Leguminous seeds are rich in nutrients such as digestible protein with good amino acids and minerals profiles [11] The percentage crude protein for most legumes have been reported to vary from 20-50% [12].

Significance of Underutilized Legumes

Underutilized legumes also called lesser-known legumes are not widely and commonly used as feed resources, despite being good sources of plant protein [13]. Underutilized legumes provide food and nutritional security to resource-poor rural populations. During periods of drought and extreme hunger, thus have possibility of saving millions of lives [13]. Some underutilized legumes have been reported to be as almost equivalent in nutrient status as soyabean, winged bean (*Psophocarpus tetragonolobus*), lentil (*Lens culinaris*), Lima bean (*Phaseolus lunatus*), Lablab (*Lablab purpureus*) and bambara groundnut (*Vigna subterrenea*) [14]. Kidney bean (*Phaseolus vulgaris*) is an underutilized tropical legume used for human food and animal feed. This has been reported as a source of animal proteins. Marama beans (*Tylosema esculentum*) is an underutilized oilseed legume crop of southern Africa, which could be a valuable alternative to other oilseeds due to its high drought-tolerance [15]. Pride of Barbados seed (*Caesalpina pulcherrima*) is an underutilized legume which contains considerable nutrients and phytochemicals [16]. It is a leguminous plant belonging to the family leguminosae. The immature seeds of Pride of Barbados are edible while the mature seeds are reported to be toxic. [17]reported that raw and roasted Pride of Barbados seed meal has good dietary quality which can be utilized as an alternative feed resources for animals.

Velvet bean (*Mucuna pruriens* (L.) DC. var. utilis (Wall. ex Wight) Baker ex Burck), is an underutilized food legume of South India origin, and it was found to contain appreciable levels of crude protein (273.2g/kg DM), lipid (60.61g/kg DM),

neutral detergent fibre (83.4 g/kg DM) and ash content (56.04 g/kg DM) [18] (Vadivel and Pugalenthi, 2010). However, the potential of velvet bean has not been fully harnassed for animal production despite having great potential as an energy protein source for livestock feed [19] [20]. It is used as a source of forage for livestock is widely accepted.

Processing methods value-addition of Underutilized Legumes

Velvet bean

In poultry, processed velvet bean replaced in an adequate proportion exhibited better growth performance of broiler birds without showing any adverse effects [18]. Velvet bean (Mucuna spp.) is used as a feed ingredient for poultry [21].

Animals fed silage containing 75% whole maize stover + 25% *Mucuna pruriens* foliage performed well and no toxic/adverse effects were observed on the health status of the West African dwarf rams used for the study [22]. It has also been reported that processed mucuna seed meal can be included up to 7.5% in the diet of weaned rabbits without any adverse effect on the performance of the rabbits [23] . Inclusion of boiled mucuna seed meal in the diets of broiler finisher chicks up to 20% has beneficial effects [24]. Inclusion of velvet bean meal at 10% of the diet have been reported to give better growth in broiler so fed. In the early 1900s in the US velvet bean was once more popular than soyabean as plant protein source [25].

Up to 2 million ha were reported to have been planted in the early 1900s [26]. In Honduras, the velvet bean plant is mostly used as a cover crop inter-cropped with corn [27]. The velvet bean plant is hardy, resistant to insects, resistant to drought, easily managed with minimal care, and also fixes nitrogen in the soil. The forage of the velvet plant also fed to cattle, pigs and chickens. In some communities velvet seed is eaten by humans.

The presence of anti-nutritional factors e.g. anti-trypsin inhibitors and 3, 4-dihydroxyphenylalanine (L-DOPA) in the velvet bean limit its uses in poultry and it leads to reduced growth, feed intake and egg production and high mortality [28]. Application of heat via autoclaving reduced anti trypsin inhibitors and L-DOPA. The L-DOPA can undergo oxidation and other chemical reactions when exposed to heat, light, or oxygen, leading to its degradation.

One report indicated that heating (autoclaving) of Velvet beans improves growth of young chicks [29]. Many other antinutritional factors present in velvet bean in terms of heating conditions, water extraction and other processing methods remain largely uninvestigated.

Bambara groundnut

Bambara groundnut (*Voandzeia subterranean*) is an underutilized legume that is grown in several parts of Africa including Nigeria [30]. Bambara groundnut (*Vigna subterranean* (L.) Verdc) originated in West Africa with a considerable genetic diversity [31]. In many parts of Africa, it represents the third most important legume after groundnut and cowpea [32]. These authors reported Bambara groundnut as an important food legume grown widely in semi-arid Africa which is closely related to cowpea (*Vigna unguiculata*). However, it is also considered as an under-utilized crop. In terms of nutrition, it is rich in carbohydrate and protein content, making it an important benefit to the diets of people who cannot afford expensive animal protein [33].

Bambara groundnut is a traditional crop in Africa that has various applications in the preparation of several indigenous food products. [34]. It was reported by [35] that

8- week old weaner pigs fed with 10% toasted bambara waste based diet had a good performance in terms of average final body weight, feed conversion ratio and feed cost/kg gain in a 56 days feeding trial. No adverse effect was recorded on the weaner pigs. Grinding and heat treatment were the processing technique employed. Feed formulated at 18% crude protein and 2800 kcal ME/kg. [36] evaluated the effect of feeding toasted Bambara waste on the performance of laying hens and concluded that up to 20% level of toasted Bambara waste can be incorporated into the diets of growing pullets without any adverse effect on the performance of the birds. Growing pullets of 10 weeks of age with average body weight of 0.85±0.02 were used for the study. [37] reported that Bambara nut can be included in the diets of Japanese quails by 30% for optimum growth and carcass yield, and no negative effect was observed in the Japanese quails. [38] reported that broiler finishers could be fed up to 15% Bambara groundnut seed meal for optimum carcass yield without any deleterious effect on the broilers at the finisher level. [39] reported that Bambara groundnut is a non-oil leguminous seed classified as a protein source, having above 20% protein in dry state and is suitable for livestock feeding. Bambara groundnut is applied as a source of poultry feed [40]. Birds fed on roasted Bambara nut diet maintained the highest digestibility values after standardization [41].

It was reported by [41] that up to 30% diet inclusion of raw Bambara nut gave good performance can be incorporated into the diet of growing rabbits while raw lima bean can be safely incorporated up to 20% level. Bambara groundnut is a useful resource for animal feed [42].

Minni parayu

Minni payaru (*Vigna stipulacea*) is an underutilized legume. it is domesticated as Indian Vigna species and it has limited published information [43]. Minni payaru (*Vigna stipulacea*) (Lam.) Kuntz] is used mainly as a source of food, animal fodder and green manure, particularly in Southern India [44].

Creole bean

Creole bean (*Vigna reflexo-pilosa* var. glabra, *Vigna glabrescens*) is an underutilized legume [45] and it is the only tetraploid species in genus Vigna and the little-known cultivated species of the subgenus Ceratotropis [43]. Creole bean and its by-product are utilized as animal feed [46]. It was first found used as a forage crop in West Bengal, Mauritius, and Tanzania, while it was used as a pulse in the same ways as mung bean in Vietnam and Philippines [47]. The crop is considered to have been domesticated in Southeast Asia from its possible wild ancestor *Vigna reflex-pilosa var. reflex-pilosa* [48]. Creole bean is used as a source of poultry feed [44].

Moth bean

Moth bean (*Vigna aconitifolia* (Jacq.) Marechal) is an underutilized legume crop and it is considered to be the most drought and heat tolerant cultigen among Asian Vigna [49]. It is widely grown in India and the Far East [50]. It was reported to have been domesticated in India, Pakistan, Myanmar or Ceylon [51]. Its nutritional content is also well appreciable for human consumption as it possesses very important nutrients, vitamins, and minerals in very good proportions. The nutritional content is 24.3% protein, 68.0% carbohydrates, 3.9% lipids, 3.8% ash, 133(mg/100g) calcium, 356(mg/100g) phosphorus, 183(mg/100g) magnesium, 11(mg/100g) iron, 0.50(mg/100g) thiamine, 0.10(mg/100g) riboflavin and 1.7(mg/100g) niacin [52].

Researchers have found that there is a substantial genetic variation between moth bean germplasms which could be used in crop improvement [53]. Moth bean is applied as a source of pasture and hay for livestock [54].

Nutritional studies involving Underutilized Legumes

Lima bean (*Phaseolus lunatus*) has crude protein content of 22% [55]. It was reported by [56] that 10% level of dietary inclusion of lima bean cooked (for 90 minutes) and toasted (to browness, milled and incorporated into the bird's diets gave a good performance on 28 day old broilers. *Mucuna utilis*, is a lesser-known legume rich in minerals like sodium, zinc and iron [57]. It has very low human preference. [58] reported that cooked *Mucuna utilis* is not nutritionally inferior to soyabean even at 20% dietary level of inclusion. Their work concluded that cooked Mucuna seed meal can quantitatively replace soyabean meal up to 20% level of dietary inclusion without adverse effect on the 28 day old broilers. [59] reported that up to 20% processed mucuna seed meal could be included in pullet chicks' diets without any deleterious effects on the chicks.

Up to 30% diet inclusion of raw pigeon pea, raw Bambara nut and raw African yam bean gave good performance can be incorporated into the diet of growing rabbits while raw lima bean can be safely incorporated up to 20% level [60]

African locust bean (*Parkia biglobosa*): is an underutilized legume highly consumed in developing and less developed countries with high cost of animal protein and it is rich in phytochemicals [61, 62]. It is rich in protein and amino acids suitable for use as a protein substitute for animal feed [63]. It was reported that *Parkia biglobosa* seed meal could replace groundnut cake (100% fermented *Parkia biglobosa* seed meal) with improved performance and no adverse effect on the haematological indices of the chicks [63]. It was reported by [64, 65] that the yellow colour of the locust bean pulp indicates that it is very rich in nutrients like beta carotene (precursor of vitamin A) and calcium, which is essential for bone development and egg shell formation and it improves the laying performance and immune function of laying hens under heat stress conditions. [66] reported that locust bean pulp is rich in nutrients which are adequate to support the growth of livestock. [66] reported that locust bean pulp is safe and can be included in the diets of laying hen up to 30% without adverse effect on the haematological and serum biochemical indices of the birds. [67] reported that differently processed African locust bean seeds were effective in enhancement of haematological and serum biochemical parameters of broiler chickens, although the cooked African locust bean seeds were more effective in enhancing the blood parameters. [68] reported that toasted African locust bean seed meal could be included in nthe broiler starter chicken's diets up to 15% with any deleterious effect on the growth of the broiler chickens. The broiler chickens showed good nutrient digestibilities. [69] concluded in their study that partially fermented *Parkia biglobosa* bean meal could be incorporated in the diets of layer chickens, so as to improve their laying performance and egg quality, including haematological and biochemical indices, carcass characteristics and also to help maximize profit. Dawadawa is the fermented seeds meal of *Parkia biglobosa* or African locust bean plant [70]. It was reported by [70] that the addition of dawadawa to chicken-type sausage beyond 4g/kg improved the protein content of the product. Dry matter intake, nutrient digestibility and nitrogen utilization of bucks can be enhanced by including 10% of *Parkia biglobosa* pulp in

the diets of Red Sokoto bucks [71].

Pigeon pea (*Cajanus cajan*) is an important tropical underutilized legume which has lots of potential as a poultry feed ingredient [72]. [73] reported that heat-treated pigeon pea seed meal could replace 50% of soyabeal meal in broiler starter diet, without any deleterious effect on the broiler chicks. [74] reported that birds fed with 5.0g/kg methionine supplementation in a pigeon pea seed meal based diets were very efficient in feed and protein utilization as well as in overall performance. A study on starter broilers (day old) revealed that the chicks could be fed 30% raw pigeon pea seed meal diet supplemented with lysine+methionine to improve the crude protein and nitrogen free extract digestibility coefficients [75] . However another report postulated that at 30% inclusion level, processing of pigeon pea seeds may not be necessary in making diets for broilers [76] . [77] showed that the use of allzyme, a cocktail of exogenous enzymes, produced no negative effect on broiler performance at 30% inclusion level of pigeon pea seed meal processed by fermentation. They concluded that allzyme supplementation of fermented pigeon pea seed meal is safe and gives profit maximization at 30% dietary inclusion level.

[60] reported that up to 30% diet inclusion of raw pigeon pea gave good performance can be incorporated into the diet of growing rabbits while raw lima bean can be safely incorporated up to 20% level. Inclusion of 30% of pigeon pea (*Cajanus cajan* L. Millsp) leaves in concentrate mixture led to a good performance of crossbred dairy cows.[78]

Prosopis africana is a tropical underutilized legume, native to Africa, and widely distributed in the savannah regions of Nigeria [79]. *Prosopis africana* is reported to contain 240 to 260g/kg protein, 45 to 200g/kg oil and 480 to 600g/kg carbohydrate. [79] reported that *Prosopis Africana* is a suitable dietary protein for laying hens if used in boiled-fermented form at 200g/kg inclusion rate.

Afzelia africana is an unconventional legume that is readily available but is underutilized [80]. It is a nitrogen-fixing legume which can improve soil fertility [81] and it plays an essential function in agroforestry [82]. It is a polyvalent tree with several applications such as wood, charcoal, fodder, and medicinal purposes [83]. The branches of *Afzelia africana* are pruned for livestock feed [84] and it is used extensively as animnal feed supplement in the dry season [85] to meet the shortage of annual fodder grasses [86, 87].

Afzelia Africana seeds has optimum performance as feed for broilers showing proper nutrient utilization and greater profit margin after roasting before feeding it to broilers [88].

[89] reported that *Afzelia Africana* seed meal can be utilized in the diet of rabbits after proper processing (roasting and re-roasting).

Sesame (*Sesamum indicum* L.) seed is an underutilized legume reported to provide a nearly complete protein supplement for most farm animals [90]. It is an oil seed, high in protein level and methionine but deficient in lysine. [91] reported that the intake of aqueous-heated sesame seeds by broiler chickens at 300g/kg DM gave significant improvements in the performance characteristics and nutrient utilization of the birds and they recommended that sesame seeds processed by aqueous heating can supplement or replace full fat soya in broiler diets.

Jack bean (*Canavalia ensiformis* L.) is an underutilized legume with large seeds and foliage yield. Jack bean (*Canavalia*

ensiformis) is an under exploited tropical dry beans, which is fairly distributed and cultivated in Africa, Asia, the West Indies, Latin America and India. The jack bean can be grown in marginal soils and arid to semi-arid regions. The jack bean seed contains about 30% crude proteins and 60% carbohydrates [92]. *Canavalia ensiformis* is also utilized as a source of poultry feed [93]. The proximate composition and nutritive value of jack bean has been established by [94]. Jackbeans processing enhances its nutritive value as animal feed [95]. This could lead to better performance of poultry birds when incorporated into their diet. [96] investigated the growth performance of Wistar rats fed with dehulled jack bean (*Canavalia ensiformis*) soaked in acidic and alkaline media or boiled. They reported that dehulled jack bean soaked in ogi liquor and boiled for 15 minutes can be fed to rats without any adverse effect on their performance in terms of growth.

Sword bean (*Canavalia gladiata* L.) is an underutilized legume which is widely available and thrives very well in on poor soils where most crops fail to thrive as a result of bits excellent adaptability to extreme climatic conditions. [97] reported that cooking of sword bean produced higher values for gross energy, crude protein, apparent metabolizable energy, true metabolizable energy and true metabolizable energy corrected for nitrogen when fed to broiler chicks (starter phase).

Lablab beans (*Lablab purpureus*) is an underutilized legume with low human preference for food and its value for livestock feeding needs to be fully exploited. [98] reported that cooking of lablab seeds at 100°C for 45 minutes significantly ($P<0.05$) reduced trypsin inhibitor activity, phytic acid, tannin and cyanide. They concluded that cooking lablab seeds for 45 minutes before incorporation into manogastric diet may be considered optimum. [98] also reported that inclusion of 20% lablab seeds in the diet of weaning pigs increased their performance without any adverse effect. [99] reported satisfactory rate of gain in birds fed 25% lablab seeds in their diet. [100] reported lablab beans as a legume that feeds people, animals and the soil. [101] reported that longer durations of cooking make the nutrients in the raw lablab seeds to be more readily available for utilization by pullet chicks. [102, 103] reported that processing improves the utilization of proteins and energy contained in legumes. [104], reported that lablab seed can be used as an alternative protein source for soyabean in rabbit's nutrition, especially when cooked. [105] reported that Shika Brown layers fed lablab seed meal (LSM) diet as the major source of protein performed well in terms of egg production and feed conversion ratio and the birds had better productivity in general. The cost of feed per gain (egg) was lower for the layers fed LSM due to their better performance although they consumed more feed. [106] observed that calves fed with maize-lablab (70/30%) silage performed better in terms of proximate composition, digestibility percentage and nitrogen utilization than the sole maize silage, and they recommended that maize-lablab should be used as supplement in dry season when natural pastures are deficient in crude protein. *Lablab purpureus* combines a great number of qualities that makes it a reliable animal forage [107].

Horse eye bean (*Mucuna urens*) is a widely available but underutilized leguminous seed that thrives well even in extreme climatic conditions. 45% of soybean meal could be replaced by the Horse eye bean meal (HEBM) in pullets' diets at the chick phase while HEBM can replace 60% soybean meal in the pullets' diet at rearing

phase. [108]. [109] reported that the cost of production was reduced when up to 30% of soybean meal was replaced with processed horse eye bean meal in the diet of growing cockerels.

Tuber cowpea (*Vigna vexillata*) is an underutilized legume recognized as domesticated Vigna species, cultivated in Bali and Timor, Indonesia [110]. That domesticated form was discovered with some important agronomic characteristics such as prominent seed size increase, loss of pod shattering and loss of seed dormancy [111]. It is cultivated for its tuber but the seeds are also used as human food. Its root protein content is 15% which is about 2.5 times higher than that of yam (6%), 3 times higher than that of potato (5%) and sweet potato (5%) and 5 times higher than that of cassava (3%) [111].

Vigna vexillata edible tubers, seeds, and forage and it is utilized as a fodder [112].

Tuber cowpea is utilized as a source of poultry feed [93]. Cowpea (*Vigna unguiculata* L. Walp) is a popular legume crop common in Africa and it is used for human and livestock diets all over the world [113].

African yam bean (*Sphenostylis stenocarpa*) (AYB) is cultivated for both tuber and seeds in tropical Africa. The AYB is an underutilized and unconventional legume can be effectively utilized as a supplement to low-nitrogen crop residues [114]. [114] also reported that inclusion of African yam bean up to 20% as protein source in cassava peel meal diets for weaned rabbits (8 weeks old) gave good performance in terms of weight gain, feed intake and feed conversion ration, with no adverse effects on the rabbits.African yam bean (*Sphenostylis stenocarpa* Hochst. ex A. Rich.; Leguminosae) is an under-utilized legume which is widely distributed in different parts of Africa for its nutritious seeds and tubers. It is widely adaptable and it can grow in acidic and highly leached sandy soil in the humid lowlands of the tropics [115]. In terms of nutrition, the seeds are known to possess high crude protein (21% to 29%) and approximately 50% carbohydrate and among the amino acids lysine (9.28g/16gN) and methionine levels (1.16g/16gN) are either comparable or even higher than that of soybean [115]. African yam bean is applied as a source of poultry feed [116]. African Yam Bean meal could be utilized as an alternative source of feed for snail production [117].

[118] reported that broiler chicks fed with toasted African yam bean seed meals with enzyme supplementation performed well at up to 20% level of inclusion in their diet.

[119] reported that up to 30% diet inclusion of raw African yam bean gave good performance can be incorporated into the diet of growing rabbits while raw lima bean can be safely incorporated up to 20% level.

Potential of uncommon high protein forage as feed resource for ruminants

African copaiba balsam tree (*Daniellia oliveri*) is native to tropical West and Central Africa and it is a lesser-known legume [120]. *Daniellia oliveri* has an excellent nutrient profile and low content of anti-nutritional factors [121]. [120] reported that *Daniellia oliveri* seed meal inclusion at 25% and 50% inclusion levels can successfully replace groundnut cake in the diet of sheep without adverse effects on the health of the sheep fed with it. [120] reported that inclusion of 2.5% raw *Daniellia oliveri* seed meal and up to 7.5% toasted *Daniellia oliveri* seed meal is a good replacement for groundnut meal and no adverse effects were recorded on the performance and blood parameters of the broiler chickens used for the study. [122] reported that inclusion of 200 g/kg toasted *Daniellia oliveri* seed meal (100%

replacement of groundnut cake) improved feed intake, nutrient digestibility, nutrient utilization, ruminal fermentation and growth performance of lambs.

Rice bean (*Vigna umbellata*) is a multipurpose underutilized as well as a neglected legume [123], neglected legume regarded as a minor food and fodder crop [124]. Rice bean is a neglected crop, cultivated on small areas by subsistence farmers in hill areas of Nepal, northern India and parts of SE Asia.

It is mainly grown for human consumption, though it is also used for fodder and green manure. There has been very little research or development support for this crop. Rice bean foliage and dry straw are valuable livestock feed and when used as a green manure it improves soil fertility. Thus, rice bean is a vibrant potential fodder legume crop which has capacity to provide balance diet to the livestock and to sustain under wide range of climatic condition [124].

Rice bean is useful for livestock feeding. The vegetative parts can be fed fresh or made into hay and the seeds are used as fodder. Rice bean straw indudes the stems, leafy portions, empty pods, and some seeds. Before feeding, the woody portions and soiled or mildewed parts of the straw should be removed [125]. Rice bean is used as an important fodder and a green manure [126]. Like other legume forages, fresh rice bean forage is relatively rich in protein, though its concentration is extremely variable (17-23% DM). Rice bean hay and straw are slightly less nutritious (16 and 14% protein in the DM, respectively). Rice bean forage is also rich in minerals (10% of the DM in the fresh forage) and particularly in calcium (up to 2% in the fresh forage).

Rice bean straw contains large amounts of mineral matter (more than 20% of DM) though it is highly variable. Rice bean forage contains variable amounts of condensed tannins (0.1-2.8% DM) [127, 128].Rice bean forage at the pre-flowering stage is palatable to sheep [129]. In Nepal, farmers have emphasized the softness and palatability of rice bean fodder for livestock [123} Stems of rice bean are cut and used as animal feed or mulch [130]. In an experiment with rice bean hay in India, bullocks consumed it hesitantly at first but within a few days the animals grew accustomed to it and DM consumption increased, indicating that the hay was palatable [131]. Rice bean straw was reported to be relished by cattle [125].

Fresh rice bean forage

In India, 22 month-old calves fed a mixture of fresh Sudan grass (Sorghum × drummondii) and rice bean forage (54:46 fresh basis) for 64 days had a DM intake of 1.90 kg DM/100 kg LW and a daily weight gain of 456 g day^{-1} [132].

In India, 22 month old calves fed a mixture of fresh Sudan grass (Sorghum × drummondii) and rice bean forage (54:46 fresh basis) for 64 days had a DM intake of 1.90 kg DM/100 kg LW and a daily weight gain of 456 g/d [132].

Rice bean hay

Rice bean hay is generally used as a protein source to supplement poor quality roughage based diets in ruminants. Rice bean hay included at 600 g day^{-1} to supplement rice straw in diets for swamp buffalo increased DM intake, digestible protein and N retention. It had a positive effect on rumen microflora, resulting in increased VFA production and lower CH_4 emissions [133]. Adding rice bean hay was reported to increase cellulolytic rumen bacteria thus improving the utilization of high fibrous feeds in buffalo diets [128].

In India, a trial with bulls showed that rice bean hay had a moderate OM digestibility (50%) but that it contained nitrogen, calcium and phosphorus in adequate

amounts to meet the maintenance needs of adult cattle [131]. In Vietnam, a mixture of cassava hay and rice bean hay (3:1 ratio) replaced 60% of concentrate in a forage-based diet *(Pennisetum purpureum* + urea-treated rice straw) offered to growing crossbred heifers, resulting in higher daily weight gain (609 g day-1), better feed efficiency and reduced feed costs [134]. In India, supplementing local goats fed grass with rice bean hay (15% of diet DM) did not increase grass intake but total DM intake and nutrient digestibility were increased. Increasing the level of rice bean level above 15% had no further effect on digestibility [135].

Rice bean straw as a fodder In India, a trial with bullocks showed that rice bean straw had a low OM digestibility (31-47%) and it was recommended to supplement a rice straw-based diet with energy-rich feed materials, such as cereal grains or bran [136].

Rice bean seeds as a feed In India, rice bean seeds are fed to buffalo calves and sheep to provide energy. Rice beans replaced half the cereals and half the deoiled cake present in the concentrate offered to buffalo calves [137]. In sheep, replacing 50% of the metabolizable energy from oat hay by rice bean seeds had no deleterious effect on sheep N balance, which remained positive [138].

From above review it can be concluded that rice bean is a vibrant potential fodder legume crop which has capacity to provide balance diet to the livestock and to sustain under wide range of climatic condition. Appropriate awareness and research focus on the crop is needed for more popularity as a potential legume crop under the climate change situation.

Limitations to the utilization of Underutilized Legumes as sources of Animal Feeds

Despite the nutritional potentials of underutilized legumes as sources of human food and animal feed, the presence of toxic and anti-nutritional factors (ANFs) are major factors that limit their use. However, the discovery of different processing techniques to inactivate and reduce these ANFs has activated interest in their utilization as human food and animal feed [139]. Many of the anti-nutritional factors are detoxified by several processing methods like soaking, germination, boiling, autoclaving, fermentation, roasting, genetic manipulation and other processing methods so as to improve the nutritional quality and bioavailability of nutrients in the legumes [139, 140, 141, 142, 143]. Hard to cook phenomenon is another challenge to the use of under-utilized legumes as animal feeds [144].

Many anti-nutritional and potentially toxic factors are found in Velvet Beans and other legumes and several of them have medicinal/pharmacological actions, among them antitrypsin factors, tannins, and cyanide [145], anticoagulants [146], analgesic, antipyretic, and anti-inflammatory factors [147], and others [148]. L-3,4-dihydroxyphenylalanine (L-DOPA), a potentially neuro-toxic agent, is found in relatively large amounts in Velvet Beans [149, 150]. Toxic and anti-nutritional factors in feed ingredients may be destroyed by heat [148] and the well-known value of heating soybean meal is an example. It was observed that heating reduced some growth-depressing factor(s) found in the raw VB and allowed market weight broilers to tolerate the 10% level. Thus, it appears that when properly heated, VB could possibly be used in commercial broiler rations to market weight up to a level of 10% [25].

Conclusion and Recommendations

Potential exist in the utilisation of seeds and foliage of uncommon legumes in

meeting protein needs of farm animals. However, the presence of toxic factors limits their uses. More research should be conducted to extend both technical and practical knowledge about these underutilized legumes so as to maximize their full potential alternative sources of livestock feeds. It is therefore expendient that effective processing technique to drastically reduce the antinutritional factors and thus improve their nutritive values should be researched. Genetc manipulation to reducing antinutritional factors is also an emerging area which should explored. Mass cultivation of these underutilized legumes should be encouraged to ensure they are readily available which will reduce their cost.

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