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Review

The Efficacy of High-Protein Tropical Forages as Alternative Protein Sourcesfor Chickens: A Review

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Received: 4 June 2018; Accepted: 14 June 2018; Published: 20 June 2018

Abstract: Smallholders of poultry production systems in developing countries are commonly found in rural, resource-poor areas, and often face food insecurity. The main constraints for smallholders in poultry production in rural, resource-poor areas are the shortage of available commercial dietary protein and the high cost of commercial diets. The beneficial effects of legume and forage cultivation are economic, through providing protein for animals, and ecological, such as soil amendment, nitrogen fixation, and stripping control which participate to increase cropping efficiency. The potential nutritive value of a wide range of forages and grain legumes is presented and discussed. The impacts of dietary protein, fiber, and secondary metabolites in plant content, as as well as their consequences on feed efficiency, animal performance, and digestion processes are enclosed in this review. Lastly, approaches to reduce the anti-nutritional factors of the secondary metabolites of plants are explained.

Keywords: tropical forages; chicken; alternative protein; anti-nutritional factors

1. Introduction

In developing countries, there is an increasing demand for animal protein, which is principally poultry products [1]. About 20% of the world's population is considered smallholders with livestock, and they have a great opportunity to improve income and raise their sustenance through the development of the livestock chain [2]. One of the most important concerns of livestock smallholders is to get good quality rations of energy, protein, amino acids, minerals, and vitamins to ensure suitably high productivity of their animals. It is recognized that soybean meal is often used as material feed, as it has high contents of amino acid profiles and energy in livestock and poultry rations. Global production of soybean reached 366 million tons in 2016, and the United States has the highest rate of soybean production (117.2), followed by Brazil (96.3) and Argentina (58.8), according to FAOSTAT [3]. After oil is extracted from soybeans, the residuals are expressed as a soybean meal, and it is mainly used in poultry production systems and for other livestock animals as ingredients in their diet. Globally, there is little quantity of soybean meal for smallholders. Additionally, the high cost of feed concentration for livestock is progressive [1]. Consequently, to meet the nourishment requirements for livestock or poultry, alternative low-cost feed resources must be recognized [4].

Tropical and subtropical areas are characterized by raised ambient temperatures and water deficiencies, in addition to tropical soils, which suffer from a lack of nitrogen. Thus, production of protein-rich material in the diets of small animals either involves the input of nitrogen fertilizer to gramineous crops, or the use of legumes either as the source of the supplement itself or as part of a rotation. Here, we have focused on the use of legume crops as alternatives [5]. Based on the large diversity of legumes in humid and sub-humid areas, about 650 genera of legumes and 18,000 certain species have been identified [6]. The International Livestock Research Institute [7], the Centro Internacional de Agricultura Tropical [8], in addition to the Australian Tropical Crops and Forages Collection and the collection of CENARGEN-EMBRAPA, have collected and evaluated many of tropical forages and crops within gene banks.

This review paper aims to distinguish alternative resources of primary feed for poultry, and identifies the options for improving smallholder production of monogastric animals in the tropics in terms of their protein needs and forage supply.

2. Nutrient Utilization Chickens

Chickens have a simple stomach which is expressed as monogastric. On the contrary, ruminants have several parts to their stomachs, which are called complex stomachs. This function qualifies these animals to digest fiber. Although clear dissimilarities between digestive systems have been observed between birds and monogastric mammals, they have commensurate general feed digestion patterns paralleled with polygastrics. It is known that feed is digested by enzymes and acid in the stomach, and soluble constituents are absorbed mainly via the epithelial cells in the small intestine. Indigestible compounds, such as non-starch polysaccharides, proteins, and resistant starches subjected to Maillard reactions, as well as some fiber bound proteins and tannins, reach the ceca and cecum in poultry, where, together with endogenous secretions, they are fermented by the gut microflora. The end products of the fermentation in hindgut are short-chain fatty acids (SCFA), which are an equally important energy source for the microbiome. In chickens and ostriches, evidence has been obtained suggesting that SCFA can provide up to 8 to 75% of their energy requirements from fermentation in the ceca [9]. A small amount of microbial amino acids, which have been synthesized by the microbiome in the gut, can be soaked up in the intestines. Thus, stomach enzymes can digest feed protein to be absorbed in the small intestine. An animal's specific amino acid requirements should be available in the feed protein as amino acids. The ideal protein requirement for an animal depends on several factors such as type of production, stage of growth, product, season, and composition of body tissue, which need to be taken into account in order for it to be sufficient for maintenance and growth [10].

3. Production System Limitations in the Tropics

It is common for deficiency of essential amino acids to be present in smallholder systems characterized monogastric production, especially diets involving cereal grain, a blend of them (e.g., rice bran, rice, sorghum, ormaize) or cassava. Farmers often do not know or comprehend the nutritional value of these alternative feeds, nor do they know their animals' feed requirements. Besides, the nutritional quality of these alternatives may be low owing to fiber-bound nitrogen [11], and compounds such as tannins and trypsin inhibitors may be related to the inhibition of enzyme function or they may bind to proteins, diminishing their digestibility. The limitation in choices of feed in developing countries makes smallholders search for alternative specific feeds for their poultry, particularly those that increase productivity of poultry. The enrichment of low-protein diets with synthetic amino acids such as lysine, reduces Nexcretion and accelerates growth rates [4,12], and it is actually significant to compensate amino acid deficiency in poultry diets.

Application of this option in commercial production systems is obtainable, but it is rarely favorable or available for most smallholders. Thus, they avoid feeding animals with high protein diets, as the excess degrades to uric acid or urea for excretion. This phenomenon makes the animal lose a large amount of energy, and moreover it causes harmful effects on the environment [13]. Smallholder farms are seeking rapid growth rates for their chickens; however, with local forages this may be less obtainable and profitable.

4. Tropical Forages as a Protein Source

As a matter of choice, it is preferable to obtain feed from crop derivatives which are part of environmentally sustainable farming systems in the region. From this point of view, biomass productivity per unit of solar energy should be optimized, inputs of agro-chemicals reduced, and soil fertility and biodiversity sustained [4]. However, most of these requirements are scarcely met at the same time, so it has been suggested that tropical forages as feed for monogastric animals can play a role in improving the sustainability of animal production within farming systems through [14,15]:

(1). Increased production of biomass in environments where it is not suitable for other crops;
(2). Feed with high protein and amino acid profiles, particularly, sulfur amino acids, methionine, and lysine, which for monogastrics sufficiently balances the constraints of cereal proteins [leaf and grain];
(3). High levels of minerals and vitamins compared to conventional energy-based feed requirements.

5. Nutritional Value and Impact on Animal Performance

Tropical forage plants have shown to widely differ in crude protein content, and have almost reach 36% of dry matter (DM)in some forages, which is parallel to soybean grain. The plants analyzed for chickens are categorized by lowering the proportion of the sulphur-containing methionine and cysteine, when comparing the amino acid profiles to the model protein for layers. Both threonine and tryptophan levels in tropical forages seem to be well balanced, and the latter is within the desired range in half of the species analyzed.

Generally, green parts of tropical plants have higher levels of tryptophan compared to the seeds. This pattern of amino acid profiles does not need a huge amount of light, because poultry diets and plant species are frequently mixtures of numerous ingredients, which when combined, should integrate with each other to cover the nutritional requirements. Forages can have further positive effects when included in diets of monogastrics. Evidence has been provided that hens' fertility improved when their diet included 14% grass meal [16]. The inclusion of lucerne and grass meal in their diet declined the level of cholesterol in their eggs [17]. With regard to the nutritional value of feed, it has been proposed that feed influences not only the critical nutrients they contain, but also their digestibility, and hence their actual availability. Both dietary fiber and plant secondary compounds (with anti-nutritional factors or toxic) are the major factors which can strongly affect digestibility.

6. Anti-Nutritional Factors and Chemical Constraints

It is well-documented that plants consist of a variety of simple to extremely complex mixtures, many of which have been well-known and described. It seems that almost all of these constituents of plants have a defense function against abiotic and biotic stresses, and more than 1200 classes assist to protect against herbivores. The study implemented by Makkar [18] clearly showed that these compounds were not implicated in the plant primary biochemical passageways for cell reproduction and growth.

The most common major groups are alkaloids, polyphenols, saponins, cyanogenic glycosides, steroids, amino acids and toxic proteins, non-protein amino acids, phyto-hemaglutinins, oxalic acid and triterpenes [19], and were either toxic or acted as anti-nutritive factors (ANF). Anti-nutritive factors are defined as "substances generated in natural feed ingredients by the normal metabolism of (plant) species and (interacting) by different mechanisms, e.g., inactivation of some nutrients, interference with the digestive process or metabolic utilization of feed which exert effects contrary to optimum nutrition. Being an ANF is not an intrinsic characteristic of a compound but depends upon the digestive process of the ingesting animal" [20]. Consequently, plants that cause harmful effects to humans or other mammals may often be vastly toxic for fish, birds, and insects or other small animals [21]. The efficacy of leaves, pods, edible twigs of trees and shrubs as animal feed is in narrow usage because of the presence of ANFs. In general, ANFs are not harmful, but may cause toxicity during periods of shortage when animals consume large quantities of ANF-rich feed.

6.1. Polyphenolic Compounds

Polyphenols are a main group often interrelated with odor, taste, and color. Flavonoids (i.e., monomeric elements of condensed tannins), lignane, and cumarine are the major mediators. Condensed tannins (CT) are complex heat-stable phenolic constituents and are widespread in abundant plants, mainly shrub legumes such as *Gliricidia sepium* Jacq., *Leucaena leucocephala* Lam., *Acacia* species, and *Albizia falcataria* L. Proteins bind tannins side by side by H bonds and hydrophobic connections. These phenomena may be related to reduce the availability and digestibility of protein [12] and other nutrients such as fibers and starch. Another limiting factor is their astringent taste, which in many cases decreases palatability, thus the animal will not engorge on it.

6.2. Tannins

Tannins have molecular weight of more than 5 KD, and are water soluble. Tannins have the ability to bind with proteins and minerals. There are two different groups of tannins: condensed and hydrolysable tannins. Grain legumes, seeds, and forages have a wide distribution of condensed tannins. Livestock are sensitive to this type of tannin (i.e., condensed), while goats are more able to adapt to high amounts of tannins. Cattle and sheep are sensitive to condensed tannins, while goats are more resistant [22]. Tannins negatively impact digestive processes, though they may bind with endogenous enzymes such as of trypsin, amylase chemotrypsin, and lipase, and have the ability to bind with vitamin B_{12}.Additionally, it has been reported that they can cause damage to intestinal cells, and interfere with iron absorption, and tannins may possibly generate a toxic effect [23].Tannins cause reductions in protein digestibility in humans and animals, inhibit digestive enzymes, and increase nitrogen in the feces. The influence of tannins on animal performance have been studies [24], they are recognized to be responsible for declines in growth rates, feed intake, and feed efficiency by binding with proteins and reducing protein digestibility. If tannin levels in the diet become high, microbial enzyme activities together with cellulose and intestinal digestion may be depressed.

6.3. Lectins

Lectins are glycoproteins commonly scattered in grain legumes and certain oil seeds (including soybeans) which possess an affinity for specific sugar molecules, and are categorized by their capability to link with receptors of carbohydrate membranes [25]. Lectins are categorized as growth inhibitory (*Glycine max* L., *Phaseolus lunatus* L., *Amaranthus cruentus* L., *Dolichos biflorus* L.), toxic (*Canavalia ensiformis* L., *Phaseolus vulgaris* L.) [26], or fundamentally beneficial or non-toxic (seeds of *Vigna umbellate* Thunb., *Vigna subterranean* L., and *Vigna unguiculate* L.) [27]. The efficacy of lectins either toxic or non-toxic is dependent on the developmental stage and part of the plant. The toxic consequences of lectins is that they usually coagulate the erythrocytes, and thus may depress the immune system [12] or interrupt nutrient absorption in the small intestine by shedding the brush boundary membrane of the intestinal absorptive cells [18]. Lectins have the ability to immediately connect with the epithelial mucosa of the intestines, interrelating the enterocytes [25], and interfering with the absorption and transportation of 0.01% free gossypol within some low gossypol cotton levels (mainly carbohydrates) during ingestion, causing epithelial lesions within the intestine. Some types of lectins are ordinarily reported as being unstable, because their stability differs among plants, many lectins are resistant to hydrolases by dry thermal and require the existence of humidity for whole destruction [25].

Three physiological reactions can be observed when used by extra-sensitive individuals. Firstly, they can cause nutrition deficiencies through severe intestinal damage and reduced digestion. Secondly, they can induce IgM and IgG antibodies causing food sensitiveness and other immune responses [10,25]. Finally, they can link to erythrocytes, concurrently with immune factors, causing anemia and hemagglutination. Generally, lectins can modify host resistance to infection, causing failure to thrive and can even lead to death in animals.

6.4. Phytic Acid

Phytic acid is one of main concerns for nutrition and health management in humans [28]. At physiological pH, the phytate molecule is negatively charged, and binds to nutritionally indispensable divalent cations, such as calcium, iron, magnesium, and zinc. These patterns of phytase are insoluble complexes, this mean trace elements are unobtainable for absorption [29]. The levels of phytic acid present were 0.624 to 1.0% (mean 0.862%). The suggestion has been made by Egli et al. [30] that there are higher levels of phytate in millet and pigeon pea. On the other hand, the inconsistencies may be expected, as according to Reddy et al. [31], phytate values differs in cereals and legumes depending on soil type, diversity, and cultivate type.

6.5. Saponins

Saponins can originate in numerous food plants such as *Amaranthus hypochondriacus* L., *Atriplex hortensis* L., *Chenopodium quinoa* Willd. [32], *Brachiaria brizantha* Hochst., *B. decumbens* Sm. [29], and *Medicago sativa* L. They are recognized as heat-stable, form a soapy froth when interacting with water, and can adjust cell wall permeability, leading to hemolysis and to photosensitization [29]. Saponins were deemed as toxic compounds, since they appeared to be exceedingly toxic to fish and endothermic animals, and many of them influenced strong hemolytic activity. The high levels of saponins in dietary plants may create an acidic taste and astringency. Feed intake or consumption can be limited by the harsh taste of saponin. In the last decades, saponins were documented as anti-nutrient ingredients, due to their reverse influences, such as for growth declines and decrease in food consumption due to the bitterness and throat-irritating activity of saponins. Furthermore, saponins were found to shrink the bioavailability of nutrients and inhibit digestive enzyme activities (trypsin and chymotrypsin) [25] consequently reducing protein digestibility.

6.6. Toxic Amino Acids

Non-protein amino acids are established in many plants as unconjugated forms, mainly in legumes, with the highest levels in the seeds. For instance, *Leucaena leucocephala* encloses mimosine, which binds totopyridoxalphosphate and minerals [18], leading to declines in the activity of the enzymes that involve them as co-factors, and eventually suppressing metabolic passageways. A study by Sastry and Rajendra [33] showed that the teratogenicity effects of non-protein amino acids can impede the reproductive process, leading to loss of wool and hair, and even to death.

Most legumes seeds such as the *Canavalia* species, *Medicago sativa* [34], and *Vicia ervilia* [35] consist of canavanine. The inhibition effect of canavanine on the development of insects is due to the competition for the irreplaceable amino acid arginine. Poultry are much more vulnerable to canavanine than mammals due to the antibiosis of arginine with lysine in birds. This disruption may be lead to autoimmune-like infections affecting the skin and kidneys. There are various plants which have been identified for their toxic effects such as L-DOPA, which is currently in the *Mucuna* species, and is cytotoxic [36] leading to haemolytic anaemia. Lathyrogenic amino acids, like BCNA (β-cyanoalanine), DABA (α,γ-diaminobutyric acid), ODAP(β-*N*-oxalyl-α,β-diaminopropionic acid), and BAPN (β-aminopropionitrile) are neurotoxic and occur in the *Lathyrus* species and *Vicia sativa* [37]. Canavanine is highly toxic and present in *Canavalia ensiformis* seeds, and is a potent insecticide [38].

6.7. More ANFs

Increasing attention has been paid to identifying other anti-nutritional factors and to stopping their negative impacts on mammals, birds, and other animals. It has been found that some proteins are heat-stable antigenics and heat-labile cyanogens proteins, amongst others. Cyanogenic glycosides, such as hydrocyanic acid, linamarin, and lotaustralin, which are commonly present in cassava

(*Manihot esculenta*) and also in *Phaseolus*, *Acacia*, and *Psophocarpus*, decrease performance and cause cyanide intoxication. If, however, "the diet is adequately supplemented with proteins, particularly with sulfur-containing amino acids, and iodine", it is safe to feed to livestock [39].

7. Processes to Improve Nutritional Value of Forages

Forages and grain legumes which contain some ANFs in their meal and seeds, and which decline the availability of nutrients [40], surely have adverse influences on animal performance and human nutrition. As pointed out earlier, these ANFs are descried above such as tannins, phenols, toxic amino acids, phytic acids, lectins, trypsin inhibitors, and cyanogenic glycosides. It was found that those ANFs in low concentration [40,41] may reduce the nutritional quality of forages and grain legumes, even if they are used for feeding animals. As a result, those ANFs need to be removed or reduced, and hence the nutritional values and bioavailability of forages and grain legumes will be improved. Numerous management procedures such as germination, fermentation, thermal management (i.e., boiling, autoclaving, and cooking), soaking, and de-hulling procedures have been useful to decrease or eliminate the concentration of these compounds from forages and grain legumes [41,42]. In general, these processing techniques superficially enhance not only the palatability and flavor of legumes, but also increase the bioavailability of nutrients and protein digestibility by destroying the ANFs [43].

7.1. Heat Treatments

Heat remediation encompasses oven and sun-drying, autoclaving, roasting, and boiling, which ordinarily decreases the content of heat-labile ANFs. It has been proposed that sun drying cassava leaves (*Manihot esculenta*) reduces hydrogen cyanide from 20 mg/kg in the leaf meal, compared with 190 mg/kg in the meal of fresh leaves. Montilla et al. [44] reported that feeding laying hens with sun-dried *Gliricidia sepium* resulted in better performance than those fed with the oven-dried legumes, but the effects of type of drying are not clear on the feed quality. Thermal management significantly reduced the trypsin-inhibitory activity of seeds of *Cajanus cajan* [45,46], *Glycine max* [47], *Psophocarpus tetragonolobus* [48], and *Arachis hypogaea* [49].

In this context, haemagglutinin can be altogether discarded by roasting. Both thermal management, autoclaving or roasting seeds of *Phaseolus vulgaris* decreased its tannin content by 30–40%, and this was minimized by autoclaving [50] and de-hulling by dry heat [51], which expressively reduced the content of L-DOPA in seeds of *Mucuna pruriens* L. Recently, to increase nutritive values of guava seeds, it was shown that they must be roasted at 150 °C for 10 min [5]. Phytic acid and tannin content were significant reduced by roasting guava seeds [5], and the highest declines were affected by roasting at 150 °C for 20 min (520.1 and 61.36%, respectively). Thermal processes destroy the naturally occurring ANFs and is implemented in order to decline anti-nutrients in plant-based foods, thus enhancing the nutritive value of isolated protein [5,52].

7.2. Soaking

Several approaches have been implemented to reduce the phytic acid level in feed, especially cereal which becomes poor in quality due to such anti-nutrients. One of these approaches is to soak the grains. Vijayakumari et al. [53] revealed that treatment by soaking grains in water for 18 h decreased the phytate level of *Mucuna monosperma* by up to one-third of the original content. Soaking in water at room temperature overnight has been linked to a 36% reduction in phytic acid in kidney beans [41]. The loss in phytates during soaking of the tested samples may be due to leaching of phytate ions into the soaking water under the influence of a concentration of a gradient (difference in chemical potential), which governs the rate of diffusion. Soaking in a mixed-salt solution (0.75% citric acid + 0.5% Na_2CO_3 + 1.5% $NaHCO_3$) led to a significant reduction in anti-nutritional factors such as tannins, phytase, orthodihydroxy phenols, and phenols in pigeon pea hybrids [40].

7.3. Pelleting

Nutritive value and voluntary feed intake can be determined by feeding texture. The digestibility of protein and starch in chicks as well as apparent metabolizable energy values of *Vicia faba* [54] has been increased by feed pelleting. Pelleting processes of three herbaceous legumes *Lablab purpureus* L., *Calopogonium mucunoides* Desv., and *Mucuna pruriens* [55] reduced the anti-nutritional factors and fiber fraction contents.

7.4. Hulling

Hulling is a simple method for removing ANFs such as tannins, which are mostly focused in the seed coat [56]. De-hulling declines the tannin level from 22.0 to 5.3 mg/100 g in *Phaseolus vulgaris* seeds. This technique might be an opportunity for farmers, such as coffee growers, who have other uses for a de-hulling mill. Other opportunities for small-scale milling are explained by Jonsson et al. [57].

7.5. Germination

Germination activates endogenous enzymes, which attack most anti-nutrients and enhances the nutritional value of grains [58]. Germination triggers endogenous enzymes and improves the nutritional value of grains through an onslaught against most of anti-nutrients [58]. Nevertheless, germination can be difficult to manage as seedlings tend to share molds and are simply spoiled. Feeding of germinated seeds must occur immediately or they should be dried, otherwise the cost will rise. Germination diminishes esphytic acid, trypsin inhibitors, certain lectins, and galactosidesin *Glycine max* [59], and compared to raw seeds, improves the in vitro starch digestibility of *Vigna radiate*, *Vigna unguiculata*, and *Cicer arietinum*, similar to the enhancements found through fermentation and pressure cooking [60].

Soaking followed by germination, decreased the trypsin inhibitory activity of *Cajanus cajan* and *Phaseolus vulgaris* seeds by 26–53%, condensed tannins by 14–36%, and phytic acid by 41–53%, while the invitro protein digestibility, and thiamine and vitamin C levels were augmented significantly, in addition to an alteration in the mineral arrangement [61]. Germination of *Lupinus albus* and *Lupinus luteus* for 96 and 120 h led to peak phytase activity, respectively [58].

7.6. Fermentation

Fermentation is a process, which occurs under anaerobic conditions by microbes, which have the capacity to ferment carbohydrates into organic acids and/or alcohols. Ensiling is an appropriate fermentation process for both whole crop forage and grains. The main product produced during fermentation is lactic acid, and the diminishα-amylase and trypsin inhibitor activity and tannins in *Sphenostylis stenocarpa* seeds were reduced by up to 100%, which is dissimilar to cooking [62]. It also reduced alpha-galactosides and cyanogenic glycosides by 85%, compared with only 10–20%when cooked. The increasing in vitro protein digestibility decreased minerals and affected various vitamin profiles through fermentation of *Phaseolus vulgaris* grains and grain meal [63], reducing α-galactosides, trypsin inhibitory activity and tannin content in seed meal. Fermenting *Mucuna* to tempera in traditional Indonesian food hydrolyzes 33% of phytic acid and reduces L-DOPA by 70% [64]. Solid state fermentation of *Cicer arietinum* gives higher digestibility of protein and lysine, and decreases tannin levels up to 13% and phytic acid concentration by 10%in raw chickpea flour [65].

Good fermentation management [66], which is achievable for smallholders, is required to avoid notable losses of tryptophan and lysine [67], and can even benefit from increased lysine content. Further information on ensiling and silo types is available through the Food and Agriculture Organization of the United Nations (FAO) [4] and Heinritz et al. [68]. All over the world, sorghum is considered a main cereal, and is drought resistant. It has been reported that it is an essential and principle source of protein, energy, and minerals in diets for both animals and humankind in tropical and subtropical areas [4]. Previous studies have shown that sorghum contains anti-nutritional factors like tannin, phytic acid, cyanogenicglucoside, oxalate, and trypsin inhibitor [69,70]. For these reasons, it is categorized as having low nutritional values. Fermentation of sorghum diminished oxalate, phytate, and tannins by 49.1%, 40%, and 16.12%, respectively [70].

8. Non-Conventional Ingredients as a Protein Source

Several reports have highlighted the proximate analyses of many non-conventional protein sources which can be used in poultry production (Table 1). Generally, average daily protein consumption in rural, resource-poor areas is less than 9 g of animal protein (capita/day), compared to over 60 g (person/day) as reported by FAO recommendations for daily protein consumption [71,72]. At the family level, alternative sources of protein for smallholders in rural areas must be provided, as they areoften resource-poor areas, and it is difficult to access commercial diets in these areas.

Table 1. The proximate chemical analysis (%) of some alternative protein sources for poultry feeding.

Items	Dry Matter	Crude Protein	Crude Fiber	Ether Extract	Ca	P	Reference
Moringa leaves	80	29.7	22.5	4.38	2.78	0.26	[73]
Moringa leaves	94	27.2	40	17.1	-	-	[74]
Leuceana leucocephala leaves	88	25.9	40	-	2.36	0.23	[75]
Neem (*Azadirachta indica*) leaves	92	20.68	16.6	4.13	-	-	[76]
Cassava (*Manihot escsulenta*) leaves	95.5	26.3	19.7	7.3	-	-	[76]
Gliricidia sepium	89.3	22.9	17.15	8.8	-	-	[77]
Pawpaw (*Carica papaya*) leaves	93.2	26.3	14.8	-	3.2	-	[78]
Cabbage leaves	87.9	14	35	2.0	3.2	-	[79]
Ipomea batata leaves meal	88.7	25.66	12.76	3.06	-	-	[80]

As cited before, in the developing and developed economies of the world, non-ruminant animal production, especially the poultry industry, plays an essential role as a principal source of animal protein including both meat and eggs. The feed cost in poultry production represents around 70%of the total cost of production. Therefore, the profitability of this industry depends largely on the quality and economics of feed production [81,82]. Expansion of the industry will therefore mainly be determined by the sufficient availability and affordability of good quality feed for birds and subsequently good poultry products, such as eggs and meats for consumers [83]. For intensive enterprise, inadequacies in nutrient supply often leads to a drop in egg production, as well as declines in growth performance on the part of broilers for meat production.

9. Application of Alternative Resources of Protein for Chickens

With increasing demand for animal protein and the development of poultry industries in all regions of the world, especially regions with extreme poverty, it is necessary to save alternative protein resources for smaller breeds of chicken. Different sources of alternative feed available for feeding chickens will raise the standard of living for small breeders. Current animal industries faceconflicting requests to produce large volumes of high-quality food at low prices. Now, nutritional elucidations have come to be even more imperative to disband such instances, and this can be accomplished by taking full advantage of the alternative feed resources, such as tropical plants, in poultry diets. Furthermore, one of the ways of reducing the cost of animal production in developing countries, and therefore making protein available to people at cheaper prices, is by using agricultural by-products and tropical plants, which are not directly used by humans as food to feed livestock [84]. As with other vegetables and fruits, great amounts of waste are produced through packaging, harvest, and processing. It has been estimated that about 30–50% of total production is discarded as waste, which consists mostly of leaves or seeds [85].

As waste production increases, there is an affiliated increase in the quantity of residues produced. These wastes or residues are often leached into the environment where they cause major negative environmental impacts (e.g., nitrate percolating into water sources). The inclusion of diets with 2.5 g/kg neem (*Azadirachta indica*) leaf meal (AILM) to broiler chicken diets improved blood indices without any deleterious effects when compared to birds fed the control diet [86]. In addition, they suggest that the dietary supplementation of *Azadirachta indica* leaf meal may lead to the expansion of low-cholesterol chicken meat. Olabode and Okelola [87] concluded that supplementing neem leaf meal (AILM) to laying birds by up to 8% did not have any negative influences on egg quality, serum biochemical indices, and the final consumer product.

Compared to conventional commercial feeds, *Moringa oleifera* meal (MOLM) as a protein supplement in broiler diets at the 25% inclusion level showed similar results in weight and growth rates [88]. Pawpaw (*Carica papaya*) leaf meal (CPLM) was reportedly incorporated at the 2% level in the diet of finishing broilers. A significant improvement of 14% in growth performance was observed compared to the birds on the control diet, and the carcasses and organoleptic indices of the birds were equally recorded with positive corresponding economic returns as observed by the significantly lower feed cost/kg gain [89]. Ayssiwede et al. [90] found that the inclusion of *Leucaena leucocephala* leaves meal (LLLM) in the diet at the 21% level had no significant adverse effect on feed intake, average daily weight gain, feed conversion ratio, and nutrients utilization (except ether extract) of adult indigenous Senegal chickens, but significantly ($p < 0.05$) improved the crude protein and metabolizable energy utilization in birds fed at the 7% inclusion level. This improvement may be attributed to the nutritional quality of protein of LLLM, and was probably due to their higher percentage of sulfur amino acids. As previously noted, because of the high price of protein ingredients such as fish meal, and soybean meal, using LLLM as an alternative protein source for feeding chickens could improve small holders poultry nutrition and productivity [90], and allow for alow cost of production and enhancement of their incomes.

On the other hand, at a 5% inclusion level, cassava (*Manihotesculenta*) leafmeal (MELM) in broiler finisher diets was reported to confer a significant ($p < 0.05$) increase in feed intake, body weight gain, feed conversion ratio, and organ weight of birds without any deleterious effects [91] over those with 10 and 15% inclusion levels.

Kagya-Agyemang et al. [92] recommended an inclusion level of not more than 5% *Gliricidia sepium* leaf meal (GSLM) in broiler diets as he recorded a better carcass dressing percentage at this level, while a progressive decrease in carcass dressing percentage was observed at higher inclusion rates, with a 15% inclusion level having a significantly ($p < 0.05$) lower carcass dressing percentage. However, there was a corresponding increase in the intensity of yellow pigmentation of the skin, shanks, feet, and beaks of the birds. This impairment might be due to increasing fiber content and anti-nutritional factors present in Gliricidia leaf meal (GLM). These constituent include alkaloids, tannins, and nitrates that can decrease the palatability of diets with GSLM [92].

Cabbage leaves are categorized by high crude protein (17%) and mineral levels, especially Ca, S, and Mn. However, some of these wastes or residuals might contain anti-nutritional factors, which may reduce animal growth performance [93].

As mentioned above, several anti-nutritional factors have been described as treatments for the alleviation of this situation. Mustafa and Baurhoo [79] evaluated the replacement of soybean meal with dried cabbage leaf residue (DCR) on broiler growth performance and nutrient digestibility. The results concluded that inclusion of dietary DCR up to 9% of the diet had no adverse influences on broiler performance. Sugar beet (*Beta vulgaris*) is a rich source of protein, carbohydrates, and has high levels of essential vitamins and micro and macro elements. Significant increases of live weight in growing geese was shown with 5–10% sugar beet pulp.

10. Conclusions

Smallholders in poultry production systems have some constraints in obtaining commercial feed. However, in tropical and subtropical areas there are large numbers of diverse forage species as protein options for their poultry, which are locally available. There is a multiplicity of options related to agricultural suitability and nutrients, and yields contents, and nutritional obstacles may be relatively or abundantly overcome by suitable processing techniques. At the farm level, successes of worthy economic returns can be achieved through ecological conditions such as individual decisions, technical and labor requirements, and already-available feed materials. Knowledge of the characteristics of nutrition, agronomics, and secondary metabolites compounds of forage species allows small breeders of poultry to make better choices for feeding and raising their poultry in rural, resource-poor areas. Creative approaches are required to appropriate forage-based feed solutions for poultry into present smallholder systems and further systematic investigation is required to describe the actual value of some less-widespread forage species for various animal species.

Author Contributions: Conceptualization, M.E.A.E.-H.; Writing-Original Draft Preparation, S.A.A. and M.R.; Writing-Review & Editing, M.E.A.E.-H.; Visualization, S.A.A.; Administration, M.E.A.E.-H.

Funding: This research received no external funding.

Acknowledgments: Authors thank their respective universities for their support.

Conflicts of Interest: The authors declare no conflict of interest.

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