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Review Article

Utilization of Amaranth as an Alternative Livestock Feed Ingredient

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Abstract

The livestock sector plays a very vital role in improving the food security status of people in the world. Maize and soybean are traditionally the main energy and protein sources in livestock diets respectively. However with the consideration that the livestock sector is growing as well as the world's population, an alternative ingredient or supplement to maize and/or soybean can be quite helpful and has to be taken into consideration. For the greater part in livestock production feed accounts for the largest single cost of about 60%-80% of the total cost and maize and soybean prices are on the rise. Since the prices are on the rise for these convectional ingredients, it implies that for farmers, in particular those in developing countries, that maize and soybean is going to be less accessible. This makes the prospects of utilizing amaranth as an alternative energy and/or protein supplement feasible. Considering its availability in some of these areas and its ease of propagation. This review article will detail the options to reconsider amaranth as an alternative suppliment to maize or soybean in animal feed.

Introduction

In general, the semi-intensive system ought to offer all the nutrients that livestock require through feed. Therefore there is need to improve productivity in the semi intensive system employed by the smallholder livestock producer which requires a steady supply of low cost feed [1*]. Kaneko et al.* [2], suggested that a possible way to reduce livestock feed costs is by replacing, supplementing, or finding alternatives to conventional feed ingredients with cheaper, efficient and locally available feed ingredients. Smallholder livestock producers need to use local feedstuffs, on farm rationing criteria's in livestock diets in a way to reduce costs and bring them into the mainstream of livestock production [3]. Efficient rations for farm animals can be created from local sources [4]. *Glatz et al.* [5] reported that there are four feeding tactics that livestock farmers can adopt depending on the feed resources accessible in the region. These tactics are (a) 'whole diet formulation using locally available feedstuffs; (b) free choice selection of feedstuffs by the animals; (c) mixing of a concentrated feed with feedstuffs found locally and (d) dilution of a commercial formulated feed with food products found in the local environment' [5]. The implementation of such feeding structures can be accepted as resolutions for ensuring the feasibility of livestock production. Particularly in developing countries that may find it difficult to meet the increasing costs of conventional feed ingredients and limited supply. Hence, smallholder operations can be substantially improved if feeding systems based at least in part on locally available ingredients can be created as an option to imported absolute feed or feed ingredients [2, 3, 5]. There are 60-70 species (spp) of amaranth of which 40 of them are natively considered to be from the Americans [6]. Amaranth spp are adapted to growing in temperate and tropical climates and are used mostly as a vegetable or grain. Consequently, amaranth species have become an essential crop which are now being cultivated in several countries and regions of the world including Africa, India, South America, the United States and China, due to their high adaptability to temperate and tropical regions [7,8]. They are considered a pseudo-cereal with high nutritional value, containing a higher protein content than rice, wheat, and maize, which are the three most important staple cereals, that contribute with more than half of the total protein at global level [6, 9]. Amaranth spp are highly nutritious, containing minerals and vitamins. In addition, they have a higher lysine content, dietary fibre, important calcium content level and iron than convectional grains (oats, barley, wheat, rice, sorghum and maize) [10,11]. They are considered a multiuse grain with a high nutrient quality and in a lot of countries used as a forage, grain or silage crop for a lot of animals, as well as chickens, cattle, rabbits and pigs [12]. However, unlike the grain, forage amaranth has received considerably less attention in research. Despite the fact that according to *Alegbejo* [11], the use of the plant as forage for livestock has a great agronomic potential and a variety of possible uses. Additionally, the shoots, leaves, grains and tender stems are ingested as pot herb in soups or sauces, cooked with a main dish, with other vegetables or by itself by the locals [7, 10, 11].

According to a study by *Orona-Tamayo & Paredes-Lopez* [8], relative to the amaranth specie, total CP ranges from 13.2-18.4%, lysine (3.2-13.1g/100g protein) and sulphur amino acids (AA) (methionine and cysteine in the ranges of 0.6-2.4 and 2.0-3.8g/100g protein, respectively). When considering amaranth's crude protein (CP) content range of 13.2-18.4%, it is quite comparable to sunflower meal (14.0-38.1 CP), soybean hulls (10.5-19.2 CP), oats (4.1-13.3%) and cotton seeds (18.0-41.3%) [13, 14]. However, the use of raw amaranth grain is limited due to the presence of heat labile non-nutritive factors (tannins, lectins, saponins and trypsin inhibitors) leading to the grain being categorized as growth inhibitory [15]. The known non-nutritional factors in the grain limit its utilization and acceptability in poultry diets and other monogastric feed. Furthermore, the plant may also contain concentrations of saponins, nitrates, oxalic acid and antitrypsin proteins that are a little too high which could present a health hazard in ruminants [12]. However, with application of proper processing techniques on the grains and plant will result in the elimination or reduction of the quantities of these non-nutritive factors. The exploitation of feedstuffs such as amaranth demands having a very good sound knowledge of the appropriate inclusion levels in livestock diets [16]. Notwithstanding, the CP content, lysine value and content of essential sulphur containing AA (cysteine and methionine) in amaranth grain and plant parts suggest that this plant can be used to an advantage at low inclusion levels in livestock diets and reduce livestock feed costs.

Alternatives or Supplementary Feedstuffs in Livestock Feed

Feed is the most crucial input in livestock production, when looking at costs, and the availability of feeds with high quality, formulated at least cost is important for the growth of the livestock sector. For the entire production feed constitutes about 70% and of the total cost, up to 95% is required to meet the energy and protein requirements [17]. The livestock sector is very dynamic globally and in countries that are still in their developing stages, it is progressing in ways to respond to the rapidly increasing need for livestock products. The forecast for the future shows that production will progressively be affected by the competition for natural resources, in particular water and land, competition between feed and food, and by the need to operate in a carbon-constrained economy [18-20]. Major developments in animal health, nutrition and breeding will continue to contribute to the increasing potential for livestock production, more efficiency and genetic gains [19]. About 30 per cent of the earth's ice-free terrestrial surface area is occupied by livestock systems and constitute a noteworthy global asset with a value estimated approximately to be $1.4 trillion [18]. As an industry it is increasingly organized in long market chains that employ at least approximately 1.3 billion persons worldwide and also directly supports the livelihoods of at least 600 million poor smallholder agrarians in developing communities [20]. The keeping of livestock is a significant risk reduction scheme for communities at risk, and livestock are vital providers of traction and nutrients for the propagation of crops in smallholder systems. At present, the production of livestock is one of the fastest growing agricultural subsectors in developing countries [18, 20, 21].

Evidence from various studies in other parts of Africa and other places of the world note that wild fruits and plants provide a significant component of the diet, predominantly for children. Wild fruits and plants contribute significantly to diet quality rather than quantity [8, 10, 20]. An additional key characteristic of some wild plants and fruits is their storage capacity. Even though there is little detailed data on the yields obtainable from wild plants and fruit trees, it is plausible that due to their high adaptability to variable climatic conditions and particularly drought, their produce and products have an exceptionally significant purpose in periods of drought-induced nutritional stress [7, 12, 19, 20]. Consequently, even though yields may be comparatively low compared to exotic fruits and plants, the ability of indigenous plants and trees to endure harsh environments is of over-riding significance, and a key factor in their utilization and protection by agriculturalists [18]. Other studies have also noted that seed oilcakes and meals of tropical oilseeds can be utilized as low cost protein sources in livestock feed [22-24]. [16, 25] postulated that a lot of research have been done on the incorporation of seed meals, leaf meals and seed oilcakes of several plants and fruits in livestock diets aimed at reducing the fluctuating and at times escalated costs of the commonly used commodities as ingredients in animal diets (Figure 1). In livestock feeding at most protein ingredients and at times energy feedstuffs used at times become too expensive, as their prices fluctuate accordingly following their production, supply and then demand trends, resulting in an increasing consciousness in the need for use of alternative livestock diets feedstuffs [26]. Taking into account that seed cakes, oilseed oil extraction process by-products, and other plants being for the most part discarded or not recognised for their potential nonetheless their plausible value in livestock feed [27]. The utilization of non-conventional feedstuffs in particular when they have so much great potential to promote a shift to other feedstuffs commonly used and edible to humans, but readily available can effect a reduction of livestock feed costs and maximize production returns [28]. To date, various plants and fruits have been researched on and a lot of them were noted to hold aromatic properties which have a lot of influence on the growth, feed intake, nutrient digestibility and meat quality in livestock [29, 30]. Figure 1, below represents some data on the fluctuation of prices of the commonly used commodities as feed ingredients in livestock feed.

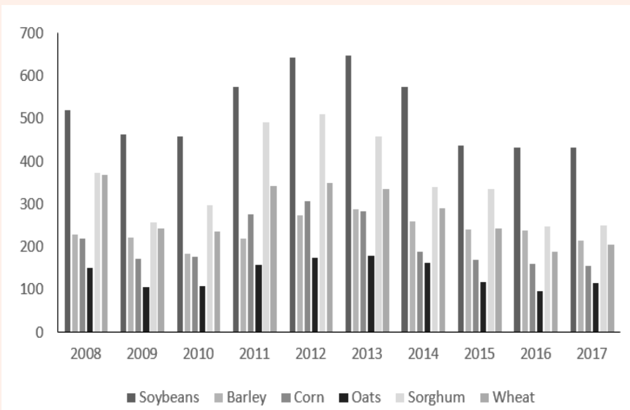

Figure 1: Trends in the prices of the most commonly used commodities as livestock feed ingredients from 2008 -2017. These prices are in USD per metric tonne. Adapted from: USDA (2018).

Potential Use of Amaranth in Animal Nutrition

At present key staple foods crop production are currently not able to meet food requirements on a global scale as a result of the increasing and relatively high population growth rate in most developing countries globally [21]. The replacement of the existing pressure on these key food crops requires an urgent need to search for other alternative unconventional foods with the potential to substitute and fulfill the increasing food demand for these crops [31, 32]. At the some time easing the pressure on the competition for convectional food crops between man and livestock. Since most of these crop foods are produced for both man and livestock, as they are also used as ingredients in livestock feed. This results in an increased interest for amaranth due to the fact that it has a great potential due to its phenotypic plasticity, genetic diversity, and its extreme adaptability to adverse propagation conditions, its resisting ability to drought and heat, not having major disease problems, and it being among the easiest of alternative crops to propagate in agriculturally marginal lands [7,11]. Species of *Amaranthus* distributed all over the globe in subtropical, temperate and tropical climate zones are about 400 [7]. As a result of its defined agricultural benefits, versatile usage and unique nutritional properties, grain amaranth (*Amaranthus spp.*) has gained more consideration way back the 1970s when it was re-discovered. It is a multi-purpose crop that can supply tasty leafy vegetables and grains of high nutritional value as human food and livestock feed, and in addition, due to its eye-catching inflorescence coloration, some cultivate amaranth as an ornamental plant [15]. The utilization of alternative food crops would result in product competitiveness, tradition, rich nutritional value, special quality and locality [10, 32]. Table 1, shows the nutrient composition of Amaranth grain relative to other grown convectional food and as feed crops. Taking into account its ability to grow under varied agro climatic and soil conditions, and its significant nutritional and medicinal properties. It has been emphasized in studies that its use as a grain and vegetable crop can be a cheap alternative substitute, rich source of nutrient and protein for deprived communities in developing countries [7, 31]. Relative to other grains it is quite small, extensive research has been done on amaranth and nowadays an astonishingly big volume of literature is now available and exists, in particular on its nutritional properties, production, crop breeding, and processing methods, commercialization and on the development of new amaranth products [10].

Table 1: Grain amaranth comparison to most of the commonly used convectional feed ingredients in livestock feed (g/kg DM). aAmaranth=Uncooked amaranth grain, bSoybean=raw (non-treated) soybean seeds, cCotton=whole non-processed cotton seeds, dSunflower = untreated non-dehulled sunflower seeds. The *protein content values were measured at (N*25). Source: Rastogi & Shukla [7] and CVB Feed Table [14].

Components	[a]Amaranth	Maize	Oats	[b]Soybean	[c]Cotton	[d]Sunflower
*Protein	145	102	76	363	207	140
Strach	627	401	649	6	19	16
Fat	102	40	36	196	192	291
Sugar	31	10	13	70	29	33
Dietary Fiber	88	106	20	58	236	285

Amaranth species (*Amaranthus spp*) are an exceedingly popular group of vegetables that have their place to diverse species, i.e. *Amaranthus hypochondriacus* and *Amaranthus cruentus* are the only grain type, whereas the rest of the species are the vegetable type [10]. Both *Amaranthus* seeds and leaves contain protein of a remarkably high quality. Amaranth grain has a higher protein content than most other food and feed cereal grains and also has a considerably higher content of lysine, which mostly is the limiting amino acid in cereals like wheat, maize and rice (Table 2) [11]. Looking at nutrient composition a seed grain of amaranth on average is composed of about 13.1-21.0% Crude Protein (CP); 5.6-10.9% Crude Fat (CF); 48-69% starch and 2.5-4.4% ash (Table 1) [7, 8, 10, 11]. Protein content in the grain ranges from 14.5-15.1% CP and for the leaf about 14.3g/kg with average CP at 12.4g/kg [7, 11]. As shown in Table 2, amaranth is rich in vital amino acids (AAs), suggesting that it is a pseudo-cereal which can be utilized as an alternative feedstuff to nutrient cereals in food and feed [7].

Growth Promoting Efficacy of Amaranth

Various literature has noted that amaranth can be used in various ways, as fresh and as a grain, ensiled or dried forage. Nevertheless some species of forage amaranth, as a result of the presence of particular anti-nutritional elements [33-35], may perhaps not be quite suitable as feed for livestock. However, with the application of an appropriate processing technique before use in feed it can be acceptable for monogastric and ruminant animals [12]. As postulated by *Peiretti* [12], cattle fed with ensiled green amaranth exhibited a lower level of dry matter intake relative to cattle fed an amaranth diet that was pelleted (Table 3). Supporting the need for processing before amaranth grain and/or leaf meal use. [12, 33, 34] all proved that, amaranth have superior nutritional quality to most common forage and cereals crops and also have a more pronounced proportion of rumen undegradable protein (RDP) relative to other common forages, the likes of Lucerne (Table 3). A study by *Alfaro* [36], and others noted that amaranth can also be considered as an alternative nutrient substitute for conventional rabbit diets and its vegetative parts could be utilized also in rabbit feeding, as a result of its chemical characteristics and high yield (Table 3). In an attempt to evaluate amaranth's feed efficiency in growing rabbits *Alfaro* [36], conducted a study with diets containing graded levels of increasing dehydrated stalks and leaves of *Amaranthus hypochondriacus* content at; 0, 15, 30, 45 and 60%, of 17.8% CP and 12.4% CF contents replacing equivalent quantities of Lucerne leaf meal of 22.0% CP and 23.3% CF contents. The results of the study propounded that the leaf meal from amaranth could efficiently replace the leaf meal of Lucerne by up to 15% in the diet, with no adverse effects on the feed intake, weight gain, carcass weights, feed efficiency or serum proteins.

Table 2: Amino Acid content (g/16 g N) for grain amaranth relative to other commonly used convectional animal feed ingredients. [a]Amaranth=Uncooked amaranth grain, [b]Soybean=raw (non-treated) soybean seeds, [c]Cotton=whole non-processed cotton seeds, [d]Sunflower=untreated non-dehulled sunflower seeds. Source: Rastogi & Shukla [7] and CVB Feed Table [14].

Components	[a]Amaranth	Maize	Oats	[b]Soybean	[c]Cotton	[d]Sunflower
Crude protein	145	76	102	363	207	140
Lysine	5.19	2.2	4.2	22.5	8.5	4.9
Methionine	2.17	1.6	1.7	5.1	3.3	3.1
Cysteine	2.12	1.7	3.1	5.4	3.5	2.4
Threonine	3.31	2.7	3.6	14.2	6.6	5.2
Tryptophan	1.31	0.5	1.2	4.7	2.5	1.7
Isoleucine	3.41	2.6	3.8	16.7	6.4	5.7
Arginine	8.65	3.6	6.6	26.9	22.1	11.3
Phenyalamine	3.66	3.7	4.9	18.5	10.8	6.4
Histidine	2.38	2.3	2.2	9.8	5.6	3.5
Leucine	5.15	9.2	7.5	28	12.2	8.8
Tyrosine	3.33	2.8	3.4	13.4	6	3.5
Valine	4.04	3.7	5.3	17.4	9.41	6.9
Alanine	3.52	5.7	4.9	16	8.5	6
Aspartic acid	7.32	5.1	8.4	42.1	19.2	12.9
Glutamic acid	15.78	13.8	9.6	65.7	39.1	27
Glycine	6.67	3	5	15.6	8.7	8
Proline	3.92	6.8	5.4	18.5	7.7	6
Serine	5.9	3.7	4.9	18.9	8.9	6

Looking at research on the inclusion of amaranth in pig nutrition there currently is a scarcity of such studies in literature relative to those in ruminant and poultry nutrition (Table 3) [12]. However, according to *Peiretti* [12], considering sustainability the replacement of feedstuffs of animal origin, the likes of bone and meat meal, in pig nutrition is with the utilization of amaranth and its' relative processed products that are able to meet pig diets requirements. This is so due the fact that amaranth grains contain a more balanced AA composition, relatively higher content of protein and a good content of dietary fibre, when compared to conventional cereal feedstuffs [9, 37-39]. Additionally, *Zralý* [40], also postulated that due to the high lipid content in amaranth, in particular of essential fatty acids, it may be expected to be effective in wholesome pork production since they modify the animal tissue fatty acid composition. Recently, in monogastric livestock feed formulations the utilization of non-traditional sources of protein and energy, the likes of sun-dried leaf meals, has escalated. In a study by *Fasuyi* [9], the author postulated that sun-dried leaf meal of A. cruentus could potentially be a rich source of nutrients and could be included in broiler finisher diets (Table 3). As stated earlier, anti-nutritional elements present in amaranth can drastically be reduced to non-detrimental levels due to the processing effects of sun-drying. The most appropriate inclusion level of A. cruentus leaf meal to obtain the best broiler performance in their finisher stages, with no detrimental effects, was noted to be at 10% [9, 12]. Additionally, with the suplementation of sun-dried A. cruentus leaf meal with an enzyme (glucanase, cellulase and xylanase) cocktail it can be included at percentages up to 25% in broiler diets [9]. Twice the quantity of protein is found in grain amaranth when compared to most convectional cereal grains and has a superior AA content with similar energy value (Tables 1, 2). Implying that it can be used as a broiler feed ingredient and should only be added as a raw material in the finisher feed (Table 3) [41, 42].

Table 3: Studies on the influence of supplementing livestock diets with Amaranth grain and/or leaf meal at different inclusion levels. The ↑ = increase/increased and ↓ = decrease/decreased.

Animal	Results and Conclusions
Calves	- 40% inclusion level of amaranth leaf meal resulted in better performance of calves in comparison to the feeding value of Lucerne meal [33].
Moghani lambs	- Total gain, carcass weight and carcass cuts were improved as a result of feeding amaranth silage without detrimental effects on the health or the lean-to-fat ratio [34].
Fattening lambs	- Dietary level ↑ of amaranth silage resulted in an ↑ of feed intake, average daily gain, nitrogen retention, microbial nitrogen supply, and ruminal butyrate [35].
Growing rabbits	- Amaranth leaf meal efficiently could replace Lucerne leaf meal up to 15% in the diet, without any detrimental effects [36].
Fattening rabbits	- Mature grain amaranth unthreshed seed-heads could be included as a concentrate feed component for rabbits, up to a 10% dietary inclusion level [12].
Rabbit diets	- Amaranth (*Amaranthus hypochondriacus*) specie resulted in an acceptable effect on growth, when the grain was included at 40% dietary inclusion level in rabbit rations [43].
Weaners	- Inclusion of up to 10% amaranth (*Amaranthus cruentus*) specie hydrolysate in pig diets ↑ digestibility, degree of nitrogen assimilation and weaner productivity [39].
Fattening pigs	- Fatteners given diets with 25% amaranth grain inclusion had no significant effects on the physical-chemical or sensory properties and chemical composition of the meat [38].
Market pigs	- Diets supplemented with amaranth did not adversely affect pigs' metabolism or health at dietary inclusion level of 10% [40].
Broiler diets	- Sun-dried leaf meal of amaranth (*Amaranthus cruentus*) specie could only be included up to 25%, in broiler diets when supplemented with an enzyme cocktail [9].
Female chickens (6-week-old)	- Amaranth diets fed to chickens resulted in a 10 to 30% ↓ in total cholesterol and a 7 to 70% ↓ in low-density lipoprotein cholesterol in comparison to the control diet [42].
Broiler diets	- Amaranth (*Amaranthus cruentus*) grain specie could be included at a maximum inclusion level of 40% for in broiler diets. However, only when proper processing is administered to the amaranth through either by extrusion or autoclaving [41].

Conclusion

Even though the role of amaranth spp have been known since long ago in native America and other parts of the world [44,45]. Its rediscovery in the 1970s and the increasing series of novel studies on its utilization by both man and livestock, only recently actively shows and demonstrates the role and potential function amaranth can play as a food and feed resource. Continued research is the key to providing the scientific basis on its full utilization, propagation and breeding for man and livestock. Research will also detail the appropriate processing techniques, inclusion levels and effects of use of amaranth as a food and feed resource. Hence there's a great deal to continue researching on amaranth to allow its full utilization as a livestock feed ingredient. As this will greatly reduce the pressure on some of the commonly used ingredients in livestock feed as they are also used as food sources by man at the sometime reducing livestock feed costs.

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Authors' Contributions

All the authors were directly involved in the design and preparation of the manuscript. TTN reviewed, corrected, edited and contributed the publication fees.

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