Alternative Protein Sources Used in Broiler Chicken Diets in Nigeria and Romania: a Review

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Abstract
Alternative protein ingredients of plant and animal origin used today in broiler chicken feed, can only be done partially to partly substitute soya bean meal in order to sustain production. Protein alternatives from various studies conducted in Romania and Nigeria have indicated that SBM and fish meal (FM) are the main conventional protein ingredients used. In Romania, in accordance with Regulation (EU) 2017/893, the use of processed animal proteins (PAP), including fish meal, is permitted in poultry and pig feed, provided that safety standards are met. Faced with many challenges, their utilization has gradually declined due high cost and competition as food for humans. More attention is tilted to use of non-conventional plant and animal alternative ingredients like roselle (*Hibiscus sabdariffa*) seed cake (RSC), baobab seed cake (BSC) and palm kernel seed cake commonly used in Nigeria, while peas, sunflower cake (SFC) and are commonly used in Romania. Others include insect and worm meals (grasshopper, black soldier ant and maggot meal) and corn gluten. Dietary inclusion levels from 0.1-20% in some cases of their incorporation into broiler chicken diets was reported to have a significant impact on weight gain, live weight, carcass, meat quality and health status of birds. In conclusion, Romania has numerous legume grain alternatives compared to Nigeria where most alternatives are grain/seed and their by-products, industrial and farm waste. Therefore, farmers can partly substitute SBM with alternative feed ingredients in both countries to reduce production cost and increase profit.

Keywords: animal/plant protein, anti-nutritional factors, broiler, nutritional quality, environmental impact

Introduction

The demand for sustainable, nutritious and balanced feed alternatives has gained more interest in investigating alternative plant and animal protein sources for broiler chicken diets. Both plant and animal protein sources have potential, according to numerous research, each with its own benefits and drawbacks. In order to produce exceptional animal products that meet the demands of a changing world, it becomes necessary to formulate sustainable and nutritionally balanced animal feeds. Moreso, meat consumption has increased globally, with per

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capita consumption reaching about 34.1 kg annually in 2016 to 2018 [1]. Projections from 2021 to 2030 [2, 3] report indicated a 14% increase in global meat consumption, in 2030 compared to 2018 to 2020. Animal-based product consumption by 2050 is predicted to rise by 60% to 70% [1]. Feed is an important component of the livestock sector and makes up between 60 and 80 % of production costs, depending on the production purpose, breed, animal's growth and reproductive stage. Therefore, in order to reduce operating costs and ultimately increase profit, it is necessary to formulate the best diet at the lowest possible cost. Additionally, the purpose of feed ration formulation is to choose suitable ingredients based on their cost, availability and nutritional composition in order to minimise overall feed costs and meet up with the nutrients requirements for various livestock categories. Broiler chickens are a group of birds among poultry species with relatively high protein requirements, approximately 24% and 20% crude protein (CP) for starter and fisher phases respectively. They are fed with high concentrated feed [4] and are efficient converters of feed to meat within a short period of time [4].

Protein is essential in poultry nutrition and plays a critical role in the growth, development, and overall health of broiler chickens, it is also very important in the development of muscle tissues. Apart from energy sources, protein feed ingredients are the largest cost item by volume in broiler chicken diets. Traditionally, animal protein sources and conventional plant protein sources such as fish meal and soya bean cake or meal and groundnut cake have been relied upon for their protein content and favorable and balanced amino acid profiles [5]. However, the competitive nature of these ingredients, high demand and rising costs, coupled with increasing environmental concerns have prompted a shift towards sustainable alternatives, particularly non-conventional animal and plant protein sources that are relatively cheap and locally available among many countries of the world like Romania and Nigeria. But the major challenges with adoption and continuous use of these ingredients is the presence of anti-nutritional factors (ANFs) and low awareness of farmers on the nutritional and medicinal health benefits of these non-conventional ingredients and the emerging ones. There exist diverse novel and alternative feed ingredients in Nigeria and Romania, which can be used to mitigate the problem of high feed cost in poultry industry [6] in both countries. Such ingredients include legume waste [7], oilseed meals [8], leaves or plants [9], leaves or plants [10], and other agricultural by-/co-products [11]. Various improvement strategies like sprouting, boiling/cooking, autoclaving, fermentation, removal of oil, enzymes treatment or heat treatment [11], roasting and germination have been employed to improve their quality. Several researches by different scientists all over the world have been conducted, to evaluate the impact of the non-conventional feed ingredients on growth performance [12], meat quality [13], cost and environmental impact [14] and overall production efficiency with results and interpretations on their best inclusion rate, and processing methods to improve their quality before incorporating them into animal diets. This is necessary because most of these ingredients, especially those from plant protein sources have antinutritional contents that are not beneficial to the animals health with adverse effects. Some of the animal sources have the problem of toxins buildup with foul odour like fish meal, and are advised to be incorporated into diets at certain recommended levels.

Soya bean meal which is a byproduct of oil extraction from soya bean seed remains the most commonly used and efficient plant protein source [15] world wide for poultry production. However, the major constraint of use in animal feed is its competition with humans as food. Therefore, in many countries there is a shift in the use of these ingredients to alternative sources that are locally available and native to the regions where they are locally produced.

Literature Review and Nutritional Evaluation

Amino acid profiles of various plant proteins must be assessed to meet the nutrients and amino acid requirements for broiler chickens diets. Most plant Factors affecting digestibility include processing methods such as toasting or fermentation, which can enhance nutrient availability. For example, properly processed cowpea seeds can significantly improve nutrient absorption in broilers [15]. A study conducted by [15] in Romania, suggested that cowpea seeds can be used as a partial replacement for soybean meal in broiler chicken diets.

Animal-based protein sources, such as insect meals derived from black soldier fly larvae and mealworms, are increasingly recognized as viable alternatives to conventional protein sources. These insect meals possess a high protein content comparable to soybean meal and have been shown to enhance growth performance in broiler chickens when included at optimal dietary levels (e.g., 2–5% for black soldier fly larvae) [1]. Moreover, their production is associated with reduced greenhouse gas emissions, offering an additional environmental advantage.

Plant protein sources on the other hand have both beneficial and adverse effects; Nyende et al. [16] reported that cold-pressed flaxseed meal for instance has higher fiber content but lower amino acid digestibility compared to soybean meal. Another study by Paler et al. [17], stated that Sesbania grandiflora meal can enhance feed efficiency but may not significantly impact weight gain. Utilizing alternative feed ingredients in broiler chickens diet can reduce the over reliance on soybean meal, the diet may lead to increased feed intake but can impair growth performance and digestibility of broiler chickens. Supplementation with phytogenic compounds can also improve feed conversion ratios and meat quality. Challenges such as lower digestibility and variable growth performance must be addressed and further research is needed in this field to optimize inclusion levels, reduce variability in growth and processing methods for these alternatives. Several alternatives exist but their adoption and utilization as an alternative source depends on their availability, affordability and accessibility in the area or region it is identified and processing method employed to improve their efficiency and quality.

Soybean Meal is the most commonly and widely used plant protein in poultry diets due to its optimal protein content (44-48%), balanced amino acid profile [15] and minimal fiber content. It is readily available but attracts competition with humans as food and is highly expensive in both Nigeria and Romania. Other Sources include cottonseed meal, palm kernel meal, insects meal, maggot meal, lentils, peas and legumes and lesser-known alternatives like quinoa or spirulina. The following presents alternative plant and animal protein sources, locally available, that can be incorporated into broiler chicken diets in Romania and Nigeria, providing viable options for improving nutritional value and reducing reliance on conventional protein sources.

Peas and Legume grains: legume grains and peas (*Pisum sativum L.*) raw or processed such as cowpea and chickpeas, lentils (*Lens culinaris Medik.*), lupines, fava bean seed and field peas, are potential solutions for partially replacing soybean and incorporating them as alternative protein sources into broiler chicken diets [15] in Romania. They are relatively low in anti-nutritional factors compared to dry edible beans (*Phaseolus vulgaris*).

Cowpea (CWP) and Chickpea (CKP): scientifically called *Vigna unguiculata* [*L*] Walp and *Cicer arietinum L.* is a type of legume that has gained attention as a potential feed ingredient in broiler chicken diets especially in regions like Romania, due to their nutritional composition and availability. The pea cultiver *cv. Vedea* (Romanian) has a CP of 26% [18], ether extract (EE) 0.7%, ash 3.8% and nitrogen free extract (NFE) 63.4%. Cowpea and CKP are not only rich in nutrients but also in nutraceuticals such as dietary fibre, antioxidants, polyunsaturated fatty acids (PUFA) and polyphenols, minerals and vitamins [19]. Cowpea is called 'the queen of the semi-arid areas; areas with Psamosoils', it has high protein content and is locally grown in Romania. Chick pea, also called garbanzo bean or Bengal gram, is an Old-World pulse and good source of dietary fibres (DF), vitamins and minerals, it has a CP of 16.8%, EE 2.7 - 6.48%, and ANFs like alkaloids, tannins, phytic acid, saponins and phenolics, trypsin inhibitors, chymotrypsin inhibitors, lectins and antifungal peptides. These seeds, depending on the variety, have low ANFs i.e. trypsin and chymotrypsin inhibitor common beans, thus offering fewer problems in poultry nutrition [20].

Lentils: it is occasionally used in the animal feed industry when they suffer from quality problems (such as frost damage, discoloration, or seed damage), low for human consumption. These obstacles do not pose any problems when such are fed to pigs and poultry of all ages [21]. The cultivars of lentils cv. Eston (green) has a CP of 26.3%, ether extract (EE) 0.5%, ash 3.3% and nitrogen free extract (NFE) 63.9%

Lupines: blue lupine (*Lupinus angustifolius*) belongs to the family Fabaceae, they are important sources of protein for chickens and other monogastric animals and are considered as alternatives compared to soya bean meal. It has high protein content of 31 - 48% CP, 6 - 10% EE [22] and the anti-nutritional factors in lupins are alkaloids, phytates, protease inhibitors, and lectins [23]. They are lower in phytic acid content and saponins, lectins and protease inhibitors, which improves protein digestion [24]. The lupine species *L. angustifolius* have low-alkaloid content; it has been increasingly used in both layer and broiler chickens diets [23].

Cottonseed meal: contains about 34.9 - 41.3% crude protein, EE 1.43 - 3.0% but has anti-nutritional factors such as gossypol [25]. Muataz [26] reported crude protein of 21.1%, 22.2% crude fiber, 8.5%, 34.6% (NFE) and 6.1% (Ash). Digestibility of CSC is said to be low because of the presence of gossypol [27]. Despite this, it can be used effectively in broiler diets if introduced gradually and managed properly, making it a potential alternative protein source in regions where cotton is cultivated in countries like Nigeria.

Sunflower meal: commonly used in Eastern Europe, sunflower meal is recognized for its protein content and cost-effectiveness. It serves as an important alternative protein source in Romanian poultry diets. The CP of whole and dehulled seeds varied from 15 to 20% and crude fiber ranges from 0.28 to 11.25 [28].

Baobab seed cake: seeds are rich in protein (20-36% CP) and energy (1 898 - 4 465 kCal/kg), it has fiber, vitamins, minerals and amino acids, particularly, lysine and methionine which are essential for livestock growth and development [29].

Insect meal: insects have gained more attention in the last 10 years and it served as a promising alternative protein source for animal feed production [1].

They can intensively be farmed in containers in large quantities within limited space and do not require cultivated land for production [30, 31]. Insect meals contain chitin, Janssen et al. [32], reported that MM chitin concentration (62.4%) is higher than that of soybean meal (49.4%) but lower than fishmeal (67.5%) NRC [33].

Black soldier fly *(BSF) Hermetia illucens L. (Dip.: Stratiomyidae)* larvae and mealworms (MW) *Tenebrio molitor L. (Col.: Tenebrionidae)*: are viable protein sources for broiler chickens, they are easy to rear [34], rich in nutrients [32] and essential amino acids with a favorable nutritional profile. They can be produced sustainably using organic waste materials like poultry litter and wood shavings, they help in waste reduction and provide an environmentally friendly protein source [15]. Black soldier fly contains 42% crude protein and 29% fat on dry matter basis [35]. Several studies conducted by researchers on the use of these meals indicated that incorporating insect meals can enhance growth performance and feed conversion ratios in animals.

Meal worm has a CP of 41% to 66%, fat content between 15% to 50%, and fiber between 9% to 19% [36], Liu et al. [36] reported a CP content of 38 to 56% and CF of 4.8 to 28%, lysine 3.58%, methionine 0.86%, rich in saturated fatty acids (SFAs) such as lauric acid, myristic acid, and palmitic acid [37]. Soybean meal (1.4%) and fishmeal (10.4%) have a lower fat concentration than MW which has 28.38% fat [38]. They have methionine of 1.11%, lysine 3.58%, threonine 2.48%, and valine 3.71, while soybean meal has lower concentrations of methionine and valine 0.95 and 3.15% respectively [1]. It contains 8 to 24% chitin [39], which comprises of fibres that can be digested by the digestive enzymes of poultry to chitooligomers [40] but are difficult to digest by humans [41]. Chitin improves their immune system and intestinal health [42]. In addition, Soetemans et al. [39] added that it contains many proteins with antioxidative properties, metal ion absorption and free radical scavenging. Dörper et al. [43] also indicated that they are rich in fatty acids with anti-inflammatory properties, like lauric acid and myristic acid.

Grasshopper: Grasshoppers improve digestibility, allowing broiler chickens to absorb more nutrients. They contain 52% crude protein (CP), 27% crude fiber (CF), and 3.28% lysine. Compared to soybean meal, the concentrations of methionine (1.42%) and threonine (9.74%) in grasshoppers are higher, while lysine (4.27%) is lower [1]. Grasshoppers are also rich in unsaturated fatty acids (UFAs; induce greater increase in β-oxidation rate than saturated fatty acids), including oleic acid, linoleic acid, and linolenic acid [1], and are an excellent source of carotenoids, which contribute to vitamin A intake. Additionally, grasshoppers help ameliorate fatty livers by inhibiting the activity of hepatic fatty acid synthase [44] and possess antioxidant properties, with β-carotene playing a crucial role in the antioxidant system of broiler chickens [1].

Maggots (larvae): can convert waste into nutrient-rich biomass [45], have strong antibiotic, antiviral, antioxidative, and anti-tumour properties [46]. Nutritional composition changes depending on some factors like age, species, breeding medium, environment, and processing methods. Pieterse et al. [13] in their studies confirmed that maggots are the more appropriate stage for feed applications and have higher amino acid content than the pupae. The nutrient composition of larval meal (LM) is similar to soybean meal, but CP content decreases while fat content increases as they mature into adults [47]. However, LM has higher levels of methionine (1.42%), Ca, P, metabolizable energy and vitamin B complex. They do not contain any anti-nutritional or toxic factors found in plant-based alternative protein sources [48] and are added in various forms to broiler chicken feed. Processing techniques like roasting results in higher density (0.80 g/cm3) than sun-drying (0.71 g/cm3) or oven-drying (0.67 g/cm3). Higher CP content was observed by Ajiboye et al. [49] for roasted maggots (43.75%) than oven-dried (42.70%) and sun-dried (39.15%).

Comparative analysis

Soya bean meal (SBM) is expensive in both countries, and therefore not economical for use in animal diets. Nigeria has vast arable land suitable for various crops production, but local agricultural practices face a lot of challenges such as climate variability, soil degradation and inefficient land use which affect productivity. Soybeans and groundnuts are primarily grown in states like Kaduna, Kano, Katsina, Sokoto, Zamfara, Jigawa Bauchi and Gombe among others. However, there is a growing trend towards incorporating indigenous plant proteins like roselle seed cake, palm kernel cake, baobab seed cake and sunflower seed cake into poultry diets. This shift not only addresses nutritional needs but also supports local farmers [50, 15]. Romania is known for its significant agricultural output within Europe, the country's agricultural landscape supports the cultivation of soybeans and sunflowers, with ample fertile and sufficient land available and suitable for various crops cultivation. The climate supports diverse agriculture with temperate conditions allowing multiple harvests per year depending on crop type. The country is endowed with a climate that is conducive for growing varieties of legume grains as well, which enhances the potential for integrating alternative proteins into broiler diets.

In the case of Romania, most of its SBM comes from genetically modified (GMO) crops [51], and Romania is among the European Union (EU) countries where there is regulation in the use of GMO soybean in animal feed [52]. Additionally, in Nigeria most of it is channeled to food processing sectors for the production of oil and other food products. Both countries have sufficient arable land but differ in how it is utilized based on local priorities (e.g., staple foods and specialized crops). Romania offers more favorable conditions for large-scale cultivation of soybeans and sunflowers due to its climate stability compared with Nigeria's variable weather patterns impacting yield consistency. Nigeria produces groundnuts on a large scale compared to Romania. In Nigeria, groundnut cake is the second and roselle seed cake the third most commonly used plant protein in livestock feed [27], while legume grain varieties are the cheapest and available plant protein sources next to SBM in Romania. Cowpea are grown successfully in crop rotations on sandy soils in Nigeria [53, 54] and Romania [54]. They are majorly cultivated for human consumption in Nigeria, while in Romania they are incorporated as alternative protein into animal feed. South Oltenia in Romania is an area with sandy soils which provides an optimal microclimate for growth and development of cowpea plant [15]. Soya beans and sunflowers are grown on a smaller scale in Nigeria compared to their output in Romania, and that of the major traditional staple crops produced in Nigeria like maize, cassava, yams, and rice. They are less commonly cultivated in Nigeria but have potential due to their oilseed value, and there are ongoing projects with the mandate on mass cultivation of sunflower seeds.

Impact on broiler performance

Research indicates that broilers fed diets enriched with alternative plant proteins show comparable growth performance metrics to those fed traditional diets. Studies highlight improvements in feed conversion ratios and overall health parameters when incorporating these alternative sources. Additionally, meat quality assessments reveal no significant adverse effects on palatability or health outcomes [55, 6]. As reported by Sedgh-Gooya et al. [56] and Elahi et al. [12], that diets supplemented with 2.5% and 4% yellow mealworms respectively, showed no significant difference in growth performance of broiler chickens, but had higher BWG when fed at 2.5% than those fed the control diet [57, 1]. Study on increasing yellow mealworm concentrations from 0 to 15% by Biasato et al. [58] and on comparison of diets containing 10% versus 5% by Vasilopoulos et al. [59], both resulted in higher broiler BW of broiler chickens, with higher BWG, feed intake (FI) and carcass weight at 10% inclusion level [60]. Amobi et al. [60] in their studies replaced 50 or 100% of fishmeal with grasshopper meal in broiler diets, and reported increased BWG and linear measurements of the body, thigh, shank, and wing and improved FCR. Another research on grasshopper by Wang et al. [61] proved that feeding broiler chickens with diets containing 5, 10, or 15% Chinese grasshopper meal did not significantly affect the growth performance. Ajiboye et al. [49] fed diets containing 4.0 or 4.5% roasted maggot meal and observed that broiler chickens had higher ether extract digestibility than the control group.

Another study by Ahmad et al. [14] reported that diets containing 0.4% maggot meal improved FCR. Đorđević et al. [62] study on increasing fresh maggot concentration and Khan et al. [63] addition of 1, 2, or 3% maggot meal in their diets revealed an elevated BWG and body mass along with improved FI and FCR. Further research by Pieterse et al. [13] testing diets containing 10% oven-dried maggot meal revealed increased live weight, carcass weight, metallic aroma, metallic aftertaste, and sustained juiciness. Akpodiete et al. [64] and Adeniji [65] in contrast reported that diets containing 17, 34, 52, and 69 g/kg and 5.5, 11, 16.5, and 22 kg/100 kg of dried maggot meal respectively had no significant effect on broiler chickens. High body weight gain score was reported by Muataz [26] in the starter phase with 33 and 25% BSC inclusion. The findings were similar to that of Shehu [27] for broiler chickens fed BSC and RSC diets at 20%, who reported that chickens on BSC group performed next to those fed SBC diet, in spite the antinutrients and fiber content of baobab seed cake among others treatment groups.

Sustainability and Environmental Impact:

The use of alternative plant and animal proteins contributes to ecological sustainability by reducing reliance on imported animal feeds and lowering greenhouse gas emissions associated with livestock production. This aligns with global objectives for food security and sustainable agricultural practices [66].

Raising insects can also be utilised effectively to turn organic waste such as food scraps and animal faeces into fertiliser other than for the purposes of producing animal feed [67]. The waste they excrete produces negligible amounts of greenhouse gas or ammonia [68] with little pollution. Maggots for instance when added directly to poultry faeces can efficiently recycle 25 to 30% of it as manure and are used for effective waste management. In a previous study by Ahmad et al. [14], 1 kg of chicken faeces were reported to produce 300 g of housefly larvae. Thus, insects are environmentally friendly and require not much capital to raise, due to their easy controlled growth and proliferation rates, low maintenance and sanitation costs [69].

Insect-based feeds have been reported by Vauterin et al. [70] to lower greenhouse gas emissions. These characteristics reveal their potential as a sustainable alternative feed source, and it is anticipated that their use will support sustainable production of nutritious feed. The findings of Shehu [27] revealed that RSC and BSC (at 20%) are viable and cost-effective alternative proteins for broiler chickens.

Challenges and limitations

Despite the benefits, challenges remain in the adoption of alternative plant proteins by farmers and feed millers. Market price fluctuations is another factor that deter farmers from switching from conventional feed ingredients to non-conventional ones. Moreover, anti-nutritional factors present in some plant proteins necessitate effective processing methods and strategies before incorporation into diets [15]. Since they have low protein compared to soya bean meal which is the primary protein source utilized in poultry diets, they can only be partially incorporated into BC diets because of their low protein levels.

Conclusion and recommendations

Utilisation of historically commonly used plant and animal protein sources in poultry feed like soya bean
meal and fish meal, has gradually become restricted due to their escalating costs in both countries. This has resulted in a shift to use of alternative protein sources for animal feed production that are readily available and less expensive. Partial incorporation of alternative plant and animal protein sources into broiler chicken diets presents significant benefits for the poultry industry in both Romania and Nigeria. Policymakers should support research into non-conventional plant and animal protein sources, while providing education and increasing farmers' awareness on processing techniques that enhance their nutritive quality. Soya bean cake remains the primary source of protein in poultry diets, the alternative ingredients can only be incorporated partly into animal feed to replace them partially. There should be an increase in awareness of farmers and poultry feed millers on the importance of adopting the emerging protein alternatives to increase profit margin, feed and performance efficiency and to reduce production cost.
Plant protein alternatives compared to the animal protein alternatives have lower amino acid profile and CP, thus requiring further processing techniques like sprouting, autoclaving, roasting, cooking, fermentation and addition of enzymes before adding them to improve the diet ingredients quality and efficiency. Despite the challenges, both alternative sources have the potential for protecting the environment, reducing feed and production cost while attaining food security and sustainability. Therefore, further studies are needed by scientists and researchers to optimize formulations that balance cost-effectiveness with nutritional adequacy.

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