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Review Article

The Major Potential of Non-Conventional Feed Resources in Poultry Nutrition in Ethiopia: A Review

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Abstract

This review was conducted with the objective of assessing the major potential of non-conventional feed resources in poultry nutrition in Ethiopia. Ethiopia has a vast array of non-conventional feed resources that can be utilized in poultry nutrition. These resources have the potential to significantly contribute This review was conducted with the objective of assessing the major potential of non-conventional feed resources to the growth and development of the poultry industry in the country. Potentially available of non-conventional feed resources (NCFR) include plant materials, such as the leaves and seeds of Moringa, Cassava, Taro leaf, Mango seed kernels, Pigeon pea, potato peel and leaf and agro-industrial by-products like, Rice bran, Filter sugar cake and brewery grain. Most of these feedstuff materials are low in energy, protein and minerals. These feed resource contain high amounts of anti-nutritional component. Appropriate processing methods like soaking, boiling, or fermenting can help reduce these anti-nutritional factors, enhancing the digestibility and utilization of NCFR in poultry diets. There are also several challenges and limitations that need to be addressed in order to fully exploit the potential of these feed resources. Some of the common problems are like limited knowledge and awareness, lack of processing and preservation techniques, limited availability and seasonal variations, lack of infrastructure and storage facilities and limited research and data. To addressing these challenges through research, extension services, and policy support can help unlock the full potential of non-conventional feed resources in poultry nutrition in Ethiopia. This would not only contribute to improved productivity and profitability in the poultry sector but also enhance food security and sustainable agricultural practices in the country.

Keywords

Cassava Leaf, Mango Seed Kernel, Moringa Leaf, Non-Conventional Feed Resources, Potato Peel

1. Introduction

In Ethiopia food and nutrition insecurity and climate change scenario of the country becomes a major concern. Population growth and urbanization resulted in a high demand of animal protein source food. Malnutrition, in particular with the lack of animal protein source food has a negative impact on growth and development of children. The consequence happened with low production and productivity of poultry with due challenges in feed quality and quantity, resulted unaffordable poultry products by majority of the society. Over 70–75% of the entire production costs in the chicken industry are attributed to feed costs [1]. Due to the high cost and limited availability of conventional protein and energy concentrates, poultry productivity has also been severely restricted [2]. The high price and poor quality of chicken feed on the

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market is a constant source of grievance for poultry farmers in this nation. This situation also made the country weaker and weaker to compete with the global market for the products. The prices of conventional feed ingredients used in poultry feed have soared and becoming uneconomic to use them in poultry feeds in current situation. The known conventional plant protein sources for poultry feeding include soybean and other oil seed meal; leguminous seeds various agro-industrial by-products. However, there is increased market price and demand for oil seed cake, particularly that of soybean meal [3]. Leguminous seeds and cereal grains are staple food of human population in developing countries including Ethiopia. However, Ethiopia's inability to produce enough cereal grains shows that chicken production must compete with human population growth for the limited supply of concentrate food and feeds [4]. The result is an unaffordable market price due to the usage of cereal grains in chicken feeding [5]. The double burden stems from the fact that maize is a common cereal grain that is consumed by humans and is also a significant grain that is fed to chickens in Ethiopia in order to provide them with energy. Furthermore, because of the increasing demand for maize across many processing industries, its availability is in doubt both now and in the future due to global conditions [6].

The economical and successful use of inexpensive, locally accessible feed supplies that have a comparable nutritional value to conventional sources is crucial to the poultry industry's profitability for farmers and the affordability of poultry products for consumers. Therefore, it is crucial to look for alternative, affordable feed sources that are readily available in the area and that are nutritionally appropriate for chickens in order to lower production costs and boost output and productivity in the poultry industry. Exploiting the usage of non-conventional feed resources (NCFR) in poultry production systems is one method of reducing a significant gap that arises between the supply and demand of conventional feed resources for feeding poultry. Therefore, the objective of this paper is to assess the major potential of non-conventional feed resources (NCFR) in poultry nutrition in Ethiopia.

2. Characteristics of Non-Conventional Feed Resource

Non-conventional feed resources (NCFRs) are feeds that are not usually common in the markets and are not the traditional ingredients used for commercial feed production [7]. Similarly, as defined by Kang *et al.*, [8]. non-conventional feeds are feeds that are not regular ingredients in the diet of farm animals. According to reports from the FAO [9], non-conventional feed supplies possess several attributes. For example: - These are the byproducts of consumption and industrial processes that have not been salvaged, repurposed, or put to use. They can be found in liquid, slurry, or solid form and are primarily of organic origin. These unconventional feed supplies are typically disposed of as waste because their economic value is less than the expense of gathering and preparing them for use. Cassava and sweet potatoes, two feed crops that produce valuable NCFR, are generally good sources of fermentable nutrient molecules. This is advantageous to livestock, especially cattle, since it allows them to use nitrogenous resources other than proteins and inorganic nitrogen.

In contrast, fruit wastes like pineapple pulp and banana peels contain sugars that are energetically advantageous. Most feeds derived from crops are heavy, low-quality cellulosic roughages that are best suited for feeding ruminants due to their high crude fiber content and low nitrogenous content. A portion of these animal diets contain anti-nutritional ingredients that negatively impact the animals. The nature of these ingredients' activities and strategies for mitigating their effects are not well understood. Non-traditional feed resources have a lot of potential as feed materials, and for some, the value of these resources could be raised if there were environmentally sound technical ways to turn them into useful products. A significant amount of data is needed on the chemical composition, nutritional value, anti-nutritional component presence, and value in feeding systems.

3. Source of Non-Conventional Feed (NCFR)

Potentially available NCFR include plant materials, such as the leaves and seeds of Moringa, Taro, Mango, Cassava, Pigeon pea, agro-industrial by-products Rice bran and Filter sugar cake. Most of these feed materials are low in energy, protein, minerals and contain high amounts of anti-nutritional components [10]. NCFR generally refer to all those feedstuffs that have not been conventionally used for feeding poultry and are not commercially used in the production of poultry ration. The majority of research in the field of animal nutrition has been redirected to examine all potential solutions to this nutritional crisis due to the scarcity of feed resources for poultry [11].

It is now unfeasible to employ these traditional protein sources in chicken diets under smallholder production methods due to their recent price increases [12]. The cost of animal feed has been rapidly rising in recent years [13]. Exploiting the usage of non-conventional feed resources (NCFR) in poultry production systems is one method of reducing a significant gap that arises between the supply and demand of conventional feed resources for feeding poultry.

Animals are also fed non-traditional foods including weeds and brewer's grains, a byproduct of the region's tella (beer) production [14]. The production of NCFR is basically from agriculture and various agro-based industries and is a role of many factors. These variables contain the amount and quality of resources produced, which are influenced by cropping patterns and the current agro climatic conditions; raw material types; production methods; production rates; types of inputs used; regulations governing the use of inputs that affect product quality; and restrictions placed on effluent discharge.

3.1. Plant Materials

3.1.1. Moringa Leaf and Seeds

Moringa (*stenopetala)* is native to Ethiopia and widely distributed in the Rift Valley of southern Ethiopia especially in Konso, Wolleita, Gidole, and Gamogofa areas where it is grown intensively [15]. While locally refer to M. *stenopetala* by several names, the majority of Ethiopians recognize it as the *Shiferaw* tree. When planted in areas that are not extremely acidic, do not retain water, and are below 2000 feet in elevation, it grows quickly [16]. The leaf sections of Moringa stenopetala, which is extensively grown in southern Ethiopia, are consumed by humans, but the pods are not; instead, they are dried on the tree and become inedible to animals when they fall to the ground. It is broadly disseminated in the Rift Valley of southern Ethiopia and is used for human consumption (Mokennen and Dräger, [17] and poultry feed [18]. The significance of M. *stenopetala* leaves in chicken diets has been demonstrated by several researches (Aberra *et al.*, [18]. However, the leaves of Moringa are also used for human consumption as well as for making tea and medicinal drugs for commercial purposes. Thus, it has been increasingly commercialized and become expensive in the recent times making difficult for smallholder farmers to use it for poultry feeding.

The study conducted by Aberra *et al* [19] indicated that the leaf part of M. *stenopetala* is rich in protein (27.3-28.2%) and contains substantial amount of essential amino acids, particularly those limiting amino acids such as methionine and lysine that are particularly essential in diets of poultry. Based on research work, the crude protein content of the pod portion of M. *stenopetala* ranged from 15.4 to 18.5%, which is similar to what is often found in wheat bran, which is fed to livestock in Ethiopia [20]. It has been further reported that the pods contained reasonable amounts of essential amino acids particularly those limiting amino acids such as lysine, methionine and cysteine. The same authors also reported that the pod contains 6.8 MJ/kg DM of Metabolizable energy. On the other hand, *M. stenopetala* pods are mainly available during most parts of the year and could be used as a good source of feed mainly during the dry season as a protein and energy supplement.

Table 1. *Summary of NCFR chemical composition.*

Non-conventional feed resources CRC	Nutrient contents						References
	DM	Ash	CP	Fat	CF	ME	
Cassava root chips	92.3	2.9	2.3	0.8	0.3	3852	[21]
Cassava leaf	92.5	12.3	25.6	11	12.5	2857	[22]
Moringa olifera leaf		11.8	30.6	4.73	8.30	2992	[23]
Moringa steno leaf		11.3	31.6	5.43	6.75	3187	[24]
Taro leaf	93	12.89	21.27	4	6.44	54.5	[25]
Sweet potato		9.93	25.2	1.08	10.6		[26]
	88	3.1	4.6	Na	2.8	Na	[27]
potato peel	92	7.63	13	0.7	5.71	2826	[28]
Pigeon pea leaves	35.54	7.35	18.68	4.25	30.51	Na	[29]
	954	75.6	230	Na	Na	Na	[30]
Rice bran	89.2		6.06	2.6	14.09	2887	[31]
RMSK	90.84	6.74	10.02	9.62	4.26	3047	[32]
BRSK	92	2.75	8.74	7.01	3.93	3275	[32]
SCFC	91.71	Na	12.67	7.50	17.50	1540	[33]
	94.52	Na	16	0.23	18.04	1105	[34]
Brewers grains	91.8	5.4	24	6.3	Na	2510	[35]

Note: RMSK=Raw mango seed kernel, BMSK=Boiled mango seed Kernel, SCFC: Sugarcane filter cake; Na: Not available

3.1.2. Cassava Leaf and Root

The tropical and subtropical plant known as cassava (Manihot esculenta Crantz) is cultivated for its underground starchy tuberous roots. Over 800 million people worldwide depend on cassava roots, also referred to as cassava tubers, as a primary diet [36]. Because cassava roots have a high concentration of soluble carbohydrates and starch, they are low in protein and high in calories. According to Kuiper et al. [37], cassava tubers can be deep-fried, mashed, or cooked. The most significant cassava products that are recycled for use in animal feed are chips and pellets, which can partially or completely replace cereal grains in hen rations [38]. According to Khieu *et al*. [39], cassava leaves are rich in protein, with a protein content ranging from 16.6% to 39.9% minerals. They are also a significant source of carotenes and vitamins B1, B2, and C. The viability of substituting maize with cassava meal in chicken feed mostly depends on the availability of a high-quality protein source and the inclusion of enough methionine in the ration to meet the body's needs and facilitate cyanide detoxification [40].

According to Tekalegn *et al.* [41], it is beneficial to replace up to 30% of the maize in a broiler ration with cassava root meal while making attempts to lessen dirtiness by adding oil and supplementing with enough methionine and lysine amino acids. Based on DM intake and broiler growth performance, Etalem *et al.* [42] suggest that cassava root chips could completely replace maize grain as an energy feed item in broiler diets. However, cassava root chips shouldn't replace maize grain by more than 50%, according to the results of major carcass parameter yields. On the other hand, 50% cassava root chips, 5% moringa olifera meal, or a combination of the two can be used effectively in the ration of layers to replace maize grain and soybean meal. This is based on the results of the main edible meat parameters, which show that cassava root chips could replace maize grain in the diet of broilers less than 50% of the time. The ultimate body weight gain, total body weight gain, and daily body weight gain of broiler hens were increased when Noug seed cake was substituted at a 4% substitution level for cassava leaf feed. Therefore, in substitution of the costly Noug seed cake, cassava leaves will make a good supply of protein for broiler diets [22].

Melesse *et al*. [12] observed decreased growth in chicken fed higher doses of M. oleifera and M. stenopetala leaf meals without influencing feed consumption. Moringa leaf meal, at 5% of the diet, can have comparable or positive impacts on egg production, egg quality indices, egg fertility, and hatchability in Dominant CZ layers [21]. Cassava root chips looked to be a high-energy source with low fiber, protein, ash, and ether extract. The high metabolizable energy (ME) content of Cassava root chips indicates its potential as a replacement for energy-rich cereals in broiler diets [21]. According to the author, based on dry matter (DM) consumption and broiler growth performance, Cassava root chips might totally replace maize grain as an energy feed ingredient in broiler diets. However, based on the results of key carcass parameter yields, Cassava root chip should not substitute corn grain more than 50%.

3.1.3. Mango Seed Kernels (Mango Kernels)

Different studies have revealed that Mango Seed Kernel is one of the wastes that can be used as component for poultry ration [43]. The FAO [44] stated that 42 million tons of mangos are produced worldwide each year, which might yield 3.78–16.8 million tons of MSK. 42 million tons of mangos are produced worldwide each year, which might yield 3.78–16.8 million tons of MSK, according to FAO [44]. Depending on the varieties mango seed contains (10.06 ± 0.12%) crude protein, (14.80 ± 0.13%) oil, (2.62 ± 0.02%) ash, (2.40 ± 0.01%) crude fibre, 70.12 ± 1.34%) carbohydrate and energy content (453.92 ± 4.32 KJ/100 g). [45].

Boiled mango kernel meal can replace up to 60% of the maize in broiler finisher diets without adversely affecting the growth, health, or carcass parameters, as evidenced by the significantly improved daily feed intake and feed conversion ratio when compared to the control diets [46]. During the starter and finisher periods, broiler birds can use up to 30% of mango seed kernel meal as an energy source; however, the diets should meet the birds' needs for sufficient protein and metabolizable energy (ME) [27]. The kernel has an amino acid equilibrium [47].

The utilization of mango seed kernel as poultry feed will help the poultry industry reduce production costs associated with high conventional feed costs in Ethiopia. Mango seed kernels have the potential to be an attractive alternative nutritional attribute that is useful when considering their inclusion in poultry diets and the cost is cheaper than the cost of maize [48]. Because MSK is less expensive than maize and even other feed ingredients, there may be less competition for cereals in general and maize in particular between humans and chickens. Using MSK as chicken feed would help the poultry industry cut production expenses associated with expensive conventional feed [32].

3.1.4. Pigeon Pea Leaf and Seeds

The pigeon pea's original origin was in India, while its secondary origin was in Africa. Pigeon pea (Ca-janus Cajan L.), where the leaves are fed to fowl and the pod is used as food [49]. It is a significant grain legume that is widely cultivated and eaten in tropical and subtropical climates worldwide. It has a high crude protein content, ranging from 21% to 30% [50]. In Ethiopia's lowland areas, where there is a large need for fodder and farmers can profit from the leaves when they use the seeds for human food, the usage of pigeon pea is advantageous. One of the most significant climatic obstacles to plant survival and productivity—and, consequently, food security—in the tropics is drought. It is an indigenous legume crop in Ethiopia, and its utilization in the poultry industry provides economic benefits. The availability of pigeon pea leaves and seeds as a locally sourced feed ingredient can reduce dependence on costly imported feed ingredients, making poultry production more economically feasible, especially for small-scale farmers.

They continue to be among the legumes that can withstand drought the best [29]. Pigeon pea leaves and seeds are utilized as important feed ingredients in poultry nutrition. Both components provide essential nutrients required for optimal growth and production of poultry. They are rich in protein, making them valuable sources of dietary protein for poultry. The protein content of pigeon pea seeds is relatively high, which helps meet the protein requirements of chickens and other poultry species [51]. It is important to note that pigeon pea seeds contain anti-nutritional factors such as trypsin inhibitors and tannins, which can reduce nutrient availability and animal performance. Appropriate processing methods like soaking, boiling, or fermenting can help reduce these anti-nutritional factors, enhancing the digestibility and utilization of pigeon pea seeds in poultry diets [11].

3.1.5. Potato Peel and Leaf

Potato peel is by-product cause's environmental pollution due to decomposition. In order to support the environmentally friendly food sectors, potato peels may be used as a food preservative, a pharmaceutical ingredient, a renewable energy source, or poultry feed [52]. Broiler (Cobb-500) and fay-oumi laying hens' meals were supplemented with potato meal, respectively [53]. Potato peel is a plant waste with high phenol content and a variety of biological uses. In urban and per-urban chicken production practices, adding up to 6% of sweet potato leaf meal to the laying diet could be an alternative feeding strategy to replace more costly protein sources like soybean seed, helping to increase income through improved nutritional status, increased productivity, and higher-quality chickens [54].

3.1.6. Taro Leaf

There is an insistent need to look for other NCFR that are comparatively less used for human consumption due to the high expense of grains and protein supplements, as well as the uncertainty surrounding their sustainable supply for poultry. In Ethiopia, taro leaves (*Colocasia esculenta*) play an important role in the poultry industry as a local feed resource. Due to taro's versatility as a crop for both food and feed, adding taro leaf meals to chicken rations may provide customers with high levels of nutrients and help solve this issue. Taro leaves are utilized as a nutritious feed ingredient for poultry, particularly for chickens and ducks. They provide valuable nutrients such as protein, minerals (iron, calcium), vitamins (vitamin C, vitamin A), and dietary fiber. Taro leaves are one of the few plant-based feed ingredients that are relatively high in protein compared to other leafy vegetables. Their inclusion in poultry diets helps meet the birds' protein requirements, especially in areas where conventional protein sources like soybean meal are expensive or limited. Taro leaves are rich in dietary fiber, which supports digestive health in poultry. Including taro leaves in feed formulations can promote proper gut function, aid in digestion, and prevent digestive disorders.

Taro leaves are commonly found in Ethiopia and are relatively inexpensive compared to other feed ingredients. This makes them an accessible and affordable resource for small-scale poultry farmers who may have limited access to commercial feed. Utilizing taro leaves in the poultry industry contributes to sustainable agriculture by reducing waste and utilizing a locally available resource. Rather than discarding or underutilizing taro leaves, they can be converted into a valuable feed ingredient, minimizing environmental impact and contributing to resource efficiency. It is worth noting that taro leaves may contain anti-nutritional factors such as oxalates and tannins, which can bound their inclusion levels in poultry diets. Proper processing techniques like boiling or fermenting may be employed to reduce these anti-nutritional factors and improve their digestibility [11]. Taro leaf is high in protein and can provide chicken diets with additional protein, carotene, and trace minerals [25]. Taro leaves provide an affordable and nutrient-rich feed ingredient for the poultry industry in Ethiopia, particularly in areas where conventional feed ingredients may be scarce or costly. Integrating taro leaves into poultry diets can help support flock health, reduce production costs, and promote sustainable agriculture.

3.1.7. Sweet Potato

As a dual-use crop, sweet potato (Ipomoea batatas) plays a essential role in crop-livestock farming systems in many rural communities of southern Ethiopia. Although the primary purpose of the crop is to produce tubers, after harvesting a significant amount of sweet potato vines (leaves and stems) remain. According to reports, the leaves account for around half of the biomass of sweet potato vines [55]. Therefore, a significant boost in the availability of dietary protein and amino acids would be anticipated if the leaves and stems could be separated [56]. When compared to other forages that are strong in protein, sweet potato leaves have a comparatively high protein concentration. The leaves' crude protein content varied from 250 to 290 g/kg dry matter (DM), making them a viable substitute for pricey traditional feeds in the nutrition of chickens [56]. Studies conducted by Van An, [56] indicated that the sweet potato leaves from southern Ethiopia contain (g/kg DM) 99.3 ashes, 247 crude proteins (CP), 101 crude fibers (CF) and 46.7 sugars. The amino acid profile of leaves is also appreciable, particularly the concentration of methionine (1.70 g/16 g N), lysine (4.62 g/16 g N) and histidine (2.75 g/16 g N) are comparatively higher than those found in other leaves of tuber plants [12]. There are few scientific investigations on the effects of sweet potato leaf on the growth and carcass characteristics of broiler chickens raised in Ethiopia. Hopeful results have been stated by the supplementation sweet potato leaf meal (SPLM) in the diets of finishing broilers [57].

3.2. Agro-Industrial By-Products

Agro-industrial by-products offer several benefits and applications in the poultry industry. They act as alternative feed ingredients, providing a cost-effective and sustainable source of nutrients. Many agro-industrial by-products, such as oilseed meals (e.g., soybean meal, cottonseed meal) and distiller's dried grains are rich in protein. These by-products can be incorporated in poultry diets to meet the birds' protein requirements, reducing the reliance on expensive protein sources like fishmeal. Because of their high protein and fiber content, brewers' grains are the most significant by-product of the brewing industry utilized as fodder for chickens [58]. Agro-industrial by-products, when processed and incorporated into poultry diets, can enhance palatability and improve feed management. For example, molasses can be used to improve the taste and acceptance of feed, while oilseed cakes can improve pellet binding and reduce feed wastage. Utilizing agro-industrial by-products in the poultry industry helps reduce waste and promotes environmental sustainability. By converting these by-products into valuable feed ingredients, the industry can minimize disposal costs and reduce the overall environmental impact of agriculture. However, it is important to note that the presence of agro-industrial by-products in poultry diets requires careful consideration of their nutritional composition, potential anti-nutritional factors, and appropriate processing techniques. Proper formulation and evaluation of the diets are necessary to ensure optimal nutrient utilization and maintain poultry health and productivity.

3.2.1. Sugar Cane Filter Cake

A byproduct of the sugar industry, sugarcane filter cake is also known as sugarcane mud, sugarcane press residue, or filter press cake [59]. It is an unconventional feed item that ranges in color from dark brown to white and is soft, spongy, and amorphous [33]. One of the byproducts of the 30 million tons of SFC produced annually worldwide, it comes from commercial sugarcane factories. In 2017, sugar plants in Ethiopia produced around 1, 606,080 tons of sugarcane filter cake, indicating an excess of production and availability [60]. It has both inorganic (water and minerals) and organic (carbohydrates, lipids, proteins, and vitamins) nutrients [61]. In the country filter cake is usually dumped as garbage. Therefore, considering the current circumstances in Ethiopia, using this by-product in a poultry diet appears appealing. Sugarcane filter cake (SFC) or sugarcane press residue (SPR) contains considerable amounts of lipids and crude fiber. The remaining vegetative portion of cane appears to be the main source of both the fiber and lipid fractions in SFC.

However, because SPR has a higher level of lipids, lipase and lecithin added to meals may improve the hydrolysis and emulsification of SPR's lipids and enhance the effects of in situ lipase and lecithin. In addition to inorganic matter, Sumaya et al. [33] reported that SFC can be added up to 15% to broiler and layer diets based on fish and soy for the purpose of utilizing protein and energy. According to Dhas [62], broiler growth performances, feed intake, and egg shell and yolk quality were all enhanced by up to 15% SFC in chicken rations. Cane sugar One such possible feed item is residue, a byproduct of the sugarcane industry, which has greater amounts of SPR. It was added to broiler rations up to 4% of the time without having a negative impact on output performance [63]. Unfortunately, due to the high fiber and lipid (wax) contents, as well as the insufficient lipase secretion and lack of fiber-degrading enzyme in chicks, its use is limited.

3.2.2. Rice Bran

The area covered by rice production, the amount of sub districts, and the numeral of farmers in Ethiopia are all growing rapidly. According to Central statistical agency (CSA), [64] data, the total area allotted for rice production nationwide improved by extra than six times, from 6,241 hectares in 2005 to 47,739 hectares in 2009. Common cereal byproduct rice bran (*Oryza sativa)* is utilized extensively as a feed element in chicken rations in rice-producing countries. Rice bran makes up 8–10% of the total weight of the paddy and is a mixture of bran and the polished rice grain's germ layers. It is a good source of B-group vitamins and has significant levels of fat, protein, amino acids, and metabolizable energy.

According to Chala et al. [31], rice bran's estimated metabolic energy content was 2887 kcal/kg DM, or 89% of the energy value of maize grain. According to the author's findings, rice bran possesses the capability to function as a substitute for cereal grains in poultry diets, filling a significant gap and reducing feed costs by easing the feed scarcity. The authors also mentioned that a higher percentage of maize energy in poultry ration appears to be able to be replaced by rice bran. In turn, as maize is a common staple meal for humans in Ethiopia, this will result in huge savings from the amount of maize provided to chickens. According to Alewi *et al*. [65], rice bran can be added to the diets of starter and finisher broilers at a rate of up to 15-20% without having a negative impact on the birds' performance in terms of production. The authors proceeded on to say that given the current circumstances in Ethiopia, substituting the energy value of cereal grains in broiler chickens with rice bran appears to be a desirable option, contingent on the production parameters measured, as well as the availability and market price of rice bran.

3.2.3. Brewer's Spent Grain

Brewer's spent grain (BSG) is a by-product of the brewing industry that has been extensively studied for its use as an alternative ingredient in animal feed. It is inexpensive, readily available year-round, and has a high nutritional value [66]. Its full utilization may have been hampered by issues with supply, storage, and transportation; due to its high moisture and high nutrient content, it can deteriorate quickly, and transporting wet BSG would be costly due to its low bulk density [66]. BSG is a by-product of barley malt, corn or rice that is treated to remove most of the readily soluble carbohydrates, protein, fibre, linoleic acid, vitamins and minerals. While some breweries sell their brewer's grains wet, others dry them and offer them as dried brewer's grains.

When fed soon after production, the feeding qualities of both varieties are identical when it comes to wet brewer's grains. About 12 brewers in Ethiopia produced 263,736 tons of wet BSG in 2015–2016, or about 22,140.64 tons on a dry matter basis. Because the availability of BSG is reliant on beer production, it could not be as reliable as the other feed ingredients that industrial feed processing facilities employ.

4. Constraints to the Uses of Non-Conventional Feed Resources

Ethiopia has a vast array of non-conventional feed resources that can be utilized in poultry nutrition. These resources have the potential to meaningfully contribute to the growth and development of the poultry industry in the country. However, there are also several challenges and limitations that need to be addressed in order to fully exploit the potential of these feed resources. Some of the common problems include:

Limited knowledge and awareness: There is a general lack of knowledge and awareness among poultry farmers and stakeholders regarding the potential of non-conventional feed resources. Many farmers are not aware of the nutritious content and utilization methods of these resources, leading to underutilization or even wastage.

Lack of processing and preservation techniques: Non-conventional feed resources often require specific processing and preservation techniques to enhance their nutritional value and decrease any potential anti-nutritional factors. However, in Ethiopia, there is a lack of proper processing and preservation techniques for these resources, which limits their utilization.

Anti-nutritional factors: Some NCFR, such as crop residues and certain tree leaves, may contain anti-nutritional factors that can affect poultry health and productivity. These factors, if not properly addressed through processing or supplementation, can lead to reduced feed intake and nutrient utilization by the poultry. Anti-nutritional elements can be found in a lot of standard diets, but they are more prevalent in non-traditional feeds. Prior to utilizing the components in the diet, these anti-nutritional elements must be eliminated or rendered inactive through a variety of techniques [11].

Limited availability and seasonal variations: The availability of non-conventional feed resources can be limited, especially during dry seasons or in areas with low agricultural productivity. Additionally, the composition and quality of these resources may also vary seasonally, making it difficult to formulate consistent and balanced diets for poultry throughout the year.

Lack of infrastructure and storage facilities: In many rural areas of Ethiopia, there is a lack of adequate infrastructure and storage facilities for non-conventional feeds. Proper storage is crucial to minimize wastage and maintain the nutritional quality of these feeds.

Limited research and data: Despite the potential of non-conventional feed resources, there is a lack of sufficient research and data on their nutritional composition, digestibility, and potential usage in poultry diets. More research is needed to better understand these resources and their potential utilization in different poultry production systems. Addressing these tasks through investigate, extension services, and policy support can help unlock the full potential of non-conventional feed resources in poultry nutrition in Ethiopia. This would not only contribute to improved productivity and profitability in the poultry sector but also enhance food security and sustainable agricultural practices in the country.

5. Conclusion and Recommendation

Based on many research finding and review, many of plant leaf and seed materials and also agro industrial by product can securely and economically be comprised in to poultry ration under the current Ethiopian conditions. Therefore, researchers should trail and evaluate other alternative feed sources to fill the gap of demand and supply.

Author Contributions

Chala Edea Muleta is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Abd El-Hack, M., Alagawany, M., FaragM and Dhama K, 2015. Use of maize distiller's dried grains with soluble (DDGS) in laying hen diets: Trends and advances. Asian J. Animal. Veterinary. Advance. 10, 690-707.

[2] Atawodi, S., Mari, J., Atawodi and Yahaya, Y, 2008. Assessment of Leucaenaleucocephalaleaves as feed supplement in laying hens. African Journal of Biotechnology. 7: 317-321.

[3] Maurer V., Holinger M., Amsler Z., Früh B., Wohlfahrt J., Stamer A., Leiber F, 2016. Replacement of soybean cake by Hermetiaillucens meal in diets for layers. J Insect Food Feed. 2: 83–90.

[4] Shiferaw, B., Prasanna, B., Hellin, J. and Bänziger, M, 2011. Crops that feed the world. Past successes and future challenges to the role played by maize in global food security. Food security, 3: 307.

[5] Kanengoni, A., Chimonyo, M., Ndimba, B. and Dzama, K, 2015. Potential of using maize cobs in pig diets—A review. Asian-Australasian journal of animal sciences, 28: 1669.

[6] Ekeyem, B., Madubuike, F, and Dike, O, 2006. Effects of partial replacement of yam peel meal for maize on performance and carcass characteristics of finisher chickens. International Journal of Poultry Science, 5: 942-945.

[7] Murgato, G., and Korato, M, 2023. Effects of Locally Available Nonconventional Feeds for Nutritional Security of Ruminant Animals. Global Journal of Animal Scientific Research, 11: 56-66. Retrieved from http://www.gjasr.com/index.php/GJASR/article/view/181

[8] Kang, SW., Ponc, NG. and Oh, WY, 1995. Effect of Moistured Citrus Pulb on the Productivity of Pregnant Improved Native Chaju Cows. Journal of Agricultural Sciences, 1: 487-493.

[9] FAO (Food and agricultural organization). The state of food and agriculture, FAO 1985.

[10] Salem, H., Makkar, H and Nefzaoui, A, 2004. Towards better utilization of non-conventional feed sources by sheep and goats in some African and Asian countries. *Options Méditerranéennes: Série A*, *59*: 177-187.

[11] Abadi, N. A, 2018. Major non-conventional feed resources of livestock. *Int. J. Eng. Dev. Res*, *6*: 786-789.

[12] Melesse, A., Getye, Y., Berihun, K and Banerjee, S, 2013. Effect of feeding graded levels of Moringa stenopetala leaf meal on growth performance, carcass traits and some serum biochemical parameters of Koekoek chickens. *Livestock Science*, *157*: 498-505.

[13] Seyoum, B., Nemi, G. and Makkar, H, 2018. Ethiopian Feed Industry: Current status, Challenges and opportunities, Feedipedia, https://www.researchgate.net/publication/341453379

[14] Feyissa, F., Tolera, A., Deresse, A., Assefa, T., Geleti, G., and Alan Duncan, A, 2014. Assessment of livestock feed production and utilization systems and analysis of feed value chain in Jeldu district. ILRI, Addis Ababa, Ethiopia.

[15] Azene, Bekele, 1993. Useful Trees and Shrubs of Ethiopia. Regional Soil Conservation Unit (RSCU) and Swedish International Development Authority (SIDA), English Press, Nairobi, Kenya.

[16] Steinmüller, N., Sonder, K., Kroschel, J, 2002. Fodder trees research withMoringa stenopetala: a daily leafy vegetable of Konso people, Ethiopia. Challenges to Organic Farming and Sustainable Land Use in the Tropics and Sub-Tropics; Deutscher Tropentag, October 9–11, Witzenhausen. University of Kassel.

[17] Makonnen, E., Hunde, A., Damecha, G, 1997. Hypoglycaemic effect of Moringa stenopetala aqueous extract in rabbits. Phytother. Res. 11: 147–148.

[18] Aberra M, Workinesh T, Tegene, N, 2011. Effect of feeding Moringa stenopetela leaf meal on nutrient intake and growth performance of Rhode Island Red chicks under tropical climate. Tropical and Subtropical Agroecosystems, 14: 485-492.

[19] Abera, M., B. Michael and K. Holger, 2009. Evaluating the nutritive values and in vitro degradability characteristics of leaves, seeds and seedpods from Moringa stenopetala. J. Sci. Food Agr., 89: 281-287.

[20] Melesse, A., 2012. In vitro evaluation of utilizable crude protein using ruminal fluid in leaves, whole and seeds-removed pods of Moringa stenopetala and Moringa oleifera grown in the rift valley of Ethiopia. *Ethiopian Journal of Agricultural Sciences*, *22*: 62-72.

[21] Tesfaye, E. B., Animut, G. M., Urge, M. L. and Dessie, T. A, 2014. Cassava root chips andMoringa oleifera leaf meal as alternative feed ingredients in the layer ration. *Journal of Applied Poultry Research*, *23*: 614-624.

[22] Melesse, A., Masebo, M. and Abebe, A, 2018. The substitution effect of noug seed (Guizotia abyssinica) cake with cassava leaf (Manihot escutulata C.) Meal on feed intake, growth performance, and carcass traits in broiler chickens. *J. Anim. Hus. Dairy Sci*, *2*: 1-9.

[23] Melesse, A., Steingass, H., Boguhn, J., Schollenberger, M. and Rodehutscord, M, 2012. Effects of elevation and season on nutrient composition of leaves and green pods of Moringa stenopetala and Moringa oleifera. *Agroforestry systems*, *86*: 505-518.

[24] Cheru Tesfaye, Aberra Melesse, and Aster Abebe, 2018. Response of Broiler Chickens to Different Levels of Moringa stenopetala Leaf Meal as a Substitute for Noug Seed (Guizotia abyssinica) Cake on Growth Performance and Carcass Components. International Journal of Research in Agriculture and Forestry, 5: 1-9.

[25] Temesgen M, Retta N, Tesfaye E, 2017. Nutrient composition and digestibility of taro leaf in the diets of chicken and effects on the meat quality. *J Nutr Health Food Eng*. 2017; 7: 286–294. http://doi.org/10.15406/jnhfe.2017.07.00238

[26] Melesse, A., Alemu, T., Banerjee, S. and Berihun, K, 2017. The effect of the partial substitution of roasted soybean seed with graded levels of sweet potato (Ipomoea batatas) leaf meal on growth performances and carcass components of broiler chickens. *Asian-Australasian Journal of Animal Sciences*, 1-7.

[27] Chanjula, P., Wanapat, M., Wachirapakorn, C., Uriyapongson, S. and Rowlinson, P., 2003. Ruminal degradability of tropical feeds and their potential use in ruminant diets. *Asian-australasian journal of animal sciences*, *16*: 211-216.

[28] Solomon, D., 2020. Effect Of Partial Substitution of Maize With Potato Peel Meal On Production Performance And Carcass Characterstics Of Cobb-500 Broiler (Master Thesis, Jimma university).

[29] Netsanet, B. and Yonatan, K, 2015. Participatory evaluation of dual-purpose pigeon pea (Cajanus cajan) leaves for sheep feeding. *Journal of Biology, Agriculture and Healthcare*, *5*: 224-230.

[30] Asdesach, Ch., 2013. The Effect of Substituting Noug Seed Cake with Pigeon Pea Leaf on Feed Intake, Digestibility, Nitrogen Utilization and Growth in Sheep Fed a Basal Diet of Rhodes Grass Hay (Msc Thesis, Hawassa University).

[31] Chala Edea, 2020. Effect of Different Levels of Rice (Oryza Sativa) Bran Inclusion on Production Performance of Broiler Chicken. MSc Thesis, Jimma University, Ethiopia. 106.

[32] Beriso Ulo, Y., 2020. Effects of replacing maize with boiled mango (mangifera indica linn) seed kernel on the growth performances and carcass characteristics of broiler chickens (Msc Thesis, Addis Ababa University).

[33] Suma, N., Reddy, B. S. V., Gloridoss, R. G., Prabhu, T. M. Suresh, B. N. Jaishankar, N. Anitha, K. C, 2018. Gross efficiency of protein and metabolisable energy utilization of sugarcane press residue incorporated in Broiler and layer diets. Int. J. Poult. Sci. 52: 1185–1189.

[34] Mariye M, 2021. Effects of Dietary Inclusion of Sugarcane (Saccurum Officinarum) Filter Cake on The Productive Performances of Broiler Chickens (Msc Thesis, Addis Abab University).

[35] Solomon Demeke, 2007. Comparative nutritive value of Atella and industrial brewers grains in chicken starter ration in Ethiopia. Livestock Research for Rural Development, 19 2007.

[36] Ecocrop, 2011. Ecocrop database. FAO.

[37] Kuiper, L.; Ekmecki, B.; Hamelink, C.; Hettinga, W.; Meyer, S.; Koop, K., 2007. Bio-ethanol from cassava. Project number: PBIONL062937. Ecofys Netherlands BV, Utrecht.

[38] Iji PA., Bhuiyan MM., Chauynarong N., Barekatain MR and Widodo AP, 2011. Improving the nutritive value of alternative feed ingredients for poultry. Proceedings of the Recent Advanced in Animal Nutrition; Australia. 115–122.

[39] Khieu B., Chhay T., Ogle R. B. and Preston T. R. (2005) Research on the use of cassava leaves for livestock feeding in Cambodia. In: Proceeding of The Use of Cassava Roots and Leaves for On- Farm Animal Feeding, Hue, Vietnam; 20: 17 19.

[40] Okereke CO and Ukachukwu SN, 2005. Effect Of Dietary Inclusion of Composite Cassava Meal On Egg Production Charateristics Of Laying Hens. Student Thesis, Micheal Okpara University. Deparament of Non-Ruminant Animal Nutrution and Biochemistry; 1-38.

[41] Tekalegn Y., Etalem T., and Getnet A, 2017. Poultry feed resources and coping mechanisms of challenges in Sidama zone, southern Ethiopia.

[42] Etalem T, Getachew A, Mengistu U and Tadelle D, 2013. Nutritional Value of Cassava Root Chips and Moringa Oleifera Leaf Meal in Broiler and Layer Rations. PhD Dissertation.

[43] Diarra, S. S. and Usman, B. A, 2008. Growth performance and some blood variables of broiler chickens fed raw or boiled mango kernel meal. *International Journal of Poultry Science*, *7*: 315-318.

[44] FAO (Food and agriculture organization of the United Nations), 2015. Top producers of mangoes, mango stems and guavas.

[45] Fowomola, M. A., 2010. Some nutrients and antinutrients contents of mango (Magnifera indica) seed. *African Journal of Food Science*, *4*: 472-476.

[46] Diarra, S. S., Usman, B. A. and Igwebuike, J. U., 2010. Replacement value of boiled mango kernel meal for maize in broiler finisher diets. *Journal of Agricultural and Biological Science*, *5*: 47-52.

[47] Anon, 1967. The Mango Grading, Storage and Marketing. Handb Indian Counc Agric Res New-Delhi.

[48] Admasu, S., Wondifraw, Z. and Gash, M, 2020. Effects of replacing maize with boiled mango (Mangifera indica) seed kernel on feed intake, body weight gain and feed conversion ratio of Cobb 500 Broiler Chicken. *Poult. Fish. Wildl. Sci*, *8*: 211.

[49] Alemu Yami, 2008. Nutrition and Feeding of Sheep and Goats. In: Alemu Yami & Merkel R. C. (eds.) Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP). Addis Ababa.

[50] Igene, F. U., Isika, M. A. and Ekundayo, D. A, 2012. Replacement value of boiled pigeon pea (Cajanus cajan) on growth performance, carcass and haematological responses of broiler chickens. *Asian Journal of Poultry Science*, *6*: 1-9.

[51] Ali, S. T., Molla, B., Abto, A., Asres, Z., Liuel, Y. and Mesifen, L., 2020. Effect of feeding pigeon pea (Cajauns cajan) seed meal on nutrients intake and growth performances of Broiler chicken breeds. *Scientific Papers Animal Science and Biotechnologies*, *53*: 1.

[52] Abebaw, G., 2020. Review on: Its potentials and application of potato peel (waste). *Journal of Aquaculture and Livestock Production*, *1*: 1-4.

[53] Sultana, F., Khatun, H. and Ali, M. A., 2016. Use of potato as carbohydrate source in poultry ration. *Chemical and Biological Technologies in Agriculture*, *3*: 1-7.

[54] Sintayehu S., and Bekele, B. 2021. Effect of Various Levels of Sweat Potato (Hawassa-83) Leaf Meal on the Laying Performance and Egg Quality of Koekoek Dual Purpose Chicken. Poult Fish Wildl Sci. 9: 230.

[55] Van An L, Frankow-Lindberg BE, Lindberg JE, 2003. Effect of harvesting interval and defoliation on yield and chemical composition of leaves, stems and tubers of sweet potato (Ipomoea batatas L. (Lam.) plant parts. Field Crops Res 82: 49-58.

[56] Van An L, 2004. Sweet potato leaves for growing pigs: biomass yield, digestion and nutritive value [Doctor's dissertation]. Uppsala, Sweden: Swedish University of Agricultural Sciences.

[57] Tsega W, Tamir B. 2009. The effect of increasing levels of dried leaves of sweet potato (Ipomoea batatas) on dry matter intake and body weight gain performance of broiler finisher chickens. Livest Res Rural Dev 21: 208.

[58] Jalata, B., 2022. "Mini Review on Comparison of Production Process and Nutritive Value of Atella and Brewers' Grain; In Ethiopian Context." J Vet Sci Technol 13: 136.

[59] Suresh, B. N. and Reddy B. S. V, 2011. Dried Sugarcane Press Residue as a Potential Feed Ingredient Source of Nutrients for Poultry. Asian-Aust. J. Anim. Sic. 24: 1595-1600.

[60] Genetu, T. 2018. Composting and Characterization of Sugar Cane Filter Cake and Vinasse for Use as Organic Fertilizer. MSc Thesis Addis Ababa University, Addis Ababa, Ethiopia.

[61] Suresh, B. N. and Reddy B. S. V, 2012. Dried Sugarcane Press Residue as a Potential Feed for broilers. Int. J. Poult. Sci. 29: 755–862.

[62] Dhas, S. K. 2016. Effect of feeding different levels of rice bran on performance of broilers. Indian J Animal Nutr., 17: 333–335.

[63] Budeppa, H. B., Reddy, B. S. V., Singh, K. C. and Doss, R. G, 2008. Influence of sugarcane press mud on serum and plasma inorganic P in broilers. Ind. J. Anim. Nutr., 25: 93- 96.

[64] Central Statistical Authority/ CSA. 2012. Report on area and production of major crops. Agricultural sample survey 2011/2012 (2004 E.C), Volume 1: Addis Ababa, Ethiopia.

[65] Alewi, M; Edea, C; Demeke, S; Tesfaye, E, 2022. Effect of Different Levels of Rice (Oryza sativa) Bran on the growth Performance of Broiler Chicken. Greener Journal of Agricultural Sciences, 12: 120-130.

[66] Mussato SI, G Dragone, and IC Roberto, 2006. Brewers' spent grain: generation, characteristics and potential applications. J. Cereal Sci. 43: 1–14.