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Nutritional and industrial applications of broiler chickens feather – a review

Abu, M.H., Okolo, G.P. and Eboh, S.

Department of Animal Production, School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Nigeria

Corresponding Author: *matt4msp@gmail.com* ***Phone Number:*** *07035822611*

Target Audience: *Researchers, Livestock farmers and Feed Millers*

Abstract

Broiler chicken feather is one of the greatest protein-containing poultry by-products that has been scantily reused. Nigeria is reported to have the largest population of chickens in Africa. Consequently, enormous quantities of feathers are generated as by-products of the processing of these chickens. These feathers are often dumped at dump sites where they constitute environmental nuisance and thus pollute underground water. Broiler chickens feather has been reported to contain crude protein content of between 82-87% that could be incorporated into diets of broiler chickens as feather meal after subjecting them to appropriate processing procedures such as boiling at high temperature or enzymatic treatment in order to denature its anti-nutrient called keratins. The use of broiler chickens feather as organic fertilizer in crop production and as raw material in the textile industry has also gained relevance, especially in the developed world. This paper, therefore, reviews the nutritional potentials of broiler chickens feather in promoting better meat quality as well as other useful industrial applications that could enhance effective recycling of this major by-product of the poultry industry towards reducing or eliminating environmental pollution with the broiler chicken feathers.

Key words: *Broiler feather, poultry by-product, environment, meat quality*

Description of Problem

The growing demand for poultry meat has led to an increased production of broiler chickens (1). In the year 2015 alone, global production of meat from poultry stood at 100.6 million tonnes and this figure is expected to hit 143.3 million tonnes by the year 2030 (2). This increase in poultry production has led to a greater attention paid to the quality of meat and meat products produced (44). Consumers of poultry products play major roles in determining meat quality and their assessment of the quality of meat is based on organoleptic qualities such as taste, colour, juiciness, tenderness, aroma (56) or a combination of other quality indices such as water holding capacity, cooking loss, cooking yield, shear force and meat pH which are useful in determining the keeping value of such meat product (22). Recent research efforts seek to incorporate cheap, readily available and nutritionally rich alternative feed resources into livestock feed (49,50,55) These alternative feed resources may be byproducts of crop processing such as rice bran, maize offal, brewers dried grain, leaf meals or byproducts of animal processing such as feather meal, rumen content, broilers offal meal and bone meal among others.

Nigeria is endowed with the highest population of chickens in Africa with a population of 180 million chickens (7). Similarly, (20) reported that 24 billion chickens were produced globally in the year 2018 and about 2.4 million tonnes of chicken feather were produced that same year. These huge quantities of poultry feather produced globally often constitute environmental pollution (72). Attempt at proper disposal of this waste in most countries have often proved uneconomical (46). Despite their enormous nutrient content, feathers have gained little

nutritional application in livestock feeding (12). This is because the bulk of the proteins in broiler feathers are in the form of keratin which is of low solubility as a result of the presence of sulphur bonds between cysteine amino acids (12), making it a low quality feedstuff. Keratins in poultry feather can be degraded either through chemical treatments or by use of keratinases isolated from microbes. Over the years, several treatment options have been applied to poultry feather to improve its nutritional quality as a feed ingredient for livestock (35, 45, 60). Although chemical treatment suffices to degrade keratins in feather, keratinases isolated from microbes are more economical, biodegradable and gives better outcomes compared to chemical treatments (17). Keratinases are proteases operating within a wide range of temperatures and pH that are capable of hydrolyzing proteins by acting on keratins to degrade it (18).

The use broiler feathers as protein source in broiler feeding has been reported to improve carcass characteristics and meat quality attributes of broiler chickens (19, 20). This review is, therefore, aimed at investigating the nutritional potentials of broilers feather meal, especially as it affects carcass yield and meat quality attributes of broiler chickens.

Proximate Composition of Broiler Feather

Broiler feathers have immense nutrients that can be utilized by animals for optimum growth and development. The proximate composition of broiler feathers has been variously reported. (21) reported crude protein content of 82%, dry matter of 90%, crude fibre of 0.60%, ether extract of 6.1%, and ash content of 4.20% for boiled feather meal. (22) also, reported crude protein content of 33.98% for broiler feathers. A crude protein of 44.67% and 87.14% were reported for enzyme -treated and NaOH -treated feather respectively (23). The results of proximate composition of broiler feather (24) shows crude protein content of 78.88%, crude fibre content of 1.90%, Fat content of 2.13%, and Ash content of 0.95% for hydrolyzed feathermeal while (25) reported crude protein content of 82.36%, 2.15% crude fibre, 1.49% ash and 0.83% lipids. The variations in the proximate composition can be attributed to the different processing methods employed in converting the raw feathers into feather meals. The various results of the proximate composition of broiler feather indicate its high content of protein which makes it a potentially useful alternative protein feed ingredient that could be effectively substitute for other expensive protein feed ingredients such as fishmeal and soybean.

In contrast with carbohydrate and other nutrients, protein is the most expensive nutrient in livestock feed. Protein ingredients that are available for livestock feeding could be of plant or animal origin. As shown by their proximate compositions earlier, broiler feathers could be an efficient substitute for the conventional protein feedstuffs in livestock feeding. Plant sources of protein for livestock feeding include soybean meal, groundnut cake, cotton seed cake etc. These are expensive and have competing demands between humans and livestock. Fish meal, which is an animal source of protein for feeding livestock especially monogastrics often imparts a fishy smell on the animal product in which it was used. Broiler feathers becomes a readily available alternative as it is neither too expensive to obtain nor does it leave any residual smell on the animal product in which it was used.

Effects of Some Conventional Protein Feedstuff on Meat Quality of Broiler Chickens

Protein for poultry feeding could come from two sources. They could be from the conventional feed ingredients and from non-conventional or alternative sources. Conventional protein feed ingredients include but not limited to soybeans, groundnut and fishmeal. The unconventional sources could come from byproducts of industrial processing or byproducts of agricultural processing (8).

The effects of different conventional and unconventional protein feed ingredient on carcass characteristics and meat quality of broiler chickens have been variously investigated. In Nigeria, Fish meal, Soybean meal and Groundnut cake constitute some of the most expensive protein feed resources that constantly drains farmers' budget. In nutritional trials, where they were used, their influence on meat quality attributes of chickens have been shown in different perspectives.

Effects of Fishmeal on Meat Quality Attributes of Broiler Chickens

Fishmeal is regarded as one of the richest protein feed ingredient with good nutrient profile that promotes optimal growth and reproductive performances in broilers and laying hens (26). Despite its immense nutrient profile, existing fishing laws in several countries coupled with its high demand for human consumption makes this product scarce and where available, it is very expensive (27). In a study to investigate the use of fishmeal as a protein concentrate in broilers, (28) reported that fishmeal did not produce any marked effect on the tenderness and juiciness of broiler meat but imparted a characteristic fishy odor on the broiler meat with increasing inclusion levels of the fish meal in diets. This author recommended withdrawal of fish meal from the diet of broilers a few days before slaughter in order to get rid of fishy odor from the final product. Although fishy odor is undesirable to consumers, total withdrawal of fishmeal from diets of broilers at the finisher stage led to a decrease in the percentages of cut-up parts such as breast, wings, thighs and drumstick in contrast with birds in which fishmeal was not withdrawn (29). The authors suggested that optimum weights of these cut-up parts can be maintained provided there is ample supply of protein from other non-animal origins. In another study, (30) reported that there were no differences observed in carcass characteristics of broilers which were fed Tilapia Meal (TM) with regards to the live weight, thigh, drumstick, and breast meat across all treatment groups. These authors also reported that there were no significant differences in the sensory attributes of the meat although the tasters showed a general likeness for the meat of the birds fed TM compared to the meat without TM. Similarly, in a study to investigate the effects of Tilapia Byproducts Meal (TBM) as replacement for soybean meal, it was observed that TBM can partially replace soybean meal in diets of broilers up to 50% without adversely affecting carcass quality of broilers meat (31). Information about the sensory attributes of the broilers meat was, however, not provided by the workers. Also, a fishmeal inclusion level of 0.5% along with bloodmeal of 1.5% in diets of broiler finishers was reported to have produced significant difference ($P<0.05$) on live weight compared to increasing their inclusion levels to 2% (32). However, the authors also observed that there were no significant differences on carcass yield and internal organs of the broilers fed up to 2% inclusion levels of both blood meal and fish meal. In some instances, treatment methods for feed ingredients may not influence greatly on the meat quality attributes especially as it relates to fat deposition and cholesterol levels. According to (33), serum cholesterol levels of broiler chickens fed fish Fermented by Lactic Acid bacteria did not differ from that of those fed fishmeal without lactic acid fermentation.

Effects of Soybean Meal on Meat Quality Attributes of Broiler Chickens

Soybean Meal is another commonly used conventional feed ingredient and probably the most widely used protein feed ingredient. The major byproducts of industrial processing of soybean seeds are cakes and soy oil. The cake, otherwise known as soybean meal (SBM) is channelled to livestock feeding while soy oil is useful in confectioneries and for domestic use as cooking oil. Globally, the use of soybean meal in livestock production indicates that 3% of global production is used as pet food, 5% in the dairy industry, 10% in the beef industry,

26% in the swine industry, 54% in the poultry industry and 2% of soybean meal is used in other industries (34). Like most other agricultural seeds, soybeans contain some anti-nutrients which could be detrimental to animals if not degraded. One of the major anti-nutrients in soybean is trypsin inhibitors. Trypsin inhibitors which are sufficiently present in raw unprocessed soybeans can depress growth performance and meat quality attributes of broiler chickens if fed to broilers without any form of processing (35). The activity of trypsin inhibitors in soybean seeds can be minimized through moderate heat treatment without denaturing the solubility of essential proteins (36). The effects of different forms of soybean meal on meat quality attributes of broiler chickens have been well documented. According to (37), Soybean Meal in diets of broilers led to an increased thigh and breast meat on day 49 in broilers compared with treatment groups which were fed Poultry By-Product Meal (PBPM). Mean weight of breast meat was reported to have decreased with increasing levels of PBPM in contrast with those of birds fed Soybean meal in their diets. Soybean processing has also been shown to impact on some meat quality attributes of broiler chickens. In a study to investigate the effect of Germinated and Fermented Soybeans (GFS) on meat quality of broilers, (38) reported that GFS significantly decreased ($P<0.05$) total blood cholesterol and cooking loss in chicken breast muscle but had no effect on meat pH and colour. Soybean seeds have been reported to possess anti-oxidative properties which can positively impact the quality of broilers meat by causing a reduction in meat drip loss (39). Similarly, (40) reported that Fermented Soybean Meal (FSBM) used as a partial replacement for Soybean Meal significantly ($P<0.05$) influenced meat colour, pH, nutritional composition and antioxidant properties of broiler chickens meat. Dietary inclusion levels of 2.5%, 5% and 7.5% had the greatest influence on the above mentioned meat quality attributes. The authors further reported that all substitution levels of FSBM did not produce any significant effect ($P>0.05$) on carcass weight, carcass yield, breast meat, and abdominal fat percentages. Other meat quality attributes like shear force, cooking loss and cooking yield were not adversely influenced by the FSBM substitution for SBM. Because of its rich protein content, soybean is also useful in human nutrition for the production of many cherished products. One of such products is soymilk. The byproduct of soybean processing into soymilk, the soy fibre has also been reported to contain essential nutrients that can influence growth performance and meat quality attributes of broiler chickens (41). In a study to investigate the effect of substituting Soybean Meal with Soymilk Waste (SMW), (41) showed that substitution levels up to 15% did not cause reduction in meat pH, Water Holding Capacity, Cooking Loss and Meat tenderness.

Effects of Groundnut Cake on Meat Quality Attributes of Broiler Chickens

Groundnut is another protein-rich feed ingredient that is commonly used in poultry. Its crude protein content is similar to that of soybean meal. Groundnut cake is highly susceptible to attack by toxic fungal agents leading to the production of mycotoxins (42). Aflatoxins are the major mycotoxins affecting protein feedstuffs (43). The impact of aflatoxins on groundnut is exacerbated by humid conditions and improper storage temperatures peculiar to the tropics (42). Consequently, additional farm budget is expended on purchase of mycotoxin binders, majority of which have been reported to cause undesirable health effects in humans and animals especially when used at higher levels in feed and food of animals and humans respectively (43,44). However, the influence of groundnut cake on meat quality attribute of broilers has been well reported by different workers. Ademulegun et al. (45), further showed that broiler chickens fed up to 25% groundnut cake in their diets had significantly

better ($P<0.05$) breast meat, wing and back meat under Late Dry Season rearing period. Better weights were also reported for other primal cuts within this period compared to the Late Wet Season rearing period. Owing to their similar protein content, groundnut cake and Soybean Meal are often used interchangeably in broiler diets. In a study to compare the effects of groundnut cake and soybean meal, (46) showed that broilers fed SBM had better live weight, carcass weight and dressing percentage. However, the authors observed that weights of internal organs were better in birds fed groundnut cake-based diets compared with those fed SBM-based diets. High-Oleic Peanut (HO-PN) diets were also reported to have significantly lowered live weight, carcass weight and weight of breast pectoralis major muscle in broiler chickens (47). The authors also showed that saturated and trans-fatty acid content of breast meat was significantly lower in birds fed the HO-PN diets. Similarly, (48) further revealed that powdered Peanut Skin increased the percentage of breast meat at week 6 but decreased the percentage of high density lipoprotein cholesterol. The sensory attributes as well as the Water Holding Capacity of the broilers' meat were, however, improved by supplementation of Peanut Skin in the broilers diets.

Methods of Processing Broiler Feather into Feather Meal

Useful proteins in broiler feathers can be harnessed for utilization by animals for proper growth and development. The high protein levels in broiler feathers make it a suitable substitute for expensive conventional protein feedstuff such as fish meal without any adverse effect on broilers growth and development (49). However, these proteins are present in the form of keratins which have poor digestibility when fed to animals (13, 50). Broiler feather is also reported to be deficient in Methionine, Histidine and Tryptophan (51), although the methionine deficiency in feather meal can be accounted for by its high content of cystin (49). In order to improve its digestibility, several processing methods have now been developed. Raw feather may be hydrolysed before being fed to animals. Hydrolysis involves cooking or boiling broiler feathers under elevated temperature and pressure; the heated product is then dried, ground into finer particles and used for feeding livestock (14, 21). It is believed that this heat processing partially breaks the keratin bonds in feather and makes it more digestible in livestock. However, this method is accompanied with emission of excess heat into the environment (52, 53, 54). Broiler feathers may also be chemically treated through a combination of techniques involving the use of acids (sulfuric acid, aluminium, sulphate) and heat treatment. The chemically treated feather is then rinsed severally (with water), dried, milled and made ready for use (55). Feather keratins can also be degraded through the use of microorganisms which possess keratin degrading properties. Certain strains of bacteria and fungi have been reported to possess keratinolytic properties and are therefore, capable of degrading feather keratins and converting them into more digestible forms (56, 57, 58). In this method, the microorganisms are isolated and cultured and their cultures are used to produce enzymes that break down feather keratins. Processing or treatment of broiler feathers with microorganism cultures is considered to be economical and produces better outcomes compared to hydrolyzing or chemical treatment (17)

Broiler Feather Meal and Meat Quality

In contrast to fishmeal, soybean meal and groundnut cake, broiler feathers are cheaper and has no competing demands between humans and livestock. Up to this time, there is no documented report about any major mycotoxic agent associated with broiler feathers which could affect humans when fed to livestock. As shown in the earlier section, the nutrient content of broiler feathers makes it a ready option to the conventional feedstuff

which are often expensive and whose continual usage in broiler nutrition has often proved expensive.

Broiler feathers are fed to livestock in the form of feather meal. Feathermeal has been reported to affect carcass characteristics and meat quality of broiler chickens in different forms. According to (19), better carcass yield and primal cuts were obtained from broilers fed feather meal supplemented with protease enzyme in comparison with those fed hydrolyzed feather meal. Similarly, when hydrolyzed broiler feathers meal (HBFM) and broiler offal meal (BOM) were combined and fed to broiler chickens, better edible portions of carcass were observed. There was also a reduced build-up of abdominal fat in birds fed HBFM and BOM compared with birds in the control (59). Cholesterol is an amphibatic lipid and a major component of the cell membrane and lipoproteins. In the blood, cholesterol is the precursor of corticosteroids, sex hormones, bile acid and vitamin D (26). Excess cholesterol in meat is considered undesirable to human consumers because it could lead to the buildup of atherosclerosis in blood vessels resulting to life-threatening cardiovascular ailments (60). Meat and meat products with lower fat content pose lesser risks of cardiovascular ailments and are more preferable option especially for health conscious consumers (61). The acceptable cholesterol range of broilers meat is reported to be in the range of 128 – 140mgdL^{1} (62). Values below or within this range are tolerable by human consumers of poultry meat while values greatly exceeding this range may be detrimental to health. The type of feed fed to animals has the capacity to modify blood cholesterol levels in them and to maintain it within acceptable range. According to (22), broilers fed Chicken Feather Meal (CFM) in their diets had lower mean blood cholesterol levels compared to those that were not fed CFM. The authors showed that the values obtained in their study were lower than the normal cholesterol range indicating that CFM possesses the ability to regulate blood cholesterol levels in broilers. Broiler feathers could also be fermented prior to feeding them to chickens. Fermentation has been linked with improvement in the feeding value of unconventional feedstuff (63). Fermented feedstuffs contain useful probiotics which improves gut health and promotes digestion (64, 65). In a study with Fermented Chicken Feather (FCF), Bidura and Partama (66) showed that broiler chickens fed FCF up to 5% inclusion levels in their diets had lower abdominal fat as well as total cholesterol levels compared to those in the control group that received no FCF in their diet. Hydrolyzing of boiling of chicken feather as observed earlier shows promising potential to make essential feather proteins available for broilers to utilize. In a study with hydrolyzed feather meal, it was observed that the carcass attributes of broilers fed hydrolyzed feather meal with or without protease supplementation was comparable with those of birds which were not fed feather meal on the bases of live weight, dressed weight, dressing percentage, breast, thigh and drumstick (19). Similarly, protease enzyme supplementation in broilers diet was reported to have resulted in better carcass yield whereas birds which were fed poultry byproduct meal (PBM) with or without protease supplementation had significantly lower breast meat yield (67).

Non-Nutritional Uses of Broiler Feathers

Broiler feathers can be applied to a variety of uses and technologies for value-added products or as raw material for useful industrial products, thereby reducing the incidence of pollution and disease transmission (34). Broiler feathers can be used as an insulating material for the industrial production of winter clothing (69). In a study to investigate the possibility of the use of chicken feathers as filling material in winter outerwear, the authors reported that fibre obtained from chicken feather showed better heat-resistance property compared to filling materials of synthetic sources. The

authors also noted that feathers from broiler chickens could provide a cheaper source of raw material for the industrial production of winter clothes compared with synthetic fibre. Better insulating property is obtained when chopping into smaller portions is avoided as this greatly reduces the insulating ability of broiler feathers used as industrial raw materials in the textile industry (68). Due to the immense protection it provides against cold, the use of chicken feather is further reported in its application as a useful material for making coats, jackets, protective clothing for mountain climbers and bedding materials (69).

Broiler feathers can also be treated and used as organic fertilizers. The use of organic fertilizer prepared from chicken feathers was reported to have increased the growth of *Vigna unguiculata* when applied at 3kg/10kg of soil (70). Similarly, (71) reported that Treated Poultry Feather Waste (TPFW), improved the growth rate of plants, resulted in a greener colour of the leaves, increased plant height and resulted in improved weight. The authors also showed that TPFW resulted in increase in the number of leaves per plant. Number of leaves per plant is usually perceived as a sign of better yields in plants. In their study, the number of plant stands was shown to increase with increasing application rates of TPFW. In another study by (72), the use of broiler feathers as liquid fertilizer when subjected to Sub Critical Water (SCW) treatment was reported. The SCW feather treatment was shown to have produced positive effects on the plants. The authors reported an increase in plant height, plant length, plant width and number of leaves when applied to spinach plant. Sub Critical feather treatment was also described to be a more eco-friendly means of treating poultry feathers compared to hydrolyzing which involves the use of higher temperatures and organic fertilizers derived from this treatment were recommended to be more useful in propagation of leafy vegetables because of its positive influence on the growth of such plants.

Conclusion and Applications

It can be concluded from this review that:

1. Broiler feather accounts for a greater percentage of waste generated from poultry slaughterhouses. Despite its rich protein content, they are often left to litter about the environment, thereby constituting environmental pollution.
2. Incorporation of broiler feathers into livestock feed particularly the feeding of broiler chickens, is an effective means of reducing its environmental nuisance.
3. The chief anti-nutrients in feathers are keratins which can be effectively degraded by several processing methods such as boiling or steaming, chemical treatment and enzymatic degradation. Of all these techniques, enzymatic degradation of keratins through the use of microorganisms is the most economical because it is cheaper and does not involve the use of hazardous chemicals nor does it involve generation of excess heat to the environment.
4. Considering the high cost of conventional protein feedstuffs such as groundnut cake, soybean meal and fishmeal, broiler feathers can be effectively used as a cheaper replacement for these expensive protein feedstuffs. This is because broiler feathers are easy to obtain and does not cost much to process into edible meal for feeding monogastrics.
5. Broiler feathers are a rich protein feedstuff that can be potentially utilized across all facets of livestock feeding for proper growth and development in order to produce wholesome animals and animal products such as meat, milk and eggs.
6. More feeding trials could help to provide useful information on the effects of feather meal on performance and carcass attributes of broiler chickens. This will increase awareness on the usefulness of broiler chickens feather as a cheaper animal protein source thereby reducing environmental nuisance posed by

indiscriminate disposal of broiler feathers and hence contribute to effective recycling of this protein-rich poultry by-product.

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