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Effect of Incorporating Cowpea (*Vigna unguiculata*) Meal into Broiler Diets on Environmental Pollution by Nitrogen from Poultry Excreta: A Review

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Abstract

Poultry feeds are formulated using soybean meal and animal by-products as sources of protein. Animal proteins like fish meal, blood meal, meat and bone meal are being shunned in formulating poultry feeds nowadays because they are associated with zoonotic diseases like salmonellosis and this has left soybean meal as the only source of dietary protein in broiler feeds. Soybean meal is in short supply in Zimbabwe and this country is relying on some soybean meal imports from South Africa and Zambia resulting in prices of poultry feed and broiler meat going upwards. Cheap and locally available alternative sources of protein to soybean meal must be found in order to reduce the cost of making poultry feed. The selected alternative source of protein must have protein which is highly digestible such that the bulk of this protein can be metabolized and utilized by broilers to synthesize meat leaving a little of it to be excreted through faeces and urine. Highly digestible protein is very important in broiler feed making because this reduces the amount of nitrogen lost through poultry excreta into the environment. Cowpea has been chosen to entirely or partially replace soybean meal in this review paper because it is locally grown, drought tolerant, cheap and its true protein digestibility (TPD) of 71% to 76% is generally comparable to 81% to 83% of soybean meal. Nowadays, people are concerned about protecting the environment from being polluted by wastes from industrial and agricultural activities. Poultry farming pollutes the environment with ammonia emitted from poultry excreta. The grain legumes used in formulating broiler feed such as soybean meal contain anti-nutritional factors which reduce protein digestibility and increase nitrogen excretion through poultry faeces. The nitrogen in faeces is volatilized into ammonia, emitted into the atmosphere and cause eutrophication of surface

waters. Therefore, the effect of incorporating cowpea meal in broiler diets on environmental pollution by nitrogen excretion from broiler faeces needs to be explored.

Keywords

Ammonia, Emission, Eutrophication, Diseases, Poultry, Pollution

1. Introduction

Soybean meal is the major source of dietary protein in poultry feeds [1]. Soybean meal contains an average of 44% crude protein (CP) which has a true protein digestibility (TPD) of 81.1% to 83%. Nyoni, 2021 [2] reported that overreliance on soybean meal as a conventional source of dietary protein in poultry feeds is becoming problematic because there is a shortage of this commodity in Zimbabwe which is evidenced by inadequate soybean harvests of 140,763 metric tons (MT), 47,755 MT and 71,300 MT which were harvested in years 2001, 2016 and 2022, respectively against a national requirement of 600,000 MT for industrial oil expressing and 240,000 MT needed for livestock feed manufacture.

Zimbabwe Poultry Association, 2019 [3] claimed that the phenomenal growth of the broiler industry in Zimbabwe which is characterized by an increase in the annual output of broiler chicks produced by local chick producers from 18 million chicks and 91 million chicks in years 2009 and 2020, respectively (shown on Figure 1) is causing a concurrent increase in the quantity of broiler feed being manufactured resulting in Zimbabwe increasing its imports of soybean meal from neighboring countries namely Zambia and South Africa to be more specific. The shortage of soybean meal in Zimbabwe is triggering a price increase for this commodity on the market which ultimately increases the cost of making poultry feed [2]. There is need to look for alternative vegetable protein sources to soybean meal which are locally available, cheap and drought tolerant.

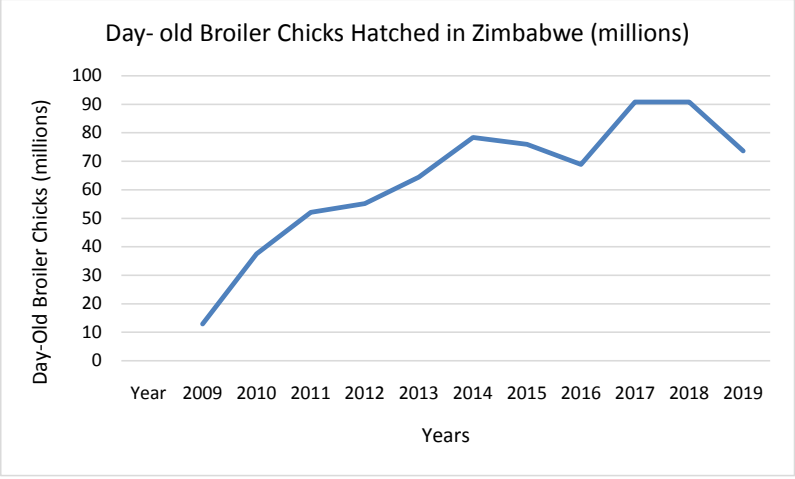

Figure 1. Day-old broiler chicks produced in Zimbabwe ZPA, 2019 [3].

The use of plant-sources of protein in the manufacture of feed for monogastric animals is limited because they contain anti-nutritional factors such as protease inhibitors, tannins and lectins which reduce the digestibility of protein by poultry [4]. Zhao *et al.* 2014 [5] emphasized that crude protein consumed by poultry is metabolized and used to build meat and eggs with the undigested component being excreted as uric acid and faecal nitrogen. Uric acid is easily volatilized into ammonia while faecal nitrogen is mineralized by microorganisms to produce ammonia. Improper disposal of poultry manure results in the washing away of this waste by rain water into open water bodies [6]. The nitrogen lost from manure in form of ammonia is emitted into the atmosphere.

Ammonia emitted into the atmosphere reacts with nitric and sulphuric acid to form haze which affects visibility [6]. Sheikh *et al.* [6] reported that when ammonia combines with moisture it forms ammonium nitrate which is deposited on open water bodies which causes eutrophication (oversupply of nutrients in coastal waters resulting in overgrowth of harmful algal blooms). Nitrogen washed by run-off water is also deposited into coastal waters leading into the formation of harmful algal blooms. Nitrogen leached from poultry manure contaminates underground water. United Nations Department of Economic and Social Affairs, 2021 [7] in its Sustainable Development Goal number 14 stated that eutrophication causes abundant growth of harmful algal blooms which prevents sunlight penetration to bottom aquatic plants thereby preventing them from photosynthesizing. This results in depleted dissolved oxygen in open water bodies. When algal blooms die, they decompose using dissolved oxygen leaving water with a deficiency of oxygen. United Nations Department of Economic and Social Affairs, 2021 [7] reported that areas that lack oxygen (Dead Zones) increased from 400 to 700 in year 2008 to year 2019, respectively. Eutrophication results in depletion of dissolved oxygen, fish kills, sea grass die-off, loss of coral reef and near shore hard-bottom habitats and health hazards to swimmers and fishers. United Nations Department of Economic and Social Affairs, 2021 [7]'s Sustainable Development Goal number 14 recommends us to protect coastal waters from land-based pollutants such as plastic pollution, nutrient and sewage run-off since these negatively affect coastal habitats and communities.

Cowpea meal is being recommended to be tried as an alternative to soybean meal in broiler feed manufacture in this review paper because cowpea is locally grown, cheap and is adapted to the semi-arid climatic conditions of Zimbabwe since it is drought tolerant [8]. Cowpea is also a low-input crop which is grown by majority of the farmers across the breadth and length of the country. Cowpea has a similar amino acid profile to soybean but is low in sulphur containing amino acids [9]. Its protein digestibility of 71% to 76% is comparable to 81.1% - 83% of soybean meal [10] [11].

The objective of this review is to evaluate the effect of replacing soybean meal with cowpea meal in broiler diets on protein digestibility, nitrogen loss through faecal material and ammonia emitted into the atmosphere from poultry manure.

2. Broiler Industry

The broiler industry is growing phenomenally from period to period due to increased demand for protein mainly caused by spiraling population growth, increased disposable incomes, low chicken prices relative to those for competitive meats and dietary preferences [12]. Food and Agriculture Organization, 2021 [13] emphasized that poultry meat consumption will increase by 2.5% per annum up to year 2030 globally, while other types of meat will grow at 1.7% or less but production in developing countries alone is expected to have an average growth of 3.4% per annum up to year 2030. Food and Agriculture Organization, 2021 [13] claimed that in year 2013 poultry meat consumption was around 15 kg per person per annum on a ready-to-cook weight and predicted that by year 2023 each person will consume an average of 17 kg. According toSukume and Malemi, 2012 [14] each Zimbabwean used to consume 13 kg of beef annually in the 1980s and this has dropped to a mere 3.3 kg, the lowest in the region. Chicken and pork replaced this gap because of their relative cheapness in comparison to beef. Zimbabwe Poultry Association, 2019 [3] revealed that in year 2009 Zimbabwe produced 12.9 million broiler day-old chicks and production rose to 78.8 million day-old chicks in year 2016. Zimbabwe Poultry Association, 2019 [3] reported that Zimbabwe's poultry industry recorded a 32% jump in output, producing 90.8 million day-old broiler chicks in 2018, the highest since 2014 (as shown on **Figure 1**). This increase in the number of broilers being produced should be complemented by a proportional increase in the quantity of broiler feed produced.

3. Broiler Feed in Zimbabwe

Broiler feeds are mainly comprised of ingredients which are rich in protein and energy [15]. Protein can either be of animal origin (fish meal, meat and blood meal) or plant origin (soybean meal, cotton seed meal, alfalfa and sunflower meal). However, each of these protein feedstuffs should be used in a specific amount in the diet and should be mixed with other protein sources [16]. Akanji *et al.* 2012 [9] claimed that mixing of a variety of protein-feedstuffs helps to achieve the target protein concentration with better amino acid profile. In addition to the target protein concentration, mixing of different protein-rich feedstuffs get rid of production and health problems associated with using only one protein source in excess of the recommended level e.g. addition of more than 25% and 20% soybean meal in broiler starter and finisher diets may cause faecal pasting around the vent. This leads to renal dysfunction due to retention of urates which interferes with passing of the droppings.

Akanji *et al.* 2012 [9] reported that there are many alternative plant, protein sources to soybean meal but the suitability of a feedstuff to be used in broiler diets depends on its availability, price and nutritional value. Oilseeds such as cottonseed and sunflower, and legume grains such as beans, peas and cowpeas are potential sources of plant protein in broiler diets [4].

3.1. Soybean (Glycine Max)

Soybean is a leguminous crop which grows better in well drained soils with an average of 20% clay [17]. It is affected by soil acidity. Chifamba, 2010 [17] claimed that optimum soil pH for the crop is 5.5 - 7 (on $CaCl_2$ scale). The crop yields reasonably in areas which receive more than 700 mm of rainfall annually [18]. Crop yields decline as rainfall distribution becomes poor which means that it cannot be grown in semi-arid areas of Zimbabwe [17]. Hot areas such as Agro-Ecological regions 4 and 5 can only grow this crop successfully under irrigation [17]. SNV-Zimbabwe, 2009 [19] emphasized that soybean productivity in Zimbabwe is low (1.55 tons/hectare) compared to 3.4 tons/hectare of producing countries such as Argentina. Fast Track Land Reform Programme, droughts and retained seed are some of the factors that affect soybean productivity in Zimbabwe [20].

Nyoni, 2021 [2] reported that the current production levels of 71,000 metric tons of soybean does not meet the national requirement of 240,000 metric tons per year for stock feed manufacture and 600,000 metric tons for oil processing. To compensate for the shortfall, Zimbabwe is importing 60% - 70% of its soybean requirements from South Africa, Malawi and Zambia [20].

3.2. Cowpeas (*Vigna Unguiculata*)

Cowpea is a leguminous plant with either trailing or upright growth habit [20]. It can be used as food for both humans and livestock [8]. Its origin is not exact due to lack of archaeological evidence [20]. Contradicting views claimed Africa, Asia and South America as continents of origin. Wakibia, 2015 [8] reported that cowpea is believed to have originated from West Africa since both wild and cultivated cultivars are still found in this area.

Cowpea is a heat-loving and drought tolerant crop [8]. The optimum temperature for germination is 8.5˚C whilst the best temperature for growth and development is 30˚C. Cowpea grows best during summer and is not tolerant of cold soils. The optimum sowing period is December to January [21].

It can grow under rainfall ranging between 400 mm - 700 mm per annum [21]. Cowpeas are drought tolerant and can utilize soil moisture more efficiently than soybean, groundnuts and sunflowers [21] Cowpeas counteract moisture stress through limiting growth and reducing leaf area by changing leaf orientation and closing stomata [21]. Flower and pod abscission help cowpeas crops to cushion themselves against moisture stress [21].

Cowpea grains contain 20.91% crude protein when compared to 37.08% of soybean grains [9]. Cowpea has a similar amino acid profile to soybean meal and its true protein digestibility of 71% - 76% is comparable to 83% of soybean [22].

However, cowpea like any other grain legume contain anti-nutritional factors which negatively affect protein digestibility by broilers and result in excretion of nitrogen through faeces leading to environmental pollution by ammonia emitted from fowl runs.

4. Ammonia

Ammonia (NH_3) is a colorless gas with a pungent smell [5]. Zhao *et al.* 2014 [5] reported that ammonia can be smelt at 5 - 18 parts per million (ppm) and can be a health hazard to both humans and animals. Sheikh *et al.* 2018 [6] and [23] claimed that ammonia can either occur naturally or be caused by human activities (anthropogenic). Sheikh *et al.* 2018 [6] asserted that ammonia is produced by either biological decomposition of organic matter or produced by industrial activities such as fertilizer, fuel and refrigerants production as shown by **Figure 2**.

4.1. Ammonia Formation in Poultry Facilities

Zhao *et al.* 2014 [5] claimed that poultry consume protein and other forms of nitrogen in feed to produce meat and eggs but only utilize less than 50% of this nitrogen with 50% - 80% of the total consumed nitrogen lost in excreta (faeces and urine). Uricase enzymes convert uric acid into urea and urease enzymes change urea into ammonia and carbon dioxide [6]. Zhao *et al.* 2014 [5] and Sheikh *et al.* 2018 [6] reported that microorganisms biologically decompose faecal nitrogen to produce ammonia. The process of ammonia formation is greatly influenced by temperature, pH, moisture and nitrogen concentration in litter [5]. High temperature and wetness of litter promote the growth and multiplication of microorganisms which speed up the decomposition of poultry manure [5]. Sheikh *et al.* 2018 [6] claimed that acidity negatively affects growth of ammonia, forming microorganisms while pH values greater than 8.5 favors the growth and multiplication of microorganisms.

4.2. Impact of Ammonia to Poultry

Sheikh *et al.* 2018 [6] reported that ammonia levels greater than 25 ppm can negatively affects production traits of broilers, poultry health and cause high bird mortalities. Sheikh *et al.* 2018 [6] claimed that ammonia damages the mucous membranes of the respiratory tract of broilers thereby exposing the broilers to respiratory infections such as Newcastle disease. Ammonia can also cause ascites, breast blisters, feet burn and eventually death to broilers [6]. Ammonia can also results in carcass condemnation after slaughter [6].

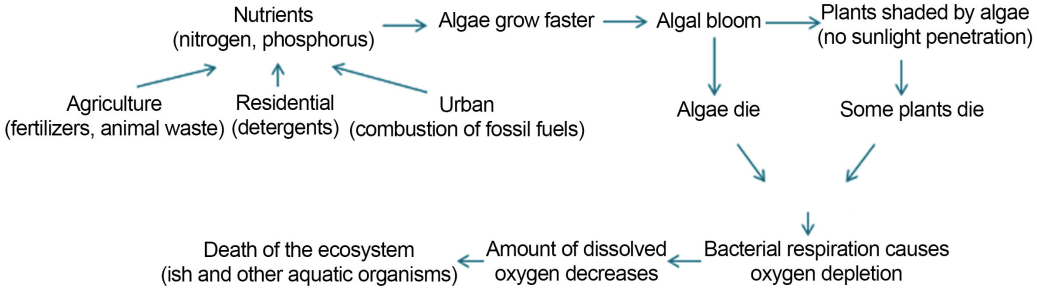

Figure 2. Eutrophication and its Effects to Fish.

4.3. Impacts of Ammonia to Human Beings

Reference [5] asserted that ammonia damages the mucous membranes of the respiratory tract leading to infection of the trachea and air sacs by microorganisms causing tracheitis and airsacculitis. It also irritates the eyes causing eye conjunctivitis.

4.4. Effect of Ammonia to the Environment

Zhao *et al.* 2014 [5] and Sheikh *et al.* 2018 [6] reported that when ammonia is emitted into the atmosphere it reacts with rain to form acid rain or ammonium nitrate which is ultimately deposited on soil, open water bodies and vegetation. Ammonium nitrate or ammonium sulphate deposited on soil and water causes soil acidification and eutrophication, respectively [6]. Ammonium nitrate or sulphate which is deposited on vegetation causes extensive growth and dominance of fast growing plant species in the expense of slow growing plant species resulting in a great change to the ecosystem [5].

Eutrophication (shown on **Figure 2**) refers to the over enrichment of open water bodies with nitrates and phosphates which results in overgrowth of harmful algal blooms (HAB). When these HABs die they use and exhaust dissolved oxygen when they decompose [6]. Depletion of dissolved oxygen result in massive fish kills since fish which love cool temperatures (bottom dwellers) relocate from oxygen-deficient bottom waters to oxygen rich surface waters but will eventually die because the temperatures at surface waters are high.

Ammonia reacts with small particles in air with an aerodynamic size less than 2.5 to form particulate matter 2.5 (PM 2.5) which cause respiratory infections in both humans and animals and also form haze and affects atmosphere visibility [5].

5. Conclusion

Crude protein in broiler feeds is traditionally supplied by soybean meal but soybean meal is scarce in Zimbabwe nowadays. Shortage of soybean meal is inviting loud calls from farmers and environmentalists who are urging researchers to conduct studies to search for alternative vegetable protein sources to soybean meal which are grown locally, cheap, drought tolerant, with highly digestible protein and environmentally friendly [6] [22].

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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