Mini-Review

The Effect of Citric Acid on Feed Intake, Body Weight Gain and Body Linear Measurement Traits on Indigenous Chickens- A Review

Zulu Blantina Fangele, Tyasi Thobela Louis, Gunya Busisiwe*

Agricultural Economics and Animal Production, University of Limpopo, Private Bag X1106, Sovenga, 0727, South Africa.

Abstract | The indigenous chickens are known to be economically, socially, and culturally important to the people of Africa, especially those from marginalised communities. Although these chickens are associated with poor productivity in terms of the number of eggs laid, most consumers prefer their flavoursome meat. Despite that, there has been a research gap in the genetic, physiological, and nutritional aspects of indigenous chickens of Africa over the past decade. The use of citric acid has higher economic potential owing to its numerous applications to chickens. This article critically reviews a detailed understanding of the description, advantages and limitations of using citric acid on indigenous chicken. Several studies have been conducted on the nutritional requirements of local chickens, but the results were inconclusive and contradictory. This review concludes that indigenous chickens play a significant role in improving livelihoods, and strategies to preserve and sustain them must be intensified. However, it has been well established that citric acid can acidify the gastrointestinal tract of the chicken which improve the feed intake, furthermore, they improve the growth performance of the chicken including the body weight gain and body linear measurements.

Keywords | Organic acid, Nutrition, Performance, Production, Chickens.

Received | October 26, 2021; **Accepted** | December 11, 2021; **Published** | March 10, 2022
***Correspondence** | Gunya Busisiwe, Agricultural Economics and Animal Production, University of Limpopo, Private Bag X1106, Sovenga, 0727, South Africa;
Email: Busisiwe.Gunya@ul.ac.za
Citation | Fangele ZB, Louis TT, Busisiwe G (2022). The effect of citric acid on feed intake, body weight gain and body linear measurement traits on indigenous chickens- a review. Adv. Anim. Vet. Sci. 10(4): 802-810.
DOI | http://dx.doi.org/10.17582/journal.aavs/2022/10.4.802.810
ISSN (Online) | 2307-8316

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INTRODUCTION

The indigenous chickens (*Gallus domesticus*) are the native breeds that have been farmed in many of the developing and underdeveloped countries throughout the world (Magothe et al., 2012). The importance of native birds for the rural economy is immense in different countries (Barua and Yoshimura 1997; Magothe et al., 2012). Though these birds are being used for rural backyard poultry production by most the small-scaler farmers since their genetic potential has not been fully exploited due to a lack of resources and knowledge (Khobondo et al., 2015). Sometimes such chickens are referred to as traditional, scavenging, backyard, village, local or family chickens due to their adaptation to harsh environmental conditions that include extensive small-scale village, free-range and organic production systems (Mahendra, 2016). Indigenous chickens are hardy and can adapt to local conditions better than other breeds because of their ability to withstand harsh climatic conditions due to their typical genetic development (Van Marle-Köster et al., 2009). Moreover, although local chickens produce less meat and fewer eggs in comparison

with conventional chickens, they have an important role to play in providing food security and a source of income generation to resource-limited local communities who rely on them at a socio-economic level (Zaman et al., 2004).

Backyard farming has over the years contributed to a great extent to the economy of different countries (Khobondo et al., 2015). In the same way, indigenous chickens play a vital role in the rapidly growing economy (Mtileni et al., 2009). They provide livelihood security to the family in addition to securing the availability of food reducing the poverty. Unemployed youth and women can also earn an income through poultry farming by selling chickens (Gunya et al., 2020). They grow slowly and take time to reach maturity due to their behaviour since are scavenging and poor productivity under an extensive farming system (FAO, 2019). To increase the productivity of these chickens, the intensive farming system is the most viable condition to rear the chicken since the feed will be controlled and manipulated by adding citric acid as a growth promoter to the feed (Vargas-Rodriguez et al., 2002; Afsharmanesh and Pourreza 2005).

This review is to collate current information on the description of indigenous chickens of Africa and strategies of using the growth promoter such as citric acid to highlight improvement at their nutritional and genetic levels of performance. Therefore, the objective of this review is to provide information on the description of citric acid, the use of citric acid in poultry diets and limitations of using citric acid in poultry and the effect of citric acid in indigenous chicken production.

Indigenous chickens

Description of indigenous chickens: "Indigenous chicken" is a word used to describe chickens that have adapted to their surroundings. Indigenous chickens are domestic animals that can survive in extremes of cold and heat, as well as wet and dry circumstances, whether in cages or out in the open, boosting on treetops. The fowl found in rural parts of Southern Africa are mostly named and classed depending on their phenotypic and geographical location, according to Van Marle-Köster et al. (2009).

Indigenous chickens' production in Southern Africa: Free-range chicken production is not commercialized in most rural regions (Manyelo et al., 2020). As shown in Table 1, indigenous chickens are predominantly raised as part of mixed farming in extensive systems and to a lesser extent in semi-intensive systems. Rural people can employ indigenous chickens to transform accessible feed resources around the house or hamlet into extremely nutritious goods like meat and eggs. Overall, local chicken farming in southern African countries is still in its infancy, according to Liswaniso et al. (2020). In Zambia, for example, just 0.5 percent of the total chicken population reaches the commercial market, with the vast majority eating in the home (Gueye, 2020; MFL 2019). Local chickens have so received little attention in terms of boosting their production rates, despite their value (Mtileni et al., 2012). The rural poultry sector accounts for approximately 98 percent of the overall chicken population (FAO, 2007), and is primarily made up of indigenous chickens (Moreda et al., 2013).

Table 1: Indigenous chicken's production system

Production system	Mapiye et al. (2018)	Assefa et al.	Tadela et al. (2019)
Scavenging/Free range	45(28.1)[2]	79.6%	100%
Semi intensive	74(46.2)[1]	20.4	-
Cage or confined	45(28.1)[2]	-	-
Extensive	15 (9.4)	-	-

Citric acid

Nutritional description of citric acid: The citric acid-producing organism requires certain trace metals for growth and metabolic reaction. The metals that must be limiting consist of Zn, Mn, Fe, Cu, heavy metals. Fe2+, Mn2+, Zn2+, Cu2+ are identified to be inhibitory to the production of citric acid by Aspergillus niger in submerged fermentation (Yadegary et al., 2013; Sawant et al., 2019). Production of citric acid from submerged fermentation by Aspergillus niger is extremely sensitive to trace metals present in starchy and molasses media. Therefore, the concentration of these heavy metals should be decreased correlate to the concentration of optimal growth as well as maximum production of citric acid. Max et al. (2010) observed the low levels of phosphate have a maximum achieved citric acid production. This effect work at the level of enzyme activity rather than at the level of gene expression. On the other hand, while the maximum lead of phosphate to a decrease in the fixation of carbon dioxide, which can increase the foundation of certain sugar acids as well as stimulate growth (Soccol et al., 2006).

In citric acid, fermentation ranged at phosphorus concentrations of 0.5 to 5.0 g/L is essential for maximum production of citric acid. Potassium dihydrogen phosphate has been a profitable source for good achieved citric acid production. The type and concentration of carbohydrates are also important factors, which determine the production of the desired product. In contrast to the effect of other factors, the relative effect of sugar concentration on the important fermentation parameters with filamentous fungi (Ali et al., 2016). However, according to Anwar et al., (2009), the high content of sugars in fermented media is considered favourable for higher production of citric acid. Chundakkadu et al. (2005) have reviewed the production

of citric acid directly correlate by the nitrogen source used in the fermentation, and ammonium salts such as urea, ammonium chloride, and ammonium sulphate are preferred. Feed manufacturers use several pro-nutrients and growth promoters to attain the highest level of genetic potential by converting feed to gain more efficiently within a minimum time duration.

Citric acid in poultry diet: Citric acid (CA) is commonly used in poultry diets to promote growth by acidifying the gastrointestinal contents, nutrient digestibility, and reducing pathogen loads (Min et al., 2007). It acts as a growth promoter through acidifying the gastrointestinal (GI) content and is considered as a favourite determinant ineffective nutrient digestion (Boling et al., 2000). In addition, it modifies intestinal pH, it also improves the performance and increases the solubility of feed ingredients and the digestion and absorption of nutrients (Nourmohammadi and Afzali, 2013). Improved digestive efficiency cannot be attributed only to morphological changes in the gastrointestinal tract.

Citric Acid has been studied in poultry for its specific antimicrobial activity (Patten and Waldroup, 1988). The production of biogenic amines is mainly influenced by temperature, availability of oxygen, redox potential, and pH (Min et al., 2007). Citric acid can inhibit microbial growth in foods and consequently reduce the BA content. Organic acids such as citric acid have mainly been used to sanitize feed to prevent issues such as salmonella infections in animals (Thompson and Hinton, 1997). Their effect in animal diets may also suppress pathogenic growth and improve digestion, absorption, mucosal immunity, and topical effects on the intestinal brush border (Mroz, 2005).

Citric acid as a growth promoter in poultry: Citric acid shows sufficient antimicrobial activity to preserve feed against bacterial spoilage but simultaneously reduces the levels of undesirable bacteria (for example *E. coli*.) in the gastrointestinal tract can ultimately improve growth rate (Falkowski and Aherne 1984; Eidelsburger and Kirchgessner 1994; Deepa et al., 2011). Cave (1984) reported that the addition of high levels of citric acid could strongly decrease the palatability of feed whereas its inclusion at low levels increased feed intake in avian species. Daskiran et al. (2004) stated that early exposure to dietary acidifiers might cause an adaptation in birds, and reduce the subsequent therapeutic activity of acidifier. Therefore, they proposed to use the acidifiers in the grower phase rather than in the starter phase to reduce economic losses from heat stress. However, Nhleko et al. (2003) stated that indigenous chickens are not easily affected by heat stress have a stronger immunity system. Shen Hui Fang et al. (2005) demonstrated the best feed conversion ratio with the addition of 0.3% CA in growing chickens. A dose titration study of Citric Acid in the diets found that up to 6% maintained live weight, but feed intake was reduced by 1.5% level and feed conversion efficiency increased till 6% level (Islam et al., 2011c). The higher inclusion level of 7.5% did not cause any sign of toxicity but caused depression of growth. Growth promoters are now recognized in the broiler industry as feed additives for faster growth and economic meat production (Bhuyan et al., 1977). They also improve the efficiency of feed utilization (Milligan et al., 1955). Citric acid works by reducing the intestinal pH caused by lowering the pathogenic microbial burden.

Citric acid as an alternative to antibiotics: It is true that the antibiotics could not be fully replaced by the organic acids in the development of specific immunity and disease prevention, but could be considered as growth promoters (Deepa et al., 2011). Some studies have been conducted to test the feasibility of Citric acid instead of antibiotics in the context of the performance of broilers. Haque et al., (2010) found that dietary supplementation of 0.5% citric acid increases weight gain, feed intake, tibia ash deposition and non-specific immunity as well as feed efficiency and carcass yield. Several antibiotics are allowed to be used in poultry production (Jones and Ricket, 2003) as a growth promoter. Sub-therapeutic levels of antibiotics in broiler feed have increased feed efficiency but the continuous use of these antibiotic growth promoters have residual effects on their products such as broiler meat.

The antibiotic residue causes resistance and cross-resistance to pathogens in the animal body and for humans and therefore it is now considered a public health hazard (Botsoglou and Fletouris, 2001). Evidence exists that, antibiotic resistance genes can be transmitted from animal to human microbiota (Greko, 2001). Probiotics, prebiotics, organic acids, herbs, and herbal products are some substitute approaches of antibiotics in poultry production (Fuller, 1989; Chaveerach et al., 2004). Among other alternatives, organic acids work in poultry, not only as a growth promoter (Abdel-Azeem et al., 2000; Fushimi 2001; Abdo 2004) but also as a meaningful tool of controlling all enteric bacteria, both pathogenic and non-pathogenic (Naidu 2000; Wolfenden et al., 2007).

Citric acid is an organic acid that decreased feed intake and increased daily weight gain and feed conversion efficiency of broilers (Deepa et al., 2011). Considering these facts citric acid is safe for humans and can be used as a growth promoter in broiler production. Another alternative to antibiotic growth promoters (AGPs) is herbal feed additive. This can be used in the poultry diet due to their antimicrobial properties (Dorman and Deans, 2000). Many herbs and their bioactive constituents possess a broad antimicrobial activity (Lewis et al., 2003). It can help in digestion aid by

stimulation of endogenous enzyme activity and absorption of nitrogen (Gill, 2001) and inhibition of odour and ammonia control (Varel, 2002).

Citric acids on indigenous chicken production:

Effect of citric acid on feed intake of indigenous chicken breeds

In applied physiology nutrition and growth are two closely related and complementary subjects which are considered with each other (Alabi et al., 2013). Gut conditions, as the main part of the body and responsible for digestion and absorption, are the subject of many researchers. The digestive system of all species including avian has a dynamic property that regulates itself depending on the physiological requirements and present circumstances. The feed intake of the chickens is affected by the gastrointestinal tract (GIT) which depends on many factors including the intestinal pH as well (Farner, 1942).

The relatively acidic pH of the avian GIT is also dependent on some factors such as health of the chicken, kind of nutrients and more important, microflora content of the GIT. The indigenous chickens like the Indigenous chicken are scavengers, most of the time do not meet their requirement. However, correlation between the pH and microflora content and microflora and nutrient are mutual (Sarra et al., 1985). The pH level in specific areas of the GIT is a factor that establishes a specific microbial population and affects the digestibility and absorptive value of most nutrients.

Most of the pathogens grow at a pH close to 7 or slightly higher. In contrast, beneficial microorganisms live at an acidic pH (5.8-6.2) and compete with pathogens (Ferd 1974). In addition, lowering the pH in the GIT by organic acids such as citric acid improves nutrient absorption (Boling et al., 2001). The history of using antibiotics in poultry ration began 60 years ago (Moore et al., 1946), and today there are several antibiotics that can be used in poultry production (Jones et al., 2003) as growth promoters such as citric acid. The citric acid decreases microbial load in the GIT and improve weight gain and feed conversion ratio because they make more nutrients available to the host meaning the feed intake is higher.

The influence of citric acid on feed intake is presented in Table 2. Khooshechin et al. (2015) reported that the inclusion of OA at 3 g kg–1 significantly increased Average Daily Feed Intake. The beneficial effect of acidifiers, such as OA, on performance is related to a more efficient use of nutrients and digestibility improvement (Nourmohammadi et al., 2012). On the other, hand Shariffuzzan et al. (2020) found that the highest feed intake was observed in birds given 0.75% CA and depressed feed intake was observed on a higher level of CA application (1%CA) as shown in Table 2. Similarly with the findings by Islam et al. (2008) found that the feed intake is higher by addition of CA. Islam et al. (2008) reported average feed intake was lower in treatment A(control) and higher in treatment D (0.5% CA+ 0.5% Acetic acid).

Table 2: Effect of citric acid on feed intake of chickens.

Treatments	Feed intake	Reference
0% CA	1442±52	Shariffuzzan et al. (2020)
0.5% CA	1450±55	
0.75% CA	1470±62	
1.00% CA	1430±27	
BD	1931±42.1	Khooshechin et al. (2015)
BD+10Ag Kg^{-1}	1885±42.1	
BD+2OAg Kg^{-1}	1905±42.1	
BD+ 3OA Kg^{-1}	2012±42.1	
Control	2913±142.90	Islam et al. (2008)
0.5 Citric acid	3118.6±126.99	
0.5 Acetic acif	3029±223.88	
0.5 Citic acid+ 0.5 Acetic acid	3101±106.8	

Effect of citric acid on body weight gain of indigenous chicken: The development of livestock and animal health has not always led to sustainable increases in farmers' welfare or animal productivity due to the lack of understanding of livestock production systems. The multipurpose functions of livestock and the complex relationships between animal health, nutrition, breeding, and biotechnology require a systems approach to optimize the use of resources (Kaasschieter et al., 1992). Therefore, multi-stakeholders directed their goals toward improving the environmental sustainability of livestock via better metrics and methods, such as acidification and fermentation of products, which provide better keeping quality (FAO, 2019).

In applied physiology, growth and nutrition are closely related and complementary subjects. The use of different strategies to explore this relationship can improve animal production (Rahmani and Speer 2005; Abdelrazek et al., 2016). The achievement of optimum broiler performance has led to the search for alternative growth promoters, especially owing to the ban on using antibiotics as growth promoters like citric acid (Fascina et al., 2012). Thus, researchers have developed physiological additives, such as organic acid like citric acid to enhance immunity and improve performance.

According to Khan (2016), these additives aid development of normal physiological functions in animals or ameliorate their deficiencies. Organic acids are weak acids that

Table 3: Effect of citric acid on body weight gain of chickens

Treatments					Reference
T0	T1	T2	T3	T4	
846±.38	906±68	926±60	882±41		Sharifuzzan et al. (2020)
64.89±5.54	66.83±5.69	66.06±5.73		66.38±5.57	Fik et al. (2021)

T0::0%CA, T1:0.5% CA, T2:0.75, T3:1% CA,T4:1.5 CA

Table 4: Financial sustainability of using citric acid in indigenous chickens

Parameters	Dietary Treatments			
	T1	T2	T3	T4
Cost/kg feed	28.02±0.00	29.67±0.00	30.00±0.00	31.12±0.00
Chicken price	45	45	45	45
Feed intake kg/bird	1.60	1.60	1.64	1.57
Cost (Feed/broiler)	44.83±0.80	47.47±1.10	49.2±1.20	49.86±1.20
Cost (Feed+chick)/broiler	89.83±0.80	92.47±0.82	94.20±0.85	93.8±0.80
Other cost	25±0.00	25±0.00	25±0.00	25±0.00
Total cost/bird	114.83±0.85	117.47±0.90	119±0.80	118.86±0.81
Cost/kg live weight	115.76±1.07	111.87±1.01	111.40±1.02	115.39±1.08
Sale/bird	124±0.00	131.25±0.00	133.75±0.00	128.75±0.00
Profit/bird	9.17±2.01	13.78±2.10	14.55±2.30	9.86±1.60

Source (Sharifuzzaman1 et al., 2020)

enhance intestinal function. Correct usage of these compounds together with proper nutrition, management, and biosecurity measures confers several beneficial effects, such as enhancement of protein digestion, leading to improved feed conversion ratio (FCR), growth performance, and immunity, as well as enhancement of mineral absorption from the intestine (Nourmohammadi et al., 2012; Wickramasinghe et al., 2014).

Citric acid increased body weight gain in chickens, according to Fik et al. (2021) and Sharifuzzan et al. (2020), as shown in Table 3. This was supported by Islam et al. (2018) and Chowdhi et al. (2009), who found that when birds were fed citric acid-rich meals, their body weight gain improved. The beneficial effect of citric acid on the gut flora is most likely responsible for the better body weight growth.

Effect of citric acid on body linear measurement traits of indigenous chickens: Poultry production in most rural parts of South Africa is characterized by small scavenging operations. Most of the poultry in these operations are indigenous chickens that are of low productivity. Mostly the body linear measurements are used to select or to determine the animal's body weight. There are higher carcasses from the chickens that are fed diets containing citric acid (Abdel-Fattah et al., 2008; Ebrahimnezhad et al., 2008). Other research has indicated numerical improvements in carcass hence the body linear measurements of the chickens will also increase or get bigger (Nourmohammadi et al., 2010). Organic acids such as citric acid become useful in promoting the body linear measurement of birds.

Financial sustainability of using citric acid in indigenous chickens: Citric acid is widely used as a food additive around the world, therefore its production and availability are plentiful. As a result, its impact on feed costs would be minimal, but gains from increased growth and lower mortality might be realized. According to Sharifuzzaman et al. (2020), the feed cost per bird was highest in the bird with 1.0 percent citric acid added and lowest in the T0 control with 0 percent citric acid added (Table 4). The feed cost per bird in the treatment with citric acid was greater because the feed consumption was raised with the supplementation of citric acid. Citric acid in the food had a substantial (P 0.01) effect on the cost per kg live weight of broilers. Control had the greatest cost per kg live weight of broiler, whereas birds in treatments with the inclusion of citric acid had the lowest cost per kg live weight of broiler. According to recent research, adding 0.5 percent CA to the diet raised diet costs, but production was more profitable because to greater growth and feed efficiency (Islam et al., 2008). This conclusion of increased profit in CA fed birds was supported by Islam et al. (2011b). In comparison to an unsupplemented control, other researchers discovered that adding CA to broiler production boosted profitability (Tolba, 2010).

CONCLUSION

Even when the specific effect of citric acid on the feed in-

take, body weight gains and body linear measurements on indigenous chicken. It has been well established that the organic acids such as citric acid can acidify the gastrointestinal tract of the chicken which improve the feed intake, furthermore, they improve the growth performance of the chicken including the body weight gain and body linear measurements. Citric acid have the ability of improve the gastrointestinal tract of the chickens leading to higher feed intake and the chicken can meet their requirements. Therefore, the increase in the feed intake will lead to increase in the body weight gain and the body linear measurements since they are sometimes used to predict the body weight of the animal.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

DECLARATION

Authors declare that this work is not published in other journal.

AUTHORS CONTRIBUTION

BG designed the review. BFZ and BG wrote the original draft. TLT and BG read, edited and approved the final manuscript.

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