DIETARY MODIFICATIONS FOR MANIPULATION OF POULTRY'S GASTRO-INTESTINAL TRACT, WHICH WAY FORWARD IN AFRICAN PRODUCTION SYSTEMS

Kahindi Roseline Kafedha

Animal Sciences Department, Chuka University,

P.O. Box 109-60400, Chuka; Tel:+254791476590; Email: rkahindi@chuka.ac.ke

ABSTRACT

The digestive tract of chicken is sterile at hatching, however, its starts gaining microbes as the bird feeds. Unlike mammals, birds would not receive colostrum or simple diet like milk first before taking solid feed. The intestinal activity undergoes major changes in passage rate, nitrogen and starch digestibility from day 0 to 14. Therefore, good feeding would influence the bird at this critical stage and later in their productive period. Microbial colonization in poultry is impacted by several factors such as diet fed, production system and breed. The intestinal microbial colonization could be by pathogenic colonization which affects poultry's health as well as cause villi atrophy hence less nutrients are absorbed. Since poultry feed costs the farmer almost two thirds of the productive expenses, researchers have put a lot of emphasis on dietary manipulation to improve nutrient availability. Feed additives such as antibiotics, probiotics, prebiotics and enzymes have been used to positively influence poultry's microbial population. Further, feed processing technologies including changes in grinding procedures, expansion, extrusion and pelleting may be used to modify the structure of the ingredients and increase nutrient availability. The nutrient type and content would also influence the type of microbe found in poultry's gastrointestinal tract. This paper seeks to review the several dietary modifications options available for poultry production and their applicability to African farmers and consumers.

Key words: Dietary manipulation; Gut health; African poultry farmers

INTRODUCTION

The digestive tract of chicken is sterile at hatching (Harrow *et al.,* 2007). However, its starts gaining microbes as the chick feeds. Unlike mammals, aves do not receive colostrum or simple diet like milk first before taking solid feed. Hence, there has to be increases in enzymes as the chick increases their feed intake. Noy and Skalan, (1995) reported that major changes in the intestinal activity and passage rate occur from hatching to 10 days post-hatching and nitrogen digestion was highest on day 21. In the early days, from day 1 to 8 chicks produce heterophil extracellular trap (HET), where heterophils release DNA to trap and ultimately kill invading pathogens, this phagocytic potential is greater at day 1 than any other day (Cho, 2018). Similarly, Ravindran et al. (2006) showed an increasing relative weights of the small intestine with a peak at day 14 post-hatching. Therefore, good feeding would impact the bird from an early stage of life and later in their productive period. Further, the diet influences the type of gut microbiota and development of chicken's intestinal tract. For example, feeding increasing levels of acetic acid in broilers of 2 to 6 weeks improved their villus height of the duodenun, jejunum (Rehman *et al.,* 2016).

As for the free range chicken besides feed, the bird's environment would play a critical role in the gut microbial population. Studies comparing in-door and free range chicken has shown differences in gut microbiota therefore affecting intestinal health (Cui *et al* 2017; Bari *et al* 2022), as well as productivity of the chicken. Over time the gut microbial population has been manipulated by use of feed additives such as antibiotics, probiotics, prebiotics enzymes. Sub-therapeutic levels of antibiotics have been used to reduce pathogenic microbe population thereby improving the chick's growth. Antibiotics reduce the growth of *Escherichia coli* and *Clostridium perfringes* while boosting beneficial bacteria such as Lactobacilli, Bacteroides, Bifidobacteria and Enterococci (Tannock, 1997).

Many of the feed additives came in as alternatives to antibiotics after the risk of build-up of antibiotic resistance in the birds and consumers. Researchers are now seeking means to adjust the main dietary ingredients given to chicken which would in turn control gut microbial population. This would not only reduce nutrients diverted to microbial use but also immunological stress to the birds and hence improvement in feed conversion efficiency.

Manipulation of poultry's gut using antibiotics

Over time the gut microbial population has been manipulated by use of in-feed antibiotics which have been used as growth promoters. Antibiotics would either kill the bacterium (bactericidal) or slows down bacterial growth (bacteriostatic). Sub-therapeutic levels of antibiotics reduce the growth of *Escherichia coli* and *Clostridium perfringes* while boosting beneficial bacteria such as Lactobacilli, Bacteroides, Bifidobacteria and Enterococci (Tannock, 1997). Such antibiotics include tetracyclines, penicillin, sulfonamides, aureomycin, ionophores, chlortetracycline. These products improved improves feed conversion and animal growth and reduced morbidity and mortality due to clinical and subclinical diseases.

However, there is development of antibiotic resistance in poultry and consumers. For example, *Escherichia coli* is a Gram-negative bacterium commensal organism living in the intestines of both humans and animals. However, some strains have been reported to cause gastrointestinal illnesses (Tenaillon *et al.* 2010). Tetracycline which is commonly used in poultry and man has been reported to be among the drugs bacteria become resistant to. Besides antibiotic resistance, the cost of poultry diets fortified with antibiotics is higher than that without thereby increasing the cost for production. Therefore, livestock producer is forced to seek for alternative means for manipulating poultry's gut to improve efficiency in nutrient utilization. Several means such as feed processing technologies, modification of nutrient content and type, use of enzymes, prebiotics, probiotics, synbiotics and production systems have been used.

Feed processing technologies

Since the digestive system of chicks is not fully developed at hatching, it is necessary to offer newly hatched chicks highly digestible feeds. Feed processing technologies such as changes in grinding procedures, expansion, extrusion, pelleting, and use of both enzymes and chemicals maybe used to modify the structure of the ingredients and increase nutrient availability.

The fine grinding of grains for poultry feed is a common practice. This reduction in particle size has an advantage of increasing digestibility and feed passage rate compared to whole grain (Kilburn and Edwards, 2001). However, the particle size of the ground grain is of importance. For chicks due to their small size it has been assumed that feeding them finely ground diet is the best practice, but is has been shown that particle size affects development of the chick's GIT (Xu *et al.* 2021) since too fine diet delays maturation as well as the activity of the GIT. Work by Nir *et al*. (1994) has shown that larger particle size stimulate peristalsis, feed intake and improve digestibility. These larger feed particles increase feed passage time reducing the time of exposure to degrading microbes. Though grinding is of importance, different types of milling methods have an influence in mineral digestibility since a wedge-shaped disc mill resulted in higher mineral digestibility in layers as compared to the disc mill (Hafeez *et al.* 2015). However, grinding and feeding chicken a mash diet has been associated the dustiness leading to adoption of pelleting.

Zang *et al*. (2009) showed that pelleting increased nutrient digestibility and animal performance compared to broilers fed mash feed. Pelleting also reduces feed wastage thus promoting growth of chickens. A study by Singh *et al*. (2012) reported that increasing of pellet size from 3.00 to 4.76 mm in diets containing ground wheat increased feed intake and weight gain in 11 to 35 day broilers. Pelleting has an added advantage of application of heat thereby improvement of digestibility. Heat processing of grains reduces the effect of anti-nutritive factors such as those found in soybean meal (Kilburn and Edwards, 2004).

Heat processing of grains reduces the effect of anti-nutritive factors such as those found in soybean meal (Kilburn and Edwards, 2004). Heat processing disrupts the structure of proteins and granules of starch and changes the physiological properties of the fiber (Mateos *et al*., 2002). However, the temperatures should be checked since heat applied beyond 100 ^{o}C tends to degrade proteins and hence a negative effect on nutrient digestibility.

Protein manipulation

Poultry should receive optimum dietary protein otherwise it would be detrimental to their performance and health. For instance, a low protein diet of 13% CP fed to broilers resulted in lower weight gain as well and lower feed efficiency compared to broilers on an optimum diet containing 20% CP (Hada *et. al*., 2013). This may be attributed to negative amino acids balance resulting from an inflammatory or immune response whereby the body has to partition protein from muscle building to synthesize immunoglubunis. Higher protein intake is beneficial in times of immune challenge as shown by Anwar *et al.* (2015) where feeding high protein diet enhanced humoral as well as cell mediated immunity of molted hens. However, for healthy birds, diets with high protein above the optimum content would boost the proliferation of microbes including the pathogenic ones. The protein quality should also be considered since feeds supplemented with essential amino acids methionine, tryptophan, threonine not only increased the growth of chicks but also reduced immune response as shown by pro-inflammatory cytokines which are produced after exposure to an immunogen (Klasing and Barnes, 1988; Takahashi *et al*. 1997). Further, besides immunity amino acids such as glutamine has more functions such as the synthesis of nuclecotides and energy production (DeBerardinis *et al*. 2007).

Carbohydrates manipulation: resistant starch and NSP

The common ingredients used for poultry diets are corn and soybean meal. Replacing some of the corn with sucrose resulted in increased weight gain from day 1 to 7 (Longo *et al*., 2007). This improvement was mainly due to increased intestinal weight. In the same study using different carbohydrates sources like cassava starch and corn gluten meal to replace corn had no impact on growth. Therefore, a highly digestible carbohydrate is important in the first days of broilers life when the digestive system is still immature. Non-starch polysaccharides (NSP) have been shown to reduce diet digestibility and could be due to increased viscosity. The increased intestinal viscosity leads to higher clostridium population and predispose birds to necrotic enteritis (Olivia *et al*, 2021). The water soluble NSP decrease the digestion and absorption of starch and proteins thus depressing growth. However, some non-starch polysaccharides such as mannan-oligosaccharides (MOS), fructose-oligosaccharides (FOS), galacto-oligosaccharides, chito-oligosaccharides arabinoxylans and glucans (Iji and Tivey, 1994) be metabolised by specialized caecal bacteria and be of benefit to chicken against pathogenic microbes. For example, feeding 35 day old broilers oat hulls which contains pentosans, was more effective in reducing caecal *Clostridium perfringens* and Enterobacteriaceae counts (Swick *et al*., 2012). Mannanoligosaccharides is a NSP extracted from the cell wall of yeast *Saccharomyces cerevisiae*. It acts through preventing the attachment of gram negative bacteria to intestinal epithelial cells as shown by (Brennan *et. al.* 2014). In another study, Baurhoo *et al*. (2007) showed that MOS increases the population of gram positive beneficial bacteria Lactobacilli spp in broilers challenged with *E. coli*. Further, *E. coli* challenged broilers supplemented with MOS had greater ileal villus height and the ratio of villus height to crypt depth than those with no dietary MOS (Wang *et al*., 2016). Inclusion of MOS at the level of 100 mg/kg to broiler's feed lead to improvement in growth performance, intestinal histomorphology and relative weight of lymphoid organs Tufali *et al*. (2019). Also, MOS acts as non-pathogenic immune stimulants, a study by Savage *et al*. (1996) reported an increase in plasma IgG and bile IgA in pouts fed diets supplemented with 0.11% MOS.

The overall growth performance in broilers has been improved through feeding MOS even to levels similar to antibiotic growth promoters (Brennan *et. al*., 2014).

Carbohydrates are a substrate for formation of short chain fatty acids (SCFA). Short chain fatty acid, that is acetic acid, propionic acid and butyric acid are formed through fermentation of carbohydrates mainly in the caecum. The SCFA diffuse through semi permeable membrane of microorganism to dissociates in the cytoplasm and suppress bacterial cell enzymes and nutrient transport systems. They are a source of energy for gut epithelial cells (Dalmasso *et al.* 2008) and are used for synthesis of long chain fatty acids. Rehman *et al* (2016) reported that supplementing 2-6 weeks old broilers with 0.3% acetic acid improved their performance and increased villus height of the duodenum, jejunum and ileum while compared to no acetic acid supplementation. Short-chain fatty acids can also be used for the treatment of several intestinal bacterial infections, including salmonellosis (van Immerseel *et al*., 2005; Fernández-Rubio *et al*., 2009). Butyric acid increases production of antimicrobial mucous and increase expression of tight junction proteins (Mariadason *et al*. 1997; Schauber *et al*. 2003; Bordin *et al*. 2004; Peng *et al*. 2007). These organic acids available as salts are easier to handle during feed manufacturing and are less corrosive. For example, a combination of sodium butyrate with essential oil improved growth of broilers but had no effect on intestinal morphology (Mallo *et al*. 2012).

Enzymes

Enzymes have been used to improve nutrient digestibility. In poultry they have been used to reduce the effect of dietary anti-nutritional factors, hence different types are available these are carbohydrases, proteases, lipases and phosphatases. Since young chicks are more affected by anti-nutritional compounds than older birds (Marquardt *et al*.,1996), enzymes have been of greater benefit to chicks. Addition of cellulase or hemicellulase or a combination of cellulase plus hemicellulase to a corn soybean meal based diet resulted in increased body weight of broilers as compared to those without enzymes (Tahir *et al*, 2005). Enzyme such as β-glucanases and xylanases have been positively used to reducing the negative effect of NSP through degradation to soluble carbohydrates (Morgan *et al*., 2022). Similar results were obtained by Rehman et al. (2016) when beta mannanase was added to a low energy diet, resulting in the improvement in broilers' growth and diet digestibility. While the beta mannans have ability of increasing viscocity and thereby lead to an increased pathogenic bacterial population in the gastrointestinal tract. Further, supplementation of beta mannanase on broilers fed on a diet of corn and soybean meal reduced the diet severity of *Eimeria* and *Clostridium* infection (Jackson *et al*., 2003).

Probiotics prebiotics and synbiotics

Probiotics are living microorganisms with beneficial effect on the host by improving the properties of the endogenous microbiota such as Lactobaccillus, Enteroccoccus spp. And *Saccharomyces cerevisiae.* The probiotic should be resistant to feed processing (coating is done), acidity, effects of bile salts and digestive enzymes, be rapidly proliferating. Their mode of action involves production of metabolites like short organic fatty acids, hydrogen peroxide or interaction with receptor sites or stimulation of the immune system. The lactic acid produced by lactobacillus is used by butyric acid producing bacteria of Clostridia cluster for production of more butyric acid (Duncan *et al*., 2004).

Prebiotics are non-digestible feed ingredients with selective effects on intestinal microbiota since they stimulate growth and metabolic activities of some microbes for instance Lactobacilli and Bifidobacteria (Gibson and Rober-froid, 1995). They are naturally occurring and synthetic oligosaccharides like arabinoxylan. Others like inulin, FOS act as substrate for beneficial bacteria, MOS has receptor for *E.coli* fimbriae and Salmonella hence preventing them from attaching to the intestinal wall. Beta glucans have immunomodulatory action as they enhance phagocytosis, monocytes and macrophages proliferation.

Synbiotics is a combination of prebiotics and probiotics, an approach is being used where the growth of bacteria is encouraged by providing substrate. For example, beta glucans improved the growth of Lactobacilli (in-vitro) (Russo *et al.* 2012) and it was also suggested that β-glucans act as antioxidants protecting Lactobacilli from harsh intestinal environment.

Production systems

In Kenya, indigenous poultry breeds are mainly kept under extensive system while exotic breeds under intensive production system. Under extensive production system, the birds are allowed to move around and fend for themselves with little feed supplementation which could be kitchen waste. The extensive system has a higher risk of exposure to infection and spreading it quickly to other birds. Further, more energy is needed for maintenance due to movement of the birds in search of feed resulting in slow growth rate. The advantage with extensive production system is that the bird will chose different types of feeds and herbs to balance their nutrient requirement. These herbs play a role in development of the gastrointestinal tract, however, more research is needed to confirm their mode of action. Under the extensive production system subtheraupetic levels antibiotics are hardly used because of the cost associated with it. Also, cost also associated with purchase of the alternatives such as enzymes, phenolics has left the poultry farmers with fewer options to choose from. Further, the alternatives have given variable response depending on dose, nature of administration, their persistence in the gut and stability during processing. Some oligosaccharides such as Raffinose have antinutritive properties where they stimulate growth of both beneficial and harmful bacteria.

Conclusion

Antibiotic resistance is a worldwide problem and survey compiled a list of ten countries in Africa that have Salmonella strains that are resistant to antibiotics (Selaledi *et al*., 2020). This made worse in countries like Kenya where antibiotics are readily sold over the counter (Kiambi *et al.,* 2021; Wanjiru, 2014). The alternatives to antibiotics discussed in this paper have worked well under intensive system. The farmers should have different antimicrobial growth promoters for different age groups since their response to poultry is also affected by age. Where available there can be substitution of feed ingredients with varieties with less antinutritive factors for example low phytate peas as well as barley. In poultry, the low phytate peas had higher digestibility compares to normal phytate peas (Kahindi *et al.,* 2015). General cleanliness is encouraged so that there is less risk of exposure to pathogens and in case of a disease outbreak he should seek veterinarian opinion as soon as possible.

Traditional means of gut health maintenance was by use of plants and prebiotics which could be used in blends. These methods are less costly, however, a good portion of indigenous knowledge is lost since it was not shared with the next generation. These are plants contain secondary metabolites such as phenolics, alkaloids and terpenoids. Their mode of action is not clear but seem to be antioxidants, antimicrobial agents or immunomodulators. Therefore, where resources are limiting, the farmers can use NSPs, essential oils, probiotics and their combinations. For some like essential oils and the gut microbes get used to their activity within a short while. Therefore, for those that the gut microbes get used to them fast, a combination of AGPs could be an added advantage.

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