

An overview of health challenges in alternative poultry production systems

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ABSTRACT Due to consumer demand and changing welfare standards on health, ecology, equity, and safety concepts, poultry production has changed markedly over the past 20 y. One of the greatest changes to poultry production standards is now offering poultry limited access to the outdoors in alternative and organic poultry production operations. Although operations allowing access to the outdoors are still only a small portion of commercial poultry production, it may impact the gastrointestinal (**GIT**) health of the bird in different ways than birds raised under conventional management systems. The present review describes current research

results in alternative systems by identifying how different poultry production operations (diet, environmental disruptive factors, diseases) impact the ecology and health of the GIT. Various research efforts will be discussed that illustrate the nutritional value of free-range forages and how forages could be beneficial to animal health and production of both meat and eggs. The review also highlights the need for potential interventions to limit diseases without using antibiotics. These alternatives could enhance both economics and sustainability in organic and free-range poultry production.

Key words: alternative poultry production, health, disease, environment, nutrition

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INTRODUCTION

Conventional large scale poultry operations remain the mainstay for commercial production of poultry meat however, consumer preference has demanded poultry producers develop other production systems such as free-range and pasture-raised systems that allow poultry to be reared in less confined spaces with access to the outdoors (Ricke, 2017; Shi et al., 2019; Ricke and Rothrock, 2020). Although free-range and pasture-raised terminology are commonly used interchangeably, these systems by definition are different. Free-range poultry are poultry reared in a system that allows limited access to the outdoors and is regulated by the United States Department of Agriculture (**USDA**). Whereas pasture-raised, a term not regulated by the USDA, involves birds reared in a system that allows for at least 108 square feet

of space outdoors and some sort of shelter (Rothrock et al., 2019).

In 2015, approximately 95% of the U.S. farmers raised livestock in conventional cages. More recently for layers in egg production, public opinion has determined conventional cages to be detrimental to animal welfare (Grandin, 2014; Thaxton et al., 2016; Shields et al., 2017). The public, with support from some members of the scientific community, demanded the ban of conventional battery cages, such as those used in the commercial egg laying industry. Consequently, new standards were established to allow for the use of enriched colony cages (Wegner, 1990; Appleby and Hughes, 1991; Appleby, 2003). As such, conventional cage systems are being systematically replaced by alternative management systems such as colony enriched cages, potentially offering a potentially more humane environment for layers while maintaining productivity (Mench et al., 2011).

Although free-range poultry farming is considered beneficial for animal welfare, these alternative systems carry health risks for poultry (Appleby and Hughes, 1991; Conraths et al., 2005). Consequently, regardless of rearing conditions, poultry remain susceptible to the exposure to disease-causing elements from multiple sources (Ricke and Rothrock, Jr., 2020). In the current review, the impact of disruptive environmental

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factors and diseases experienced by poultry reared in a pasture or free-range production systems will be discussed, as well as their relationship to the gastrointestinal tract (GIT). The general nutritional challenges experienced by birds raised in these conditions and the potential value of free-range forages and how they are beneficial to improve animal health and their products (meat and eggs) will be described. This review will also highlight the need for potential nonantibiotic interventions to limit diseases that could enhance both economics and sustainability in organic and free-range poultry production.

ALTERNATIVE POULTRY PRODUCTION SYSTEMS

Poultry pasture-based rearing is not a new concept. Most broilers, layers, and other domesticated birds were farmed in open-air conditions before the now-dominant confined animal management style operations emerged at the end of the 1950s (Guèye, 1998). More recently, changing consumer expectations for meat product sources has led to the development of nonconventional poultry production systems also known as “alternative” systems (Harper and Makatouni, 2002; Schröder and McEachern, 2004; Castellini et al., 2008; Miele, 2011; Spain et al., 2018). To meet this increased demand for these types of poultry products, government regulation and definitions have been introduced to generate clarity on the specific production standards. For example, this demand led to the USDA to develop standards for organically-raised chickens which require some form of bird access to the outdoors such as the presence of an open-air area (USDA-AMS, 2017).

Access to an outside enclosure is a critical factor for consumers that have poultry welfare concerns (Heng et al., 2013). The sustainability of poultry farms is dependent on optimal use of a pasture in terms of the environment (nitrogen recycling), animal welfare (reducing pecking incidence), feed autonomy (valorization of the raw resources on the range), and public awareness (poultry reared in an open environment) (Gregory, 2000; Berg, 2002). In addition, the pasture or free-range poultry production system combines animal welfare, economic, and environmental performance to potentially meet organic agriculture requirements and can be an option to achieve a 100% organic diet (Ponte et al., 2008; Fanatico et al., 2009; Wang et al., 2009; Rodenburg and Turner, 2012; Singh and Cowieson, 2013; Chen et al., 2018).

Not only do pasture and free-range systems potentially improve bird performance and GIT health, outdoor-based poultry farming potentially promotes animal welfare (Pedersen et al., 2003). Indeed, free-range production not only provides the space, fresh air, direct sunlight but allows the birds to express natural behaviors such as dust bathing, scratching, foraging, running, flying, while reducing pecking incidence due to decreased stocking density (Bestman et al., 2018). In more recent

years, free-range and pastured poultry farming have proven to possess marketable benefits perceived by customers such as antibiotic-free poultry products, high quality eggs, and desired meat flavor, which have resulted in overall commercial appeal (Sossidou et al., 2011; O'Bryan et al., 2014; Petterson et al., 2016; Bray and Ankeny, 2017).

ENVIRONMENTAL CHALLENGES

Although pasture-based systems are the preferred means to rear poultry by some consumers, in terms of animal welfare, two points should be considered (Coffey and Baier, 2012; Nordquist et al., 2017). First, free-range environments are more likely to be influenced by varying weather conditions (temperature, rain, sunshine, wind), season and age. Secondly, increased live-stock mortality can be a consequence of many factors: predation, contact with outside wildlife, along with parasitic infestations and therefore must be considered from an economic standpoint (Dahl et al., 2002; Singh and Cowieson, 2013; Campbell et al., 2016). As such, the pasture environment can also serve as a source of disease-causing organisms (parasites, pathogenic bacteria, or viruses) originating from wildlife (Lay Jr. et al., 2011; Wuthijaree et al., 2019; Rieke and Rothrock Jr, 2020). Certainly, there are several factors to consider when free-range or pasture systems are implemented, many of which are influenced by the bird's GIT and the digestion and metabolism of highly variable dietary sources.

In conventional poultry operations, predation is minimal as the space is environmentally controlled and inspected daily. However, in alternative outdoor-based farming systems where flocks have access to free-range areas, exposure to predators may be much more frequent, which results in economic losses (Iqbal and Pampori, 2008). The primary difference between the two systems is in how the flocks are housed and managed. In the absence of secured building shelters, poultry will be threatened by small predators and birds **Table 1**, Bestman and Bikker-Ouwejan, 2020). Bestman and Bikker-Ouwejan (2020) studied 11 free-range flocks in the Netherlands. In addition to creating an online survey among poultry farmers, they performed model calculations to determine the contribution, predation has on

Table 1. Mortality of free-range and pasture reared poultry due to predation.

Signs of Mortality	Predators	References
Missing birds or heads	<ul style="list-style-type: none"> • Kites • Domesticated Dogs • Domesticated Cats • Undomesticated Cats • Jackals • Mongooses • Fox • Birds of Prey 	Iqbal and Pampori, 2008 Moberly et al., 2004 Bestman and Bikker-Ouwejan, 2020
Missing eggs or chicks	<ul style="list-style-type: none"> • Snakes • Hawks • Domesticated Dogs 	Aboe et al., 2006 Ajala et al., 2007

the mortality of free-range or organic poultry production systems. Among the 79 observations made at the 11 farms, they observed a bird of prey 141 times with 16 of those observations including attacks by buzzards and northern goshawks. Among online survey takers (27 farms), an estimate of 3.7% of the hens in organic and free-range flocks were killed by predators. Lastly, [Bestman and Bikker-Ouwejan \(2020\)](#) concluded that per flock, predation caused a loss of \$5,700 EUR (\$6,850 USD) on an average organic farm (size 12,700 hens) and \$6,700 EUR (\$8,000 USD) on an average free-range farm (size 25,000 hens). Ultimately, they recommended that several nonlethal methods could be used to avoid those problems, including motion detectors, moving objects, chemical or pheromone repellents, installing electric fences, and eliminating access to the outdoors at nightfall.

A direct comparison between free range and conventional production systems by [Lima and Nääs \(2005\)](#) was made that investigated the differences in production parameters of these systems. In the conventional production system, Cobb/Hybro birds were utilized whereas Label Rouge was employed in the free range system. After rearing the birds in both systems under industry standards, [Lima and Nääs \(2005\)](#) demonstrated that higher mortality and stocking density were observed under the conventional rearing system. However, birds reared in the conventional rearing system still had a lower feed conversion ratio (**FCR**) and there were detectable differences in processing characteristics.

In addition to predation, heat stress may also impact mortality and poultry performance. Heat stress can be a limiting factor for free-range poultry production systems. Historically, several studies have demonstrated decreased egg weight and shell thickness as temperature increases, as heat stress is experienced ([Payne, 1966](#); [Mowbray and Sykes, 1971](#)). In addition, the ambient temperature can affect egg mineral composition ([Smith et al., 1954](#)). As such, heat stress leads to a reduction in food consumption by negatively affecting adipokine, which controls feeding behavior ([Bernabucci et al., 2009](#)). In respect to free-range poultry, demographics on semi-intensive free-range egg farms (stocking density of ≤ 1500 hens/hectare in Australia) demonstrated that free range systems experienced up to 10% mortality (40% respondents) with predation (34%), cannibalism (29%), heat stress (24%) and grass impaction (19.5%) as the leading causes of mortality ([Singh et al., 2017](#)).

Due to the abrupt reduction of feed intake, physiological and immunological responses in the GIT, impairment of the intestinal integrity and inflammation may be observed ([Wu et al., 2018](#)). The exposure of heat stress (31 ± 1 and $36 \pm 1^\circ\text{C}$) from d 31 to 45 d of age increased the corticosterone serum levels and decreased body weight gain and food intake of broilers infected with *Salmonella* Enteritidis ([Quinteiro-Filho et al., 2010](#)). When exposed to high environmental temperatures, the hypothalamic-pituitary-adrenal axis of

poultry is activated and has been reported to be responsible for the decrease in performance, reduced immune function, and detrimental intestinal mucosa changes ([Lara and Rostagno, 2013](#); [Calefi et al., 2017](#); [Rostagno, 2020](#)).

Although heat stress can impact free range poultry performance and health, both cold and heat stress are critical concerns to producers these stresses can not only reduce performance but negatively impact the GIT ([Hai et al., 2000](#)). [Hai et al. \(2000\)](#) reported that the chyme concentration in the entire GIT of conventionally reared broilers was decreased by exposure to 5°C , 60% relative humidity and the chyme concentration was increased by an ambient temperature of 32°C with 60% relative humidity, compared with the control environment that was held at an ambient temperature of 20°C , 60% relative humidity. When broilers were reared at 32°C , the expulsion of the digesta from the crop or small intestine was suppressed. In addition to motility of the GIT being suppressed, a decrease of intestinal enzymes (trypsin, chymotrypsin, and amylase) was also observed; however, those enzymes were not influenced by the cold environment ([Hai et al., 2000](#)). [Ward et al. \(2001\)](#) demonstrated that when Ross broilers were reared under conventional and free-range systems there were no detectable differences between the thermal resistance of the plumage of the back and leg of the broilers reared under either condition. However, there was a difference in the plumage of the pectoral region of the two rearing systems with free-range birds having a thicker pectoral plumage with higher resistance to heat transfer ([Ward et al., 2001](#)).

NUTRITIONAL AND DIETARY CHALLENGES

Feeding alternative poultry can differ significantly from conventional agriculture depending on the type of alternative poultry operation. For example, only products that are produced under the authority of the Organic Foods Production Act (**OFPA**) and the National Organic Program (**NOP**) and can be labeled as “USDA certified organic” can be fed to organically raised birds ([Van Loo et al., 2011](#); [Chalova and Rieke, 2012](#); [Burley et al., 2016](#)). Consequently, with few exceptions synthetic amino acids used in conventional systems are not permitted in organic production systems ([Fanatico et al., 2009](#); [Chalova et al., 2016](#)). In addition, cereal mixtures obtained from the farm are supplemented by feed additives based on animal nutritional needs as long as they meet restrictions imposed on the specific alternative poultry production system ([Chalova and Rieke, 2012](#); [Fanatico et al., 2016](#)). Pasture forage and additional feed sources are available at low cost to improve alternative poultry production welfare, eggs, and meat ([Buchanan et al., 2007](#)). In addition, dietary sources such as dehydrated pasture and citrus pulp (10%) may be effective dietary supplements to add into broiler diets to alter meat fatty acid profiles, decrease monounsaturated fatty acids and palmitic acid,

and increase the predominance of n-6 and n-3 polyunsaturated fatty acids (Mourão et al., 2008).

Although, poultry diets generally consist of corn and soy with high energy and low fiber content (Wang et al., 2005); soybean-free diets may be a viable strategy for reducing carcass contamination in pasture-based chicken production systems. Lourenco et al. (2019a,b) determined the effect of feeding a soy-based and soy-free diet on the intestinal tract microbiota, feces, ceca, and carcass over a 12 wk rearing period spanning over 5 flocks and 2 y. In their first study, Lourenco et al. (2019a) performed 16S rDNA sequencing on the whole GIT, feces, cecal contents, and whole carcass rinses of Freedom Ranger (Freedom Ranger Hatchery, Reinholds, PA, USA) broilers (n = 375) provided either soybean based (2 flocks) or soybean-free diets (3 flocks) and reared in free-range pastures with shelter (3 shelters, n = 125/shelter). The results of the first study demonstrated that *Firmicutes* was the dominant phylum (50 to 90% of Operational Taxonomic Units [OTUs]) regardless of age and diets (Lourenco et al., 2019a). Although the number of observed OTUs increased as birds matured among those fed soybean-based diets, those fed soybean-free diets did not. However, despite the dietary addition of soybeans, there was no difference among the cecal alpha diversity estimates (Shannon's Diversity) between diets but cecal content collected at slaughter had a higher diversity than the GIT and fecal samples collected at an earlier age. In addition, regardless of diet, as the birds matured, the abundance of *Oscillospira*, *Faecalibacterium*, *Ruminococcus*, and 2 unidentified genera from the orders *Clostridiales* and RF39, and the abundance of *Lactobacillus* decreased. Lourenco et al. (2019a) also used predictive metabolomics of the microbiota which revealed no differences occurring between the metabolism of amino acids, carbohydrates, lipids, and energy of free-range broilers fed soy and soy-free diets throughout the study.

During the second study, Lourenco et al. (2019b) collected fecal samples at 4, 7, and 12 wk of age, whole carcass rinses (WCR) and ceca at processing, and WCR 1 mo post processing (final product). The results of the second study demonstrated that again, regardless of diet, *Firmicutes* were the dominant phylum among the fecal and cecal samples (approximately 60%). However, among the WCR, the abundance of *Firmicutes* was approximately 30% regardless of diet. Although differences in alpha diversity were noted, Lourenco et al. (2019b) did not differentiate a detectable pattern between the dietary treatments, soy and soy-free diets. With beta diversity metrics, the inclusion of soybean in the diets had a significant impact on the diversity of all sample types. In addition to impacting the Beta diversity, *Campylobacter* was less abundant among the feces collected at 12 wk of age and WCR from the final product of those fed soy-free diets (Lourenco et al., 2019b). Also, *Acinetobacter* was less abundant among WCR of those supplied soy-free diets. Therefore, the removal of soy from poultry diets may not only impact the microbiota of the GIT of poultry but, in turn reduce

foodborne pathogens such as *Campylobacter* and *Acinetobacter*.

FORAGE GRAZING AND BIRD PERFORMANCE CHALLENGES

Not surprisingly, birds grazing on pastures have an opportunity to consume a wide range of high fiber containing forages (Dal Bosco et al., 2014; Sossidou et al., 2011;2015). One benefit to forage consumption includes the additional uptake in vitamin and minerals beyond what is provided in commercial pelleted diets (Singh and Cowieson, 2013; Spencer, 2013; Tufarelli et al., 2018). A wide variety of forages, such as alfalfa, perennial ryegrass, marigolds, and red clover, in addition to their high levels in fibers, are significant sources of xanthophylls and can be used in foods as natural pigmenting agents (Hammershøj and Johansen, 2016; Grigorova et al., 2017). Grass ingestion behavior seems to be encouraged when birds are in free-range environments and is potentially beneficial as grasses also contain high potassium concentrations that influence weight gain and feed conversion rate (Dhama et al., 2015; Blair, 2018). In contrast, other studies mention potential disorders that may occur due to grass consumption, particularly nutrient dilution, electrolyte balance disorders, and GIT overload (Singh et al., 2017).

Poultry digestive systems can sequester calcium from forages as efficiently as calcium derived from limestone or oyster shells which are commonly provided in poultry diets (Horsted et al., 2006; Spencer, 2013; Tufarelli et al., 2018). Poultry can also use most of the amino acids contained in the fodder, which represents a significant content of amino acids, including digestible methionine and lysine (Buchanan et al., 2007). Although low in energy, fodder can still contribute up to 3% of the birds' nutritional energy intake via pasture forage consumption (Ferre et al., 2001). Combinations of enzymes (xylanase, amylase, and protease) can be used to enhance the utilization of high fiber diets. Laudadio et al. (2014) explored low-fiber alfalfa (LFA) effects on laying performance and egg quality. The experiment was conducted over 10 wk on layers, 18 wk of age, which were randomly allocated to 2 dietary treatments: soybean meal (SBM;15% of diet) and a test diet containing LFA (15% of diet) as the primary protein source (Laudadio et al., 2014). The partial substitution of SBM with LFA had no adverse effect on early-phase laying hens' growth performance (Laudadio et al., 2014). Egg production and none of the egg-quality traits examined were influenced by dietary treatment, except LFA addition did improve yolk characteristics including color, percentage, cholesterol, and β -carotene content. Serum and β -carotene also increased, and a reduction in serum cholesterol concentration was noted in hens given diets supplemented with LFA meal (Laudadio et al., 2014). Collectively, these results may be related to the number of natural pigments contained in the alternative feed ingredient.

As nutrition contributes to the quality of poultry meat, the nutritional challenges faced during alternative poultry production impact the final product. As such, most consumers are interested in fairly white skinned poultry carcasses; however, the inclusion of carotenoids, more precisely xanthophylls, from foraging can yellow the skin and muscle of poultry (Mortensen and Skibsted, 2000). Once the skin is removed the meat color is linked to muscle pH with lower pH associated with lighter color (Fletcher, 2002). After cooking meats with lower pH levels, the final product can be tough and dry (Sonaiya et al., 1990; Allen et al., 1998; Fletcher, 2002; Mir et al., 2017). Thus, optimal control of protein intake at the final stage, especially for slow-growing stocks that tend to yield more acidic meats, helps to promote muscle development, limit fattening and energy deposits (glycogen) at the origin of acidic pH (Woelfel et al., 2002; Kim et al., 2014). The fatty acid profile of chicken meat is also directly impacted by the nutritional profile of the diet (Castellini et al., 2006; Wang et al., 2009; Dal Bosco et al., 2016). For example, the use of linseed in poultry diets has led to an increase in omega-3 content in muscle of chickens (Castellini et al., 2008). Lastly, the fat content and the protein/energy ratio of the diets may impact the fat content on the subsequent carcass. Quantitatively, the protein content and essential amino acid, particularly methionine and lysine (Castellini et al., 2006; Dal Bosco et al., 2014), can influence the muscle yields and the animal's conformity.

For organic and free-range layer nutritional management, feed distribution and nutritional composition (energy and protein concentration) should carefully be considered to prepare the digestive tract and potentially increase egg production in the future of the laying hen. Depending on its age, the layer receives a “starter” feed (0 to 6 wk) then a “growth” feed (7 to 20/23 wk) prior to egg production. The needs are significantly modified when layers begin producing eggs. Egg production is mainly reflected in the high calcium requirements needed for the egg's shell formation (Rodrigues et al., 2013). The egg yolk yellow color is related to the presence of carotenoid pigments, xanthophylls, a lipid-soluble antioxidant pigments, depends precisely on pigment types (yellow or red) and the amounts to be added (Marusich et al., 1960; Nys, 2000; Hammershøj et al., 2010). In the mixed feed of organic poultry, pigmentation agents are provided by cocksfoot, perennial ryegrass, red clover, corn, cornmeal, corn alfalfa protein concentrate, and natural pigments (Chauveau-Duriot et al., 2005). In summary, grass consumption on free-range does constitute a complementary, but irregular, contribution in pigments (Chauveau-Duriot et al., 2005).

DISEASE-CAUSING PATHOGENS AND PARASITES

In free-range farming, poultry are colonized by a varied bacterial population present in their environment; however, it is well established based on commercial

conventional poultry production that exposure to different pathogens present in the environment can adversely influence flock health. This exposure can lead to deleterious outcomes such as microbiological contamination of eggs due to the more extended period of contact with free-range hens, shavings, and feces resulting in a higher number of *Enterobacteriaceae* on eggshells (Parisi et al., 2015). One of the significant challenges is disease, which can be either clinical, resulting in mortality and perceptible disease, or subclinical, resulting in reduced performance and other nonperceptible conditions (Whay et al., 2007; Weeks et al., 2016; Scott et al., 2018).

Several viruses can impact bird health. Marek's disease (animals' wings and legs are paralyzed), is an alpha herpesvirus that is characterized by T-cell lymphomas and peripheral nerve enlargement (Gimeno et al., 1999). It can be transmitted to flocks by older flocks, migratory birds, and by contaminated dust or litter. The disease appears in young birds approximately 6 wk after infection and can cause problems in slow-growing chickens. Disease development is often insidious in young animals and causes reduced weight gain (Upadhayay and Ewam, 2012; Souillard et al., 2019). In the U.S., chicks are typically vaccinated against Marek's disease on d 1, and the protection provided is generally adequate (Weiss and Biggs, 1972; Abreu et al., 2016). Infectious Bursal Disease (IBD), also known as Gumboro disease, is caused by the infectious bursal disease virus and is highly contagious among poultry. An infection of IBD leads to lesions of the Fabricius bursa (a cloacal gland that plays a crucial role in the immune system of poultry, as does the spinal cord in humans) and intramuscular hemorrhages (Van den Berg et al., 2000; Dey et al., 2019). Anus pecking, prostration, and watery droppings are observed in 3- to 6-wk-old chicks infected with IBD (Swai et al., 2011).

Infectious bronchitis (avian coronaviruses (ACoVs)) is also a virus of bird health concern, with infectious bronchitis virus (IBV) being one of the most critical ACoVs affecting the poultry industry. The pathogenicity of IBV is highly complicated as it is influenced by numerous factors, such as the strain of the virus, the breed of chicken, environmental conditions, and concurrent infection from other pathogens (Promkuntod, 2016; Adebiyi and Fagbohun, 2017). This respiratory disease causes inflammation of the upper respiratory tract, kidneys, and proventriculus and leads to mortality in one out of three birds (Promkuntod, 2016; Adebiyi and Fagbohun, 2017). The most prevalent signs in layer hens include decreased egg production, deformed eggs, and increased mortality (Promkuntod, 2016; Adebiyi and Fagbohun, 2017). In addition to IBV (Adebiyi and Fagbohun, 2017), metapneumoviruses (Abdel-Azeem et al., 2014; Al-Shekaili et al., 2015), and paramyxoviruses (Newcastle disease) (Alexander, 2000), can also be detected in free-range avian flocks.

As one of the world's leading poultry industry problems, coccidia develop in humid environments between 20 and 25°C (Shirley et al., 2005; Chapman et al., 2013;

Blake et al., 2015). Coccidiosis is caused by intestinal unicellular parasites (Shirley et al., 2005; Chapman et al., 2013; Blake et al., 2015). There is precedent for potential exposure of free-range poultry to intestinal parasites in grazing areas (Van de Weerd et al., 2009). Exposure to coccidia occurs by ingesting their unicellulars' encystic forms (coccidial oocysts), found in feces or infected litter (Allen and Fetterer, 2002; Quiroz-Castañeda and Dantán-González, 2015). Several types can infect the GIT depending on their location in the digestive system (Jatau et al., 2012). The mortality rate due to this disease can be very high. Immunity is crucial since coccidia are naturally present (Lillehoj and Trout, 1993; Tewari and Maharana, 2011; Quiroz-Castañeda and Dantán-González, 2015). Several species of *Eimeria* can infect poultry with different species invading different sections of the intestinal tract (Chapman, 2014; Acharya and Acharya, 2017). Chicks can be vaccinated against coccidiosis at 1 d of age which is commonly done in the commercial U.S. poultry industry (Sharman et al., 2010). While vaccination remains a common means of controlling coccidiosis for conventional poultry and is available globally, there may be natural alternative products to combat coccidiosis for specific use in free-range chickens, such as phytochemicals, probiotics, prebiotics, and nutritional supplements (Al-Fifi, 2007; Chapman et al., 2013; Chapman, 2014; Acharya and Acharya, 2017).

Other GIT parasites of concern include nematodes or roundworms. The most common genera of roundworms on poultry farms are *Ascaridia* (Gauly et al., 2007; Phiri et al., 2007), *Heterakis*, and *Capillaria*. *Ascaridia* and *Heterakis* can be visible and often live in the intestine and/or cecum, leading to stunted growth, increased consumption, diarrhea, prostration, and mortality in case of high infestation. Cestodes are segmented flat worms, commonly called tapeworms, with an obligate intermediate host (insects, slugs) (Puttalakshamma et al., 2008; Belete et al., 2016). The most frequent species are *Davainea*, *Hymenolepis*, and *Raillietina*, which are visible to the eye. Cestodes live in the small intestine, which leads to stunted growth, prostration, and mortality. The most common cestodes are minimally pathogenic. *Davainea*, a tiny species, is the most pathogenic (Magwisha et al., 2002). These parasites do occur in free-range chickens. For example, three nematodes and one tapeworm, *Gongylonema ingluvicola* (29.2%); *Ascaridia galli* (10.3%); *Heterakis gallinarum* (4.7%); *Capillaria contorta* (2.83%); *Raillietina tertagona* (38.6%) were identified as GIT parasites in 106 free-range chickens at ages between 1 and 2 y (Pinckney et al., 2008).

Helminth infections in free-range chickens, even when they occur in low numbers, may result in subclinical disease (Pinckney et al., 2008). A study by Permin et al. (1999) revealed a higher risk of helminth GIT diseases in free-range and backyard systems, but prevalence may also be high in deep litter systems. In the free-range/organic operations, the following helminths were found: *Ascaridia galli* (63.8%), *Heterakis*

gallinarum (72.5%), *Capillaria obsignata* (53.6%), *Capillaria anatis* (31.9%), and *Capillaria caudinflata* (1.5%). In the deep-litter systems: *A. galli* (41.9%), *H. gallinarum* (19.4%), and *C. obsignata* (51.6%). In the battery cages: *A. galli* (5%) and *Raillietina cesticillus* or *Choa-notaenia infundibulum* (3.3%). The exact identification of the cestodes was not attainable because of missing scolexes. In the broiler/parent system: *C. obsignata* (1.6%), and for the backyard system: *A. galli* (37.5%), *H. gallinarum* (68.8%), *C. obsignata* (50.0%), *C. anatis* (56.3%) and *C. caudinflata* (6.3%) were detected (Permin et al., 1999).

Permin et al. (2002) described the prevalence of parasitic infections and infestations in free-range village chickens. All chickens (50) harbored ecto- and endoparasites, and 32% were infected with hemoparasites (Permin et al., 2002). Eight different ectoparasites were identified; the more prevalent including *Argas persicus*, *Cnemidocoptes mutans*, *Echidnophaga gallinacea*, *Goniocotes gallinae*, *Menacanthus stramenius*, and *Menopon gallinea*. The most prevalent nematodes identified were: *Allodapa suctorica*, *Ascaridia galli*, *Gongylonema ingluvicola*, *Heterakis gallinarum*, and *Tetrameres americana*. For cestodes, the prevalences were: *Amoebotaenia cuneata*, *Hymenolepis* spp., *Raillietina echinobothrida*, *Raillietina tetragona*, and *Skrjabinia cesticillus*. Prevalences of haemoparasites in young and adult chickens were: *Aegyptinella pullorum*, *Leucocytozoon sabrazesi*, *Plasmodium gallinaceum*, and *Trypanosoma avium* (Permin et al., 2002; Sharma et al., 2018).

In a more recent study, Wuthijaree et al. (2019) surveyed GIT helminths' prevalence in indigenous chickens raised under Northern Thailand's backyard conditions. Specifically, they sampled over 200 male and female birds from 11 small poultry farm operations. Fecal and GIT samples were collected from the birds during slaughter. Fecal egg and oocyst counts and the presence of parasites in the GIT were determined in these birds. Over 30 % of the birds examined were positive for fecal eggs and over 50 % for fecal oocysts. Over 70 % were infected with at least one identifiable helminth species, with the most prevalent being *Heterakis gallinarum*, then *Ascaridia galli*, and *Capillaria* spp. Bird gender did not appear to be a factor as only *A. galli* occurred at a statistically higher frequency in male birds. Despite the widespread occurrence of subclinical helminth infections in these backyard birds, the authors noted that bird growth was not impacted negatively. This is consistent with observations by Sharma et al. (2018) that performance, egg production, or quality in free-range laying hens were not affected by infection with *A. galli*. It would be interesting to further characterize the bird GIT of these infected birds to determine if helminths' presence influenced GIT microbial composition and infection by opportunistic pathogens and in turn, if levels of *Salmonella* and *Campylobacter* contaminated carcasses were altered.

Some of the more common external poultry parasites are red lice and mites, which can cause scabies in poultry (Hinkle and Corrigan, 2020). Lay Jr. et al. (2011) noted

that noncage and free-range management systems are highly complex and offer numerous opportunities for ectoparasites, such as red mites, to hide. Abrahamsson and Tauson (1998) reported red mites' appearance on laying hens housed in an aviary housing system with three tiers, the lower two with feeders and the top resting tier serving as a perch. They concluded that the red mites' presence and parasitic disorders accounted for the production unpredictability observed. Specific features of aviaries may impact the level of red mites that birds are exposed to. For example, Heerkens et al. (2015) examined risk factors for feather damage, mortality, and egg-laying performance of laying hens held in multitier aviaries with two flooring types, either wire mesh or plastic slats. Along with other factors such as type of aviary access to free-range space, age of the barn, and other housing structural features, the infestation level of red mites was classified as either absent, mild infestation, or severe infestation. Red mites occurred in over 60% of the aviaries, specifically on supporting house beams, nest boxes, or near perches, and were more frequently detected in plastic slatted floors. The red mite level was identified as a risk factor for plumage, cloacal discharge, and bird mortality. While housing flooring systems seem to make a difference in red mite infestations, natural plant products such as the essential oil linalool have been proposed as a feed or litter additive to serve as an insecticide by Beier et al. (2014).

POTENTIAL INTERVENTIONS

Free-range poultry husbandry and the variability of environmental conditions adds complexity to the ability to manage risk of pathogen exposure (Sossidou et al., 2015). Cleaning and disinfection of the facilities between batches of birds is recommended (Sossidou et al., 2011; Souillard et al., 2019). Maintaining optimal pasture conditions as well rotating pastures have also been suggested as supportive of bird health along with constant inspection and attention of flocks by management personnel (Sossidou et al., 2011). However, it is not possible to prevent poultry from being exposed to potential intermediate hosts present in flocks, such as insects, snails, or slugs (Van de Weerd et al., 2009; Sossidou et al., 2015). In addition to applying good management practices in alternative poultry production, disease prevention through feed additives considered acceptable for alternative poultry can also be implemented (Sirsat et al., 2009; Shi et al., 2019). Phytotherapy, one of the more frequently used methods, refers to medicinal plant uses (Diaz-Sanchez et al., 2015; Blair, 2018; Tufarelli et al., 2018). It has been shown through numerous studies that phytogenic feed additives, also referred to as phytobiotics, exert their action through immunomodulatory effects such as the increased proliferation of immune cells, elevated expression of cytokines, and increased antibody titers (Lee et al., 2010; Pourhossein et al., 2015).

Brindha et al., (2017) conducted a 35-d experiment was conducted to analyze the effects of dietary inclusion of aloe vera (basal diet + 1% aloe vera in drinking water), turmeric powder (basal diet + 0.5% turmeric powder in feed), and buttermilk (basal diet + 1% buttermilk in drinking water) on growth performance, feed conversion ratio and carcass yield in free-range broiler chickens. The highest body weight gain was noticed in those supplemented with aloe (1875 ± 41.22 g) followed by those fed diets containing turmeric (1746 ± 64.21 g) and buttermilk (1737 ± 54.49 g) during the fifth week age of broiler chicken (Brindha et al., 2017). The lowest FCR was noted in those supplemented with diets containing turmeric (1.826 ± 0.020 g), followed by those fed diets containing aloe and buttermilk (1.853 ± 0.020 g and 1.938 ± 0.022 g, respectively). The highest carcass yield occurred among those supplemented with aloe (1454.67 ± 40.30 g), followed by diets supplemented with turmeric and buttermilk (1429.16 ± 32.24 g and 1351.50 ± 22.87 g, respectively) (Brindha et al., 2017). Similarly, the highest dressing percentage was noticed in those fed diets containing turmeric (72.45 ± 1.41), followed by those supplemented with aloe and buttermilk (70.93 ± 0.98 and 70.85 ± 0.48 , respectively) (Brindha et al., 2017). The crude extract of *Aloe secundoiflora* has also provided effectiveness against *Salmonella Gallinarum* in experimentally infected free-range chicken, which led to a decreased mortality rate (Waihenya et al., 2002).

Poultry may have an affinity for some aromatic plants. Aromatherapy is based on aromatic plant extracts and essential oils (Bullitta et al., 2007; Lans and Turner, 2011). Quantitative observations of free-range laying hens' preference for four different cultivated aromatic plants have been determined (Kosmidou et al., 2006). Twenty laying hens aged 50 wk were used. They were given daily entry to a specifically created pasture area enriched with *Ocimum basilicum* (basil), *Origanum vulgare* (oregano), *Petroselinum crispum* (parsley), and *Anethum graveolens* (dill). All four aromatic plants were cultivated separately. Hens were observed more frequently visiting the *Ocimum basilicum* area than the other plant areas, and this preference remained constant throughout the observation period (d 1 to 3). On d 1 the mean percentage values of hens visiting *Ocimum basilicum*, *Origanum vulgare*, *Petroselinum crispum*, and *Anethum graveolens* areas were 21.6%, 4.5%, 8.4% and 6.1%, respectively, while in d 2 and 3 values were 21.6%, 5.5%, 9.7% and 5.0% and 20.5%, 5.3%, 11.6% and 5.3%, respectively. A constant and clear preference for *Ocimum basilicum* was noted (51% of the total number of hens). Among the other three aromatic plants, *Petroselinum crispum* was preferred by 24% of the hens. According to this study, hens can consume cultivated aromatic plants in the pasture area, but some aromatic plants may be preferred. Homeopathy is based on similarity and distinctiveness (El Jalil et al., 2020) and may be an effective nutritional strategy for livestock, to help reduce the use of antibiotics (Doehring and Sundrum, 2016).

Deworming can be among other possible interventions to prevent free-range poultry diseases (Illango et al., 2008). Changes in management strategies can also be useful. For example, Maurer et al. (2013) followed *Heterakis*, *Ascaridia*, and *Capillaria* spp. GIT worm burden and fecal egg counts in certified organic layers raised with access to both covered outdoor areas and outdoor paddocks. Two types of paddock management were used: access to the entire paddock or access to only a quarter of the paddock over 3 to 4 wk. They also examined the impact of covering the openings to the paddocks with wood chips. Vegetation was maintained in the unused quarter by cattle grazing or mowing. While overall GIT worm burden was not influenced by paddock management, paddock space rotation significantly decreased *Heterakis* and *Ascaridia* fecal egg counts overall by approximately 10% compared to the nonrotated paddock raised birds. The inclusion and consistent removal of wood chips also appeared to offer relief from fecal egg occurrence. The authors concluded that the reduction detected over the experimental period in this particular study might have only a limited immediate practical impact, but could become more substantial after several years. Conceptionally, efforts to decrease infective agents' accumulation by pasture rotations and other approaches to reduce exposure would seem to be an essential tool for minimizing subclinical disease in birds raised outdoors.

FUTURE DIRECTIONS AND CONCLUSIONS

As alternative poultry production systems continue to increase in consumer preferences and market demands, more management issues have also emerged. A primary concern is retaining the bird health during the production cycle experiencing a myriad of environmental and other stresses characteristic of living outdoors. Likewise, nutritional challenges are prevalent with dietary formulations being somewhat restrictive due to specific requirements of these types of production systems, particularly organic birds. A critical factor is the free-range availability of a multitude of different types of forages which can offer some nutritional support. However, it is difficult to assess quantitatively what the exact dietary contributions might be to the birds consuming these high fiber forage sources. The other critical issue is the exposure of outdoor birds to predators, pathogens, and parasites. Restrictions in treatment options for some of these deleterious agents can present challenges that are difficult to overcome with interventions that would be considered acceptable. There are management options, such as pasture rotation, which can reduce exposure as well as grazing preferences of birds toward certain aromatic plants that may provide some reduction in exposure and/or limit the harm manifested by certain organisms. Phytogenic feed additives offer some promising potential for controlling some of these pathogenic organisms and parasites, but more research needs to be done to determine mechanisms and identify the

components within these substances that are most efficacious. If market demands continue to grow, it will be important to continue to develop bird management and nutritional approaches that optimize bird health and ultimately performance under these environmental conditions. Ideally, economic considerations and management friendly strategies would be a goal of any research activities designed to improve alternative poultry production.

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DISCLOSURES

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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