

CURRENT CONCEPTS IN NUTRITION AND FEEDING OF HYBRID LAYER CHICKEN

R. Richard Churchil*¹ and R. Suresh²

*Department of Poultry science
Madras Veterinary College
Tamil Nadu Veterinary and Animal Sciences University
Chennai, Tamil Nadu, India*

ABSTRACT

The genetically improved modern commercial layers are capable of producing 330 eggs in their productive life of up to 72 weeks. The journey of genetic improvement continues and the breeding companies now developed 'long life' layers that can lay 500 eggs in 100 weeks of age. The changing production dynamics of layer chicken calls for better understanding of nutrient requirements and good nutritional programming. Prediction models are being used to assess the nutrient requirements of the hybrid layers; while, precision feeding of quantity of feed and or nutrients can lower feed costs and ensures more predictable bird performance. In-ovo and early chick nutrition give jump start at juvenile stage of chicken. The idea of split feeding, although beneficial in certain production parameters, suffers the disadvantages of additional infrastructure and workforce requirements. The nutritional programme for egg size, shell quality and feeding for value added designer egg production is aimed at increasing the profit to the farmers. In recent days, feeding for healthy gut that enables efficient digestion and absorption of nutrients has also gained paramount importance. The concept of feed nanotechnology can help in increasing nutrient availability and environment protection; while, phytogetic products can some extent replace the role played by antibiotic growth promoters. The advancements in biotechnology has opened up not only numerous opportunities for the development of products and technologies for poultry feeding, but also to study the influence of nutritional factors on genomics, proteomics and metabolomics.

Key words: Feeding methods, layer chicken, nutrients requirement, recent advancements

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* Corresponding author, email: drchurchil@gmail com

¹ Professor and Head

² Assistant Professor, Department Animal Nutrition, Veterinary College and Research Institute, Tamil Nadu Veterinary and Animal Sciences University, Orathanadu, Tamil Nadu, India

INTRODUCTION

Hybrid layer chickens are sexed at day old and the females are reared for producing eggs. Due to genetic improvement, the number

of eggs laid between 18 and 72 weeks period has increased tremendously during past few decades. Modern-day layers are high-performers producing around 330 eggs up to 72 weeks of age. The strenuous efforts of genetic selection has stretched productive life cycle further to 95 weeks of age with a hen-housed egg production of 450 eggs. Exploiting the maximum genetic potential of these modern layers requires a better understanding of nutritional need of the birds and good nutritional programming. The production cycle of a layer is 95 weeks; whereas, it is only 5 weeks for broilers. The long journey of layers requires careful nutrition, management and disease control strategies. Any adverse nutritional changes during the starting to grower phase will affect the growth of the birds and reproductive organ development thereby influence the bird's laying performance. Inadequate nutrition during the pre-laying and laying phases significantly affects egg size, number, mass and shell quality.

This article describes the recent understanding on nutritional requirements for better gut health and production, *in-ovo* and early chick nutrition, pros and cons of split-feeding program, nutrition for eggshell quality, egg size, designer egg production and application of recent developments in the fields of biotechnology, nutrigenomics, nanotechnology and phyto-genics on hybrid layer chicken production.

Genetic potential of present-day layers

The age at sexual maturity of commercial layers has shortened over a period of time as an indirect response to selection for high egg production. The modern-day

commercial layers start egg production in 16 weeks of age, when their reproductive tract is still developing. However, the environmental factors like feed and light are restricted during growing phase so as to postpone the egg production to 19th week of age. The 'long life' layers, which are capable of producing 500 eggs in a laying cycle of 100 weeks are therefore on the horizon. This long life layers bring with it benefits of a more efficient utilization of diminishing resources including land, water, raw materials for feed as well as a reduction in waste, and an overall reduced carbon footprint (Bain *et al.*, 2016).

As per the product guide of a commercial layer (Babcock, 2021), the egg production starts in 19th week of age, crossing the peak egg production of 90% in 23rd week. The production continues to increase to reach the maximum production of 95% at 25th week of age and even to 98% in well managed farms. This maximum production (more than 95%) persists up to 39 weeks of age. Thereafter the production gradually reduces to 85% at 72 weeks of age. The decline continues to reach around 75% at 100 weeks of age. The egg mass production also steeply increases from the onset of egg production to 55 gram per day at 26th week. The momentum of peaking of egg mass production loses its pace but still increasing to reach 59.1g per day in 34 weeks of age. Thereafter, the egg mass output gradually reduces to reach 51.5 gram per day in 100 weeks of age. Thus a commercial layer excretes 6.5 gram protein through egg every day at 26th week; which increases to 7.0 gram per day in 34th week and gradually reduces to 5.7 gram per day in 50th week. The daily calcium output through eggs for the corresponding stage of

egg production was 6.1, 6.5 and 5.7 gram respectively.

One should also keep in mind that the body weight is increasing at faster rate of, on an average 46 gram per week from 17 to 23 weeks to reach 1,550 gram from 1,275 gram. The rate of body weight increment becomes slower thereafter (7.0 gram per week) between 23 and 50 weeks and stays almost static (0.24 gram per week) from 50 to 100 weeks of age. At 72 weeks of age, with cumulative feed consumption of 42.1 kg and cumulative egg mass production of 20.4 kg, showing a feed efficiency per kilogram egg mass of 2.06 while the corresponding values at 100 weeks of age are 63.6, 30.4 and 2.09 respectively. While formulating feed for commercial layers, one should keep in mind these production dynamics of commercial layers.

Nutritional requirements and feed formulation

The use of prediction models to stimulate feed intake and production parameters under given husbandry conditions is a new approach in assessing birds requirements. Sakomura *et al.* (2015) concluded that a modeling approach is possibly the best way to determine the optimum economic feeding program for broilers and laying hens, and for predicting performance in the future. Such models are effective tools for: i) comparing actual versus potential performance and ii) providing economic analysis of alternative feeding regimens. Several commercial growth models are available for predicting the production performance of laying hens (Sakomura *et al.*, 2019). There is a need for accurate and detailed information and data

from a variety of production systems to enable the development of robust models that can provide an accurate prediction of performance.

The energy and protein requirements of a layer chicken are influenced by several factors and are subject to constant change. Uniformity in genotypes, advancement in housing and husbandry practices helped the researchers to define the nutrient requirement of various classes of poultry. The daily metabolizable energy (ME) and amino acid requirement of the modern laying hens should be based on environmental conditions in which they are reared, maintenance needs and egg production. Many times, inadequate nutrition limits laying hen's performance. The amount of energy, protein (amino acid), vitamins and minerals required by a layer chicken vary according to the physiological stages (chicks require a higher protein ration, whereas laying hens comparatively require less protein (Poultry Hub, 2021). Any amino acid deficiency will result in a reduction in growth rate and an increase in the FCR. In hot climates, the amino acids and minerals concentrations should be slightly higher than in temperate climates. The quality of protein, in the sense, the amino acid balance in the diet is very important. Under hot summer conditions, a reduction of 2% CP concentration and supplementation of dietary lysine, methionine, threonine and tryptophan to laying hens do not impair performance (Torki *et al.*, 2017). Presently the rations are formulated based on ME and ideal protein concept to meet the daily requirement.

The ideal protein concept uses lysine as the reference amino acid, and

the requirements for other essential amino acids are set as percentages (or ratios) of the lysine requirements (Ravindran, 2013). Presently researchers are formulating rations on a digestible amino acid basis to reduce the undigested amino acid nitrogen reaching the ileum. Undigested amino acid and non-amino acid nitrogen act as substrates for microbes present in the ileum and produces toxic substances like ammonia, amines, indoles and branched-chain fatty acids; thereby, causing subclinical necrotic enteritis in birds. Efficient utilization of amino acid and nutrients not only reduces the production cost, but also helps to maintain gut health and immunity. Compared to total amino acid values, bird performance is superior when feed is formulated based on digestible amino acid values (Li *et al.*, 2002). The use of digestible amino acid content is particularly relevant in developing countries, where highly digestible conventional ingredients are not available and diet formulations may include ingredients of low digestibility. Formulating diets based on digestible amino acids makes it possible to increase the range of ingredients that can be used and the inclusion levels of alternative ingredients in poultry diets. This improves the precision of formulation, may lower feed costs and ensures more predictable bird performance (Ravindran, 2013).

The quantity of feed reaching the beak and the amount of nutrients utilized by the bird is important. Meeting the nutritional need of a layer chicken up to the pre-laying phase is vital to achieving desirable body weight and reproductive organ development at the start of lay and egg production at right time. Meeting the requirement of a laying

hen is important to get standard egg size, maximum and long-standing peak production, reduced feed cost per egg and good cull bird body weight. Desirable feed intake is a key factor to meet the requirement of a bird. Hence, any factor which affects the feed intake will significantly and directly affect the performance of layer chickens in terms of body weight and egg production. The energy concentration ranges from 2800, 2500, 2600 and 2400 ME kcal/kg for starting, growing and laying phase I (21 to 45 weeks) and II (above 45 weeks) respectively. Similarly, the protein requirements of the corresponding phases are 20, 16, 18 and, 16% under Indian conditions (BIS, 2007). The recommendations given by NRC (1994) are 2800 – 2900 kcal ME/kg energy and 18, 16, 15 and 17% crude protein for starter, grower, pre-layer and layer, respectively.

However, the genetic improvement is a continuous process and the revision of nutrient standards should also be frequent to satisfy the needs of the improved genetic stocks. A four phase feeding regimen, namely, starter (0 - 4 weeks), grower (5 - 10 weeks), pullet (10 - 16 weeks) and pre-lay (17 weeks – 2% lay) has been prescribed by a breeding firm for its commercial layer chicken during growing period (Hendrix Genetics, 2021). The recommended ME during these phases are 2950-2975, 2850-2875, 2750 and 2750 kcal/kg and the crude protein requirements for the corresponding periods are 20.5, 19.0, 16.0 and 16.8%. During lay, 2750 to 2850 kcal/kg is recommended from 18 to 35 weeks and 2600 to 2750 kcal/kg thereafter. The daily amino acids and protein requirement values are estimated based on total or digestible and ideal

proteins established for a production of 59.5 egg mass per day (Hendrix Genetics, 2021).

***In-ovo* and early chick nutrition**

A chick's first meal occurs when they consume the amnion fluid before internal pipping and *in-ovo* feeding may 'jump-start' development, improving the nutritional status of the newly hatched chick. Some critical nutrients in the amnion may be limited because of parental nutrition constraints related to weight control and egg production rate. The *in-ovo* feeding has positive effects on hatchability and post-hatch growth, immune response, embryo metabolism and transcriptomics (Kadam *et al.*, 2013). The methods and nutrients like amino acids, carbohydrates, vitamins and other substances used in *in-ovo* feeding and their benefits are reviewed extensively by Kowalska and Dębowska (2017). In a recent study, prenatal supplementation of arginine showed improvements on the parameters like early intestinal development, caecal microbiota and host metabolism in juvenile leading to an improved growth performance (Dai *et al.*, 2020).

The rate of embryonic growth during incubation is influenced by internal factors like egg size and external factors like duration, temperature of pre-incubation holding of hatching eggs and incubation conditions. The timing of pipping of eggs of a single setting may vary extensively, often spread over a period of one day, leaving the chick hatched early to wait for a day or more before it is pulled. Uni and Ferket (2004) reviewed the effect of delayed access to food and water and early feeding and watering of chicks in hatchery

itself on the future performance of the bird. A good start leads to a uniform flock of chicks and it reduces mortality and transit weight loss; minimizes slow starters; eliminates ketosis, improves appetite, increases average daily gain and growth performance, enhances immunity, improves livability thereby reduces overall mortality. Early chick nutrition has more advantages in broilers (Panda, 2006; Mahapatra *et al.*, 2017) in decreasing carcass condemnations, improves dressed weight and breast meat yield in broilers. In order to meet the needs of food deprived hatchlings and to alleviate their problems, Willemsen (2010) suggested that factors or techniques like *in ovo* feeding, shortening the hatching window, shortening the time of first feeding and early nutrition programs or specific pre-starters are necessary.

Split-feeding program for layers

Split feeding is a novel precision nutrition alternative feeding program for layers. Keshavarz (1998) hypothesized that the quantity of nutrients required by a laying hen in a day is not uniform. The nutrient required for the egg formation varies throughout the day, providing a single diet throughout the day may not be useful to the birds, keeping this in mind split feeding program was developed. Keshavarz (1998) first tested a split feeding of different levels of protein, available phosphorus, feed quantity and calcium in morning and afternoon feeds and obtained inconclusive results. Page (2017) explained the idea behind split feeding as to meet the dynamic requirements (per day) for egg formation; two diets (morning and afternoon diets) are formulated. The morning

diet is designed to target albumin production/ deposition and the ovulation and oviposition. The afternoon diet is designed to meet the requirements for eggshell formation. The intake of nutrients (energy, amino acids, calcium and phosphorus) are reduced and the performance of the birds are at par with the traditional feeding (single feed) program. Besides, the eggshell weight and thickness are also improved in split feeding. Further, split feeding can lead to a reduction in greenhouse emission, ammonia production and phosphorus excretion by 10, 12 and > 20 per cent, respectively. The disadvantages for poor adoption of this feeding program, as explained by Page (2017) are equipment limitation, management constraints and additional infrastructure needs (e.g., second bin, control systems and scales). Contrasting reports are arising against this concept with Molnár *et al.* (2018) reporting that split feeding with two feeds with varying calcium levels for first and second half of the day, although had positive effects on shell quality during the start of the experiment in brown laying hens, they were not able to form proportionally more shell in the last phase of their production cycle when reared for an extended production cycle of 85 weeks. On the other hand, the flock exhibited health problems like necrotic enteritis, colibacillosis and welfare problems such as aggressive feather pecking.

Nutrition for eggshell quality

The chance of breakage is more if the quality of the eggshell is poor. Loss due to poor eggshell quality is a huge hidden cost to the egg producer. The egg breakage causes huge losses at various stages in production to

consumption. Mertens *et al.* (2016) reported 6.73% egg breakage in classic cage system and 10.72% breakage in furnished cage systems at point of lay; whereas the egg breakage was very low in aviary (1.94%) and free-range (1.99%) systems. They also reported that the logistic chain, grading and packing of the eggs caused 1.50 to 2.65% breakage; while, transportation caused 0.16 to 2.65% breakage. Calcium is important for the development of bones in growing birds. During the pre-laying phase medullary bone calcium deposition takes place and in the laying hens calcium is utilized for the eggshell formation. Better hen-day and hen-housed egg production, egg size, egg mass output, feed efficiency and egg feed price ratio and low pullet production cost were reported by Sujathaa *et al.* (2014) with inclusion of a pre-lay diet. The dietary calcium source, concentration and particle size also influence the calcium retention, eggshell quality and overall calcium requirement in laying hens (Lichovnikova, 2007). The source, particle size, time of feeding and solubility of dietary calcium are important criteria for better digestion and absorption. Less than 1 mm (diameter) calcium particles easily pass out the gizzard into the duodenum with the chyme. This will lead to the raise of pH of the chyme. Once this occurs, no further calcium will be available from the feed. The retention of calcium is 52 and 64% when the laying hens are fed with 0.5 to 0.8 mm and 2 to 4 mm particles, respectively. Further, the percent of particles stored in the gizzard later than 24 hrs is 0 and 10% when the laying hens are fed with 0.5 to 0.8 mm and 2 to 4 mm particles. Hence, in the laying phase feed mixture of particle size, 65% marble grit of 2 to 4 mm size and 35% lime powder is generally used

(Rao et al., 1992). One-third of the daily calcium is provided in powder form to replenish calcium in the medullary bone during the morning, the remaining two-third should be of 2 to 4 mm (coarse) particles with a low solubility to retain in the gizzard to support grinding of food particles and to improve the availability of calcium at the end of the night period for the eggshell formation. Feeding coarse calcium in the afternoon is more efficient.

The chief vitamin involved in calcium metabolism is vitamin D (cholecalciferol). Cholecalciferol is converted into 25-hydroxycholecalciferol in the liver microsomes, then it is converted into 1, 25-dihydroxycholecalciferol in the kidney. In the small intestine selectively bioactive 25-hydroxycholecalciferol promotes the calcium ion uptake. So any toxin which causes damage to the liver, like aflatoxin (Fouad *et al.*, 2019) and kidney, like ochratoxin A (Maei *et al.*, 2017) reduces vitamin D metabolism, thereby affects calcium absorption. Supplementing nutrients to support liver functions, like betaine, choline, vitamin B₁₂ and folic acid have also an indirect effect on eggshell quality by the production of 25-hydroxycholecalciferol from cholecalciferol.

Feeding management for egg size

Egg size is largely dependent upon the level of dietary protein and level of linoleic acid. A higher intake of balanced protein produces larger eggs. So feeding higher levels of proteins at the onset of production will help to increase egg size more rapidly. Ribeiro *et al.* (2016) recommended the crude protein level of 17.2% in diets for white-eggs laying

Hy-Line W-36 hens from 27 to 43 weeks of age for good egg size and internal egg quality. A level of 1% linoleic acid in the diet is considered adequate for maximum egg size. The egg size and egg mass are significantly affected by the amino acid methionine, the first limiting amino acid in layers (Stavrou, 1978). Methionine level of 0.40% or methionine + cystine level of 0.63% is recommended for modern-day high producers with daily feed intake of 110 gram (Hendrix Genetics, 2021). Mineral calcium does not necessarily affect egg size, but it is vital to support the larger egg sizes (Ryan, 2019). Standard egg size, maximum and long-standing peak production, reduced feed cost per egg and good cull bird body weight can be achieved through good nutritional programming.

Feeding for Designer eggs

Certain nutrients are essential for human health and enriching those nutrients in the egg by providing a particular nutrient-enriched diet is called designer egg production. Eggs are an ideal carrier for enriching human diets with several vitamins (folic acid, vitamin B₁₂ and Vitamin E), few minerals (iodine and selenium) and omega n-3 PUFAs (Farrell, 2013a). Marine origin products are rich in iodine; people living in areas without access to marine food sources and soils depleted of iodine are particularly of high risk groups. Egg is one of the alternative protein sources which can be enriched to correct iodine deficiency. Normally 100 g edible egg contains 53 µg iodine, which is 33 per cent of RDI (Recommended Daily Intake). Supplementing 5 mg of potassium iodide per kilogram of feed increases iodine content in an egg weighing 60 g, from 26 to 88

µg, without affecting the bird's performance (Röttger *et al.*, 2008). Mineral selenium plays several important functions *viz.*, a potent antioxidant, helps in the proper functioning of the immune system and biologically active T₃ (triiodothyronine) hormone synthesis, reduces some forms of cancers (particularly prostate cancer) and improves sperm motility. Surai and Sparks, (2001) and Surai (2002) have demonstrated simultaneous enrichment of eggs with selenium along with several important nutrients like omega-3 fatty acids, vitamin E and carotenoids. This implies that a single egg can deliver around 50% of the human RDA for selenium. Organic selenium (0.4 mg/kg layer diet) supplementation increases the selenium content of a 100 gram edible egg from 20 to about 60 µg which is the minimum RDI of an adult (Farrell, 2013a).

Normal layer diet and egg contain a certain quantity of n-3 fats. The edible egg content of 100 gram contains 150 mg of total n-3; of this, 20 mg is Docosahexaenoic acid (DHA) + Eicosapentaenoic acid (EPA). Including 10% flaxseed (2% ALA) in layer diet, will increase the n-3 fatty acids to > 600 mg/100 gram of edible egg; of this one-third will be DHA + EPA. It has been demonstrated that the designer eggs can offer balanced 1:1 ratios of PUFA: SFA or ω-6/ω-3 PUFA that supply high level ω-3 PUFA (>600 mg) to the consumer (Ahmad *et al.*, 2012). Feeding of omega (n)-3 PUFAs rich rapeseed oil and seeds included diet to laying hens results in lower concentrations (DHA and EPA) in eggs, compared to flaxseed fed hens. Marine origin sources like fishmeal, fish waste and fish oils are rich sources of n-3 PUFAs and feeding these products included in layer diet will

increase the egg n-3 PUFAs (EPA and DHA), but if included in a higher percentage in the diet may cause fishy taints in eggs (Farrell, 2013b).

Nutrients for better gut health and production

Healthy gut is of paramount importance for the efficient digestion and absorption of nutrients. Apart from this, gut act as a largest immunological organ and works as a first defensive mechanism to exogenous pathogens. Pathogenic changes in the gut microbial system cause intestinal dysfunction, which leads to increased passage rate, reduced retention time, poor nutrient utilization (reduced digestion and absorption of nutrients especially minerals), reduced feed intake, increased feed conversion rate (FCR) and excess immunological response. Healthy gut and good gizzard development is a key concern in laying hens for the efficient utilization of nutrients for egg production. Larger feed particle size helps in the development of larger and more muscular gizzard and longer intestinal tracts. Further, larger feed particles retained longer duration in the gizzard and stimulate pH drop, which has a bactericidal effect. The transit time of larger size feed particles improves the intestinal microvilli length and increases the absorptive surface area. Feeding whole grain along with concentrate feed to the layer is a newer concept, it improves the performance and flock health by two physiological actions *viz.*, gizzard development and increased proventriculus secretion (Ravindran, 2013). Though crude fibre is an inert nutrient in monogastric animals, five per cent crude fibre is allowed in the laying hens' diet. Insoluble

fibre also helps in gut development, whereas soluble fibre affects intestinal function by increasing the gut viscosity, due to its higher NSP (non-starch polysaccharide) contents. Excess protein intake also negatively affects the intestinal health by an increased supply of undigested amino acid and non-amino acid nitrogen to the ileum. This undigested nitrogen causes overgrowth of pathogenic bacteria, alteration in the gut ecosystem, dysbacteriosis, gut irritation and in a few cases subclinical necrotic enteritis. Probiotics (direct fed microbials), prebiotics and synbiotics positively affect gut ecosystem by increasing the beneficial microorganisms (WATT Poultry, 2020a). Apart from gut health, all these nutrients reduce the incidence of dirty eggs and help in clean egg production.

DDGS (Distillers Dried Grains with Solubles) in layer diets

The higher cost of soybean meal necessitates the search and use of alternate protein sources in the layer diet. DDGS is an alternate protein source, which is rich in energy and amino acids. The amount of nutrients present in the DDGS is two to three times more than the amount of nutrient present in the grain (Świątkiewicz and Koreleski, 2008). Darker colour DDGS contains a lesser concentration of xanthophyll pigments due to oxidation of carotenoids during overheating. Whereas, lighter colour DDGS has a higher amount of xanthophylls, due to its liposoluble nature. DDGS are rich in fat (PUFAs), especially linoleic acid, which is important for yolk formation and egg weight. Results of El-Hack *et al.* (2019) confirmed that DDGS can be added at a maximum inclusion level of around 12% for the best performance and

egg characteristics. They also found that the yolk color density increased as dietary DDGS level increased (0, 6, 12, and 18% of diet). The eggs produced by the layers fed DDGS had higher levels of tocopherols, tocotrienols, and xanthophylls in the yolk in addition to increased yolk yellow and red color (Trupia *et al.*, 2016). PUFAs are highly susceptible to oxidation, drying process of DDGS hasten this oxidation process. Feeding oxidized lipids containing diets adversely affects liver status, thereby affects egg quality and production. Sulfuric acid is added during the ethanol production processes to maintain the desired pH for the propagation of yeast and better conversion of starch to ethanol (fermentation), and also for cleaning purposes. Hence, while using DDGS in layer ration, checking the sulfur level is important. Excess sulfur (0.6 per cent greater than the poultry requirement) produces wet litter and 1.2 percent resulted in depressed growth in poultry (WATT Poultry, 2020b).

Products of biotechnology in layer diets

Biotechnological advancements have provided new opportunities (e.g., feed enzymes, gut ecosystem enhancers (probiotics and prebiotics), antimicrobials and crystalline amino acids). The products derived using modern biotechnology tools like feed enzymes have a positive effect on feed digestibility, flexibility in diet formulation, performance, productivity and mitigation of environmental pollution (Alagawany *et al.*, 2018). Enzyme phytase plays a key role in the effective utilization of phosphorus (phytate phosphorus) present in the feed ingredient, reducing the pollution by excretion of excess

phytate phosphorus in to soil. The benefits of phytase in poultry nutrition is multi-various including improved feed utilization, weight gain, egg production and egg traits, nutrient digestibility, energy availability, retention of important minerals in blood and bones as reviewed by Abd El-Hack *et al.* (2018).

The byproducts of confectionary industry (single-cell protein and yeast protein) and designer ingredients like high-oil corn (yellow dent corn), lysine-rich corn (opaque-2 maize), high-methionine lupins, quality protein maize (QPM-SR-SYNTH and QPM Longe 5), low oligosaccharide soybean meal (SBM-LO), low-erucic acid and low-glucosinolate rapeseed varieties ("00", double-zero, double low, canola) and low phytate maize (*Ipa-1* mutant hybrid corn) are the products of biotechnological innovations made for enhancing the efficiency and productivity of animals through improved nutrition (Ravindran, 2013).

Feed nanotechnology

Nanotechnology is a promising and emerging technology that has many benefits in poultry. Mineral nano particles have been shown as potential mineral supplements compared to inorganic mineral supplements because of their better absorption and low antagonism with other minerals (Patra and Lalhriatpuii, 2020). The preparation of nanoparticles (of particle size from 1 to 100 nm) from plant sources is referred to as green synthesis. As this process involves plant extracts which consist of sugars, polyphenols, terpenoids, proteins, etc. in reducing the particle size less than 100 nm. In poultry

nutrition, nanotechnology is mainly used in the preparation of nano-minerals especially trace minerals, whose bioavailability is low. In addition, minerals as nanoparticles reduce intestinal mineral antagonism, thereby reducing excretion and environmental pollution. Studies have suggested that feeding of nanoparticles improved the digestive efficiency, immunity and performance in livestock and poultry. Patra and Lalhriatpuii (2020) reviewed the current state of knowledge on various mineral nanoparticles such as calcium, zinc, copper, selenium, chromium, manganese and iron, which have been studied in poultry. Encouraging results have been shown on egg production and FCR (Abedini *et al.*, 2017), egg mass, eggshell thickness, and shell strength (Abedini *et al.*, 2018) and immune response (Lin *et al.*, 2019). However, Tsai *et al.* (2016) reported no effect on egg production, egg weight, FCR, eggshell strength and egg weights.

Nutrigenomics

It has been demonstrated that nutritional factors have a major influence on healthy gene expression (genomics), protein synthesis (proteomics) and metabolism (metabolomics). The study of how genes and gene products interact with dietary chemicals to alter the phenotype and conversely, how genes and their products metabolize nutrients is called nutritional genomics or 'nutrigenomics' (Das *et al.*, 2018). The most powerful molecular tools for examining nutrient effects at the most basic level comes from high-throughput microarrays (gene chips), that allow for the examination of the expression of thousands of genes at a time (Masotti *et al.*, 2010). These

arrays have allowed investigators to directly examine the effects of nutrient supplies in great detail and at the most rudimentary level of gene transcription (gene expression). Nutrigenomics will provide methods and specific markers for rapidly evaluating the nutritional status of individual and groups of animals. Such markers will open new avenues for nutritional research and truly change the way we think about nutrition as a science. The gene-level nutrigenomics data combined with the production data (e.g., weight gain, egg production) from chicken will elucidate how nutrients influence animal health and production. Nutrigenomics provides a way to precisely formulate the ration so as to elicit maximum benefits (Brennan, 2017).

Phylogenics

The phylogenics are receiving much attention for their potential to replace antibiotic growth promoters in poultry nutrition for a wide range of activities. They are a wide variety of herbs, spices and products derived thereof and are mainly essential oils. Gut microflora has significant effects on host nutrition, health and growth performance by interacting with nutrient utilization and the development of gut system of the host. In addition, some phytogetic compounds seem to promote intestinal mucus production. The antibacterial, antifungal, detoxicant, anticoccidial, and immunomodulatory properties of phytobiotics have been well documented and reviewed by El-Ghany (2020). These activities of phytobiotics include but are not limited to sensorial stimulation, improvement of palatability, increment of enzymatic activity in the intestinal tract, enhancement of nutrient

utilisation, increased antioxidant protection, intestinal cell turnover and barrier function, and acting as quorum sensing (QS) inhibitors (Muller and Aumiller, 2016). In layer chicken, use of phytogetic products on deposition of total carotenoids in egg yolk (Kotrbaek *et al.*, 2013) and improvement of shell thickness (Mary, 2015) have also been recorded.

CONCLUSIONS

Modern layers are high performers and exploiting the maximum genetic potential out of them requires a better understanding of the nutritional need of the birds and good nutritional programming. The challenge for nutritionists and husbandry people is to provide the feed and husbandry conditions to enable that genetic potential to be achieved. Using newer feed ingredients (unconventional feed ingredients) and analytical tools in feed formulation, understanding and adopting various proven nutritional strategies and incorporating the knowledge of emerging fields of science like biotechnology, nanotechnology, nutrigenomics, phytogetic are important to reduce the production cost and to improve flock health, productivity and profit.

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