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Breeder Nutrition and Offspring Performance[1]

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ABSTRACT

Vertical integration in poultry industry strongly emphasizes the importance of cost control at all levels. In the usual broiler production operations, the costs involved with the production of the hatching egg or the day old chick are negligible if seen in the perspective of the cost per kg of live bird.

From a research point of view, anyway, the greatest attention is usually given to the performance of broiler breeders, and most of the research in the field is focused on the improvement of their relative performance, mainly in terms of saleable chicks produced per hen, while less attention has been given to the quality of the chick and to the improvement of its growth performances, even if these last parameters have an effective impact on the overall economics of the poultry growing business. Most of the data available is quite dated, as can be seen from some recent reviews, and in general little attention is given to the impact of parental nutrition on the subsequent broiler performance. It is in fact more usual to find data about dam nutrition influence on egg fertility and hatchability than on subsequent progeny performance.

The objectives of this review were to assess, on the basis of published reports, the effects of selected nutrients and anti-nutrients normally prevailing in commercial broiler breeder feeds – vitamins, micro-minerals, mycotoxins, – trying to pinpoint which could be the positive and the negative effects of both on the subsequent broiler performance, with a particular attention to the impact on immune function and carcass yield.

INTRODUCTION

The nutrition of breeding hens has been subjected to a steady improvement in the years, and the more it came clear how to feed them in order to obtain the best production and fertility, the smaller became the field of possible improvement.

The possibility of improving broilers production parameter by means of manipulation of the parent stock diets has been the subject of research for many years, with the aim to find ways to influence the growth of their offspring in a most economical way.

This is due to the fact that the relative incidence of layer feed costs on the total feed cost of production of one live bird is very small, as it can be seen from the calculations shown in Table 1 and 2, and Equations 1, 2, 3, 4 and 5.

Breeders

Table 1 - Basis of estimating breeders feed cost

kg of feed per 100 chicks hatched	*chicks per hen housed from 24 to 63 wks*	*kg of feed per hen from 0 to 23 wks*	*kg of layer feed per 1 hatched chick*
40.6	145	13.9	0.31

Calculation of the amount of feed:

kg of feed per 145 chicks:

40.6 x 1.45 = 58.9 ***Eq.1***

kg of feed per hen housed from 24 to 63 wks:

58.9 – 13.9 = 45.0 ***Eq.2***

kg of feed per 1 chick hatched:

45 / 145 = 0.31 ***Eq.3***

Broilers

Table 2 - Basis of estimating breeders feed cost

42 days live weight (kg)	*42 days FCR*	*feed per 1 chick at day old*	*feed per 1 broiler at 42 days*
2.474	1.721	0.31	4.47

Calculation of the amount of feed:

kg total feed consumed at 42 d:

2.474 x 1.721 = 4.26 ***Eq.4***

kg of feed consumed plus 5% mortality equivalent:

4.26 x 1.05 = 4.47 ***Eq.5***

$$\text{Ratio} \left\{ \frac{\text{Feed per 1 chick at day old}}{\text{Feed per 1 broiler at 42 days}} \right\} \text{x } 100 = \left\{ \frac{0.31}{4.47} \right\} \text{x } 100 = 6.94\% \qquad \textbf{\textit{Eq.6}}$$

Any nutrient manipulation of layer feed has then a minimal impact on the overall feed costs of broiler production since, as shown above, the maternal feed consumption for one hatched chick accounts for less than 7% of the total feed consumed by the chicken during growth. This explains why this research area is so interesting, considering how huge the return could be. A problem arising in this field has always been the need to distinguish between nutrient manipulations that gave their positive effect on broilers by means of a better – or more appropriate – nutrition of the dams, and real improvement of broiler performance through nutritional manipulation of their mother's diets, whose effects "jump" onto the offspring. The first ones are as interesting as the latter from an economical point of view, but much easier to verify and put into practice, as it has been done.

Impact of maternal macronutrient, mineral and vitamin nutrition on progeny

A recent paper (Kidd, 2003) gives an excellent review on the possibility to impact the offspring performance by means of manipulation of dam's nutrition. We will try to update this option with the most recent findings.

Macronutrient and mineral and vitamin nutrition at large have been historically the first areas tested for possible development, followed by two areas that have recently gained interest, broiler carcass modification and immuno-modulation.

Let's take into consideration the macro-nutrient side of breeder nutrition (Table 3).

It can be easily seen that, as the available data on protein and energy is quite dated and spread on a large date interval, the evolution of the genetic background of the birds tested casts doubts on the relevance of the overall data for today's birds.

Some of the nutrient manipulations presented have been put to work in practical diets, like the reduced protein levels later in lay, as most of the positive ideas presented have either become integral part of the know-how in poultry reproduction or abandoned because not feasible due to genetic or managerial problems.

Mineral nutrition trials (Table 4) show little improvement – one recent paper about organic manganese and zinc supplementation (Virden et al., 2003) – while most test are more relevant as deficiency assessment than as positive dietary manipulation.

Table 3 - Effects of breeder hen macro-nutrient on progeny performance (adapted from Kidd, 2003).

Nutrients modification in breeder feed	*Effects on progeny*	*Parameter*	*Authors*
CP, TSAA, Lysine, Arginine, Tryptophane Calcium, Phosporus, Sodium	No	Body weight at 49 d	Wilson & Harms, 1984
15 or 17% CP	Yes	FCR at 41 d (best with low CP)	Prrtoudfoot *et al.*, 1985
9, 11, 13, 15% CP	Yes	Body weight at hatch and at 24 h only in female(higher with 15% CP)	Lopez & Leeson, 1994
9, 11, 13, 15% CP	No	Productive performance and carcass traits at 49 d	Lopez & Leeson, 1994
10, 12, 14, 16% CP	Yes	Chick weight at hatch (lower with 10-12% CP)	Lopez & Leeson, 1995a
10, 12, 14, 16% CP	No	Body weight up to 48 d	Lopez & Leeson, 1995b
14.6% CP, 2490 kcal/kg ME *vs* 17.5% CP, 2880 kcal/kg ME	Yes	Growth rate at 42 and 63 d (higher with high density diet)	Aitken *et al.*, 1969
1.88, 1.73, 1.52 MJ MEa and 19.4 or 27.2 g CP/bird/d	No	Growth rate, FCR, mortality	Pearson & Herron, 1981
13.1% CP + 12.2 MJ/kg *vs* 16% CP + 11.3 MJ/kg	No	Productive performance	Proudfoot & Hulan, 1986
19, 25 g CP and 325, 385, 450 kcal/kg ME	Yes	Body weight in male chicks at 1 and 20 d (higher with 450 kcal/kg ME)	Spratt & Leeson (1987a)
19, 25 g CP and 325, 385, 450 kcal/kg ME	Yes	Increased carcass protein and decreased carcass fat at 41d (with 450 kcal/kg ME)	Spratt & Leeson (1987a)
Increasing CP and energy	Yes	Body weight, particularly of male	Brake *et al.* (2003)
High energy in male breeder	Yes	Body weight at 42 d	Attia *et al.*, (1993, 1995a)
Oleic, linoleic and linolenic	Yes	Fatty acid composition of embryos	Cherian & Sim, 1993
Palm butter, safflower oil	No	Body weight at 35 d	Halle, 1999
No added fat, corn oil, poultry oil, lard	No	Body weight, FCR, feed intake, liver weight from day 1 to 22	Peebles *et al.*, 1998
1,5 or 3 % corn , poultry or coconut oil	Yes	Body weight, front half carcass yield at 43 days	Peebles *at al.*, 1999b
Less saturated fat	Yes	Live performance and carcass yield	Peebles *et al.*, 2002b

Table 4 - Effects of breeder hen mineral nutrition on progeny performance (adapted from Kidd, 2003).

Nutrients modification in breeder feed	*Effects on progeny*	*Parameter*	*Authors*
Restricted calcium levels	Yes	Chick body weight at hatch	Buckner *et al.*, (1925)
2, 6, and 10 g/kg of avail. P	No	Body weight at hatch	Triyuwanta *et al.*, (1992)
2, 6, and 10 g/kg of avail. P	Yes	Progeny ossification at hatch	Triyuwanta *et al.*, (1992)
Addition of 3,5 g/kg defluorinated P to 3,4 and 3,9 g/kg diets	No	Ash, calcium and phosphorus levels of chick tibia at hatch and 2 wks post hatch	Harms *et al.*, (1964)
15 mg zinc/kg	Yes	No zinc deficient symptoms	Turk *et al.*, (1959)
28, 34 or 40 mg zinc/kg	Yes	Feather fraying with unsupplemented diets (28-34 mg/kg)	Stahl *et al.*, (1986)
28, 34 or 40 mg zinc/kg	No	Growth from hatch to 21 days	Stahl *et al.*, (1986)
0, 20, 200 and 2000 mg zinc /kg	No	Body weight or zinc, copper and iron metabolism at 21 days	Stahl *et al.*, (1990)
BD (100 mg zinc/kg) + 80 mg/kg zinc methionine	Yes	Improved survival to an *Escherichia coli* challenge	Flinchun *et al.*, (1989)
BD (100mg zinc/kg) + 40 mg/kg zinc oxide or zinc methionine	Yes	Improved cellular immunity (only with zinc methionine)	Kidd *et al.*, (1992)
BD (72 or 82 mg/kg) + 40 mg/kg of zinc oxide or zinc methionine	Yes	Improved humoral immunity (only with zinc oxide), improved cellular immunity (only with zinc methionine)	Kidd *et al.*, (1993)
Manganese deficiency	Yes	Abnormal shortening of the bones in embryo and progeny	Caskey & Norris, (1940)
BD (75 mg/kg zinc and 83 mg/kg manganese) + 75 mg/kg zinc + 80 mg/kg manganese	Yes	Improved liveability from 1to 18 d and from 1 to 34 d with organic forms of Zn and Mn *vs* inorgarnic form	Virden *et al.*, (2003)
0 or 0.03 mg Se/kg	Yes	Poor growth in deficient diet	Cantor & Scott, (1974)
0.05 or 0.1 mg Se/kg	Yes	Bilateral paralysis and skeletal and muscular degeneration with deficient diet	Bains *et al.,* (1975)
100 mg/kg of sodium fluoride in drinking water	No	Growth in progeny until 28 days	Merkley & Sexton, (1982)
0, 300, 600, 900 and 1200 mg fluoride/kg	No	Growth rate and FCR from hatch to 14 days	Van Toledo & Combs, (1984)
Mg deficient diets	Yes	Chicks with convulsions and comas that died within 2 days	Sell *et al.*, (1967)

BD: basal diet

Most of the vitamin trials reported (Table 5) show the importance of an adequate vitamin supply to the dams in order to avoid deficiency problems in the chicks, but cannot demonstrate the benefits of increasing the levels above recommended - with some notable exceptions like vitamin D_3 (Ameenuddin *et al.*, 1986) and its derivatives (Atencio *et al.*, 2005b, c) and vitamin E (Haq *et al.*, 1996; Hossain *et al.*, 1998) – and often show problems of toxicity or are too old to be fully relevant.

An interesting report (Hossain *et al.*, 1998) indicates that high concentrations of vitamin E in hen feeding support not only better progeny performance but also their ability to increase the immune response; however the *in ovo* administration of vitamin was more effective in increasing the antibody response.

Rebel *et al.* (2004), investigating the effect of high dietary supplementation of vitamin and trace element premix in broiler breeder, confirmed the importance of some micronutrients in modulating the immune response in birds. The Authors observed a fast recovery in the state of the intestine of broilers hatched from breeders fed the high supplemented premix after Malabsorption Syndrome (MAS) inoculation associated to a higher level of lymphocytes in day old chicks.

It is well documented that in general nutrition might greatly affect immuno-competence in birds, with particular regard to vitamins and minerals (Latshaw,

Table 5 - Effects of breeder hen vitamin nutrition on progeny performance (adapted from Kidd, 2003).

Nutrients modification in breeder feed	***Effects on progeny***	***Parameter***	***Authors***
363, 544, 2,268 IU Vit. A /kg diet	Yes	Accelerated growth with 2,268 IU vit A	Hill *et al.*, (1961)
β-carotene, cantaxhanthin, lutein and vitamin E	Yes	Bursal and splenic lymphocyte proliferation (vit. E and β-carotene), humoral immunity (increased by vit.E and reduced by β-carotene)	Haq *et al.*, (1996)
Vit. E and Se deficient diet	Yes	Reduced growth and plasma tocopherols and increased exudative diathesis	Combs, (1976)
0 to 120 μg/g of retinol equivalents	Yes	High liver lipid peroxidation with excess of vit. A	Surai *et al.*, (1998)
0 or 150 mg/kg vit. E	Yes	Higher agglutination titers at 2 and 7 days (150 mg/kg vit E)	Jackson *et al.*, (1978)
5,000 μg/kg cholecalciferol	Yes	Higher tibia ash	Ameenuddin *et al.*, (1986)
0, 1, 10 mg vitamin K_1/kg or 1, 10 mg/kg menadione sodium bisulfite	Yes	Prothrombin levels were higher in chicks fed vit. K_1	Griminger (1964)
Vit. K deficient or adequate diets	Yes	Blood clotting time increased with deficient diets	Lavelle et al., (1994)
Biotin deficient diet	Yes	Leg abnormalities	Cravens *et al.,* (1944)
0, 20, 40, 60, 100, 180, 340 μg biotin/kg	Yes	Higher body weight at 14 days with biotin supplementation	Brewer & Edwards (1972)
Deficient biotin diets	Yes	Reduced plasma biotin at hatch, reduced viability and growth	Whitehead *et al.,* (1985)
Deficient biotin diet	No	Male and female progeny body weight at 0 and 21 days	Leeson *et al.*, (1979 a)
200 mg biotin/kg	Yes	Reduced foot pad dermatitis and incidence of breast blisters in progeny	Harms *et al.,* (1979)
Riboflavin deficient diet	Yes	Curled toe paralysis	Whitehead *et al.*, (1993)
Riboflavin deficient diet	No	Growth rate	Leeson *et al.,* (1979a)
Vit. B_{12} deficient diet	No	Growth rate	Leeson *et al.*, (1979b)
0 or 10 μg vit. B_{12}/kg diet	Yes	Enhanced body weight gain at 21 days (with 10 μg vit. B_{12}/kg diet)	Patel & McGinnis, (1977)
6-8 mg pantothenic/kg diet	Yes	Better viability and growth rate	Beer *et al.*, (1963)
6.6 and 9.9 mg pantothenic/kg diet	Yes	Improved body weight gain at 10 days	Balloun and Phillips, (1957)
Pantothenate deficient diet	No	Growth rate	Leeson *et al.*, (1979a)
25, 50, 75, 100 ppm vit. E	Yes	Higher body weight, better FCR, lower mortality, higher immune response to ND vaccine with high level of vit. E	Hossain *et al.*, (1998)
0, 2.5, 5 mg/egg vit. E *in ovo* injection	Yes	Higher body weight, better FCR, lower mortality, higher immune response to ND vaccine	Hossain *et al.*, (1998)
High or low vitamin and trace mineral premixes	Yes	Higher blood cell and specific antibody reaction	Rebel *et al.*, (2004)
0, 125, 250, 500, 1,000, 2,000, 4,000 IU/kg vit. D_3	Yes	Body weight gain and lower Ca rickets incidence (2,000 or 4,000 IU)	Atencio *et al.* (2005a)
0, 3,125, 12,500, 50,000 ng/kg vit. D_3 or 3,125 and 12,500 ng/kg 25-OHD_3	Yes	High body weight, FCR, bone ash, low mortality (with high level of vit. D_3 or 25-ODH_3)	Atencio *et al.* (2005b)
0, 125, 250, 500, 1,000, 2,000, 4,000 IU/kg vit. D_3 or 3,125 and 12,500 ng/kg 25-OHD_3	Yes	High body weight gain, tibia ash and low leg and bone disorders (with high level of vit. D_3 or 25-ODH_3)	Atencio *et al.* (2005c)
0, 25 mg L-carnitine/kg	Yes	Low carcass fat and high breast meat (in progeny fed high density diet)	Kidd *et al.*, (2005)

1991). The effect of nutrients has been more largely explored in broiler chicken nutrition rather than in broiler breeder and their progeny, so further researches are needed for better elucidate the immuno-modulatory nutrient requirement that will positively impact the overall health of chickens and, consequently, profitability in poultry industry.

Effects of nutrients manipulation in broiler breeder feeding on progeny carcass traits

This section addresses to the latest published reports that have not been dealt in the previous review (Kidd, 2003).

It is worldwide recognized that in broiler breeder formulation several parameters have to be taken into account: in particular requirements for maintenance, growth and reproduction need to be carefully considered for maximizing the reproductive and productive performances of parents. Thus, the nutrient profile commercially adopted to obtain the best performance from breeders has been selected to obtain the highest economically productive performance, represented by the number of saleable chicks produced per hen. However, good breeder hen performances and also hatchability do not necessary positively correlate with high percentage chicks of good quality with high liveability and growth potential (Decuypere & Michels, 1992). Therefore a gap among the goals of breeding, hatchery and farming exists since very little attention has been paid, from the top of the chain, to the quality of day-old chicks for the reason that is not yet fully perceived as high performance potential chicks.

Starting from these considerations, a “new concept” has been developed based on the possibility of positively influencing the offspring performance with particular regard to their carcass composition, through adequate supplementation and balance of nutrients in dam nutrition.

The effect of nutrient manipulation in broiler breeder feeding on progeny carcass composition was firstly explored and documented by Spratt & Leeson (1987). The Authors observed that protein and energy in dam nutrition can alter the carcass fat and protein deposition of offspring at slaughtering and processing. In particular, providing 150 g of feed per days with 19 or 25 g of crude protein and 325, 385 or 450 kcal/kg ME from 19 weeks onwards, the progeny performances of chicks hatched at weeks 29, 32, 36 and 40 were monitored. Beside a better growth rate of male progeny chicks from hens receiving the highest energy diet (450 kcal/kg ME) an increased protein retention with a reduced fat deposition at 41 days of age was observed in comparison with chicks of hens receiving the lowest energy diet (325 kcal/kg).

Some other experiments aiming at understanding the role of the type of fat included in the maternal diet on the offspring body composition at slaughter were carried out by Peebles *et al.*, (1999; 2002). Different fat sources such as corn oil, poultry fat and lard and two levels of inclusion, 1.5 and 3%, were tested in broiler breeder hens and their effects were monitored on progeny hatched at 35, 51 and 63 weeks. Corn oil had a positive effect on progeny at days 43 by enhancing the proportion of carcass yield (breast, wings and back) compared with the animal origin fat. These findings demonstrate that a reduction of the unsaturated-saturated ratio in hen feeding positively impacts on progeny carcass yield at processing.

Furthermore, the effect of L-carnitine supplementation (25 mg/kg) in breeder hen diet on progeny performance and carcass traits was recently investigated by Kidd *et al.* (2005). The Authors demonstrated that the hen dietary manipulation affects carcass fat and breast meat differently in male and female progeny. Indeed, offspring from hens receiving no supplemented diet produced male with lower relative fat than female and this effect decreases in progeny from hens with supplemented diets. Moreover the L-carnitine supplementation was able to reduce the difference of relative breast meat yield between male and female where it is commonly higher in the latter. The Authors postulated that L-carnitine inclusion in hen diets modified the energy metabolism in progeny making fatty acids and energy more available and consequently allowed males for higher tissue accretion because of their rapid growth rate. However these results were observed only with hens fed high, but not low, density diets. This nutritional approach represents a successful and cheap strategy to improve the efficiency of the poultry food chain and, in general, this opportunity should be further investigated with the aim of better understand the breeder hen nutrient requirements in relation to the maximization of the offspring overall performance.

As already mentioned, great attention has been focused on the possibilities to stimulate the early growth of the chicks, starting from the embryonic stage, by providing the egg with higher concentrations of micronutrients with particular regard to vitamins. It is well known that the egg vitamin profile it is easily modifiable through the hen nutrition and this possibility might represent an important tool also in breeder nutrition to deliver essential nutrients in proper amount in the yolk sac with the aim of positively modifying some metabolic processes occurring during the embryonic life and early growth phase of chicks.

A clear effect of the influence of the maternal dietary regimen on the progeny performance and particularly on bone characteristic was highlighted by a series of recent works (Atencio *et al.*, 2005 a, b, c). These studies explored the possibilities to improve the bone formation efficiency to reduce the incidence of leg abnormalities and metabolic calcium related imbalances through the dietary maternal supplementation of increasing levels of vitamin D_3 or 25-OHD_3. Interestingly, the progeny hatched from hens supplemented with high doses of vitamin D_3, showed better performance (higher body weight gain), tibia ash content and lower leg abnormalities when fed different calcium levels. However, the supplementation of 25-$OHD_{3,}$ a vitamin D metabolites, in the offspring's diet reduced the effects of the inclusion of high levels of vitamin D_3 in the maternal diet. Moreover, also the dam supplementation of 25-OHD_3, as described for vitamin D_3, improves the same progeny performance. The authors concluded that, when comparing vitamin D sources in the feeding of breeder hens and on their progeny, 25-OHD_3 has greater potency than D_3 only at very low levels of supplementation. In general, from these works clearly emerge that the breeder hen requirements for vitamin D_3 and its derivatives to produce effects on progeny performance and health is considerably higher than the NRC (1994) recommendations and to the levels allowed by the current EU regulation.

Effects of toxic compounds in broiler breeder feeding on progeny

The deleterious effects of some compounds that accidentally may contaminate breeder hen feed such as fungal metabolites or toxic products and their repercussions on progeny health status and performance have not received from a scientific point of view as much attention as the dietary nutrients. As reviewed by Kidd (2003), researches on this topic are sparse (Table 6). The effects of mycotoxins contamination of breeder feed has been mainly focused on Aflatoxins and Zearalenone and the biggest concern and threat related to their transfer to from dam to egg is represented by the impact they exerts on progeny immune function (Qhreshi *et al.*, 1998). Further investigations should be addressed in this field to verify the impact of other classes of mycotoxins normally occurring in feedstuffs for poultry with particular regard to the effects exerted on immune response. Indeed, nowadays due to the negative effect of intensive genetic selective processes and to the ban of most growth promoter molecules in the EU it is becoming increasingly important to hatch healthy chicks without altered function in their immune system and functions.

Another serious threat that might impact on the health status of chickens but also of consumers is represented by the accidental contaminations or voluntary use of some antibiotics of course in broiler feeding but also in breeder hen feeding. Indeed, even though nitro-furans have been banned from the EU, a recent work (McCracken *et al.*, 2005) demonstrated as the residues of these molecules can be transferred from the hen diet (400 mg/kg) to their offspring and that semicarbazide, a nitro-furazone metabolite, can be found in chicken at slaughter.

Table 6 - Effects of non nutritional compounds in breeder hen nutrition on progeny performance (adapted from Kidd, 2003).

Compounds in breeder feed	*Effects on progeny*	*Parameter:*	*Authors*
0, 5, 10 μg/g aflatoxin	No	Chick weight from hens fed treatment diets for 1, 2 or 4 wks	Howarth & Wyatt, (1974)
0, 5, 10 μg/g aflatoxin	No	Mortality, feed efficiency and weight gain at 14 d	Howarth & Wyatt, (1974)
0, 0.2, 1, 5 mg/kg aflatoxin B	Yes	Decreases cellular and humoral immunity	Qhreshi *et al.*, (1998)
0, 10, 25, 50, 100, 200, 400, [1]800 mg/kg zearalenone	No	Body weight at 0 and 21 days	Allen *et al.*, (1981)
0, 30, 300, 3000 mg/kg insect regulator CGA-72662 (Larvadex®)	Yes	Depressed body weight at 14 dwith high levels in progeny from young dam	Brake *et al.*, (1984)
0, 30, 300, 3000 mg/kg insect regulator CGA-72662 (Larvadex®)	No	Feed efficiency and mortality at 14 days	Brake *et al.*, (1984)
400 mg/kg furazolidone, nitrofurazone, furaltadone, nitrofurantoin	Yes	Residues of nitrofurazone metabolite (semicarbazide) in liver and muscle of day old chicks.	McCracken *et al.* (2005)
400 mg/kg furazolidone, nitrofurazone, furaltadone, nitrofurantoin	No	Residues in chicken at 40 days	McCracken *et al.* (2005)

Also the effects of synthetic compounds, as those used to control pests in poultry houses, on progeny performance have been investigated (Brake *et al.*, 1984). It was clearly demonstrated that feeding hen with diets containing an insect growth regulator negatively affected broiler chicken performance.

FINAL REMARKS

This area of research, overall, is quite interesting but it is rapidly being superseded by the fast developing technology of *in-ovo* injection of drugs and nutrients: this will undoubtedly make the possibility of influencing broiler performance much more easily than it has been in the past, giving a real, practical tool to the large scale poultry producers.

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