VITAMIN SUPPLY AND ITS INFLUENCE ON THE RESISTANCE OF POULTRY TO INFECTIOUS DISEASES, PARASITE INFESTATION, AND OTHER STRESSES.*

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The principles involved in the fortification of poultry feeds with vitamins have undergone considerable changes over the years. Initially attention was given to meeting the minimum requirements of the bird, usually determined by some easily measured factor such as weight increase or laying capacity or by the prevention of obvious deficiency symptoms. The basis for these requirements was obtained from data on healthy animals under optimum conditions of husbandry and nutrition. It was held to be sufficient to add to feeds enough of the essential vitamins to make up the difference between the natural vitamin contents and these minimum requirements.

The components of feeds are of widely varying and frequently unknown origins. They are also obtained as by-products from a number of processes in the food industry and some of these processes reduce the vitamin contents. It was soon found that, in practice, further additions had to be made in order to ensure adequate coverage to account for the fluctuations which occur in natural vitamin contents and for the losses incurred in the manufacture, transport, and storage of feeds. Such procedures were followed until synthetic manufacturing developments led to large scale production at practical prices, allowing their unrestricted use in feeds. New types of feeds with high energy and protein contents suitably adapted to age, capacity, and environment were developed. This coupled with an intensive scientific breeding program resulted in more productive species. It was realized in the course of development that superior performance in animal efficiency requires a more intensive supply of the major nutrients and of the vitamins. It was discovered that the natural vitamin content of the components of feeds can vary very much, and also that the vitamin contents of mixed poultry feeds as determined by chemical or microbiological methods may be only partially utilized.

The change made was to supply the entire requirements of a number of the more important vitamins most likely to be deficient: in the first instance, the vitamins A, B_2, D_3,

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and then later B_{12}. Other vitamins, for example, vitamin E principally, also pantothenic acid, niacin, B_1, B_6, and K were added in such amounts that only a part of the requirement was supplied, allowance being made for the natural vitamin content of the components of the feeds.

Reliance was no longer placed on *minimum* vitamin requirements. More recent figures were ascertained under practical experimental conditions. Growth and laying capacity are no longer the only determining factors. The *quality* of the products, for example, meatiness, deposition of fat, the presence of breast blisters and bruises, fat and meat stability and storage life of broilers, egg-shell quality and the incidence of blood spots in laying hens, and in breeding hens, fertility, hatchability (of the eggs) and the early development of the chick are participating factors.

The supplemental vitamin requirements following this trend were multiples of the minimum requirements; they were incorporated in recognized standards such as the specifications for the vitamin supplementation of poultry feeds recommended by poultry authorities which were subsequently adopted by official and semi-official organizations.

In practice, these levels are often exceeded, as witness the labels on feedbags—or (even more instructive) the formulae of commercial mixed feeds. We believe that the feed industry has very good reasons for these additions as both research and practical experience have pointed the way. Emphasizing our point, it may be said that one of the determining factors was the general realization that stress phenomena can be relieved, *inter alia*, by increased vitamin supply.

The term "stress" is frequently encountered, and it is understood to mean the state of alarm in the animal organism evoked by physical and/or psychological irritation. Depending upon the magnitude and the duration of the stress the animal will strive to fend off the damaging influences and will either overcome them or will succumb to them. These stresses include heat, cold, infections, parasite infestation, injuries, crowding or even medication or combinations thereof.

Poultry are being increasingly exposed to these stresses. Trade in live poultry and poultry products across all frontiers, increasing densities of population and other factors have caused the spread of a number of new diseases due to bacteria and viruses. As a consequence, vaccination practices have in-

creased in some countries. It has been found that vaccination *per se* produces stress and, taken in conjunction with other factors, stimulates outbreaks of new diseases. Moreover, other infections have occasionally been spread by live vaccines.

Caecal coccidiosis has declined as a result both of improved husbandry and the use of coccidiostats, whereas coccidiosis of the small intestine has shown a marked increase. The incidence of *Capillaria* worms has also increased in the last few years and has attained significant importance.

All-the-year-round broiler production and the adjustment of the raising season for laying hens (in order to accommodate the sales peak in the winter and spring) have resulted in increased attention being given to the effect of summer temperatures, to mention only one of the factors that influence conditions on the farm.

Serious attention must be given to climatic conditions in developing poultry industries in tropical and sub-tropical countries.

It has now been established both by research and in practice that vitamins are required in increased amounts during stress conditions and that prophylactic or therapeutic vitamin administration in increased amounts enables animals to better tolerate stress factors. This principle is now accepted as being true for man as well as domestic animals.

1. *Parasite Infestation*

The relationships between parasite infestation, as a form of stress, and vitamin supply are particularly well known. As long ago as 1927, still in the early days of vitamin research, Ackert and others[1,3] succeeded in demonstrating for the first time that the natural resistance of animals to worm infestation is lowered by nutritional deficiency. These workers found that poultry on a vitamin A-deficient diet had more and larger *Ascaridia* than control birds maintained on a balanced ration.

This observation has since been repeatedly confirmed (cf.[47,54]). Vitamin A deficiency also favors the propagation and development of gapeworms (*Syngamus*).[15] The incidence of tape worms (*Hymenolepis*) and caecal worms (*Heterakis gallinae*) on the other hand was not altered under vitamin A deficiency.[13,14]

Moreover, it was found that *Ascardia* and *Capillaria* infestations considerably interfered with the vitamin A balance: vitamin A deficiency symptoms occurred more frequently, and

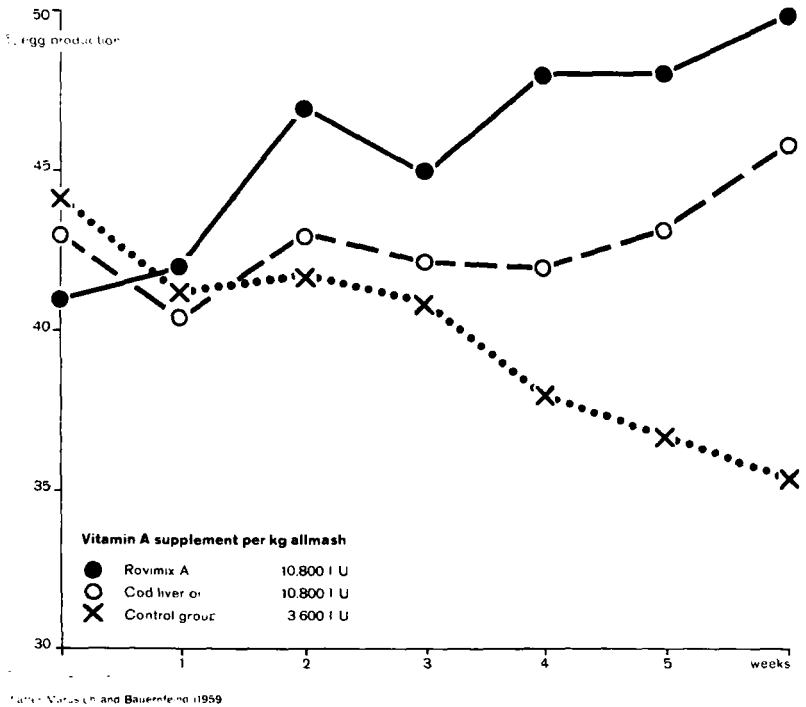
the vitamin A reserves in the bodies of chicks were reduced.[22,23,47,66]

When increased amounts of vitamin A have been supplied to infested chicks, the health of the animals has improved with an increase in growth and production. In addition parasitic infestations have been inhibited. This effect can be utilized especially when dealing with a parasite like *Capillaria* against which no really effective drugs are available.

The practice of vitamin supplementation has been recommended by veterinary advisers to the poultry industry in the USA[6,46] for some time, and it has been confirmed by experimental treatment of poultry infected with thread worms (*Capillaria columbae*).[7] A control group was given a commercial feed for laying hens with a vitamin A content of 3,600 I.U. per kg allmash, and in two other groups (100 animals each) the vitamin A content was brought to 10,800 I.U. per kg by the use of a dry stabilized vitamin A (Rovimix A) or, alternatively, cod liver oil.

FIGURE I

Capillaria infestation and vitamin A supply in laying hens*



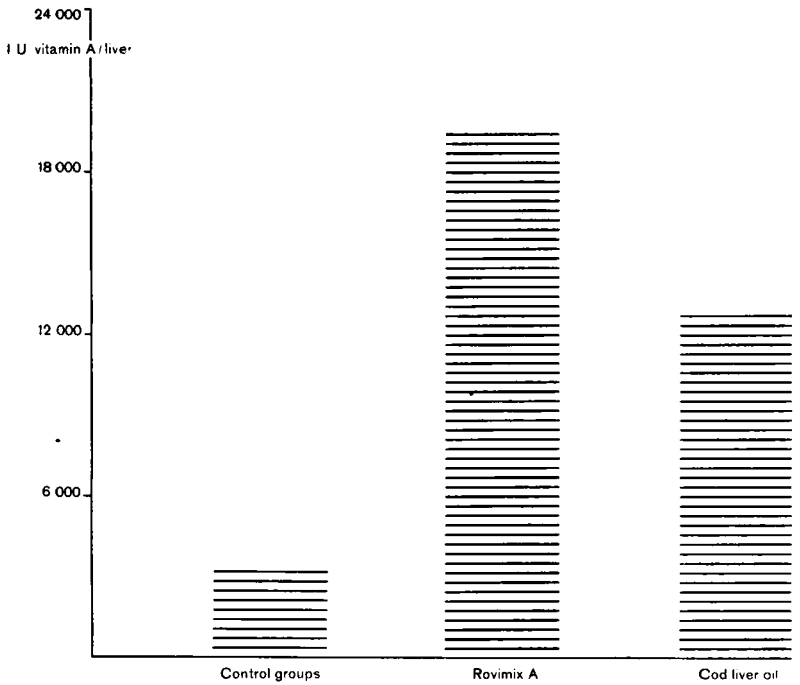
and Bauernfeind (1959)

As Figure 1 shows, after one week the hens in Rovimix A group were already responding with a continuous increase in laying capacity; after cod liver oil feeding this effect was delayed, whilst the laying activity of the control animals declined still more.

Five weeks after the commencement of the experiment, the vitamin A content in the liver of ten hens chosen at random from each of the groups was determined (Fig. II). The results show the close inter-relationships between vitamin A supply and parasite infestation.

FIGURE II

Capillaria infestation and vitamin A supply in laying hens*



* after Bauernfeind and Marusch 1959

We have discussed vitamin A first, partly for historical reasons and partly because of its importance. Vitamin A is the one most frequently lacking in feeds, yet there is particular significance attached to it where the resistance of animals to parasites and infectious diseases is concerned.

This is due first to the fact that, being the "epithelial protecting" vitamin, it maintains normal functioning of the

mucous membranes of the respiratory and upper alimentary tract, and of the skin. It is also essential for the constant regeneration of this tissue. In vitamin A deficiency, the epithelial cells become keratinized, the ciliary current ceases, and the bactericidal action of the normal mucous secretion stops, thus leaving the epithelia unprotected against the invasion of disease carriers (Fig. III).

Fig. III. In the pharynx and oesophagus of a chick suffering from vitamin A deficiency, numerous white nodules are seen. These are mucous glands blocked with whitish clots (courtesy E. Hess, Veterinarbakteriologisches Institut, Universitat Zurich).

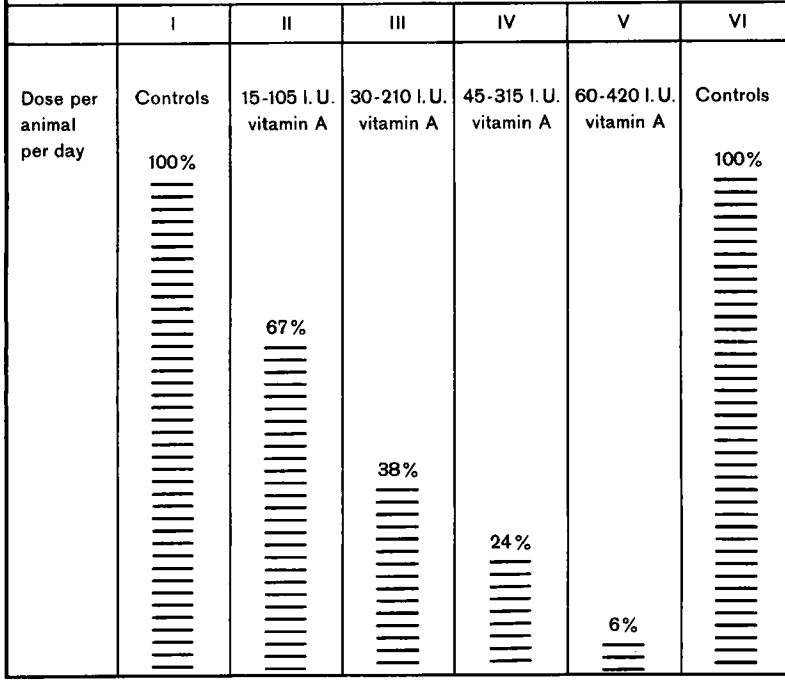
It has not yet been precisely established why intestinal worms find particularly favorable conditions in vitamin A deficient animals although it has been suggested that the damaged epithelia, and perhaps the increased supply of nutrient materials resulting from disturbed intestinal absorption, may provide improved conditions for the worms. Furthermore, the increased incidence of parasites due to the lowered resistance of the host animal, as a result of the deficiency, subjects the animal to bacterial invasion as defensive substances are impaired. It has recently been shown that the serum properdin level in rats is clearly dependent on the amount of vitamin A supplied.[39] This plasma protein, together with magnesium ions and components behaving similarly to the serum complement, is one of the factors responsible for natural immunity.

Despite the priority to be given to good vitamin A supply in obtaining high resistance to intestinal worms, it should be mentioned that poultry also show increased susceptibility to *Ascaridia* in B-vitamin deficiency. Apparently the worms

were also affected, as they tended to be smaller than usual.[4,51,68] Vitamin D deficiency had no influence on the incidence of *Ascaridia* in poultry,[2] but there are indications that vitamin C metabolism may be disturbed in infested chickens (cf.[50,61]). Coccidiosis, the most important poultry diseases caused by protozoa, has a close inter-relationship with vitamin A and has been the subject of detailed investigation in recent years. This disease takes a much more serious course when a vitamin A deficiency is a factor. However, losses can be reduced considerably and convalescence accelerated by a vitamin A supply considerably in excess of minimum requirements.[12,19,38,42,53,64] Betacarotene was unable to maintain feed-intake to the same extent as stabilized vitamin A, nor did it produce normal weight-gains.[19]

Results recently reported by Gerriets[23] have shown that mortality from caecal coccidiosis is related to the vitamin A supply (Fig. IV).

Mortality in spontaneous coccidiosis of chicks as a function of vitamin A supply*



* after Gerriets (1960)

In poultry houses with unfavorable climatic conditions in which caecal coccidiosis regularly occurred, the chicks, with the exception of the two control groups (I and VI), were given vitamin A in a water-miscible form in the drinking water at various dosage levels. (For the dosage shown in Fig. V, the first figure indicates the daily dose per animal administered in the second week of life; this dose was doubled each week, until the dose indicated by the second figure was reached in the eighth week.) Coccidiosis appeared in the fourth week; no therapy was attempted. Losses in the control group were 100 percent. It is impressive to observe that with increasing doses of vitamin A, mortality progressively declined to six percent.

Coccidiosis, moreover, depletes vitamin A reserves.[17,18,19] Investigations on rabbits have shown that the vitamin E reserves are also affected.[18]

In balanced rations, vitamin C supplementation had no beneficial influence on coccidiosis caused by various species of *Eimeria*.[25,31,41] However, it may have a favorable effect on the course of *E. brunetti* infestations.[41]

Intestinal hemorrhage plays a critical part in chick mortality from coccidiosis. If the tendency to hemorrhage is increased as a result of vitamin K deficiency, exceptionally high losses may occur (cf.[31]). Mortality due to coccidiosis has been reduced to about one half by adding vitamin K to vitamin K deficient rations. In this respect vitamin K_1 was found to be four times as effective as menadione sodium bisulphite complex, and this latter was six to seven times as effective as menadione ("Vitamin K_3").[52]

Although effective coccidiostats are available today, continual attention must be given to maintaining a good vitamin A supply for chicks and hens. Coccidiostats are not equally effective against all species of Eimeria, and the development and maintenance of resistance—after the termination of medication—depends on the vitamin A status of the bird. It is also advisable to guard against other eventualities, such as errors in dosage and mixing by an adequate vitamin A fortification of the feed.[29]

Lastly, attention must be given to the adverse effect of certain coccidiostats on the vitamin balance. Nitrofurazone or furazolidone appear to increase, *inter alia*, the requirements of the B vitamins (B_1, B_2 and B_6);[20,21,33,44,45] a similar observation has been made with regard to furazolidone and vitamin E.[58] A number of sulfonamides are known to cause vitamin

K deficiency in chicks and other animals; this can be prevented by the administration of vitamin K (cf.[26,43]). Appropriate increases of the B vitamin and/or K supplements when using such coccidiostats are therefore recommended.[11,20]

2. *Infectious Diseases*

In principle, similar relationships exist between infectious diseases and vitamin supply as have been described above for parasite invasions. It is an ancient truth that hunger and disease are inseparable companions. In the same way, many infections evidently increase vitamin consumption by the body, and insufficient diet leads to the collapse of local and general defense mechanisms.

Fortunately, by intensifying vitamin supply, it is possible to exert a favorable influence on stress conditions to alleviate and shorten the course of the infectious disease, to restrict mortality, and to restore production.

Innumerable scientific publications confirm these findings; therefore, we must again restrict our discussion to a few of the results published in recent years. Once more—as was to be expected, considering that it is essential for the defensive capacity of the epithelial cells—we immediately encounter vitamin A. It has been known for many years that vitamin A deficiency initiates outbreaks of coryza and catarrhs in the upper respiratory tract of fowl (cf.[8,54,55]). Losses among the offspring of pullorum-infected hens are less under a good vitamin A regimen than among hens on a vitamin A deficient diet.[55]

Decreases in the vitamin A content of the blood were observed in chicks suffering from Newcastle disease, fowl cholera, or coryza.[59] More recently, Squibb and Sanslone[60] have found that chicks experimentally infected with Newcastle disease survived outbreaks with reduced losses under vitamin A treatment. In this instance prophylactic administration was particularly effective.

Tuberculosis was reported to decrease the vitamin A-liver reserves in chicken; generous supply of the vitamin, however, retards the clinical outbreak of the disease, prolongs survival time and restricts the size of the tuberculous lesions.[40b]

Changes (mostly a marked decline) in the vitamin C content of the blood have also been observed (cf.[61]) in various infections and diseases of fowls (pullorum disease, fowl typhoid, coccidiosis, coryza, etc.). It appears strange that in fowl cholera and Newcastle disease, the vitamin C content of

the blood should have increased.[57] By prophylactic treatment with vitamin C Biondi nevertheless succeeded in prolonging the survival time of chicks experimentally infected with Newcastle disease.[9]

In recent years, research and practice have shown that the resistance of poultry to infectious diseases can evidently be increased still further if, instead of administering single vitamins, groups of vitamins including vitamin C are given prophylactically, wherever possible in increased doses. It is noteworthy that the course and severity both of bacterial infectious diseases, such as fowl typhoid,[36,37] or of virus diseases, such as fowl pox, are thus favorably affected. The establishment of immunity after vaccination with fowl pox vaccine was considerably assisted by high doses of all the vitamins required by the chick, including vitamin C. Similarly, chicks on a diet of this kind recovered more rapidly from infections with virulent pox than the controls; they also showed improvement in growth.[10]

The adverse consequences of the world-wide scourge of chronic respiratory diseases can also be considerably restricted by vitamin treatment of this kind (cf.[40a,61]).

Controlled therapeutic tests with high doses of vitamins and antibiotics administered to chicks[40a,67] have shown that supplemental vitamin administration is one of the early steps to be taken in ill-defined syndromes of unknown etiology.

Since it is impossible for economic reasons in most cases to adjust the vitamin content of feeds so as to ensure an adequate supply under *all* conditions of stress, it would appear to be advisable to administer supplemental vitamins to animals in the form of special "stress feeds", or in suitable forms that could simply be added to the drinking water. Considerable experience has been gained in Belgium, in the West German Federal Republic, in France, and in Holland by poultry health authorities and other advisory bodies with these stress feeds or with "vitamin shocks" which usually contain the vitamins A, D, and E, but frequently also including the other fat- and water-soluble vitamins. Their use has proved beneficial not only in speeding up convalescence after infectious diseases, but also in improving the vitality of chicks during critical raising periods. In addition, a noticeable reduction of losses and a general improvement in health have been observed in establishments which had repeated this "stress" treatment at regular intervals.

Hitherto unspecific infections of the intestinal tract, particularly among broilers, are being increasingly observed, either alone or together with other disease symptoms.[56,57] Gylstorff[28] pointed out that chronic, atypical vitamin A deficiency symptoms among broiler chicks were increasing. The animals show scab-like coatings in the mucous membrane of the mouth (similar to the thrush-stomatitis observed after antibiotic treatment of aging human patients) as a result of the propagation of the fungus Candida albicans. In poultry, thrush is an infectious disease of the upper digestive tract, particularly the crop. Thrush occurs sporadically as an epidemic affecting chickens, turkeys, geese, ducks, and pigeons in many countries.[5] To a limited extent in the USA, antimycotics are added to feeds for poultry. It had previously been suggested that vitamin (B ?) deficiency favored the outbreak of thrush. Recent investigations have shown that vitamin A increases resistance to this fungal infection; and that, conversely, thrush disturbs the vitamin A balance. Nervous vitamin A deficiency symptoms are twice as frequent in infected animals than in Candida-free chicks.[52]

3. *Environmental Factors*

Such factors as heat, humidity, cold, draughts (due either to climatic changes or to conditions within the premises) are additional stresses influencing the vitamin balance of poultry which may necessitate an increased vitamin supply.

It has been known for some time that feeds containing an increased vitamin A content should be administered to laying and breeding hens in hot weather in order to maintain laying capacity and hatching at a high level and to reduce mortality.[35] Recently interest in this respect has centered on vitamin C (cf. [61]). Shell breakage is known to increase during the summer, interior egg quality deteriorates and both the feed intake and production generally decline.

It has been discovered, surprisingly, that relatively small supplements of vitamin C lead to marked improvement in the thickness and breaking strength of shells, and in the quality of the eggs of laying hens exposed to heat. The calcium supplied with the feed grain must also be increased in order to improve the breaking strength of the eggs.[34,62]

Under exceptionally trying climatic conditions, for example, exposure to humid heat throughout the day and night (such as exists in tropical and subtropical countries) several favorable effects of vitamin C supplementation have been ob-

served: an increase in laying capacity, a decrease of losses, an increase of egg weight, and an improved fertilizing capacity of cocks.[48,49] Stimulation of chick growth has been observed in other experiments.[63]

The fact emerges therefore that vitamin C which in normal circumstances can be synthesized in the body by the chick must under certain stress conditions be supplied to the bird. It is not yet known whether in these conditions the vitamin C consumption of the bird is increased, or whether biosynthesis is impaired.

Accommodation in draughty premises may also favor the occurrence of vitamin A deficiency, as observations on turkeys have shown.[8] The keeping of chickens underground in abandoned coal mines is said to be on the increase in Eastern Germany. Birds kept in these mines have also shown increased vitamin A requirements; an increased incidence of coryza was prevented by administering large amounts of vitamin A.[27]

4. *Other Stress Factors*

A detailed discussion of the stresses caused by dietary factors or associated with intensive performance would be beyond the scope of this review. Attention must however be drawn to the fact that high output, whether as weight-gains or as egg production, makes exceptional demands on the animals. This is proved by the fact that it is the most rapidly growing chicks which are the first to show crazy chick disease or that cage fatigue occurs most frequently in pullets in the first months of laying. Encephalomalacia can of course be prevented by appropriate vitamin E supplementation of the feed. Cage fatigue also would appear to be due to an unbalanced diet[16] for which cures have been achieved through the use of vitamin C injections (cf.[61]).

In conclusion it may be stated that both sound husbandry and balanced feeding including a good vitamin supply are required to make poultry raising a safe and economical endeavor.

We are of the opinion that responsible feed manufacturers are taking these requirements into account, particularly since the cost of fortification with vitamins is low and has little influence on the price of the feed.

To meet the increased requirements of poultry during periods of stress, stress feeds with increased vitamin and antibiotic content are in extensive use. Complex vitamin preparations which can be added to the drinking water are also available for this purpose. After several years of practical experi-

ence regular prophylactic vitamin shock treatment is now recognized as one of the steps which can reduce the adverse effects on productivity and on reproduction which result from stress and disease.[24,30,57]

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PRODUCTIVE AND REPRODUCTIVE CHARACTERS OF EGYPTIAN GEESE

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Geese differ from chickens, turkeys and ducks by having a restricted breeding season. The normal method of reproduction is that each goose lays a nest of a number of eggs that differs according to breed, then incubate them naturally and