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A Strategy for Quality Poultry Egg Production II. Egg Interior Quality; Cholesterol Content, Egg Yolk Pigmentation, Controlling Egg Weight and Organic Eggs

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양질의 계란 생산전략
II. 계란내용물의 질, 콜레스테롤 함량, 난황색, 난중조절, 유기란

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ABSTRACT : The egg's interior quality is one of the most important criteria for commercial producers and consumers. Internal quality is complex, including aesthetic factors such as taste, freshness, nutritional and processing values, and the genetic influences upon these factors ranges from none to considerable. The rate of cholesterol synthesis in the hen is very high compared to other animals and humans. Genetic selection, diet drugs and other chemicals can alter cholesterol concentration in the plasma of laying hen, but attempts to manipulate the cholesterol concentration in the egg yolk are generally unsuccessful since the cholesterol can only be changed to a small extent. Factors which may affect the degree of pigmentation of the yolk include the type of xanthophyll and its concentration in the feed, the feed composition, and the health of the hen. Several feed ingredients interact with carotenoid pigment to improve or reduce their deposition rates in yolks. Egg weight is determined by genetics, body size prior to first egg housing density, environmental temperature, lighting program, total feed consumption, calcium, phosphorus, niacin, water, methionine, total sulfur amino acids, energy, linoleic acid, fat and protein levels. Eggs need to be promoted as a versatile commodity and new processed egg items need to be developed. Organic eggs are laid by hens which were raised in chemical and drug free environments. There are still difficulties in producing these eggs due to the availability of organic poultry feeds and the cost of organic grains.

(Key words: egg quality, cholesterol, egg pigmentation, egg weight, organic eggs)

INTRODUCTION

The 21st century will mean more people demanding higher-quality diets. One of the major difference that will be apparent between the egg products industry of today and that of the year 2000 will be the emphasis on the product safety and quality. This change will be brought about by more stringent consumer requirements and sophisticated in-house quality control (Nahm, 1996). In the developed nations like North America, UK. European countries and Australia where heart disease is responsible for half of annual mortality, quality egg products which contain low cholesterol, low fat or are fat free and high in omega-fatty acids would be in demand. As a result of this, Blair (1996) said that there is likely to be an increased recognition of niche markets and the development of products such as omega eggs with altered fatty acid content to meet specific consumer demands.

Generally, quality egg production involves strong eggshells, eggshell pigmentation, reducing cholesterol content, yolk pigmentation favorable for consumers and marketing, controlling egg weight and developing the concept of 'organic eggs'.

This review paper in the second of a series entitled "Factors to be considered for quality egg production", and it describes methods to reduce the cholesterol content of eggs, yolk pigmentation favorable for consumers and marketing, controlling egg weight and developing the concept of 'organic eggs'.

EGG QUALITY

1. Interior Quality of Eggs

The egg's interior quality is what is the most important for commercial producers, processors and traders and for consumers. Interior quality is complex, including aesthetic factors such as taste, freshness, nutrition and processing values, and the genetic influences upon these factors ranges from none to considerable.

1) The Visible Characteristics and Flavor

Aesthetic factors of the egg's interior quality are divided into visible characteristics, odor and taste. Albumin and yolk color, inclusions such as blood and meat spots, and the yolk's position are the most obvious visible concerns. Blood and meat spots have been shown to the heritable characteristics, with significant differences existing between breeds. Blood spots are more common in white-egg layers and meat spots are found more commonly in brown-egg layers. There has been no connection found between albumin firmness or genetics and the yolk's position, but storage conditions do affect the position (Kuit, 1984).

As for the flavor or taste, the concept of positive flavor is disputed. Studies (Sim and Bragg, 1977; Hargis, 1990) have shown that hens vary by strain and within strain in the ability to break down trimethylamine from feed ingredients into a neutral product. Failure to neutralize this compound results in an odor or taste in the egg.

2) Freshness

Freshness means that the egg does not contain a visible embryo. More specifically, freshness involves albumin quality, degree of moisture loss, degree of oxidation and microbiological status. The latter three factors are affected most by egg shell quality and storage conditions and time. Egg freshness has been traditionally associated with the albumin height. Research dating back twenty years demonstrated that strain. Laying stage and storage conditions affect albumin height. The genetic influence on albumin height is moderate while the genetic role in interior quality is minor (Nahm and Chung, 1995).

3) Nutrition

The egg is considered an excellent food for most people, since it is an excellent source of iron, phosphorus, trace minerals, unsaturated fatty acid and vitamin A, B, D, E and K, especially Vitamins B_{12} and D. The egg is the standard or perfect protein, yet it is the least expensive protein food (Nahm et al., 1997)

The effects of methionine intake on liquid egg component yield and composition were examined (Shafer et al., 1996). They reported that the 512mg methionine/hen-day (HD) intake significantly increased the egg weight, component mass and total solids in both albumin and yolk compared to 326mg methionine/HD. And methionine intakes of 392 and 423mg/HD did result in significantly increased crude protein contents of albumin and yolk compared to 328 and 354mg/HD methionine.

2. Food Safety and Egg Quality

The emergence of Salmonella enteritidis as a public health concern in the past decade has important consequences for the egg industry. Salmonella has historically been linked to poultry consumption and may cause flu-like symptoms, and worse, it may be fatal.

A variety of techniques may be implemented in egg production programs which can result in low incidences of Salmonella. Of the 2,500 types of Salmonella bacteria, only one Salmonella enteritidis is associated with eggs.

The American Egg Board (AEB) recommended the following safety tips to protect against Salmonella poisoning.

- Avoid eating raw eggs. Cook to destroy the bacteria.
- When separating eggs, do not pass from shell to shell. Use an egg separator to eusure safety.
- When coloring hard-boiled eggs, always wash your hands.

1) Egg Shell Quality

Egg shell breakage is a continuous source of frustration for producers and irritation for consumers. The eggs are much more likely to be contaminated due to bacterial invasion from the shell contamination. The two factors that determine if an egg wil crack are the strength of the insult and the strength of the shell. The insults to the egg are random and unpredictable, and each event leading to the cracking of an egg is unique and difficult to study or analyze.

On the other hand, shell quality and the factors that effect it have been extensively studied. The role of calcium in egg shell formation has provided and several researchers have reported that oyster shell was superior as a source of calcium than calcium carbonate of mineral origin (Scott et al., 1982). Genetics, mycotoxins, molting and other environmental stresses on the shell structure and quality are important in eggshell formation. The structure of each shell results from a unique combination of these and other factors. Fertile eggs have no documented nutritional benefit other than revenue to the producer. The type of egg, such as brown, organic or fetile, has no effect on shelf life. Eggs should be stored in a refrigerated enclosure. They can pick up odors from the food stored next to them (Nahm and Chung, 1995).

2) Washing Shell Eggs to Increase Quality

Washing shell eggs was in the past widely condemned due to increased spoilage during storage. At the same time, it is clearly necessary to wash soiled eggs, both because of their appearance and the shell surface contamination that exists when the egg contents when they were broken out. It was then determined that spoilage occurred when eggs were washed in water colder than the egg contents. This caused the egg contents to contract and draw bacteria through the pores into the interior. When eggs were washed in water warmer than the egg contents, this effect did not occur and washing of eggs was not detrimental to quality (Moats, 1978). Presently, washing eggs in universally practiced and even required by regulatory agencies.

Alkaline egg cleaning formulations are used in commercial egg washers and these give a pH of almost 11 in the wash water. During operations, the wash water is recirculated and becomes contaminated with the contents of broken eggs by manure and other soils washed from the egg. The wash water must be continuously diluted by rinse water and allowed to overflow during the course of the operation. Some operators add additional cleaning formula at intervals to compensate for dilution. The wash water is completely replaced at certain intervals, usually at the end of each shift (Moats, 1981a).

It used to be thought that Salmonella bacteria on the shell surface contaminated the contents of the egg. Now it appears that some eggs contain Salmonella when they are laid. The number of bacteria on the shell have been counted by removing the egg contents and grinding the shells in a blender to release bacteria imbedded in the pores. Moats (1978, 1979, 1981b) and Kinner and Moats (1981b) reported that: bacteria on the shell surface were effectively removed by ordinary washing; bacteria embedded in the shell pores were not removed by washing and were also unaffected by rinsing the shells with chlorinated sanitizers; bacterial numbers on the shells after washing were not correlated with numbers in the wash water; and bacterial numbers on the shells after washing were correlated with numbers on the equipment surfaces. They also reported that thorough cleaning of equipment surfaces is necessary. The alkaline egg cleaners were found by these researchers to be effective in killing Salmonella and Escherichia coli bacteria at normal egg washer temperatures. It is important to maintain levels of the cleaning formulation in the wash water to keep the pH 10 or higher. The chlorine in chlorinated egg cleaning formulations is rapidly inactivated in wash water, indicating that the use of chlorinated egg cleaning formulations would be of no benefit under commercial conditions. Use of a chlorinated rinse following washing was no more effective than a water rinse in removing bacteria. Bacteria not removed by washing were not susceptible to a chlorinated rinse.

Some washing procedures have also been found to damage the protective cuticle layer on the surface of the egg shell which resists bacterial penetration. This is not a problem unless the eggs become wet during storage. Since eggs are dried and packed after washing they are not likely to be exposed to water containing bacteria.

3) Problems with Eggshell Types and within Eggs

Good laying hens when properly cared for can lay up to 300 eggs in a year. With such a large number of eggs being produced, it should not be surprising that some abnormalities in the egg producing mechanism may occur which results in problems with eggshell types (flat sided eggs, body-check eggs, pimples or calcium spots, stained or discolored eggs, soft shelled and shell-less eggs, misshapen eggs) and problems within eggs (blood and meat spots, mottled egg yolks, milky white eggs, double and triple yolked eggs, eggs within an egg, roundworms in eggs) (Nahm and Chung, 1995).

CHOLESTEROL CONTENT OF EGGS

For many years the general public has been told that cholesterol is a major killer and that food high in cholesterol such as eggs should be avoided. This has been extremely damaging to the egg industry. Many national heart foundations have recognized their serious error and now recommend four eggs be consumed by each person per week. It is now known that dietary cholesterol is not an important risk factor for 98% of the population. There are many other important factors such as the amount and nature of the fat in the diet.

Greenland Eskimos consume almost twice as much cholesterol in their diet than their neighbor the Dane, but the incidence of heart disease related deaths is almost seven times higher in the Dane. The answer to this fact lies in the source and nature of the fat consumed by each group. Dutch scientists have found that people who consume 32g of fish daily are 50% less likely of dying from coronary heart disease than those who did not consume fish (Bang and Dyerburg, 1972).

1. Egg Lipid Synthesis and Composition

The average egg of 60 g contains approximately 6 g of lipid, which is almost wholly confined to the yolk. Consistent patterns of egg laying involve the sequential maturation of the ova or yolk at approximately 24h intervals. With the approach of the onset of egg laying, both the weight and lipid content of the liver undergo dramatic increases (Bang and Byerburg, 1972).

The changes in the liver lipid levels are in response to the lipid requirements for egg production and are manifested through extensive and interrelated hormone changes (Miettien, 1971). The gross lipid changes are accompanied also by changes in fatty acid composition (Balnave, 1970). The accumulation of lipid in the liver largely occurs through a stimulation of fatty acid and lipid synthesis which, in contrast to mammals, is predominantly associated with the liver rather than the adipose tissue (Hargis and van Elswyk, 1993). The liver lipid changes are accompanied by marked increases in the concentrations of plasma lipids, in particular triglycerides.

Almost all the lipid of the yolk exists in the lipoprotein form. The overall lipid protein ratio of the yolk is about 2:1. Extractable lipid accounts for about 33 % of the total weight of the yolk and 60 to 65 % of its dry matter content. The major yolk lipid fraction is triglyceride (63.1 %), which is accompanied by a substantial quantity of phospholipid (29.8 %); the only other major component is free cholesterol (4.9 %) and cholestryl esters (1.3 %) (Moore, 1989; Hargis, 1990).

The fatty acid compositions of the major lipid fractions (triglyceride) are oleic acid (40.1 %), palmitic acid (29.1 %) and linoleic acid (18.0 %). The phospholipid fraction contains a high level of other PUFA (Beitz, 1990).

About 5 % of the yolk fat is free cholesterol and it is accompanied by approximately 1 % of the cholesterol in an esterified form. By comparison, the free cholesterol level in liver fat is approximately 8 % which, with the addition of that present in the esterified form, gives a proportion of total cholesterol in liver fat of nearly twice that of the egg yolk. Comparisons of the individual and total PUFA levels in the yolk and live are also interesting. The level of linoleic acid in the yolk is approximately 16 % of the total fatty acids, which, with the addition of C_{18}, C_{20} and C_{22} PUFA give a total PUFA content of some 20 %. By comparison, the levels of linoleic and total PUFA in the fat of the liver, 7 and 13 % respectively, are only about one-half that for egg yolk fat. Of the remainder of the fatty acids in the yolk, mono-unsaturates account for approximately 46 % and saturates 34 %. Thus, yolk fat can be considered as predominantly unsaturated (Griffin, 1990; Richardson and Jimenez-Flores, 1990).

A recent parameter of PUFA adequacy in the diet is the ratio of the total polyunsaturated to saturated fatty acids (the P/S ratio). As an objective to healthy eating is was suggested that a higher P/S ratio 0.32 be consumed (Hargis and Vans

Elswyk, 1993; Farrell, 1997).

2. Regulation of Cholesterol Production in the Human Body

Human beings, as well as other higher animals, make their own body supply of cholesterol from acetate, a simple two-carbon molecule produced from energy yielding nutrients and metabolites.

When the energy inputs from nutrients such as protein, carbohydrate and fat are in excess, acetate is also generated in excess. As a result, there is a larger acetate supply that is used for making fatty acids and cholesterol. Body fat is produced from the fatty acids and this results in body weight gain. Interestingly, obese subjects make 20 % more cholesterol per unit of body weight than normal subjects (Miettinen, 1971). Obesity is related to increased cholesterol production in humans. Excessive cholesterol production in humans may be avoided by maintaining proper body weight.

Acetate has a more specific role in the regulation of cholesterol in the body. A complex chemical mechanism in the body converts acetate molecules into cholesterol, but a control point exists at which the enzyme HMG-Co A reductase is essential in controlling cholesterol production. Hormones such as insulin and glucagons influence this mechanism, but it is also affected by intermediate products leading to cholesterol production. Cholesterol itself has a very important role in limiting the activity of this enzyme and therefore exerts feedback control on body cholesterol production (Hargis, 1989).

Normally the body regulates cholesterol production by making more cholesterol in response to lowered body levels of cholesterol. When dietary cholesterol is reduced, the body would respond by increasing cholesterol production. Limiting dietary cholesterol would not result in limited body and blood cholesterols when cholesterol regulation is normal. Abnormalities in cholesterol metabolism in humans are related to cholesterol carriers or receptors and inadequate regulation of HMG-CoA reductase resulting in elevated blood and tissue cholesterol levels. Limiting dietary cholesterol under these abnormal conditions may help to reduce blood cholesterol levels.

Liver and intestinal synthesis in the body contributes about twice as much cholesterol as does the normal human diet, 800 versus 400mg per day. This means that changes in dietary cholesterol intake would be expected to be compensated for by changes in synthesis of cholesterol by the body (Hargis, 1989; Moore, 1989).

Cholesterol balance is also controlled by outputs., this involves the conversion of cholesterol in the liver to neutral sterols and bile acids that are released into the intestine and recycled or excreted from the body. Loss in the feces is compensated for by inputs from diet and synthesis. Drugs that reduce blood cholesterol reduce liver synthesis of cholesterol or increase conversion to and excretion of bile acids and neutral sterols (Griffin, 1990).

An egg yolk contains an average of 5 g of fat. Cholesterol contents depend on the egg with a small egg containing 160 mg and a jumbo egg containing 270 mg. The National Cholesterol Education Program in the U.S. recommends less than 300 mg of cholesterol be consumed each day, so three or four egg yolks should be eaten weekly (ANON, 1989; Froning, 1991).

3. Egg Cholesterol Resists Change

The normal diet of the laying hen contains little or no cholesterol since most of the ingredients are products of plant origin. Despite some notable exceptions, most published studies indicate that the amount of cholesterol in the egg yolk is relatively resistant to change. The rate of cholesterol synthesis in the hen is very high compared to other animals and humans. This is a point in that cholesterol balance in laying hens is very different from humans. This cholesterol input side of the balance is driven almost entirely by a high rate of liver synthesis in normal laying hens. The major output of cholesterol by the hen is transport of cholesterol and ovarian transport to the egg. Smaller amounts of output occur in bile acids and sterols in the feces (Vargas et al., 1986).

The cholesterol content of the egg is regulated mainly by the rate of cholesterol synthesis in the hen, so factors that might regulate synthesis in the hen may be expected to influence the cholesterol in the egg. The manner in which the cholesterol output into the eggs takes place also influences cholesterol content to a minor degree. Larger eggs that have large yolks have higher cholesterol contents than small eggs with small yolks. Hens producing more eggs will lay eggs containing less cholesterol than hens with lower rates of production. The number and size of ova undergoing rapid development in the ovary affects the cholesterol output of individual yolks (Weiss et al., 1967).

Most of the cholesterol in the yolk (> 90 %) is present as free (non-esterified) cholesterol in the lipoprotein of the yolk. Almost all of the cholesterol in the body of the hen and in the egg is synthesized in the liver of the hen as a response to estrogen and is transported by the blood to the ovary. The lipoproteins and other yolk precursors pass into the capillaries of the developing follicles. They pass through the various tissues (the capillaries in the thecal layer, the basal lamina layer and between the granulosa cells before binding to the oocyte plasma membrane) that form the follicle wall and are taken up into the oocytes (yolk) through receptor-mediated endocytosis (Fig. 1) (Griffin, 1990).

The lipid composition of the yolk is determined by the lipid composition of the individual lipoproteins since the plasma lipoproteins are taken up into the yolk intact. The affinity of the lipoprotein receptors on the oocyte plasma membrane is high. Plasma lipoprotein concentration does not affect the rate of uptake of yolk precursors from the plasma and their concentration in the yolk. Cholesterol, phospholipid and protein combine to stabilize the surface of the lipoprotein(Fig. 2) (Froning et al., 1990; Griffin, 1990).

The resistance of yolk cholesterol to change may be due

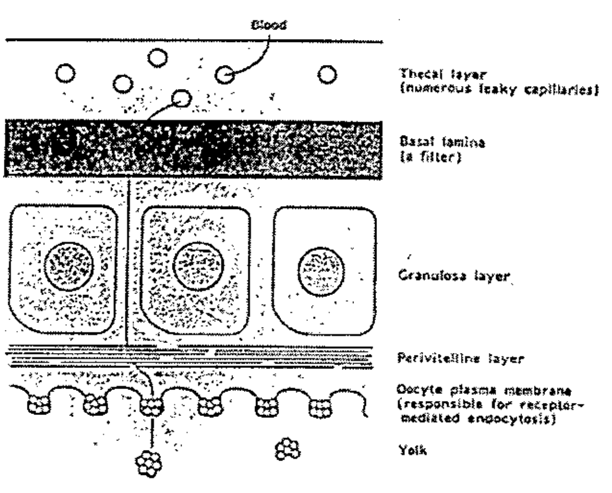

Fig. 1. Cross-section through the wall of the ovarian follicle (a copy reproduced by kind permission of H. D. Griffin, Roslin Institute, Roslin, UK).

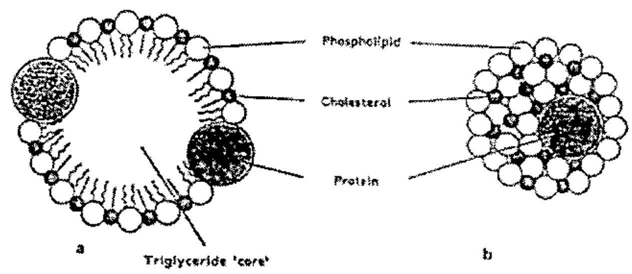

Fig. 2. Structure of triglyceride-rich lipoproteins, with non-esterified cholesterol, phospholipid and apoproteins combining to stabilize the lipoprotein surface and triglyceride and cholesterol esters forming the "core". a, section; b, surface view (a copy reproduced by kind permission of H. D. Griffin, Roslin Institute, Roslin, UK)

to the specific needs of the embryo. Studies on the lipid metabolism, however, suggest that the amount of cholesterol in the yolk is greater than the need for chick growth. There is also no reason why the embryo cannot synthesize its own cholesterol (Hargis, 1989; Froning, 1991).

Lipoproteins synthesized in the liver of the layer are unusually small and regular in size. This is important in allowing them to pass through the basal lining of the follicle wall. The connective tissue of this layer acts like a selective filter that allows the small yolk precursors to pass through but excludes from the yolk the larger lipoproteins synthesized in the intestine. Variation in the lipoprotein surface area : volume ratios (and cholesterol contents, since cholesterol is a surface component) is limited by the synthesis of small lipoproteins by the liver (Griffin, 1990).

4. Changing Egg Cholesterol by Dietary Alterations

Genetic selection and diet can alter cholesterol concentration in the plasma of laying hens but these effects seem to be due to changes in lipoprotein concentrations rather than lipoprotein composition. Egg from hens fed diets containing 30 % vegetable oil contained significantly more cholesterol than did those from hens on a low fat control diet. It was later established that high levels of dietary unsaturated fat stimulate the hen to synthesize more cholesterol in the liver and to deposit increased amounts in the egg (Naber, 1983).

While dietary cholesterol increases egg cholesterol, dietary plant sterols may reduce egg cholesterol. The plant sterols contribute to the inhibition of cholesterol absorption in the gut because the fecal excretion of sterol metabolites is enhanced when soysterols and cholesterol are fed (Sim et al., 1980). 2 to 4 % sitosterol emulsified in carboxymethylcellulose to make this sterol absorbable had to be used (Clarenburg et al., 1971). And 2 % soybean sterols added to laying diets containing 8 % coconut oil or safflower oil reduced blood and egg yolk cholesterol concentration (Sim and Bragg, 1977). These scientists found a significant reduction in cholesterol levels in both serum and egg yolk (ranging from 16 to 33 % depending upon the lipid in the diet) when 2 % soysterols were added to diets containing saturated or unsaturated oil with or without cholesterol. These reductions in yolk cholesterol levels are encouraging but, again, probably not significant in practical terms to the industry. A minimum decrease of 50 % in yolk cholesterol to levels ranging from 100mg to 150 mg cholesterol per egg (one-half the recommended maximum daily intake level of cholesterol) would potentially be of benefit commercially. Still, cholesterol lowering effects in the egg from feeding sitosterol or a mixture of plant sterols could not be demonstrated in several research studies.

There has been an interest in fiber and its relationship to cholesterol in the gastrointestinal tract. Certain types of fibers have been shown to bind with sterols, resulting in increased amounts of them being excreted in the feces and preventing enterohepatic circulation of these sterols. Excessive energy levels in the diet may cause increased cholesterol production. The energy content of the diet may be lowered by addition of fiber, and this limited energy intake may result in reduced cholesterol production, especially if energy intake was previously excessive. Therefore fiber may effect cholesterol metabolism in different ways, depending on the source and level of fiber in the diet (McNaughton, 1978; Vargas and Naber, 1984).

When laying hens were fed varying levels of crude fiber from alfalfa meal, ground oats, sunflower meal, rice mill feed and wood shavings, a statistically significant reduction in egg yolk cholesterol of 6 to 11 % was observed from the higher fiber levels employed (McNaughton, 1978). Ground oats and wood shavings seemed to be most effective (9 to 10 % reduction). Fractions of barley kernels, including high-protein barley flour, may contain substance which inhibit hepatic cholesterol synthesis. When these feeds were fed to chicks (Beyer, 1991) and laying hens, those that were fed barley produced eggs with less cholesterol that a corn-fed control group (Qureshi et al., 1986).

Yolk cholesterol was correlated to feed intake with body weight gains exceeding 100 g, but was not correlated when weight gains were less than 110 g per day (Beyer, 1991). In egg yolks, there is a physiologically minimum concentration of cholesterol. Increases in this minimum cholesterol level may occur when there is insufficient energy intake to support egg production or when there is excess energy retained in the body. Egg cholesterol concentration can be altered by the energy balance, but the extent of this alteration depends on the magnitude and direction of energy balance, change. Thus, when the bird is in positive energy balance, the concentration of egg yolk cholesterol increases. When the hens are losing weight or consuming less than 340 Kcal/day, yolk cholesterol is then inversely related to body weight (Vargas et al., 1986).

Other studies have indicated that fatty acid composition of the egg can be substantially changed through the diet of the hen. One study found that wheat to triticale-base diets gave good production of eggs of lower cholesterol contents, and that soybean oil supplementation gave eggs with a high unsaturated to saturated fatty acid ratio (Hargis, 1990; Hargis et al., 1991). Several recent studies have shown that feeding hens a diet high in fish oils or fish meal will increase the omega-3 fatty acids (Adams et al., 1989).

5. Effect of Processing on Yolk Composition

Research studies emphasize processing innovations for modification of the yolk's composition. Formulation, organic solvent extraction, enzymatic treatments, use of absorbents, blending of components and super critical fluid extraction are some of the processes that have been studied. Use of organic solvents to remove cholesterol and lipids from the eggs has been attempted. When a hexane : isopropanol (2:1) solvent was used to extract egg oil from the yolk, the cholesterol content was reduced by 40 % (Larsen and Froning, 1981). Various organic solvents could extract lipid components from dried egg yolk (Warren and Ball, 1990). Solvents which were tested in this project were hexane, hexane : isopropanol (2:1) and chloroform : methanol (2:1). The results suggested that the more polar solvents removed more of the cholesterol and carotenoid pigments.

The use of cholesterol reductase has been used to generate a low-cholesterol or cholesterol-free food (Beitz, 1990). Cholesterol reductase is found in many biological sources such as alfalfa, cucumbers, peas, young corn, etc. It catalyze the conversion of cholesterol to coprostanol, which is not absorbed well by humans.

Increased pressure and temperatures enabled the removal of more lipids and cholesterol. Two-thirds of the cholesterol was removed when extraction conditions were elevated [306 atm/45 ℃ or 374 atm/55℃] (Froning et al., 1990). In this study, phospholipids were concentrated under super critical conditions.

In a series of works, scientists (Smith et al., 1995; Awad and Smith, 1996; Awad et al., 1997) have reported that beta-cyclodextrin (CD) could be used to produce a low cholesterol egg product with compositional and functional properties similar to control egg yolks. In previous works, surface methodology was used to optimize a CD process for extraction of cholesterol from liquid egg yolk based on the dissociation and solubilization of the granular fraction at an alkaline pH. CD are cyclic oligosaccharides comprised of seven glucose units that have been found to form complexes with cholesterol (Saenger, 1984).

6. Changing Egg Cholesterol with Drugs and Other Chemicals

The hypocholesterolemic drugs such as triparanol, azasterols, alpha-ketoisocaproic acid (KIC), and olvastatin are potent inhibitors of the last step of cholesterol synthesis and its inclusion in laying hen diets causes the replacement of cholesterol in yolks with its immediate precursor, demosterol (Elkin and Rogler, 1989; Luhman et al., 1990). Desmosterol cannot act as a precursor for hormone synthesis as does cholesterol, and as a result the hens rapidly stop laying. Lovastatin acts as an inhibitor of the regulatory coenzyme for cholesterol biosynthesis (3-hydroxy-3-methylglutaryl coenzyme A reductase or HMG-CoA reductase) (Elkin and Rogler, 1989). Even though lovastatin reduces egg cholesterol by 3 to 12 % in a dose dependent matter, egg) cholesterol reduction by HMG-CoA reductase inhibitors and KIC has yielded inconsistent results (Elkin and Rogler, 1989; Beyer and Jensen, 1992).

7. Genetic Selection to Control Egg Cholesterol

Egg cholesterol levels have been shown to vary with species of bird, breed or strain, as well as age of fowl. One report showed that 3 generations of selection for lower yolk cholesterol of a White Leghorn population was successful and that egg cholesterol levels were reduced 5.4 % (or 9 mg/egg) by the third generation (Ansah et al., 1985). In practical terms, these reduction in egg cholesterol of 9 to 10 mg are not significant if an average daily consumption of approximately 250 mg of cholesterol is to be adhered to. The response of several production trails to 5 generations of selection for high and low plasma cholesterol levels was examined in a population of Single Comb White Leghorn hens (Marks and Washburn, 1977). Yolk cholesterol concentrations were significantly reduced (approximately 7 %, again not a significant reduction in practical terms) by selection for low plasma cholesterol but were not affected by selection for increased plasma cholesterol.

Selection for lower egg cholesterol has been modest with only a 5 to 7 % reduction possible (Hargis, 1989a). Some progress may be made through production changes, but this small reduction is unlikely to satisfy the consumers.

8. Manipulation of Egg Cholesterol Content

Manipulation of the cholesterol concentration in the egg yolk is generally unsuccessful since the cholesterol can only be changed to a small extent. In persons that need to reduce their dietary cholesterol, this amount may not contribute significantly to this reduction. Drugs have been shown to be the most consistent in reducing egg cholesterol levels, but these reductions are small. These drugs may potentially harm the chicken, alter the nutrient composition of the egg, lead to drug residues remaining in the egg and increase production costs.

Most people consume a diet that contains 400 to 600 mg of cholesterol per day. In the U.S., the average egg consumption from all sources was 0.67 eggs per person per day in 1988. This means that eggs provide 140 mg of dietary cholesterol per day. If egg cholesterol could be decreased by 10 % through any of the methods described previously, the average daily intake would be reduced by only 14 mg, which is insignificant. Changes made to decrease cholesterol levels in eggs will remain meaningless unless the hen could be made to radically reduce the cholesterol levels in her eggs (Froning, 1991).

In patients with artherosclerotic heart disease, total energy intake and saturated fat intake have been shown to affect the blood cholesterol levels. Dietary cholesterol levels appear to have little or no effect on blood cholesterol levels in normal humans, within reasonable limits. Even though egg consumption per week in three countries (U.S., France and Japan) were 4.2, 4.7 and 6.1 eggs each, the rate of heart problems was lowest in Japan (Poultry Digest, 1997). Dietary changes that contribute most to lowering blood cholesterol levels are first restricting energy intake, then reducing saturated fat intake and finally reducing dietary cholesterol intake would make a relatively insignificant contribution.

Other criticism on the egg as a contributor of cholesterol is not based on the relative proportion of cholesterol in yolk or on the gross amount of cholesterol provided through the consumption of egg fat, but rather on the gross amount of cholesterol within an arbitrary egg of yolk weight. The mode of presentation of compositional data enables different interpretations to be placed on the cholesterol content of the egg. There are many instances where it has been concluded that the egg should be considered as a rich source of cholesterol when compared with a range of other common dietary constituents. For example, whereas it has been reported that there are 504 mg of cholesterol in 100g egg, the figure has also been expressed as 1,480 mg cholesterol per 100 g yolk (Findlay and Silberner, 1989). Expressed in either of these ways, the egg appears to provide more cholesterol than all the major red meats of our diet. In the main, however, it is whole eggs that are consumed and when the cholesterol contents of a range of food are based on average daily dietary consumption, the relative rating of the egg is entirely different (Naber, 1976).

EGG YOLK PIGMENTATION

One of the factors of economic importance to the egg industry is the egg yolk color. Yellow corn, corn gluten meal, dehydrated alfalfa meal, grasses and marigold meal are the most important traditional sources of pigmentation. Synthetic pigments can be added to fed in small quantities to achieve the color desirable to consumers.

Factors which may affect the degree of pigmentation of the yolk include the type of xanthophylls and its concentration in the feed, the feed composition, and the health of the hen. Pigmentation can be altered by respiratory infections and other disease, and there are certain feed bone meal that can inhibit the formation of pigments. Certain storage conditions can also cause the deterioration of yellow xanthophylls in corn (Braeunlich, 1974).

1. Classification of Carotenoids

Carotenoids have been classified into two groups : (1) hydrocarbons containing only hydrogen and carbon, which are called carotenes, and (2) oxygen containing derivatives, called xanthophylls and oxycarotenoids (Henken, 1974).

Carotenoids have also been classified as follows (Maurusich and Buernfeind, 1981):

a. Viatamin A precursors that do not pigment. such as alpha and beta-chrotenes:
b. Vitamin A precursors that pigment, such as cryptoxanthin, beta-apo-8'-carotenal, and beta-apo-8'-carotenoic acid ethyl ester:
c. Nonvitamin A precursors that either do not pigment or pigment poorly, such as wiolaxanthin and neoxanthin : and
d. Nonvitamin A precursors that pigment, such as lutein, zeaxanthin and canthaxanthin.

Carotenoids of type b and d are of significant economic interest in the pigmentation of egg yolk.

Beta-carotene is structurally split at the 15=15' carbon atoms by the enzyme, beta-15, 15'-dioxygenase yielding two molecules of vitamin A for each molecule of beta-carotene (Goodman and Hyang, 1965). Beta-carotene which is transformed into vitamin A in the bird body has no pigmenting activity (Braeunlich, 1974). This scientist also stated that pigmenting carotenoids are mainly found in groups which have no vitamin A activity at all, they are transferred unchanged to the yolk or to the skin.

Carotene ($C_{40}H_{56}$) is a highly unsaturated hydrocarbon. In the yolk it is found in two isomeric forms known as alpha- and beta-carotene (Kim et al., 1995). It is soluble in chloroform and ether, but insoluble in water, acid or alkali. Xanthophylls usually contain at least two hydroxy groups. They are closely related to carotene structurally. Unlike carotene, xanthophylls dissolve readily in alcohol and ethyl ether, but only slightly in petroleum ether. Cryptoxanthin ($C_{40}H_{56}$) is a monohydroxy derivative of beta-carotene. It is difficult to distinguish from beta-caraotene and zeaxanthin. Lutein and zeanthin ($C_{40}H_{56}$) are isomertric dihydroxy derivatives of alpha- and beta-carotene, respectively. They can be differentiated by lutein's greater solubility in boiling methanol. The various carotenoids differ in their color values (Martusich and Banernfeind, 1981). The xanthophylls, especially lutein and zeaxanthin, are approximately twice as intense in color as the carotenes.

2. Sources of Xanthophyll Pigments

Green alfalfa, clover and pasture grasses contain a number of xanthophyll pigments in addition to the chlorophyll that gives them their green color. When chlorophyll is removed or destroyed from these leaves, as during exposure to frost in autumn, the yellow and red xanthophylls appear since they are no longer masked by the green of chlorophyll. The most common carotenoid rich plants are corn (mainly zeaxanthin) and grasses (carotene and lutein) (NRC, 1994).

Carotenoids are the red, orange and yellow pigments found in the chloroplasts (cholorophyll granule). The molecules of carotenoids are long and have many conjugated double bonds, which are the chemical basis of color in organic compounds along with other patterns of unsaturation. Even though many carotenoids have been isolated from plants, only a few are found in the yolk of eggs (Karunajeewa, 1980).

Besides the two carotenes (alpha- and beta-) and the three xanthophylls (cryptoxanthin, lutein and zeaxanthin), traces of other carotenoid pigments have been found in egg yolks, i.e. lycopene (Karunajeewa, 1984)., flavoxanthin-like compounds and neoxanthin (Chung, 1991). The usual ratio of carotene to xanthophyll in he egg yolk is 1:10.

Of all the common poultry feedstuffs, only dehydrated alfalfa, Lucerne meal, yellow corn and yellow corn gluten meal contain significant quantities of xanthophyll. Many naturally occurring plant contain carotenoids, as lutein (grass, lucerne), zeaxanthin (maize), canthaxanthin (chanterelle), violaxanthin (pumpkin), capsanthin (paprika), and lycopene (tomato) (Hencken, 1974).

A recent work has shown the contents of natural xanthophylls in various feed ingredients (Liu, 1997). Minimum levels of xanthophyll exist in wheat corn and corn gluten are a rich source, but variation is substantial, depending on many factors such as corn variety, growing condition and storage.

Natural forms of xanthophyll are high unsaturated lipids and therefore readily oxidized, their pigmenting power is then lost. They can be bleached by photo-oxidation from sunlight and by classical lipid autoxidation. In the gastrointestinal tract, any factors affecting intestinal absorption will have an impact on pigmentation. Moldy corn has poor pigmentation in that microorganisms consume fat with carotenoids and mycotoxins further affect intestinal absorption as proven by many researchers (Liu, 1997).

3. Metabolism of Carotene

1) Effect of Ration Ingredients on Pigmentation

Certain feed components can interfere with metabolism of the carotenoid pigments. Vitamin E or antioxidants such as butylanted hydroxy toluene (BHT) enhance pigmentation of the vitellus of the egg and stabilize the pigments (Bartov and Borenstein, 1976). Carotene metabolism can also be affected by cereals, rice bran, fatty acids and vitamin A.

2) Digestive Transport and Intestinal Absorption

Absorption of beta-carotene takes place through a process similar tot eh absorption of fatty acid. Prior to absorption from the intestine, beta-carotene is dispersed in micellar form. The micelles are composed of bile salts, monoglycerides and long-chain fatty acids, and together with vitamin D, E and K they facilitate transfer of beta-carotene to the intestinal cells. Much of the beta-carotene is converted to vitamin A here (El Boushy and Raterink, 1989).

Other carotenes are transported through the fatty acids in the intestinal mucosa of the chicken to the blood stream through the liver to their final target in the ovary and ovum of the adult laying hen. Zeaxanthin and lutein were at higher concentrations in the serum, adipose tissue, liver and egg yolk than beta carotene (Scott et al., 1982).

The yolk color depends on the extent to which carotenoids in the feed are absorbed by the digestive system and deposited in the yolk. The site of absorption of xanthophylls is the jejunumileum. A small amount, if any, is absorbed in the duodenum and large intestine, and that takes place in the cecum (Littlefield et al., 1972).

4. Metabolism of Apo-8'-carotenoic Acid, Ethyl Ester

In the chicken, apocarotenoic ester occurs as a metabolite of apo-8'-carotenal, which is found in many plants such as Lucerne, alfalfa meal, grass, green vegetables and citrus fruits. The beta-apo-8'-carotenal has been shown to be an effective pigmentor for coloring egg yolks in vivo (Glover and Redfearn, 1954). Beta-apo-8'-carotenal reduces to vitamin A aldehyde, which in turn is reduced to vitamin A (Glover and Redfearn, 1954). Echinenone, crytoxantin, beta-apo-8'-carotenal, beta-apo-8'-carotenoic acid ethyl ester and citranaxanthin act not only as vitamin A precursors, but also as egg yolk pigments (Hencken, 1974).

1) Pigmentation Measurement and Practical Utilization

The evaluation of egg yolk color is based on an "optimal-yellow", which must be "appetizingly pretty". As determined by the "corruptible" human eye (Borenstein and Bartov, 1966). The visual impression of the consumer does ot always correspond to the chemical concentration of yolk pigments because:

- The human eye is not sensitive to the dartker shades of yellow;
- The standard colorimetric method (AOAC, 1992) is not sensitive to reddish pigments, which deepen the visual color of yolks (Bartov and Borenstein, 1967); and
- The color of the broken egg yolk is not the same as the whole yolk (Ashton and Fletcher, 1962).

The color fan of Hoffman-LaRoche is used presently is many countries in its new from with 15 different color shades. The feed industry must be able to determine which pigments deposit in the egg yolk and produce certain colors. The ability of certain carotenoids in the diet to influence yolk color has been investigated by measuring the light (at 514nm) reflected by the egg yolk. Yolk color was not influenced gy beta carotene and bixin, but the pigments carotenal and carophyll improved the color significantly. Cantaxanthin and capsanthin should not be used alone since they produce an unnatural red tinge to the yolk, but may be used together with yellow pigments of natural or synthetic orgin. Equal amounts of red and yellow pigments are deposited in the egg yolk by using a combination of beta-apo-8'-carotenoic acid ester and canthaxanthin (Fletcher and Hallorang, 1981).

Pigmentation is an inherited characteristic that is also influenced by feed ingredients and light. Pigmentation has been attributed to variations in feed ingredients, availability of xanthophylls, oxidation during storage and health factors. The genetic ability to absorb and deposit xanthopylls has been found to vary among hens within stains and between breeds (Braeunlich, 1974).

Xanthophyll varies in its ability to produce dominant wavelength depending on the natural ingredients used. Xanthophylls from corn and corn gluten meal, for example, produces a greater wavelength than xanthophyll from alfalfa meal. Consequently, alfalfa meal and marigold meal are used to produce lightly colored broilers and egg yolks, but if more deeply colored birds or yolks are desired, corn or corn gluten meal should be fed as these impart a higher dominant wavelength (Fletcher, 1982).

In formulating rations, the dominant wavelength of the pigment and the amount of biologically available pigment in the ingredient must be considered in determining the color influence sought. Birds grown in windowless buildings do not express pigment as well as birds grown in open houses; and among birds exposed to natural diurnal light cycles, those birds restricted by pens or other means to the inside did not pigment as well as those birds to the outside (Janky, 1983).

Broiler chickens respond to pigments in much the same way as laying hens. Dietary pigments are absorbed and are carried in the serum proportional to the dietary levels. A combination of red and yellow pigments greatly enhances the visual egg yolk scores and broiler skin scores (Couch et al., 1971).

5. Factors Influencing Pigmentation

Several feed ingredients interact with carotenoid pigment to improve or reduce their deposition rates in yolks.

1) Rice Bran

Inclusion of 60 % non-autoclaved rice bran led to an adverse effect on laying hen egg yolk color, reducing the intensity of the Roche color fan score (Majun and Payne, 1977). They suggested that non-autoclaved rice bran contains some factors that cause changes within the lipid fraction which in turn affects the yolk color.

2) Cereals

Yellow maize is high in pigments, which in turn leads to production of eggs with reasonable yolk color. Wheat is superior to barley in contributing to egg yolk color when using the same concentrations (Karunajeewa, 1980). Some samples of barley which have the absence or deficiency in a fungal enzyme (endo-beta-glucanase) give rise to a highly viscous state of the glucans in the gut and this probably inhibits the absorption of nutrients and xanthophylls (Burnett, 1966). Triticale, a cross between wheat and rye, also has been shown to inhibit the transfer of oxy-carotenoids from the diet to the egg yolks. Replacement of maize of wheat in layer diets with triticale reduced pigmentation of egg yolks by 7 to 11 % (Choudhary and Netke, 1976). The deposition of carotenoid pigments is inhibited also by some feedstuffs such as meat scraps, fish meal and soybean meal (Culton and Bird, 1941).

3) Fats

Dietary fat supplementation may effect egg yolk color, depending on the degree of saturation of the fatty acids (Abu-Serewa, 1976).

4) Antibiotics

Antibiotics added to layer diets have been shown to increase yolk color significantly (Scott et al., 1982)

5) Vitamin A Content

Extremely high level of vitamin A markedly depress egg yolk color, while normal levels have little effect. As the vitamin A content increased, the amount of xanthophylls decreased. A competition between vitamin A and xanthophyll absorption and/or transport occurs under conditions of low lipid intake, but no competition exists under conditions of adequate dietary fat levels (Scott et al., 1982).

6) Vitamin E and Antioxidants

Vitamin E or antioxidant supplementation to poultry diets enhances egg yolk pigmentation. Antioxidants are normally seeded to feeds to prevent oxidation of fats, fat soluble vitamins, xanthophylls and other components. Copper, iron and other metal ions can enhance the rate of oxidation and increase the demand for antioxidants.

Feeding 125 ppm ethoxyquin resulted in a statistically higher level of yolk pigmentation at each level of alfalfa meal (1.25 to 6.25 % of the corn-soy diet) fed (Anjaneyain et al., 1963). These scientists reported that analyses of dietary xanthophylls in mixed feed indicated a less of 24 % of xanthophyll components within three weeks without anti-oxidant protection, compared to a 6 % less with antioxidants during high temperature period (35.5 to 39.8 ℃). Studies conducted during cooler months (20.0 to 23.0 ℃) indicated an improvement of 19.2 to 23.5 % in yolk pigmentation with 125 ppm ethoxyquin. There was little less in dietary xanthophylls during the cooler weather. However, a minimum of 150 ppm is necessary to provide protection to the xanthophylls of alfalfa meal (Chung, 1991).

7) Aflatoxin

Dietary aflatoxin has been shown to raise the yolk and plasma carotenoid concentrations (Huff et al., 1975).

8) Source, Harvesting and Storage Conditions of the Feed-stuffs

Xanthophyll content from different sources of yellow corn cannot be considered to be equally available for egg yolk pigmentation (Bartov and Borenstein, 1967). This may be caused by different carotenoid patterns, the presence of labile factors such as tocopherols of the effects of dietary free fatty acids.

Considerable loss of carotenoid pigments can be caused by improper storage. During unfavorable storage conditions, there was particularly a marked decrease in the xanthophyll concentration of maize (Bartov and Borenstein, 1967). In one study, corn lost 25 % of its pigment content after drying to reduce its moisture content from 11 % to 3 %, concluding that stored corn for one year at 25 ℃ lost 50 % of its pigment content due to xanthophyll and carotene xanthophyll content is decreased by sun curing (Miettinen, 1971).

9) Stability

Natural xanthophyll sources are usually found in a dry form. Destruction of xanthophophylls occurs through exposure to heat, light and air. The use of antioxidants like ethoxyquin helps to stabilize xanthophylls (Bartov and Borensein, 1967).

10) Breeds and Strain Variations

The ability to absorb and deposit carotenoids in egg yolks varies with different breeds and hybrids. Yolk color is also influences by genotype and the rate of egg production in hens. There is some variation between breeds, strains and individual hens in their ability to absorb and deposit oxycarotenoids in egg yolks (Karunajeewa et al., 1984).

11) Heath Conditions

Any disease that reduces the efficiency of absorption of nutrients from the alimentary tract (jejunum-ileum) can reduce the uptake of carotenoids. The following summarizes the action that disease has in reducing yolk color in commercial layers (Scott et al., 1982; Nahm and Chung, 1995).

- Ingestion of pigments: Reduction in food consumption causes lack of pigmentation through insufficient supplies of pigments.
- Digestive transit: Changes in transit time affect intestinal absorption and serum transport of pigments.
- Plasmatic pigmentation: Oocytes of the parasite *Eimeria tenella* cause a plasmatic discoloration that results in decreased pigmentation in the egg yolk.
- Deposit in the vitellus: Inoculation with *Eimeria acervulina* caused a discoloration of the egg yolk.

12) Age of Birds and Feed Intake

Old layers (53-week-old) showed 10 to 20 % lower efficiency in depositing beat-apo-8'-carotenoic acid ethyl ester in egg yolks than those which were 32 to 38 weeks old. This may be due to the absorptive power of the gut declining in older layers (Karunajeewa, 1980).

13) Housing System

Birds housed in cages laid eggs with higher yolk color than those of hens housed on deep litter; the differences were equivalent to 2 units on the Roche color fan in favor of the caged birds (Fletcher et al., 1978). The cause may be a result of differences in feed intake and consequent differences in pigment intake. High calcium levels in diets also reduced egg yolk color and droppings of hens housed on deep litter were found to be rich in minerals, mainly calcium and phophorus (El Boushy and Vink, 1977).

6. Variations in Biological Availability of Xanthophylls

The sound and level of natural dietary pigmenting ingredients determines the pigmentation of the egg yolk. Formulation of layer diets for specific yolk color is difficult due to variances in xanthophyll content and variations in the biological availability of certain feedstuffs. When the beta-apo-8'-carotenal is used as a standard, the relative availability values of xanthophylls from alfalfa, yellow corn and corn gluten meal were 57.4, 75.5 and 107.9 %, respectively (Fry and Harms, 1975). This means that a chemical assay of xanthophyll content of a given feedstuff cannot be used directly to estimate the value of that material for pigmenting egg yolk (Scott et al., 1982). Some other sources of xanthophyll pigments suggested for use by some researchers are algae meal and marigold petal meal. Non-conventional feedstuffs fed up to certain percentages for sources of pigment include cirtrus pulp (apocarotenal), tomato waste (lycopene), paprika waste (capsanthin) and lobster waste (astaxanthin) (Scott et al., 1982).

Marigold petal meal produced by drying and grinding of marigold flowers contains up to 17 different carotenoids. The pigments are mainly present in the esterified form. Lutein-diester, a yellow carotenoid, makes up to 70 to 90 % of the total carotenoid content. Zeaxanthin-diester, a red carotenoid, is the second most important carotenoid present and makes up about 10 to 25 % of the total carotenoids. All other xanthophylls are present in traces and contribute insignificantly to the total pigmenting efficacy of marigold products (El Boushy and Raterink, 1985). Marigold petal meal normally contains 0.6 to 1 % xanthophylls, and marigold concentrate products have been developed from extraction of the xanthophylls from marigolds. These concentrates contain 1 to 4 % xanthophylls and contain varying levels of ethoxyquin as an antioxidant. The richest sources of xanthophylls are marigold petal meal (6,000 to 10,000 mg/kg), algae (4,000 mg/kg), dehydrated clover meal (490 mg/kg), corn gluten meal 41 % protein (90 to 180 mg/kg) and yellow corn (20 to 25 mg/kg) (Fletcher, 1982; El Boushy and Raterink, 1989).

7. Synthetic Carotenoids

A few carotenoids have been synthesized and tested as supplements for egg yolk pigmentation.

Canthaxanthin (beta, beta-carotene-4, 4'-dione) is the red pigment of chanterlle mushrooms, and when added to the natural yellow pigments of yellow corn and alfalfa, it helps to produce an orange-yellow color (Fletcher et al., 1978). Only 2 to 10 g of canthaxanthin per ton of feed is needed to supplement the natural xanthophylls in the yolk in the normal rations (Scott et al., 1982).

Beta-apo-8'-carotenal or preferably the ethyl ester of beta-apo-8'-carotenoic acid (8'-apo-beta-carotene-81ft-al) is also used as a feed supplement (Fletcher et al., 1978). They are yellow pigments that act as a provitamin A. They have been isolated from grass, Lucerne, green vegetables and citrus fruits. Addition of 2 to 8 grams per ton of feed supplements the natural pigments to produce higher quality yolk color (Scott et al., 1982)

Synthetic carotenoids are added as small particles in which the carotenoid pigments are finely distributed in a gelatin base to prevent oxidation. They may be mixed into compound feeds, concentrates and mineral mixtures and are highly stable during storage due to their gelatin coating.

8. Levels of Carotenoids in Layer Rations

Alfalfa (lucerne) meal which is commonly used in layer rations is rich in xanthophylls (150-310 mg/kg), but its use is limited due to its high fiber content(Scott et al., 1982). Synthetic carotenoids must be used to achieve the required yolk color to satisfy both the consumer and the industry.

The consumer of each country prefers different levels of pigmentation. For example, the yellow pigments in layer feed are much lower in Sweden than in Germany. In Sweden, 0.5 mg canthaxanthin per kilogram of feed is used to improve the color of the yolk to 4 degrees on the Roche color fan. In Germany, a minimum of 13 is required to satisfy consumers. The manufacturers use top quality maize at the highest levels possible. The yellow pigments alone are not able to increase the color beyond 11 Roche, so a red synthetic carotenoid is added to improve color further (Braeunlich, 1974).

CONTROLLING EGG WEIGHT BY DIET AND MANAGEMENT

Egg producers have always faced the problem of getting their flocks to lay table eggs with market weight, and at the same time controlling egg size once it starts to increase excessively. Egg weight is mainly determined by the size of the egg yolk. The size increases as the hen ages because the yolk size increase. Other components such as albumin and shell are proportional to the yolk size but this proportion decreases with age of the hen and are influenced by components of the blood.

1. Early Egg Size

Various factors such as genetics, body weight and shank length of pullets, season of maturity, environmental temperature and lighting programs have influences on egg weight(Scott et al,. 1982; Lesson and Summers, 1992; Nahm and Chung, 1995).

2. Dietary Manipulation

1) Energy

In early maturing pullets, low feed intake for the first two to three months of production is a problem. It also undoubtedly contributes to small egg size. Egg weight was significantly reduced by 15 % feed restriction, but it has also been reported that egg production is reduced by any restrictions greater than 5 %(Kim et al., 1995).

2) Proteins and Amino Acids

Dietary protein and amino acid levels, especially methionine, have been reported to influence egg size under different environmental and dietary situation. At the peak of production, a layer should receive 18g of protein and 400mg of methionine daily to meet requirements for egg output, body maintenance and growth. In field trials when pullet were consuming 100 g daily of an early lay ration with less than 0.4 % methionine, addition of 451 to 908 g(1 to 2 lb.) of DL-methionine per ton improved early egg size. The weight of eggs from pullets was not affected by increases in dietary levels of methionine, linoleic acid or protein above the established requirements (Aghir, 1991).

Most of the beneficial effects of the a high protein level(17, 19 and 21 %) or supplemental fat(2 or 4 % tallow, blended fat of corn oil) on early egg weight(18 to 38 weeks of age)discontinued upon changing the feeds of a 16.5 % protein diet (Keshavarz, 1995). This research pointed out that egg weight of the heavy-weight groups remained greater that the light-weight groups.

After peak egg mass, dietary protein and methionine level manipulation is used to control egg weight. A reduction of only 0.5 % protein and methionine level manipulation is used to control egg weight. A reduction of only 0.5 % protein at any one time with intervals between subsequent reductions of at least 3 to 4 weeks is recommended (Daghir, 1991). If production decreases occur beyond the predicted age, this scientist suggests a safer procedure is to reduce dietary methionine rather than protein. Methionine reductions of 0.01 % at any one time with intervals between reductions of 3 to 4 weeks can reduce the terminal egg weight by up to 2 g. attempts at reducing or tampering with egg size later in the production cycle by phase feeding of protein or methionine have met with only limited success (Daghir, 1991).

3) Low Protein Diets (after Peak Egg Mass)

Most research studies have shown that laying hens must be fed a diet containing at least 16 % protein to maintain maximum egg weight. Low protein diets may support maximum egg production but usually fail to support maximum egg weight when compared to diets with 16 % protein or more. When the protein intake is low(less than 14 to 15 g/day), there may be a reduction of egg size when energy levels are increased. The response of the layer to protein is most likely associated with the sulfur containing amino acids, especially methionine. When the intake of methionine daily is lower than 255 mg, egg size is reduced but egg production rate is not changed (Summers and Leeson, 1984; Leeson and Summers, 1989).

An experiment comparing a 16 % crude protein practical diet with a 13 % crude protein diet and various additions of amino acids to the 13 % crude protein diet was conducted (Jensen and Penz, 1990). This study showed that egg yolk as a percentage of total egg was generally higher for diets based on the 13 % crude protein while albumin weight as a percentage of the total egg weight was usually lower. Synthesized amino acid supplementation did not influence albumin or yolk percent. The reduction in egg weight appeared to be the result of a reduced albumin. These researchers noted that the protein deposited in the yolk is synthesized in the liver and accumulates continuously in the ovum over a period of several days until ovulation occurs. On the other hand, albumin is synthesized in the oviduct and must be supplied to the egg during a 3 to 3.5 hour period of time when the ovum is in the magnum of the oviduct (Jensen and Penz, 1990). The level of amino acids, originating from the diet and not from synthesized amino acids, circulating in the blood during the time when albumin is being actively synthesized and deposited in the magnum may have an effect on the amount of albumin synthesized. This need for additional amino acids during albumin synthesis suggests that feeding a high-protein diet at this time may improve egg weight.

4) Linoleic Acid

Linoleic acid is known to be a requirement for maximum, egg size, but the optimum of maximum requirement for birds has been debated. It has been recommended that layer diets contain 1.4 % linoleic acid with a gradual reduction starting after peak egg mass (Daghir, 1991). Another study showed that increasing the level of dietary linoleic acid from 0.6 to 4.3 % increased the egg weight during the first 14 weeks of production : however, average egg yield was not affected(March and McMillan, 1990).

5) Dietary Fats

The addition of fats to diets of laying hens has been shown by several investigators to increase production and egg size. Incorporation of 1 to 2 % feed grade animal fat to the layer diet has been shown to be effective in decreasing the percentage of small plus medium-sized egg and increasing the percentage of large and extra-large eggs during 22 to 28 weeks of age. In another study, addition of up to 5 % vegetable oils such as corn oil to layer diets increased egg weight(Jensen et al., 1958). This effect was attributed to a specific property of the oil rather than to its energy content, since replacement of the oil by starch to provide the same amount of energy depressed egg size (Kennedy and Vevers, 1975). Increasing the ME of laying hen diets by adding 4 % animal tallow also increased egg production and egg size (Reid, 1983).

Egg size was increased .with the fat supplementation regardless of the dietary energy levels. The increase in egg size was observed with the addition of poultry fat, corn oil and tallow. However, the addition of fat to pullet rations during the rearing stages had no effect on egg production, irrespective of the fat content in the laying diet (Whitehead, 1981). Three major effects of added fats to poultry diets were recognized. The first of these is still improvement in feed conversion, which accrues from the increased caloric density of the diet and can result in substantial saving in feed costs. The second benefit from fat has been termed the "extra-caloric effect" that apparently results from improved nutrient availability in ingredients and mixed diets. Many studies designed to measure the metabolizable energy (ME) of fat have found values that are higher that the gross energy(GE) of the fat. The third major benefit of fat involves the "extra-metabolice effect" that is noted as improved performance and increased energetic efficiency.

6) Ingredient Quality

Early egg size can also be influenced by ingredient quality. Differences in the digestibility and available amino acid levels are most responsible for these effects. Decreasing the dietary energy level, as may occur when sorghum or barley is substituted for corn, may decrease egg weight (Coon et al., 1988).

7) Age and Limiting Amino Acids

Older laying hens produce a high proportion of extra-large eggs for which the monetary returns often do not offset the costs of production. When formulators wish to reduce the weight of eggs laid by older hens, the most limiting amino acid level is lowered below the required level, which results in proportional reductions in egg weight and rate of egg production. For example, weight of eggs produced by hens more than 38 weeks of age was reduced by limiting methionine intake to 270 mg per hen daily, compared with feeding 300 mg methionine per hen daily (Peterson et al., 1983).

ORGANIC EGGS

The egg industry is constantly being challenged to sell more eggs. Eggs need to be promoted as a versatile commodity and new processed egg items need to be developed. The entire industry must join with the poultry science community in this effort. Organic produce and / or produce that has been tested pesticide residue free by an independent company has shown promise as a new area of interest in the U.S. and other countries for the retail grocery business (Ernst, 1993; Nahm and Chung, 1995).

1. Production of Organic Eggs

Hens that are used to produce organic eggs need to be raised without chemicals or drugs to stimulate or regulate growth or tenderness and without drugs or antibiotics, except for treatment of specific disease malady. Theses hens are fed a ration formulated from ingredients produced, harvested, stored, processed and packaged free from the application of synthetically compounded fertilizers, pesticides or growth regulators.

2. Difficulties in Producing Organic Eggs

Finding a source of organic poultry feeds has been the most difficult problem to overcome in producing organic eggs. Feed mill operators have reported that it was virtually impossible for them to find sources of organic grains when they were asked to produce organic feeds. They thought farmers would find it too expensive to raise organic grains and they could not believe that a grain Was actually organic just based on the word of the broker. Synthetic vitamins at normal levels and minerals of rock origin need to be supplemented in the organic feed. Labeling on the feed should state that organically grown corn and soybeans were used to formulated the organic ration.

The cost of the organic grains is the greatest expense incurred by farmers wishing to produce organic eggs. Despite the increased cost of producing these eggs organically over the conventional methods, consumers seeking organic products are willing to pay significantly higher prices for the eggs. Producers considering the production of organic eggs should consider all the production changes necessary before attempting to switch from the conventional or traditional production methods. A market survey should also be carried necessary before this change is done.

CONCLUSION

Eggs have to compete with other foods since a wide variety of products are becoming available to consumers. The disadvantage of egg consumption are becoming more relevant, because the consumer is demanding guarantees for quality. The quality of an egg is a complex relationship between internal quality of the egg, cholesterol content, egg size, eggshell strength and shell color. Internal quality of the egg is of great importance for commercial producers, processors and traders, as well as consumers. It is measured through the visible characteristics of the egg, its freshness and nutrition. Public concern about the emergence of Salmonella contamination of the egg has led to changes in egg production methods.

Dietary cholesterol, blood cholesterol and their relationship has been a high profile health issue for many years. The manipulation of the cholesterol concentration in the egg yolk, however, is generally unsuccessful since the cholesterol can only be alter to a small extent. New information and research data about the role of dietary cholesterol should take the pressure and attention off of eggs in recommendation to the general public.

Consumers generally prefer eggs with well pigmented yolks. Pigmentation is inherited, but is also influenced by feed ingredients and light. Variations in carotene and xanthophyll contents in feed ingredients, availability of xanthophyll, oxidation during storage and other dietary or health factors may alter pigmentation. Feed manufacturers should insist that ingredient suppliers provide ingredients that have been properly treated with antioxidants and stored properly.

Egg size classifications are used throughout the marketing system to determine egg price. Factors such as body weight of the hen, housing temperature, lighting programs and dietary manipulation affect egg size. There is no doubt that the egg size can be controlled. The most common methods used for this are limiting protein intake, limiting total sulfa-amino acid(TSAA) intake, limiting methionine intake and practicing feed restriction. It is important that egg weight control begins before excessive egg weight occurs.

Organic egg laid by hens raised in chemical and drug free environments are a area of interest in the U. S. and other countries for the retail grocery business because the egg industry is constantly being challenged to sell more eggs. There are still difficulties in producing these eggs due to the availability of organic eggs, the consumers appear willing to pay more money for these eggs according to market survey research. Further research is needed before increasing the organic egg production.

적 요

계란 내용물의 질적 향상은 소비자나 생산자 모두에게 중

요한 일이다. 내용물의 질적 향상이란 여러 가지 요인이 함축된 것으로 맛, 신선도, 영양적 및 가공적 가치, 여러 수준에서의 유전적인 영향 등이 함유된다. 암탉에서 콜레스테롤을 합성하는 율은 인간이나 다른 동물에 비교하여 아주 높다. 그래서 유전적인 선발이나, 약품첨가 또는 화학시약 첨가 등으로 산란계 혈중 콜레스테롤 수준을 변화시켜 보고저 시도했지만 결과는 아주 미미한 정도여서 난황에서 콜레스테롤 농도를 조절하기 위한 시도는 현재까지 성공을 거두지 못하고 있는 형편이다. 난황의 색깔에 영향을 미치는 요인들로는 여러 가지 형태의 xanthophyll과 사료 중의 농도, 사료조성, 그리고 산란계의 건가 유무 등을 들 수 있다. 또 단미사료는 색소의 농도와 관계가 있으며 이는 난황의 색소침적을 늘일 수도 있고 줄일 수도 있다. 난중을 결정하는 요인들로는 유전적 요인, 초란전 산란 체중, 사육밀도, 환경온도, 점등계획, 총사료 소비량, 사료중 칼슘, 인, 나이아신, 물, 메티오닌, 총함유황아미노산, 리노라익산 그리고 단백질함량 등이 있다. 계란이란 다양한 상품성을 가져야 하며 또 새로이 가공되는 항목들을 개발하는 것이 필요하다. 유기란이란 약품을 전혀 가미하지 않은 환경속에서 기른 암탉으로부터 산란된 알을 의미한다. 그러나 현실적으로는 화학제제 첨가가 없는 사료를 급여하는 것이 어렵고 또 그러한 사료의 가격이 비싸다는 점이 유기란 생산을 어렵게 하고 있다.

(색인어 : 난질, 콜레스테롤, 난황색, 난중, 유기란)

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