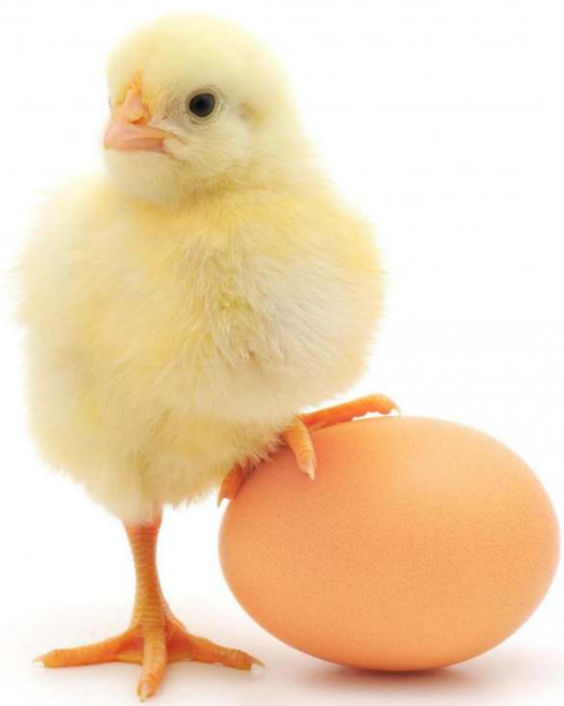
ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 5 (10): 905-911, 2006
ISSN 1682-8356

Factors That Affect Feed Intake of Meat Birds: A Review

Peter R. Ferket* and Abel G. Gernat[1]
*Department of Poultry Science, North Carolina State University, Box 7608, Raleigh, NC 27695-7608, USA
[1]Escuela Agricola Panamericana, El Zamorano, P.O. Box 93, Tegucigalpa, Honduras

Abstract: Feed intake is the major factor that influences both the body weight gain and feed efficiency in meat-type poultry. Because so many factors can influence feed intake, it is often difficult to correct a problem of poor feed intake unless a complete review of feed and management practices is made. Management and flock health issues are usually more likely to reduce feed intake than dietary factors. Dietary factors that influence feed intake would be common among all flocks in a complex rather than on individual flocks. In contrast, environmental or immunological stresses have the most profound effects on flock variation in feed intake. Any management protocol that would alleviate these stressors will improve feed intake. To improve flock feed intake, initially investigate the source of greatest stress or disease challenge.

Key words: Feed intake, broilers, energy, protein, stress, water, anti-nutrients, receptors

Introduction

Control of feed intake is an extremely complex area involving a number of factors and theories which have attempted to explain this phenomenon. Factors such as dietary (dietary nutrient composition, feed formulation and feedstuff inclusion levels, and feed pellet quality) and managerial (feed and water availability to the birds, environmental management, stocking density, and disease control). There are theories which are based on both physiological (controlling mechanisms within the bird which limit and encourage consumption of a particular nutrient or energy yielding components) and physical, the bird eats the maximum gut fill. Both mechanisms require the presence of sensors within the bird by which it is informed of intake.

The amount of feed consumed is closely associated with growth performance in meat-type poultry. Modern commercial broilers and turkeys will not grow to their full genetic potential unless they consume their full nutritional requirement each and every day. Aside from adequate diet formulation, maintaining maximum feed intake is the single-most important factor that will determine the rate of growth and efficiency of nutrient utilization.

Feed intake control: The fundamental physiological theories of feed intake control have been studied primarily in mammals yet very little information exists on poultry (Gleaves, 1989). The control of feed intake in mammals is attributed to the hypothalamic region of the brain, which responds to various sensory stimuli and regulatory mechanisms. A number of different mechanisms have been discovered which have been implicated in the control of appetite or feed intake. No one theory can explain such phenomena. A number of signals arrive at the cerebral cortex or hypothalamus and stimulate those nerves that pass through the hypothalamus, from where other nerve networks transmit information to the organs, such as the gizzard, liver, intestine and pancreas. These signals come directly from the food itself (color, shape and smell), whereas others originate from the intestinal tract following the ingestion of food. In contrast to mammals, visual and textural properties of food have a much greater influence on feed intake of birds than taste or smell. The bird will not readily consume feed if it does not recognize it as food by visual means. Birds are sensitive to shape. Once they have become used to one particle form of presentation of food, a certain amount of adaptation is necessary if another is provided. Birds that were fed pellets will need a few days to get accustomed before being able to eat the same quantity of food if the diet were to be changed to a meal. But birds are less sensitive to smell if compared to mammals.

Sensory factors that influence feed intake: The sensory aspects of feed intake can be categorized in three basic stages of food ingestion: 1) food recognition; 2) food prehension and ingestion; and 3) gastrointestinal activity. Food recognition in poultry primarily involves vision. Newly hatched birds have an innate preference for food of certain colors. Hess (1956) reported a bimodal color preference with peaks in the orange and blue region of the visual spectrum. A preference for green over red was found in chicks (Capretta, 1969) and turkeys (Cooper, 1971), which is the reason Oasis® (Novus International, St. Louis, MO) used to stimulate feed intake initiation of hatchlings is colored green. Young poultry have a natural curiosity to explore green-colored material as a potential source of food. Poultry also have an innate preference for food with certain shape and size (Gentile, 1985) similar to small seeds. However, poultry also have a strong bias to use visual (shape and color) in learning situations. For example, birds will learn to avoid a substance based on visual characteristics if it produced an illness or other unpleasant post-ingestion effects (Gillette *et al.*, 1983). In contrast, an increase in food intake is associated with positive visual-tactile-gustatory stimuli from the food. It is important to associate good textural characteristics of feed (good crumbles and pellets) with good nutrient composition and diet formulation. Finally, social facilitation is important aspect of feed intake among poultry. Chicks will initiate more pecking behavior when they see other birds exhibiting this behavior. Feed intake in a group of birds is often synchronized at specific times during the day even though feed is available *ad libitum* (Hughes, 1971).

Chickens and turkeys are seed-eaters and the efficiency of feed intake is greatly dependent upon the particle size and shape that complements the physical attributes of the bird's mouth. They have difficulty consuming food that is too large or too small relative to the dimensions of its beak. Chicks and turkeys do not have teeth, so large particles cannot be "bitten" and divided into smaller ones. Although fowl can prehend fine feed, they cannot do it efficiently without significant feed wastage. Moreover, they must work more to consume a fine feed than pelleted feed, essentially reducing the productive energy of the feed. If the diet is offered as a meal, consumption will diminish in the young bird when particle sizes are small. If the mean diameter is below 8000 microns this response becomes clearly noticeable. The depressive effect is proportional to the reduction in mean diameter of the particle. On average each reduction of 100 microns is associated with a decrease in intake of 4%. Finely ground feeds are poorly consumed by poultry.

Because of the high degree of keratinization of the beak, birds have very little ability for oral manipulation of food. Feed particles must first be picked up and positioned by the beak and then a forward thrust of the head along with particle release moves the food to the back of the mouth where it is coated with viscous saliva before swallowing. If the feed is too finely ground and not properly pelleted, it interacts with the saliva and forms a sticky mass that solidifies and interferes with prehension, especially when the diet contains wheat or other small grains. Feed prehension and intake will also be compromised by any alteration to the integrity of the beak, such as excessive debeak trimming used to manage flock cannibalism, or lesions due to fusariotoxin T-2.

Feed consumption in the bird is perceived *via* mechanoreceptors, thermoreceptors, and chemoreceptors in the mouth. Mechanoreceptors helps the birds rapidly discern a feed's quality by its textural properties. Thermoreceptors in chickens respond to cooling of the surface of the beak and oral epithelium, but not to warm food temperature (Gentle, 1975). The chemoreceptors in fowl are clustered into taste buds. Chickens have an average of about 360 taste buds (Saito, 1966), 54% located in the palate, 42% in the floor of the mouth, and only 4% in the tongue. This taste bud distribution in the mouth is directly associated with the contact time of the food on the different areas of the mouth to enable better gustatory discrimination (Berkhoudt, 1977). Even though fowl have far less number of taste buds than mammals, they do have an acute sense of taste and changes in taste (Gentle, 1975). Kare and Maller (1967) demonstrated that chickens fed low energy diets have a marked preference for sucrose solution. Hughes and Wood-Gush (1971) found that chickens would quickly select calcium carbonate-supplemented diets when they are calcium deficient. Similar responses to other nutrient deficiencies are likely. In condition-aversion studies, birds are more responsive to weakly flavored foods than strongly flavored foods (Gillette *et al.*, 1983), indicating that a bird's sense of taste can be overwhelmed.

Theories of feed intake regulation: Once feed is consumed, there are several possible mechanisms that regulate feed intake. The common regulatory mechanisms of feed intake include: the glucostatic theory, the thermostatic theory, distention of the gastrointestinal tract, circulating amino acids and protein intake, the lipostatic mechanisms (Gleaves, 1989). The glucostatic theory ascribes to the regulation of blood sugar and the amount of glucose entering the liver after a meal. Hypoglycemia stimulates a nervous center for intake where as hyperglycemia stimulates the center for satiety Shurlock and Forbes (1981) observed reductions in feed intake after they infused glucose into the hepatic portal vein of fasted chickens at physiological rates, whereas no effect was observed when glucose was infused into the jugular vein. The glucostatic control mechanisms seem to have a priority over all others as birds tend to consume feed to satisfy their energy requirement first. The second priority is to consume feed to satisfy daily amino acid intake requirements. Under free-choice feeding conditions where different dietary sources are available, birds will modulate their feed intake to satisfy both energy and daily amino acid needs. In commercial conditions where there is only one choice of feed available, feed intake is greatly influenced by both the dietary energy and amino acid profile.

The thermostatic theory is closely associated with a bird's thermal regulation. The major environmental factor controlling feed intake is ambient temperature. Birds are homeothermic which means that they must maintain a constant internal temperature against a background of an environmental one, which will vary. The thermoneutral zone is the ambient temperature range over which heat loss from the bird arising from normal metabolic activities will be sufficient to maintain internal temperature constant. Within the range, the optimum temperature for general performance (feed intake and feed conversion combined) is around 20^{0}C. However, there comes a point with declining ambient temperature is not sufficient, at which point it is referred to as lower critical temperature. The bird must generate more heat. This means that it has to increase feed intake. Under very hot conditions birds may be unable to dissipate heat arising from thermogenesis heat associated with normal metabolic activity, including nutrient metabolism. In addition, maintenance energy requirements will fall. The combined effect of these factors will be a reduction in feed intake. Under these circumstances, the concentration of nutrients should be increased such that, at the known level of feed intake, requirements are met. Feed intake decreases as ambient temperature rises above thermal neutrality (Hurwitz *et al.*, 1980). Because the metabolic processes associated with digestion adds significantly to the body heat load, feed intake must decrease to maintain body temperature when the birds are exposed to chronic heat stress conditions. The latent heat of digestion is dependent upon diet composition. Dietary energy in the form of carbohydrate generates significantly more latent heat of digestion because of active transport than when energy in the form of dietary fat. Likewise, providing the bird with an ideal amino acid balance will generate less metabolic heat than a poorly balanced diet because less excess amino acids must be catabolized. Therefore, feed intake of birds reared under heat stress conditions can be optimized by increasing dietary fat at the expense of carbohydrate and protein, and using supplemental amino acids to improve dietary amino acid balance. The thermostatic control of feed intake may also be important in birds experiencing a fever response during an innate immune challenge. Pro-inflammatory cytokines cause an increase in basal metabolic rate and body temperature as nutrients are mobilized away from growth to support the immune system (Koutsos and Klassing, 2001). Consequently, feed intake decreases to alleviate any additional metabolic heat load during the fever response similar to the decrease in feed intake during a heat stress.

Gut distension and gut motility most likely influence feed intake of birds, but relatively little is known about how gastrointestinal activity influences feed intake in comparison to other factors. There are also physical signals transmitted by receptors within the crop. These receptors are sensitive to the pressure to which they are subjected. Once perceived, messages sent to the brain are integrated into the signal of satiety, thus reducing feed intake. Hodgkiss (1981) demonstrated the presence of two types of distension-sensitive receptors in the crop: slowly adapting receptors and rapidly adapting receptors. The slowly adapting receptors signal distension of the crop for prolonged periods of time and are associated with feed transit rate. The fast-adapting receptors are associated with meal feeding behavior. Distension receptors also exist in the gizzard (Duke *et al.*, 1977) and help control food grinding and gut motility. Distension receptors in the duodenum are associated with sensing osmotic pressure.

Gut distention and tactile receptors in the gizzard, play an especially important role in the control of gut motility. The gizzard is the “pace-maker” of normal gut motility (Duke, 1994). Unlike mammals, vigorous gut reflexes (reverse peristalsis) are normal in birds to compensate for a short intestine. The reflexes serve to re-expose intestinal digesta to gastric secretions, vigorously mix digesta with enzymes to enhance digestion, and nutrient absorption over a short segment of the gut, and discourage microbial proliferation that may cause disease or compete for nutrients. Poor gut motility will result in an unstable gut microbial ecosystem, increase the severity of enteric disease, and thus cause significant reductions in feed intake (Ferket, 2000).

Osmotic receptors also exist. Infusion of solutions with high concentrations of potassium chloride into the crop or the duodenum slows down the rate of food intake.

The lipostatic theory of feed intake control likely plays an insignificant role in meat chickens with older birds. As in many other species, adolescent and adult birds defend changes in body fat content by modulating dietary energy intake or energy expenditure. In other words, birds have a certain body fatness set point and their intake of energy will increase to the point where this minimum body fat content is reached. Because modern meat birds have been selected for weight gain and feed conversion with minimal control of body fat content, this body fatness set point has apparently drifted upwards as evident by the observed increase in body fat. According to the lipostatic theory of feed intake control, the modern broiler has become hyperphagic in order to accommodate the genetic propensity for high body fat content. This is one reason why the feed intake of broiler breeders must be restricted to keep body fat at acceptable levels to support optimum reproductive performance.

Dietary factors that influence feed intake: There are several dietary factors that influence feed intake, especially if dietary nutrient composition is either deficient or in great excess relative to the bird’s requirement. Because meat-type poultry have been selected for body weight gain, they are less responsive to dietary influences on feed intake than laying hens. Meat-birds tend to consume to maximum gut fill if not limited by dietary toxicities, environmental, management, or disease factors.

Dietary energy: Dietary energy content has the most predictable effect on feed intake on meat birds. As mentioned in our discussion about the lipostatic theory of feed intake control, birds will attempt to consume feed to meet their metabolic energy requirement. Energy requirement is dependent on the energy needs for body maintenance and growth or production. Body maintenance requirements, which have a priority over production, are influenced by the bird's health status, its degree of mobility (influenced by stocking density, physical activity, and social interactions), and body heat loss (influenced by ambient temperature, humidity, air speed). Therefore, feed intake will increase as dietary energy content decreases until it is limited by either gut fill or other physiological limitations. Because feed conversion is economically important in the raising of meat-type poultry, it is impractical to stimulate feed intake by reducing energy density. Limitations to feed intake are almost always associated with factors other than dietary energy content. Homeostatic mechanism of consumption is rarely perfect. Thus laying hens adjust their energy consumption as a consequence of dietary energy concentration almost perfectly. However broiler breeders are unable to reduce their intake adequately when dietary energy concentration increases. It is the smaller birds that are most capable of maintaining energy intake constant with fairly large variations in dietary energy concentrations. On the other hand heavier breeds tend to maintain intake constant irrespective of the dietary energy concentration.

Dietary protein and amino acids: Dietary protein and amino acid content has more of an indirect effect on feed intake than any direct effect. Growth can be very sensitive to daily amino acid intake and changes in food intake may reflect only changes in production rather than being a primary response to protein (Boorman, 1979).
Specific amino acid imbalances can modify food intake in chicks very rapidly and this suggests that the ensuing growth depression is not the immediate cause of the response. That the mechanism which controls food intake is sensitive to the concentration of certain amino acids in the blood is shown by acute changes in intake which follows the intravascular injection of amino acids into chicks receiving deficient or imbalanced diets (Tobin and Boorman, 1979).

Dietary vitamins and minerals: Vitamins and minerals function primarily as cofactors of metabolism, while macro minerals, such as calcium, phosphorus, and magnesium also serve as structural components of the body. Vitamins and minerals influence feed intake only when dietary levels are deficient or several fold above requirement. Deficient dietary levels cause metabolic disorders that cause an indirect adverse effect on feed intake. Slight mineral deficiencies may stimulate feed intake as the bird attempts to achieve its intake requirement. In contrast, excessive dietary vitamins and minerals are detected by the bird's sense of taste, resulting a refusal to consume the feed. Mineral excess are also associated with significant increases in water consumption. Excess in dietary salt will depress feed intake and stimulate water consumption. Excess in dietary calcium will have depressed feed intake in growing meat birds. Deficiencies of trace mineral will not affect appetite unless they are prolonged.

Anti-nutritional factors: Naturally occurring compounds such as protease inhibitors, goitrogens, alkaloids, oxalates, and phytates are innate natural components of particular feed ingredients that can impair the availability of nutrients, depress feed intake, and reduce the growth in animals that consume them (Hathcock and Rader, 1994; Shahidi, 1997). Other antinutritional factors in foods are produced as a result of fungal or microbial metabolism or by the plants themselves as defensive mechanisms against injury or infection. Fortunately, the presence of a toxic factor per se does not preclude the utilization of the material as a feedstuff. Numerous processing methods are available to neutralize or detoxify the deleterious components of by-products and waste materials.

Water consumption: Water is the most essential nutrient of the bird’s diet, although a requirement value cannot be easily determined as with other nutrients. The water requirement of meat birds depends on the environmental temperature and relative humidity, the composition of the diet, growth rate, and the efficiency of water resorption by the kidney.
Meat birds drink at least twice as much water as the amount of feed consumed on a weight basis. Actual water consumption relative to feed intake varies depending environmental temperature and dietary factors. Increasing dietary crude protein increases water intake and water: feed ratios (Marks and Pesti, 1984). Crumbled or pelleted feed increases both water and feed intake relative to mash diets, but water: feed ratios stay relatively the same (Marks and Pesti, 1984). Increasing dietary salt and other osmotically active minerals increase water intake (Marks, 1987) in attempt to flush excess minerals *via* the kidneys.
Water consumption has its most profound effects on feed intake only when water consumption is restricted to the point that it begins to affect body hydration. Water availability is dependent upon stocking density and access to drinker space, drinker placement and height, drinker design, and water flow capacity. Although nipple drinkers are efficient and sanitary, they do not provide sufficient water flow for turkeys beyond 6 weeks of age, and consequently feed intake rate is adversely affected.

Management factors that influence feed intake: Feed intake can vary significantly among flocks or different housing facilities even if they are all consuming the same feed and follow similar general management practices. These differences are almost always associated with differences in management and disease challenge. There are three general management factors that can have additive effects on feed intake of meat birds: 1) access to feed and water; 2) environmental stress; and 3) disease challenge.

Access to feed and water: Meat birds must have free, unimpeded access to feed and water whenever they want it from the day of placement until the day they are sent to market. Sufficient feeder and drinker space must be provided so that there is minimal competition among feeding birds. The feeders and drinkers must never be fully occupied throughout the day because the submissive birds within the flock will not be able to consume their required feed intake *ad libitum*. A high variability in flock body weight is an indication that there is not enough feeder space per bird. Even if there is sufficient feeder space per bird, placement of the feeder lines must be such that all the birds can easily access the feed without excessive maneuvering through a crowd of other birds.

Feeder and drinker height must be adjusted properly to allow each bird to easily access the feed without excessive spillage. Feeders that are adjusted too high will discourage the smaller birds from optimum feed intake, resulting in further degradation of flock uniformity. Make sure the litter level under the feeder lines does not have excessive hills and hollows which in effect increases variability in feeder height.

Proper feeder design and adjustment of feed flow for each pan is important for birds to easily access feed when they eat. The feeder design must suite the size of the bird, with proper grill wire spacing, feed flow and depth in each pan, and timely refilling. Too often, several feeders within the feed line are empty because of poorly adjusted feed flow, or the feed line operation switch in the last feeder is not functioning properly.

Environmental stress: Stress has adverse effects on feed intake of meat birds. Elevation of the stress hormones associated with the stress response causes body reserves to be mobilized to fuel the “fight or flight” response. Nutrient absorption and gut motility decreases substantially during the stress response and feed intake decreases accordingly. Although acute stress may cause a momentary decrease in feed intake with minimal impact on performance, chronic stress will have a marked and persistently detrimental effect on feed intake. In general, chronic stress can be influenced by three environmental stressors: heat stress; poor air quality; and poor litter quality.

Heat stress clearly has adverse effects on feed intake of meat birds. The degree of heat stress endured by a bird is dependent upon several factors, including the body size and growth rate of the bird, ambient temperature and relative humidity, and the amount of convective heat loss as influenced by air speed.

Poor air and litter quality are environmental stresses that will indirectly depress feed intake. Ventilation rate and the litter management are the predominant determinants of air and litter quality. Adequate ventilation reduces air moisture, dust, ammonia, and carbon dioxide and brings in more oxygen. High air moisture decreases evaporative cooling and thus adversely affects feed intake in response to an increase in sensitive heat load. Excess air dust causes inflammation of the pulmonary system and immunological stress, which depresses feed intake as explained further below. Excess ammonia not only irritates pulmonary tissues, but it also is a metabolic stressor that causes depressed feed intake. Finally, high levels of carbon dioxide or low oxygen levels in the air results in depressed metabolic rate that ultimately causes depressed feed intake. In addition to adversely affecting air quality (increases ammonia volatilization and dust), poor litter quality is also a medium of many pathogens that challenge the health status of the flock.

Disease challenge and immunological stress: Immunological stress caused by a disease challenge has a rather profound and significant effect on feed intake. Although enteric disease has obvious effects on reducing feed intake, any antigen (pathogen or vaccination) that mounts an immune response will depress appetite. The innate immune response is more nutritionally demanding and adverse to feed intake than the acquired immune response. The pro-inflammatory cytokine cascade associated with the innate immune response directly modulates the bird’s behavior. Lethargy reduced social interactions and anorexia result from the actions of IL-1 and TNF-α on the brain and basal metabolic rate and fever. These behavioral changes results in reduced feed intake and body weight gain (Koutsos and Klassing, 2001). In addition to reduced feed intake, the nutritional status of a bird mounting an immune response is compromised by reduced absorption of specific nutrients. For example, water, sodium, chloride, and glucose absorption are reduced significantly by sepsis and is often associated with diarrhea (Kanno *et al*., 1996). About 70% of the reduced performance that occurs during an infectious challenge can be attributed to decreased feed intake and the remaining 30% is due to inefficiencies of nutrient absorption and utilization (Klasing *et al*., 1987). Immunological stress has a marked effect on the hormonal milieu of poultry. The pro-inflammatory cytokines decreases anabolic hormones, such as growth hormone (Elsasser *et al.,* 1997), insulin-like growth factor 1 (IGF-1) (Elsasser *et al.*, 1995), and increases the release of catabolic hormones, such as glucocorticoides (Elsasser *et al.*, 2000). The catabolism of skeletal muscles is further exacerbated by the reduction of IGF-1 associated with the decreased feed intake. However, once the bird has mounted an effective immune response and the pathogen is cleared, the pro-inflammatory cytokines declines and feed intake increases to normal levels or higher, ensuing a period of compensatory growth. In situations of chronic immunological stress, feed intake never has a chance to return to normal levels.

Behavioral: Birds under intense management practices will gradually associate the noise of feeders with food. Thus, mechanical delivery of food can often act as a stimulus to food intake. Even the sight and sound of other birds eating may promote feed intake.

Feeding rhythms: Domestic birds consume their food regularly throughout the day. They do not eat discrete meals. Slight increases in intake, however, are observed at the beginning and at the end of the light period. On the other hand under continuous lighting conditions the pattern of intake is constant whatever the time. If specific meal times or regimes (reduction in amount of feed offered) are imposed on birds then an adaptation is observed as they become capable of consuming an amount of food in a shorter and shorter space of time.

Conclusion: Feed intake is the major factor that influences both the body weight gain and feed conversion in meat-type poultry. Because so many factors can influence feed intake, it is often difficult to correct problem of poor feed intake unless a complete review of feed and management practices is made. Management and flock health issues are usually more likely to cause feed intake problems than dietary factors. Dietary factors that influence feed intake would be common among all flocks in a complex rather than on individual flocks. In contrast, environmental or immunological stresses have the most profound effects on flock-to-flock variation of feed intake. Any management protocol that would alleviate these stressors will improve feed intake. For greatest success in improving flock feed intake, start with investigating the sources of greatest stress or disease challenge.

References

Berkhoudt, H., 1977. Netherlands J. Zool., 27: 310-331.

Boorman, K.N., 1979. In: Food Intake Regulation in Poultry, pp: 87-126. K. N. Boorman and B. M. Freeman, Editors. Edinburgh.

Capretta, P.J., 1969. Animal Behaviour, 17: 229-231.

Cooper, J.B., 1971. Colored feed for turkey poults. Poult. Sci., 50: 1892-1893.

Duke, G.E., 1994. Anatomy and physiology of the digestive system in the fowl, In: Proceedings 21st Annual Carolina Poultry Nutrition Conference, December 7- 8th, Charlotte, NC, pp: 46-49.

Duke, G.E., W.D. Kuhlman and M.R. Fedde, 1977. Evidence for mechanoreceptors in the muscular stomach of the chicken. Poult. Sci., 56: 297-299.

Elsasser, T.H., K.C. Klasing, N. Filipov and F. Thompson, 2000. The metabolic consequences of stress: Targets for stress and priorities for nutrient use. In: The Biology of Animal Stress, ed. G.P,. Mobergand, J.A. Mench., pp 77-110. New York: CAB International Press.

Elsasser, T.H., S. Kahl, N.C. Steele and T.S. Rumsey, 1997. Comp. Biochem. Physiol., 116A: 209-221.

Elsasser, T.H., T.J. Caperna and T.S. Rumsey, 1995. J. Endocrinol., 144: 109-117.

Ferket, P.R., 2000. Practical nutritional perspective on gut health and development, In: Proceedings 27th Annual Carolina Poultry Nutrition Conference and Soybean Meal Symposium, November 15-16, Research Triangle Park, NC., pp: 74-86.

Gentile, M.J., 1985. Sensory involvement in the control of food intake in poultry. Proc. Nutr. Soc., 44: 313-321.

Gentle, M.J., 1975. In: Neural and Endocrine Aspects of Behaviour in Birds, pp: 305-318. P. Wright, P. G. Caryl and D. M. Vowles, Editors. Amsterdam: Elsevier.

Gillette, K., D.K. Thomas and W.P. Belingham, 1983. Chemical Senses, 8: 41-57.

Gleaves, E.W., 1989. Application of feed intake principles to poultry care and management. Poult. Sci., 68: 958-969.

Hathcock, J.N. and J.I. Rader, 1994. Food Additives, contaminants, and natural toxins. In: Modern Nutrition in Health and Disease. M.E. Shils, J.A. Olson and M. Shike, Eds. 8th Edition, 2: 1593-1611.

Hess, E.H., 1956. Psycholgical Reports, 2: 477-483.

Hodgkiss, J.P., 1981. Slow synaptic potentials in AH-type myenteric plexus neurons. Pfugers Arch., 391: 331-3.

Hughes, B.O. and D.G.M. Wood-Gush, 1971. Animal Behaviour, 19: 490-499.

Hughes, B.O., 1971. Allelomimetic feeding in the domestic fowl. Br. Poult. Sci., 12: 359-366.

Hurwitz, S., M. Weiselberg, U. Eisner, I. Bartov, G. Riesenfeld, M. Sharvit, A. Niv and S. Bornstein, 1980. The energy requirements and performance of growing chickens and turkeys as affected by environmental temperature. Poult. Sci., 59: 2290-2299.

Kanno, S., S. Emil, M. Kosi, H. Monforte-Munoz and J. Atkinson, 1996. American Surgeon, 62: 793-799.

Kare, M.R. and O. Maller, 1967. Taste and food intake in domesticated and jungle fowl. J. Nutr., 92: 191-196.

Klasing, K.C., D.E. Laurin, R.K. Peng and D.M. Fry, 1987. Immunologically mediated growth depression in chicks: influence of feed intake, corticosterone and interleukin-1. J. Nutr., 117: 1629-1637.

Koutsos, E.A. and K.C. Klassing, 2001. Modulation of nutritional status by the immune response. In: Proceedings 28th Annual Carolina Poultry Nutrition Conference, pp: 1-6. November 14-15th, Sheraton Imperial Hotel, Raleigh, NC.

Marks, H.L., 1987. Water and feed intake, feed efficiency, and abdominal fat levels of dwarf and normal chickens selected under different water:feed ratio environments Poult. Sci., 66: 1895-900.

Marks, H.L. and G.M. Pesti, 1984. The role of protein and diet form in water consumption and abdominal deposition in broilers. Poult. Sci., 63: 1617-25.

Saito, I., 1966. Bulletin of the Faculty of Agriculture, Miyazahi University, 13: 95-102.

Shahidi, F., 1997. Beneficial health effects and drawbacks of antinutrients and phytochemicals in foods: An Overview. In: Antinutrients and Phytochemicals in Foods. ACS Symposium Series 662. American Chemical Society, Washington, DC., pp: 1-9.

Shurlock, T.G.H. and J.M. Forbes, 1981. Br. Poult. Sci., 22: 333-346.

Tobin, G. and K.N. Boorman, 1979. Carotid or jugular amino acid infusion and food intake in the cockerel. Br. J. Nutr., 41: 157-62.