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The Management of Heat Stress Through Nutrition

Introduction

Poultry is subject to multiple environmental factors (Table 1). None of these factors are completely constant and are all interrelated. These factors counteract/reinforce the impact each one has on the bird. Acclimatization tends to allow poultry to withstand sudden short-term excursions from normal (NRC 1981).

Table 1. Environmental factors influencing poultry production (NRC,1981)

1) Temperature	5) Wind velocity (Air movement)
2) Humidity	6) Solar energy
3) Light (Length/Intensity)	7) Quality of air and water
4) Altitude (Air pressure & partial pressure of Oxygen/Carbon dioxide)	8) Density of population

Temperature is one of the important factors, affecting poultry production. Most parts of India are tropical, and the temperature in some parts of the year exceeds 35°C.Heatstressisa problem with broilers from 4 weeks age onwards and with layers and breeders in production. Heavier birds are affected more than the light weighted ones. The physiology of heat production and dissipation, the effects of high ambient temperature and the strategies to minimize the effects of heat stress are mentioned briefly.

Heat Production and Dissemination

Birds require energy for maintenance and production. The metabolic reactions associated with digestion, absorption, utilization of nutrients for production (tissue production: deposition of protein, fat, carbohydrates, minerals, vitamins and water) and excretion of waste products also require energy. This energy is wastage for the bird and is known as heat increment. The energy after meeting the requirements for maintenance and the energy of heat increment are released as heat into the environment. The proportion of feed energy that is deposited or converted to product is a small fraction of ingested energy and the remaining portion represents the energy requirement for maintenance and heat increment (Fig 1). Poultry is homeotherms i.e. maintain same body temperature irrespective of the surrounding temperature. In a narrow environmental temperature zone known as thermoneutral zone (Table 2), the energy required (and so the heat produced) for essential physiological

Fig 1. Feed energy partition within the animal (after Young, 1975; See NRC, 1981).

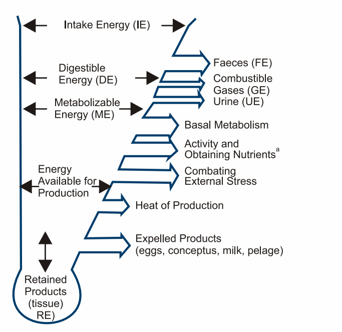


Table 2. Thermoneutral zone (TNZ) for chicken

Age (week)	Broiler °C	Pullet °C	Layer °C
1	32-33	34-35	
2	30-31	31-32	
3	27-29	28-30	
4	24-27	27-29	
5	18-22	26-28	
6		25-27	
7			
			19-22

Table 3. Methods of heat dissipation in chicken	
A. Sensible Heat loss[1] (Heat loss depends on thermal gradient)	
1. Conduction Heat flows through a solid medium (between objects in physical contact)	Heat flow (Thermal energy) from higher to lower temperature
2. Convection Heat flows through a fluid medium (e.g. air) (between objects in physical contact)	Heat flow (Thermal energy) from higher to lower temperature
3. Radiation Heat flows without the aid of media	All surfaces radiate energy. The net heat flow (Thermal energy) from higher to lower temperature
B. Latent Heat (Evaporative heat loss) (Vapor/Pressure gradient) Heat flows by conversion of liquid to gas	Heat (Energy) transfer influenced by relative humidity, Temperature, and air movement
[1]Effective when environmental temperature is below or within TNZ. Proportion of heat flow depends on the temperature difference between bird and environment. When environmental temperature exceeds 25-26°C, evaporative heat loss starts.	
Modified from Anderson and Carter, 1993.	

Table 4. Heat Loss by Respiratory, Cutaneous and Evaporative routes at Different Environmental Temperatures from White Leghorn

Temp	BW	Heat Production	Evaporation		
			Cutaneous	Respiratory	Total
°C	Kg	kcal/h	Kcal/h	kcal/h	kcal/h
10	1.70	6.55	0.166	0.251	0.417
20	1.66	5.09	0.201	0.277	0.478
30	1.69	4.43	0.323	0.482	0.805
35	1.67	5.27	0.597	1.561	2.158
40	1.65	5.33	0.995	3.443	4.438

Adapted from van Kampen, 1974. NRC 1981.

Table 5. Energy required for evaporative cooling

	Cal/ml	Respiratory Rate No./min
		25
Latent heat of vaporization of water	574 (At 41°C)	260 (acute stress)
Heat absorbed by warming consumed water to body temp	20	

(See Summers, 2006)

metabolic reactions to survive (basal metabolism) is minimum and the bird need not alter the behavior pattern. In the thermoneutral zone, the heat production equals to heat loss.

At temperatures less than the thermoneutral zone, birds have to increase energy production so as to produce heat to maintain body temperature. At temperatures above the thermoneutral zone, birds also have to increase energy production to dissipate heat. In the latter case, the additional energy produced is dissipated as heat. The Thermoneutral zone decreases, as the age of the bird increases (Table 2).

Heat Loss: Heat from the birds is lost to the surroundings either by sensible means (conduction, convection, radiation) or by insensible or latent means (evaporative heat loss) (Table 3). Poultry have no sweat glands. At high temperatures, the heat loss through evaporation exceeds the sensible heat loss (Table 4; Fig 2; Wiernusz,1998). At temperatures above the thermoneutral zone, (above 32°C and 50% relative humidity) the bird resorts to Evaporative cooling. Energy is required for evaporative cooling (panting) and thus heat is lost to the environment (Table 5). High rate of respiration also markedly increase the heat load through higher metabolic activity.

Relative Humidity: Relative humidity can markedly affect evaporative cooling potential during heat stress. As the relative humidity rises, the ease with which the bird can evaporate water by exhaling declines (respiration efficiency declines) and body temperature increases unless heat production is reduced. At above 70% relative humidity, it is almost impossible for the bird to lose a significant amount of heat through panting as the moisture gradient between expired and poultry house air is similar. Heat stress index number is a numerical that combines temperature and relative humidity [air temperature (°F) + Relative humidity (%)], which indicates the degree of comfort/discomfort for Poultry (Table 6). At heat stress index number of 170, high mortality may be noticed.

Table 6. Heat stress Index Numbers

	Air Temp (F) + RH (%)
150 or <	No problem with heat stress or heat Prostration.
155	Borderline of beginning to lose Performance
160	Reduce feed intake Increase water intake Lower performance
165	Mortality begins Damage to lungs and cardiovascular system
170	Mortality rises drastically
Barnwell and Rossi, 2002	

Table 7. Effects of high ambient temperature

High ambient temp	Bird's heat load increases. Environmental heat gain. High energy required for heat dissipation.
Heat Dissipation	Postural adjustments to increase surface area vasodilation, increased water intake, respiration rate (25 to 250).
Respiration	Water evaporation - a critical route fordissipation. Evaporative cooling only partially compensates for the diminished heat loss.
Wiernusz, C. 1998	

Effects of High Ambient Temperature

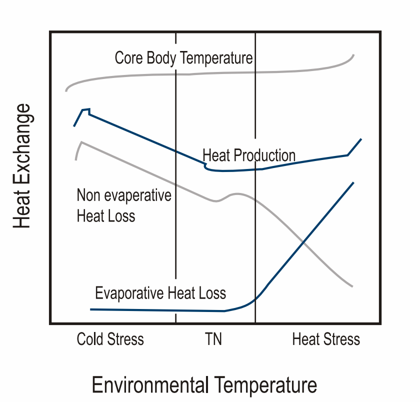
The effects of high ambient temperature are given in Table 7, 8 and Fig 2. High ambient temperature affects poultry production adversely. Relative humidity complicates the problem further. Heat stress decreases feed intake. Encouraging broilers to increase feed intake increases body weight but results in increased mortality

At high ambient temperature, birds make postural adjustments to increase surface area for heat dissipation. Vasodilation of peripheral vessels facilitates heat dissipation due to temperature gradient

Table 8. Adverse effects of Heat stress

	Broilers	Layers
Feed intake	Reduced	Reduced
Growth	Poor	
Body weight	Loss	Loss
Meat quality	Lowered	
Egg Production		Lowered
Egg weight		Decreased
Shell quality		Poor
Egg: Internal Quality		Lowered
FCR	Lowered	Lowered
Immunity	Decreased	Decreased
Susceptibility to Diseases	Increased	Increased
Body Temperature	Rises	Rises
Mortality	Increased	Increased

Fig 2. Ambient Temperature and Heat Exchange Wiernusz. 1998



between the bird and the surroundings and respiratory rate that facilitates heat dissemination through vaporization of water (Wiernusz, 1998). With the peripheral vasodilation, the blood supply to gastrointestinal and reproductive parts decreases by about 50-70% resulting in reduced digestion and absorption of nutrients and reduced egg production efficiency (Miles, 2005).

Strategies to Minimize the Effects of Heat Stress

Adaptation to heat stress is a physiological mechanism for survival. It may take up to about 15 days for adaptation depending on the temperature and duration of heat stress. Most of the research on the effects of heat stress on poultry is based on the data in temperate countries. In these

countries, heat stress means the temperature of about 30-32°C and rarely above 32°C. In Tropical countries (e.g. India), environmental temperatures of 35°C and above (uncomfortable for chicken), are recorded for many days in a year. The high temperature is coupled with high relative humidity at certain times of the year.

Table 9. Poultry house design : Maintaining poultry in summer

1	Width	max	6-8 meters	In houses with broilers or layers, sprinklers, foggers and fans may be operated depending on the necessity. Arrangement can be made to get the water from sprinklers to fall on to the gunnies hanging from the roof edges. In these houses, ventilation takes away the exhaled air and also the water vapor. (Foggers: Little value when RH exceeds 70%.
2	Height Side	min	3 meters	
3	Height - Side Wall	min	0.5 meters	
4	Roof		Sloping Ridge ventilation Sprinklers	
5	Inside		Foggers and fans	
			Cooling pads and exhaust fans	Work well to reduce temperature. In such houses, bird density can be increased.
6	Stocking density		To be reduced	Reduced stocking density results in less heat production in the house and better heat dissipation from the birds

Heat stress has to be managed by a combination of management methods.

A. Housing Management

B. Nutritional Management

1. Drinking Water
2. Energy and Protein in Feed
3. Vitamins in Feed and Water
4. Electrolytes in Feed and Water
5. Form of Feed
6. Time of Feeding
7. Feed Additives to improve Health and Immunity
8. Anticoccidials

A. Housing Management

Maintaining coolness in the poultry house is an important management option. It starts with the planning of house design and also the management of the house and the birds after the house construction. Only a mention is being made on the methods to maintain the poultry house cool. Broiler or layer houses, in our country, are mostly open sided houses. The poultry houses may be designed as follows (Table 9)

B. Nutritional Management

1. Drinking Water

a. Availability of cool drinking water:

Water is the important media for heat loss. About 70-80% of the bird's heat production during heat stress is dissipated via panting (evaporative cooling). Adequate water provision is a must as water restriction even for a short period is disastrous for poultry in hot weather. Reduction of water temperature and addition of salts are helpful in improving water intake.

b. Reduction of water temperature:

Overhead water tanks are exposed to constant heat in summer months. Location of water tanks in shaded area or provision of shade over water tanks keeps water cool. Insulation of water tanks and provision of sprinkling water on to the water tanks with water retaining material (layers of Gunny etc) reduces the water temperature further. Water pipes must run under ground and any exposed pipes have to be covered to prevent heating of the pipes. When the water temperature is less than 28°C at bird level, an improved performance of birds is observed.

c. Water Treatment:

Water may contain microorganisms and hence may be treated with sanitiser and acidifiers to minimize microorganisms in the gut.

2. Energy and Protein in Feed

Stimulation of feed intake in heat stress improves weight gain but mortality also increases. Increasing the ME content of feed also improves energy intake. The increased energy intake results in improved growth but also in increased fat in the carcass and also the mortality (Table 10; See Summers, 2006)

Table 10. Diet energy density on broiler performance (4-7 weeks) subjected to thermoneutral (TN) and heat stress environments (HD)

Diet energy kcal/kg	Weight gain g		Energy intake kcal		Carcass fat %		Mortality %	
	TN	HD	TN	HD	TN	HD	TN	HD
2826	1151^{a}	947^{c}	7498^{c}	6452^{d}	12.2^{e}	13.0^{d}	2.0^{a}	8.0^{ab}
3200	1294^{b}	998^{d}	8420^{b}	7152^{e}	13.1^{c}	13.7^{c}	3.0^{a}	4.0^{c}
3574	1301^{b}	997^{d}	10571^{a}	8079^{f}	14.2^{a}	14.9^{ab}	5.0^{ab}	20.0^{d}

Selected and rearranged data from Teeter 1994 (See Summers, 2006).

Several reviews (Ojano-Derain, Waldroup, 2002; Furlan et al., 2004; Gous and Morris, 2005; Aftab et al., 2006; Gonzales-Esquerra and Leeson, 2006; Lin et al., 2006) and research publications, on the diet protein and amino acids, indicate that heat stress reduces feed intake, productive performance and protein deposition in the body. The research conducted on protein and amino acid nutrition in strategies to minimize the effects of heat stress is inconsistent and also controversial. It appears that there is no interaction between environmental temperature and dietary nutrient concentration. Increased protein in diet cannot increase protein deposition, and proves harmful. The heat increment with protein (amino acid) catabolism is more than that of carbohydrates and fat. Reduction in protein in diet to reduce heat increment increases feed intake, due to the deficiency of amino acids. Less protein in diet also reduces water intake, a disadvantage in strategies to minimize the effects of heat stress. The influence on the effect of heat stress on absorption of amino acids is not clear and so the ideal amino acid pattern needs to be followed in practical diets. In diets with a fixed ME:protein ratio, higher energy diets under supply protein relative to net energy, which leads to all the effects reported as consequences of increasing nutrient density. Such effects are not confined to high temperature conditions only (See Gous and Morris, 2005). Alteration in ME: protein is having a general applicability on the nutritional performance of poultry. In hot weather, alteration of ME: protein does not improve the performance of poultry.

Under thermoneutral zone of temperatures, reducing dietary protein did not bring any beneficial effects. Under heat stress conditions, feed formulation based on the digestible amino acids and not by protein minimizes the catabolism of amino acids for elimination and reduces heat production associated with the elimination of excess amino acids. High energy and high protein ingredients with more digestibility and the commercially available amino acids (lysine, methionine and threonine) may be considered in diet formulation to meet the amino acid requirements rather than the protein requirements. This reduces protein content of the diet from the values practiced in other seasons by about 5-10% of the original value. Supplemental fat (prohibitive cost for layer) may also be considered at least for shorter periods as a high-energy ingredient.

3. Vitamins in Feed and Water

Vitamin A, D, E, Candfolic acid are known to reduce the effects of heat stress. It is well known that vitamin C enhances antioxidant activity of vitamin E.

Supplemental dietary ascorbic acid (vitamin C) limits and alleviates the metabolic signs of stress and improves the performance, immunological competence and behavior of birds. Optimum responses in growth, feed efficiency and/or liability in broilers under heat stress seem to occur with supplements of about 250 mg vitamin C/kg feed. Laying hens have also shown responses to supplemental ascorbic acid (250-400 mg/kg) in terms of improvements in liability, feed intake, egg production and egg quality with dietary ascorbic acid (Whitehead and Keller, 2003). Supplemental vitamin C influences energy stores, that are used during periods of reduced energy intake (Mckee et al., 1997).

Vitamin E can be supplemented to broiler diets (250 mg/kg) as a protective management practice to reduce the negative effects of stress and to result in optimal performance (Sahin et al., 2002). Vitamin C (250 mg/kg) and folic acid (Img/kg) supplementation arrests decline in performance and antioxidant status caused by heat stress. Supplemental dietary vitamin C (200 mg) and vitamin E (250-500 mg) offers a good management practice to reduce heat stress related decreases in performance of Japanese quails (Sahinetal., 2002). Higher levels of vitamin D3 (3500 IU/kg) and vitamin C (200 or 400 mg/kg) can improve eggshell quality (Faria et al., 2001). Supplemental vitamin C, vitamin E, organic zinc and selenium improved the performance of broilers due to lower feed intake resulting in better-feed conversion, independently on the environment (Lagana et al., 2007). Supplemental vitamin A (15000 IU/kg) and zinc (30 mg/kg) improves the performance and carcass traits in broilers, and decreases abdominal fat pad. A combination of vitamin A (15000 IU/kg) and zinc (30mg/kg) offer a potential protective management practice in preventing heat-stress-related depression in performance of broiler chickens (Kucuketal., 2003). Elimination of vitamin fortification from the diets of broilers from 22d age exposed to heat stress results in significant reductions in live bird and carcass performance. The data (Table 11) suggest that trace mineral supplementation may be responsible for a further reduction in bird performance via oxidation of the vitamins already present. Body weight, F/G and survivability were adversely affected by the absence of vitamin supplementation. Carcass fat, as estimated by specific gravity and fat pad were significantly increased by the lack of vitamin supplementation.

Table 11. Effects of Elimination of Vitamin and/or Trace Mineral Supplement from Broiler Diets During Heat Stress

Supplement		Weight Gain g	F/G	Sur-vivabi-lity %	Fat Pad %	Carcass density
Vitamin	TM					
Yes	Yes	1278[a]	2.66[c]	90.4[a]	1.56[b]	1.051[a]
No	Yes	1101[c]	3.12[a]	82.5[b]	1.67[ab]	1.046[b]
Yes	No	1257[ab]	2.76[bc]	88.0[a]	1.77[ab]	1.049[a]
No	No	1242[b]	2.86[b]	86.8[ab]	1.91[a]	1.049[a]
P-Value	P<.06	P<.06	P<.06	P<.06	P<.02	P<.02

[1]Fat Pad expressed as a percent of carcass weight.
TM = Trace mineral

BASF, 1998

4. Electrolytes in Feed and Water

Addition of various salts to water alters the birds osmotic balance, resulting in increased water consumption, influencing water balance during heat stress. No growth response has been observed by adding salts to drinking water for non-heat stressed birds. Increased water consumption benefits the bird by acting as a heat receptor as well as increasing the amount of heat dissipated per breath. Such thermo balance effects are principally observed when water temperature falls below 28°C. Birds in positive water balance are better off in maintaining normal body temperature. This has special significance for the commercial broiler as heat stress increases urine production, independent of water intake, thus forcing birds to sustain higher water consumption levels than required to simply replace water loss due to evaporative cooling (See Summers, 2006).

There are significant interactions between adding salt to drinking water and water temperature. If the temperature of the drinking water is below that of the birds body, then only, adding potassium chloride will increase consumption. Lowering the temperature of the water, with no salt addition, also improves water intake. Indeed water temperature and potassium chloride effects appear to be additive. Such responses are given in Table 12 (See Summers, 2006). Potassium chloride even at 0.2% gives beneficial results in increasing water intake of laying hens (Table 13, Daiand Bessei, 2007). During heat stress mineral excretion via the urine and feces is increased. Whether specific benefits with mineral supplementation exist, independent of their effect on water intake, is not known. It would appear that potassium based salt mixtures are superior to sodium when added to drinking water.

Table 12. Effect of water temperature and potassium chloride (KCl) supplementation on heat stressed broilers

Water Tempe-rature ℃	Weight gain g/b/d		Water intake ml/b/d	
	Control	+0.5% KCl	Control	+0.5% KCl
12.8	55.4^{ab}	60.2^{a}	364^{b}	470^{a}
31.1	50.3^{c}	56.5^{ab}	359^{bc}	466^{a}
42.2	47.0^{cd}	42.5^{d}	364^{b}	340^{c}

Selected and rearranged data from Teeter 1994 (See Summers, 2006)

Table 13. Water intake (ml/b/d)of laying hens with supplemental potassium chloride (KCl) in drinking water

KCl (% in water)	1 day	2 day	3 day	4 day	5 day	6 day	7 day
0	289	315	311	299	296	301	291
0.2	355	379	405	398	409	408	404
0.4	345	385	396	387	399	388	399

Dai and Bessei, 2007.

Acid-Base Balance

Electrolytes maintain ionic and water balance in the body. Broiler growth is affected when blood pH is below 7.2 and above 7.3. During heat stress electrolytes are lost from the body. The loss of electrolytes can be prevented by intake of electrolytes in feed and water. Increased respiration rate during heat stress also results in carbon dioxide loss and acid-base alterations (Bottje and Harrison, 1985; Teeter et al., 1985). The various drinking water supplements may act through increased water intake of birds (Wiernusz,1998).

Favorable broiler responses were observed through the supplementation of various salts to the drinking water (Table 14, See Lin et al., 2006)

Table 14. Supplemental electrolytes in drinking water

Drinking water supplement		Dose	Reference
Ammonium chloride	NH_4Cl	0.2%	Teeter and Smith, 1986
Potassium chloride	KCl	0.15%	Ait-Boulahsen et al, 1995
Sodium bicarbonate	$NaHCO_3$	0.2%	Hayat et al 1999

Lin et al., 2006

Acid base balance is influenced by the degree and duration of thermal stress and acclimatization. During panting (increased number of respirations) excessive loss of carbon dioxide (C02) occurs, resulting in reduced partial pressure of carbon dioxide (C02) in blood plasma. The bicarbonate buffer system lowers the concentration of hydrogen ion, increases plasma pH and plasma bicarbonate levels (Table 15). This is known as respiratory alkalosis. More bicarbonate is excreted through kidney while retaining H^+. A consequence of respiratory alkalosis is reduced feed intake. The respiratory alkalosis may start at 35°C and becomes severe with rise in temperature. However, these effects of altered acid-base balance are, at present, little understood.

Table 15. Bicarbonate buffer system

	Sodium (Na)	Chloride (Cl)	Sodium Chloride (NaCl)
Plasma bicar-bonate (HCO)	Increases	Decreases	Little effect
Plasma pH	Increases	Decreases	Little effect

Supplemental broiler grower diet (4-6weeks age) with l.0%KClorl.0% NaHC03 or 0.5% NH4C1 + 0.5% KC1 +0.5% NaHC03 had beneficial effects on the growth performance under high environmental temperature during summer season in uncontrolled broiler houses (30.19-32.90°C and 48.08-51.03% RH) (Osman, 2000). Supplemental nonchloride sodium salts (sodium bicarbonate, sodium carbonate and sodium sulphate) to broiler diets in heat stress conditions (29.3 to 38°C) increased water intake, reduced mortality, improved body weight and yield of carcass and parts. Sodium bicarbonate was better than the other sodium salts (Ahmad et al., 2006).

Dietary electrolyte balance (DEB), under practical considerations, is considered with sodium (Na+), potassium (K+) and chloride (Cl) (Mongin,1981) (Table l6).

Table 16. Calculation of DEB in poultry feed				
		Atomic wt)	% in diet	DEB mEq/kg
Sodium	Na	23.0	0.18	
Potassium	K	39.1	0.85	240
Chloride	Cl	35.5	0.20	

DEB (mEq/kg Feed) = ((%Na/At wt(23)+% K/At wt(39.1)-%Cl/Atwt(35.5))xl0000)

A DEB of 240-250 mEq/kg feed appears to be adequate for broilers, under normal and heat stressed conditions (Borges et al., 2004; Ahmad and Sarwar, 2006). DEB can be varied with supplemental NH4C1, NaHCO, and Chloride. The relationship ((K+Cl)/Na>l) has to be maintained always. High DEB (e.g. 340) results in metabolic alkalosis and low DEB (e.g. 0) in metabolic acidosis. Extreme DEBs are to be avoided (Ahmad and Sarwar, 2006).

Weight gain has been enhanced with water carbonation or supplementation with acids such as NH4cl or Hcl, suggesting that acid-base balance is critical for maximizing weight gain. While a number of additives have been used to try and alter acid/base balance all seem to act by increasing water intake. Thus, while water intake is an important consideration there is also an acid-base balance effect, which must be considered. High DEB had a direct relationship on water intake, which in turn on survivability. Commercial electrolyte mixtures are available and used with many encouraging results by poultry farmers to reduce heat stress and to increase water intake. Some of the commercial preparations contain vitamins, citrates and phosphates in addition to chlorides, bicarbonates and other salts. The effect of electrolytes may be based on blood pH, water intake, respiratory rate and productive parameters.

5. Form of Feed

a. Crumbles and Pellets

Most feed used in commercial broiler production is in the form of crumbles or pellets. Some integrators use mash feed in starter and or finisher period to reduce the feed cost. On pelleted feed, less energy is required for feed intake (Table 17; Jensen et al., 1962) (about 67% reduction in the energy required for taking feed; See Gous and Morris., 2005). Pelleting has no effect on ME content of feed. The energy sparing effect of pellets, due to reduced activity for feeding is about 6% (McKinney and Teeter, 2003). The advantage of pellets would be lost when pellet quality is poor (Fines more than 10%) (Jensen, 2000).

Table 17. Feeding pattern of chicks on mash and pellet diets		
Chicks 21-28 d	Mash	Pellets
Meals/d, No	35	27
Eating time, min	103	34
Time/meal, min	2.9	1.3
Feed consumed, g	38	37
Jensen et al., 1962		

b. Wet Mash

Wet mash feeding results in increased feed intake and improved performance, mediated by more water intake. However, applicability for commercial practices on large scale is not feasible. If the feeders are not cleaned properly, fungal infestation and toxin production are the major problems.

6. Time of Feeding

Heat increment is associated from the time of feeding up to about 4-6 hours after feeding. Survivability of the bird will increase by feeding the birds during night and withdrawing thefeedfromabout4-6hoursbefore the initiation of heat stress.

7. Feed Additives to Improve Heath and Immunity

Poultry feeds are supplemented with trace minerals, vitamins and coccidiostats. In heat stress, the resistance of the bird to infections is reduced. Several feed additives are available to improve the resistance of the birds to infections. Besides vitamin E and vitamin C mentioned earlier, the following feed additives may be considered to improve immunity and resist the infections (Table 18).

Table 18. Feed Additives to be supplemented	
Antioxidants	Reduces oxidative damage
Vitamin E (Mentioned earlier)	
Vitamin C (Mentioned earlier)	
Gut acidifiers	Maintains intestinal integrity
Emulsifiers	Improves absorption
Organic trace minerals	Improves immunity
Liver protectives	Protects and stimulates liver
Enzymes	Improves digestion
Pre and probiotics	Maintains intestinal integrity
Toxin binders	Binds toxins
Ammonia binders	Reduces ammonia in intestines
Nucleosides	Improves growth
Phytobiotics	Control/regulate microflora

At high environmental temperatures fungal infestations are common, particularly when relative humidity is high. Storage of feed ingredients to reduce fungal infestation, supplemental fungi stats to feed ingredients and feeds to minimize fungal contamination and toxin binders to bind the toxins present in the feeds are important in heat stress.

8. Anticoccidials

The toxicity of Nicarbazin (an effective anticoccidial), in hot weather, appears to be related to increased heat production (WiernuszandTeeter,1995). It may be avoided in hot weather, even in combination with other anticoccidials.

Summary

Temperature is one of the important environmental factors, affecting poultry production. The proportion of feed energy that is deposited or converted to product is a small fraction of ingested energy. The remaining

portion used for maintenance and heat increment, is released as heat into the environment. At high temperatures (above 32°C and relative humidity 50%), the heat loss through evaporation exceeds the sensible heat loss (conduction, convection and radiation). At heat stress index of 170, high mortality may be noticed.

Heat stress has to be managed by a combination of management methods including House and Nutrition management. Protein and amino acid nutrition in heat stress is not clear. Feed formulation may be based on the digestible amino acid basis, following ideal amino acid profile (reducing the imbalances, minimizing the excesses), considering high energy and high protein ingredients with more digestibility and the amino acids available commercially (lysine, methionine and threonine). Supplemental fungistats to feed ingredients and feeds to minimize fungal contamination and toxin binders to bind the toxins present in the feeds are important in heat stress. Supplemental dietary ascorbic acid (250-400 mg/kg), vitamin E (250 mg/kg), folic acid (1 mg/kg), vitamin D3 (3500 IU/kg), vitamin A (15000 IU/kg), organic zinc and selenium are beneficial in heat stress.

Addition of various salts (potassium chloride (0.2-0.5%), ammonium chloride(0.2%), sodium bicarbonate (0.2%) and a combination of these alters the birds osmotic balance, maintains acid base balance and increases water consumption influencing water balance beneficially during heat stress.

On pelleted feed, less energy is required for feed intake (about 67% reduction in the energy required for taking feed). The advantage of pellets would be lost if pellet quality is poor (Fines more than 10%). Survivability of the birds can be increased by reducing chances of heat increment in hot periods (feeding the bird during cooler parts of the day and withdrawing the feed from about 4-6 hours before the initiation of heat stress). Nicarbazin, an anticoccidial, may be avoided in hot weather.

Antioxidants, gut acidifiers, emulsifiers, organic trace minerals, liver protectives, enzymes, pre and probiotics, ammonia binders, nucleosides, phytobiotics and flavor enhancers may reduce microbial contamination, improve the resistance of the birds to infections, improves feed intake and increases performance. Drinking water may be treated with sanitizer and acidifiers to minimize microorganisms in the gut.

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