Optimizing Production of Heat Stressed Broilers

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خلاصة : للدجاج اللاحم قابلية عالية للاجهاد الحرارى خلال الفترات التي يكون فيها معدل نموه في أقصاه. لكي يمكن تلافى الآثار المترتبة على الاجهاد الحراري يجب الاهتمام بالطرق التي يمكن بها موازنة الانتاج الحراري للطائر مع قدرته على التخلص من الحرارة الزائدة في الوقت الذي ما يزال فيه الطائر قادراً على الأكل والنمو السريع. الطرق التي يمكن بها عمل هذا التوازن تتضمن تغييرات في البيئة الدقيقة للطائر وإحداث تعديلات في الحرارة المنبعثة بتغييرات فى التوقيت، وكمية الغذاء ونوعيته مع تمكين الطائر من الوصول إلى الحد الأقصى لاستعمال سوائل الجسم للتبريد.

ABSTRACT: Broiler chickens are highly susceptible to heat stress during the time at which their growth rates ought to be highest. In order to overcome the deleterious effects of heat stress, consideration has to be given to ways in which the heat production of the bird and its ability to dissipate heat are brought into balance whilst still permitting the birds to eat and grow rapidly. Methods for adjusting this balance include changes in the micro environment of the birds, alterations to heat output by variations in the timing, quantity and quality of food and enabling the bird to maximise its use of fluids for evaporative cooling.

Today's commercial broiler is the fastest growing and most efficient bird ever produced by the combined efforts of man and nature. However, with this tremendous potential also comes a greater susceptibility to many different types of stress. Since growth itself taxes numerous physiological systems and since stress consequences are typically additive, we should not be surprised that our modern bird frequently exhibits unwanted stress susceptibility. Significant among potential stresses and the topic of this treatise is heat stress.

Commercial broilers are particularly susceptible to heat stress because metabolic heat production increases with growth rate while heat dissipation capacity does not. Heat dissipation is of particular concern during high ambient temperature exposure because, of the two heat dissipation routes (evaporative and nonevaporative), the potential for nonevaporative heat loss is reduced. In other words for the broiler to avoid overheating it must increasingly rely on respiration rate mediated evaporative cooling. Unfortunately, evaporative cooling only partially compensates for the diminished heat loss and the elevated respiration rate further increases heat production.

The poultryman can do much to either positively, or negatively, impact broiler performance during heat stress. Optimal broiler production during high temperature exposure necessitates that the appropriate combination of nutritional and management therapies be applied. But, therapy selection can be confusing. Indeed, some therapeutic approaches are diametrically opposed making the selection process less than straight forward unless one has a sound working knowledge of bird physiological and behavioral responses.

General Considerations

Heat stress consequences are frequently disproportionately dispersed within a particular region, company or farm. Such variability may makes the heat stress occurrence appear somewhat random. However, when thermobalance considerations are interactively related to age, body size, ration type, management style and bird environmental exposure history, the heat stress occurrence and required therapy become more predictable.

The comfort zone for poultry declines from ≈32°C at hatching to ≈24°C at 4 weeks of age. Therefore, poultry producers rarely worry about heat stress with young birds, but do so increasingly as they mature. Heavier breeds generally have more of a problem with heat stress since they have less surface area for heat dissipation per unit weight. Yet another variable influencing heat stress susceptibility is the bird's previous exposure to heat stress. The chick's ability to survive acute heat distress is dramatically increased by prior heat stress exposure. This phenomenon, termed acclimatization, is measurable in that body temperature of the acclimated broiler is lower than unacclimated birds during heat stress. Part of the acclimatization response is attributable to reduced feed consumption. However, work in our laboratory suggests that the acclimation response also enables the bird to repartition daily heat production to cooler periods within the day (Teeter et al., 1988). Additional studies indicate that high fat rations have the potential to negate acclimation effects by obligating the bird to high levels of heat production. But, more about fat later. The bottom line is that the poultryman can use these relationships, not so much as a means to avoid heat stress, but as a relative index to judge the critical nature of the therapeutic avenues discussed below.

Thermobalance

HEAT PRODUCTION: Bird thermobalance is a composite of heat production and its dissipation. Broiler heat production is particularly high because its growth rate is supported by feed consumption with an inherent efficiency of ME use optimistically reaching 40%. This means that 60% of ME consumption will be lost as heat. In environments at or below thermoneutral, heat production has no adverse consequence. But as discussed above, the bird's ability to dissipate heat during heat stress is compromised, making excessive heat production potentially life threatening. The broiler, in its effort to survive, attempts to lower heat production by consuming less feed. In contrast the poultryman, who is continually seeking to avoid the growth suppression associated with heat stress, attempts to encourage feed consumption. At this point man and nature collide. Though the poultryman can successfully influence nature the results range from dismal failure to marginal success.

GROWTH RATE POTENTIAL: Relatively little work has been conducted to actually estimate the growth rate potential of heat stressed birds. If the stress, independent of feed consumption, reduces the growth potential then efforts to offset the reduced feed intake maybe without positive effect or simply exacerbate carcass fatness. Indeed, much published work indicates that the heat stressed bird is not only lighter, but also fatter (Kubena et al., 1972)with total and abdominal fat increasing by 0.8% and 1.6% respectively with each degree rise in ambient temperature (Howlider and Rose, 1987). This lipogenic response may be another form of acclimatization as the net effect is less heat production. Nonetheless, studies conducted in our laboratory have established that the growth rate of heat stressed broilers,including protein as well as lipid, can be successfully increased (Table 1). But, note that force feeding birds to higher feed consumption levels markedly increased mortality. This is important because it demonstrates that successful manipulation of energy consumption will improve growth rate, but it also demonstrates that increased energy consumption can be devastating during survival-limiting heat stress. In this case we won the growth rate battle and lost the survival war. The heat dissipation considerations, discussed below, are critical when one attempts to offset the consequences of reduced feed intake.

TABLE 1

Feed intake effects on bird growth rate and mortality of heat stressed broilers.

Controlled Feeding Level[1]	Daily Gain (G)	Carcass Gain (CG)	Survivability
6.5	30.4^{a}	246^{a}	100^{a}
8.3	41.9^{b}	335^{b}	92^{b}
9.6	55.7^{c}	403^{c}	70^{c}
(%) Ad Libitum Consumption[1]			
8.5	38.6^{b}	339^{b}	91^{b}

[1] Consumption values represent daily feed intake as a percentage of body weight

^{a,b,c} Means within a column with unlike superscript differ ($P < .05$).

Temperature Regulation

NONEVAPORATIVE COOLING: All poultry classes utilize nonevaporative cooling as the principle means of heat dissipation when housed in low and intermediate ambient temperature environments. Nonevaporative cooling is the most energetically efficient means to dissipate heat. Birds manipulate nonevaporative cooling by increasing surface area and blood flow to the body surface (Bottje and Harrison, 1984). We suspect that such blood shunting impacts digestion rate, lowering feed metabolism and thereby metabolic heat production during heat distress. Conversely, feed metabolism and hence heat production is increased during subsequent recovery periods. Poultry producers must make wise use of ventilation systems during the evening hours to remove waste heat as quickly as possible so that nonevaporative cooling potential is restored and maximal time is provided for compensatory growth. When handled properly, the evening hours provide considerable opportunity for the broiler to regain lost growth potential.

EVAPORATIVE COOLING: As ambient temperature exceeds the birds thermoneutral zone nonevaporative cooling extent declines and evaporative cooling becomes the principle heat dissipation route. The latent heat of vaporization for water at 41°C is 574 cal/ml (van Kampen, 1981) while heat absorbed by warming water to body temperature is just 20 cal/ml (Weast, 1987). If the bird is going to loose heat during heat stress it is going to be largely governed by these simple laws of physical chemistry. However, there is a biological side to this story. Recent work conducted in our laboratory has established that evaporative heat dissipation is not only impacted by respiration rate, but also by water consumption level and flux through the tissues. Though the bird can dramatically increase evaporative cooling by increasing its respiration rate, which makes respiration rate an important means of temperature regulation (Mather, 1980), the efficiency of this process can be manipulated. The astute poultryman will do more (discussed below) than simply allow his broilers to increase their respiration rate from 25 breaths per minute within a thermoneutral environment, to over 250 breaths per minute, when acute heat stress is encountered (Linsley and Berger, 1964). Respiratory efficiency of heat stressed broilers is particularly important as the increased respiration rate requires energy expenditure and adds calories to the birds heat load, further increasing its dissipation requirements. Yet another consequence of elevated respiration rate is the ensuing respiratory alkalosis. Nonetheless, evaporative cooling represents the only means by which the heat stressed broiler can increase calorie dissipation; we just need to make it as efficient as possible.

Relative humidity dramatically impacts bird evaporative cooling potential during heat stress. The ability of air to contain water is not constant, increasing dramatically with temperature. Relative humidity provides us with an estimate of air saturation with water at a given temperature. As the relative humidity rises the ease with which the bird can evaporate water declines (respiration efficiency declines) and body temperature will consequently increase unless heat production is reduced. These relationships must be considered for optimal management of ventilation and in-house evaporative coolers such as foggers and cooling cells. Generally speaking, foggers are of marginal value when the relative humidity exceeds 70%.

Management Options

Today's poultry producers are confronted by numerous techniques that have been proposed as possible therapies to offset the consequences of heat distress. Often the selection among the various management methods can indeed be an uncertain task, as some techniques are effective for enhancing growth rate while others are more effective at impacting bird survival. The "bottom line" will most likely be enhanced if a balanced management approach is utilized where emphasis is not placed exclusively on any one production variable. Just how to seek a balance between these options for maximal product yield is the objective of this section.

FACILITIES: The importance of adequate poultry housing can not be overemphasized and is the place to begin an effective heat stress management program. The poultry house should have an east-west orientation with enough roof overhang to keep direct sunlight (a significant heat source) from entering the building. Roof height should be approximately 17 feet to enable heat to move freely up and away from the birds. Roof insulation should be R-30, or greater. Ventilation is critical as it impacts both ambient temperature and relative humidity within the poultry facility. All obstructions such as trees, tall grass and shrubs etc. should be removed from open sided building for maximum benefit from prevailing winds. Grass cover around the building, however, is desirable for reducing reflected heat. Fans should be located throughout the house to facilitate air movement. Much could be written regarding housing, but the topic of this treatise is related to biological approaches.

FEEDING: The greatest proportion of economic loss associated with heat stress the result of lowered feed intake. Indeed, as discussed above, the heat stressed bird increases its growth rate as feed consumption increases so the potential for a growth rate approaching the nonstressed state is still present. As a result, measures such as running automatic feeders more frequently or physically shaking feeders, lighting and utilization of high nutrient density rations, have been used by poultry growers to offset reduced nutrient intake during heat stress. However, as, discussed, the bird's natural response to heat stress is to reduce ration consumption in an effort to lower its heat production. Therefore, efforts to offset this physiological response might, at times, be expected to be counterproductive by needlessly increasing the birds heat load and mortality risk during acute heat stress. A major limitation for managing broiler feed consumption is that we simply do not know when the acute "heat spell" will occur, if we did elevating feed consumption would be the last thing on our mind.

TABLE 2

Effects of feed withdrawal time on ability of broilers to survive acute heat stress in two experiments.

Time of feed withdrawal relative to stress initiation[1]	Ambient temperature (°C) at feed withdrawal	Survival (%)	
		Experi ment 1	Exper iment 2
24 hr before	26.7	92.0^a	--
12 hr before	26.7	86.7^a	81.7^a
6 hr before	26.7	80.0^a	70.0^{ab}
3 hr before	26.7	--	67.7^{ab}
Stress Initiation	32.2	--	60.2^{bc}
2 hr after	35	--	48.7^{cd}
3 hr after	36.7	--	49.0^{cd}
4 hr after	38.8	--	48.7^{cd}
Not Withdrawn	--	51.6^b	45.2^d

[1] Heat distress defined as an environment providing 32.2°C and 55% relative humidity.
[a,b,c,d] Means within a column with unlike superscripts differ ($P < .05$). Extracted from Nutrition Report International, 1987.

WATER MANAGEMENT: Water consumption by the heat stressed bird is a critical consideration. Its importance is underscored by the fact that heat stressed birds dissipate over 80% of their heat production via evaporative cooling (Wiemusz, et al., 199 1; Van Kampen, 1974). Addition of various salts to the drinking water alters the bird's osmotic balance, increases water consumption and influences water balance. No growth or feed intake response has been observed in our laboratory when individual salts are added to the drinking water of birds housed in thermoneutral environments. Heat stressed broilers, however, are a different matter especially for Kcl where this salt has been observed to not only improve performance, but also to reduce serum corticosterone (Deyhim and Teeter, 1990). Studies (Smith and Teeter, 1986; Teeter and Smith 1987; Belay and Teeter, 1993a, 1993b; Beker and Teeter, in press) indicate that increased water consumption benefits the bird by acting as a heat receptor as well as increasing the amount of heat dissipated per breath. These thermobalance effects are principally observed when water temperature falls at or below 28°C. Benefits on performance (growth rate, feed efficiency, survivability) are environment dependent. Each performance variable has been improved by improving water management under specific conditions.

Evaporative heat dissipation extent and calories dissipated per breath were well correlated ($R^2 > .8$) with water consumption level and balance (Belay and Teeter, 1993). Birds in positive water balance were better able to maintain body temperature homeostasis. This relationship has special significance for the commercial broiler, as heat stress increases urine production independent of water intake, and forces birds to sustain higher water consumption levels than that required to simply replace water lost due to evaporative cooling. Wild birds, in contrast have the capacity to reduce urine production and elevate evaporative cooling extent and efficiency. Managing broilers for maximum evaporative cooling potential and calories dissipated per breath centres on water consumption. Increasing water intake with Kcl and/or reduced water temperature elevates evaporative cooling and heat dissipated per breath. Data indicate that increasing water consumption by 20% over basal levels can increase heat loss per breath by as much as 30%. Reasons for this phenomena in commercial broilers are speculative, but may include the fact that most genetic selection occurs in the presence of continuously available feed and water. Our modern birds have simply lost the capacity to conserve fluids while exposed to heat stress, that we have observed in wild bird strains. Future heat stress therapies may well address this dilemma.

TABLE 3

Effects of water temperature and Kcl effects on heat stressed broilers[1].

Water Temp (°F)	ADG (G)		Daily Water Cons (Ml)		Body Temp (°C)	
	Control	+ .5% Kcl	Control	+ .5% Kcl	Control	+ .5% Kcl
55	55.4	60.2^{b}	364^{b}	470^{a}	42.8^{ab}	42.7^{b}
88	50.3^{c}	56.5^{ab}	359^{bc}	466^{a}	43.1^{a}	42.9^{ab}
108	47.0^{cd}	42.5^{d}	364^{b}	340^{c}	43.3^{a}	43.1^{a}

[1] Three trials combined.

[a,b,c,d] Means within a classification with unlike superscripts differ ($P < .05$).

DRINKING WATER TEMPERATURE: Significant interactions apparently exist between the effects of salt addition to drinking water and drinking water temperature. Data presented in Table 3, representing a three trial average, indicate that Kcl drinking water fortification increased ($P < .05$) feed consumption and growth rate when the temperature of the consumed water was lower than the bird's body temperature. Addition of salt to drinking water with a similar temperature as the bird was without beneficial effect. However, lowering the water temperature without salt addition to stimulate water intake also proved to be beneficial. Indeed the addition effects of lowering drinking water temperature and salt were additive. Growth rate enhancements were due to the birds consuming more feed, which probably offset a portion of the hypothermic effect.

MINERAL FORTIFICATION OF DRINKING WATER: Belay et al. (1990), utilizing colostomized birds, observed that heat stress increases urinary excretion of potassium, sodium, zinc and molybdenum and increased faecal excretion of calcium, manganese, selenium and copper. Mineral retention for magnesium and phosphorous was reduced by a combination of urinary and faecal excretion. Whether specific benefits, attributable to individual minerals, exist independently of water consumption has not been concretely established. The strongest evidence is that potassium based salt mixtures appear superior to sodium. Specific anion effects are also possible and are currently under investigation. Though this area is ripe with claims and short on fact, efficacious therapies will be likely to emerge from studies underway with applications directed at acute stress, chronic stress and compensatory gain following stress.

Ration Composition

CALORIC DENSITY AND CALORIE SOURCE: Numerous dietary manipulations have been evaluated for efficacy

TABLE 4

Ration caloric density effects on 4-7 week body weight gain, feed and energy consumption and gain/feed in broilers housed in thermoneutral (TN) and cycling temperatures heat distress (HD) environments.

Caloric Density	Live Gain (g)		Feed Cons. (g)		Energy Cons.		Gain/Feed	
	TN	HD	TN	HD	TN	HD	TN	HD
2826	1151^{a}	947^{c}	2650^{b}	2283^{c}	7489^{c}	6452^{d}	$.42^{b}$	$.38^{c}$
3200	1294^{b}	998^{d}	2631^{b}	2235^{c}	8420^{b}	7152^{c}	$.48^{a}$	$.38^{c}$
3574	1301^{b}	997^{d}	2957^{a}	2259^{c}	10571^{a}	8079^{f}	$.42^{b}$	$.35^{d}$

GLM Summary By Major Heading Source of Variation	DF	Probability			
Caloric Density	2	***	*	***	***
Environment	1	***	***	***	***
CD x Environment	2	*	**	***	*

^{abcdef} Means within a major heading with unlike superscript differ.
* P<.05
** P<.01
*** P<.001

TABLE 5

Ration caloric density effects on 4-7 week bird survivability, dressing percentage, fat pad weight and carcass fat content.

Caloric Density	Survivability (%)		Dressing (%)		Fat Pad (g)		Carcass Fat (%)	
	TN	HD	TN	HD	TN	HD	TN	HD
2826	98^{a}	92^{ab}	70.7^{b}	71.5^{a}	1.0^{c}	1.1^{c}	12.2^{e}	13.0^{d}
3200	97^{a}	86^{c}	71.5^{a}	71.9^{a}	1.3^{b}	1.5^{a}	13.1^{c}	13.7^{c}
3574	95^{ab}	80^{d}	71.5^{a}	71.5^{a}	1.5^{a}	1.6^{a}	14.2^{a}	14.9^{ab}

GLM Summary By Major Heading Source of Variation	DF	Probability			
Caloric Density	2	***	NS	NS	NS
Environment	1	***	*	***	***
CD x Environment	2	*	NS	NS	NS

^{a,b,c,d,e} Means within a major heading with unlike superscript differ (P<.05).
* P<.05
** P<.01
*** P<.001

to reduce heat stress consequences (Moreng, 1980; Leeson 1986). Growth rate has been increased through fat supplementation (Dale and Fuller, 1979). Such ration formulation effects are supposedly mediated by less waste heat which enables the bird to have greater nutrient consumption and tissue assimilation. However, the effect of reducing dietary heat increment by converting calorie sources to fat is frequently associated with an elevation in energy consumption, which in most cases, overshadows the bird's reduced heat increment. Belay et al. (1993) evaluated such dietary manipulations, placing emphasis on bird survival, in cycling temperature environments and found that increasing dietary energy increases (P<.01) mortality as well as gain during survival limiting heat stress (Tables 4-5). The bottom line with fat use appears to be that the poultry industry is faced with the dilemma of placing emphasis on growth rate enhancement or mortality reduction. Unfortunately, even with fat mediated growth rate enhancement bird heat production increases. Growth rate should not be the only consideration. If carcass composition is important the added fat gain associated with the elevated caloric density may be enough to curtail its use.

PROTEIN CONSIDERATIONS: A subject of significant controversy regarding management of heat stressed broilers centres upon protein-amino acid nutrition. Recommendations for protein range from its elevation (Kubena et al., 1972) to reduction with concomitant improvements in amino acid balance (Waldroup et al., 1976). Work conducted in our laboratory confirms the findings of Waldroup and his group that lowering the dietary protein, while maintaining essential amino acid fortification levels, was observed to improve bird growth and survivability. Indeed, such as approach is the only one that we have observed to simultaneously improve both growth rate and survivability.

TABLE 6

Heat distress (4-7 week) and overall (0-7 week) DL-Methionine and Alimet effects on production and carcass yield data in straight run Ross x Ross broilers in thermoneutral (TN) and heat distress (HD) environments.

	DL-Methionine		Alimet	
Production Data				
Gain (g)	1078		1078	
Feed consumption (g)	2315		2325	
Feed efficiency (gain/feed)	.40		.40	
Survivability (%)	93		93	
Carcass Data				
Carcass weight (g)	1440		1437	
Chill weight (g)	1505		1508	
Dressing percentage	72		72	
Breast weight (g)	263		266	
Breast percentage	17.5		17.6	
Specific gravity	1.043		1.043	
	TN	HD	TN	HD
HP[1]	4.23	4.47	4.47	5.19
EHD[1]	1.60	3.04	1.46	3.32
NHD[1]	2.91	1.29	3.06	1.60
Resp. eff[2]	1.05	0.53	0.88	0.57
Resp. rate	31	184	35	188

[1] Kcal/hour/body weight^{66}

[2] cal dissipated/breath

METHIONINE SOURCE: To achieve lower calorie:protein ratios, less intact protein and more crystalline amino acids must be used in broiler rations. Corn and soyabean based rations require methionine supplementation to elicit optimal broiler performance. DL-2-hydroxy-4- methylthiobutanoic acid (DL-HMB) and DL-methionine (DLM) are commonly used as sources of supplemental methionine. Swick et al. (1989) reported that DL-HMB improved feed efficiency compared to DLM during heat stress, but was unable to successfully repeat the results in a following study (1991) where numerical advantages were noted. In another study Swick et al. (1992) using six six-week old cockerels indicated a tendency ($P<.11$) for DL-HMB supplemented birds to have lower body temperature than DLM supplemented birds during heat stress. Though DL-HMB efficacy during high ambient temperature exposure has not been concretely established, the concept has led to some uncertainty by industry personnel seeking enhanced productivity of heat stressed broilers.

Two experiments, conducted in our laboratory have failed to detect performance differences between DL-HMB and DLM. No significant differences ($P>.1$) between DLM and DL-HMB were detected for live weight gain, feed efficiency or mortality at 49 days of age following heat stress exposure from 28 days (Table 6). Likewise, all carcass variables including carcass weight, chill weight, dressing percentage, breast weight, breast percentage of carcass and carcass fat were judged similar for the two methionine sources (Table 4). One intriguing methionine source effect observed to be significant during the first trial and numerically so in the second was that heat stressed birds consuming DL-HMB had greater heat production compared to birds receiving DLM. The added heat produced by the DL-HMB supplemented broilers (11% trial 1, 3% trial 2) was successfully dissipated by evaporative cooling. Consequently, no differences ($P>.1$) were observed for body temperature or performance. Possible explanations for this effect, since overall feed consumption was similar for the two sources, include an altered feed consumption pattern and/or other metabolic alteration(s). Results from trial 2, where feeding pattern was evaluated, did indeed pick up a DL-HMB effect on feeding pattern early in the trial. During trial 2, DL-HMB birds had elevated ($P<.05$) feed consumption during a 5 h period prior to peak high temperature at 4 weeks compared to DLM. No differences between methionine source was observed in any period during weeks 5 or 6. Nonetheless, any elevation in heat production, as observed in experiment 1 for DL-HMB, would be

TABLE 7

Gain, feed consumption, G/F and mortality of broilers fed two levels of Virginiamycin in thermoneutral (TN) and heat distress (HD) environments.

VM[1] (ppm)	Gain (g)		Feed consumed (g)		Gain/Feed (kg per kg)		Survivability (per cent)	
	TN[2]	HD[3]	TN	HD	TN	HD	TN	HD
0	1336^a	1141^c	2642^a	2439^b	$.49^a$	$.40^c$	97.4^c	86.3^b
15	1353^a	1176^b	2684^a	2429^b	$.50^a$	$.43^b$	98.9^a	$89.4^{a,b}$
20	1363^a	$1160^{b,c}$	2625^a	2418^b	$.52^a$	$.44^b$	99.5^c	92.5^a

^{a,b,c} Means with different superscript within a row and a column are significantly different ($P < .05$).

[1] Represents virginiamycin

expected to elevate mortality under survival limiting stress if not concomitantly associated with improved heat dissipation capacity.

GROWTH PROMOTANTS: Growth promotant mode of action has been debated for a number of years. Central to many theories is the improved dressing percentage mediated by less gastrointestinal tract mass. Since the gastrointestinal tract represents a significant source of metabolic heat one might anticipate significant interaction with heat stress. Virginiamycin (VM) has been used in our laboratory to evaluate growth promotant efficacy to alleviate heat stress (Table 7). Virginiamycin levels evaluated included 0, 15 and 20 ppm. In the two studies conducted birds were exposed to either thermoneutral (24°C), or cycling temperature heat stress (24-35°C). Within the cool environment, 15 and 20 ppm VM supplementation impacted, compared to TN controls, gain (+1.3%, +2.2%), gain/feed ratio (+2.0%, +6.1%) and survivability (+ 1.5%, +2.1%). Within the heat distressed environment, 15 and 20 ppm VM supplementation, compared to the heat distressed controls, impacted gain (+3.1 %, +1.7%), gain/feed ratio (+7.5%, +10%), and survivability (+3.1%, +6.2%). Virginiamycin effects on bird mortality during heat distress were indeed marked and are presumably the result of either reduced immune challenge and/or heat production. Lowered heat production would be expected by both the reduced gastrointestinal tract mass theory and the reduced immune challenge theory. Whether other growth promotants will provide the same advantage during heat stress as virginiamycin is not known.

Conclusion

Optimal broiler production during periods of heat stress begins with good overall management. Management considerations include facility design as well as ration and drinking water concerns. Therapeutic approaches should seek to impact bird thermobalance in a manner consistent with stress severity. Survivability may be increased by elevating heat dissipation and/or reducing heat production. An improved growth rate is generally associated with elevated heat production and, unless efforts are made to simultaneously increase heat dissipation, will increase mortality.

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