FEED ORIGIN HEAT INCREMENT AS A MAJOR CONTRIBUTOR TO HEAT STRESS*

IMPACT ON PRODUCTIVITY AND DISEASE MANAGEMENT

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FACT

- Animals raised in the tropics of similar breed and following similar nutritional protocol currently achieve >25% lower productivity and are 40% more susceptible to diseases than that achieved in temperate countries

- Heat Stress identified as major cause

- inspite of a host of microclimate control measures instituted (raised roofs, fans,etc) , heat stress remains a major factor, more pronounced during summer and early rainy season

- current nutritional system does not consider dietary related body heat generation

HEAT STRESS

- occurs when there exists a difficulty of the animal to eliminate body heat production > most of the body heat generated confined inside the body to uncomfortable, and up to certain point, stressful levels

- temperatures above temp-humidity index of 74 - ambient temperatures >80oF(26oC) and humidity above 75% (called the threshhold point) > decreased capacity to eliminate body heat thru natural convection/radiation > sweating for animals with developed sweat glands and panting/hyperventilation for those with undeveloped ones (pigs and poultry)

TEMPERATURE-HUMIDITY INDEX FOR DOMESTIC ANIMALS

	INDEX	TEMPERATURE	RELATIVE HUMIDITY
Comfort zone	62-74	65 - 79ºF (18-25ºC)	50-74%
Threshold point	74	80ºF (26ºC)	75%
Uncomfortable	74-84	81-87ºF (27-30ºC)	75-85%
Stress zone	85 up	87ºF (30ºC) up	> 85%

At index beyond threshold, capacity to dissipate generated body heat thru natural convection/radiation is greatly impaired > sweating for animals with developed sweat glands (like horse) and panting/hyperventilation for those with underdeveloped sweat glands (pigs, poultry, temperate cattle).

Ability to dissipate Body heat production at Threshold point appears to be at maximum of 1.8ºC/hr. Body heat production beyond 2ºC/hr at this index tends to generate stress progressing to Heat Stroke.

Source: OSU; WSU

PATHOGENESIS/ EFFECTS OF STRESS

1. Physical - Hyperventilation > disruption of blood acid-base balance > circulatory constriction

2. Physiological - Suppression of insulin secretion > decreased cell absorption of nutrients > decreased cell/organ metabolic functions > increased breakdown of body stores and structures (glycogen to glucose; protein to amino acids; adipose/lipids to fatty acids > hyperglycemia > increased heart rate and respiration > shock

Subclinical stress level - insidious, not commonly recognized

suppressed immune function > susceptibility to disease challenges > higher morbidity
decreased reproductive function
depressed growth/weight gain

Clinical stress level
hyperventilation
depressed appetite
increased water intake
increased mortality

DIETARY HEAT INCREMENT (HI)

- the amount of energy spent by the body in digestion, metabolism and utilization of food

- released as body heat

- measured as a percentage of ME (ME-NE)

- digestibility, biologic value and intake volume related

The lower the digestibility and biologic value of feed, and the higher intake needed to satisfy requirement > the higher is the HI.

HI Profiles of Feed Nutrients (in descending order)

Fiber - highest HI
Protein - vegetable proteins higher HI than animal proteins - due to fiber bound and predominantly D amino acid type of proteins
Uncooked Starch
Fats and cooked starch - lowest HI

Established Energy costs/kg of dry matter intake (corn soy based diets) NRC 1998
320 - 450 kcal spent in digestion
280 - 390 kcal spent in metabolism

260 - 320 kcal spent in utilization

on average, about 28-35% of ME intake is spent from digestion to cell utilization of nutrients in a kg of standard corn soy bean based diet

expressed as HI of around 30%

Reason: std. soybean meal (solvent) has protein biologic value of less than 55% (fiber bound and mainly D amino acids) and HI value of 47%

PROTEIN BIOLOGIC VALUE OF STANDARD CORN-SOY RATION

Feed
55 gm N/100%

Retention	Feces	Urine
17 gm N/30%	11 gm N/20%	27 gm N/50%

***From: Aarnink, et.al. 1997; Nitrogen chain tests on growing-finishing pigs**

30% N retention indicates only 30% of proteins in the ration were actually utilized as amino acids for protein accretion

50% N in urine indicates at least 45% of protein fed (allowing for N from normal structural protein breakdown/replacement) was deaminated and apparently converted/utilized into energy.

The apparently low protein digestibility and biologic value of corn soy based rations require large amounts of energy to digest, deaminate, and convert leading to high Heat Increment and Heat stress potentials.

PROTEIN TRUE DIGESTIBILITY AND HEAT INCREMENT VALUES OF COMMONLY USED INGREDIENTS

Ingredient	True Dig./ Biologic Value	HI
Soybean meal, solv. ext.	55%	47%
Soybean meal, mech ext.	48	42
Soybean meal, dry ext.	76	23
Fish meal, rotadisc	60	38
Fish meal , vlt	78	25
Blood meal, rndrd.	46	41
Blood meal, spray	78	24
Meat and bone meal, rndrd	44	39
Meat meal, low heat	86	18
Skim milk, std. dry	79	29
Skim milk, spray	89	21
Egg powder, spray	95	10
Corn, grnd	70	21
Corn, ext or cooked	56	17
Rice, grnd	74	20
Rice, ext or cooked	57	16

Adapted from: Machiascavelli, et. al 1996; TLCP, 1997; NRC 1998

CONVERTING HI INTO BODY HEAT GENERATION VALUE

Standards (NRC 1998)

1 kcal HI/kg BW $^{0.75}$ /hr will raise body temperature by 1^{o}C
or 1.33 kcal HI/kg BW/hr will raise body temperature by 1^{o}C

Time frame from intake to utilization (return to resting metabolic rate) - 3 hrs

Example: Lactating sow , 200 kg BW, fed standard corn soy diet of 2.5 kg/feeding, 2 x a day, ration ME of 3000 kcal and HI of 30%.

Total caloric intake/feeding: 2.5 kg X 3000 kcal = 7,500 kcal
Total HI/feeding = 7,500kcal X 30% HI = 2,250 kcal

2250 kcal/200 kg BW = 11.25 kcal/kg BW/3 hrs = 3.75 kcal/hr / 1.33
= 2.82 degrees Centigrade/kg BW/hr

The ration HI will raise the body temperature of the sow by 2.8 degrees C/hr. from feeding to 3 hrs post feeding.

If sow is unable to significantly dissipate such level of heat generation (as in hot and humid conditions) > HEAT STRESS

In Western countries

- ambient temperature and humidity are naturally low
- the sow will have no problem dissipating the body heat generated
- high HI is needed to keep animal bodies warm.

SUCH IS NOT THE CASE IN HOT AND HUMID TROPICS

- almost year round high heat and humidity impairs the elimination of body heat thru natural convection and radiation

- most of the body heat confined inside to uncomfortable up to stressful levels

- pigs and poultry lack sweat glands as a tool to eliminate body heat generated

- hyperventilation (panting) is resorted to, which hastens the stress cycle.

Continuous low level heat stress brought about by high HI rations depress productivity and increase morbidity

Exacerbation of HI effects during high heat/humidity summer and early rainy season periods > more pronounced clinical heat stress

Inspite of a host of microclimate control facilities (high roof, ventilating fans, etc) - marked productivity drops and high morbidity/mortality rates commonly encountered - only half of the problem addressed, and the other half - HI - disregarded

Studies reveal that reducing ration HI levels to less than 22% in tropical environments can dramatically reduce Heat Stress, both in subclinical and clinical effects.

REDUCING HEAT STRESS THRU NUTRITION

- addressing the cause - **REDUCTION OF HI**
- traditional measures (electrolytes/vitamins/antibiotics, etc) only reduce the effect/symptoms

A. Reduction of Heat Increment from Feed

> increasing digestibility and biologic value of feed; decreasing intake volume yet satisfying requirements

> following the "biological basis" in establishing nutrient requirement

Increasing Digestibility and Biologic value of Feed and Reducing Intake Volume

>modifying feed assessment values used - from dependence on just Chemical Analysis (CP, ME, Total Amino acid content, etc) to inclusion of True Digestibility and Net Energy values

>selecting high digestibility & biologic value ingredients

increasing animal protein component (L-amino acids, non-fiber bound)

low heat processed (spray dry,atomizing spray dry, vlt, extrusion) and predigested proteins

Heat processed energy sources (i.e. cooked/extruded corn)

use of Chelated Minerals

use of appropriate exogenous digestant enzymes (for NSP and fiber bound proteins)

> High Density/Digestibility/Biologic Value and Low Heat Increment System of Nutrition

B. Following the "Biologic basis" in establishing nutrient requirement

> established and verified by NRC (see 1998 edition)
> recognizes the interactive effects of genetic potential (growth rate, protein accretion), climate (temperature and humidity), stocking rate and caloric intake in establishing nutrient requirement
> identified the interactive effects of nutrients once inside the gut and in the metabolic pathways (energy:protein ratio, mineral buffering and concentration effects, etc)
> quantified the Heat increment values of caloric sources
> veers away from standard, pre-set, common nutrient requirement setting
> developed in response to to common observations where different farms following the same feed and feeding program perform differently

> allows farm/operation type specific formulation of feed and feeding program

FORMULATE & FEED ACCORDING TO NUTRIENT REQUIREMENT OF ANIMALS POSSESSING DETERMINED GENETIC POTENTIALS AND RAISED IN SPECIFIC CLIMATIC AND MANAGEMENT SETTINGS

> reduces chances of over/under nutrition commonly observed
> allows accurate feeding based on genetic potential, reactions to barn environment and stocking rate
> reduces feed waste production (manure)
> reduces HI
> allows formulation of appropriate nutrition program for maximized productivity at lower bottom line costs (cost-benefit)

SUMMARY

ADOPTION OF A NUTRITIONAL SYSTEM APPROPRIATE FOR THE TROPICS IS INDICATED

FOLLOWING A HIGH DENSITY/DIGESTIBILITY/BIOLOGIC VALUE, LOW HEAT INCREMENT AND BIOLOGICALLY BASED NUTRIENT REQUIREMENT SETTING, ALONG WITH MICROCLIMATE CONTROL MEASURES CAN:

LOWER HI TO LESS THAN 22%
REDUCE HEAT STRESS EFFECTS BY AT LEAST 50%
REDUCE DISEASE SUSCEPTIBILITY BY AT LEAST 50%
IMPROVE PRODUCTIVITY BY AT LEAST 12%
IMPROVE OVERALL PRODUCTION EFFICIENCY BY AT LEAST 15%
ACTUALLY REDUCE BOTTOM LINE COST - FEED COST/KG LW

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