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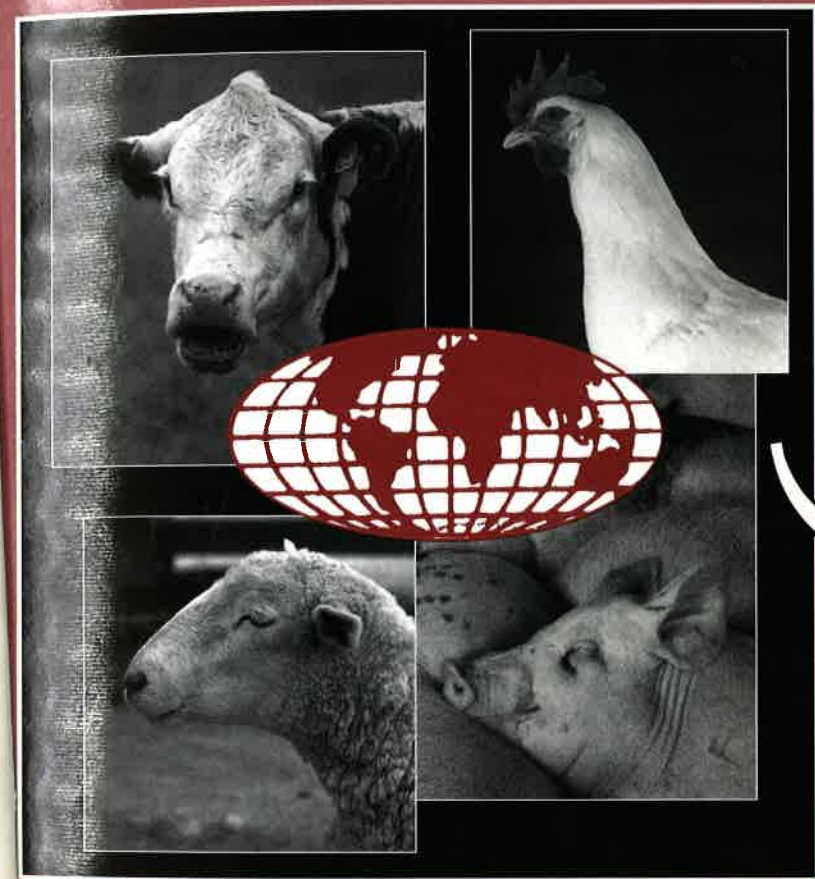
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LIVESTOCK ENVIRONMENT VI



Louisville, Kentucky
May 21-23, 2001



The Society for engineering
in agricultural, food, and
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Page 2 of 15

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Table of Contents

Preface.....	xv
Sponsors and Co-sponsors.....	xvi
Conference Planning Committee.....	xvii

Keynote Speakers

Changes in Animal Welfare Needed to Maintain Social Sustainability <i>J.D. Armstrong, and E.A. Pajor</i>	1
Environmental Design and Management for Livestock in the 21 st Century: Resolving Conflicts by Integrated Solutions <i>C.M. Wathes, S.M. Abeyesinghe, and A.R. Frost</i>	15

Heat Stress Management – Dairy

Effectiveness of Fan and Feedline Sprinklers in Cooling Dairy Cattle Housed in 2- or 4-row Freestall Buildings <i>M.J. Brouk, J.F. Smith and J.P. Harner, III</i>	15
Animal Welfare Indicator and Behaviour of Dairy Cows Exposed to Different Climatization Systems During Summer Season <i>E. Frazzi, L. Calamari and F. Calegari</i>	22
Performance of Tunnel Ventilation for Freestall Dairy Facilities as Compared to Natural Ventilation with Supplemental Cooling Fans <i>R.R. Stowell, C.A. Gooch and S. Inglis</i>	29
A Study To Compare Nighttime Cooling Strategies on Commercial Dairy <i>J.N. Spain, D.E. Spiers and J.D. Sampson</i>	41
Effect of Cooling Strategy and Night Temperature on Dairy Cow Performance During Heat Stress <i>D.E. Spiers, J.N. Spain, M.J. Leonard and M.C. Lucy</i>	45



The Effects of Nighttime Versus Continuous-Cooling on Thermal Balance and Milk Production of Lactating Dairy Cows <i>J.N. Spain, D.E. Spiers and J.D. Sampson</i>	56
--	----

Animal Growth & Performance

Monitoring Growth and Statistical Variation of Grow-Finish Swine <i>R.L. Korthals</i>	64
A Hands-Off Method to Estimate Pig Weight by Light Projection and Image Analysis <i>H. Minagawa and T. Murakami</i>	72
Effect of Pre-Weaning Housing System on Growth Performances and Carcass Composition of Pigs <i>V. Fitas da Cruz, E.M. Lucas and F.J. Baptista</i>	80
Effect of Season (Summer vs. Fall) and Diet Nutrient Density on Performance and Carcass Characteristics of Growing-Finishing Swine <i>R.O. Myer and R.A. Bucklin</i>	87
Modeling the Changing Genetics of Swine Growth <i>T.C. Bridges, T.M. Brown-Brandl, L.W. Turner and J.A. Nienaber</i>	95
Goat Growth as a Function of Feed Intake <i>E. Risch, J.M. Dzakuma, P.M. Johnson, C.O. Smith and H.D. Blackburn</i>	103

Heat Stress Management – Feeder Cattle

Adaptation of Feedlot Cattle to Repeated Sinusoidal Heat Challenge <i>M.J. Leonard, D.E. Spiers and G. L. Hahn</i>	119
Heat Wave Impacts on Feedlot Cattle: Considerations for Improved Environmental Management <i>L. Hahn, T. Mader, D. Spiers, J. Gaughan, J. Nienaber, R. Eigenberg, T. Brown-Brandl, Q Hu, D. Griffin, L. Hungerford, A. Parkhurst, M. Leonard, W. Adams and L. Adams</i>	129

Strategies to Reduce High Heat Load on Feedlot Cattle <i>J.B. Gaughan, T.M. Kunde, T.L. Mader, S.M. Holt, A. Lisle and M.S. Davis</i>	141
--	-----

Heat Load Management for Feedlot Cattle <i>T.L. Mader, S.M. Holt, J.B. Gaughan, G.L. Hahn, M.S. Davis A.M. Parkhurst and D.E. Spiers</i>	147
---	-----

Feed Intake Response of Heat Challenged Cattle <i>J.A. Nienaber, G.L. Hahn, R.A. Eigenberg, T.M. Brown-Brandl and J.B. Gaughan</i>	54
---	----

Effects of Water Application to Feedlot Mounds During the Summer <i>M.S. Davis and T.L. Mader</i>	165
--	-----

Response of Swine to Environment

Monitoring Water Intake in Pigs: Prediction of Disease and Stressors <i>B.K. Pedersen and T.N. Madsen</i>	173
--	-----

Pen Fouling in Pig Houses Affected by Temperature <i>A.J.A. Aarnink, J.W. Schrama, R.J.E. Verheijen and J. Stefanowska</i>	180
---	-----

Pregnant Sows Housed in Kennel Systems at Low Temperatures <i>K.E. Boe and I.L. Andersen</i>	187
---	-----

Feeding Systems for Pregnant Sows <i>I.L. Andersen and K.E. Boe</i>	195
--	-----

Sow and Litter Performance in Farrowing Pens vs. Crates <i>P.A. Phillips and D. Fraser</i>	203
---	-----

Comparison of Electronic Sow Feeding and Crated Management of Sows with Different Genetics <i>R.L. Korthals</i>	211
--	-----

Heat Stress Management - Poultry

A Survey Study of Environmental Control for Poultry in Central Regions of Saudi Arabia <i>I.M. Al-Helal</i>	219
Thermal Environmental Analysis for Broiler Housing: A Case Study <i>M. Amendola, D.R. Azevedo, J.E. Oliveira and I.A. Naas</i>	226
Effects of Drinking Water Temperature on Laying Hens Subjected to Warm Cyclic Environmental Conditions <i>M.C. Puma, H. Xin, R.S. Gates and D.U. Ahn</i>	235
Cooling Caged Laying Hens in High-rise House by Fogging Inlet Air <i>H. Xin and M.C. Puma</i>	244
Effect of Different Ventilation Systems on Hot Weather Thermal Comfort and Performance of Broiler Chickens Raised at High Placement <i>I.F.F. Tinoco, N. Zanolla, R.C. Alvarenga e Melo, F.C. Baeta, A.L.A. Tinoco, T. Yanagi Jr., S.R.P. Moraes and J.N. Silva</i>	250
Effects of Stocking Density on the Performance of Broiler Chickens Grown Under Water Fogging and Tunnel Ventilation Systems <i>I.F.F. Tinoco, J.M. Fonseca, R.C. Alvarenga e Melo, A.L.A. Tinoco, S.R.P. Moraes and T. Yanagi Jr.</i>	256

Ventilation Systems and Performance

Air Motion and Temperature Distribution within Covered Pig Creep Zones in Rooms <i>G. Zhang, S. Morsing, J.S. Strom and P. Ravn</i>	262
Air Velocities in the Occupied Region of a Ventilated Livestock Room <i>J.S. Strom, G. Zhang and S. Morsing</i>	270
Odour Reduction in a Swine Barn by Isolating the Dunging Area <i>J. Feddes, I. Edeogu, B. Bloemendaal, S. Lemay and R. Coleman</i>	278

Numerical Simulation of Airflow in a Room with Multiple Wall Inlets <i>B. Bjerg, K. Svidt, G. Zhang, S. Morsing and J.O. Johnsen</i>	285
Development of a Simulation Model for a Ventilation System for Swine Confinement <i>L. Zhang, T.F. Smith, and P.T. O'. Shaughnessy</i>	293

Development of a Stereoscopic Particle Image Velocimetry System for Full-Scale Room Air Flow Studies. Part I: Algorithms and Validation <i>Y. Sun, Y. Zhang, S. Zhang, L. Zhao and X. Wang</i>	301
---	-----

Thermal Modeling

Heat and Moisture Production of Broiler Chickens in Commercial Housing <i>H. Xin, I.L. Berry, G.T. Tabler and T.A. Costello</i>	309
Heat and Moisture Production of Poultry and Their Housing Systems – A Literature Review <i>H.J. Chepete and H. Xin</i>	319
Measurement and Simulation of Camel Core Body Temperature Response to Ambient Temperature <i>A.A. Al-Faraj and A.A. Al-Haidary</i>	336
Evaporative and Convective Cooling of Cows in a Hot and Humid Environment <i>P.E. Hillman, K.G. Gebremedhin, A. Parkhurst, J. Fuquay and S. Willard</i>	343
Climate Change Effects on Livestock Production in the Great Plains <i>K.L. Frank, T.L. Mader, J.A. Harrington, Jr., G.L. Hahn and M.S. Davis</i>	351

Indoor Air Quality

Protocol for Determination of Environmental Parameters in Animal Housing <i>E.F. Wheeler, R.E. Graves, J.L. Zajackowski, J.T. Tyson, D.F. McFarland and P. Richie</i>	359
Thermal Environmental Conditions in Curtain Sided Naturally Ventilated Dairy Freestall Barns <i>K.A. Janni and D.M. Allen</i>	367
Evaluation of Broiler Housing Indoor Air Quality During Heating and During the Use of Two Types of Ventilation: Natural and Tunnel <i>M.S. Baracho, I.A. Naas and M.Y. Miragliotta</i>	377
Horse Facility Temperature and Humidity During Winter Conditions <i>E.F. Wheeler, J.L. Zajackowski and R.E. Graves</i>	386
Reducing Fatality Risks from Livestock Manure Storage Facilities <i>M.J. Robert, R.A. Aherin and Y. Zhang</i>	394
A Comparative Analysis of Biogas Yield from Poultry, Cattle and Piggery Wastes <i>I.N. Itodo, J.O. Awulu and T. Philip</i>	402

Heat Stress in Cattle

Vital Functions of Gir Calves in the First 7 Days of Life. Relationship with the Temperature-Humidity Index <i>F. Baccari, Jr., J.A.N. Lisboa, E.G. Lo Turco and W.S. Marcal</i>	406
Efficiency of Modified Evaporative Cooling in Midwest Dairy Freestall Barns <i>M.J. Brouk, J.F. Smith and J.P. Harner, III</i>	412
Corn By-products to Feed Grazing Dairy Cows during Summer <i>M.R. Gallardo, S.E. Valtorta and J. Maiztegui</i>	419

Meteorological Effects on Reproduction of Grazing Dairy Cows <i>J.L. Alonso, R.E. Seguro, O.J. Garnero, J.D. Bertero, J.G. Bertoli, P.E. Leva and S.E. Valtorta</i>	426
--	-----

Monitoring Thermal Response of Cattle

Comparison of Methods of Measuring Deep Body Temperatures of Dairy Cows <i>L.C. Hicks, W.S. Hicks, R.A. Bucklin, J.K. Shearer, D.R. Bray, P. Soto and V. Carvalho</i>	432
Development of a Respiration Rate Monitor for Cattle and Swine <i>R.A. Eigenberg, G.L. Hahn, T.M. Brown-Brandl and J.A. Nienaber</i>	439
Correlations of Respiration Rate, Core Body Temperatures, and Ambient Temperatures for Shaded and Non-shaded Cattle <i>T.M. Brown-Brandl, R.A. Eigenberg, G.L. Hahn and J.A. Nienaber</i>	448
Effect of Shade After Exposure to Direct Solar Radiation on Body Temperature Dynamic Responses in Alentejana and Limousine Beef Cattle <i>A. Pereira, F. Baccari, Jr., E. Titto and A. de Almeida</i>	455

Thermal Environment for Poultry

Adapting a Tunnel Ventilation for High Density Broiler Production - A Case Study <i>M.E. Corria and L.A. Naas</i>	461
Development of a Mathematical Model to Determine Broiler Weight Gain as a Function of Poultry Housing Orientation, Shading and Forced Ventilation <i>D.J. Moura and I.A. Naas</i>	468
Study of Thermal Environment for Scaled Models of Broiler Houses, Using Tiles of Clay, Asbestos and Aluminum, under Summer Conditions <i>S.R.P. Morais, I.F.F. Tinoco, F.C. Baeta, T. Yanagi, Jr., R.B. Vigoderis and P.R. Cecon</i>	473

- Determination of the Effectiveness (E) of Different Types of Roof Materials on Broiler Buildings Under Summer Conditions in Brazil*
S.R.P. Morais, I.F.F. Tinoco, F.C. Baeta, T. Yanagi, Jr., R.B. Vigoderis and A.L.R. Oliveira.....478

- Prediction of Black Globe Humidity Index in Poultry Buildings
T. Yanagi, Jr., G.S. Damasceno, V.H. Teixeira and H. Xin.....482

Energy & Building Environment

- Ventilated Roofs as a Tool for Improving the Internal Environment of Animal Houses in Hot Summer Climates
P. Liberati and P. Zappavigna.....490

- Renovation of Ancient Agricultural Buildings for Livestock or Poultry Housing
M.A. Garcimartin, E.M. Sanchez and M.P. Larraneta.....499

Odor Measurement

- Phytase-Induced Volatile Fatty Acid Production in Growing Pigs
A. Woldegehebriel, A. Koenigfeld and A.G. Mathew.....507

- Measurement of Odors and Odorants in Swine Building Airflow Using Aspirated Fabric Swatches and Dust Samples
R.W. Bottcher, K.M. Keener, R.D. Munilla and L.L. Oehrl-Dean.....513

Transportation of Animals

- Heat and Moisture Generation of Livestock During Transportation
P.J. Kettlewell, C.J. Hampson, N.R. Green, N.J. Teer, B.M. Veale and M.A. Mitchell.....519

- Response of Early Weaned Piglets to Simulated Transport Duration and Temperature
R.J. Berry and N.J. Lewis.....527

- Remote Physiological Monitoring of Livestock - An Implantable Radio-Telemetry System
M.A. Mitchell, P.J. Kettlewell, J.C. Lowe, R.R. Hunter, T. King, M. Ritchie and J. Bracken.....535

- Mortality of Broiler Chickens in Transit - Correlation with the Thermal Micro-environment
R.R. Hunter, M.A. Mitchell and C. Matheu.....542

- Physiological Stress Response Modeling - Application to the Broiler Transport Thermal Environment
M.A. Mitchell, P.J. Kettlewell, R.R. Hunter and A.J. Carlisle.....550

- Controlled Ventilation System for Livestock Transport Vehicles
P.J. Kettlewell, R.P. Hoxey, R.L. Hartshorn, I.R. Meeks and P. Twydell.....556

Indoor Air Quality - Dust

- Relationship between Airborne Bacteria and Dust Concentration in Layer House
A. Ikeguchi.....564

- Full-Scale Model Experiments on Airborne Particle Transport between Pigs in a Room
H. Takai, G. Zhang, P. Dahl, B. Bjerg, E. Joergensen and J.P. Nielsen.....571

- Temporal Variation in Swine Confinement Indoor Air Quality
C. Achutan, Z.E. Nelson, A.W. Karsten and P.T. O' Shaughnessy.....579

- Effect of Air Outlet Location on Dust Spatial Distribution and Ventilation Effectiveness in a Full-Scale Experimental Room
X. Wang, Y. Zhang, L.Y. Zhao and G.L. Riskowski.....587

- An Aerodynamic Deduster to Reduce Dust and Gas Emissions from Ventilated Livestock Facilities
Y. Zhang, J.A. Polakow, X. Wang, G.L. Riskowski, Y. Sun and S.E. Ford.....596

Animal Behavior

- Early Weaning of Calves - How Does it Affect the Behaviour
K.E. Boe and I.L. Andersen.....604
- Feeding Behavior of Dairy Cows in an Automatic Milking System at Two Different Feeding Regimes
H.H. Oostra and K. Sallvik.....611
- Effects of Housing Typologies on the Welfare of Growing-Finishing Hogs
M. Barbari.....618
- Using Transponders for Determining Breeder Behavior Versus Environmental Temperature
I.A. Naas, F.P.F. Curto, D.F. Pereira, M. Amendola, and F.H. Behrens.....626
- Shade-Seeking Behavior of Rotationally-Grazed Cows and Calves in a Moderate Climate
T.M. Widowski.....632
- Global Positioning Systems (GPS) and Grazing Behavior in Cattle
L.W. Turner, M. Anderson, B.T. Larson and M.C. Udall.....640

Manure Gas and Odor Emissions

- Ammonia Emissions from Animal Production and Possibility of their Reduction in the Slovak Republic
J. Sottnik.....651
- Validation of the Collection Efficiency of Passive Ammonia Flux Samplers
D.C. Welch, T.G.M. Demmers, J.J. Colls and C.M. Wathes.....656
- Characterization of Odor and Gas Emitting Potential from Mechanically Ventilated Deep and Shallow Pit Swine Finishing Buildings in Illinois
G.Y. Miller, M.J. Robert, R.G. Maghirang, G.L. Riskowski, A.J. Heber and K.R. Cadwallader.....664

- Oil Sprinkling and Dietary Manipulation to Reduce Odour and Gas Emissions from Swine Buildings - Laboratory Scale Experiment
S. Godbout, S.P. Lemay, R. Joncas, J.P. Larouche, D.Y. Martin, J.F. Bernier, R.T. Zijlstra, L. Chenard, A. Marquis, E.M. Barber and D. Masse.....671

- Influence of Weather Conditions on Field Evaluation of Odor Dispersions from Animal Production Sites
L.D. Jacobson, H. Guo, D.R. Schmidt and R.E. Nicolai.....679
- Simulation of Odor Dispersions as Impacted by Weather Conditions
H. Guo, L.D. Jacobson, D.R. Schmidt and K.A. Janni.....687

Animal Welfare & Environment

- Light, Poultry and Vision
N.B. Prescott and C.M. Wathes.....696
- Environmental Conditions in Plastic Film Covered Calf Facilities
C.A. Gooch and S.F. Inglis.....703
- Using Behavioral Indicators and Injury Scores to Assess the Effect of Stall Flooring on Cow Comfort
J. Rushen, A.M. de Passille, D.B. Haley, E. Manninen and H. Saloniemi.....716
- Using Force Between Cow and Feed Barrier as a Design Parameter for the Eating Place
K. Hansen and J.S. Strom.....724

Housing Systems for Improved Manure Management

- The Eco Barn: Good for Animals and Good for the Environment
J.C. Luymes.....732
- Indoor Air Quality and Pig Performance within a High-Rise™ Hog Facility
R.R. Stowell, H. Keener, D. Elwell, T. Menke and S. Inglis.....741

Development of an Energy Efficient Swine Building Using Conveyor Belts
for Manure Handling

*K.A. Elmer, C.A. Rimbach, R.W. Bottcher, F.J. Humenik, J.J. Classen,
J.M. Rice, T.A. van Kempen, E. van Heugten, K.D. Zering,
J. Gregory and J. Hardesty*.....749

Composting Swine Manure: A Technical and Economic Analysis

R.C. Lacy, W.A. Frank and R.D. Little 758

Preface

"There are only two ways to live your life - as if everything is a miracle or as though nothing is a miracle." - Albert Einstein (1879 - 1955)

The Sixth International Livestock Environment Symposium (ILES VI) continues a tradition of gathering specialists from around the world to share information on the effects of the environment on the rearing of animals. Beginning with the first Symposium in Lincoln, NE in 1974, through Ames, IA; Toronto, CANADA; Coventry, ENGLAND; and Minneapolis, MN, the "miracles" of animal response have been investigated, reported and discussed. The formal and informal discussions of those investigations among the diverse groups of engineers, animal scientists, veterinarians, behavioralists, physiologists, nutritionists and economists have led to greatly improved knowledge of the importance of the environment on livestock and poultry production. This knowledge continues to advance livestock and poultry care and improve production systems. The foresight of the first organizers, Ted Bond, Jim DeShazer and LeRoy Hahn, has provided members of the Environment of Animal Structures Committee of the Structures and Environment Division of the ASAE with a roadmap to success.

It is with this multiple-disciplinary background providing contributions to previous conferences that we invited interested investigators from around the world to participate in ILES VI. As you can see, it has been a successful international effort with nearly half of the 97 publications originating outside the United States. Subject matter is wide ranging from feeding and caring of animals to effects of animal waste, all with respect to the impact of environmental factors on animals. Measured animal response variables used to evaluate the effects of the environment have been broadened and improved since the first Symposium 27 years ago, with considerable emphasis now on the dynamics of those responses. Then systems were discussed, now models can more accurately analyze those systems, tomorrow - is up to you.

The sixth installment of this series was held in Louisville, Kentucky, USA at a time when the world was caught up in controlling the spread of foot and mouth disease, which caused the unprecedented cancellation of tours to livestock production facilities in connection with the Symposium. The problem was striking evidence of the scope of this conference and the global community we have become. We planned to showcase the unique beauty of "bluegrass country" in addition to those tours but plans changed. So it is with science, the more deeply we investigate, the more we uncover for further investigation, the more surprises we encounter and change occurs. As an international community we can address these issues and resolve our problems. Let us move forward with that spirit of connectiveness, among countries and among disciplines.

Comparison of Methods of Measuring Deep Body Temperatures of Dairy Cows

L. C. Hicks, W. S. Hicks, R. A. Bucklin, J. K. Shearer, D. R. Bray, P. Soto and V. Carvalho*

ABSTRACT

Physiological parameters, such as body temperature, are key indicators of heat stress and disease in dairy cows. Heat stress is a major complication in dairy production and is known to predispose cows to significant health problems such as mastitis, poor reproductive performance, and lameness. It is therefore important to develop improved means of monitoring deep body temperature. The purpose of this project is to show a comparison between two methods of measuring deep body temperature of dairy cows. Cow body temperatures measured by ingested and implanted CorTemp™ sensors and rectal thermometers were compared in an effort to develop an accurate and relatively non-invasive means of monitoring body temperature.

The CorTemp™ sensor, patented by HTI Technologies, Inc., is a wireless transmitter in the shape of a pill. It consists of a quartz crystal temperature sensor, a telemetry system, and a battery. The size of the pill varies based on the application. The smallest pills intended for human use or poultry are 27 mm long and 10 mm in diameter. The size differs based primarily on the size of the battery; the larger the battery the longer the life of the sensor. The transmitter pill can be ingested by the cow or implanted. The sensor provides a continuous and accurate means of monitoring temperature of dairy cows when implanted or as it travels through the digestive tract. Two tests of the sensor were conducted at the Dairy Research Unit (DRU) at the University of Florida. The first trial was conducted on a rumen fistulated Holstein cow. A CorTemp™ sensor was manually placed into the lower rumen of the cow through its cannula. Temperatures recorded by the external receiver were compared to rectal temperatures measured using a mercury thermometer. A second trial was conducted using three Holstein cows at the DRU. A sensor was surgically implanted into the abdomen between the greater omentum and right abdominal wall. Again, temperatures were recorded by the receiver, as well as rectally by a mercury thermometer. The trials were conducted to compare temperatures measured by the CorTemp™ sensor to temperatures measured by a rectal thermometer. Both the rectal thermometer and CorTemp™ sensor gave deep body temperatures within the normal range for dairy cows (38.3-39.4°C). Analysis of the temperatures indicated that the temperatures measured by the CorTemp™ sensor were statistically the same at the 98% level for Cow 1, 97% level for Cow 2 and 95% level for Cow 3. Further studies are planned to develop the CorTemp™ system as a tool to measure cow deep body temperature.

KEYWORDS. Dairy cows, heat stress, deep body temperature

BACKGROUND

Deep body or core temperature is an important indicator of heat stress in dairy cows. Heat stress causes disease and declines in dairy milk production and fertility. It is therefore important to

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develop improved methods of monitoring deep body temperature. The primary objective of this project was to compare deep body temperatures of dairy cows measured using CorTemp™ sensors to temperatures measured with a rectal thermometer. The purpose is to use this information to determine an accurate method of continuously monitoring deep body temperature of dairy cows as a tool to study heat stress.

Cows use thermoregulatory systems to maintain a narrow range of deep body temperatures, termed the zone of thermal neutrality. In order to maintain thermoregulation, adjustments are made to the cardiovascular, respiratory and endocrine systems placing less priority on lactation, growth and reproduction. As a result, during times of high temperatures and humidity dairy cows experience a reduction in performance caused by heat stress.

A cow uses three primary means of heat dissipation under normal conditions: conduction, convection and radiation. These methods are sensible heat loss mechanisms that rely on a thermal gradient to operate. However, when ambient air temperature increases to levels approaching cow body temperature, the thermal gradient reduces and the cow must rely on evaporative heat loss as its primary mode of heat dissipation. This requires the adjustment of cardiac output, blood volume and peripheral vasodilation causing greater stress on the cardiovascular system. Furthermore, there is an increase in the respiratory rate as the evaporative heat loss increases, resulting in stress to the respiratory system. This panting and open mouth breathing at higher temperatures alter blood CO₂, O₂, and pH. In addition, as body temperature rises due to heat stress, there is a decrease in hormone secretion. The adjustments in the endocrine system's thyroid stimulation hormone, growth hormone, and prolactin result in a decline in growth, metabolic rate, and milk production (Collier and Thatcher, 1982; Hahn, 1982, 1985; Bucklin et al, 1992).

It has been shown that heat stress predisposes cows to develop diseases such as mastitis by increasing susceptibility to infection. Disease not only decreases milk yield, but also the quality of the milk produced. These effects of heat stress result in a necessity to develop a means of monitoring heat stress in an attempt to combat it. One means of doing so is to measure deep body temperature as an indicator of heat stress.

Several studies conducted at the University of Florida (Bray et al, 1992, 1994a; Bucklin et al, 1992) have evaluated different methods of cooling dairy cows. Most of these studies used deep body temperatures as one measure of the effectiveness of cooling systems. Deep body temperatures can be determined by measuring rectal, vaginal or tympanic temperatures. The rectal thermometer is the most widely used measure of deep body temperature. It is an inexpensive means of measuring temperature and is accepted as the deep body temperature. However, the rectal temperature has seldom been compared to internal temperatures of dairy cows. Temperatures at other internal locations in a cow's body would be expected to vary from rectal temperatures by at least small amounts. Furthermore, using a rectal thermometer requires direct contact with the cow that can be a difficult task in the field. Tympanic temperatures have been recorded by inserting an ear probe in the external ear canal near the area of the tympanic membrane. This method is effective in monitoring deep body temperature (Beede et al, 1987; Hahn et al 1990, 1992; Turner et al, 1987; Wiersma and Stott, 1983); however, tympanic probes can be uncomfortable to the cow and inserting the probe in the cow's ear canal is difficult. Vaginal temperatures can also be measured as method of monitoring heat stress. A series of studies used radio frequency transmitters to monitor vaginal temperatures of dairy cows at the University of Florida (Bray et al, 1990, 1991, 1992, 1994a, 1994b). The transmitters effectively transmitted temperature signals to a receiver coupled to a computer. However, the transmitters could only be left in place in the cows for a period of a few days before infection around the transmitters became a problem. The system was also expensive and required frequent time consuming calibrations. Because of the limitations of current methods of measuring rectal, tympanic and vaginal temperatures, this study was conducted to evaluate the potential of CorTemp™ sensors to monitor deep body temperatures of dairy cows.

SENSORS

The CorTemp™ sensor system has been used for accurate, continuous monitoring of the deep body temperature of humans. The results of human studies have shown that temperatures measured in the core of the bodies of humans can differ from rectal temperatures (O'Brien et al, 1998; Sparling et al, 1993). The CorTemp™ sensor was originally developed by Johns Hopkins University Applied Physics Laboratory in collaboration with NASA (Cutchis et al, 1988), and is currently licensed to HTI Technologies, Inc. The CorTemp™ sensor is a wireless pill, consisting of a quartz crystal temperature sensor, a telemetry system, and a battery that is implanted or ingested by the cow. The size of the sensor varies based on the application. For human use it is approximately 27 mm in length and 10 mm in diameter, about the size of a large vitamin pill. In this application for cows, the pill was approximately 9 cm in length and 2.5 cm in diameter. The differing sizes are based primarily on the size of the battery; the larger the battery, the longer the life of the sensor.

The sensor can be either ingested or surgically implanted. When ingested by a cow, the sensor allows for a continuous, relatively non-invasive, accurate means of monitoring temperature as it travels through the digestive tract. It is expected that an ingested sensor will eventually come to rest in the cow's reticulum. One of the future uses of the sensor will be to compare the reticulum's temperature to rectal temperatures to determine if it can be used as a measure of deep body temperature. Surgically implanting a sensor is invasive and a more complicated procedure, but with proper location would be expected to provide a reliable deep body temperature.

Once in the cow, the crystal in the sensor vibrates in direct proportion to the temperature of the surrounding substance. A signal is then sent to an external receiver that translates the signal into a digital temperature. The size of the receiver is based on the application. The one used in this case is 12 x 6 x 2.5 cm in size and weighs 193 g. It is powered by a 9 V DC battery and has an internal antenna. The receiver can store up to 10 sensor calibration numbers and 50,000 data points into memory. Larger receivers can store up to 50 sensor calibration numbers and two different pill frequencies. The receiver can be preprogrammed to display and record time correlated temperature data at predetermined intervals, allowing for continuous, real-time deep body temperature monitoring. Once the data is stored, it can then be downloaded to a computer through a RS232 connection. The pill is encapsulated in food-grade epoxy and coated in food-grade silicon, that allows for harmless passage through the cow. The sensor is FDA approved for use in humans and has undergone more than a decade of monitoring temperatures in medical and industrial applications. Each sensor is factory calibrated to ensure an accuracy of at least $\pm 0.1^\circ\text{C}$. The sensor is calibrated with the use of a stable-temperature water bath, a RTD certified by NBS, and a frequency counter. Frequencies corresponding to various temperatures are recorded and then analyzed to produce a calibration number, consisting of a slope and offset. This unique calibration number and its serial number are then entered into the receiver (262kHz).

The rectal thermometer is the traditional method of determining deep body temperature. A thermometer is inserted into the cow's rectum and held in place for approximately one minute. It is then removed and the temperature read. The benefits of this method are accessibility and low cost of thermometers. However, major disadvantages include errors when manually reading the temperature, and the difficulty involved in securing the cow to measure the rectal temperature.

COMPARISON OF METHODS

The initial trial consisted of one rumen fistulated Holstein cow that was tied in an enclosed flat barn at the Dairy Research Unit at the University of Florida during testing. Relative humidity and ambient air temperature were measured and recorded. A sensor calibration number was programmed into the receiver and then a manual reading was taken to determine that an accurate signal was received. The sensor was then manually placed in the lower rumen through the cannula. The cannula was resealed and another manual reading was taken of the sensor to ensure

signal reception. The cow was in a temperature-controlled environment where her temperature was stable. Periodically, rectal and sensor temperatures were read and recorded. As shown in Table 1, sensor and rectal temperatures both averaged 38.7°C . The sensor temperatures had a standard deviation of 0.05°C and the rectal temperatures had a standard deviation of 0.24°C .

Table 1. Temperatures measured by a CorTemp™ sensor in a cow's rumen and rectal temperatures for a Holstein cow housed under constant ambient conditions in a flat barn.

Measurement	Time (am)	Temperature ($^\circ\text{C}$)
Sensor	9:20	38.6
Rectal	9:20	38.9
Sensor	9:37	38.7
Sensor	9:50	38.7
Rectal	9:50	38.4
Sensor	10:00	38.7
Rectal	10:00	38.8

Ambient Air Temperature: 27.3°C ; Ambient Relative Humidity: 89%

Sensor Temperature Average: 38.7°C (Standard Deviation: 0.05°C)

Rectal Temperature Average: 38.7°C (Standard Deviation: 0.24°C)

The second trial consisted of three Holstein cows, two of which were rumen fistulated. The three cows were initially placed in a flat barn at the DRU in order to perform surgical implantation. Two of the cows underwent surgery on October 18, 2000, and the third cow underwent surgery on October 23, 2000. All surgeries were performed in the same manner. The cow was shaved over a small section of her abdomen on her right side. She was then scrubbed down and given a local anesthetic. One cow was nervous and was tranquilized with 10 mg of Xylazine by intravenous injection. An incision approximately five inches in length was then made. The CorTemp™ sensor was placed into the sac of the greater omentum. The incision was then sutured closed. A similar procedure was also performed at the MARC in Clay Center, Nebraska using the CorTemp™ sensor for a study involving beef cows (Brown-Brandl et al, 2001).

The cows were released and kept in an enclosed field at the DRU. The rectal and sensor temperatures shown in Table 2 were recorded over an eight day period. Rectal temperatures averaged 0.4°C greater for Cows 1 and 2, and 0.6°C for Cow 3. T-tests were conducted to determine if rectal and sensor temperatures were statistically different. Analysis of the temperatures indicated that the temperatures measured by the CorTemp™ sensor were statistically the same as rectal temperatures at the 98% level for Cow 1, 97% level for Cow 2 and 95% level for Cow 3.

Table 2. Temperatures measured by CorTemp™ sensors implanted in the cows body cavity and rectal temperatures for Holstein cows in an unshaded lot.

Day	Ambient Temp. (°C)	Sensor Cow1 (°C)	Rectal Cow 1 (°C)	Cow 1 Dif (°C)	Sensor Cow 2 (°C)	Rectal Cow 2 (°C)	Cow 2 Dif (°C)	Sensor Cow 3 (°C)	Rectal Cow 3 (°C)	Cow 3 Dif (°C)
10/20	22 / Cloudy	38.4	38.3	+0.1	38.5	38.4	+0.1	--	--	--
10/22	29 / Sunny	38.8	39.1	-0.3	38.4	38.6	-0.1	--	--	--
10/24	27 / Sunny	38.1	38.8	-0.7	38.4	38.9	-0.5	38.6	38.8	-0.2
10/25	28 / Cloudy	38.2	38.6	-0.4	38.1	38.7	-0.6	38.4	38.8	-0.4
10/27 (am)	24 / Sunny	37.9	38.6	-0.7	38.0	38.6	-0.6	37.8	38.8	-1.0
10/27 (pm)	30 / Sunny	38.6	38.9	-0.3	38.3	39.0	-0.7	38.1	39.1	-1.0
Avg (SD)				-0.4 (0.3)			-0.4 (0.3)			-0.6 (0.4)

The deep body temperature of a cow under normal conditions is approximately 38.3 to 39.4 °C. Both trials of the rectal thermometer and CorTemp™ sensor gave deep body temperatures within this range. Analysis of results showed no statistically significant differences between sensor and rectal temperatures in the same cows, showing the validity of using the sensors as a means of measuring deep body temperature. Further trials are also planned to test temperature monitoring using ingested sensors. The performance of the implanted sensors will be periodically monitored during the expected six month lifetime of the sensors. The rectal method requires contact with the cow and does not provide continuous monitoring. In contrast, the CorTemp™ sensor is capable of monitoring continuously. Further trials will be conducted to develop a method of placing the receiver on the cow to ensure continuous signal reception. One goal will be to then use this method as a means of monitoring heat stress of dairy cows in the field.

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Development of a Respiration Rate Monitor for Cattle and Swine

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ABSTRACT

Respiration rates (RR) were used in studies to investigate bioenergetic responses of cattle to heat challenges. Separate studies also considered RR as a response measure for growing-finishing swine exposed to adverse thermal environments. Both studies incorporated RR monitoring using small battery powered micro-computers and specially adapted sensors to store data. This paper reports the development of the monitors and the relevance of the data as an indicator of stress for both cattle and swine. Characteristic cattle data obtained in environmental chambers, as well as representative swine data from a calorimetry study, all indicate an association of RR and ambient temperature ($P < 0.01$). Data reduction and analysis are also discussed, based on representative samples of records collected.

KEYWORDS: Bioenergetic, Respiration rate monitor, Transducer, Micro-computer, Cattle, Swine

ABBREVIATIONS: USMARC (U.S. Meat Animal Research Center), RR (respiration rate), T_a (ambient temperature), RH (relative humidity), UMC (University of Missouri at Columbia), BPM (breaths per minute)

INTRODUCTION

For most mammals (homeotherms), respiratory heat transfer is a significant mechanism of heat loss under a wide range of environmental conditions (Ingram and Mount, 1975). Respiration rate (RR) provides an easily observable measure of an animal's thermal state and can be a valuable physiological parameter in conjunction with additional information, such as ambient temperature (T_a), humidity, radiation heat loads (Garrett et al., 1967; Hahn, 1976) and air velocity (Monteith, 1974).

Physiological responses of cattle have been studied intensively and RR has been shown to behave predictively, increasing with rising ambient temperature (Hahn et al., 1997; Ingram, 1974; Morrison and Lofgreen, 1979; Webster, 1974; Kibler and Brody, 1949) and likewise for swine (Brown-Brandl et al., 1998; Liao and Veum 1994). However, respiration rate response is non-linear. As T_a increases beyond a threshold, RR increases rapidly; this threshold occurs near heat stress conditions for cattle (Hahn et al., 1997) and RR increases exponentially (Brown-Brandl et al., 1998) for swine.

An improved understanding of the RR signature for cattle and swine would provide researchers a better interpretation of physiological response to thermal conditions, as well as providing a better tool for producers to recognize animal distress. While RR is easily observable by traditional means (e.g., using a stopwatch while counting flank movement), long-term studies require

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Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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