WORKSHOP OF CIGR SECTION II

CIGR Section II Working Group
in cooperation with EurAgEng

ANIMAL HOUSING IN HOT CLIMATES:
A multidisciplinary view

Editor
Irenilza de Alencar Nääs
Co-operating Editor
Daniella Jorge de Moura

Organizers
Irenilza de Alencar Nääs
Paolo Zappavigna
Vasco de Fitas Cruz, Secretary of the Working Group
Panagiotis B. Panagakis, Co-operating Secretary

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Historical Picture

Participants of the Workshop on Animal Housing in Hot Climate at the Agricultural Engineering Department, Catania, Italy.

Dipartimento di Ingegneria Agraria dell'Università degli Studi di Catania

http://www.dia.unict.it/index

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Index

Table Index

Figure Index

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Part I

1 Preface

Søeren Pedersen and Krister Sällvik

This report is the first brief report from a new established CIGR Working Group on "Animal Housing in Hot Climate", which summarizes the papers presented in Catania, Italy, July 24-27, 2005, with participants primarily from Mediterranean areas, and it can be considered as a continuation of the former CIGR working Group 13 on Climatization of Animal Houses 1977- 2004.

1.1 Participants/members present – Catania, June 2005

Abdelilah Araba, Morocco
Antonio G. Torres, Spain
Avi Arbel, Israel
Daniel Berckmans, Belgium
Epraim Maltz, Israel
George Attard, Malta
Giovanni Cascone, Italy
Hans-Joachim Müller, Germany
Irenilza Alencar Nääs, Brazil
José Carlos Barbosa, Portugal
Krister Sällvik, Sweden
Mohamed H.Hatem, Egypt
Nemesio Fernandez, Spain
Panos Panagakis, Greece
Paolo Zappavigna, Italy
Pavel Kic, Czech Republic
Søren Pedersen, Denmark
Thuy Hyunh, Vietnam
Vasco Fitas Cruz, Portugal
Victoria Blanes Vidal, Spain

1.2 The history

In brief, the past chairman of CIGR Section IV, professor Rolf Henriksson, took in 1976, the initiative to start a Working Group (WG) on Climatization of Animal Houses and appointed Dr. Michael Rist, Institut für Tierproduktion, ETH, Zurich, Switzerland as chairman. The goal was to come up with the best possible common guidelines on international basis for calculation of indoor environment in animal houses for all kinds of domestic animals. The working group which had about twelve members from different countries in Europe plus some corresponding members from USA has met once a year on their own expenses, somewhere in Europe.

The work with making common guidelines was more complicated and time consuming than expected, due to different national rules for how to calculate total, sensible and latent heat. Another problem was the lack of up-to-date information on animal heat production. Most of the available literature was from laboratory experiments primarily from USA in the fifties and sixties, and therefore needed carefully considerations. In spite of the fact that Dr. Michael Rist presented a draft to that report already at the first meeting in 1977, it took seven years to finish the first report (CIGR, 1984) containing information on heat and moisture production for cattle, pigs, poultry, sheep, goats, rabbits and horses. Already in the late seventies it was clear that there was a gap between laboratory conditions and normal animal housing, in respect to moisture from spilt drinking water, moist feed and manure management and some provisional correction factors for adjustment of sensible heat was introduced. Regarding cattle for instance, it was considered in the CIGR 1984 report that 20% of the sensible heat on laboratory scale should be converted to latent heat for production conditions with moist feed (sugar beets and silage) and wet floors. Unfortunately, in the seventies and in the eighties it was difficult to check the heat production under normal housing conditions, compared to the theory, due to difficulties in making continuous measurements on indoor temperature, relative humidity, ventilation flow and other parameters on farms. In the mean time, data logging systems measuring wind speed, and other data became more accessible making verifications of calculation rules related to farm conditions possible.

The Report from 1984, also includes recommendations for acceptable indoor relative humidity at different indoor temperature, expressed as the sum of temperature and relative humidity as (^{o}C + RH,% <90). It is e.g. maximal 60% RH at 30 °C. Also information on climate maps from most countries in Europe was included. Altogether that report was a mile stone with basic knowledge for calculations on indoor climate, needed ventilation and heating capacity.

After finishing the first report (CIGR, 1984), the work continued with some changes in membership and with Dr. Krister Sällvik, Swedish University of Agricultural Sciences as chairman. In the following period the work focused on improving calculation methods for animal heat production, design of ventilation systems, climate control, energy recuperation, cooling, dust and gases in animal houses. The second working group report (CIGR, 1989) was ready in 1989 and revised 1992. The third report (CIGR, 1994) concerns air flow pattern, gases, odor and airborne particles.

Until the middle of the nineties the working group consisted of permanent members, but after that time, the group was opened to all scientist interested in the work. Mostly members of EurAgEng (SIG group 14) took part of the meetings, normally arranged in relation to conferences. The fourth report (CIGR, 2002) was a complete revision of the animal heat and moisture production in first report (CIGR, 1984). The CIGR 2002 report brought the calculation rules in good agreement with the normal production conditions. Because no permanent members existed any more, that report was written on the basis of current exchange of knowledge among scientists with Dr. Søren Pedersen, DK and Prof. Krister Sällvik, SE, as authors, issued as a common report for CIGR and EurAgEng. That report deals with new equations for animal heat production taking into account not only the bodyweight, but also the feed intake for growing pigs and young cattle. Equations for heat production are available in this report for the following species: Cattle, pigs, poultry, sheep, goats, minks, rabbits and horses. A special chapter is dealing with the diurnal variations in animal heat and moisture production. Thanks to comprehensive measurements in recent years of animal activity and heat production on diurnal basis, it is to day well documented that there is a typical diurnal variation in animal heat production with a typical increase in the daytime of 20-25% and a corresponding decrease of 20-25% in the night time. Taking that into account, calculations on diurnal basis can be improved considerably, in respect to maximum ventilation need on warm summer days and need of supplemental heat in cold nights.

1.3 The future

With the work on the reports CIGR, (1984, 1989/92, 1994 and 2002) it has often been discussed that there was a lack of information on animal heat and moisture production in areas with hot climate, because most of the available research results world wide are from the tempered climate zone. At the Board Meeting of CIGR Section II in 2002 it was discussed further and people were encouraged to contribute with information in that field. Also at the board meetings in 2003 and 2004 the need was emphasized. In the CIGR Section II Board Meeting agenda May 2004, Evora, Portugal was concluded:

“New working group on hot climate housing”

The idea of organization of a new working group on Hot Climate Animal Housing was debated again. Finally it was agreed that a workshop needs to be organized to gauge the opportunity for creating a new working group. It was also agreed that Prof. Irenilza A. Nääs is going to coordinate the organization of this workshop with the help of Prof. Vasco Cruz. If there is enough interest and enthusiasm among the workshop members, a working group will be formalized. The idea of compiling the current knowledge in the area of livestock housing and environment control in hot climate countries was also discussed (Prof. Vasco Cruz informed the group that the EurAgEng SIG 14 also had interest in this area and could work together with the proposed CIGR working group)”

In the spring 2005 Prof. Vasco Cruz, Portugal and Prof. Irenilza A. Nääs, Brazil sent an e-mail around to potential participants informing about the first meeting planned to be held in Sicily, Italy, June 24 – 27, 2005. Due to positive response from scientists especially from the Mediterranean area, the working group meeting was confirmed with Prof. Giovanni Cascone, Dipartimento di Ingegneria Agraria; Catania, Italy as host.

During the meeting all participants had the opportunity to give a short presentation of results and actual questions in relation to their regions. The presentations showed in brief that the questions to deal with in the tempered climate zone and in the subtropical zone are different. In the tempered zone, most of the animals are kept in enclosed building, with mechanical/natural ventilation and normally insulated, where it most of the year around is possible by climate control, to keep the attempted indoor temperature and relative humidity as set, but on hot summer days the acclimatization problems with over temperatures are identical with the problems in subtropical zones. In the subtropical and tropical zones, many animal buildings are open sided and un-insulated, although e.g., broiler houses are normally enclosed as in tempered zones, but also open sided houses exist as e.g. in Brazil. The main question is in which way it is possible to reduce animal heat stress and subsequently reduce production losses and maintain animal welfare, during hot weather and especially, when the relative humidity is high.

During the meeting several papers included how to evaluate heat stress, based on measurable parameters as dry and wet bulb temperatures, black globe temperature, relative and absolute air humidity, air velocity etc. Different equations for calculation of THI indexes were presented and it was agreed that a comparison of different methods is needed. The discussion showed clearly that the present working group will have the three main topics:

I. Animal heat and moisture production at high ambient temperatures

II. Methods to define heat stress and "upper critical temperature"

III. Methods to reduce heat stress i.e. facilitate animal heat dissipation when exposed to high temperatures and high relative humidity.

Especial topics I and II are of great interest all over the world, while topic III is mostly of interest in areas with hot climate. The sub-themes to include for theme III could e.g. be:

- ✓ Increased air velocity around the animals
- ✓ Reduced ambient temperature by water evaporation in the air and use of wet pad
- ✓ Evaporative cooling of animals by water spraying on the body
- ✓ Mechanical air cooling in certain areas e.g milk centers
- ✓ Heat exchangers with or without heat pumps
- ✓ Air cooling via earth tubes
- ✓ Feeding the animals morning and evening to reduce the heat production in daytime
- ✓ To use building materials with big heat capacity (where possible) or integrate suitable insulation, efficient shading and appropriate orientation

Finally during the WG meeting it was decided that the first report on Animal Housing in Hot Climate should be ready before September 1, 2005 and Panos Panagakis, from Greece agreed to be the secretary for collecting the contributions from the working group members.

2 Background

Søeren Pedersen and Krister Sällvik

The indoor environment in enclosed animal houses is the results of the following parameters:

- -Animal heat and moisture production
- -Sun radiation in day time
- -Building solar orientation and shading
- -Outdoor temperature
- -Outdoor relative humidity
- -Air velocity inside and outside
- -Good insulation of pipes to assure fresh water distribution
- -Insulation of the structure
- -Heat capacity of structure and floors
- -Ventilation rate and air distribution
- -Supplemental heat
- -Evaporative cooling and other treatments of air

Animal heat and moisture production

One of the classic graphical models on animal heat and moisture production and deep body temperature for homeothermic animals is given by Mount (1973) in Figure 1. The figure illustrate that there is a span of ambient temperature, where the total animal heat production can be considered constant, and in which the sensible heat is decreasing and the latent heat is increasing with increased temperature, which is explained by the law of heat transfer.

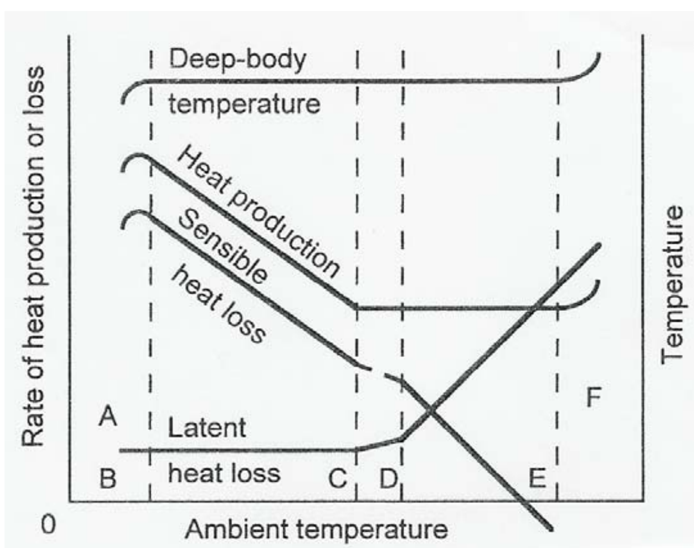

Figure 1.Diagrammatic presentation of relationship between animal heat and moisture production and deep body temperature (Mount, 1973).

A more operational relation between total, sensible and latent heat in respect to ambient temperature is given by Strøm & Feenstra (1980) and CIGR (1984) on animal level, as a general model for cattle, pigs and poultry.

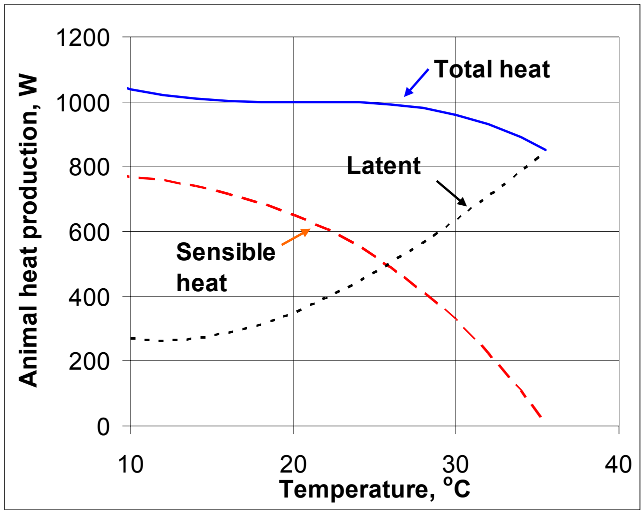

Figure 2. General guideline for animal heat production.

On house level, taking into account the practical situation with possibilities for huddling, spread out and wallowing, the temperature span with constant total heat is not so pronounced, why a linear relation between animal total heat production and ambient temperature fits better to practical conditions. Figure 3 shows the animal total heat and moisture production if no further information is available on species or housing conditions. For more specific situations, diagrams are available for some combinations of species and housing in (CIGR, 2002)

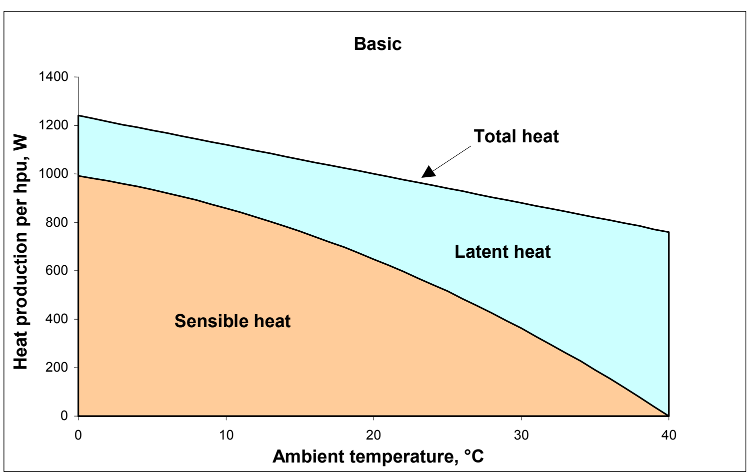

Figure 3. Basic diagram for the proportion between sensible and latent heat in relation to ambient temperature applicable for species and housing conditions where no further specific information is available. Base 1 hpu = 1000 W at 20°C.

The sensitivity of animal total heat production to variations in ambient temperature depends on the species and size of the animal. The total heat production reduces roughly with 0.4% per degree decrease in temperature for cattle, 1.2 % for pigs and 2.0% for poultry as shown in Figure 4

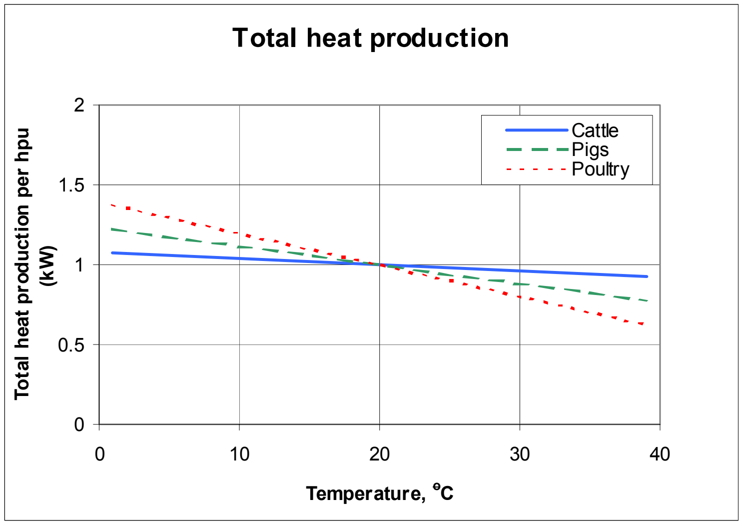

Figure 4. Total heat production for cattle, pigs and poultry in respect to temperature

Another factor to be taken into account, is the diurnal variation in animal heat production due to diurnal rhythm in commercial animal houses. The two general models are the *Drommedar model* in Figure 5 and the *Camel model* in Figure 6.

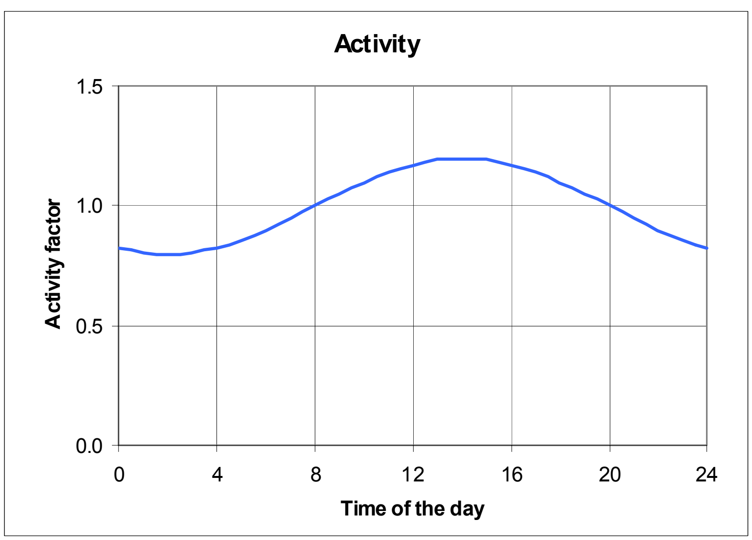

Figure 5. Standard correction of animal heat production due to diurnal variation (*Dromedary mode)*

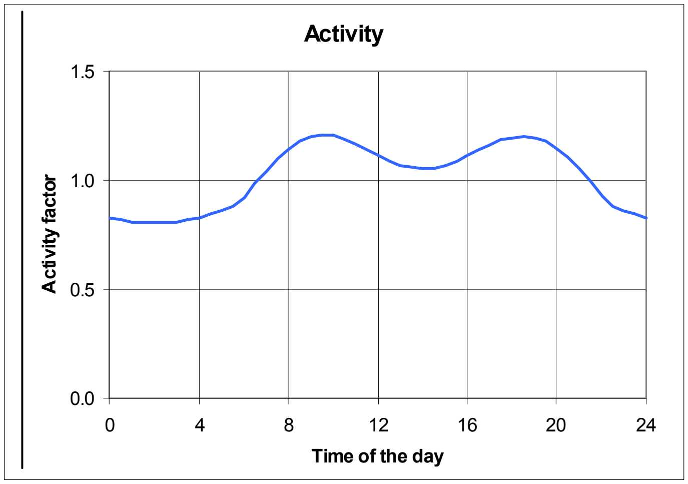

Figure 6. Diurnal variations in animal activity, based on a combination of two sinusoidal curves (*Camel model*).

More details with equations on animal heat and moisture production and adjustment for diurnal rhythm can be found in CIGR (2002)

The challenges for the future will be to characterize the climate for for the actual region and to evaluate the possibilities to for making a good climate for the animals with minimum risk for heat stress.

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3 Glossary, Basic Definitions and Mitigation Actions

Vasco Fitas Cruz and José Carlos Barbosa

3.1. Basic Definitions

- **Air conditioning:** The process and/or conditioner for modifying air temperature extremes, such as changing humidity, removing dust or odor, etc., to increase comfort and productivity (usually by mechanical means).
- **Air distribution or circulation: Pattern of air movement in a livestock building.**
- **Air duct: Pipe, tube or passageway for conveying air.**
- **Air inlet:** Opening designed to supply fresh air to a facility, e.g., hole, slot, lower door, etc.
- **Air outlet:** Opening through which exhaust air leaves a facility, e.g., hole, door, window, open ridge, louver or exhaust fan.
- **Cold barn:** Naturally ventilated barn, usually constructed with no or minimum insulation. No supplemental heat is provided and inside temperature varies with outside temperature.
- **Condensation:** Water vapor removed from the air and formed, in a liquid state, on a surface, in a building usually caused by poor insulation and/or high humidity.
- **Conduction:** Heat transfer through or between bodies in physical contact; involves no fluid motion.
- **Controlled or warm environment:** Insulated livestock housing where temperature, humidity, lighting, air movement, radiation, etc., are controlled by appropriate construction and environmental modifications.
- **Convection:** Heat transfer by fluid motion.
- **Dewpoint temperature:** Temperature at which air is totally saturated with moisture.
- **Distribution duct:** Inflatable tube or rigid duct through which ventilation air is distributed in the building.
- **Draft:** Natural air movement with sufficient velocity, humidity, and/or cold temperature to cause discomfort.
- **Earth tempering:** Heating and/or cooling of air by moving it through a buried conductor, using the thermal mass of the earth to moderate air temperatures.
- **Enthalpy:** The heat energy content of an air-water vapor mixture. Includes both sensible heat (indicated by dry-bulb temperature) and latent heat of vaporization (energy content of the water vapor).

- **Evaporation:** Latent mode of heat transfer in which heat is absorbed during water's change in state from liquid to vapor.
- **Evaporative cooling:** The reduction of dry-bulb air temperature by the evaporation of moisture into the air. The heat required for the evaporation is supplied by the sensible heat loss of the air.
- **Fogger:** System for dispersing water in fine droplets to provide evaporation for air cooling.
- **Heat balance:** Condition in a structure or an animal's body in which incoming heat plus that produced inside is exactly offset by that leaving the body or structure.
- **Heat exchanger:** Device that transfers heat between flowing fluids without direct fluid contact; usually metal or plastic tubes with one fluid inside and the other outside.
- **Heat loss:** Common term that refers to gross loss of heat from livestock or a building through surfaces and openings.
- **Heat production:** Heat released during metabolism.
- **Latent heat:** Energy absorbed or released by a material when it changes phases (e.g., from solid to liquid); no temperature change is involved.
- **Lower critical temperature:** Effective environment temperature below which the livestock must increase heat-production rate to achieve heat balance.
- **Mechanical ventilation:** Air movement through a building caused by electrically or hydraulically powered fans.
- **Moisture balance:** Condition whereby water vapor brought into a building, plus that released inside, is exactly equal to that leaving.
- **Natural convection:** Heat transfer caused by the density difference between hot and cold fluids.
- **Natural ventilation:** Air exchange in structures caused by wind, temperature, and air density induced forces.
- **Negative-pressure (or exhaust) ventilation:** System in which air is forcibly vented from the building and in which make-up air from outside is drawn by negative pressure into the building to replace that vented.
- **Positive-pressure ventilation:** System in which outside air is forced into the building, which in turn forces out inside air by positive pressure (synonym: pressure ventilation).
- **Radiant heating:** Heating primarily by thermal radiation.
- **Ridge vent:** Opening along a roof peak for natural ventilation air outlet or an inlet for mechanical ventilation.
- **Sensible heat:** Energy applied to raise or lower the temperature of a material.

- **Shade:** Building or other object used to shield livestock from direct solar radiation; generally lightweight structure with solid or perforated roof and open walls to permit maximum air movement while blocking direct sunlight.
- **Spray evaporative cooling:** Scattering water in drops (and/or intervals). When water particles are very fine it becomes "fogging" or "misting". The difference is in droplet size: a mist droplet is larger than a fog droplet and will drop slowly to the floor evaporating as it falls (so the animal surface can be wetted, but very little, and the floor can keep quite dry); a fog particle stays suspended in the air and evaporates before it touches the surface. Sprinkling means to use large droplets to wet the hair coat and skin of the animals (the floor is also wetted).
- **Thermal environment:** Those environmental components that affect the heat content of an animal's body.
- **Thermal neutral zone:** Environmental temperature at which an animal's body is at equilibrium; i.e., neither tends to gain or lose heat.
- **Upper critical temperature:** Environmental temperature above which the livestock must increase heat loss rate to achieve heat balance.
- **Ventilation:** Exchange of air in a confined space.
- **Warm barn:** A well-insulated livestock housing unit; supplemental heat may be added and indoor temperature is kept above freezing.
- **Zone cooling:** Localized cooling within a larger room by ducts transporting cool air.
- **Zone heating:** Localized heating of a small area within a larger room.
- **Zone ventilation:** Controlled ventilation of a particular part of a space; for example, zone cooling around a sow or snout cooling of a sow.

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3.2. Thermal comfort indexes

Irenilza de Alencar Nääs and Daniella Jorge de Moura

Thermal comfort indexes were developed for characterizing and quantifying adequate comfort zone for distinct domestic animal species. The idea of the index is to present in one function with correlated variables that is able to express the resulting environment at a certain time (Clark, 1981).

Thermal comfort indexes may be classified as:

- ✓ Biophysics indexes: based on thermal exchanges between the animal body and the environment and correlate the specific animal's comfort elements;
- ✓ Physiological indexes: based on animal's physiological responses originally compared to ideal known environmental conditions;
- ✓ Subjective indexes: based on specific and subjective experimental data relating thermal sensation response and production.

Several publications used thermal comfort index at distinct environmental profile mainly temperature and humidity. Temperature and Humidity Index (THI) was developed by Thom (1959) basically for humans as a function of dry bulb temperature and dew point temperature. Afterwards Johnson et al. (1965) noticed that milk production in dairy cows decreased with the increase in THI. The index was then adapted for evaluating dairy cows production under specific profile of environmental exposition. The authors showed that milk production reduced as well as the ingestion of dry matter when THI reached the value of 77.

$$THI = DBT + 0.36\ DPT + 41.2 \qquad \text{(Johnson et al., 1965)} \qquad \text{Eq 1}$$

Where: THI = Temperature and relative humidity index;
DBT = Dry bulb temperature (°C);
DPT = Dew point temperature (°C).

Buffington et al. (1981) developed the Black Globe Humidity Index (BGHI) associating the use of black globe temperature instead of dry bulb temperature for adding the solar radiation effect to the concept of the Temperature and Humidity Index (THI).

$$BGHI = BGT + 0.36\ DPT + 41.5 \qquad \text{(Buffington et al., 1981)} \qquad \text{Eq 2}$$

Where: BGHI= Black Globe Humidity Index;
BGT = Black globe temperature (°C);
DPT = Dew point temperature (°C).

From Johnson et al (1965) THI values Table 1 was developed and used by Nienaber & Hahn (2004) for measuring and estimating heat stress conditions in beef cattle confinement as well as in dairy cows and swine production.

The normal values were considered ≤ 74, alert values were those from 75 to 78, danger values are those from 79 to 83, and emergency values were the ones ≥ 84.

Table 1. Temperature and humidity index values related to heat stress safety (USDC-ESSA, 1970)

Temperature-Humidity Index Values
Relative Humidity (%)

Temperature (°C)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
20	63	63	63	64	64	64	64	65	65	65	66	66	66	66	67	67	67	67	68	68
22	64	65	65	66	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72
24	66	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74	75	75
26	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	77	77	78	78	79
28	70	70	71	72	72	73	74	74	75	76	76	77	78	78	79	80	80	81	82	82
30	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
32	73	74	75	76	77	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90
34	75	76	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90	91	92	93
36	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	93	94	95	96	97
38	78	79	81	82	83	84	85	86	88	89	90	91	92	93	95	96	97	98	99	100

Gates et al. (1995) adapted THI function for birds and added variation according to the use of evaporative cooling systems within housing. The results were added to a geographic information system and helped poultry producers decision making according to the weather forecast.

As ventilation has an important role in the bird's response to heat stress Tao & Xin (2003) adapted THI for a function using wind speed as a variable, and called this index as Temperature-Humidity-Velocity Index (THVI). They also adopted several stages of thermal comfort such as: normal, alert, danger and emergency, based on the bird's body temperature variation

$$THI = 0.85DBT \times 0.15WBT \quad \text{(Gates et al., 1995)} \quad \text{Eq 3}$$

Where: THI = Temperature and relative humidity index

DBT = Dry bulb temperature (°C);

WBT = Wet bulb temperature (°C).

$$THVI = (0.85 \times DBT + 0.15 \times WBT) \times V^{-0.058}$$ (Tao & Xin, 2003) Eq 4

Where: THVI = Temperature-Humidity-Velocity Index

DBT = Dry bulb temperature (^{o}C);

WBT = Wet bulb temperature (°C);

V = Wind velocity.

Assessing the impact of specific climate on livestock performance is a difficult task. Superficial general analysis of impacts can be based on the animal response. However, combining the relationship between livestock performance and the thermal environment is needed for more precise assessment, and to provide adequate quantitative and qualitative performance evaluation.

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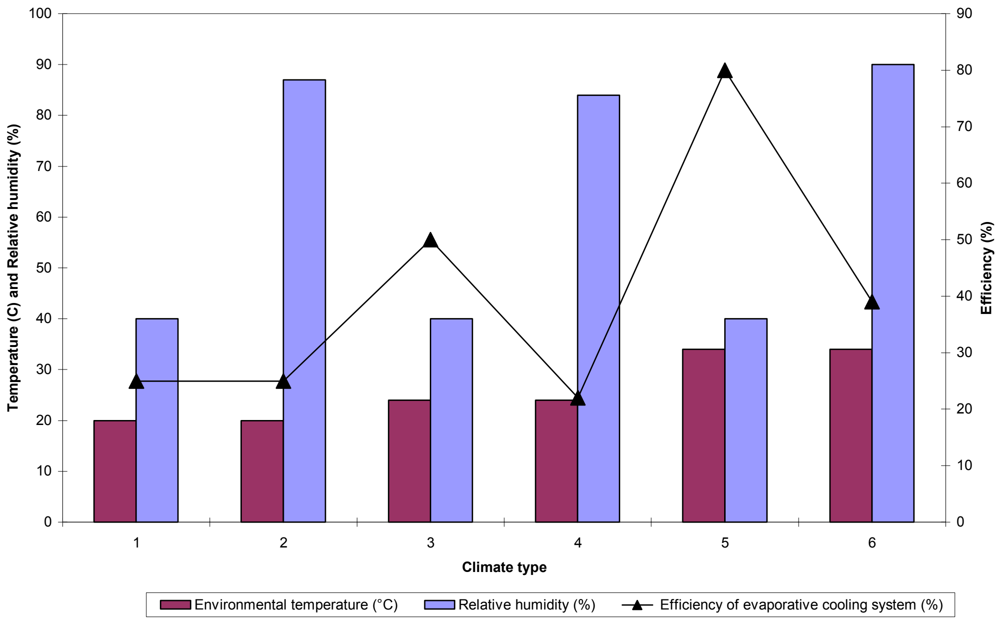
3.3. Mitigation actions

Avraham Arbel and Vasco Fitas Cruz

Introductory Remarks

The efficiency of alternative solutions presented in this chapter has different responses depending on the local climate, as shown in Figure 7 (Romijn & Lorhorst, 1966).



1 = normal dry; 2= normal humid; 3= warm and dry; 4= warm and humid; 5=hot and dry; 6=hot and humid

Figure 7. Efficiency of evaporative cooling systems related to climatic characteristics profile (adapted from Romijn & Lorhorst, 1966)

Cooling livestock buildings by integrated high pressure fogging system with air ventilation and circulation systems: Israel's solution

Avraham Arbel

For year round operation of livestock buildings, their climate control systems must maintain desirable air temperatures, humidity and velocity. However, in many buildings; hot weather operation is limited because the natural or mechanical cooling methods do not provide the desired conditions.

Evaporative systems for cooling greenhouses (1-12) and livestock buildings have been developed to provide desired conditions during the hot season. These systems are based on conversion of sensible heat into latent heat of evaporated water, with the water supplied mechanically. Establishing the appropriate combination of air and water supply depends on the animal's excessive heat and environmental conditions, such as solar radiation, ambient temperature, and ambient relative humidity. The main evaporative cooling methods used today are sprinkling, pad-and-fan, and fog.

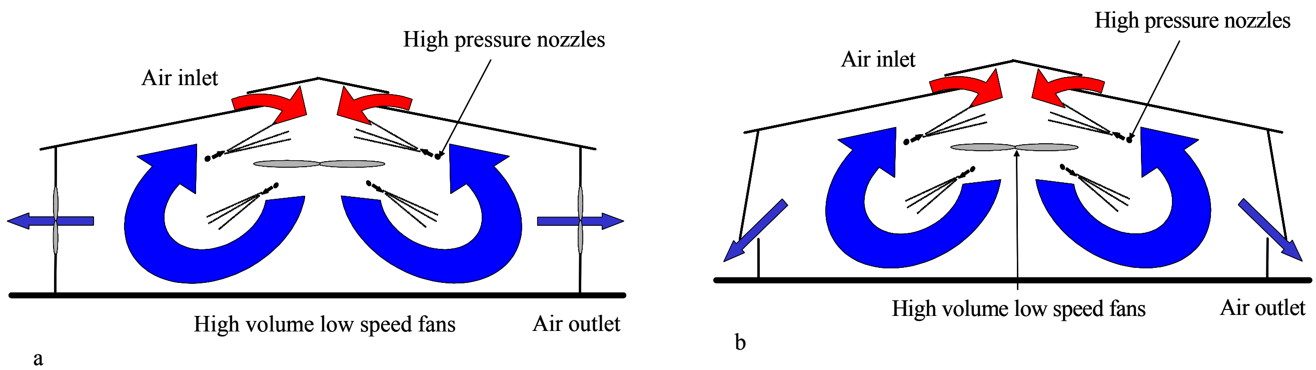
Sprinkling systems combine fans and spraying water from sprinklers onto the animals surface (mainly used in dairy cows housing), results in an increase of the free water surface area and consequently of the evaporation rate. As a result, the animal's body is cooled directly and its temperature is decreased. Thus, from thermodynamic point of view, this method has the highest performance, but required good skin and fur wetted. This method is inexpensive, but its cooling effect under practical condition is limited and its use involves a significant waste of water and increased sewage. Also, sprinkling usually results in contagious conditions for diseases. Therefore, sprinkling is inferior in this respect to the pad-and-fan and fog systems.

The pad-and-fan system is based on forcing outside air into the building through a wet pad, which humidifies and cools it only at the entrance, where the wet pad is situated. The disadvantages of the pad-and-fan system are: (a) the air must be forced through the pad, (b) significant temperature and humidity gradients, along the building, are created; (c) installation, operation and maintenance are expensive; and (d) continuous operation and poor water quality cause progressive clogging of the pad, resulting in declining cooling performance.

The fogging system is based on spraying the water as small droplets (in the fog range, 2-60 m in diameter) in order to increase the water surface in contact with the air. The free-fall velocity of the droplets is slow and they are easily carried by the air streams inside the building. These results in a high efficiency of water evaporation combined while keeping the animals and area dry. Fog droplets can be generated by several methods, but using the high pressure nozzles is the most economic. The efficiency of this system can be increased by full or partial control of the air movement and circulation through the building.

For a given state, the ventilation flow rate defines the air enthalpy and the evaporation flow rate defines the air humidity ratio. Both air enthalpy and humidity ratio define the air state. The circulation flow rate defines the air velocity. Increasing air velocity yields improved heat exchange from the animal's skin and fur. The combination of the operation state may be selected in accordance with the actual climatic conditions and economic considerations.

In the light of these considerations, the following scheme is recommended (Figure 8) comprising: roof openings, high volume low speed circulation fans, ventilation fans or opening in all walls and nozzles distributed at the height of the building. The air that enters the building through the roof openings, circulated and carries the water drops with it, and the water evaporates within the flow. As a result, the air is cooled (by water evaporation), both on its entry into the building and in the course of its passage among the animals, and absorbs excess heat.

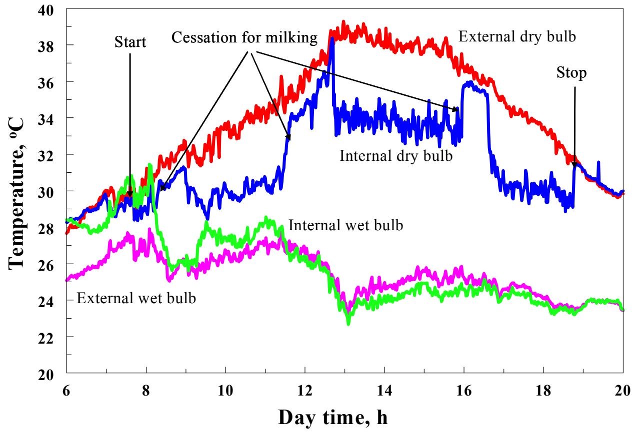


(a) (b)

Figure 8 Schematic view of the proposed system: (a) forced ventilation and (b) natural ventilation

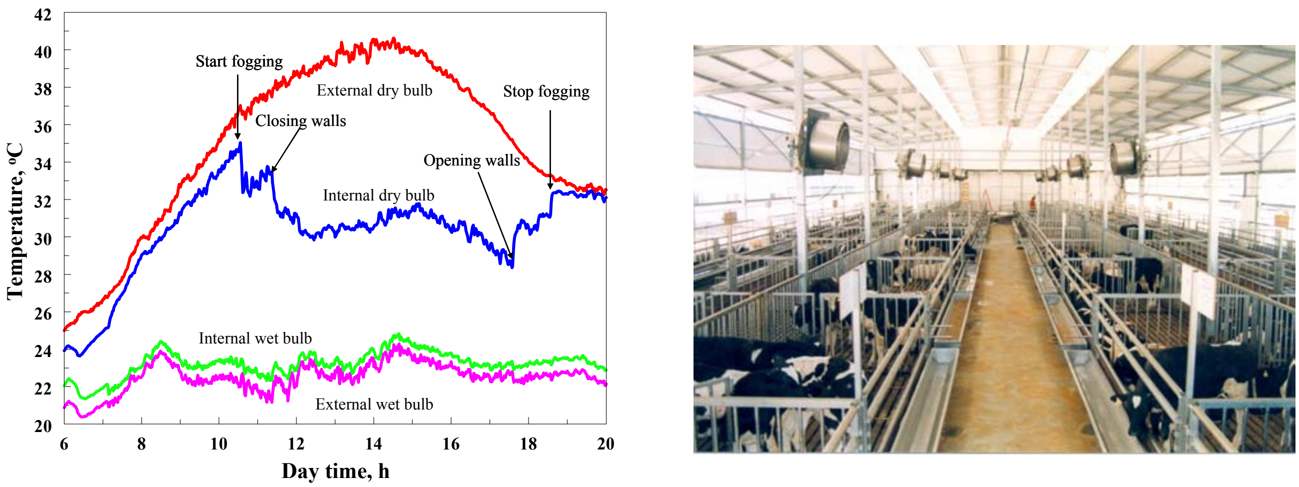
Preliminary results: The proposed cooling system was partially installed mainly in open dairy houses in accordance to the local commonly wind direction and in poultry houses. Two cooling systems were examined under summer conditions.

The first one was in open dairy house of two groups separated by the feeding trough (Figure 9b). The fogging nozzles were installed alongside the fans lines (located in accordance to the common wind direction) and feeding lanes. Climatic results of a typical day are shown in Figure 9a. These results indicate that the inside dry bulb temperature (mean) was lower by 4-5 ^{o}C than that of the outside, while the wet bulb temperatures almost the same.



(a) (b)

Figure 9. Climatic conditions obtained in the Bet-Zera dairy barn l



(a) (b)

Figure 10. Climatic conditions obtained in the Mechola fattening calves house

Figure 10b describes the cooling system in a fattening calf's house. The fogging nozzles were installed on two lines of fans located at both side of the middle lane and facing each other. This house included four ventilation openings and two windows on each longitude opposite walls. Typical results are shown in Figure 10a. As long as the side windows were open these results were similar to those described above. However, when windows were partially closed, further inside dry bulb temperature reduction was achieved to reach total difference of 9-10 °C between inside and outside dry bulb temperatures.

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Computational Fluid Dynamics (CFD) for simulation of air-flow and climatic conditions in livestock buildings and surrounding

Avraham Arbel

Computational fluid dynamics (CFD) is a simulation robust design tool. It is widely used in the industry in fields regarding transport processes, fluid flow, heat and mass transfer. Typical outputs from CFD simulations are spatial and temporal distributions of flow speed and direction, pressure, temperature and concentration. A more recent application for CFD is its use in agricultural research where, it is used for modeling the external and internal airflows and climate patterns of greenhouses and livestock houses (1-14 and 15-23, respectively). Although CFD is widely used in other engineering domains, its use in agricultural engineering is limited and not yet straight forward.

The external and internal flows in livestock buildings involve complex interactions of inviscid and viscid flows; viscous effects are more strongly manifested near the surfaces and inviscid characteristics are more important outside the boundary layers. As livestock buildings are usually large, large Reynolds numbers, indicating turbulent flow, predominate. The best currently available compromise between acceptable computing cost and accuracy in the simulation of turbulent flow phenomena is provided by the standard k-ε turbulence model developed by Launder and Spalding (24). This model includes two additional differential equations for the specific turbulence kinetic energy (k), and the turbulence energy dissipation rate (ε), and uses a turbulent viscosity analogous to laminar viscosity; this turbulent viscosity is considered to be isotropic.

As an example of the simulation capability of CFD, full scale of a typical open dairy house (Fig. 4) was modeled and examined. This house comprise two groups (A and B) of 30 cows each standing along the feeding lane. As shown in Fig. 5, the chosen domain was large enough to insure the independence of air flow's behavior to the boundaries location. This domain was discretized with fine grid near the floor, roof and cow's surface. Unless otherwise stated, this house was modeled under the following boundary conditions: a wind speed of 7 m/s at reference height (10 m), atmospheric boundary layer was assumed at the inlet boundary, roof temperature - 50 °C, cows' surface temperature - 40 °C, air and floor temperature - 30 °C.

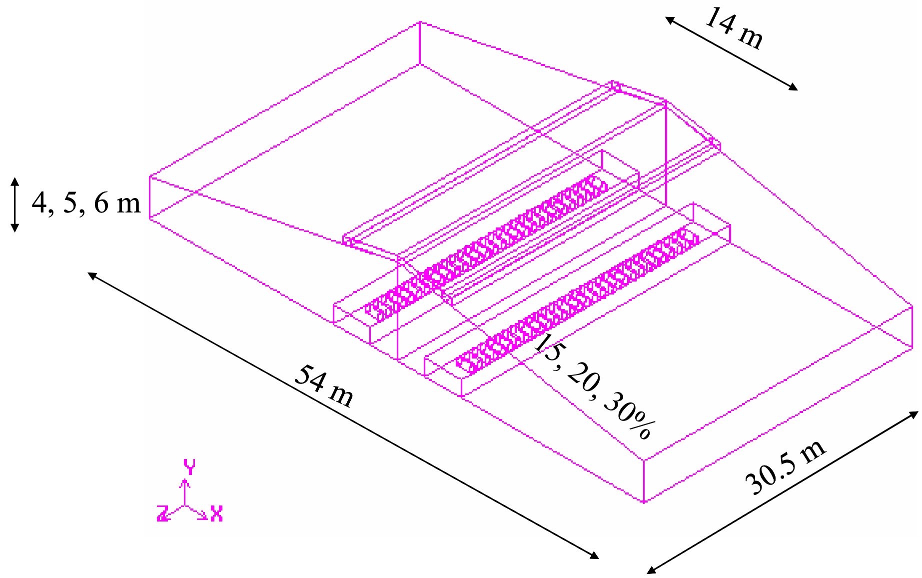

Figure 11. Schematic view of the open dairy house

The obtained result at each cross section may be presented by air speed, air temperature, or combined air speed and heat flux as shown in Figures 11, 12 and 13, respectively.

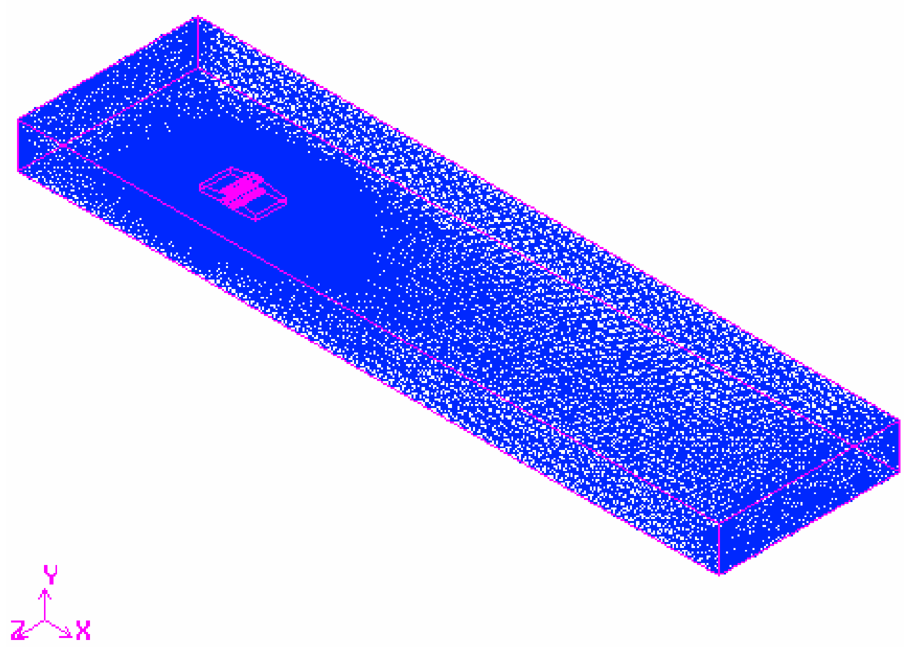

Figure 12. Simulation domain and its discretization

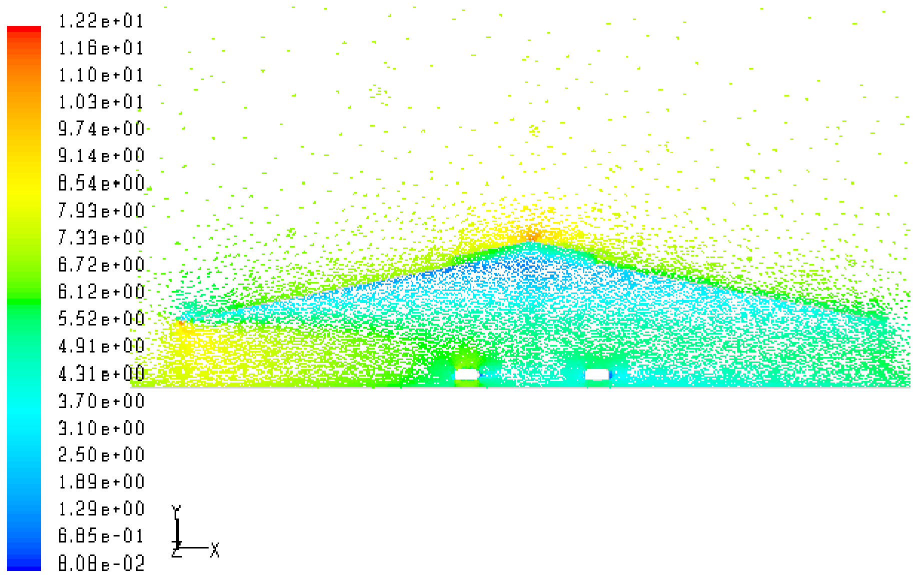

Figure 13. Air flow pattern of a vertical plane for the wind direction perpendicular to the roof ridge where house side height 5 m and ceiling slope 20%

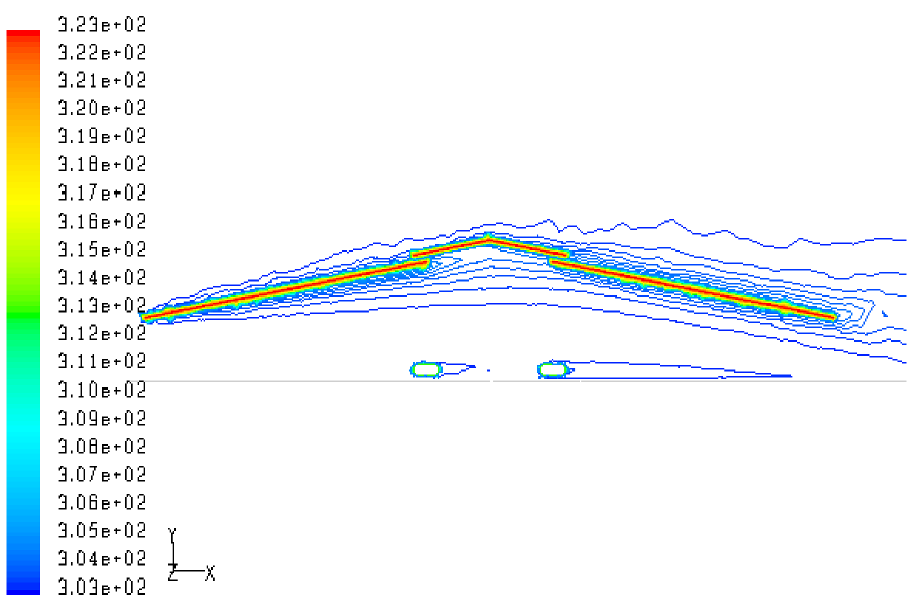

Figure 14. Air temperature pattern of a vertical plane for the wind direction perpendicular to the roof ridge where house side height 5 m and ceiling slope 20%

As function of house height at wind direction perpendicular and parallel to the house ridge are shown in Figures 14 and 15, respectively.

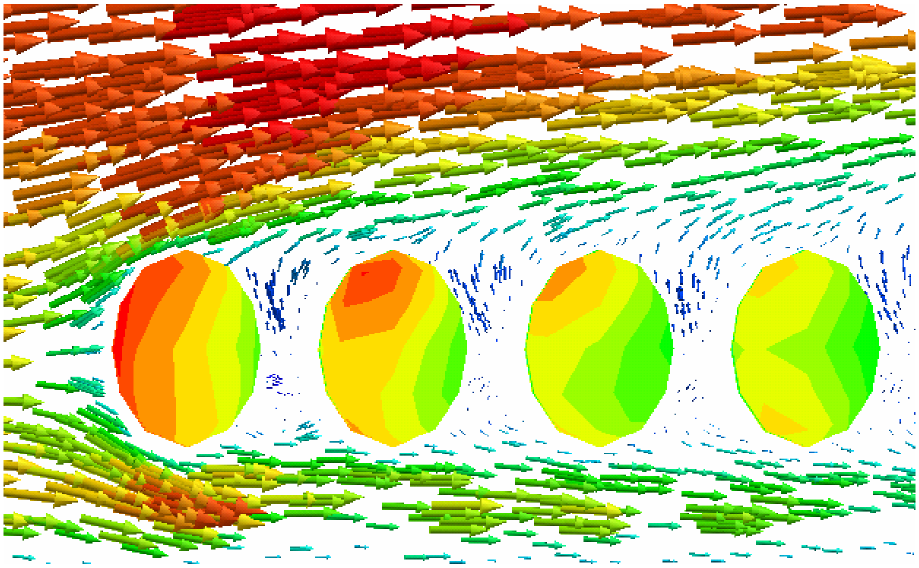

Figure 15. Air flow of a vertical plane and heat flux from the cow's surface for the wind direction parallel to the roof ridge where house side height 5 m and ceiling slope 20%

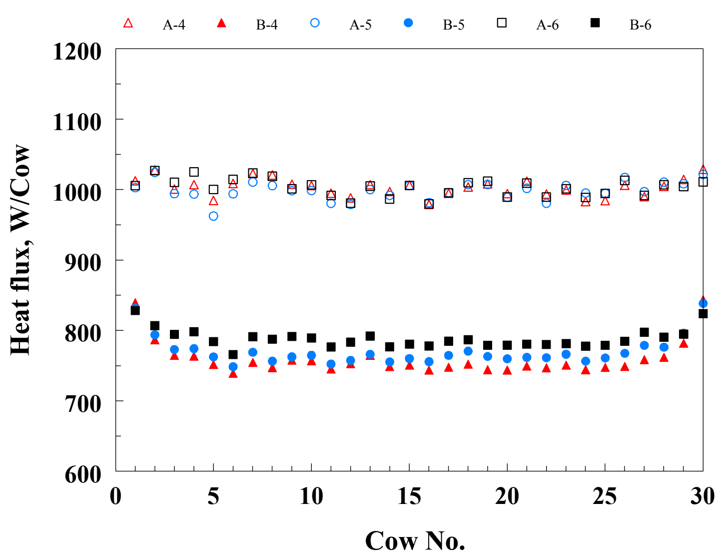

Figure 16. Total heat flux of cows at groups A and B as function of the house height where the wind direction perpendicular to the roof ridge and ceiling slope 20%

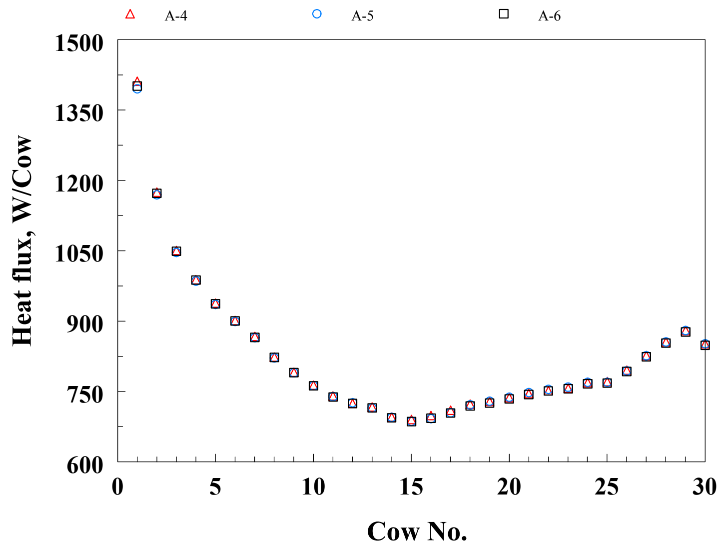

Figure 17. Total heat flux of cows at groups A as function of the house height where wind direction parallel to the roof ridge and ceiling slope 20%

Concerning the total heat flux of each cow the following result were obtained:

As function ceiling slope at wind direction perpendicular to the house ridge are shown in Figure 16. As function of wind speed at wind direction perpendicular to the house ridge are shown in Figure 17.

As function of temperature deference between the cow's surface and reference air at wind direction perpendicular to the house ridge are shown in Figures 18, 19 and 20.

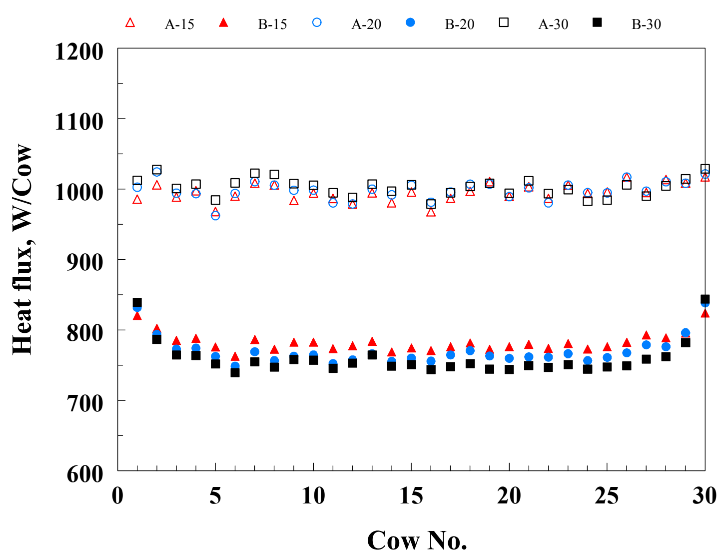

Figure 18. Total heat flux of cows at groups A and B as function of the ceiling slop (%) where wind direction perpendicular to the roof ridge and house side height 5 m

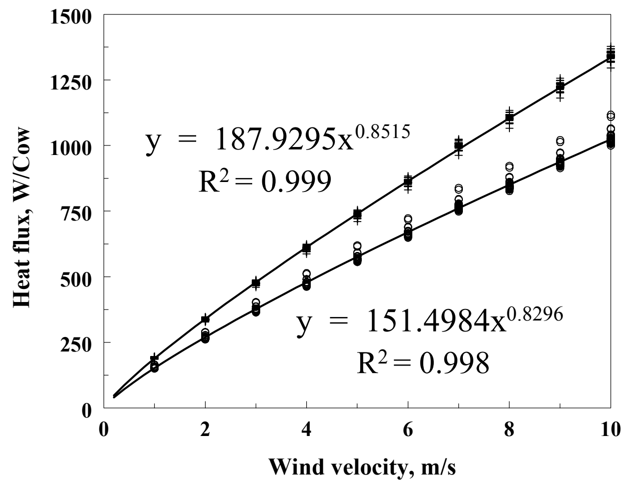

Figure 19. Cows heat flux at groups A and B as function of the wind speed where wind direction perpendicular to the roof ridge, house side height 5 m and ceiling slop 20%

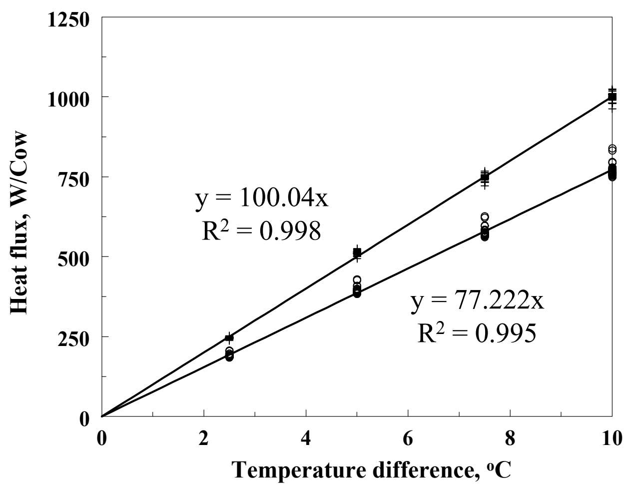

Figure 20. Cow's heat flux at groups A and B as function of the temperature deference (between the cow's surface and reference air), where wind direction perpendicular to the roof ridge, house side height 5 m and ceiling slop 20%

These results, obtained at wind direction perpendicular to the house ridge, may be summarized by the following equation:

$$Q = C\Delta T V^{n} \qquad \text{Eq 5}$$

Where: Q is the total heat of each cow, ΔT is temperature deference between the cows surface and reference air, V is the reference wind speed, C = 19 for group A and C = 15.3 for group B, and n = 0.8515 for group A and n = 0.8296 for group B.

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Cooling Livestock Buildings by Pad and Fan Evaporative Cooling System (Pad Cooling)

Vasco Fitas da Cruz, Mauricio Perissinotto and Eduardo Lucas

Evaporative cooling is an adiabatic humidification process (Wiersma & Short, 1983) that does not involve heat gain or loss, because sensible heat of the air is used to evaporate the water that comes in contact with the air (Simmons and Lott, 1996). The sensible heat is then converted to latent heat in the added vapor, resulting in a reduction of the dry-bulb temperature with a complementary increase of the relative humidity and water vapor content of the air.

Figure 21. Pad cooling system in a Brazilian commercial farm

One of the main evaporative cooling systems is the pad cooling or pad-and-fan system. This system is based on forcing outside air into the building through a wet pad which humidifies and cools the air (Figures 21 and 22). Compared with the sprinkling and with the fogging systems some disadvantages like: a) the air must be forced through the pad, b) significant temperature and humidity gradients, along the buildings, are created, are appointed to the pad cooling system. However in a lot of zones of the South Iberian Peninsula the system is in use with a great efficiency (Lucas et al., 2000; Montero, 1996). The main advantages of this system are: a) the we part of the system affects only the equipment and not the animals, b) the saturation point is never passed because the air only absorb the moisture allowed by the temperature, so the condensate water remains in the equipment, c) this system makes a air cleaning because the pad retains dusts that are continuously removed by the spare water.

Cooling efficiency is affected by several factors, such as pad design, location and material, area and thickness of the pad, water temperature, water and airflow rates and outside air temperature and relative humidity (Timmons and Baughman, 1984). Cooling efficiency, ηc, in % can be defined as follows (Koca et al., 1991; Heber et al.; 1991; Al-Massoum et al., 1998):

$$\eta c = (DBT - DBTC)/(DBT - WBT) \times 100 \qquad \text{Eq 6}$$

Where DBT and WBT are the dry and wet bulb temperatures of the outside air, and DBTC is the dry bulb temperature of the cooled air.

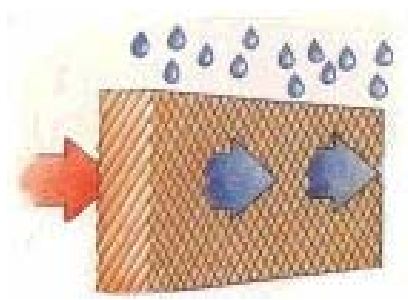

Figure 22. Working principle of pad cooling systems

Reported cooling efficiencies vary according to different authors in different situations and with different equipment. Using a fixed 100mm thickness and various pad materials, and several air and water flow rates, Al-Massoum et al.(1998), found cooling efficiencies, from 52,1 % to 90.1%. McNeill et al. (1983) found an efficiency of 85% with external conditions of 38.0ºC of ambient air temperature and 30% of relative humidity. Also Fehr et al. (1983) and Timmons & Baughman (1984) in hot and dry conditions obtained 80% of efficiency using evaporative cooling pad systems.

Information collected in broilers buildings located in the Southwest of Portugal during the summer of 1998 show that this system reduced the outside air temperature from 39.0ºC to 27ºC after pass the cooling pad. This means that the system operated in commercial facilities located in hot and dry zones with an efficiency of 80% which is the desirable efficiency according to the literature. However, if the re-circulating water tank and the wetted pad were exposed to the sun, the efficiency could be reduced by 15%. These results illustrate the importance of shading the pad system and water tank and probably also insulating the tank. Also the pad materials are very important in the efficiency of the system. Using different materials Cruz et al, (2005) found efficiencies from 22 to 84% in the same summer situations. These results also show that wood shavings, coal-dust and celdek are the materials that lead to a big efficiency.

The velocity of the air crossing the pad is also a fundamental factor to the system efficiency since the contact time between the air and the pad is determinant in the heat changes. When tunnel ventilation is associated with this system the cooling of the buildings is increased (Silva, 2002).

According with Perissinotto et al. (2005) in regions characterized by thermal stress periods due to high temperatures and low humidity which causes a negative influence in animal performances the utilization of evaporative cooling systems is justified due to the decrease in the temperature humidity index that they promote.

Air conditioning systems based in evaporative cooling process are one low energetic cost free from pollution alternative to the maintenance of thermal comfort in big closed areas such as animal buildings. The main characteristic of those systems is the his efficiency increase with the increase of air temperature and the decrease of humidity so these systems are specially adequate for hot and dry regions. Figure 23 gives indications about the world zones more appropriate to the use of evaporative cooling systems.

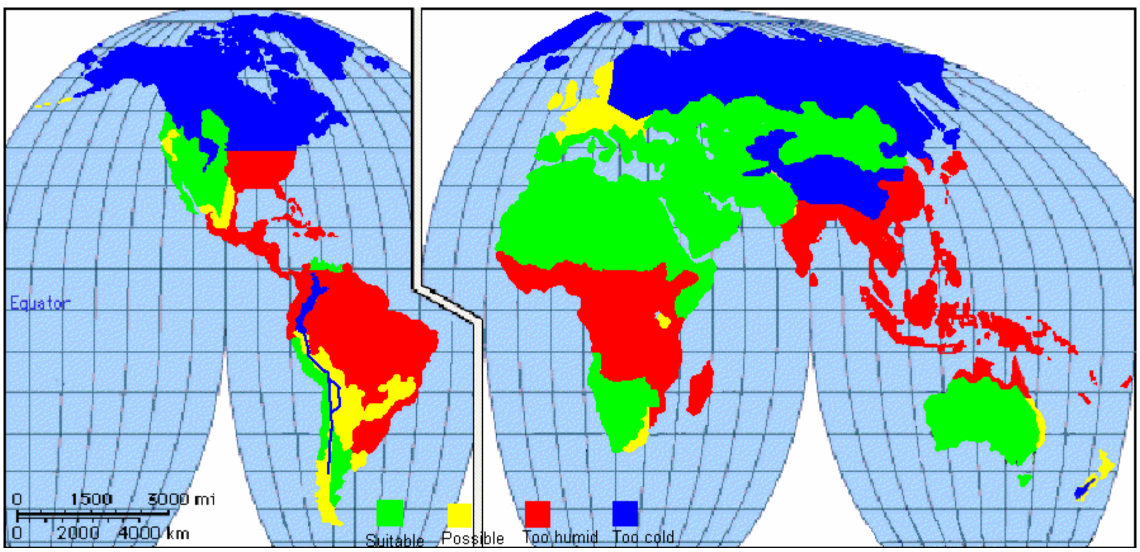

Figure 23. Indications for evaporative cooling use around the world (from coolmax)

According with Figure 23 it is possible to see that there some zones where the utilization of the evaporative cooling is not recommendable by excess of cold (North) or by excess of humidity (tropical and sub-tropical zones). However this map was elaborated in great scale and it not reflects the local microclimates.

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4 Summarized report on each participant country: General Aspects

• *Brazil*

Although 90% of the country is within the tropical zone, the climate of Brazil varies considerably from the mostly tropical North to temperate zones below the Tropic of Capricorn (23°27' S latitude), which crosses the country at the latitude of the city of São Paulo. Brazil has five climatic regions--equatorial, tropical, semiarid, highland tropical, and subtropical. There is little seasonal variation near the equator, although at times temperature can get around 24°C, especially in the rain season. At the country's other extreme, there are frosts South of the Tropic of Capricorn during the winter (June-August), and in some years there is snow in the mountainous areas, such as Rio Grande do Sul and Santa Catarina. Temperatures in the cities of São Paulo, Belo Horizonte, and Brasília are moderate (usually between 15°C and 30°C), despite their relatively low latitude, because of their elevation of approximately 1,000 meters. Rio de Janeiro, Recife, and Salvador on the coast have warm climates, with average temperatures ranging from 23°C to 27°C, with constant trade winds. The Southern states have a subtropical climate.

High and relatively regular levels of precipitation in the Amazon contrast sharply with the dryness of the semiarid Northeast, where rainfall is scarce and there are severe droughts in cycles averaging seven years. The Northeast also constitutes the hottest part of Brazil, where during the dry season between May and November, temperatures of more than 38°C have been recorded. Most of the Center-West has 1,500 to 2,000 millimeters of rain per year, with a pronounced dry season in the middle of the year, while the South and most of the Atlantic coast as far North as Salvador, Bahia, in the Northeast, have similar amounts of rainfall without a distinct dry season.

Swine and poultry production are mainly located in the Southeastern and Southern states, however lately both productions are moving towards the center West part of the country following the grain production. Beef cattle are mainly located in the center West region even though small herds are distributed along the country. Dairy cattle is most located in the Southern region where it is kept in free stall buildings while it is possible to find small herds in extensive systems all over the country. In the 80's acclimatization concepts and systems were imported mainly from the US, and from then several local research results were implemented.

Selected Publications

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- ***Belgium***

Belgium has a moderate climate, and is rarely very hot or cold. Maximum temperatures during the summers range between 20 and 30°C and the winters are relative cold with temperatures between 0 and 5°C. Belgium's average annual temperature is 8 °C Rain is plentiful, with April and November being the wettest months. The country's annual rainfall is 699 mm. At hot summer days, heat stress is observed in animal houses for fattening pigs and broilers, resulting in increased mortality.

Research concerning the relation between outdoor and indoor environment and the resulting production data were studied during field inventories carried out by the Catholic University in Leuven during 10 years on the data of about 100 fattening pig farms (Geers et al., 1983; 1984a,b,c; 1987). Statistical analysis of this data demonstrated that the way the ventilation equipment was used had an overall effect on the indoor environment and animal performance (Berckmans et al., 1988). More specific, inadequate control of ventilation rate and air distribution were found to be the major causes of production losses in livestock buildings

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• *Czech Republic*

The period of climatic conditions with high outside temperatures, which can cause the heat stress to the domestic animals, starts in Czech Republic since May and lasts till September. It represents usually about 130 days potentially dangerous by heat stress for housed animals. The highest temperatures, with the tropical days (temperature over 30°C) are during June, July and August. The designing outside temperature for the calculation of ventilation and air-conditioning in summer is 30°C.

The main principles of the ventilation and climatization of animal houses for the use of designers are described in the Czech National Standard ČSN 730543-2: Internal environment in buildings for animals: Part2: Ventilation and heating, 1998 (in Czech). This Standard includes all definitions and information about the biological production of all species and categories of domestic animals (cattle; sheep; goats; pigs; poultry – laying hens, chickens, turkeys, gooses, ducks; rabbits) in equations and tables: heat, moisture and CO_2 productions. The basic equations for calculation of airflows needed for ventilation in summer periods are included as well. Determination of the maximum ventilation capacity of the animal house in summer conditions is based on the calculation of ventilation rate per one animal.

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• *Denmark*

Over the last fifty years, the farms are increased in size, by merging farms together and at the same time the number of animals per farm is increased drastically.

The number of dairy cows is e.g. in average over fifty years increased from 25 to 80 cows per dairy farm. The number of growing-finishing pigs is increased from 20 to 600 pigs per pig farm and the number of broilers is increased from 50 to 30 000 broilers per broiler farm.

Because Denmark is placed in a windy tempered zone, it is necessary to keep most of the animals inside during the winter season. Only a minor production of beef cattle and farrowing sows are kept outdoors with access to shelters or huts.

The production systems in respect to animal welfare are changing fast over time du to new EU rules and Danish laws. Some examples:

Calves must only be housed in single boxes until the age of 8 weeks and there are rules for minimum box areas per young cattle.

In 1960 all pig pens had solid floor and since, the solid floor was gradually changed to slatted floor. In the nineties ¾ of growing-finishing pig pens had fully slatted floors and ¼ had solid or partly slatted floor. Due to EU rules, at least 1/3 of the pen floor shall be solid floor in all pig pens from 2013.

For broilers in floor keeping the body mass per square meter floor will in the future be restricted to 40 kg and for layers in cages there is a need of enriched cages, in respect to space, perch and claw shortening devices.

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- ***Egypt***

Egypt Climate: Egypt is located between latitudes 31.5° S and 21° N. It is situated in the moderate Northern region of Africa. Egyptian climatic conditions are mostly arid, warm and dry, because Egypt is considered as a part of Africa's main Sahara desert, except for a strip along the Mediterranean coast and another strip along the sides of the Nile River.

Temperatures reach the utmost limit during the period of July - August, and the lowest limit during the period of December - January. The average maximum temperature during summer is 30°C in the Northern coast and 41°C in Upper Egypt whereas during winter is 18°C in the Northern coast and 22°C in Upper Egypt. In general, the temperature increases toward the South.

The average air relative humidity along Mediterranean coastal area reaches the utmost limit (80%) during summer and the lowest (70%) during winter. However, in Delta the relative humidity reaches its higher level (85%) in winter and its lower level (65%) during May and June. In general, the relative humidity decreases toward South.

Egypt climate is characterized by its aridity and dryness. Therefore, a scarce rainfall pours down annually in Egypt. The rainfall season is between May and October. The average precipitation in the Mediterranean coastal reached 150 mm/y, and 30 mm/y in Cairo. There is a scarce rainfall in Upper Egypt.

In most days of the year, the prevailing wind is a North-East wind in Lower Egypt and northerly in Upper Egypt. Dusty wind blows over Egypt from the West side during the period of March to May at irregular times. The average wind speed (measured at 2 m height) is 2.1 m/s over Upper Egypt, 2.3 m/s over Mid-Egypt, and 2.8 m/s over Lower Egypt. Table 2 shows an overview on Egyptian climate.

Table 2. Climate characteristics for towns in Egypt with different latitude and months

1. Climate characteristic for towns in Egypt with different latitude and months

Town, EGYPT From North to South	Month	Max. Temp. (°C)	Min. Temp. (°C)	Relative Humidity (%)	Total Rain (mm)	Radiation (MJ/M^2)	Sun shine (Hours)	Wind Speed (Knot)
Alexandria Longitude: 29.95 E Latitude: 31.2 N Altitude: 6 meter	January	18.4	9.1	70	54.9	10	5	7.5
	April	23.5	13.1	65	4.2	19.3	7.1	7.3
	July	29.7	22	72	0	26.1	10.9	7.4
	October	27.6	17.6	68	33.1	11.2	5.7	5.8
Tanta Longitude: 30.93 E Latitude: 30.82 N Altitude: 8 meter	January	18.7	6.3	74	6.4	12.5	7.5	5.4
	April	26.1	10.8	60	5.7	23.2	9.8	6.1
	July	32.6	19	66	0	28.7	12.6	4.3
	October	29.4	15.1	65	4.3	18.5	9.8	3.9
Cairo Longitude: 31.4 E Latitude: 30.13 N Altitude: 65 meter	January	19	8.8	58	5.2	12.4	7.1	6.7
	April	28.3	14.2	45	1.1	22.6	9.3	7.6
	July	34.9	21.8	54	0	27.6	11.9	5.8
	October	29.8	17.8	57	1	18.9	9.9	6.2
Minia Longitude: 30.73 E Latitude: 28.08 N Altitude: 44 meter	January	20.2	3.9	58	0.5	14.1	8.1	4.9
	April	30.8	12.1	40	0.3	23.8	9.9	7.8
	July	36.7	20.2	45	0	29.7	13.3	7.6
	October	31.4	15.5	54	0.4	16.7	7.6	6.4
Asyut Longitude: 31.01 E Latitude: 27.05 N Altitude: 230 meter	January	20.6	7	50	0	15.4	8.9	5.6
	April	31.8	15	26	0.2	25.5	10.9	7.4
	July	36.6	22.2	37	0	29.9	13.4	6.8
	October	31.5	17.6	43	0	21.3	11.1	6.4
Aswan Longitude: 32.78 E Latitude: 23.97 N Altitude: 199 meter	January	23.5	8.1	35	0	16.2	8.9	7
	April	35.3	17.9	14	0.5	25.4	10.7	8.1
	July	41	24.8	16	0	28.5	12.4	7.2
	October	36.4	19.6	22	0	21.1	10.4	7.2
From West to East								
Matrouh Longitude: 27.22 E Latitude: 31.33 N Altitude: 30 meter	January	18	8.4	66	33.2	10.7	5.7	11.5
	April	22.7	12.1	61	2.8	20.9	8.2	10.2
	July	29.7	21.1	73	0	27.4	11.8	9.8
	October	26.9	16.9	67	15.6	15.7	7.6	8.1
Arish Longitude: 33.75 E Latitude: 31.27 N Altitude: 15 meter	January	19.2	8.5	70	20.3	11.2	6.2	4.7
	April	23.7	13.3	67	6.1	20.4	7.9	4.8
	July	30.6	21.3	74	0	26.9	11.4	4.3
	October	28.5	18	73	6	15.9	7.7	3.5

Source: http://www.clac.edu.eg/tab_nor.asp

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• *Greece*

Ambient Greek climatic conditions favor livestock housing during 'cold' (December to February) and 'mild' (October-November and March-April) seasons. However, 'hot' weather (May to September; Table 3) causes significant problems to all animals grown for their meat, milk or eggs.

Table 3. Greek hot weather climatic conditions

Month	T (°C)	RH (%)
May	20.1	59.0
June	24.6	59.0
July	27.1	47.0
August	27.0	48.0
September	23.2	56.0

Research focusing on such problems is currently running at the Agricultural University of Athens (Lab. of Farm Structures) and specializes mainly on swine and sheep. Productive traits, physiological parameters and welfare aspects, along with appropriate engineering solutions are studied aiming at resolving or reducing the problems.

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• *Israel*

Early research to measure heat and moisture production/loss from animals had been based on the standard metabolic rate (SMR) (Gordon et al., 1985), or basal metabolic rate (BMR) (Hayssen & Lacy, 1985), that related it to the metabolic body size (originates from the work of Klieber, 1932, and Brody, 1945). However, livestock animals under commercial production conditions do not meet SMR and BMR constrains, even more so today, when livestock production is increasing rapidly imposing physiological and morphological changes. The increased metabolism that backs up physiologically this trend generates excessive heat that has to be dissipated. In hot climates, failing to do so results in reduced production and animal discomfort up to the level of suffering.

Proper housing and microclimate control is the tool that provides the optimal conditions for the animal to thermoregulate efficiently while maintaining sustainable production especially in hot climates. The components on which this is based are: air movement (passive and active ventilation), and water (direct cooling and evaporation. These two components involve energy and environmental (manure handling) considerations as well as water wastes that have to be dealt with. Livestock housing in Israel address the main problem of Israeli climate which is hot summers that in some areas develops to severe heat load (THI) due to the combination of high temperatures and high relative humidity (RH). Housing design and location takes advantage of local climatic conditions like direction of winds on one hand, and cooling systems that involves water (direct wetting and/or air cooling) and artificial ventilation on the other.

Whenever possible, livestock housing is build with its longitudinal axis vertical to the air movement during the critical diurnal heat loading hours. The summary related to dairy cows and poultry includes mainly housing for adult and producing animals.

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- ***Italy***

Despite its geographical position at the centre of the temperate zone, a variety of hydro-orographical factors influence the climatic characteristics of Italy (i.e. the presence of the Mediterranean, whose warm waters mitigate thermal extremes; the Alpine arc, which forms a barrier against the cold North winds; the Apennine chain, which causes considerable climatic differences between the opposite sides of the peninsula as it confronts with the wet winds from the Tyrrhenian and dry and cold ones from Eastern Europe; the less deep of the Adriatic sea, which is not much capable of mitigating the atmosphere).

Although many climate graduations can by observed moving from the North to the South and from the coastal to the inner regions of the peninsula, studies carried out on the design of livestock buildings have pointed out that in Italy the monthly average maximum summer temperatures are generally higher than the upper critical temperatures of the thermoneutral zones of the various species of livestock concerned. It is necessary, therefore to find building and plant engineering solutions to mitigate the negative effects of the climate on the animals during the summer period.

The researches carried out in Italy (in the sector of agricultural engineering) can be divided into two main fields: the building design and management (passive solutions) and the equipment design and management (active systems). With reference to the building design the investigated aspects are:

- <u>the roof structure and materials</u> (to reduce the solar impact). In this case works have been done on the effects of the insulation materials, the study of reflective materials, the function of ventilated interspaces or slots, the shading structure and materials;
- <u>the openings geometry</u> (to improve ventilation). Studies are going on regarding the improvement and control of ventilation using also CFD models.
- <u>the building geometry and orientation</u> (to optimize all the variables depending on site, wind and sun). In particular a complete theoretical model to predict the internal conditions in animal houses has been set up including all the variables: animals, building materials and surfaces, opening geometry, wind, sun.

With reference to the equipment, the following aspects are investigated:

- the use of fans inside the house;
- the evaporative cooling (pads and fogging);
- the sprinkling of water onto the animals with fans;
- a system based on earth tube air exchangers was also investigated years ago.

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• *Malta*

In Malta, livestock husbandry has evolved as a highly intensive type of production systems due to some interesting facts: 1) By definition space is physically restricted, 2) Government own 66% of the territory and 3) Livestock produces do not have are not land owners. Thus all livestock is stall fed and no arable land is given over to grazing. The very fact the animals spent there entire life cycle indoors would in principal evoke an interest to optimize animal housing. Unfortunately this is not the case. The extent of animal husbandry activity in Malta does not justify efforts to invest in launching a full blown project aimed at developing home grown solutions for modern livestock husbandry. Very often technology in the form of hard ware and occasionally also prefabricated modules are imported from Italy, UK, Germany and Spain. Due to the lack of land, livestock agriculture evolved into an intensive type of production. Nonetheless, the animal numbers present on site on any single holding is of humble amount when compared to other production systems in the Mediterranean. There are a few issues that have to be tackled to resolve the issue of adequate animal housing in Malta.

- Only architects are recognized by the competent authorities as being privileged in submitting a request for development to obtain permits for the construction of animal barns. Very often these professions have a poor understanding of the needs required by the animals and by the stockman to accommodate modern production systems. Very often, farmers dictate to architects designs that are often outdated and tend to compromise proper design due to lack of proper information or purely due to lack of space available. In situations of adequate space, farm designs are distorted with time as most of the units evolved under a gradual growth pattern. Further more, producers will willingly accept modifications, at the cost of smooth management as long as permits are issued. A site with a building permit or a standing building has a value many times higher that that of a barren field.

- Very often locally quarried stone (the globigerina limestone) forms the basic unit of building material. It is soft and easily worked, but on exposure it hardens slightly and weathers to form a protective crust which slows down the natural process of erosion. This has it’s own intrinsic limitation and presents certain structural problems. Nonetheless, designs that provided for shelter, i.e. cool in summer and warm in winter were developed that also took into account the scarce availability of water. Buildings have flat roofs so that rain water could be collected and harvested for later use. Walls were very often thick double walls and with small openings tended to retain a constant internal temperature within. This thermal insulation makes these buildings relatively cool in summer and cozily warm in winter.

- Besides the globigerina, the much harder upper and lower coralline limestone was used especially for walls exposed to rain and sea spray. Because of its low water absorption this hard limestone was particularly suited for foundations as a damp proof section. In the absence of damp proofing, the high ambient moisture, warmth and general lack of ventilation promoted the proliferation of moulds. Thus any organic matter has to be stored above ground and away from the walls so as to prevent decomposition and rotting.

- Building orientation: South facing walls took advantage of the long hours of sunshine and an arched veranda was generally built to face the sun on a South, South-East or South West wall. The walls inside this arched veranda are given a white wash to help in dissipating the heat and providing a pleasant cooling effect.

- Livestock is housed and fed in the main animal rooms (a noteworthy feature is that inside the animal rooms is the absence of conventional windows) which commonly comprise a number of arched stables of modest size built around the yard each with a separate and unusually wide doorway to allow the animals to go in and out without difficulty. The animal rooms did not normally interconnect, though the larger ones could have been partitioned off by means of low walls. The ground was generally left rough, often with exposed foundation rock.

- Design limitations were mostly dictated by two factors: 1) the shape and size of the site in question and 2) the limitations imposed by the materials being used. Major difficulties were encountered when roofing was concerned. While the arch built with stone was a natural solution, this technique is only suitable for roofing over the ground floor. The resultant forces exerted by arches will require the provision of buttress.

Thermal comfort indexes; environmental control concepts and techniques

- Maltese rural buildings were fundamentally designed to protect animals and farmers from the vagaries of the seasons: the scorching mid-day summer sun, the uncomfortable cold in winter, the sudden freak downpours and thunderstorms and the diurnal fluctuations in temperature.

- Courtyards that are surrounded with walls (and more effectively if supplemented by fences and tress in the vicinity) offer a high degree of protection and shelter from winds, providing adequate shelter and cutting down on wind speed. On the other hand, the yard, being sufficiently low and based on an open plan, will in hot weather make the most of the cool sea breezes. It will also act as a ventilation link between the free spaces at the back of the building and those in front. Interestingly to note that cool breezes may also be artificially induces thermally by means of a vine trellis which by providing alternate shade and sunny areas in the yard cause air currents that replace the raising hot air with cooler air. Because of the low walls, the sun could easily shine through and in winter it provides a source of warmth. Additionally, in summer the foliage of indigenous plants and trees (figs, olive, and carob) give the place a very primitive form of sun protection acting as heat filters to reduce glare. In winter, when the same trees shed the leaves, sunlight and sunshine would be allowed top enter.

- Walls were very often thick double walls (129 cm externally and 76 cm internally) to act as thermal insulation, making them relatively cool in summer and cozily warm in winter. Another thermal factor is that created by the stone capillarity action. In walls that do not have a damp proof membrane, the rise of water evaporates at the surface of the stone causing floors and walls to become cool and comfortable, especially in summer.

• *Morocco*

Morocco is located at the Northwest of Africa. It is bordered in the North by the strait of Gibraltar and the Mediterranean Sea; to the South by Mauritania; to the East by Algeria and to the West by the Atlantic Ocean. One of the main constraints to livestock development is heat stress in summer because of the high temperature and humidity as Morocco extends on 600 km over the Mediterranean cost and 2800 km over the Atlantic cost.

The dominating weather in Morocco is Mediterranean, temperate in the West and the North by the Atlantic Ocean and the Mediterranean see. Inside the country, the weather is more continental, hotter and drier with significant differences of temperature. In the Atlas area, it is very humid and it even snows in winter. The South has desert weather, very hot and dry throughout most of the year, with the nights coolest in the months of December and January.

Rain falls generally from November to March, and its importance decreases from North to South and from coastal to inner areas. The following table presents climatic conditions in the area of Marrakech.

Table 4. Climatic conditions in the area of Marrakech

Month	Temp. (max), ºC	Temp. (min), ºC
Jan	17	5
April	23	11
July	38	20
Oct	26	13

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- ## ***Portugal***

Portuguese climate is classified as Mediterranean with cold and wet winter and hot and dry summer. Autumn and spring are the seasons most favorable for animal housing. The climate of the South region, particularly in Alentejo and in the Northeast part of the country is characterized by a very hot and dry summer with average air temperatures higher than 30ºC and absolute maximum temperatures upper than 40ºC as is possible to see in Table 5.

In those regions animal production is an activity with relative economical importance and with great social importance due to the absence of other activities. Their climatic conditions are the responsible by heat stress periods with interference in animal production, as is possible to analyze with the utilization of THI index.

Table 6 shows the number of animal for specie.

The kind of buildings to lodge the animal is very heterogeneous, between very old and modern buildings, or between completely closed buildings and open-air buildings. However the main axis in East-West it is the building solar orientation general adopted. In dairy housing during the last years there is one trend to house the animals in buildings with large open-air zones. Few farms have mechanical ventilation systems.

Table 5. Climatic conditions of several zones of Portugal during the summer (June, July, August and September)

LOCAL	Average Maximum Temperature	Absolute Maximum Temperature	Average Relative Humidity
BRAGA (41º33'N; 8º24'W, Hs=190m)	26.8	41.3	68
MIRANDELA (41º31'N; 7º12'W, Hs=250m)	30.0	41.7	44
GUARDA (40º32'N; 7º16'W, Hs=1019m)	22.9	33.8	44
COIMBRA (40º12'; 8º25'W, Hs=141m)	28.5	45.8	47
CASTELO BRANCO (39º49'N; 7º29'W, Hs=380m)	30.2	40.6	35
CAMPO MAIOR (39º01'N; 7º04'W, Hs=280m)	32.3	45.6	37
SANTARÉM (39º15'N; 8º42'W, Hs=54m)	30.0	45.3	56
ÉVORA (38º34'N; 7º54'W, Hs=309)	33.3	45.6	28
BEJA (38º01'N; 7º52'W Hs=272)	32.7	47.3	33

Table 6. Swine, cow, sheep and goat distribution according with the number of animals by farm.

Type of animal	<49 animals	50 to 199 animals	200 to 399 animal	400 to 1000 animals	>1000	Total
Sows	122918	77558	57943	54137	21586	334142
Fattening pigs	145941	73637	77066	146814	303267	746725
Dairy Cows	238911	94867	18769	2612	1202	356361
Beef cattle	153672	133830	45027	5612	3121	341262
Sheep	499308	713048	497128	409727	309726	2428937
Goat	239027	112185	66166	36068	2984	356430

The farms for sheep and goats adopt the extensive systems with pasturages but a lot of times the animals are housed during the night period or during the hottest hours of the day, due to the impossibility to maintain the animals in the pasturage because of the large amount of direct solar radiation. However, in this kind of building there are no specific techniques or equipments to minimize the effects of the heat. Poultry, swine and rabbit buildings are in general close buildings with passive techniques of environmental control, like natural ventilation, shading, with bright colors to avoid direct solar radiation.

Some buildings provided mechanical ventilation and few buildings are equipped with refrigeration system, particularity the use of evaporative cooling techniques by evaporation pads, water micro-aspersion on the roof and walls or direct to the animals or floors. Also the fogging systems are used mainly in pigs.

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• *Spain*

Climate in Spain shows a great variability. In fact, not all the regions of Spain can be considered as being under hot climate conditions.

Among those areas under hot climate, there are subdivisions. Three main groups can be found:

1) Regions with high daily temperatures, but where the temperatures show a marked decrease during night time. These regions are usually very dry.

2) Regions with high daily temperatures, where the decrease during the night is not as important as in the regions mentioned above. The relative humidity is only slightly higher than in regions 1.

3) Regions with high temperatures during the daytime and night time. The temperatures are not as high as in the regions 1 and 2, but the relative humidity use to be very high (up to 90% or 100%). These regions are hot and humid.

Constructive designs and the techniques for preventing the heat over the animals, vary depending on the type of climate (region 1, 2 or 3), but there are some measures that are used almost in the whole country, as a protection from the hot outdoor environment.

These decisions which are common to different kind of farms are:

- Positioning the longitudinal axis of the building in East-West direction, in order to decrease the surface area of the building's face exposed to the South, as in the Northern hemisphere, the South face of the buildings is affected by the highest direct solar radiation. In Spain, in the summertime the solar radiation on the Southern face of the building can be an important cause of heat entering the animal house;
- Constructing open zones for the animals, surrounded by buildings, where there are shadows and the air is cooler;
- Painting the walls and roof in white or using reflective materials for the roof, in order to increase the reflection of the solar radiation, and decrease the heat that is transmitted into the houses;
- Wetting the roof (and sometimes the walls), directly or by means of the use of fogging systems;
- Planting trees next to the farm buildings to protect them from the direct sunlight; and
- Isolating the roof for decreasing the thermal transmission.

Finally, the choice that is most commonly used for protecting the animals from the heat stress is the utilization of ventilation systems, although sometimes they are not useful enough, due to the high environment temperatures. In these situations, cooling becomes necessary.

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- ***Sweden***

Swedish agriculture policy has since early 1900s been aimed to be self sufficient for basic food such as milk, meat and bread. Sweden joined the EU in 1995 with the accordingly quota for milk and sugar. The agricultural production is still constant or decreasing due to competition import from other EU countries and also countries in Latin America and the Far East. There are 66,000 agricultural enterprises in Sweden and the average arable land is 40 ha.

Sweden is a long country; from South to the North has a distance of 1,800 km. The climate differs between the South with an average temperature in January of -6°C in the South and -20°C in the North. Days with snow cover per year varies from 50 in the South to 200 in the North.

Summer temperature in the agriculture areas is almost the same independent of location and is in average 14°C. The annual precipitation is 500 - 800 mm.

For calculation of ventilation and heat balance in animal houses during winter there is five different climatic zones (-10 to -24°C) based on the probability of low average outside temperature lasting for a 7-day period and occurring every second year.

5 Summarized State of Art of Animal Housing in Warm/Hot Climate: Productive Traits

Abdelilah Araba, Antonio G. Torres, Epraim Maltz, Daniella J. Moura, George Attard, Giovanni Cascone, Irenilza Alencar Nääs, Krister Sällvik, Mohamed H.Hatem, Panos Panagakis, Paolo Zappavigna, Pavel Kic, Søren Pedersen, Vasco Fitas Cruz, Victoria Blanes Vidal

5.1. Ruminants

Since energy balance, thermoregulation and environmental aspects of "high producing dairy cows" were thoroughly studied (Brody, 1945; Flatt et al., 1969; Berman et al., 1985), the high producing dairy cow more than doubled production with a body weight increase of about 10-20% which imposed a three fold increase of heat increment (Kadzer et al., 2002). There is an apparent world wide lack of realization that changes in the physical and genetic constitution of cows may have affected their thermoregulatory capability in hot climate for example, blood plasma fluctuation in volume and constituents (Maltz et al, 1994); as well as how they cope with heat stress (Kadzer et al., 2002). As a result, research in thermoregulation in relation to housing facilities and cooling management falls behind (except for few exceptions seen below) the aggressive selection for increased production that livestock undergoes as well as changes in technology and housing materials. Therefore, most of the improvements in this area are farmers and designers initiatives based on common sense and experience.

- **Dairy**

BRAZIL:

Milk is one of the largest sources of the agricultural revenue in Brazil. Most of the milk production is concentrated in the central, Southern and Southeastern part of Brazil, which holds about 80% of the total milk production in the country. The raising systems applied to dairy cattle in Brazil can be of extensive and intensive types. The extensive systems use only pasture and mineral feeding in most part of Brazil, except in the Southern and Southeastern areas where a better economy allows a more selected breeding with a higher milk yield per cow. In these cases, housing, balanced feeding, and a better sanitation against parasitological and bacteriological plagues are provided.

The construction used in extensive systems are mostly handling corrals enclosed on its sides using wood lumbers and hoof coverings, usually fiber-cement, on top of the feed and mineral bunks only and in the milking parlor area. Intensive programs apply freestall systems for full herd enclosed; East-West solar oriented, concrete construction buildings, and most of them with some type of spray cooling system, except in the coldest regions near the Southeastern region where it is rarely necessary.

CZECK REPUBLIC:

The microclimatic conditions in the large capacity cowsheds have been studied in Czech Republic during the last decades. Different systems of natural, forced and combined ventilation systems were tested in many dairy farms. The influence of the special double roof construction made either from timber or concrete on the indoor microclimate was studied in several cowsheds.

The method for reduction of heat stress in cowsheds is recommended according to the milk yield and to the altitude above the see level (low productive cows or dairy farms in the mountain areas are not so sensitive, Table 7).

Table 7. Recommended methods of heat stress reduction for dairy cows

Milk yield (kg.cow^{-1}. 300 days^{-1}	**Altitude (m above the sea level)** Under 200	200-350	350-500	Over 500
Under 5000	IncrVent	CM/IncrVent	CM	CM
5000-8000	EC	IncrVent	IncrVent	CM
Over 8000	EC	EC	IncrVent	CM/IncrVent

Where:

CM = conventional methods (changes of feeding method)

IncrVent = increased ventilation

EC = evaporative cooling

EGYPT:

Egypt has 3.4 million dairy herd producing 1.6 million tons of milk, which covers 70% of the national needs. More research must be performed aiming to increase milk yield, especially since Egypt has hot climate which is an obstacle facing the high milk production.

When temperature is between 5 to 15°C the cows are most productive, and when the temperature is between 15 to 25°C a small degree of loss in production occurs, however when temperature exceed the upper critical temperature (25°C) a great degree of loss in production occurs.

The country has hot dry climate. The environmental temperature reaches its highest degrees at summer months (July and August) when mean maximum temperature is 41°C (44°C for Upper Egypt and 38°C for the Northern part of Egypt); consequently, there is a gap between summer temperatures and the upper critical temperature for cows, which causes great losses in milk production. For these reasons, a comfortable housing condition is needed for dairy cows.

The open housing system is a good choice to be used under hot climate conditions (like in Egypt), with varying systems of protection from heat stress, depending on the ambient temperature. The open housing system consists of shade structure covering a yard. This system is frequently used in Egypt; about 90% of the dairy cows housing systems are open housing. Recent researches suggest that the shed height (roof height) should be between 5 to 8 m, and oriented from East to West. Moreover, the roof should be constructed from reed mats. The micro-sprinklers and fans cooling system should be installed.

The type of housing system depends on animal sizes; therefore, for big animals open buildings or sheds are used, however for small animals closed buildings are used. The type of housing arrangement depends on herd sizes: large herds (50-250 heads) use free or loose system under sheds; medium herds (10-50 heads) uses free or tie systems under sheds; and small herds (3-10 heads) uses tie system under sheds or closed building. The types of building orientation are East-West i.e. the main axis's of building is oriented from East to West, or North-South, i.e. the main axis's of building is oriented from North to South. The common environmental control systems are misting (fog system), and micro-sprinklers, as well as fan cooling system.

ISRAEL:

The dairy industry of Israel undergoes a reform aimed to increase efficiency and improve manure management through benefiting the advantages of size. This is done by encouraging merging of quota of several producers into one dairy, which leads to increasing dairy size (a general trend in the Western hemisphere) accompanied by building new facilities. As a result, the housing facilities and cooling systems and management presented in this summary are the state of the art that is currently in use in Israel.

<u>Housing</u>

The dairy cows' shades built during the last five years are designed for improved ventilation characterized by size and height of fully (or almost fully) roofing the entire living environment of the cow. The basic designs of dairy housing follows the general instructions of the Division for Mechanization and Technology of the Extension Service in the Ministry of Agriculture (Shoshani, 2000), but the final outcome is in many cases also a result of designers and farmers initiations and experience without solid research behind it. The final outcome, in terms of performance of cows inhabiting these facilities, suggests that they provide favorable conditions. Yet, it has still to be asked if similar (or better) results could not been achieved with housing of lower cost in size and building materials.

For optimal ventilation, it is recommended that shade height above the feeding lane should be at least 6 m and declining by 28-30° to 3-4.5 m above the ground at its low boundaries (Shoshani, 2000). However, it is not unusual to see sheds much higher than these reaching 6 m above the ground at its low boundaries with a similar roof slope. The recommendations include also adding an open yard along the shade of about 6 m width, to provide a lying area for cows to dissipate body heat by radiation during the night. The most popular shades are of the double type. Mirror images shades slopping down from both sides of a feeding lane above which there is a roof opening of about 1 m with or without a gable. Each side inhabits 80-120 cows. The technical details are: living area per cow – 22 m^2, minimal roofed lying area per cow 12 m^2, minimal lane width along the feeding trough – 3 m, roof slope 28-30°. In addition to the thermoregulatory advantages of the fully roofed barn, this type of facility simplifies the manure handling. The large roofed area provides enough covered space that prevents cows gathering in a small area that requires bedding and/or frequent manure evacuation. In fact, the ground is sufficiently dry even during winter, and manure is evacuated once a year or every two years. This leaves to clean daily only the feeding alley, which is done by scrapers or flashing.

It is becoming more popular to build a slated shade roof or with overlapping panels that can be opened in relation to the position of the sun thus, improve ventilation, radiation (body heat at night), and manure drying. In the case of overlapping panels that slide on one another, it is recommended to have a roof slope of 30°.

The free stall barns comply in general to the characteristics of the fully roofed ones with the exception 5-4 m^2 per cow in open yard, in addition to the lying stalls.

Cooling

Led by common sense, fans are used since a long time ago to ease heat load in dairy barns. But, it was not until the eighties that a combination of sprinkling and forced ventilation was developed as a cooling system for dairy cows in Israel (Flamenbaum et al., 1986), which was gradually adopted by the Israeli dairy industry with excellent results (Israeli Milk Board, 2004). This system is currently implemented in two segments: forced cooling in the milking parlor, waiting yard, and in the feeding alley, and voluntary cooling in the feeding alley and lying area. The forced cooling system comprises of restricting the cows to an area were the cows are sprinkled and ventilated successively for about a 1/2-1 h. This takes place in the milking parlor waiting area before and between milking, and in the feeding alley were the cows are yoke-locked when reaching for the freshly distributed food. The superior effect is reported by the farmers to be the forced cooling in the milking parlor waiting area. The voluntary cooling is operated by timing the sprinkling and ventilation in each shade according to diurnal heat load and expected presence of cows in accordance to milking and feeding time.

Both, forced and voluntary cooling involve a significant water waist (an important resource in many hot environments) which makes this cooling system also an environmental concern. The waist of energy and water when voluntary cooling is much greater because in the absence of an efficient control system, the system often wets and ventilate areas empty of cows. Therefore, on-line control that includes sensors for environmental conditions and cow's presence and scattering around the barn is required. So, that the cooling system is operated only when needed and affecting the animals.

Recently, there was an attempt to adopt the fogging system that only cools the environment without wetting the cows or the manure. It should be added, that cows crowding in the summer during the hot hours of the day occurs in dairies sometimes without an obvious reason. Usually poor ventilation is blamed. However, this phenomenon was not yet thoroughly investigated.

ITALY:

In addition to the building general aspects much work has been carried out in the field of cooling by fogging or direct sprinkling onto the animal and fans. The investigations have been done in the Northern area of Italy, where summer climate is quite wet (minimum RH around 40%), so reducing the possible cooling effect. However some interesting results were obtained showing a significant improvement especially in the animal welfare (body temperature, respiration rate, resting time) and in the milk quality (rheological parameters); less significant gain in terms of milk quantity. Some interesting results were achieved showing the relevant influence of the nocturnal temperature, even more than the diurnal. The investigations are still going on wishing to extend the fogging to the entire resting area, using sand as litter material.

Among the passive systems for environmental control of buildings used for the dairy houses in the summer heat typical of the South of Italy climate, natural ventilation takes on particular importance as it represents the most efficient way to modify the thermo hygrometric condition of the air and reduce the concentration of noxious gas and dust.

The theoretical approach generally adopted to determine the summer natural ventilation flow for a livestock building consists of setting up an energy balance of sensible heat flows, based on the hypothesis that all the heat produced by the animals will be removed from the environment by the ventilation, allowing an increase in temperature of about 2-3°C between the inside and the outside. However with this method it is not possible to obtain information on the ventilation flow distribution or the form and dimensions of the openings and no account is taken on the effect of the wind on the ventilation capacity, or the effect that differences in temperature can have on the movement of air within the livestock building environment.

A more modern method for the study of natural ventilation conditions in livestock buildings consists of a thermo and fluid dynamic analysis of the livestock environment. This method makes it possible to determine the value and the distribution of the thermo and fluid dynamic parameters of the air by means of a numerical integration of the differential equations describing the physical phenomenon of air movement within the building and immediately around it (Computational Fluid Dynamics).

In Sicily the research on the ventilation of dairy houses based on thermo and fluid dynamic analysis has been accompanied by experimental trials that have constituted an adequate basis for the identification of appropriate design solutions as regards building cover and openings for natural ventilation.

MALTA:

The dairy cow is a relatively recent introduction in Maltese agriculture. It was introduced in attempts to curb on milk infected by Brucellosis Melitensis. In 1956, a program was launched where a herdsman was offered one pregnant Dutch Friesen heifer for 12 diseased goats. The introduction of the dairy cow led to the following problems. Over night, the Maltese herdsmen, or more correctly shepherds were transformed to dairy farmers. Modern dairy cow units consist of a system of cover open sided structures that lack a clear sense of design, functionality and purpose. Concrete and pre-stressed cement slabs are widely used. Total milking population 9,000 cows.

MOROCCO:

Dairy production in Morocco is based on small herds (average of 4-5 cows per farmer). Therefore, barns are designed to accommodate such a size.

In many cases, the type of housing is selected based on availability of funds and on “what worked best for neighbors”.

A variety of housing configurations are found in Morocco. The most frequent are:

- The loose housing. Such barns are used either full time or part time according to the feeding system adopted by the farmer. Animals have very often free access to a paddock with no bedding. Straw bedding is used inside the barns especially in winter. The paddocks are used during almost the whole day except during milking time. The animals receive forage in the paddocks and concentrate feed during milking. The space per cow (barn and paddocks) varies very often between 10 and 30 m^2. The paddocks may or may not have shade. This housing system is found mainly in more specialized dairy farms; and

- For many small farmers, the animals go out for grazing (grass in spring, stubble in summer, etc.) during day time and are tied in a barn at night and at milking time.

Very few farmers manage the animals by group. So the heifers are very often reared with the cows. Headlocks which can separate and restrain the animals at the manger are used only by very few farmers.

Orientation: alignment of the long axis in a North-South direction is the most frequent orientation as it allows sunlight to dry out the floor. Such orientation is advantageous in winter, but allows a greater solar radiation exposure in summer than the East-West orientation. Some farmers in the Southern part of Morocco choose an orientation that allows for less morning and afternoon solar exposure. Concrete slab floor are preferred by many farmers with slopes varying from 0 to 2%. Roof slope is nil, which reduces air flow and exchange. The stall length varies mostly between 1.6 and 2.6 m, and the width between 1-1.20 m, with or without separation.

Air exchange and ventilation: natural air exchange is a function of sidewall openings, barn width, etc. In Morocco, farmers avoid large sidewalls openings. They believe that large openings will be detrimental to animal health through development of respiratory diseases.

Water location: an important mean of managing heat stress in cattle is to provide enough fresh and clean water. Unfortunately, very often water is provided to animals in buckets once or twice a day. Water consumption increases as temperatures increase. Therefore, it is critical to have adequate water available for animals.

The management of heat stress is accomplished mainly with shade. Very few dairy farms combine shade and sprinkling. Only one farm uses forced ventilation (fans) as well. The shade is provided either naturally by trees particularly in small herds or artificially through the use of constructed shade structures or barns.

The young calves are reared in individual or collective boxes. Some small farmers keep the calves with their mothers. The individual boxes vary in size: most farmers have boxes with 0.9-1.2 m width, 1.2-1.8 m length, providing about 1.5-2 m^2/calf. The collective boxes present the disadvantage of potential disease transmission between calves. The area per calf varies between 1.5-2 m^2.

The material used in building: The barn's floor is very often made from concrete. The walls are made either from:

- Bricks, with or without coating (especially in the Northern part of Morocco);

- "adobe" bricks, which is a combination of clay and straw (about 40 cm width);

- "pisé" which is a rammed clay (about 50 cm width); and

- rocks with mortars of cement or soil and straw.

The roof is made either from concrete, asbestos cement, aluminum or local material. The local material consists of an upper layer of soil and straw on a plastic film under which there is a layer of reeds. This local material is used mainly in the Southern part of Morocco because of its thermal resistance.

PORTUGAL:

Dairy production in Portugal is located in Azores Islands with continental climate (without heat stress problems) characterized by small familiar units, in the sea zone of the North of the country also with small units in intensive forage and pasturage systems, with closed buildings were the animals are tied, sometimes without any acclimatization system and provided by natural ventilation by walls. Some recent farms have a building with both a closed free stall zone and an open zone. In the South of Portugal there are some big units with more than 500 milk cows. In this case the open buildings are used with a complete open zone and very often the inside zone is divided in cubicles (free stall systems). In this case some cooling system like fogging or direct sprinkling on the animals and fans are used.

SPAIN:

Dairy cattle farms are not very common in hot regions of Spain, but the few farms use open barns.

All the generally typical characteristics used in dairy cattle farms are:

- High buildings with isolated roofs; and
- Big windows or completely open faces of the buildings, to facilitate the ventilation.

SWEDEN:

As in all countries the structure of agriculture is developing towards bigger and fewer enterprises. Since 1950 the number of dairy producers has reduced by 50% every 10 years. Today Sweden has 8,500 dairy producers with an average herd of 50 cows and yielding 9,300 kg ECM per cow and year. Forty percent of the cows are kept in loose housing.

Grazing is compulsory for all cattle except bulls and small calves. The pig production has even more changed today's; 2,000 producers is just 15% of the number 15 years ago.

Because Sweden has a cold, rainy/snowy winter climate, it is necessary to keep most of the animals inside during the winter season. Only a minor production of beef cattle, sheep and dry sows are kept outdoors with access to shelters or huts. This is also enforced by the animal protection legislation. Sweden has a special Animal Protection Agency since 2003.

• Beef Cattle

BRAZIL:

Beef cattle in Brazil, is mostly raised in extensive systems due to the large farming areas found in large regions of the country. Intensive systems are rarely used as compared to the whole country's extension but, when adopted, it can be found mostly in the Southeastern part of Brazil. The construction used in extensive systems are mostly handling corrals enclosed on its sides using wood lumbers and hoof coverings, usually fiber-cement, on top of the feed and mineral bunks only. Feeding is composed, mostly of pasture and some places can add concentrate feeding (minced corn, soybeans, etc.).

Intensive systems apply full enclosed concrete or wood constructions types, and feeding is composed of a complete balanced formulation, roughage and mineral inside the barns for improved fattening of bulls. For both systems, it is applied only basic sanitation for disease control methods such as parasitological and regular vaccination.

EGYPT:

Geographically, the heaviest concentration of beef cattle inventories are located in the Northern part of Egypt, which is called Lower Egypt, and has about 69.1% of the total fattening projects. The Middle Egypt is located in the second rank with about 20.4%, then the New Desert areas with about 6%, and finally Upper Egypt with about 4.5%.

For large herds, the suitable housing for beef cattle is the open housing system with the same standards mentioned previously for dairy cows. The breeding is in small groups of 9-12 heads which are enclosed with rails. For medium herds, the total confinement housing system with tie-stall is the utmost used housing system. For smaller herds, the housing system used is an open yard with a simple shade made of brick columns and a ceiling of natural materials such as hay.

The most common building materials used for feeder calves barns were: bricks and limestone blocks for walls. While for ceiling, which was always slab ceiling, the common materials were: reinforced concrete, corrugated sheets, wood sheets, or hay. Floors are made of ingot concrete.

MALTA:

Beef cattle production has a long history Malta. Store cattle of various genetic backgrounds were imported from within the Mediterranean basin. These cattle were fattening for slaughter. The Modern beef industry is an offshoot of the dairy industry in as much as the cull cows together with the male born form the bases of this industry. The majority of beef is housed on the dairy farm. Same comments apply. Total beef cattle herd is 7,000.

MOROCCO:

Housing systems for beef cattle vary less across Morocco. While loose housing is most common for dairy cattle, tied housing is the most frequent in the country.

Barn length varies according to the size of the herd and may reach 60 m. The width is generally in the range of 4.5 – 10.5 m, while the height may vary between 2.5 and 5 m. The following Table 8 shows results of a study done in 16 farms.

Table 8. Results from study done in Morocco on barn length

Dimensions	Min. (°C)	Max. (°C)	Average (°C)
Length (m)	6.0	60.0	27.0
Width (m)	4.5	10.5	7.4
Height (m)	2.5	5.0	4.0
Area (m^2/animal)	2.5	8.5	5.7

The material used to build the barns is the same as the material used for dairy cattle. The farmers prefer walls in bricks and concrete roof. However, this building option is the most expensive. Some farmers use aluminum for the roof, but presents the disadvantage of being thermal conductive, generally cold in winter and hot in summer. Some farmers, when it is hot, put trusses of straw on the aluminum roof and spray water over it to decrease temperature inside the barn. As well, many barns have openings in the roof that are opened in summer time. The floor is made of concrete in most cases.

The mangers vary in length, width and depth, as shown in the following Table 9 from a study on 16 farms.

Table 9. Study done in Morocco on manger's length

Dimensions	Average (°C)	Min. (°C)	Max. (°C)
Length (cm)	62	46	100
Width (cm)	53	43	76
Depth (cm)	27	20	40

In these systems all or part of the excreta is collected in the form of slurry. If solid manure is produced, it is removed from the barn daily.

Buildings in which the cattle are held in tied stalls need less space than loose housing, and they prevent the animals from fighting as the fattened cattle are not castrated. Some farmers tried the group-housed animals system and experienced conflicts and aggression between animals arising from rank-dependent social dominance.

In these tied-system buildings, the tether design allows the animal to move little bit forward and backward when rising and lying down. However, very often the tether does not give the animal sufficient leeway to lick itself over most of the body without being forced to assume unnatural positions. These tethered animals do not have daily access to a suitable exercise area for welfare considerations. Chains are used to tie the animals to the mangers. Their length may vary between 0.5 and 1 m according to the behavior of the animal. The distance between animals is sometimes small which is favorable for competition for feed. Furthermore, as cattle have a need for social contact, the tie-stall system, with animals facing the walls may induce a stressful situation as reported in some studies.

The majority of the farmers use buckets of water to the animals. Some others, especially those having a big number of animals, use the mangers as water flowing through. Very often, animals receive water once a day, sometimes twice. Almost half of the cattle feeders avoid to have water troughs aside of the animals to prevent the animal from the feed. Some other farmers do not see any economical advantage from such investment. Straw is very often used as bedding for animals, especially in winter. The daily amount of straw per animal used is about 2-3 kg, and may increase or decrease in accordance to the price of straw. Such straw-based systems allows for solid manure production.

The feed manger is usually placed against the sidewall, at 0-20 cm above floor level. In the very few group-housing systems, there is generally enough feeding space so that all animals can eat at the same time. The width of the individual eating place in the tie system barns is 0.9-1.1 m. Very often no separation is placed between animals.

In summer, the sidewall windows and the possible roof openings are open to allow air exchange in the barn. In winter, the barns are totally closed which generate an accumulation of harmful gases inside the barns.

PORTUGAL:

There are two typical situations for beef production in Portugal. The first is the herds with beef cows and cattle in pasturage systems where the animal housing is almost absent. The second is the intensive fattening systems with small closed building, with natural ventilation to house the fattening animals, according to their age or weight. The floor of these buildings is made by concrete covered by straw or is soil floor.

SPAIN:

Most of the beef cattle farms in Spain are intensive and specialized fattening farms. These farms use to be natural ventilated buildings that can have open areas. Most of the general measures for preventing from the heat stress are applied in all farms, but when the farms have open areas for the animals, the surface per animal is increased.

• Small Ruminants (Sheep and Goat)

BRAZIL:

The housing should attend a production system defined by the producer, according to his objectives and financial capabilities. When a producer makes a choice of an extensive system, the installations could be simpler, comprised only by milking parlor units, grazing and animal handling. When he decides for an intensive confined or semi-confined system, the project becomes more complex and should have, besides these, food storage and animal confinement buildings. Generally, the production of goats and sheep use semi-confinement, where the mothers remain loose in the pasture in the mornings, whereas the young are confined in the buildings during the first week of life. After that, the young start to follow the mother.

CZECH REPUBLIC:

Sheep farms are mostly situated in the mountains, without grave problems of heat stress during summer. Several sheep farms were tested during eighties (in winter periods: comparison of timber and brick constructions, natural and forced ventilation and different systems of housing and manipulation technology). Dramatic reduction of sheep breeding has been since nineties.

EGYPT:

Building type for sheep and goats are closed building for night time, and open yard with sheds for day time.

Generally, the most common sheep housing system used in Egypt can be described as following: the main layout is a rectangular shape; one third of the total area is dedicated to a closed building, in other words a total confinement system which is useful to accommodate the sheep at nights and during winter. The remaining two thirds of the total area are dedicated to a big open yard part of it (about one third of the open yard area) is shaded with a shed in condition of using natural materials to construct the roof, such as hay or reed mats. The mangers and the water pails should be located under the shed in shade.

GREECE:

Summer experiments try to investigate the differences among various breeds with regards to the effects high temperatures and solar radiation has on physiological parameters (e.g. heart and respiration rates, body temperature) and welfare aspects (e.g. body posture, feeding behavior). Although too early for conclusive results, it seems that hot weather conditions significantly affect all the above.

ISRAEL:

The housing design for the small ruminants complies with the climatic and environmental considerations guiding those of the dairy barns. Namely: good ventilation during the hot summer, but also a dry and wind-sheltered environment during the winter. This is done by a proper closing (wall) around the shade of at least 1.8 m height. It is recommended to add an open yard connected to the shade. In this case the openings to the yard have to be wide with the possibility to close them during cold days in the winter. However, an open yard is not a must. Because of wind directions in Israel, it is recommended whenever possible to build the shade so that the longitude axis is from North to South. The space details for sheep and goats are summarized in Table 10.

Table 10. Space details (m_2 per animal) for housing of sheep and goats. For grazing sheep (meat) the space per mother can be reduced (from Shoshani, 2000).

	Sheep			Goats	
Location	Mothers and Litter	Mothers	Kids	Mature goats	Young goats
Shade	3.5	2.5	1	3.5	1
Yard	3	2	1	2	1

There are two main types of small ruminants housing that are recommended in Israel (Shoshani, 2000):

1. A shade with a yard on one side or both sides, shade width – 12 m. 13 m when there is a service lane in the middle of the shade. Shade height 5 m maximal part, and 4 m minimal part. Width of each open yard - 8-10 m with one sided trough for full herd capacity alongside the yards or shades (when no yards). Concrete feeding trough width - 0.8-1 m, concrete feeding alley - 1 m alongside the trough; and

2. A covered feeding passage with shades and yards on both sides; a covered passage 4.5 m wide, with two 6 m wide shades on both sides, and connected to the shades, two open yards 6-8 m wide each. Forced ventilation is needed because of the width of the shade. A roof opening in the middle is recommended to improve ventilation in both shade types, but it is more significant in type 2.

ITALY:

As regards sheep studies have been carried out on the effects of environmental factors and management techniques that can influence the animal welfare and their reproductive and productive performance. The hyperthermia brought about by high environmental temperatures provokes in sheep physiological processes of a compensatory nature, such as increase in the rectal temperature and in water consumption, and a decrease in milk production, in the quantity of heat produced, in food consumption and in thyroid activity.

Heat stress, moreover can negatively influence the colostrum composition and growth and reproduction. In particular, when a sheep or lamb is subjected to hot environmental conditions either in the initial or the final phase of pregnancy, there is a reduction in the placental and fetal development. Most of the studies on sheep, however, have been carried out in different types of environments and with different genetic types from those found in Italy, with the purpose of evaluating the thermoregulatory response to heat stress. Few studies have measured the effects on the animals' performance.

In the Sicilian livestock breeding system, the sheep generally give birth between August and October and so the sheep have to face the final phase of pregnancy and the beginning of lactation in the most critical period.

Among the ways it is possible to operate to mitigate the negative effects of high temperatures; the use of simple and economical structures providing shade has had encouraging results.

The advantage of trials carried out directly in the field in comparison with those carried out in a climatic chamber, despite the greater difficulty in controlling the numerous climatic and physiological variables, lies in the fact that the thermoregulatory response of ruminants raised in climatic chambers differs both qualitatively and quantitatively from that of animals exposed to natural environments.

MALTA:

Traditionally the most numerous milk producing animal was the Maltese goat. They together with the sheep population were important because they could utilize the great extent of waste land as natural pasture. Thus unsuitable for cultivation, provided a yield in the form of goat and sheep milk and meat. Today the total sheep and goat population numbers adds up to 8,000 animals. Most are still kept in the traditional housing as described above. There are recent efforts to reintroduce the local goat and sheep breed and to exploit these animals for milk and other dairy products. Thus efforts in evaluating suitable housing are justified.

PORTUGAL:

The sheep and goat production has major importance in the inside zones of Portugal. In some zones, milk from specialized breeds or from local breeds for cheese fabrication is the main product of the farms. The pasturage system is used and the animals are housed during the night periods or during the hottest periods of the day, due to the strong solar radiation.

In the North of the country the buildings are closed with few and small ventilation overtures. In the South there are open buildings with big ventilation overtures. In general buildings are East-West oriented.

SPAIN:

They use to grow under extensive or semi-extensive production systems. The animal houses are characterized by its simplicity. The general techniques for protection from the heat are applied.

- **Camel Housing**

EGYPT:

Camels are housed in open yard (10 m2/head) as free or loose system, the yard ground is sand and the yard is surrounded by a wall of 1.8 – 2 m height. Some sheds of 3.5 m height and 3 m width were located at the yard borders, under these sheds some feed bunks and some water troughs were placed. At the yard borders and under shed some tie-means were fixed; therefore, camels are tied up when needed.

5.2. Birds

- **Poultry**

BRAZIL:

Poultry production in Brazil has undergone significant advances in the last three decades. East-West construction orientations are predominant and construction materials insulating capacity are being improved. Building construction materials, in poultry houses, are mostly concrete and bricks. Lateral walls use concrete as well and are approximately 30cm in height with moving lateral curtains used to improve the climatic environment within the bar, activated when necessary.

Cooling system equipments used inside the barns are mostly tunnel ventilation or axially installed positive pressure fan types. The ceilings are built mostly from plastic canvas covered with ceramic, galvanized metal or fiber-cement or vegetal-cement roofing types, and the pavement is mostly concrete but, compacted dirt is not uncommon.

CZECH REPUBLIC:

Many poultry farms were adapted according to the Council Directive 1999/74/EC during the last years. The ventilation systems are mostly modernized during the reconstruction as well. The ventilation by fans of big diameter (over 1000 mm) with low specific consumption of energy, the application of tunnel ventilation during the summer period and the use of evaporative cooling (in broilers farms) are more common now. The research work was focused on the modeling and simulation of the indoor conditions during the different periods of the year and to the comparison of different methods of evaporative cooling. Commercial high-pressure nozzles were compared with low-pressure nozzles and with pneumatic nozzles.

EGYPT:

There are 18000 broilers' farms in Egypt, which houses 700 million birds of foreign breeds. The domestic small farms houses 150 million birds of local breeds. There are 39 companies or huge farms which house the grand parents (200,000 female) in order to produce parents' stocks (broiler breeder) which are approx. 7 million birds. Broilers are housed either in closed buildings as total confinement system or in open yards as open housing system. The used types of environmental control system differ according to the used housing system. For open yards, natural ventilation is used, but in total confinement system an evaporative cooling system should be installed such as cooling pads and extractor fans cooling system or fogging systems. The building is oriented East-West i.e. the main axis of Building is oriented from East to West, meanwhile prevailing wind direction from North.

ISRAEL:

The environmental physiological challenge for poultry in Israel is similar to that of other livestock animals that is heat load during the long hot summers. Poultry houses (excluding turkey) in Israel follow Donald (2001) Guide, and are all climate-controlled by ventilation, active, passive, and combined. If it is passive, than the poultry house will be build in accordance with the wind direction during heat loading diurnal hours, aiming its longitudinal axis to be perpendicular to the wind direction. Passive ventilation is controlled by shutters or curtains or both. The active ventilation systems take all shapes and sizes, depending on the degree of passive ventilation, and local conditions. The fans can be located on the width axis as tunnel ventilation or transitional ventilation with air entrances on all or part of the longitudinal and opposite width axis. When fans are located on the longitudinal axis, the air entrances can be on part or the entire opposite wall as well as on the width axis. The principles outlined by Donald (2001), were adopted by a company AGROTOP® (mail@agrotop.co.il) that gives design, technical, and operation solution regarding all components of poultry houses. Recently, evaporation cooling systems that include pad and fan cooling and fogging can be seen. Roof sprinkling during strong solar radiation is performed in layers houses.

In Israel the annual production of broilers is 350 thousand tons out of which 87% are farmed in climate controlled housing of some sort. Most of it is a combination of passive and forced ventilation which is also used during winter to dry the bedding. Another 13% are farmed in open shades relying on natural ventilation sometimes with roof sprinkling (publications of The Egg and Poultry Board of Israel, and Yahav, S. personal communication).

ITALY:

Not much has been done in Italy concerning the reduction of the heat stress in poultry housing. Often the evaporative cooling is used in the houses. The attention is generally given to the ventilation systems and control being the mechanical ventilation mainly adopted.

MALTA:

The poultry industry as such is the results of huge efforts invested in the late 1960's. In this sector internal equipment is 100% imported. Barn constructions are usually standard units that could be built with the least of expenses using stone walls and cement roofs. In order to prevent the introduction of beams the standard with is of about 20 Feet. Typically broiler housing is designed to carry 2500 birds (the average daily slaughtering capacity of the abattoirs). Layers on the other hand have a typical capacity of about 5,000 layers in cages. In both cases temperature control is very primitive, with the exception of evaporative cooler. Total poultry population: layers 400,000 and broilers 3,000,000. Pigeons are found as backyard animals and turkeys have a highly seasonal production.

PORTUGAL:

Broiler production in Portugal is based in big production units with more than 20.000 birds per building in littered house system. These buildings are in general well insulated, provided with heating and mechanical ventilation systems and, in a significant number, with evaporative cooling systems as fogging or cooling pads.

SPAIN:

Broiler production in Spain is done under intensive conditions for the most part, in closed buildings and with no outdoor areas for the animals. When the farms are naturally ventilated, apart from the thermal isolation (for reducing heat transmission), it is very common to reduce the number of animals in the hot season. Therefore, in winter and spring season, stocking rate is of 8-9 birds.m^{-2}, and it is reduced to 6 birds.m^{-2} in the summer season.

Another typical group of poultry farms in Spain, in relation to its climate facilities, are those that are mechanically ventilated, build usually with prefabricated materials, with a high thermal isolation coefficient, and provided with an environment control system. They are usually ventilated by cross ventilation, and they also employ evaporative cooling systems, by using wet pads or high pressure fogging systems.

Finally, longitudinal ventilated buildings are not widely used in Spain, although their number is increasing recently. These buildings, also known as tunnel ventilated farms, provide higher air velocities inside of the house, for decreasing the animals heat stress.

SWEDEN

The production systems in respect to animal welfare are changing fast over time due to new EU rules, Swedish laws and animal welfare organizations. The Swedish animal protection legislation is very rigid and detailed. Size of pens and stalls, floor type, specified values for aerial environment (temperature, humidity, air velocity, gases, noise and dust) must be fulfilled or not exceeded. New or rebuild animal buildings must get their drawings approved according to animal protection before they are allowed to be built.

- **Layer**

BRAZIL:

In majority, egg laying poultry have simpler construction housing designs than meat poultry. East-West construction orientations are also predominant for this type and construction materials are usually wood, concrete and metal. They are mostly open on the sides and on one of the fronts with a compartment for feed stuff storage on the front side. The pavements are made of concrete on the handling corridor area and between the hanging pens. These barns have also moving lateral curtains and use ceramic, galvanized metal, fiber-cement or vegetal-cement roofing types. Cooling systems are hardly used, but when applied, are mostly forced ventilation without sprinkler systems.

EGYPT:

The laying hens in Egypt are mostly housed in total confinement housing system which is a totally closed building. The floor breed type is mostly used, so that the floor of the building is made of ingot concrete then covered with a layer of litter (15 cm in depth). The roof is made of corrugated aluminum; in order to avoid high heat flux the roof is internally isolated. The natural insemination is used, so that the laying hens are breed in the same place with males in ratio of 1 male / 9-12 female depending on the species. The fans cooling pads system is extremely used to maintain the ambient temperature between 24 and 28 ^{o}C. The feed is distributed to females by belts-conveyors, and to males using pan feeders and screw conveyors. Egypt produces approx. 7.5 billions eggs/year.

ISRAEL:

There are seven million layers in Israel but only 1/5 a million (7%) are farmed under active climate controlled housing conditions. All the rest live under passive controlled conditions in open housing batteries equipped with roof sprinklers and curtains.

PORTUGAL:

The traditional housing system for laying hens in Portugal is the battery cage design. However with the legislation concerning with animal welfare there is a transition to the deep-littered house or to slatted floor house systems with individual nest. In both cases, as in broilers, the buildings are well insulated with systems of environmental control.

SPAIN:

Regarding laying hens farms, the most common production system, consists of battery cages, inside of LTC buildings. The techniques to reduce the effect of the heat that are used in farms under hot climate conditions are two:

- Pad cooling systems, in cross ventilated buildings; and
- Tunnel ventilation, together either with pad cooling, or without cooling systems.

SWEDEN:

For laying eggs there is a ban of conventional housing since 1990 and today's cages must contain nest, sand bath and perch.

- **Turkey**

BRAZIL:

Turkey housing in Brazil has similar typology characteristics as well as the construction methods as broiler housing. Feeding and drinking equipment are more robust and acclimatization equipments are usually adapted for larger animals, similar to those used for broiler breeders. Two phases are generally considered when the birds are transferred from nursery housing to a fattening housing up to slaughter.

Supplementary heat is used during the first stage to maintain temperatures around 20°C. For older birds necessary ventilation is usually provided by axial fans distributes inside housing. Density used for light female (4-6 kg) is 8 birds.m^{-2} while heavy birds (9-11kg) are housed at 4.5-5.5 birds.m^{-2}. Heavy hales are housed at approximately 4.5 birds.m^{-2} . Turkeys are slaughtered aging around 150 days weighting up to 20kg.

EGYPT:

Different housing systems are used to house turkeys in Egypt. One of the most popular types is the open system using shade structure. Other housing systems, most recently used contain totally shaded sand yard by a shed of 3 m height and is made up of corrugated aluminum; the yard is enclosed by a metal fence which allows total natural ventilation. The recent economic housing type is used to lodge large herds; this type is similar to barns of laying hens.

ISRAEL:

Most of the turkeys in Israel are farmed in open shades.

5.3. Swine

BRAZIL:

Swine production in Brazil has highly controlled feeding as well as sanitary care. Housing is built for specific production such as gestating sow's housing, farrowing building, nursery and growing and finishing housing. The most common type of environmental control used is the association of axial fans with fogging or spraying systems especially for gestating and finishing houses. Several research have been carried out in order to determine the most effective way of housing swine in all ages.

CZECH REPUBLIC:

Different farms, different kind of construction and different principles of ventilation were tested during the last decades. The evaporative cooling is sometimes used in breeding farms (reduction of heat stress of sows).

GREECE:

Since 1988 research work has studied or simulated (Panagakis et al., 1991; Panagakis et al., 1992; Axaopoulos et al., 1992; Panagakis et al., 1996; Panagakis and Axaopoulos, 2004) the performance of early-weaned piglets and growing-finishing pigs under Greek summer conditions. A first finding of all the above was that the performance traits (i.e. daily weight gain, feed conversion and daily feed intake) were hindered when heat-stress indices such as the duration and the intensity exceeded certain levels.

These indices first introduced by Nienaber et al. (1987) were explicitly defined as follows:

Duration of heat-stress: Number of hours the inside temperature exceeds the upper critical

Intensity of heat-stress: $$I = \int_T \int_t \Delta T \cdot \Delta t \qquad \text{Eq 7}$$

Where: I is the heat-stress intensity (°Ch), ΔT: is the difference between the predicted inside dry-bulb temperature and the UCT (°C) and Δt is the time span (h).

Another important finding was that the commonly used Temperature Humidity Index, defined by Roller & Goldman (1969) to be:

$$THI = 0.45 \cdot T_{iwb} + 1.35 \cdot T_i + 32 \qquad \text{Eq 8}$$

where: Tiwb (also named in this document as WBT) is the inside wet bulb temperature (°C) and Ti (also named in this document as DBT) is the inside dry bulb temperature, cannot be considered as an appropriate heat-stress index as it exceeds the value of 85 (set by Fehr et al., 1983) for very few hours, the reason being the low ambient relative humidity.

Use of the Production Space (a quadrilateral specified by the desired inside min. and max. temperatures and the corresponding min. and max. relative humidity) helped identify the likely heat-stress growing-finishing pigs are undergoing. In all corresponding papers it was shown that the period from May to September represents the major problem for swine housing in Greece.

On-going research (Panagakis & Axaopoulos, 2005; submitted to Transactions of the ASAE) simulates the effect that evaporative pad systems and fogging systems have on the reduction of heat-stress of growing swine. Four strategies were studied, namely: 'strategy a' - no evaporative cooling, 'strategy b' - use of evaporative pads, 'strategy c' - use of fogging with the same amount of water evaporating as within the evaporative pads and 'strategy d' - use of fogging with the necessary water evaporating so as to result to the same intensity of heat-stress as strategy 'b'. Indices such as the THI, the hours THI was above 85 and the duration and intensity of heat-stress were used. Initial results support the findings of Timmons & Baughman (1983) and Bottcher et al. (1991), that the evaporative pads system is much more efficient than the fogging system. Among all, 'strategy b' was considered the most effective, because it resulted in maximum reduction of heat-stress intensity, smaller daily inside dry-bulb temperature variation and lower total consumption of water.

MALTA:

The modern swine industry is the result of the drastic changes that happened in the late 70's early 80's. Nonetheless new farms were constructed using the principle of open sided and also of enclosed barns. In the case of enclosed barns concepts of ventilation are not well understood and ventilation related problems are common. With open sided barn, pigs suffered sunburn and heard boars may also compromise on fertility during the hottest times of the year. Design standards are those established by least cost material use as the priority.

ITALY:

In addition to the general aspects mentioned above, a lot of work has been carried out regarding the direct sprinkling and/or blowing air on animals, especially the gestating or farrowing sows.

For farrowing sows two systems have been investigated: the "drip cooling" (using water) and the "snout cooling" (blowing air). In the second case air was blown through a plastic pipe near the sow's head at a speed of 7.2 m s^{-1} and rate of 88 m^3 h^{-1} per animal.

The results showed that the combination of both the systems could be the most effective solution, and that a full solid floor area under the head of the sow could be helpful to reduce heat stress.

For the gestating sows the use of showers revealed more effective than misting. Tests are still going on about the use of individual stations for showering animals with free access.

PORTUGAL:

There are three basic systems for pig production in Portugal: piglet production (first phase), growing-finishing pigs (second phase) and close or complete cycle. Pig production was located near Lisbon and in the centre of Portugal in the coast zones due to more favorable climatic conditions and proximity to the great cities. The buildings located in these zones are old buildings with roof insulated with mechanical ventilation systems and without cooling systems. The new pig farms are located now in Alentejo zone which is characterized by great extensions of land far from urban centers but with poor climatic conditions (cold winters and very hot summers). In these farms the new buildings for the first phase have automatic feed systems for sows when they are not tied. Cooling with sprinklers directly on the animals is common during pregnancy. In the nursery period the fogging systems in the windows before air inlets are also used. The buildings for weaning piglets are provided with mechanical ventilation systems with heating. The fattening house is, in general, well insulated with natural ventilation. Some times evaporative cooling systems are utilized.

Also the outdoor pig production systems are very popular in Portugal, not only for local breeds but also for “industrial” breeds. In this system, the main building is composed of insulated individual small building for the sow and the piglets, spread out in the fields.

SPAIN:

Apart from the general measures that are also applied in swine farms, another specific technique is used in these farms, that is, wetting the animals by showers. In mechanically ventilated buildings (those that are more adapted to hot conditions), cooling systems can also be used, mostly by means of wet pads.

SWEDEN:

The pig production nowadays has changed dramatically. Today’s 2,000 producers is just 15% of the total number of swine producer’s number 15 years ago.

5.4. Rabbit Housing

EGYPT:

The Egyptian people like so many foods made of rabbits, so that rabbit's projects are economically important. The widely spread rabbits housing system is the total confinement housing system, with installing fans and pads cooling system to decrease the indoor high temperatures. Rabbits are mostly breed in cages or batteries. The building roof which is made of corrugated aluminum sheets should be internally isolated with an isolation material such as rock-wheal, and externally with hay.

CZECH REPUBLIC:

Several farms of different capacity equipped by different technological equipment for housing of rabbits and by different methods of ventilation were compared. The air-conditioning on one of the farms was used. Positive influence of air-cooling was paid on the other side by the high consumption of energy and by very high investment costs.

ITALY:

Very little research in hot climate housing has been done for rabbits. The evaporative air cooling is often adopted.

MALTA:

Rabbits are a very heterogeneous industry, having individual producing units of 5 does and units having 100 does and more. The smaller units are usually kept as back yard animals and would meet the needs of the immediate family. Units of 50 does or higher are usually run on a commercial scale. Commercial rabbit units adopt unused swine and broiler barns, resulting in many compromises very often to the determent of production performance. New rabbit farms of 500 does and over are opting of importing prefabricated modules from Italy or Spain, fully equipped with cages and environment control systems. The issue is if the Farmer understands how to manage the cooling and ventilation systems.

PORTUGAL:

Rabbits house are made by the specialized firms of feedstuffs, slaughter houses and equipment design. They follow the model that is general in use for all Europe. Buildings well insulated with cages and automatic systems of manure collection, mechanical ventilation and cooling pad are easily found in Portuguese rabbit production.

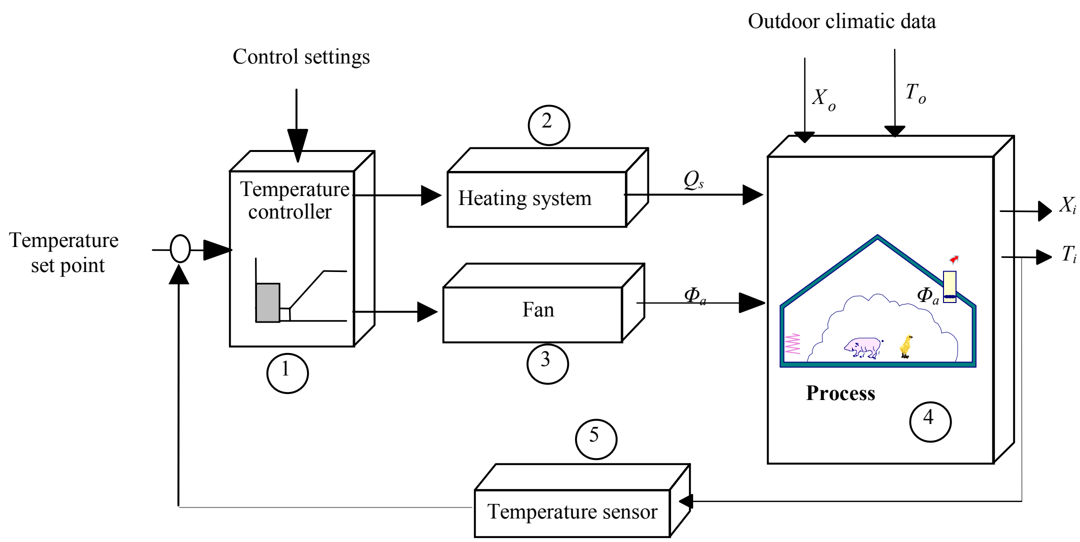
SPAIN:

Rabbit’s farms usually are cross ventilated buildings, with cooling systems, always with wet pads.

6 Preliminary Conclusions and Recommendations

BELGIUM:

To get a better insight in the effect of ventilation control on indoor climatic conditions, simulations can be very useful. The mechanistic model of Berckmans et al., 1992 consists of different sub models, as presented in Figure 24. These parts describe by a set of mathematical equations the dynamic behavior of different sub-systems of a mechanically ventilated pig house, such as the (1) ventilation controller, (2) the heating system, (3) the fan, (4) the process of heat and mass exchange within the ventilated structure and (5) the temperature sensor. The inputs of the model are the control settings (minimal and maximal ventilation rate, proportional band) and the temperature set points as a function of time. Disturbance variables are the outdoor climatic data of temperature and humidity, originating from a reference year (Dogniaux et al., 1980).



Where: QS, heat supply of heating element; Ti , indoor temperature; To ,external temperature; Xi, indoor absolute humidity; Xo, outdoor absolute humidity; Φa, air flow

Figure 24. The different sub models in the climate simulation model

The global simulation model calculates the dynamic changes of the indoor temperature and air humidity in a livestock building with a time step of 3 seconds over a time period of one year by using outdoor temperature and humidity data obtained from a dynamic reference year. The time step was chosen at 3 seconds, corresponding to the smallest time constant of the system, in this case the fan.

The model uses a number of input data, such as the time constants of the different sub systems, the dimensions and thermal characteristics of the building structure, the simulation period; the animal growth data, the heat and moisture production, and finally the control settings.

A typical simulation output for a typical Belgian fattening pig house compartment of 80 pigs is shown in Figure 25 (Vranken et al., 1997).

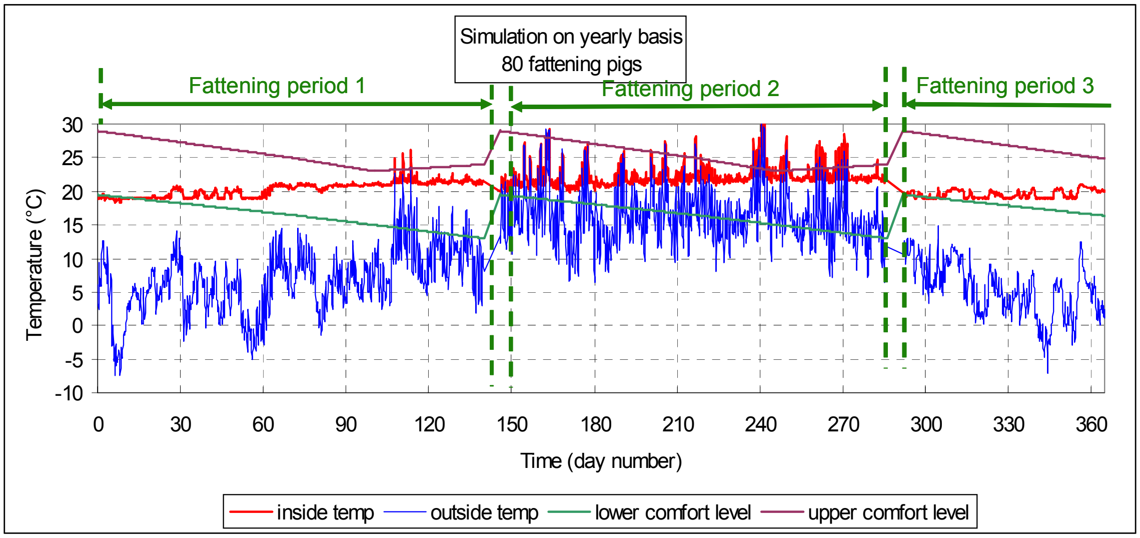


Figure 25. Simulation output of indoor temperature on yearly basis for a typical Belgian pig house compartment.

Figure 25 clearly shows the critical periods in relation to the thermal comfort zone of the animal. During the first 10 days (January), the indoor temperatures are just below the lower comfort level and in the second half of fattening period 2, the temperature are above upper critical values during hot summer days.

This type of analysis is very helpful for design of ventilation control equipment, such as fans, heating systems or cooling equipment. Such a tool can also be used to evaluate the effect of evaporative cooling systems, such as fogging on indoor climate in pig facilities (Haeussermann et al., 2005 a, b). Adapting the fogging and ventilation control to the respective circumstances can help reducing working costs. General information whether to install a fogging system in a particular country or not, as well as information about their adequate and effective control can be received by the simulation model.

Simulation of evaporative cooling for a Belgium reference year showed a reduction of the maximum indoor temperature by 2.3°C, while for a reference year from the Hohenheim region in Southern Germany a similar cooling system reduced the maximum indoor temperature by about 4.8°C. The difference in the reduction of the maximum temperature was mainly caused by the outside relative humidity, which averaged at 85 % in Belgium and at 76 % in Southern Germany, giving a higher potential to use adiabatic cooling at the latter region (Haeussermann et al., 2005a).

BRAZIL:

Brazil has mainly raining tropical climate with a central area called "Cerrados", where the dry season is well determined. As the high temperatures are generally associated to high relative humidity the major challenge is to improve the thermal comfort of housed animals using mostly ventilations systems. Evaporative cooling is also used by the association of fogging and ventilation, however during the hot weather the efficiency of those systems is significantly reduced due to high relative humidity. White coated roof is generally recommended due to high solar radiation incidence in all country regions. Also due to high solar radiation high sheds are used in dairy cattle free stalls. Poultry housing uses generally 12x100m building equipped with ventilation and fogging systems. They are open sided buildings closed with plastic curtains and bird's density is usually within recommended limits for export. Welfare issues are observed and controlled mainly in broiler housing for export. Beef cattle is reared extensively in grazing land, however there are few herds intensively reared under sheds without cooling devices.

EGYPT:

Egypt has hot dry climatic conditions causing heat stress for animals which negatively affect their productivity; thus, milk production decreases and some losses in weight and meat quality were recorded. Therefore, physical alleviation means (high sheds and cooling systems) should be used in order to decrease heat stress affecting the animals. It is highly recommended that animals should be housed in open yards shaded by high sheds of 5 -8 m height for big animals and 3.5 -5 m height for small animals. These sheds should be oriented East-West and be made by reed mats not by corrugated aluminum. An effective cooling system should be placed under sheds as results of recent researches. The most effective system under Egyptian conditions and for open housing system is the micro-sprinklers and fans cooling system which directly sprinkle the animals i.e. it directly cools the animals, but the mist cooling system cools the air surrounding animal which has been found effective for total- and semi-confinement systems.

For poultry, it is highly recommend using closed buildings or barns. Cooling pad and extractor fans should be installed instead installing other feeding means, as belt conveyors and feeding pans.

ITALY:

The practical recommendations in Italy vary according to animal species, climatic conditions and environmental control systems. In general a good ventilation is considered the most important factor for the heat stress reduction and it can be pursued (when natural) with wide openings and a good orientation towards the prevailing breezes. Especially the nighttime ventilation is considered relevant to give the animals a relief from the diurnal stress. Also the reduction of the solar load is an important object and to this purpose the roof insulation, the shading of the building surfaces and external areas, the light colors and, mainly, a proper orientation (main axis East-West oriented) are the factors to be considered. Cooling systems are used in two different ways: for dairy cows fans alone and fans with a direct water sprinkling are used in the North, while fogging can be more useful in the drier South climate. Pad and fans are used in both areas with poultry and rabbits. With pig housing, in the Northern areas some systems based on showers or direct sprinkling of the animals seem useful (although not very used), whilst in the Southern areas the pad and fan cooling system is more adopted.

GREECE:

Greek climate is characterized by mild winter (with few exceptions in the Northern part of the country) and adverse summer. Swine, dairy cattle, poultry (e.g. layers and broilers) and sheep/goats are the main species reared. In terms of environmental control (e.g. use of ventilation fans and heating/cooling systems) and waste management (e.g. use of anaerobic lagoons) swine and poultry are housed in modern units, whereas dairy cattle is housed under mediocre conditions. Sheep and goats are grown under very poor conditions mainly because they are raised at the most mountainous areas of the country.

MALTA:

Using modern materials and equipment many challenges could in principal be overcome. Nonetheless a comprehensive study should be conducted keeping in mind the general nature of the problems faced with hot climate and the trends that are highly probable to face the Maltese livestock sector. We could see the remerging of the rustic type of production with a lower lever of intensification. All this enclosed within the framework of agricultural tourism and local gastronomy.

MOROCCO:

First, enhance natural ventilation through designs which allow for maximum natural ventilation and protection from solar radiation. Critical areas include barn orientation, sidewall height and clear opening, roof slope, ridge opening, building width and removal of wind shadow. Second, provide adequate water space and volume. Third, for big size farms, utilize effective supplemental cooling systems which are cost effective. Using feed line sprinklers which wet the cow and then allow the water to evaporate are very effective in reducing heat stress. In addition to the feed line sprinklers, fans are needed to increase air circulation. Fourth, Manure, stored on the floor, in open-air, may be a source of pollution of underground water. It is recommended to make the farmers aware of the risks of such a way of storage and to the need to build pits. Fifth, some transformations are needed to adapt the stall length to the animals, have a slope towards the gutters and widen the gutters.

PORTUGAL:

Research activities developed by the Portuguese team are related with the design of outdoor buildings for swine and poultry, design of small ruminants and dairy cow buildings and environmental control of livestock buildings. In this subject aspects like the use and efficiency of evaporative cooling techniques (cooling pads, fogging and sprinkling systems) and also the aspects related with the effect of environmental conditions in animal production and welfare were object of many publication.

SPAIN:

Two different climatic conditions can be found in the hot regions of Spain: high temperature and low relative humidity; and high temperature and high relative humidity. The measures that are used, as a protection from the hot outdoor environment, differ depending on the climatic condition. If the farm is located in a hot and dry area, mechanical ventilation and evaporative cooling systems (foggers or wet pads) are used. However, if the outdoor environment is hot and humid, the evaporative cooling systems are not efficient, and it is recommended to use alternative methods, such as increasing air velocity over the animals by means of fans.

When mechanical ventilation is not available in the farm, the ventilation can only be performed by natural methods. In this case, it is a common practice to relieve the effects of the high temperature by reducing the stocking density during the hottest months of the year.

7 Final Remarks

Panos Panagakis, Paolo Zapavigna,
Irenilza de Alencar Nääs, and Vasco de Fitas Cruz

According to the Sustainable Development (SD) Department of the FAO, the global climate is classified as seen in Figure 25.

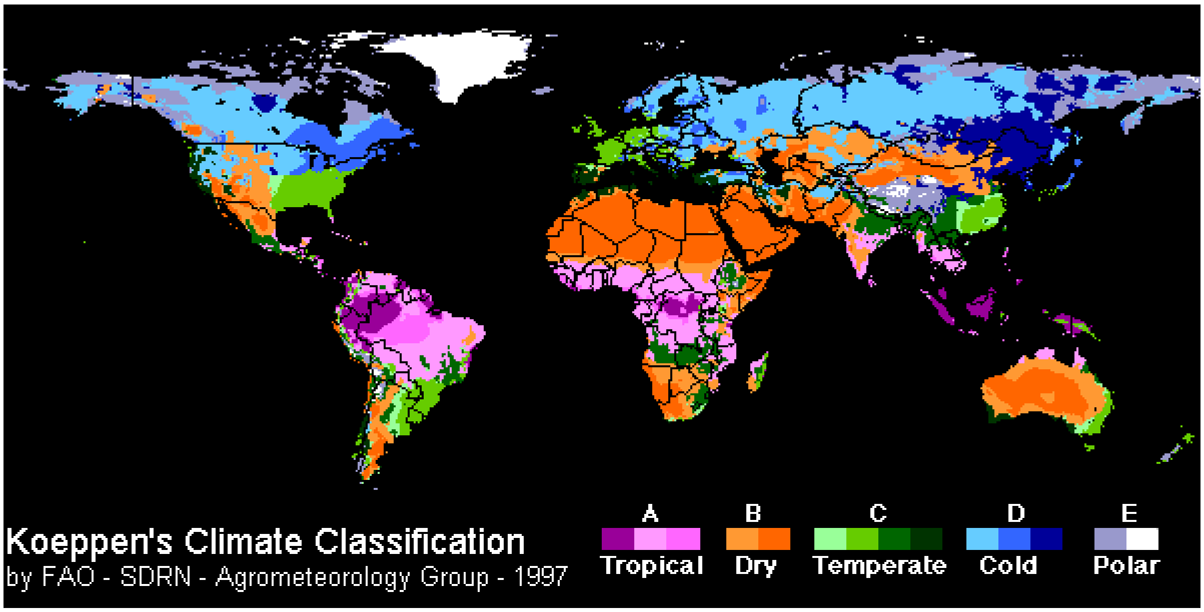


Figure 26. Global climate classification

(http://www.fao.org/sd/EIdirect/climate/EIsp0002.htm)

With regards to animal housing under hot climates and the resulting apparent heat-stress it is important to know the average monthly temperature of the warmest month (Figure 26).

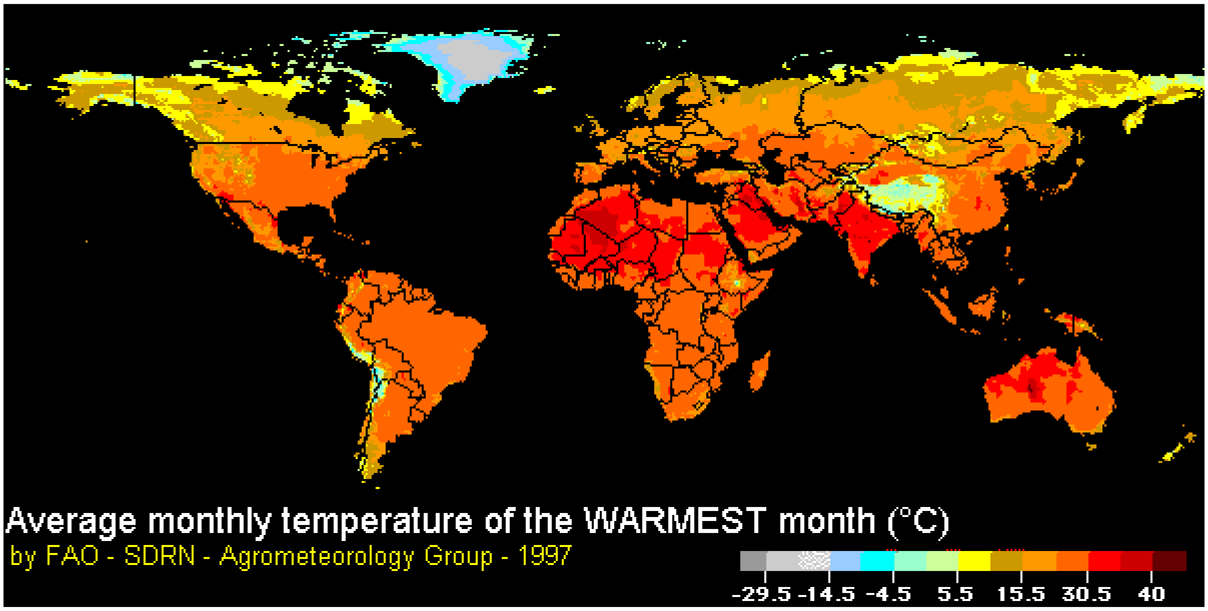


Figure 27. Monthly temperature of the warmest month
(http://www.fao.org/sd/EIdirect/climate/EIsp0002.htm)

From the figures above it is evident that within the Tropical, Dry and Temperate zones, temperatures above the Upper Critical of most livestock species occur during the warmest month of the year.

This poses a major challenge to the WG, namely:

- The definition of the Upper Critical Temperature based not only on dry-bulb temperature data, but also taking into account the relative humidity, the air velocity and the solar radiation
- The description of heat-stress tolerance limits (i.e. duration and intensity) and indices for animals housed both under intensive (e.g. enclosed buildings; temperate zone) and extensive conditions (e.g. open buildings; dry and tropical zone)
- The examination of the relation between heat-stress and production level taking into account the variance among species and the effect of diurnal temperature fluctuation (e.g. night and early-morning compensation)
- The investigation of various cooling methods (i.e. fans, fans and pads, sprinkling, fogging, etc.) and their efficiency in terms of reducing heat-stress
- The determination of design criteria for buildings (i.e. shape, orientation, thermo-physical properties of construction materials, ventilation openings efficiency, protection from sun-load, etc.) accounting for the everlasting issue of environmental protection (i.e. waste management, odor and gases emission, etc.) and sustainable development (proper technologies for different areas and energy/water saving)

- The study of management practices (e.g. night feeding, housing density), welfare issues (e.g. physiological and hematological parameters) and health matters (e.g. infections, mortality) with regards to heat-stress and its alleviation

All that puts forward the need for further independent or cooperative research, which will attempt to give answers to the questions raised in this introductory report, considering the interrelationships among Animals, Environment, Technology, Economy and Human Operator and setting as the most important factor the animals presuming as main object the fulfillment of their needs.

8 Authors Resume

ABDELILAH ARABA

Born in Kenitra, Morocco, 1960. He got the Agronomy Engineering Degree from the Hassan II Institute of Agronomy and Veterinary Medicine (IAV), Rabat, in 1986, and the Doctoral Degree from the same Institute with collaboration from Texas A & M University in 1993, Major: Animal Science. His current position is Professor at IAV, Department of Animal Production. His field of interest is Animal Nutrition and Cattle Management. He investigated the relationships between many locally produced feedstuffs and milk and meat production and quality, as well as ruminant production systems in Morocco.

ANTONIO G. TORRES

Agricultural Engineer, graduated at the Polytechnic University of Madrid (Spain) in 1974, and received his PhD in 1977. Since 1979 he is professor at the School of Agricultural Engineers at the Polytechnic University of Valencia (Spain), where gives lectures, and researchs in “Animal Production Systems and Technologies”. In the last years, the subjects that he has lectured have been: «Design of Livestock and Poultry Houses», «Equipment and Materials for Animal Farm», «Management of Animal Farm» and «Livestock and Environment», all of them at the School of Agricultural Engineers. He has published numerous books and monographs, technical and scientific articles, about “Animal Production Technology and Engineering”, and more specifically, about “Milking machine for sheep”, “Characterization of livestock buildings”, “Climatization of livestock buildings” and “Treatment of animal manure”.He is head of a research group that is composed by 17 researchers (6 Doctors, 8 Master engineers and 3 Bachelor engineers), working on several research projects.

He is at present directing two research projects about Animal Production Technology, financed by public funds, titled: “Assessment of ammonia and greenhouse gases, from intensive poultry and rabbit buildings, in connection with the environment facilities used in Mediterranean climate conditions” and “Development of a computerized instrumentation system for air velocity and other environmental parameters measurements in occupied poultry buildings”. He is technical adviser of the Ministry of Environment, on “Livestock Farming and Environment”, and he contributes to perform the Spanish inventory of gas emissions from livestock buildings.

AVRAHAM ARBEL

Born in Safad, Israel, 1953.1970 – 1973; high-school education in Yad Natan Technical College, Israel Major Subject: Farm Machinery; 1973 – 1976; military service in the Armament Corps of the Israel Defense Forces. Married, three children. 1980 – 1984 B.Sc. in Engineering at the Department of Mechanical Engineering, Faculty of Engineering, Tel Aviv University, Israel. 1986-1989 M. Sc. in Engineering at the Department of Fluid Mechanics and Heat Transfer, Faculty of Engineering, Tel Aviv University, Israel. 1991-

1998 Ph.D. in Engineering at the Department of Fluid Mechanics and Heat Transfer, Faculty of Engineering, Tel Aviv University, Israel.

1991, Senior research scientist at the A.R.O., The Volcani Center, Institute of Agricultural Engineering, Department of Controlled Agriculture and Environment Engineering, Bet Dagan. 1986 –1991 Research scientist at the A.R.O., The Volcani Center, Institute of Agricultural Engineering, Department of Controlled Agriculture and Environment Engineering, Bet Dagan. 1984-1986 Research Engineer at the A.R.O., The Volcani Center, Institute of Agricultural Engineering, Department of Protected Crop Engineering, Bet Dagan. 1977-1984 Research Technician the A.R.O., The Volcani Center, Institute of Agricultural Engineering, Department of Protected Crop Engineering, Bet Dagan.

EPHRAIM MALTZ

Born in Magnitogorsk, Russia, 1945. 1983-to date Senior scientist in The ARO, Volcani Center, Institute of Agricultural Engineering. Current Positions: Head of Department, Engineering of Growing, Production, and Environment. 1968-1971 B.Sc. in Biology, Tel Aviv University, Faculty of life Sciences, Tel Aviv, Israel. 1972-1975 M.Sc. in Animal Physiology, Tel Aviv University, Israel Faculty of Life Sciences 1976-1981 Ph.D. in Animal Physiology, Tel Aviv University, Israel., Faculty of life Sciences. 1981-1983 Post Doctoral training, Phsiology of Lactation, The Hannah Research Institute, Ayr, Scotland, UK. Research interest: Physiology of lactation, environmental physiology, precision dairy and other livestock management. Publications: More than 100 articles (not including abstracts) out of which more than 60 peer reviewed publications.

GIOVANNI CASCONE

Giovanni Cascone graduated with honours in Civil Engineering at the University of Catania. Since 1983, he has cooperated in research with the Institute of Topography and Rural Building of the University of Catania. He was professor by contract in the Agricultural Faculty of Catania University in the Academic Year 1990-91 running a course on "Environment and microclimate in agricultural buildings". At the same University as Associate professor from the Academic Year 1992-93 and as Full Professor from the Academic Year 2001-2002, he runs courses on "Agricultural buildings" and "Buildings for animal husbandry". He is a member of AIIA (Associazione Italiana di Ingegneria Agraria), of CIGR (International Commission of Agricultural Engineering) and of EurAgEng (European Society of Agricultural Engineering). He was among the leaders of a research group within a CNR (National Research Commitee) project, he was the scientific leader of three projects financial supported by (ESF) European Social Fund (one POM Mis.2 project and two POP Sicilia 94/99 Mis.10.4 projects), he has the scientific head of two year national research program on “Building solutions, systems and facilities for the improvement of the animal welfare in intensive farms” supported by Italian Ministry of University and Scientific Research (M.I.U.R.).

He is now involved in research on different subjects related to the agricultural building and, in particular, on the following subjects: environmental conditions in the livestock buildings, with specific regard to the animal welfare and functionality of spaces and equipment; constructional and functional characteristics of agricultural buildings, with specific regard to human health; climate control and structural organization of greenhouses and vineyard pergolas; modeling of greenhouses microclimate and analysis of soil solarization processes under greenhouse. He is author of more than 80 publications on journals and proceedings of national and international conferences.

IRENILZA DE ALENCAR NÄÄS

She has Civil Engineer degree from UNICAMP; Master in Mechanized Agriculture from Cal Poly State University and PhD in Agricultural Engineering from Michigan State University. She is full professor at UNICAMP-Agricultural Engineering College and adjunct professor at University of Florida. She has more than 100 peer-reviewed papers published in the topic of Animal Housing and Environment published in Brazil and abroad; 10 books and book chapters published; has 5 patents of software, processes and products. Major Professor of 35 students enrolled in the Graduate Program at the Agricultural Engineering College, State University of Campinas- UNICAMP, Campinas, SP, since 1992 to present. Major Professor of 42 undergraduate students, since 1980.

Coordinator of the National Program for Agricultural Engineering, National Council for Scientific and Technological Development, CNPq, 1980-1985. Director for Extension Courses. State University of Campinas- UNICAMP, 1991-1994. Director of the Foundation for the Scientific and Technological Development for Poultry Production, FACTA, 1995 to present. Coordinator for the National Research Group in Precision Animal Production, 1999 to present. President of the Brazilian Society of Agriculture Engineering, SBEA, 1999-2003. President of the Latin American and Caribbean Association of Agricultural Engineering-ALIA, 2000-2004. President of the NGO Technology for All-TechnallBR. Incoming President of CIGR-International Commission for Agricultural Engineering (CIGR), 2005-2007. Received several awards for best research and paper presented in conferences, and the award Prof. Zeferino Vaz, by the State University of Campinas, for the best academic production at the Agricultural Engineering College.

MOHAMED H. HATEM

He received his B. Sc. in Agricultural Engineering from Alexandria University, Egypt in 1967. He then followed graduate studies at Cairo University and received his M. Sc. degree in Agricultural Engineering in 1970. He had a scholarship from DAAD to complete his graduate studies at the University of Hohenheim, Stuttgart, Germany and obtained his Ph. D. in Agricultural Engineering in 1980. Since then he is serving as a faculty member in the department of Agricultural Engineering, Faculty of Agriculture, Cairo University, and from 1990 he is full professor at the same department. In his research activity he has investigated the problems concerning the development of small farm machinery equipments, the composting of municipal solid waste, the thermodynamic behavior of building construction, the biogas production from animal manure, the development of animal housing for the tropics, the evaporative cooling in farm building, the orientation of farm building, the environmental control for poultry housing, the spray cooling system in greenhouses, the urban planning in development of rural societies, the drying of poultry manure, the solar drying of medicinal herbs and the housing system for dairy cow. He is, till now, Director of the Computer and Network Center, Faculty of Agriculture, Cairo University. He was as Visiting Professor from Canadian International Development Agency (CIDA), at Agric. Eng. Dept., Technical Univ. of Nova Scotia, Canada 1994. He was as Visiting Professor at King Saud University, Riyadh, Saudi Arabian, 1983-1986. Awarded received: A Research Fellowship from DAAD for two months at Hohenheim University, Germany on years 1983, 1996, 2001. Awarded received: a Research Fellowship from DFG for two months, Germany 2003.

He has carried out several researches sponsored by the Egyptian Ministry of Agriculture and USAID: 1982 – 1983 Principle Investigator in Project "Agricultural unit for water supply", 1982 – 1983 Co-Investigator in Project "Biogas unit construction by using local building material", 1990 Co-Investigator in Project "Energy Producing from town refuse", Soils & Water Res. Inst., Agric. Res. Center, MOA., 1991 Principle Investigator in Project "New technology for biogas and natural organic manure from city refuse", Egyptian Academy of Scientific Research and Technology, 1992 Co-Investigator in Project "Housing modules for small animals under Egyptian condition", NARP, Ministry of Agriculture, 1993 Co-Investigator in Project "Solar cooking devise", NARP, TTC, Ministry of Agriculture, and 2000 Consultant in Project “Agriculture–Led Export Businesses, Supporting Egypt’s Processed Export Industry”, USAID Funded Project, No.263-0264. He is member in Professional Societies: Misr Society of Agric. Engineers, [MSAE], Germany Society of Engineers, [VDI], Baden-Wuerttemberg Society of Agric. Eng., [ALB], American Society of Agric. Engineers, [ASAE], Canadian Society of Agric. Engineers, [CSAE], Association for Renewable Energy and Environment Protection, NGO, Egypt [AREEP] and Germany-Egypt-Arab-Region Inter–Alumni-Net [GEAR]. Since 1995 he is a member of the evaluation scientific committee for university faculty members at King Saud University, Riyadh, Saudi Arabian, and since 2000 is a member of the evaluation scientific committee for university faculty members at FRCU, Egypt. He has participated in many congresses at national and international levels, as an invited speaker and session chairman. He has given many lectures at various institutions of technical training and specialization. He is the author of more than 82 publications, including congress reports, magazine articles, and chapters in books. He has supervised 25 master’s students and 5 doctoral students at the Agricultural Engineering Department, Faculty of Agriculture, Cairo University

PANAGIOTIS B. PANAGAKIS.

Born in 1963 he received his B.Sc. in Agriculture form the Agricultural University of Athens, Greece in 1985. He then followed graduate studies at the University of Florida and received his M.E. in Agricultural Engineering in 1987. He finally completed his graduate studies at the Agricultural University of Athens and earned his Ph.D. in Agricultural Engineering in 1993.

Since then he is involved in research projects concerning Animal Housing and Use of Energy in Agriculture. This involvement has resulted to more than 50 articles, among which: 14 peer-reviewed publications, 5 papers in International Conferences, 1 Chapter in an International Edition Book and 4 other publications related to Animal Production.

From 2003 he serves as an Assistant Professor in the Department of Natural Resources Management and Agricultural Engineering at the Agricultural University of Athens, Greece.

PAOLO ZAPPAVIGNA

Graduate in civil engineering is full professor at the Faculty of Agriculture of the University of Bologna, and head of the Unit of Agricultural Engineering at the Department of Produzione e Valorizzazione Agroalimentare.

In his research activity he has particularly investigated the problems concerning the farm buildings and, in particular, the design and constructive requirements of the animal houses and plants, with special reference to the methods and techniques for the environmental control, and more recently, the automated and computerized systems for animal husbandry.

He has carried out the following researches sponsored by the Italian National Council of the Researches: IPRA (Increasing the Productivity of the Agricultural Resources); EDILIZIA (Buildings) on the subject “Design innovation of animal houses”; RAISA (Advanced Researches for Innovation in the Agricultural System).

He has been leader of research units within the following projects of national interest granted by the Italian Ministry of the Research: Design and technology innovation of cheese factory buildings; Treatment and management of solid and liquid wastes from intensive animal breeding; Design of Animal Houses in relation to animal welfare: building ad plant solutions for the reduction of heat stress.

He has been leader of researches promoted by the Italian Ministry of Labour in studies for evaluation and improvement of work safety in animal husbandry.

He has participated in, and coordinated, various research units granted by the Ministry of University, among which the most recent concern: Effects of roof materials on microclimate of animal houses; Techniques for automated monitoring of dairy cows; Automatic detection of oestrus in dairy cows; Development of automation in dairy houses.

He has been leader of various research projects sponsored by the Emilia-Romagna Region, in particular on the following subjects: Study of industrialized buildings for animal housing; Construction of animal houses using innovative and low cost technologies; Study on systems for cooling dairy cows; Study on automated systems for monitoring of dairy cows; Evaluation of the dairy cow houses from the point of view of the animal welfare.

He has participated with his own contributions in many Congresses at national and international level, also as invited speaker and Session chairman. He has given many lectures at various Institutions of technical training and specialization. He is author of more than 110 publications, including Congress reports, magazine articles, chapters in monographic books.

PAVEL KIC

He is full Professor at the Technical Faculty of the Czech University of Agriculture Prague (TF CUA Prague). He is teaching the courses: Technological Equipment of the Buildings in Animal Production; Environmental Engineering Technology; Transport and Manipulation Machinery. He was tutor of more than 70 students for MSc. and PhD. thesis. He is coordinator of Socrates-Erasmus Program with EU and other countries. His research and scientific activity covers the field of buildings, ventilation and environmental technology in agriculture. He published over 200 publications (articles in scientific and professional journals, papers in national and international congresses, books, research and technical reports, teaching books and booklets). He is a member of several scientific and professional societies (Committee of Ventilation and Air-conditioning in Society of Environmental Engineering; International Building Performance Simulation Association; Czech Bio-climatological Society; Club of Bologna); member of the Scientific board of the TF CUA and Scientific board of Institute of Tropics and Subtropics at CUA Prague; Chairman of the Commission of PhD studies Technology of Production Processes at TF CUA Prague; member of the Commission of PhD studies Environmental Engineering at Faculty of Mechanical Engineering of Czech Technical University of Prague.

SØREN PEDERSEN

Agronomist at the Royal Agricultural University, Copenhagen, 1965. Ph.D. from the Royal Agricultural University, Copenhagen 1971.Thesis: Draught Force Requirement of Ploughs. Honorary Doctor at Swedish University of Agricultural Sciences, 2005. Head of Section at Department of Agricultural Engineering, DIAS, formerly National Institute of Agricultural Engineering, Bygholm, Denmark since 1978. Member of CIGR (Commission Internationale du Genie Rural) Working Group on "Climatization of Animal Houses" since 1977. Responsible for the Danish part of the EU project PL900703 "Reduction of Aerial Pollutant Emissions in and from Livestock Buildings". 1992-96. Secretary of CIGR Section II on "Farm Buildings, Equipment, Structures and Environment".1998-2002 Chairman for CIGR Section II on "Farm Buildings, Equipment, Structures and Environment" 2002- 2006.

Main activities: Ventilation equipment, Climatization of animal houses (dust, gasses and animal heat and moisture production) and Working environment

VASCO FITAS DA CRUZ

Born in 1962 he is Animal Science Engineer from Évora University; Master of Science in Animal Production from the Mediterranean Agronomic Institute of Zaragoza and PhD in Agricultural Engineering from Èvora University. He is Associate Professor and also Dean of the Agricultural Engineering Department of Évora University. He is also senior researcher of the Mediterranean Agrarian Sciences Institute and coordinator of the Laboratory of Biometeorology and Animal Welfare of this Institute. He has more than 50 papers published in Portugal and abroad in the topic of Animal Housing Design and Environment. He has also 4 manual for students published. He has given many lectures at various Universities, Research Institutes, and institutions of technical training and at private enterprises. He is supervisor or tutor of 5 students enrolled in post-graduation programs and he is Major Professor of 47 undergraduate students, since 1990. He has participated with several own papers in many Congress or other Scientific meetings at national and international level, also as invited speaker and session chairman.

His main research activity concerns with Environmental Control and Design of Animal Buildings and he develop research projects on “Effects of environment in growing-finishing swine” in collaboration with Dr. Jean Le Dividich from INRA_France, on “ Applications of evaporative cooling techniques”, in collaboration with UNICAMP-Brasil, on “Alternative outdoor housing systems for pigs”, on “ Energetic and agronomic valorization of animal wastes” in collaboration with INETI-Portugal and EMBRAPA-Brasil, on “ Adaptation of animal welfare codes in Portuguese animal buildings”. Recently he is enrolled in a research project concerning to adaptation of methodologies to measure emissions from pig houses in Portuguese systems of swine production. He is also the coordinator of Animal Science Engineering graduation degree in Èvora University and of the Master Degree in New Technologies for BioSystems Engineering from RUPEA. He also belongs to the EurAgEng Council and is the coordinator of the Portuguese Society of Agricultural Engineering.

VICTORIA BLANES VIDAL

Victoria Blanes Vidal was born in Valencia (Spain) in 1977. She graduated in Agricultural Engineering in 2001, at the Polytechnic University of Valencia (UPV). From 2001 she is Assistant professor at the UPV, where she has carried out teaching and researching activities. She is lecturer of several subjects of the Agricultural engineering studies at the university, such as “Animal Production Technology”, “Livestock Farming and Environment”, “Farming Equipment and Facilities” and “Impact of Agrarian Techniques”. She has also published several books for the Agricultural Engineering students, related with animal buildings and facilities. Regarding the research activities, the investigation works that she has carried out in Spain, have been mainly related with the study of air velocity and temperature patterns in livestock buildings in hot and humid climates, by means of the development of a computerized instrumentation system for air velocity and other environmental parameters measurements in occupied poultry buildings. She has also performed research works in foreign institutions (Research Center Bygholm, Denmark; the Pennsylvania State University, USA). Her investigation studies have been published in different journal or international conference papers. She is now collaborating in the research project financed by public funds, entitled “Assessment of ammonia and greenhouse gases from intensive poultry and rabbit buildings, in connection with the enviroment facilities used in Mediterranean climate conditions”.

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