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

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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.

Housing

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.