# A REGIONAL SURVEY OF EMERGING HOT CLIMATE CONDITIONS IN PORTUGAL AND THE NEW CHALLENGE TO ANIMAL HOUSING

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## ABSTRACT

Portugal, located in the South-western Europe, is characterised by a Mediterranean climate with hot and dry summer.
According to data from Portuguese IM (Instituto de Meteorologia) during the last decade, summer temperatures tend to be higher, and several heat waves have occurred, with temperatures above 40 ºC. During summer, days with high temperatures and heat waves are becoming more and more common in Portugal. The past four summers have been among the hottest ever registered.
These frequently high temperatures can cause problems in intensive animal production. In most cases, the livestock buildings are not prepared for animal production under high temperatures and most of them do not have environmental control equipments adequate to control indoor environment under such conditions.
From a geographical point of view, and examining climatic data, we find two regions (Alentejo and Trás-os-Montes) where high temperatures are more usual and summer tend to be hot. In these two regions, livestock is quite relevant and have a great significance to the regional economy.
Two locations were chosen in these regions to register and analyse air temperature in order to identify the occurrence of hot climate conditions; and to evaluate its influence on the inside animal housing climate.

**Keywords**: hot climate, animal housing, farm buildings

## INTRODUCTION

Portugal is located in South-western Europe (37º to 42º N and 9,5º to 6,5º W), bounded by Spain on the east and the north; and bordered by the Atlantic Ocean on the west and the south. Despite the fact that it has a large Atlantic coast, its climate is mainly Mediterranean. In general, summers are hot and dry; and winters are cold and wet. Rainfall occurs mainly in winter and summers tend to be dry. In littoral areas, the climate is milder and the rain is more frequent. It is a small country (surface 92 391 km$^2$), however, it is marked by a great diversity of climate from region to region, which has an effect on agricultural activity and also on the animal production. In addition to other factors, these climatic conditions have a major influence on the geographical distribution of domestic animal species. Briefly, dairy cattle are more common in the littoral North and beef cattle are more common in Alentejo region, in the South. Pigs are mainly raised in the littoral centre of the country and in Alentejo. Sheep and goat rising is more common in Alentejo, and in the inland regions of the Centre and North (INE, 2005).
Considering the last decades, it is possible to admit that hot climate conditions have been emerging in Portugal and, progressively, this fact can affect animal production, especially in summer.
According to data from IM (2006) during the last decade, temperatures in summer tend to be high (mainly along the months of June, July and August) and have tended to be above the average of the reference period 1961-1990, according to the Climatological Standard Normals (WMO, 1983).
Likewise, days with significantly high temperatures have become more frequent; also increased the number of days with minimum air temperature (generally, during night time) over 20 ºC; and several heat waves occurred in recent years.
These frequently hot climate conditions (high temperatures and heat waves) can cause problems in animal production, mainly in intensive systems. It is recognized that these adverse hot climate conditions, mainly heat stress, have several negative effects on animal behaviour and production causing livestock damages with losses to the farmer. Heat stress decreases voluntary feed intake

(Fuquay, 1997; Nienaber et al, 2004); retards animal growth (Cruz et al, 2000); affects carcass composition and meat quality (Nienaber et al, 1987); decreases milk production while reducing milk quality (West et al, 2003; Perissinotto et al, 2005); and disturbs animal activity and interactive social behaviour (Frazzi et al, 1998; Hahn, 1989).
In Portugal, emerging hot climate conditions create a new challenge to animal housing and also to livestock in extensive systems. Usually, breeders are not familiarized with this situation and they have difficulties to deal with this problem. Besides, in most cases, the buildings for livestock are not suitable for animal housing under high temperatures and they lack appropriate equipment to control indoor environment under such conditions.
High temperatures combined with a lack of the necessary equipment to control the environmental conditions inside buildings and deficient acclimatisation of animal facilities can increase this problem. Also, livestock in extensive systems, or raised outdoors, can be affected by high temperatures associated with humidity, as well as by the absence of shade, airflow or wind. The risk increases when these conditions persist for several consecutive days (Nienaber et al, 2004).

**Emerging Hot Climate Conditions in Portugal**

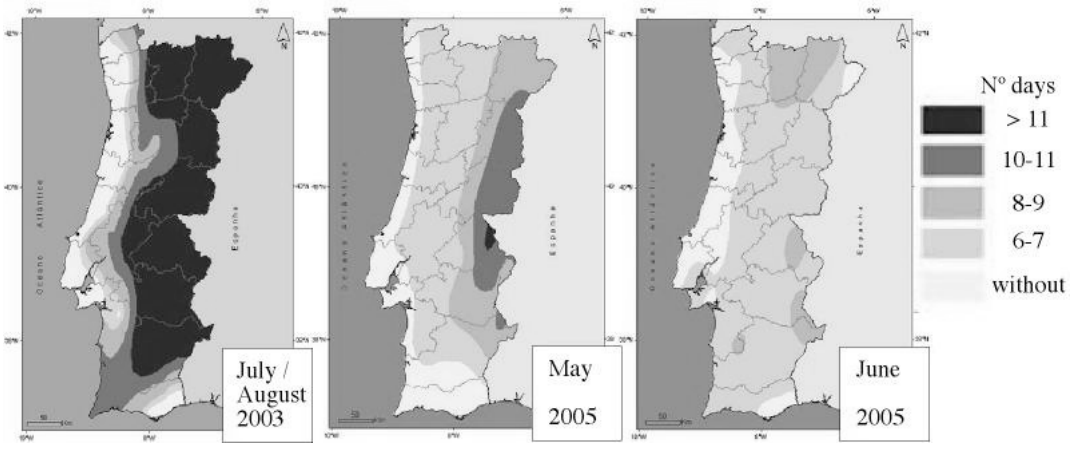
As mentioned above, hot climate conditions emerged in Portugal during the last decade especially in summer period.
Table 1 shows the five hottest summers since 1931 considering the variation over the average of the reference period. The summer of 2005 was the hottest since 1931 and presents an anomaly of +2,38 ºC in mean air temperature. Between 2003 and 2006 four summers were exceptionally warm and among the hottest since 1931.

**Table1. The five hottest summers since 1931, in Portugal (source IM, 2006).**

| Year | anomaly in Mean Air Temperature (ºC) |
|---|---|
| 2005 | + 2,38 ºC |
| 1949 | + 1,98 ºC |
| 2004 | + 1,92 ºC |
| 2003 | + 1,91 ºC |
| 2006 | + 1,80 ºC |

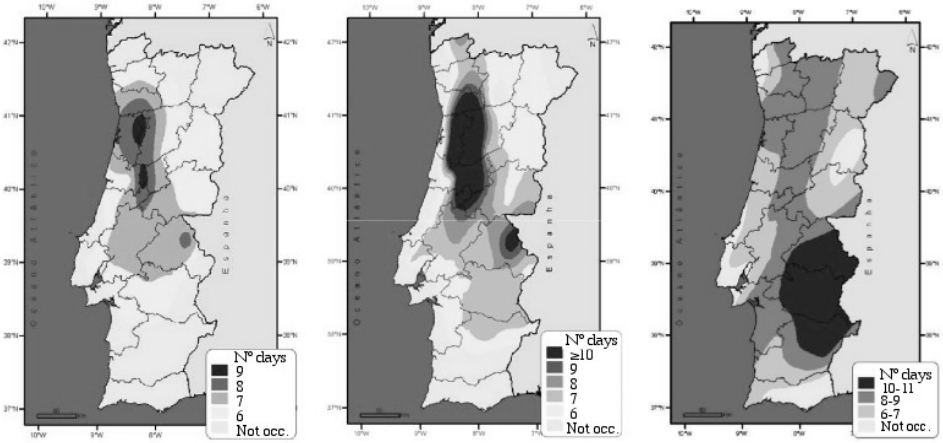
Another consequence of emerging hot climate conditions is the regular occurrence of heat waves. In recent years, several heat waves have occurred, with temperatures above 40 ºC.
Considering a heat wave as defined by the Heat Wave Duration Index (WMO, 2001) since 2003 eight heat waves have occurred in Portugal. In 2003, from 29 July to 14 August; in 2005, from 30 May to 11 June, during eleven days, with temperatures over 40ºC in some places; and again in 2005 from 15 to 23 June with temperatures over 40ºC degrees, in several regions (Figure 1).

**Figure 1. Heat waves duration and regions affected during 2003 and 2005 (source IM, 2006).**



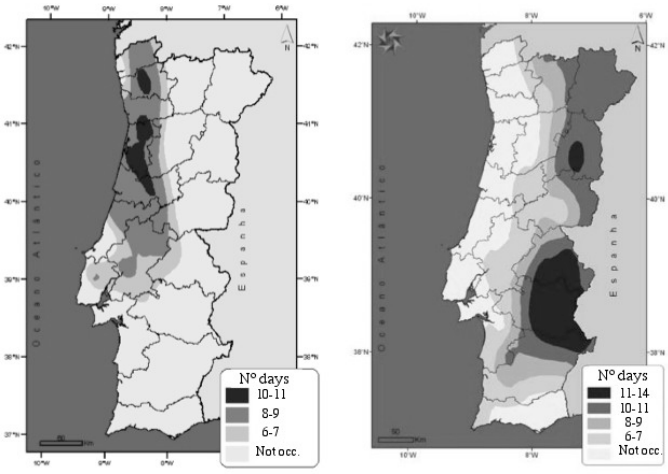
Maps in Figure 1 allow seeing that the most intense heat waves affect mainly inland regions in the North and the South.
Again, in summer 2006 five heat waves occurred in the period from 24 May to 9 September. These five heat waves affected different regions for several days.
Figure 2 shows the three heat waves occurred from May to June 2006. In these maps it is possible to observe a new feature in territorial distribution: there were heat waves that affected littoral regions instead of the inland areas. Justly mention the heat wave that began on 7 July had the greatest territorial extension ever registered.

**Figure 2. Heat waves during May, June and July 2006 (source IM, 2006).**



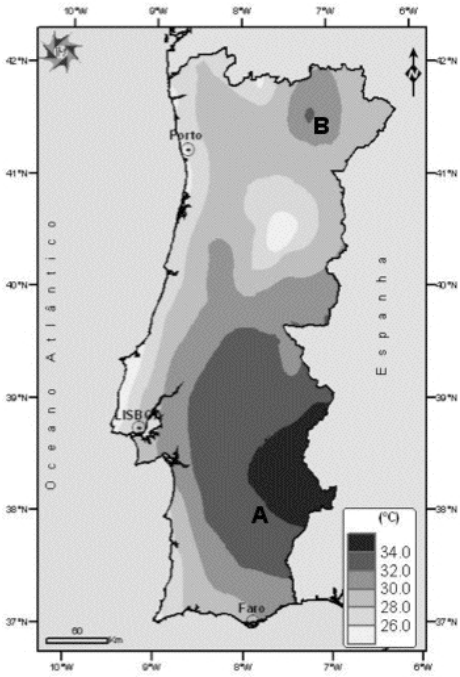

Again, in August a heat wave covered only littoral regions. From 27 August to 9 September 2006 occurred the longest heat wave ever registered, with duration of 14 days in some places (Figure 3) affecting mainly inland regons.

**Figure 3. Two heat waves occurred during August/September 2006 (source IM, 2006).**




Occurrence of high temperatures is more probable in some regions, generally in the South and inland regions. Figure 4 shows territorial distribution of the average daily maximum air temperature in summer 2006, between June and August. In this map we can identify two regions where high temperatures are more usual: Alentejo, in the South and Trás-os-Montes, in the inland Northeast.

**Figure 4. Distribution of Maximum Air Temperature (ºC) in Summer 2006 (source IM, 2006)**




Looking at the maps in preceding figures, it is clear that the regions of Alentejo and Trás-os-Montes have a higher risk of high temperatures or extended heat waves. In these two regions, livestock is very significant and animal production is quite relevant to the regional economy.

## OBJECTIVE

The main objectives of this work were: 1. to identify the occurrence of hot climate conditions during recent years, in two different Portuguese regions, where high temperatures are more frequent and 2. to identify and quantify periods of hot climate conditions in these regions that can result in a threat to animal production.

## MATERIAL AND METHODS

Considering the two regions with higher temperatures, one located in south and the other in Northeast of Portugal, two places were chosen, one in Alentejo (location A) and the other in Trás-os-Montes (location B), as marked in Figure 4. Climatic data, mainly air daily temperatures, maximum and minimum (Tmax, Tmin) were measured and recorded in weather stations between 1 of May and 30 of September of 2005, 2006 and 2007. In location B, relative humidity was also registered. All data were recorded every 10 minutes.
Data was analysed in order to identify heat stress which can conduct to animal production risks. Based on in this analysis it was possible to:
- identify high temperatures during those periods;
- evaluate the periods with days presenting hot climate conditions and the values of those temperatures;
- identify the occurrence of consecutive days presenting hot climate conditions. This is an important aspect since this can increase the risks for animal production, mainly during the periods when minimum temperatures are relatively high reducing the possibility of nigthtime recovery.
In order to evaluate heat stress we used the Temperature Humidity Index,

$$THI = 0{,}8T_{db} + \left[\frac{RH}{100} \times (T_{db} - 14{,}3)\right] + 46{,}4$$

were $T_{db}$ is the dry-bulb temperature and RH is the relative humidity.

Considering the categories of the Livestock Weather Safety Index associated with the THI: normal values THI ≤ 74, alert values for heat stress those between 75 and 78, danger values between 79 and 83, and emergency values for heat stress when THI ≥ 84 (Nienaber and Hahn, 2004). Hourly THI was calculated for location B for twelve days.

## DATA, RESULTS AND DISCUSSION

According to data collected during the period considered (summers 2005 to 2007) some days present very high temperatures, above 40 ºC. Table 2 shows, for both locations and for each year, the hottest days considering the maximum air temperature (Tmax). In these days Tmax reached values higher than 41º C.

**Table 2. The hottest days (Tmax) registered for each year, from 2005 to 2007**

| | location A | | location B | |
|---|---|---|---|---|
| Year | day / month | Tmax | day / month | Tmax |
| 2005 | 20/07 | 41,2 | 07/08 | 42,1 |
| 2006 | 04/09 | 41,6 | 17/07 | 41,3 |
| 2007 | 30/07 | 42,4 | 04/08 | 41,8 |

Considering the 153 days analysed, each year, between 1 of May and 30 of September, it is possible to see that 2007 summer was less hot than 2005 and 2006, in spite of presenting occasionally some very hot days, with maximum air temperature over 40 ºC. The same happened in all the country, with 2007 being less hot (IM, 2007).
Table 3 shows the number of days according to different categories for maximum air temperature (Tmax). In location A, Tmax ≥ 35 ºC occurred along 45 days in 2005; 54 in 2006 and 21 in 2007. Regarding location B, Tmax ≥ 35 ºC occurred during 58 days in 2005; 62 in 2006 and 21 in 2007. In location B these values represent 38% of the analysed days of 2005 and 41% in 2006. Also, in these years it was registered 9 days with Tmax ≥ 40 ºC.

**Table 3. Number of days with Tmax according to different categories**

| | location A | | | location B | | |
|---|---|---|---|---|---|---|
| Tmax | 2005 | 2006 | 2007 | 2005 | 2006 | 2007 |
| < 30 ºC | 49 | 57 | 76 | 43 | 45 | 70 |
| 30 ºC to 34 ºC | 59 | 43 | 56 | 52 | 46 | 62 |
| 35 ºC to 39 ºC | 41 | 46 | 17 | 49 | 53 | 18 |
| ≥ 40 ºC | 4 | 7 | 4 | 9 | 9 | 3 |

This suggests that breeders should be alert for a significant number of days, since it may be possible that problems occur related with heat stress and some actions should be implemented in order to minimise the negative effects. Moreover, consecutive days with high temperatures increase the difficulty to control animal heat stress which could be aggravated by insufficient nightime recovery, due to warm nights.
Table 4 presents the longest period with consecutive days with minimum air temperature (Tmin) ≥ 20 ºC for each location. This period of consecutive hot days (high values of Tmax and Tmin) was coincident with the heat wave registered in July 2006 (see Figure 2) and occurred simultaneously in the two locations. In this period, location A registered 9 days with Tmax higher than 39 ºC and location B registered 10 days with Tmax higher than 37 ºC.

**Table 4. Largest periods of consecutive days with Tmin equal or over 20ºC.**

| location A | | | location B | | |
|---|---|---|---|---|---|
| Date | Tmax | Tmin | Date | Tmax | Tmin |
| | | | | | |
| | | | 2006.07.07 | 35,7 | 20,7 |
| | | | 2006.07.08 | 37,8 | 20,5 |
| | | | 2006.07.09 | 40,2 | 19,8 |
| 2006.07.10 | 38,2 | 20,0 | 2006.07.10 | 39,6 | 21,5 |
| 2006.07.11 | 39,8 | 22,4 | 2006.07.11 | 40,3 | 22,5 |
| 2006.07.12 | 39,3 | 23,3 | 2006.07.12 | 40,1 | 23,1 |
| 2006.07.13 | 39,9 | 21,4 | 2006.07.13 | 38,2 | 23,4 |
| 2006.07.14 | 39,0 | 20,9 | 2006.07.14 | 37,8 | 20,9 |
| 2006.07.15 | 39,8 | 20,8 | 2006.07.15 | 37,8 | 21,1 |
| 2006.07.16 | 40,7 | 23,3 | 2006.07.16 | 39,9 | 22,2 |
| 2006.07.17 | 39,2 | 24,0 | 2006.07.17 | 41,3 | 22,3 |
| 2006.07.18 | 34,3 | 22,2 | 2006.07.18 | 30,1 | 20,4 |

The period presented in Table 4 can be an example to show that hot climate conditions can occur in these regions and the risks that can affect animals, mainly in intensive production. Theses risks can be worse due to the fact that most breeders are not familiarised with these problems and generally the buildings are not equipped to carry out mitigation actions. Also, in extensive production, only with nocturnal housing some problems can occur due to hot climate conditions and again breeders should be prepared to solve the problem.

Table 5 shows the values of the Temperature Humidity Index (THI) calculated every hour along the period referred in Table 4 for location B. THI values were considered Normal when THI ≤ 74; Alert 75-78; Danger 79-83; and Emergency for THI ≥ 84 (Nienaber and Hahn, 2004).

Observation of Table 5 allows to say that during half of the days, THI values were higher than 75 for more than 15 hours per day. It should be noted that on the 17 July 2006 THI reached emergency values for 7 consecutive hours. For the rest of the hours (between 9 and 23 h) THI reached danger values. This Table allows also observing that for most of the days between noon and 20 h THI presented danger values with animal risks.

**Table 5. Hourly values of THI along the period from 7 July 2006 to 18 July 2006.**

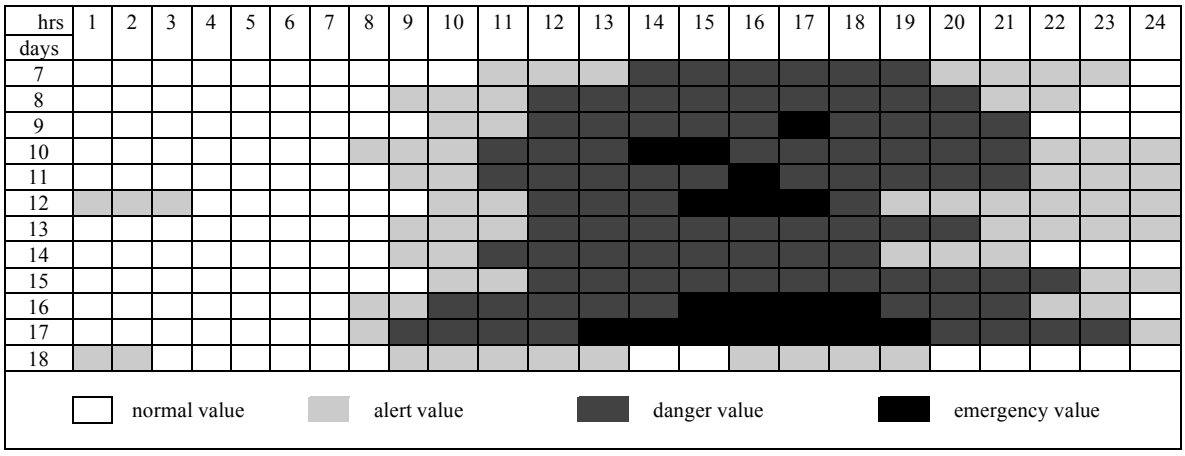



Table 6 shows THI ≥ 79 (danger values) and it is possible to see that even with temperatures of 29, 30 and 31 ºC danger situations occurred. When temperature was higher than 35 ºC it was frequent to find THI ≥ 80.

**Table 6. Air temperature and values for THI (when THI ≥ 79) and respective frequencies.**

| Air Temperature | THI values | Frequency THI ≥ 79 |
|---|---|---|
| 29 | 79 | 2 |
| 30 | 79 | 3 |
| 31 | 79 | 3 |
| 32 | From 79 to 81 | 8 |
| 33 | From 79 to 81 | 11 |
| 34 | From 79 to 82 | 8 |
| 35 | From 79 to 82 | 15 |
| 36 | From 80 to 83 | 8 |
| 37 | From 81 to 83 | 13 |
| 38 | From 82 to 84 | 11 |
| 39 | From 82 to 84 | 12 |
| 40 | From 83 to 85 | 12 |
| 41 | 85 | 2 |

Considering data of Tables 3, 5 and 6 it should be considered the existence of risks for animal production due to hot climate conditions, in these regions. The occurrence of temperature ≥ 32 ºC, simultaneously with relative humidity ≥ 40% increases the possibility of danger heat stress levels for THI, since these climatic conditions limits latent heat exchange.
This can be worse since the breeders are not prepared to deal with these situations and to the absence of equipments to minimise the problem and to develop the necessary mitigation actions.

## CONCLUSIONS

After analysing the climate data registered in two different regions, in recent years it is possible to say that:
- it seems to exist a tendency for hotter summers than before;
- it arise periods of consecutive days with temperature higher than the usual, classified as heat wave;
- in Alentejo and Trás-os-Montes, where usually summer is hotter than in the rest of the country, it occurs, with relatively high frequency, temperatures higher than 40 ºC.
- in these regions it occurs consecutive days with minimum air temperature higher than 20 ºC;
- all these situations presents risks for the animals associated with heat and it will be necessary to prepare animal housings and breeders to implement some measures of prevention and mitigation actions.

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