AWARTECH Project: a New Tool of Precision Livestock Farming for Growing-finishing Pigs

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Abstract

The world is, day by day, more demanding for high quality food, produced according to animal welfare regulations and ethical principles, and both social and environmental responsibility. This requires a special care with cost rationalization and increased efficiency in the use of production factors and value chains. Intensifying production pursing self-supply or higher competitiveness objectives may decrease animal welfare. Therefore, it's important to monitor the environment inside the swine facilities and the animal welfare conditions. The main objective of the AWARTECH (Animal Welfare Adjusted Real Time Environmental Conditions of Housing) project was to create and develop an innovative precision livestock tool that will support and reinforce the pig value chain, by management solutions based on monitoring, analysis and control of environmental, physiological, behavioural and productive parameters. Environmental data were collected by sensors of temperature, relative humidity, air velocity and gas concentration, which are integrated in an environmental control system (Webisense) and a platform (Nidus). Webisense controlled the ventilation system, the cooling system and the heating system. The physiological data (rectal temperature, surface temperature) were collected manually and automatically. In order to monitor the behaviour of the animals, video cameras were installed. An individual feeding machine equipped with a scale has been installed. That allows, through an RFID system, individual monitoring and control of the amount of food supplied and ingested; number and duration of visits; and animal's weight. The development of AWARTECH platform results from the integration of physiological data manually supplied and real-time data provided by Webisense, Nidus, feeding machine and video analytics, that allow the control of the environmental conditions in order to promote the animal welfare.

Keywords: Animal housing, Environmental control, Animal welfare, Pig.

1. Introduction

It is expected that the world population will increase by about 30% and reach more than 9 billion of habitants by 2050. Consequently, the food demand will increase by about 70% and human consumption of livestock products will double from 258 to 455 million tonnes (Rojas-Downing et al., 2017). In order to find solution for this problem, livestock farming systems need to increase production through intensive systems (Berckmans, 2014). However, intensive production systems, currently face enormous challenges due to environmental impacts and to the public perception opinion, that these systems, characterized by high animal density, reduce animal health and welfare. In this sense, it is important to raise awareness in the animal production sector about the need to accurately monitor animal welfare conditions within the facilities used in the intensive systems.

One of the most important aspects in the definition of animal welfare is the environmental conditions of housing. Environmental control systems in animal housing are a very important tool to provide environmental conditions that allow for adequate levels of productivity and animal welfare (Cruz, 1997; Babot and Revuelta, 2009). However, environmental control of livestock facilities is typically based on rates/balance of heat and moisture production at predetermined ambient temperature levels. This traditional control method cannot reflect the true thermal animal's needs because it does not account some environmental, physiological and behavioural factors (such as air quality, animal surface temperature or animal feed intake).

In this sense, the main challenge for intensive production systems in the future is to monitor and control not only the environmental conditions (microclimate and emissions), but also the growth, behaviour, productivity and health (diseases) of the animals in large groups (Berckmans, 2017; Fournel et al., 2017; Vranken and Berckmans, 2017).

Precision livestock farming (PLF), defined as the application of technology engineering processes in livestock management, is the potential solution to respond to these challenges (Banhazi et al., 2012) once offers many innovative technologies and tools through which the animal response to housing environmental conditions can be continuously observed, monitored and controlled.

Precision livestock farming has used a lot of technological equipment (sensors, microphones and video cameras, thermographic cameras, automatic scales, automatic feed stations, etc.) since the beginning of the 21th century. The information provided through this equipment can be subject to monitoring, allowing to demonstrate animal's feedback in relation to the environment, which can help farmers to control the productive process and management decisions (Fournel et al., 2017). The use of these technologies can also reduce production costs and make production systems more competitive (Berckmans, 2017), and animal and environment friendly.

The main goal of the AWARTECH was to develop a new tool (AWARTECH Smart Sensing platform) that would respond in real time to the environmental needs of animals through physiological, behavioural and productive indicators using smart-sensing technologies. The development of this tool was based on a facility for growing-finishing pigs.

2. Materials and Methods

The experimental work was developed in an environmental control room. The main goal of this phase was test/validate a set of equipment and parameters in order to develop a technological platform prototype.

After the experimental work the technological platform prototype developed was tested and evaluated in a commercial pig facility, where the animals were subjected to real environmental conditions.

The architecture of the technological component developed in AWARTECH Project (Figure 1) consisted of using different equipment for continually, automatically and real-time collection of environmental, productive, behavioural and physiological data.

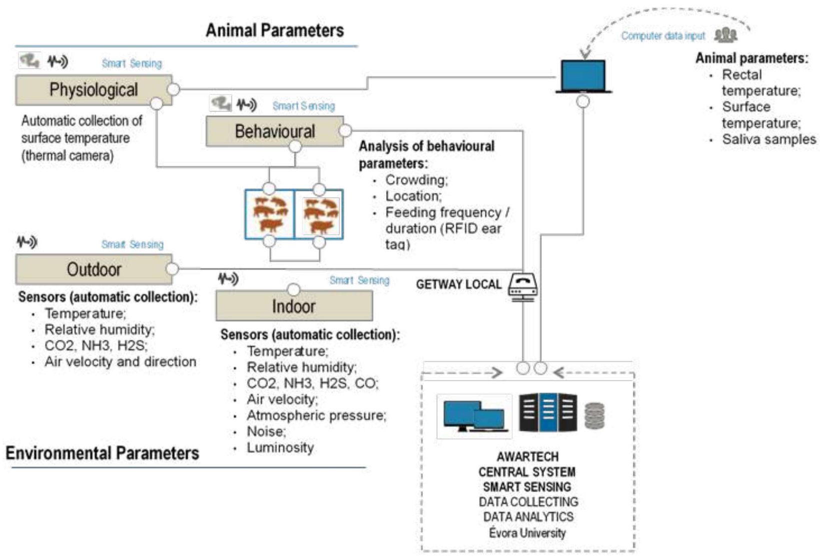


Figure 1. Lay-out of the technological component of Awartech Project

2.1. Structures and Equipment

To develop the platform, a pen with an area of around 12,0 m^2 was installed in the environmental control room. The pen had a manure pit and was equipped with an automatic feed station and two nipple drinking bowl. The floor was partially concrete cover with anti-slip tactile.

Environmental control was carried out through ventilation, heating and cooling systems. Ventilation system was compound by two vertical extractors fans. The air came into the facility through a false ceiling to protect the animals and left through the extractors (negative pressure). The heating system consisted of a conventional gas heater. The cooling of the facility was made by a nebulization system.

The environmental control room was equipped with different equipment and technologies as temperature, relative humidity and gas concentration sensors and video/thermal graphic cameras that allowed to record environmental, behavioural and physiological data.

2.2. Experimental design

In the experimental phase, three trials were carried out in the environmental control room at University of Évora. Three different conditions were set: Winter (W) – cold stress (trial 1), Thermoneutrality (TN) – thermal neutrality (trial 2) and Summer (S) – hot stress (trial 3) (Table 1).

Table 1. Experimental environment set points

Environmental Conditions	Winter (W)	Thermoneutrality (TN)	Summer (S)
Temperature (ºC)	10 ± 2	18 ± 2	30 ± 2
Relative Humidity (%)	80	70	60

In each trail 8 female pigs of *Piétrain* x *Topigs Norsvin* (TN60) genotype were used whit an initial body weight around of 48 ± 3kg. Each animal had 1,5 m^2 of area in the pen. The animals were identified with an RFID ear tags system and each trail started after 15 days of habituation period in TN conditions (Tmean = 18 ± 2ºC and RHmean = 70%) and finished when the animals reached a commercial slaughter weight of around 95-105kg live weight.

2.3. Data collection

2.3.1.Environmental measurements

The environmental variables measured were temperature (T), relative humidity (RH), air velocity, gas concentration and noise/luminosity levels. This data collection was made continuously and in real time through an environmental control system (Webisense) and a data collector (Nidus).

2.3.2.Animal measurements

The productive data measured were initial and final body weight (BW) and feed intake (FI). These data were recorded using the electronic feed station, which through the RFID ear tag system, allowed to monitor and control individually, in each feeder access, the amount of food supplied and ingested (grams); number and time of visits to the feed station (h:m:s); and animal's weight (grams). This precision livestock farming tool allowed to calculate the average daily gain (ADG) and feed conversion rate (FCR).

The physiological data were measured manually and automatically. The rectal temperature was collected manually using a digital thermometer. In order to have a non-invasive method to monitor the animal surface temperature a thermal camera was used. The physiological data collection had as methodology the protocol described at Cruz et al., (2021).

The behavioural data was measured through video cameras strategically placed in the environmental room. An algorithm was developed in order to detect abnormal behaviours such as crowding/removal of animals. This algorithm receives video images and process frame by frame. The analyse process occur in two phases. Using a Delaunay triangulation method, the algorithm searches individual or group animal shapes and, after animal identification, records its position in the pen. In a second phase, in function of animal's position, the software calculates the crowding index developed (1 = crowding; 0 = removal).

3. Results and Discussion

3.1.1. Environmental conditions and Animal measurements

The environmental control system helped to control (more or less easily) climatic variations inside the environmental control room.

Inside and outside environmental conditions recorded in the experimental trials are presented in the next Table.

Table 2. Environmental conditions recorded in the experimental trials

Environmental Conditions									
Conditions	t_0 Average (ºC)	t_0 max (°C)	t_0 min (°C)	t_i Average (ºC)	t_i max (ºC)	t_i min (ºC)	ΔT (°C)	RH_0 Average (%)	RH_i Average (%)
Winter	10.4	29.7	0.2	12.5	19.4	8.3	2.1	80	75
Thermoneutrality	18.8	44.1	3.7	20.7	24.9	16.0	1.9	65	74
Summer	26.2	45.7	12.0	28.9	33.3	23.2	2.7	56	63

T_0 = Outside temperature; Ti = Inside temperature; RH_0 = Outside relative humidity; RHi = Inside relative humidity.

Table 2 shows that the average temperatures and relative humidity recorded inside the environmental room were in accordance with project goals and represented real winter, thermoneutrality and summer conditions.

Other parameters recorded inside the environmental control room and with particular relevance in the animal welfare are presented in Table 3.

Table 3. Inside environmental parameters recorded in the experimental trials

Conditions	CO_2 (ppm)	Noise level (dB)	Luminosity level (lux)
Winter	882	67	23
Thermoneutrality	1120	65	177
Summer	1704	64	121

According with Table 3, the higher CO_2 concentration occurred in the summer condition. This can be explained because under high temperatures and low humidity levels (Table 2) the animals tends to increase their respiratory rate. Regarding the noise level, these values didn't variate between environmental conditions and wasn't possible to identify stress situations (levels > 85 dB). The luminosity level recorded in the winter was substantially different from the other conditions. It can be explained because in order to increase the thermal insulation at windows level the outside blinds were closed which decreased the light incidence inside the environmental control room.

Productive data recorded in the experimental trials are presented in Table 4:

Table 4. Productive data recorded in the experimental trials

Conditions	$BW_{initial}$ (kg)	BW_{final} (kg)	FI (kg/day)	ADG (kg/day)	FCR (kg/kg)
Winter	45.9	96.0	2.701	0.792	3.41
Thermoneutrality	45.9	103.4	2.560	0.930	2.75
Summer	49.4	98.7	2.310	0.859	2.69

In general, some environmental and productive data allow to understand that the environment had an influence on pig's performance and that animals improved their results under thermal comfort conditions. In addition, environmental control systems have demonstrated their efficiency to simulate environmental conditions and the ability to be a powerful tool to provide adequate housing and welfare conditions.

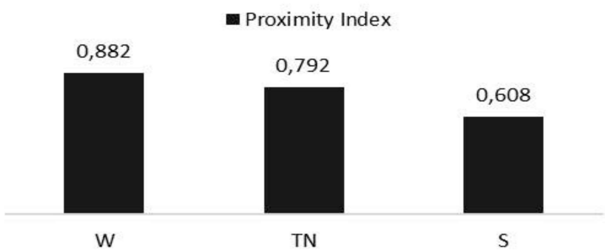
Physiological data recorded in the experimental trials are presented in the next Table:

Table 5. Rectal and surface temperatures recorded in the experimental trials

Conditions	Rectal temperature (ºC)	Surface temperature (ºC)
Winter	38.7	32.2
Thermoneutrality	39.0	35.9
Summer	39.2	36.9

This table demonstrates that rectal and surface temperatures have higher values in animals housed in summer conditions. These values are in accordance with expectations, since under conditions of high temperatures, pigs have difficulty in dissipating their body heat, which causes an increase in internal and surface temperature (Cruz, 1997). This effect is most evident in surface temperature.

Behavioural data recorded in the experimental trials are presented in the next Graph:



Graph 1. Proximity index recorded in the experimental trials

Based on this graph, it appears that the animals were more close in winter condition. This behaviour is very common in pigs that tend to huddle when subjected to low temperatures, in order to avoid loss of body heat to the surrounding environment. The opposite is verified in the summer condition, since the animals disperse in order to increase the heat exchange with the surroundings and to maintain their body temperature.

3.1.2.Awartech Smart Sensing Platform

The Awartech Smart Sensing Platform is a precision livestock farming tool developed in the AWARTECH Project aim and resulted from the integration in real-time, of data provided by the technological devices used in the experimental trials.

This platform is a WEB-based application used to view and control sensory systems and operates according GRID system. GRID is a data and IoT system that supports many protocols and is available to communicate with different systems/tools (thermal cameras, video cameras, environmental sensors, electronic feed stations, etc.). It allowed to register automatically/manual and continuously many variables related to animals and environment. The different parameters were recorded with variable periodicity and this information could be consulted in real time or in databases due to the ability to store all data over time

All of this information allowed that, according to the animal's feedback, the platform could control the environmental conditions (in real time and automatically) in order to promote the animal welfare.

The platform's automation processes were based on stream processing mechanisms. That is, the sensor data were available in real time when received on the platform. To develop these mechanisms, the Awartech Smart Sensing platform incorporated a rules engine that evaluated the environmental/animal data in real time and, according to the configured rules, could perform one or more actions on the environmental control system (ventilation, heating or cooling).

Automation mechanisms were one of the most difficult tasks to develop during the project due to the complexity of the animal-environment interactions. The major problem with this approach was the interconnectivity between the environmental parameters. As a physical system, when any parameter changed, the environmental conditions also changed. However, in terms of air quality, the results were quite satisfactory and this parameter revelled to be a promising indicator for providing animal welfare conditions.

4. Conclusions

The AWARTECH Project contribute to the scientific and technological advance of the pig sector through the development of a precision livestock farming tool that allows to assist productive systems, contributing to the future sustainable pig production.

The zootechnical results taken from the case study confirm the extraordinary influence that environmental conditions of housing have on animal production and welfare. These results contributed to the development and operation of the Awartech Smart Sensing Platform.

In general, the Awartech Smart Sensing platform operated according to expectations in the experimental trials and in the commercial pig facility. During the project development some expected problems occurred due to the complexity of technologies adopted. However, the tested technologies demonstrated great potential for use in intensive production systems.

Automation process based on animal and environmental real data is a pioneer approach that revelled to be, as expected, a difficult and complex process. However, the AWARTECH Project contributed to develop some technological knowledge that opens doors for future works, in particular the development of a comfort or animal welfare index. This index that will integrate animal and environment information could be the base for balanced actuation rules.

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Please, use the following format for paper citation:
Author(s) (2021). Title. In: Barbosa, J. C., Silva, L.L., Lourenço, P., Sousa, A., Silva, J.R.,Cruz, V.F., Baptista, F., (Eds.) Proceedings of the European Conference on Agricultural Engineering AgEng2021. Évora, Universidade de Évora, pp. xxx-xxx.