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Pigs Stunning Optimisation

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Abstract *– Pigs are stunned by means of electrical current or carbon dioxide in order to avoid pain during debleeding to death. This is important from the point of view of animal welfare and meat quality. The latter is linked to the first: meat from animals that do not experience stress and pain before and during slaughter, is tastier and more tender.*
The electrical stunning process is not perfect as sometimes carcass exhibits damages. Researchers try thus to improve stunning methods in an experimental way: several groups of animals are stunned using different stunning currents and electrode positions, after which results are compared.
A project has been started with the goal of optimising the electrical energy storage during stunning. In this paper we will describe the steps used to better characterize the knowledge of pigs electrical properties and present some results.

Keywords *– Electrical stunning, pig slaughter, animal welfare.*

I. INTRODUCTION

The EU regulation 93/109/C requires that animal slaughter occurs in a painless way and without stress. Authorised methods are shooting, electronarcose and gas inhalation. The electronarcose has the theoretical advantage over gas inhalation to be very fast, thus limiting the emotional impact.

In the case of pigs, electronarcose is used in slaughter plants for practical reasons. The first step renders the animal unconscious by stunning, the second step cause ventricular fibrillation and heart arrest.

This solution is not 100 % efficient, as revealed by damages detected on carcass after slaughter. Those ranges from internal bleeding (15 %) to broken bones or back (0.5 %), leading to loss of quality in the obtained meat. Problems may be caused by bad electrode placement or by a too high value of the contact resistance: stunning devices operates as voltage sources.

Researches [1–5] have been conducted in order to correlate the properties of the stunning process (current type, electrode position, . . .) with the obtained meat quality.

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II. STUNNING OPTIMISATION

A project has been started at the Centre for Animal Health Care of the K.U.Leuven, in order to improve the electrical stunning method.

Optimisation of the current will be carried out by modeling the electrical impedance of a pig's head. This computer model will be used to determine the electrode placement and the type of current in order to administer a maximal amount of energy to the brain.

The model will be based on low-current impedance measurements on chemically anaesthetised pigs, to protect their welfare. To cope with the problem of electrodes contact resistance, a four-point measurement method is used. This method is similar to the three-dimensional electrical impedance tomography [6].

As the current is distributed inside the head, it would be more correct to speak about the ratio between induced voltage and total current, or to say that the measured resistance consists of a part of the head.

The parameters of the stunning current are frequency, waveform, amplitude, duration and position of the electrodes. If deemed necessary, an adaptive stunning process could be devised, using a current which depends on the weight of the pig or the electrical impedance measured between the electrodes before stunning.

III. EXPERIMENTAL FRAMEWORK

A. Context

The first stage of this research is to investigate the electric properties of the tissue of pig heads. Semi-quantitative results can be found in scientific literature [7–9], but they are rather old, while recent results are difficult to find. For this reason, it was decided to work in a systematic way and determine the range of variation.

Impedance of living tissues has a resistive and a capacitive component. Therefore measurements at different frequencies are needed.

According to [10], electrical behaviour of animal tissue is complex: its impedance is non-linear (dependent on voltage or current) and it breaks down when voltage is applied. To investigate this behaviour, measurements at different current levels are necessary.

In order to maximise the animals welfare, they were anaesthetised with a combination of Zoletil and Xyl-M under control of a veterinary. The electrodes application site was first shaved and cleaned with acetone. The four electrodes were always positioned in the same way:

- two on each side of the head, between the eye and the ear,
- two about 1 to 2 cm above, at the height of the temporal bone.

The electrodes used are of type medical adhesive Ag/AgCl for paediatric use (smaller size). A photo of an anaesthetised pig wearing the electrodes can be seen on figure 1.

Figure 1. Instrumental setup

The following frequencies were used: 100 Hz, 400 Hz, 600 Hz, 900 Hz, 1200 Hz, 1400 Hz, 2000 Hz, 2600 Hz, 4000 Hz.

For security reasons, the pig heart rate is constantly monitored during the anaesthesia, in order to take appropriate steps in case of problems.

B. First set of measurements

At a first stage, the aforementioned measurements were performed manually. The required values were evaluated with TRMS multimeter, while the injected voltage was chosen by the operator.

Those experiments conducted at low-current, *i.e.* less than 12 mA, were performed to test and practise the measurement procedure, investigate the correlation between impedance and weight of an animal and study the dependence on frequency and current of the impedance at low current.

A set of 24 pigs of both sexes were tested, with weights ranging from 50 to 80 kg.

A statistical summary can be seen on figure 2. The measurements at 100 Hz were more limited, as current values higher than 8 milliamperes often caused fibrillation.

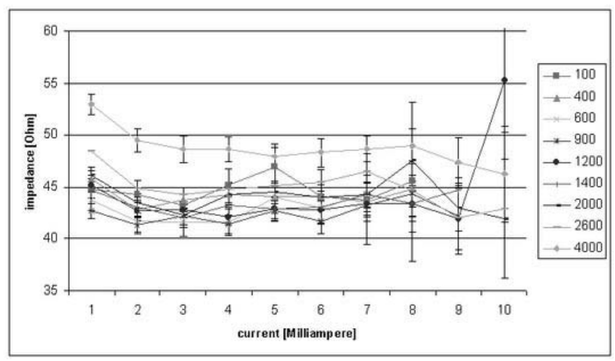

Figure 2. Impedance norm dispersion

A number of significant correlations have been found within those data:

- The impedance level slightly changes with the applied voltage. This is currently under investigation in order to see if this can be explained by non-linear behaviour, as sometimes the induced current was not sinusoidal;
- The impedance level is not constant with frequency;
- There is a slight impedance variation with the weight. This can probably be related to the dimensions of the pig head, which in turns modulates the electrodes distance.

A typical pattern of impedance as a function of frequency is presented in figure 3. This can be analysed as follows: the 4-points impedance presents a minimum at around 900 Hz, with a range of variation between 42 and 50 Ω. No range of expected deviation is given, as it appeared that the obtained values, resulting from True

RMS measurements, were sometimes overestimated due to noise and parasitic signals. This will be addressed as described later.

The behaviour may seems odd at first sight, as the measured impedance is supposed to be capacitive, with the impedance norm decreasing with the frequency. A hypothesis is that the current repartition inside the head is a function of the frequency, leading to an increase of the induced voltage on the skin and to a higher value of the apparent impedance.

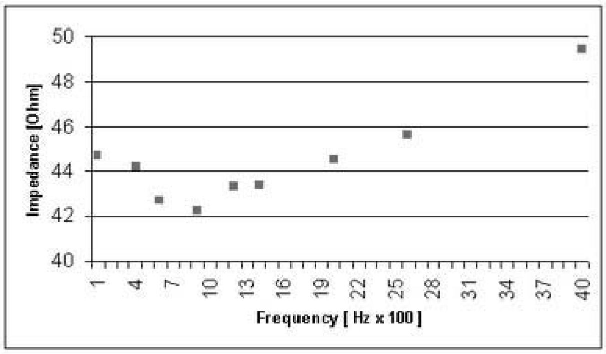

Figure 3. Impedance variation with frequency

C. Second set of measurements

A measurement campaign took place between October and November 2003. During this period, 160 pigs were used, with a average weight of 70,3 ± 9,8 kg, extremal values being 48 and 92 kg.

Of those, 106 animals were also scanned using X-Ray techniques, in order to determine a number of biometric data relevant to their body composition:

- fat weight and density
- muscles weight and density
- bone weight and density

To simplify the measuring process, it was fully automatised in the following way: temporal waveforms are acquired on a oscilloscope, then transferred on a computer for later numerical processing. The excitation voltage is produced by a voltage generator driven by the same computer. A number of voltage steps are applied with a duration of 5 seconds, and the acquisition occurs at the end of each step, in order for the values to stabilise.

The same frequencies where used, and 10 voltages steps applied, leading to 90 measurements for one scan. With most animals, the anesthesia duration was long enough to repeat the scan 4 or 5 times.

D. Automatic impedance determination

The measured voltages may be contaminated by noise. Possible causes are bad contact between the electrode and the tongs, or between the electrode and the skin, both resulting from head movements at the respiratory rhythm. At higher current values (around a few milliamperes), non-linear waveforms have sometimes been observed.

One of the concern of this campaign was the reliability of the results. At the end of the measurements, around 54 000 points have been collected.

Scanning individually the whole set of results for problems was definitively not an option. So it was deemed necessary to include, together with the computed results, enough information about their reliability.

All the results were collected in a database, to permit easier data extraction in a later stage of the processing.

E. Numerical Processing

The numerical processing consists first of describing the waveform as a sum of constant term (offset), sines and cosines at the generator frequency, and noise.

As the acquisition window does not necessarily contains an integer number of periods, the Fourier method was not used and a simple correlation analysis performed.

This way, the standard deviation of coefficients can be obtained. Using error propagation method, the error about the obtained impedance can also be established, and dubious values rejected.

More specifically, the following steps are applied:

1. identify the quantification step (depends on scope range)
2. apply a Savitsky-Golay smoothing filter to attenuate the quantification noise;
3. compute sine and cosine coefficients using a standard least-square approach;
4. compute the residuals standard deviation;
5. test for outliers. Criterion: there should be no point where the absolute value of the residual is greater than 3.9 SD (p = 1e-4);
6. outliers sometimes occurs repeatedly at the same numerical code and signal phase. Such outliers are considered as an artifact of the quantification process and replaced by the numerical code of the predicted value at this point, and iteration restarted at step 3. In some cases, this helped reducing the standard deviation of the residuals by up to 30 %.
7. compute the covariance matrix for the coefficients, and translate it for a polar representation (magnitude and phase uncertainty);
8. compute global and skin impedance norm together with their uncertainty, based upon the uncertainties on the phasor coefficients

An advantage of this approach over the previous one is that it will be possible to also compute phase shift between measured waveforms and to refine the modelling by introducing a resistive as well as a capacitive term.

IV. RESULTS

By combining electrical impedance measurements and body composition results, a number of significant correlations have been found:

A. Global impedance

The impedance value, averaged over all animals, is a decreasing function of frequency.

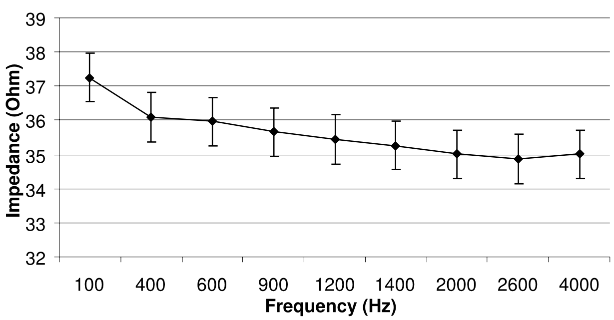

Figure 4. global impedance

B. Fat percentage

A correlation was found between the head impedance and fat percentage, by selecting the heavier animals. Indeed, the animal weight during the slaughter process ranges from around 100 to 110 kg.

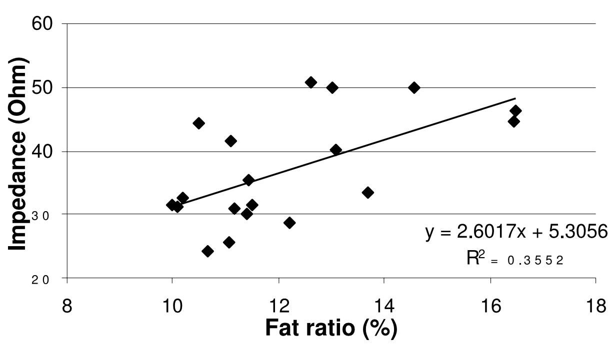

Figure 5. Fat percentage

C. Bone mass density

A correlation was found between the head impedance and the bone mass density, on the same subset of animals.

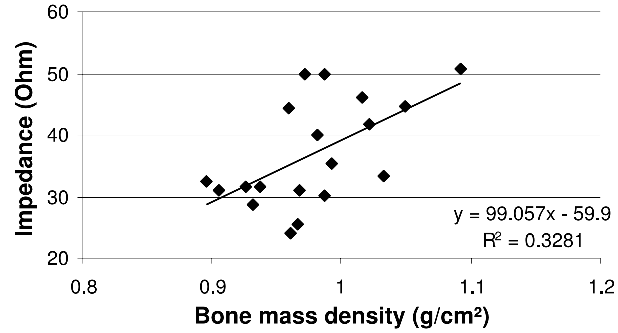

Figure 6. Bone density

V. CONCLUSIONS

A project aiming at optimising electrical stunning method has been presented. The first part of this project is to characterize the electrical properties of pigs head and in particular to establish a range of expected values.

Two sets of measurements have been performed, from which ranges of impedance variations and behaviour have been determined by statistical means.

The next step will be to produce and validate a model of the impedance of a pig head, as a function of relevant input variables in order to choose the best suited stunning current.

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