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Potential impact of biomedical techniques on the progression of boar fertility predicting methods

Prof. Ioannis Tsakmakidis, DVM, PhD

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ITM Magapor 17 MAY 2025 - ZARAGOZA

Key points

- Boar fertility plays key role in pig production efficiency
- Accurate prediction of fertility remains a challenge in modern pig breeding programs
- Emerging biomedical technologies offer promising avenues for improving prediction accuracy

Boar is a critical component of pig industry

- Each boar fertilizes more than a thousand sows per year
- Each boar produces thousands of piglets per year
- Economic study: the cost of purchasing a boar corresponds to about 0.5 % of the total value it brings back into the farm

Predicting fertility remains a challenge...

Literature reports / recommendations

Boars with highly motile and morphologically normal sperm are usually highly fertile

Boars that do not meet these criteria should be re-evaluated at 30 - 60 days intervals and, if not improved, replaced

Especially, boars in AI studs should be examined at least once a month after any disease or injury

Understanding the importance of the boar...

* 25% of the used boars provide farrowing rate < 80%

* One more piglet / farrowing increases the annually income about 120 million $

* 1.700.000 $ U.S. Department of Agriculture (USDA), prognosis of boar fertility

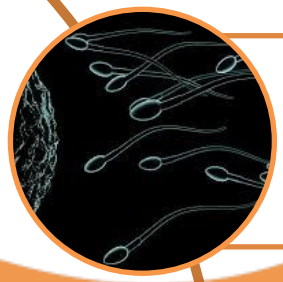
Source: https://www.cals.iastate.edu/news/releases

Understanding the importance of the boar…

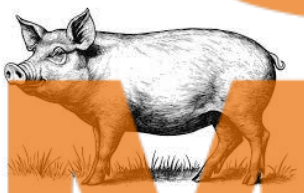
* Data: 1193 boars - 116749 AIs
* Removal of 10% of less fertile boars results in 2.23 more piglets per litter
* More than 10000 euros/year for a farm of 1000 sows
* Uncovering the sub-fertile boars maximizing the pig farms' productivity

Source: Roca et al. (2015). *Reproduction in domestic animals*, *50*, 48-55.

Traditional methods of boar fertility prediction



Basic semen analysis (volume, motility, morphology)

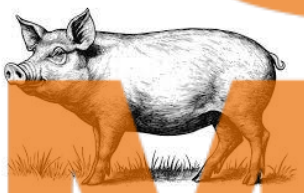


Clinical examination and testicular measurements

Data of reproductive performance and progeny testing

Limitations of traditional methods

High variability among individuals



Inability to detect subfertile boars early

Lack of standardized, predictive biomarkers

Basic semen analysis

All Time Classic

Subjective

Objective

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CASA analysis: VCL, BCF, VAP, VSL, ALH positively correlated with farrowing rate and litter size

Specialized traditional methods of boar fertility prediction

Evaluation and combination of multiple semen quality characteristics, e.g. sperm morphology and DNA integrity is positively related with farrowing rate

Source: Tsakmakidis et al. (2010). *J Vet Sci*.

Specialized traditional methods of boar fertility prediction

Sperm Morphology + DNA Integrity Combo:

this pairing predicts farrowing rates 12-18% more accurately than morphology alone

* e.g. for a 500-sow farm: that's 85 more litters/year

Specialized traditional methods for predicting **high** boar fertility

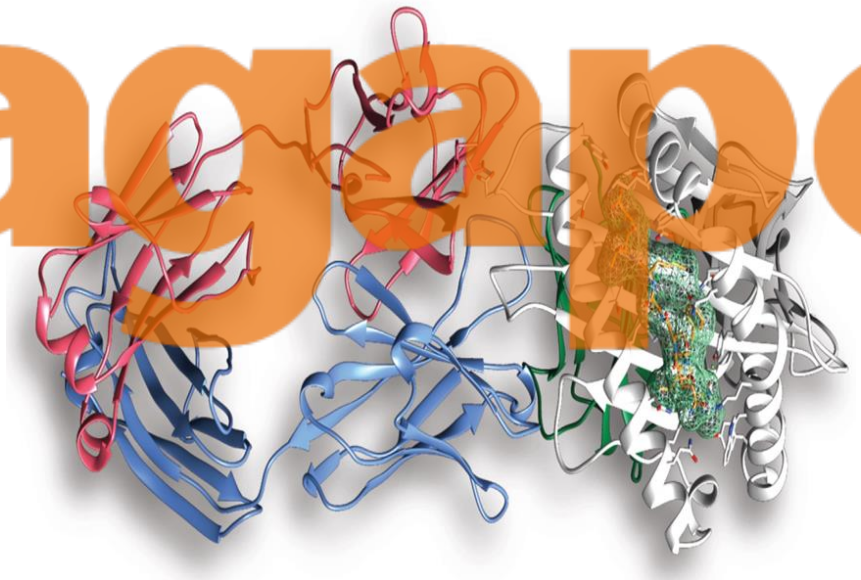
- In vitro fertilization (IVF)
- Sperm pen. assay (SPA)
- Hemizona assay (HZA)

- ✓ **Time – consuming**
- ✓ **High - cost equipment**
- ✓ **Trained operators**

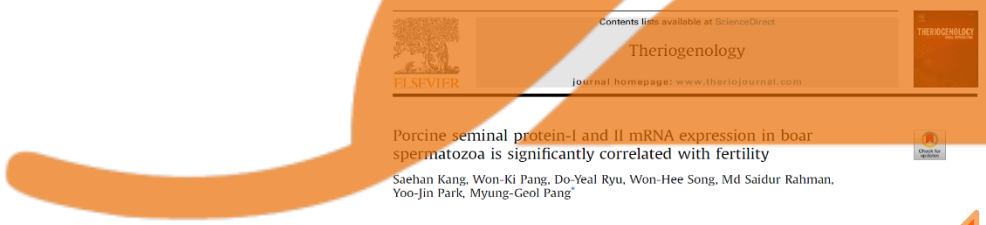
New, but current in use methods

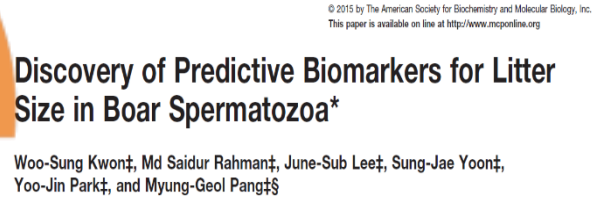
Molecular techniques, genetic background and potential biomarkers

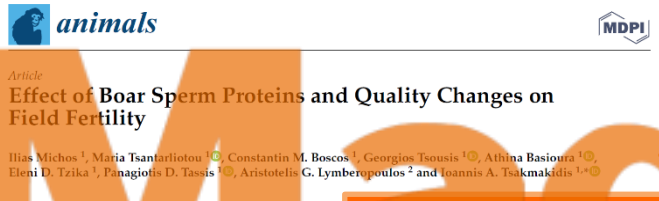
Genomics, transcriptomics, proteomics, and metabolomics: a combination of complex and specialized techniques to recognize molecules that play a key role in major reproductive events



Molecular techniques, genetic background and potential biomarkers







OPN70 +
GPX5

PSP-1 +
PSP-2

AWN, TPI, −
RAB2A, AQ3

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Molecular techniques, genetic background and potential biomarkers

SCIENTIFIC REPORTS

OPEN

Proteomic approaches for profiling negative fertility markers in inferior boar spermatozoa

Received: 18 June 2015
Accepted: 05 August 2015
Published: 08 September 2015

Woo-Sung Kwon, Shin-Ae Oh, Ye-Ji Kim, Md Saidur Rahman, Yoo-Jin Park & Myung-Geol Pang

Spot No.	NCBI No.	Protein description	MASCOT score[a]	Expression level	
				Small litter size	Large litter size
2	1127023	pancreatic glycoprotein 2 (GP2)	158	▲	▼
3	47522754	Trifunctional enzyme subunit alpha, mitochondrial (HADHA)	202	▼	▲
4	359811347	60 kDa heat shock protein, mitochondrial (HSPD1)	243	▲	▼
5	73985642	Cytochrome b-c1 complex subunit 1, isoform2, mitochondrial (UQCRC1)	148	▲	▼
6	28336	mutant beta-actin (beta'-actin) (ACTB)	107	▲	▼
7	57086887	actin-related protein T2 (ACTRT2)	205	▲	▼
8	84579847	actin related protein T3 (ACTRT3)	197	▲	▼
9	3891849	Chain B, crystal structure of bovine mitochondria	105	▲	▼
10	300763221	pyruvate dehydrogenase: SUBUNIT= beta precursor (PDHB)	155	▲	▼
12	4929676	Homo sapience CGI-104 protein mRNA, complete cds	236	▲	▼
13	109102081	cytosolic 5′ nucleotidase IB isoform 1	87	▲	▼
14	75052483	Acrosin-binding protein precursor (Proacrosin-binding protein sp32) (ACRBP)	335	▲	▼
16	190201	Porin	48	▲	▼
17	4505773	Prohibitin (PHB)	207	▲	▼
18	114053087	glutathione S-transferase Mu3 (GSTM3)	336	▲	▼
20	27807305	ATP synthase subunit d, mitochondrial (ATP5H)	145	▲	▼
21	311253799	Ras-related protein Rab-2A (RAB2A)	59	▲	▼
22	76779289	glutathione peroxidase 4 (GPx4)	147	▲	▼
23	13195731	glutathione peroxidase 4 (GPx4)	241	▲	▼
25	28417	Arginine vasopressin receptor 2 (AVPR2)	203	▲	▼

Molecular techniques, genetic background and potential biomarkers

Using genomic markers instead of usually analyzed sperm parameters may be more accurate for assessing male fertility

Potential for **genomic selection** in AI studs

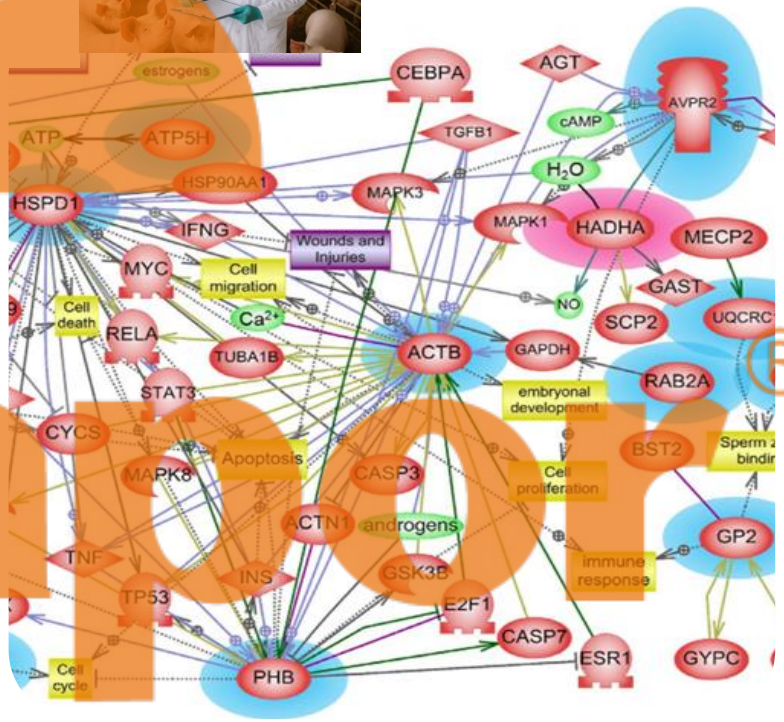
Early-life prediction of reproductive potential

Development of **diagnostic fertility kits**

Molecular techniques, genetic background and potential

Point of View

Signaling pathways associated with fertility-related proteins in boar spermatozoa



Source: Kwon, Woo-Sung et al., (2015). *Scientific Reports 5.1 (2015): 13821.*

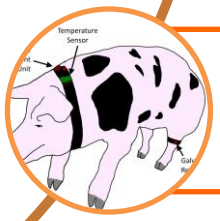
The challenge of the scientific community

Development of predictive models for boar fertility / semen quality

Statistical models - database of many influencing factors (animals, environmental, seasonal etc.)

AI - Machine Learning models

Biophysical methods: microfluidics and microchip technologies



On animal biomedical measurements in combination with semen quality variables

Development of predictive models for boar fertility / semen quality

Research project: Investigation of boar reproductive capacity using biomedical techniques

www.digipig.gr

This project has received funding from

ΕΛΙΔΕΚ

ΓΓΕΤ
ΓΕΝΙΚΗ ΓΡΑΜΜΑΤΕΙΑ
ΕΡΕΥΝΑΣ ΚΑΙ ΤΕΧΝΟΛΟΓΙΑΣ

An under-development method

Biomedical techniques:

applications of biological

and physiological principles

in clinical practice

Knowledge and queries

Boar, critical important unit. The prediction of boar fertility saves resources

Stress affects semen quality reducing the boar value

Periodic semen evaluation is required, waiting for the report of laboratory results

Questions to answer about the under-development method

Real time measurements?

Under boars' living conditions?

Specific stress factors of each farm / AI station?

Strong indications of semen quality before its' lab evaluation?

The aim of the study

Is feasible to get reliable biomedical measurements of boar behavior?

Is feasible to develop a prognostic boar fertility model based on biomedical measurements?

Implementing the purpose of the study

Biomedical measurements of the boar behavior during semen collection within their living space

Objective boar semen evaluation

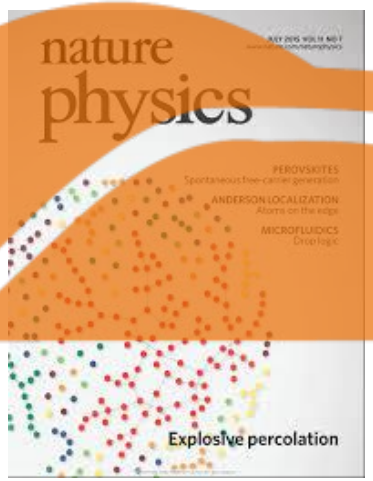
Correlation of biomedical and seminal data to establish a predictive model of boar semen production capacity

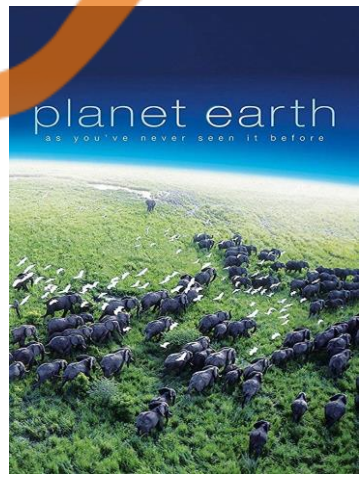
Selected biomedical parameters / measurements

1

- Boar orientation and movements / magnetic fields
- Emotional status of the boar
- Temperature (body, scrotal, dummy's / environmental)
- Salivation of the boar
- Scrotal contractions / relaxations

How was the idea born?





Animals have:

- Hyper-sensations and emotions
- Different perception of magnetic fields
- Orientation and navigation is based on the different perception of magnetic fields

Animals' migration based on magnetic fields

Poot, H., B. J. Ens, H. de Vries, M. A. H. Donners, M. R. Wernand, and J. M. Marquenie. 2008. Green light for nocturnally migrating birds. *Ecology and Society* **13**(2): 47. [online] URL: http://www.ecologyandsociety.org/vol13/iss2/art47/

E&S

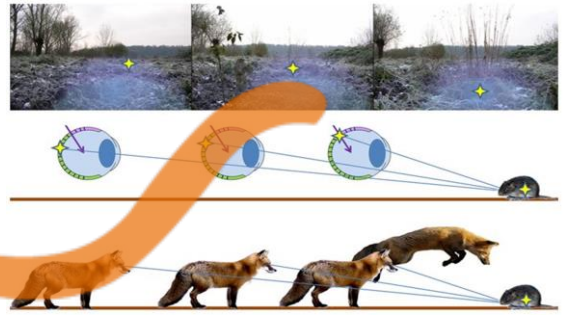
Research

Green Light for Nocturnally Migrating Birds

Hanneke Poot [1], Bruno J. Ens [2], Han de Vries [3], Maurice A. H. Donners [4], Marcel R. Wernand [5], and Joop M. Marquenie [6]

ABSTRACT. The nighttime sky is increasingly illuminated by artificial light sources. Although this ecological light pollution is damaging ecosystems throughout the world, the topic has received relatively little attention. Many nocturnally migrating birds die or lose a large amount of their energy reserves during migration as a result of encountering artificial light sources. This happens, for instance, in the North Sea, where large numbers of nocturnally migrating birds are attracted to the many offshore platforms. Our aim is to develop bird-friendly artificial lighting that meets human demands for safety but does not attract and disorient birds. Our current working hypothesis is that artificial light interferes with the magnetic compass of the birds, one of several orientation mechanisms and especially important during overcast nights. Laboratory experiments have shown the magnetic compass to be wavelength dependent; migratory birds require light from the blue-green part of the spectrum for magnetic compass orientation, whereas red light (visible long-wavelength) disrupts magnetic orientation. We designed a field study to test if and how changing light color influenced migrating birds under field conditions. We found that nocturnally migrating birds were disoriented and attracted by red and white light (containing visible long-wavelength radiation), whereas they were clearly less disoriented by blue and green light (containing less or no visible long-wavelength radiation). This was especially the case on overcast nights. Our results clearly open perspective for the development of bird-friendly artificial lighting by manipulating wavelength characteristics. Preliminary results with an experimentally developed bird-friendly light source on an offshore platform are promising. What needs to be investigated is the impact of bird-friendly light on other organisms than birds.

The fox uses the earth's magnetic field to hunt!!!



Source: http://dsc.discovery.com/tv-shows

What about farm animals?

Cows: tendency to orient towards north or south when they are resting and grazing

Research included 8000 cows

Sense of magnetic fields

Source: D. Cressey, Nature, 2008

Boar behavior, movements and orientation

Commerc collars

On boar

Self-made collars

- Fitting collars with sensors
- Receive and send signals
- Processing, algorithms

Boar behavior, movements and orientation

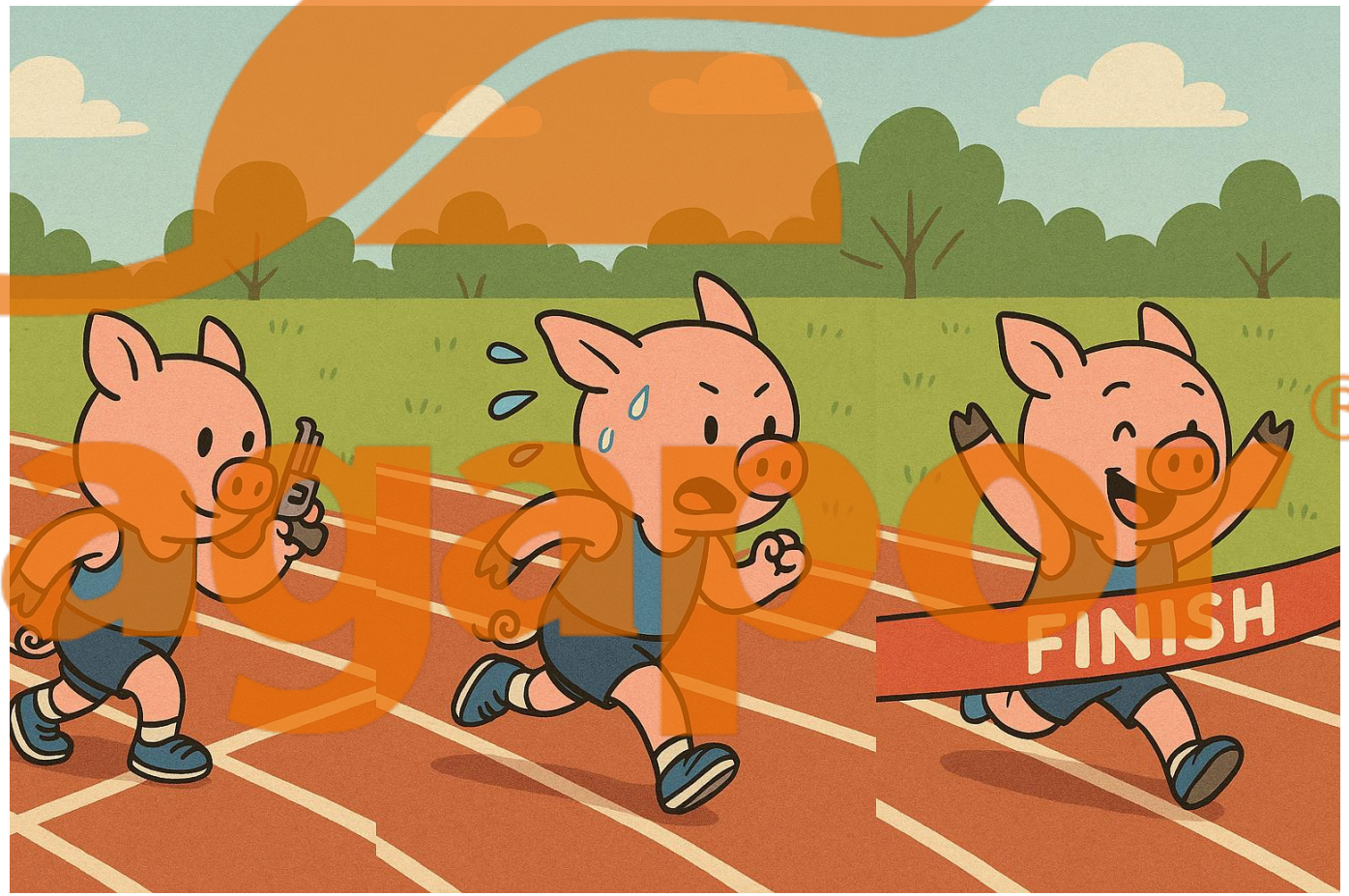
Sensor

Inertial measurement unit (IMU)

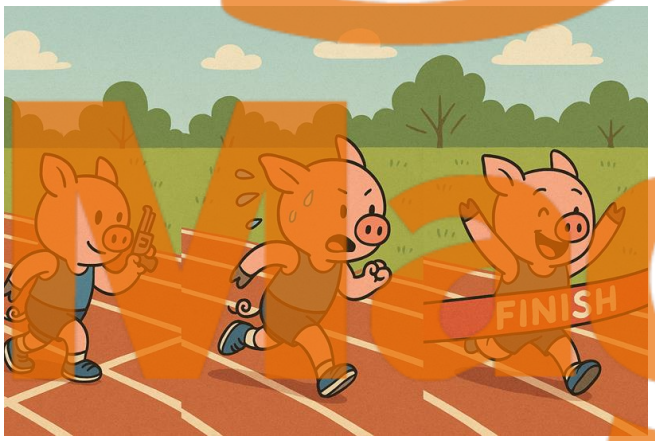
Triple axis gyroscope, accelerometer and magnetometer

Barometric pressure and humidity

A race to semen collection pen…



Boar behavior, movements and orientation



Boar orientation approaching the dummy

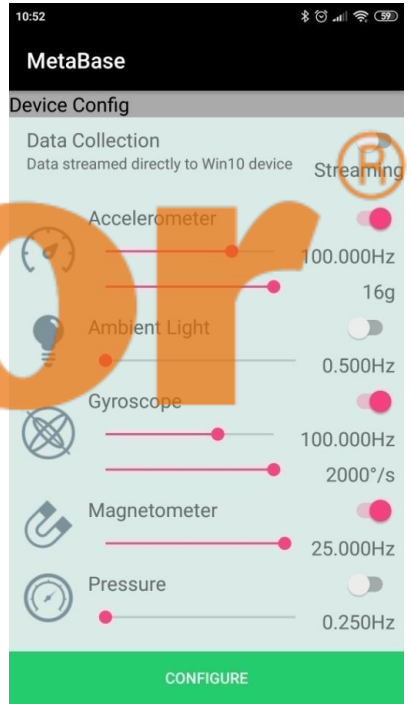
Boar movements' repeatability or not

Number of circular movements around the dummy and mounting attempts

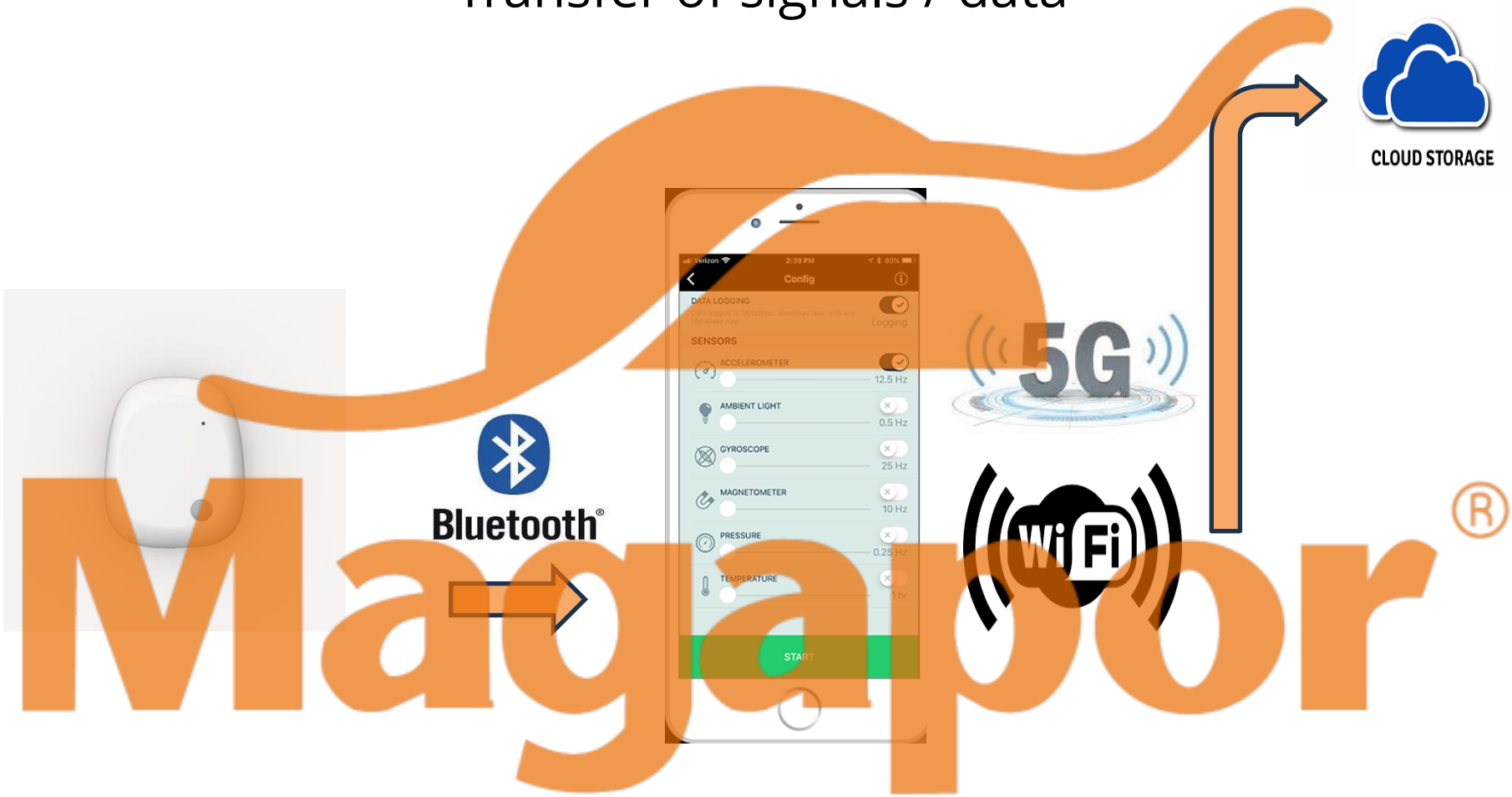
DigiPIG – Methodology

MetaMotionRL

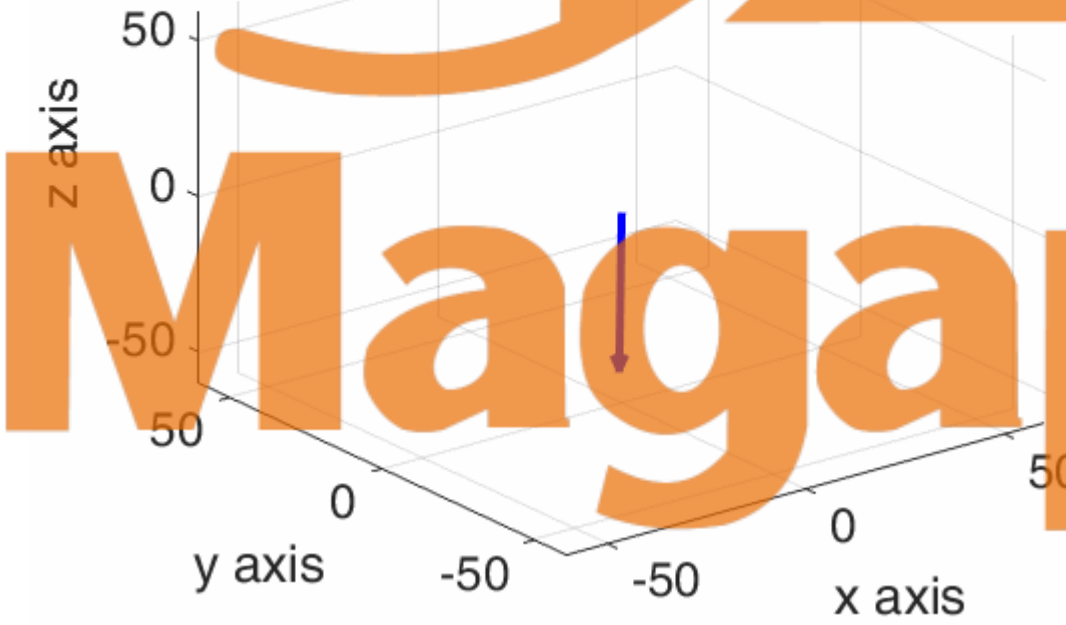
MbientLab

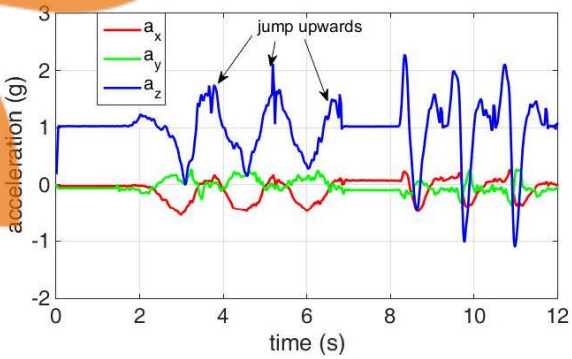


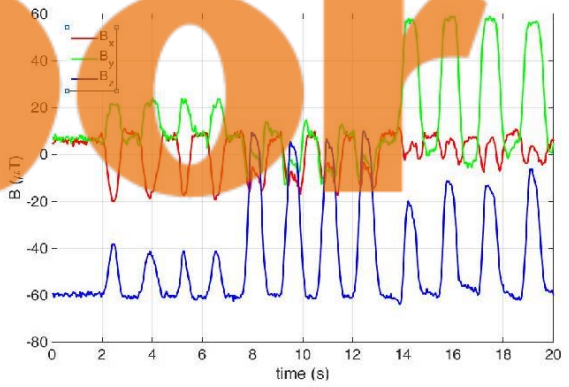
Transfer of signals / data



Biomedical techniques





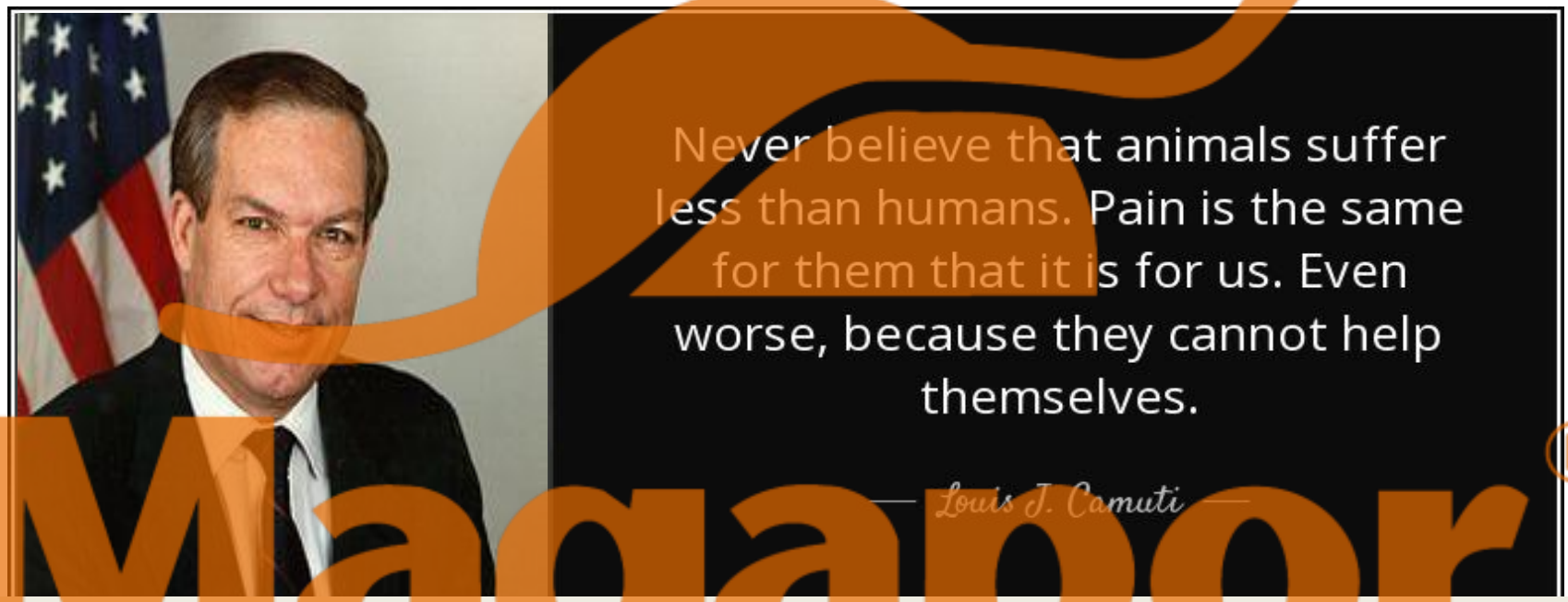


Selected biomedical parameters / measurements

2

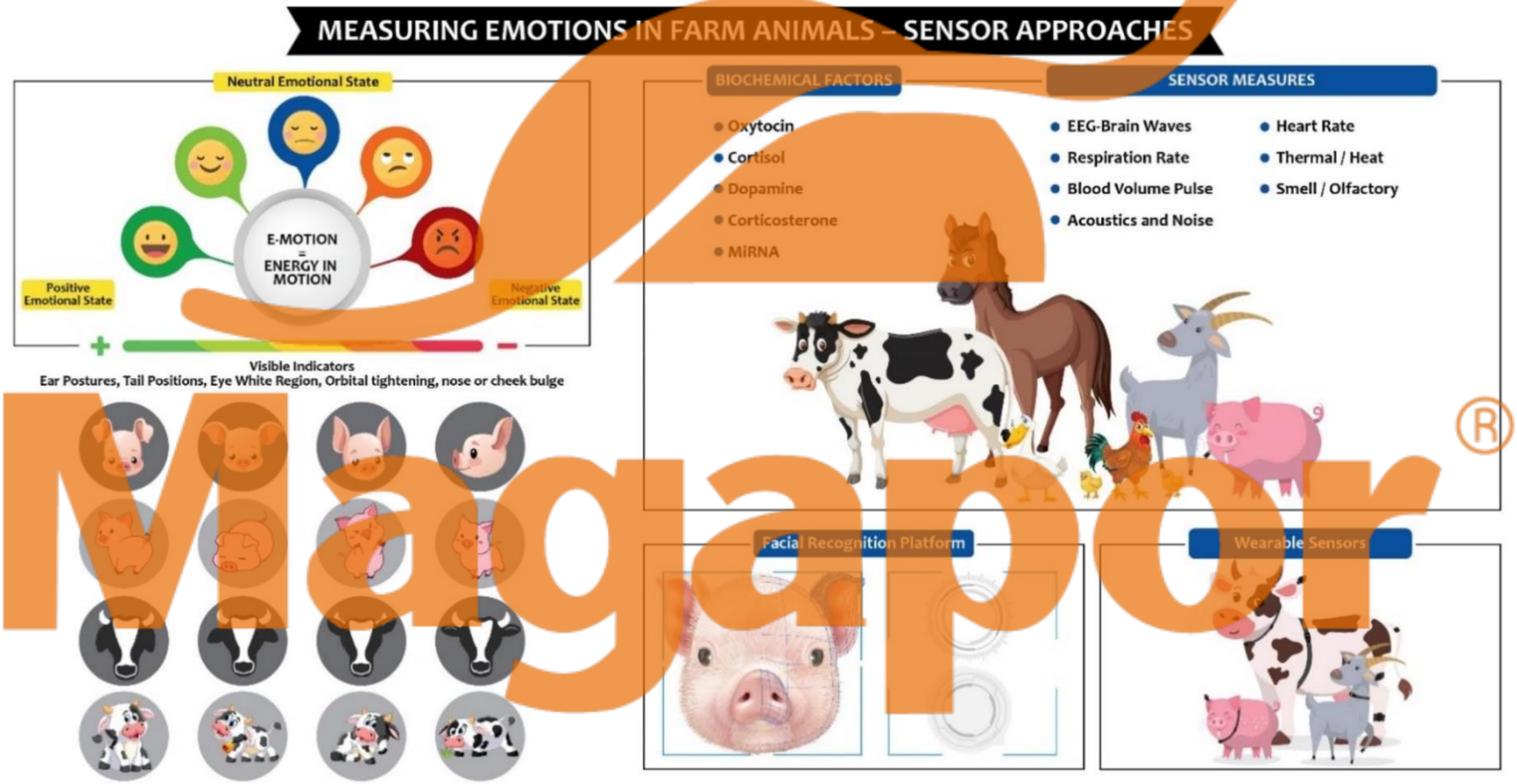
- Boar orientation and movements / magnetic fields
- Emotional status of the boar
- Temperature (body, scrotal, dummy's / environmental)
- Salivation of the boar
- Scrotal contractions / relaxations

Animals have emotions!!!



Louis J. Camuti: a New York City veterinarian and author

Animals have emotions!!!



Source: Neethirajan, S., Reimert, I., & Kemp, B. (2021). *Sensors* 21(2), 553.

Are the breeding boars happy???

The 5 freedoms - Farm Animal Welfare Council (FAWC)

Freedom from thirst, hunger and malnutrition

Freedom from thermal and physical discomfort

Freedom from pain, injury and disease

Freedom from fear and distress

Freedom to express normal behavior

Source: Llonch. (2024). *Animal Reproduction Science* 269, 107549.

Breeding boars' emotional status…

They:

Recognize collection pens and handlers

Change vocalizations when they separated from mates

Stress Memory: Cortisol persists for > 72 hours after bad handling

Source: Grandin T. Behavioral Principles of Livestock Handling (2018).

How emotional status can be measured?

Electrodermal activity (EDA) **or** Galvanic Skin Response (GSR)

Variations in the electrical properties of the skin in response to sweat secretion.

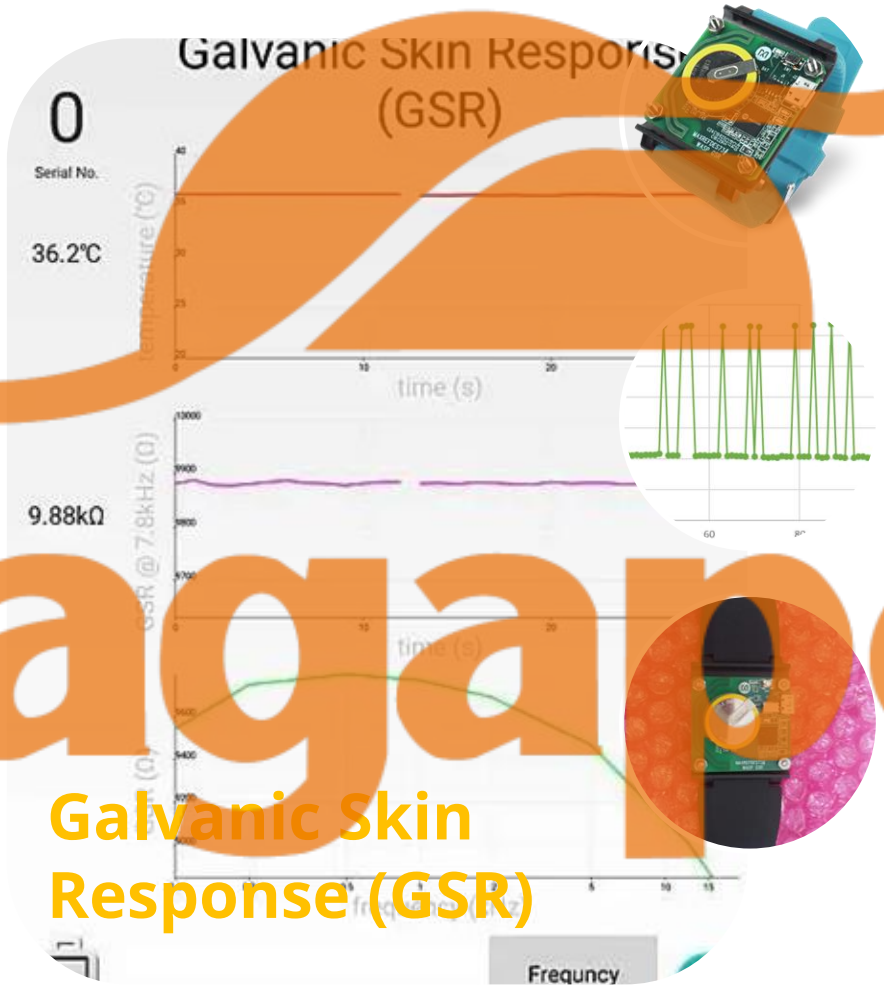
Source: Munsters et al. (2012). *Early Human Development*, 88, 21-26.

Electrodermal activity (EDA) or Galvanic Skin Response (GSR), the body property that causes continuous changes in the electrical characteristics of the skin

MAXREFDES73#

maxim integrated™

Electrodermal activity (EDA) or Galvanic Skin Response (GSR)



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Galvanic Skin Response (GSR)

Selected biomedical parameters / measurements

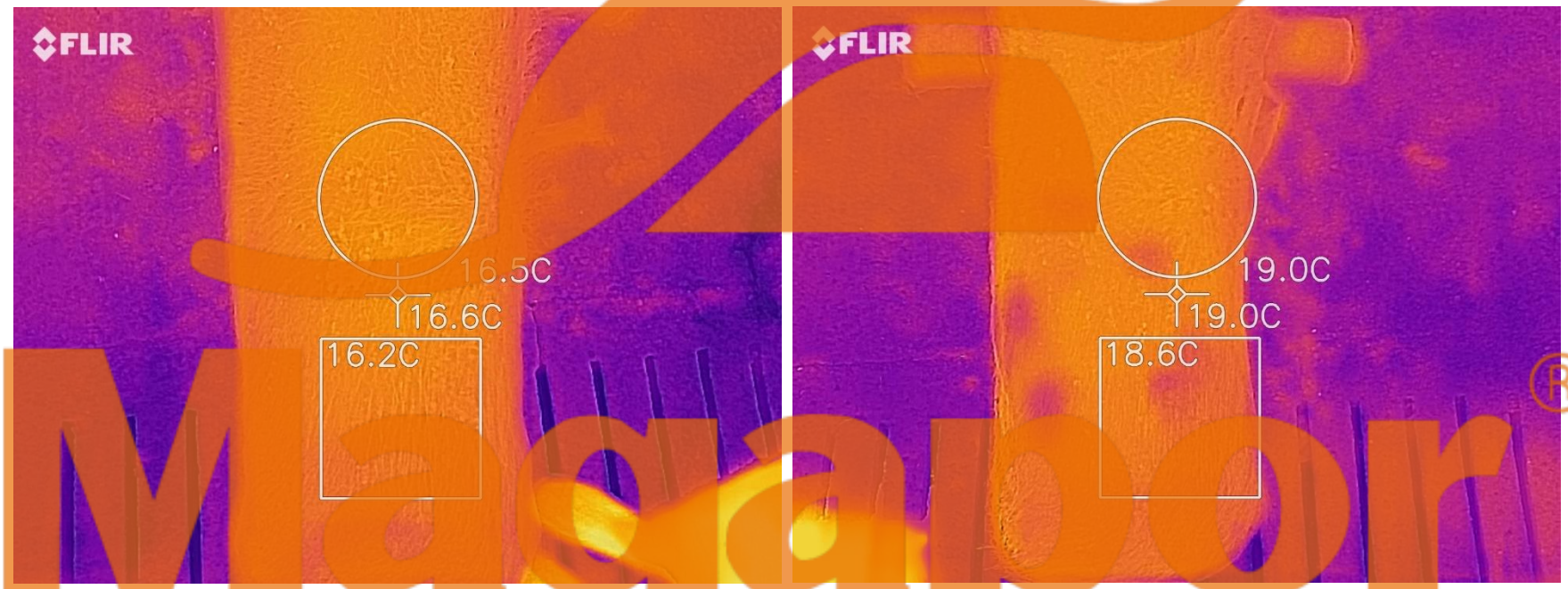
- Boar orientation and movements / magnetic fields
- Emotional status of the boar
- Temperature (body, scrotal, dummy's / environmental)
- Salivation of the boar
- Scrotal contractions / relaxations

Temperature measurement by infrared thermo-camera

Sperm quality is affected by scrotal temperature

Dummy’s temperature "maybe" affects the boar's mounting mood

Dummy’s temperature measurement

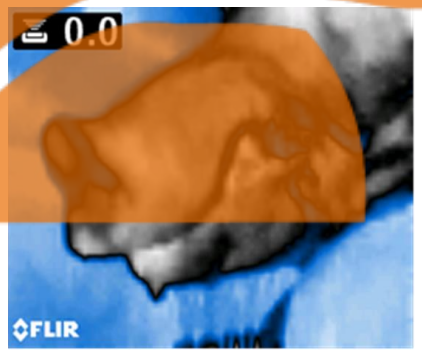


Scrotal temperature measurement

Selected biomedical parameters / measurements

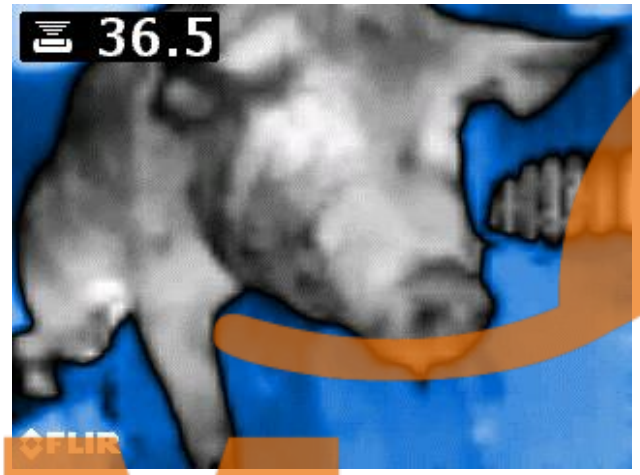
- Boar orientation and movements / magnetic fields
- Emotional status of the boar
- Temperature (body, scrotal, dummy's / environmental)
- Salivation of the boar
- Scrotal contractions / relaxations

Estimation of salivation using an infrared (moisture) imaging camera



The boar during ejaculation shows more salivation

Estimation of salivation



Transfer of images / data

Selected biomedical parameters / measurements

- Boar orientation and movements / magnetic fields
- Emotional status of the boar
- Temperature (body, scrotal, dummy's / environmental)
- Salivation of the boar
- Scrotal contractions / relaxations

Recording of scrotal contractions using a video-camera

Contraction

Number and intense of scrotal contractions

Relaxation

DigiPIG – Scrotal contractions (Matlab)

Movie Player

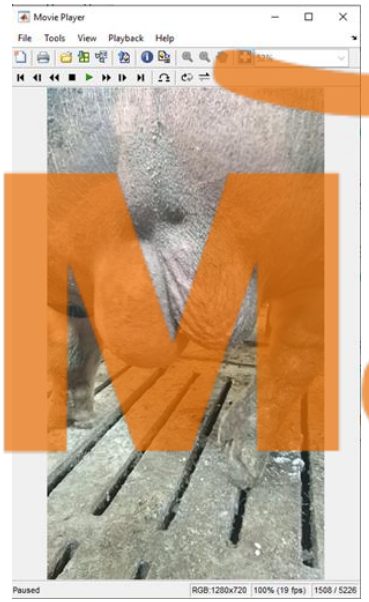


Image Tool

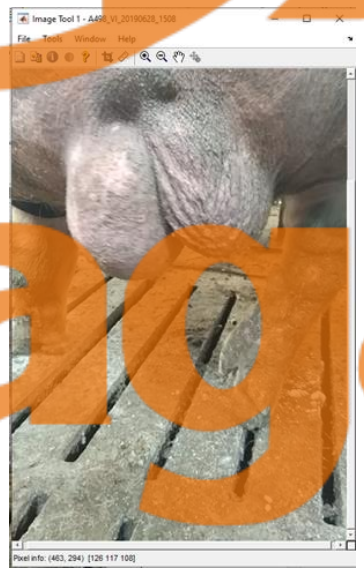
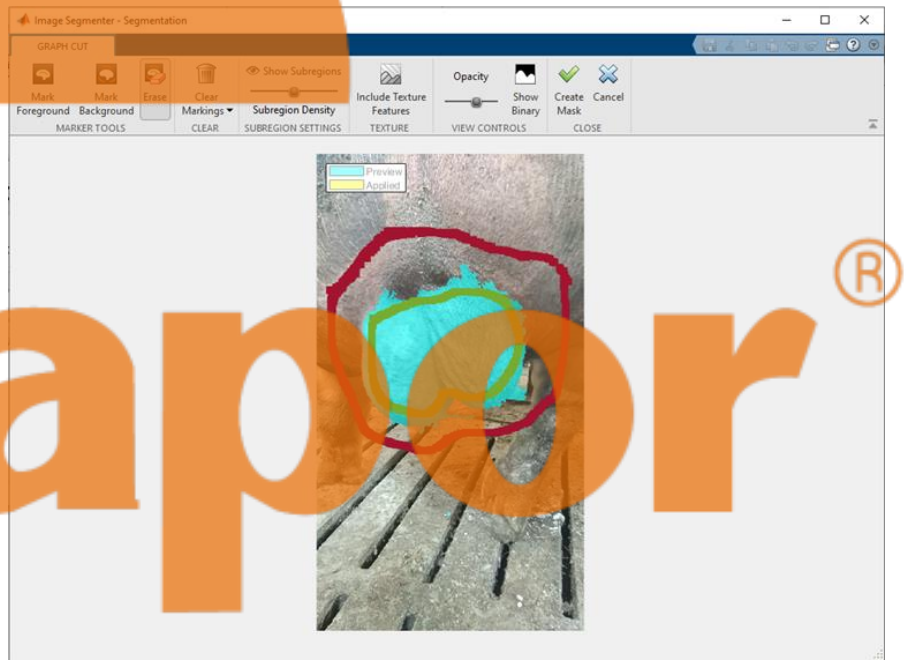
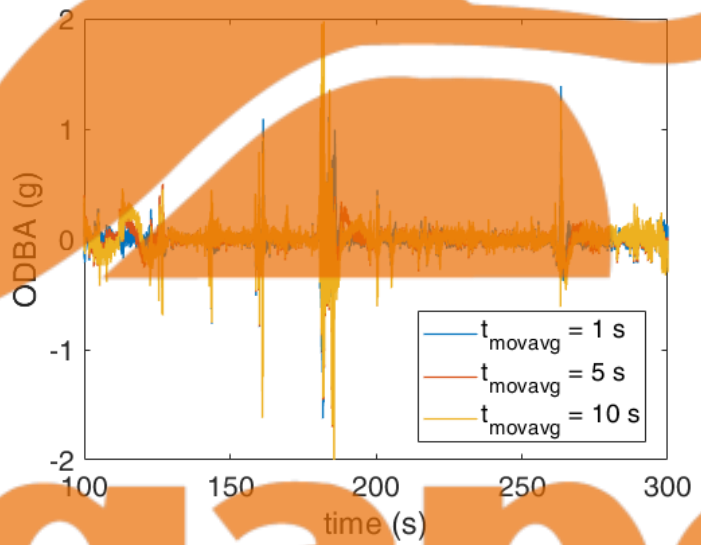
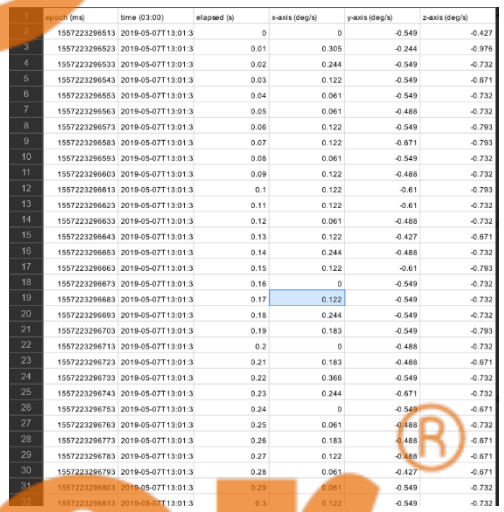


Image Segmenter



Processing of biomedical measurements





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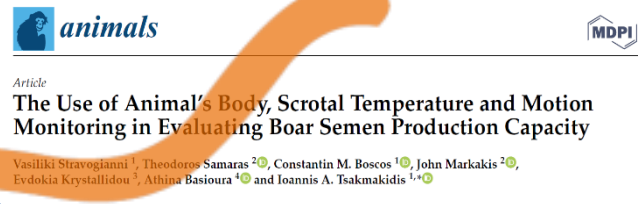
Objective semen evaluation

Semen variables
CASA analysis
Viability
Morphology
Sperm Membrane Biochemical Activity (HOST)
DNA integrity

Biomedical techniques


animals

MDPI

Article

The Use of Animal's Body, Scrotal Temperature and Motion Monitoring in Evaluating Boar Semen Production Capacity

Vasiliki Stravogianni [1], Theodoros Samaras [2], Constantin M. Boscos [1], John Markakis [2], Evdokia Krystallidou [3], Athina Basioura [4] and Ioannis A. Tsakmakidis [1,*]

Progressive motility

Rapid moving spermatozoa

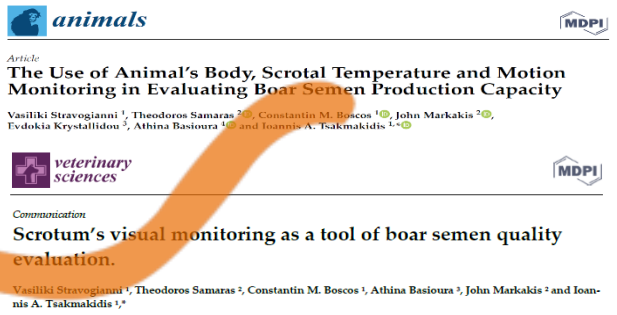
VSL

Temperature of the body, dummy and scrotum

VCL

ALH

Biomedical techniques



animals

MDPI

Article

The Use of Animal's Body, Scrotal Temperature and Motion Monitoring in Evaluating Boar Semen Production Capacity

Vasiliki Stravogianni [1], Theodoros Samaras [2], Constantin M. Boscos [1], John Markakis [3], Evdokia Krystallidou [2], Athina Basioura [1] and Ioannis A. Tsakmakidis [1,*]

veterinary sciences

MDPI

Communication

Scrotum's visual monitoring as a tool of boar semen quality evaluation.

Vasiliki Stravogianni [1], Theodoros Samaras [2], Constantin M. Boscos [1], Athina Basioura [3], John Markakis [2] and Ioannis A. Tsakmakidis [1,*]

Morphology

Volume of the ejaculate

BCF

Temperature of the dummy and scrotum

Total time of ejaculation

Cytoplasmic droplets

VAP

Boar movements - Total dynamic acceleration

Intense of scrotal contractions

Five persons teamwork

Mobile app under development

Feasible methodology?

- Feasible measurements
- Real time signals' collection
- Related with semen variables

Take home message (1)

Biomedical techniques complement our understanding of boar fertility

Biomedical techniques can be real time used in the boars' housing environment, reflecting the effects of any influential factor

Take home message (2)

- Research about the development of new boar fertility prediction models is rising, providing encouraging results
- Next steps include deeper collaboration between veterinarians, geneticists, data scientists, and animal behaviorists
- By integrating biomedical, molecular, physiological, and computational methods, we move toward a new era of fertility prediction

Research team “DIGIPIG” *www.digipig.gr*

THANKS

GRACIAS

Ioannis Tsakmakidis

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