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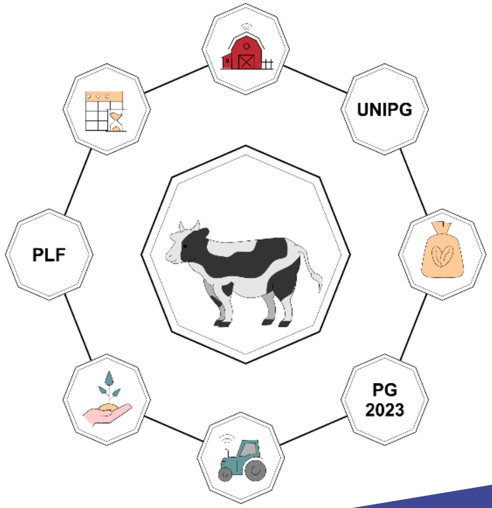
SEMINAR:
Infrared Thermography



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1. What is Infrared Thermography?
2. Applications in Animal Production.
3. How do we use it?
4. Practical exercises.

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2. Applications in Animal Production.
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What is Infrared Thermography?

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It refers to the **recording of temperature** using **infrared radiation** emitted from a **body surface**, forming an image called a **thermogram**.

Thermograms are **visual representations** of the amount of **infrared energy emitted, transmitted, and reflected** by an object.

Thermographic Cameras or **Thermal Imaging Cameras** detect radiation in the infrared range of the electromagnetic spectrum *(9,000-14,000 nm or 9-14 microns)* and **produce thermograms** based on the **amount of heat dissipated** at the surface.

The **amount of radiation emitted** by an object **increases with temperature** and depends on their natural heat production *(homeothermic animals versus poikilothermic animals)*

Thermography **allows** you to see **temperature variations.**

What is Infrared Thermography?

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Infrared Thermography or IRT, measures **infrared emitted rays** in objects, while the usual cameras measure the **light falling** on objects. The **amount of heat** produced **varies** according to the **animal**, the **region** from the body and their **physiological conditions**.

The **measurement** of the IRT of an object/individual **depends** on:

- **EMISSIVITY**: Represents the **material's ability to emit thermal radiation**. Range: 0.00 *(no light output)* to 1.00 *(all light output)*.
- **TEMPERATURE and HUMIDITY**: They **change Emissivity** and therefore, the thermal radiation transmitted.

OTHER FACTORS AFFECTING IRT ASSESSMENT

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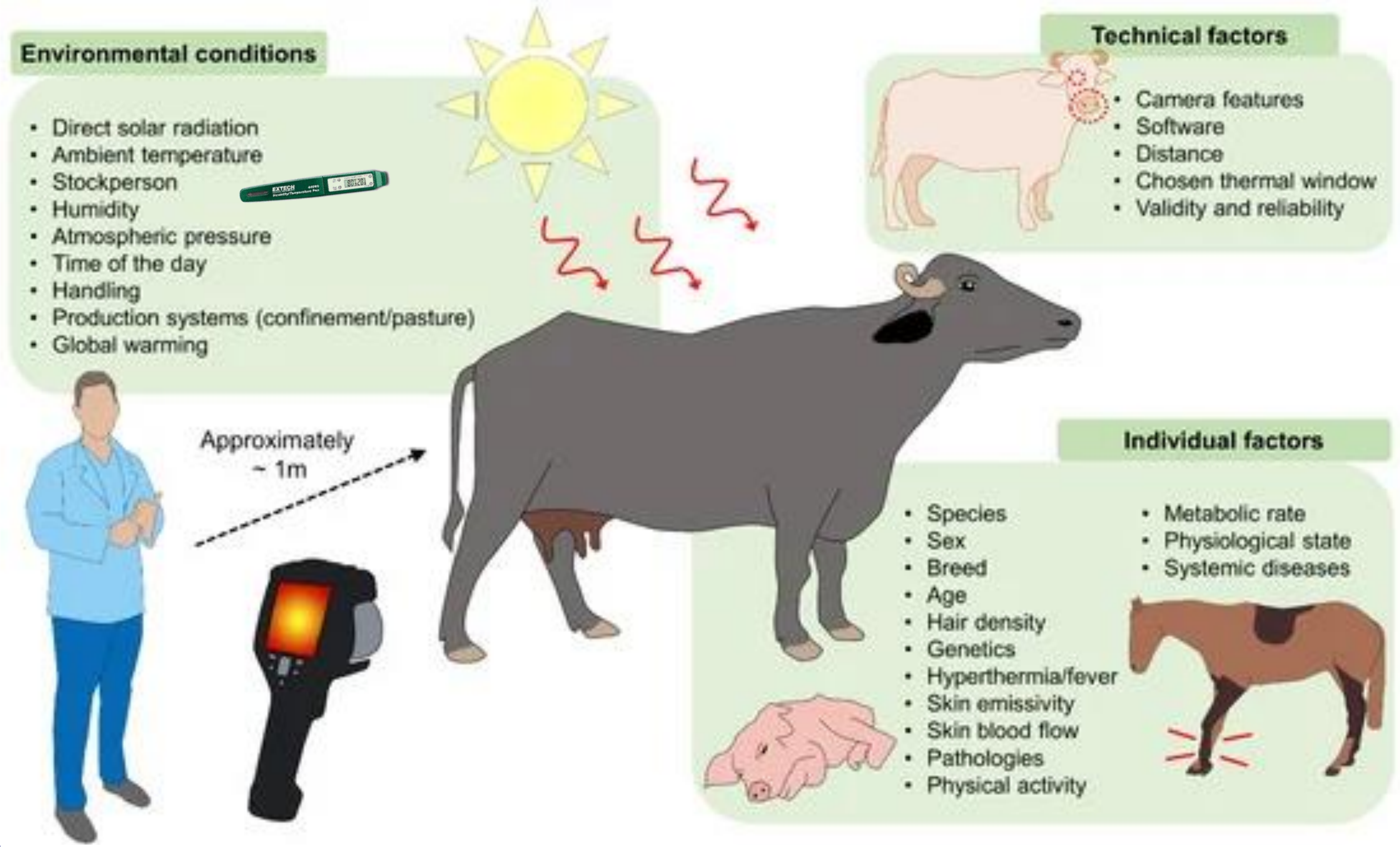

Figure obtained from Mota-Rojas, et al. (2021) *Animals*, *11*, 2247.

- An Infrared Camera **senses infrared radiation**, enabling us to **visualize** the thermal world.

- A thermal imaging camera consists of **5 components**:

    1. An **optic** system
    2. An **infrared detector**
    3. An **amplifier**
    4. A **signal processing** system
    5. A display **monitor**.

What is Infrared Thermography?

- Some examples of IRT cameras:

Trotec GmbH & Co. KG [DE] | https://www.trotec24.com/
TROTEC AT WORK.

https://es.trotec.com/shop/

FLIR

https://www.flir.es/

FLUKE.

https://www.fluke.com/es-es

ICI
Infrared Cameras Inc
Products

https://www.iciscientific.com/

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GENERAL THERMAL IMAGING APPLICATIONS

- INDUSTRIAL APPLICATIONS
- MEDICINE APPLICATIONS
- SECURITY APPLICATIONS
- BUILDING CONSTRUCTIONS
- NIGHT VISION

ANIMAL PRODUCTION APPLICATIONS

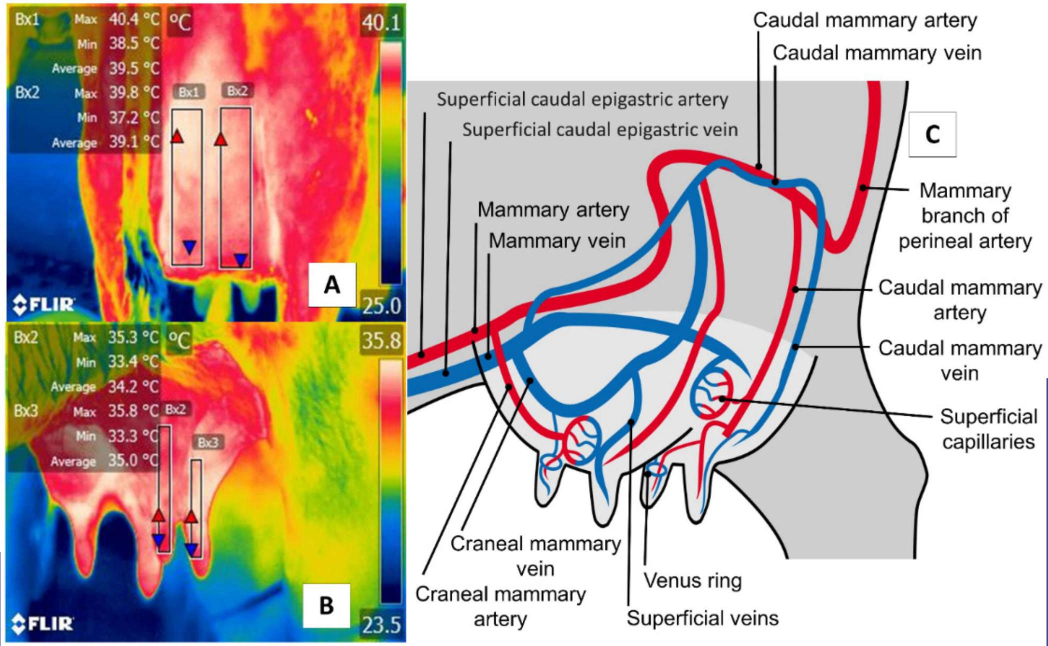
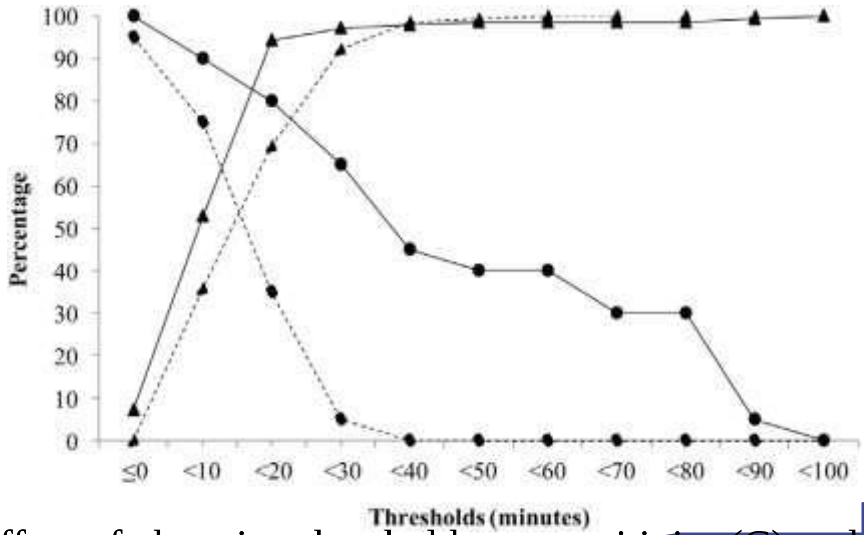


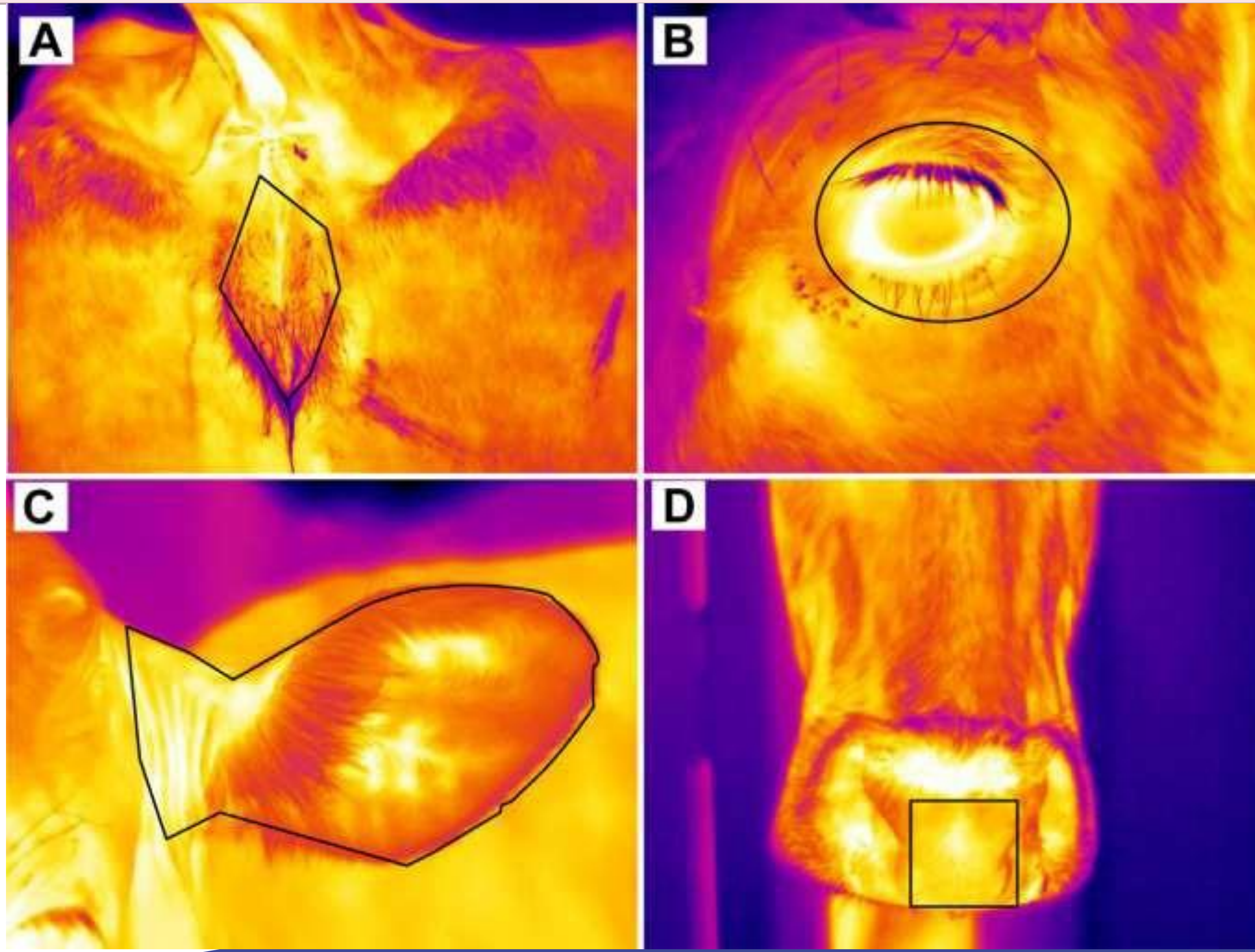
Figure obtained from Mota-Rojas, et al. (2021) *Animals*, *11*, 2247.

Talukder, S. et al (2014) Evaluation of infrared thermography body temperature and collar-mounted accelerometer and acoustic technology for predicting time of ovulation of cows in a pasture-based system. Theriogenology 80(480-491).

Body areas	n	Mean
Vaginal temperature	1142	38.5
Vulva	1140	35.0
Left eye	1115	36.3
Right eye	1113	36.2
Left ear	1114	34.8
Right ear	1114	34.6
Muzzle	1112	32.8
Daily activity level	14990	835.2
Daily rumination level (min)	14990	502.0
Daily milk production (kg)	665	28.71
Milk protein (%)	665	2.74
Milk fat (%)	665	3.97

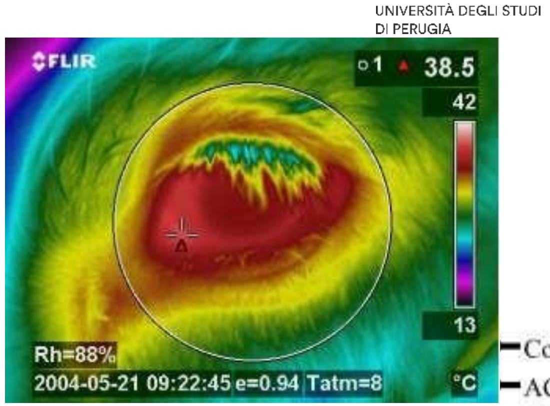


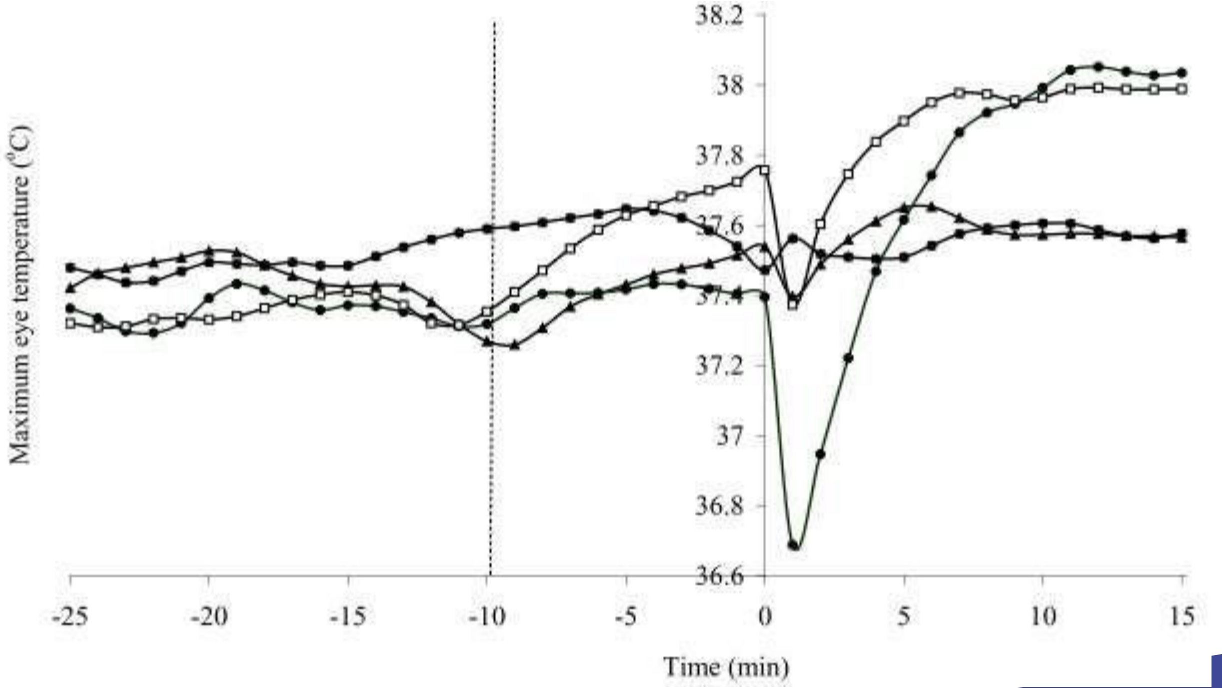
Effect of changing thresholds on sensitivity (C) and specificity (:) for SCR tags measuring activity (solid line) and rumination level (dashed line).



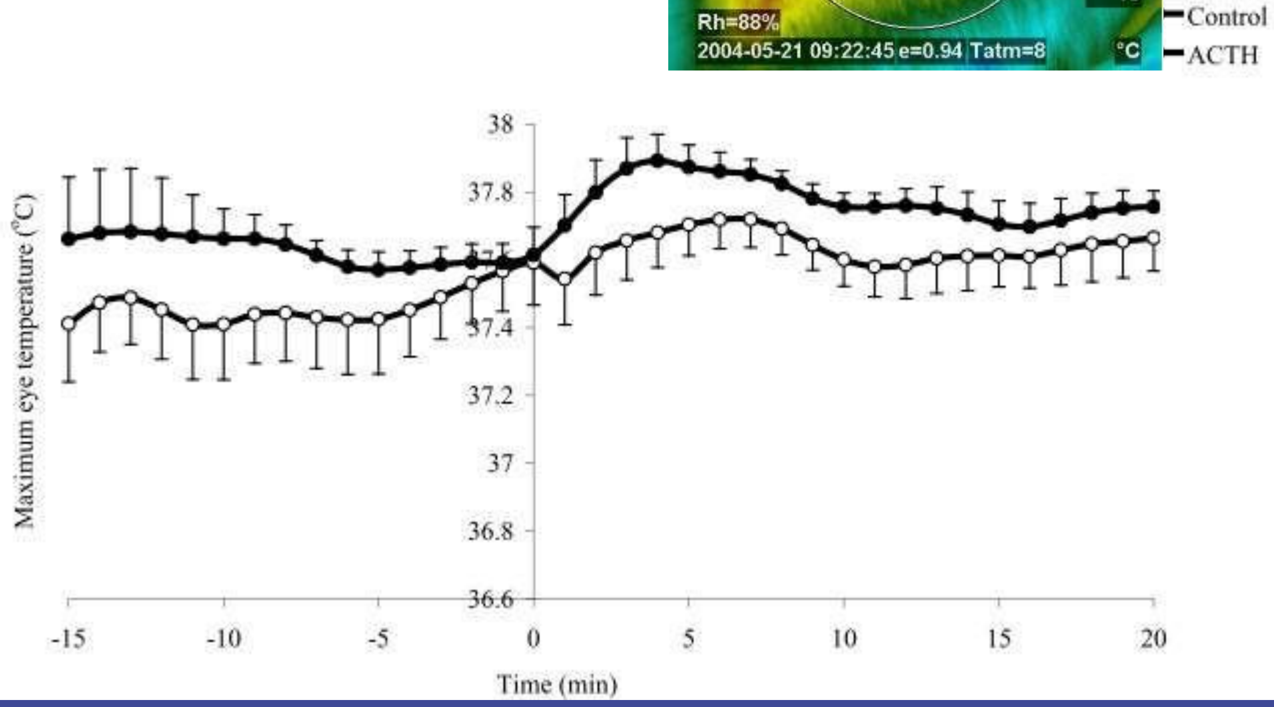
Hand-drawn area of vulva (A), eye (B), ear (C), and muzzle (D), which defined the temperature data area used by the support software.

Stewart, M. (2008) Non-invasive measurement of stress and pain in cattle using infrared thermography. PhD thesis. Massey university, Palmerston north, New Zealand





Maximum eye temperature for control (■, n=8), local anaesthetic control (▲, n=8), disbudded with local anaesthetic (□, n= 8) and disbudded without local anaesthetic (●, n=6).



Maximum eye temperature following administration (0 min) of ACTH (●, n=6) or saline-control (○, n=6).

ELSEVIER
Livestock Production Science 77 (2002) 349–353
www.elsevier.com/locate/livprodsci

FLIR T-Series Thermal Imaging camera

Short communication

Evaluation of naturally ventilated dairy barn management by a thermographic method

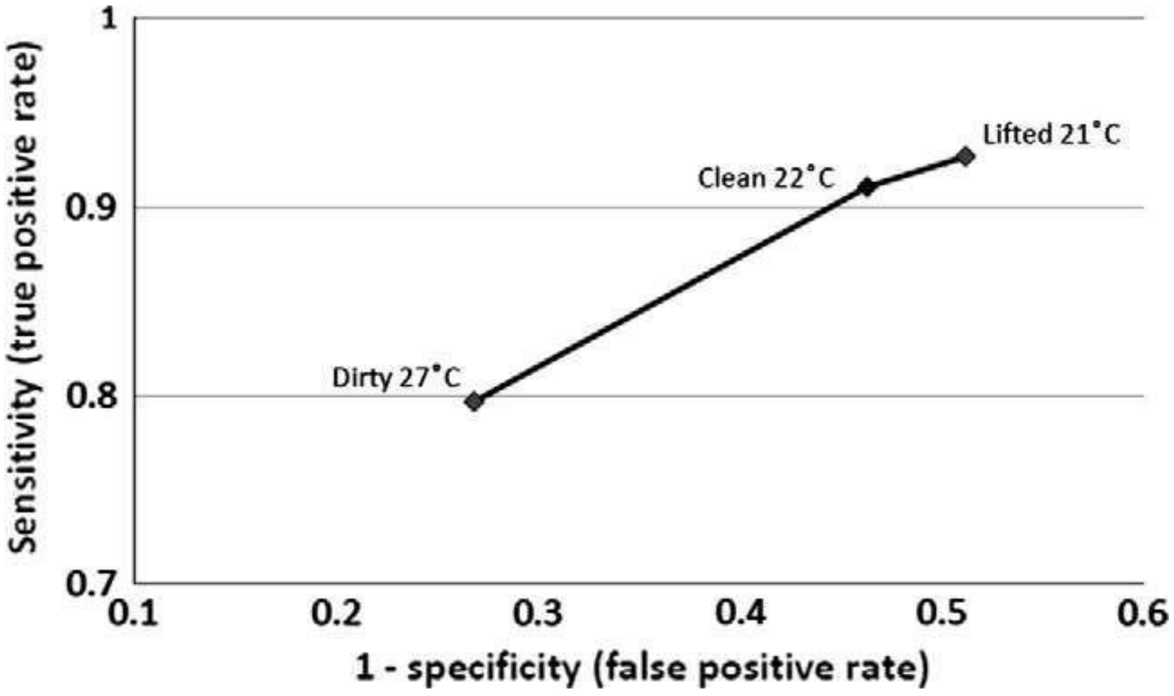
Ivana Knížková[a,*], Petr Kunc[a], Marie Koubková[b], Jan Flusser[c], Oldřich Dolezal[a]

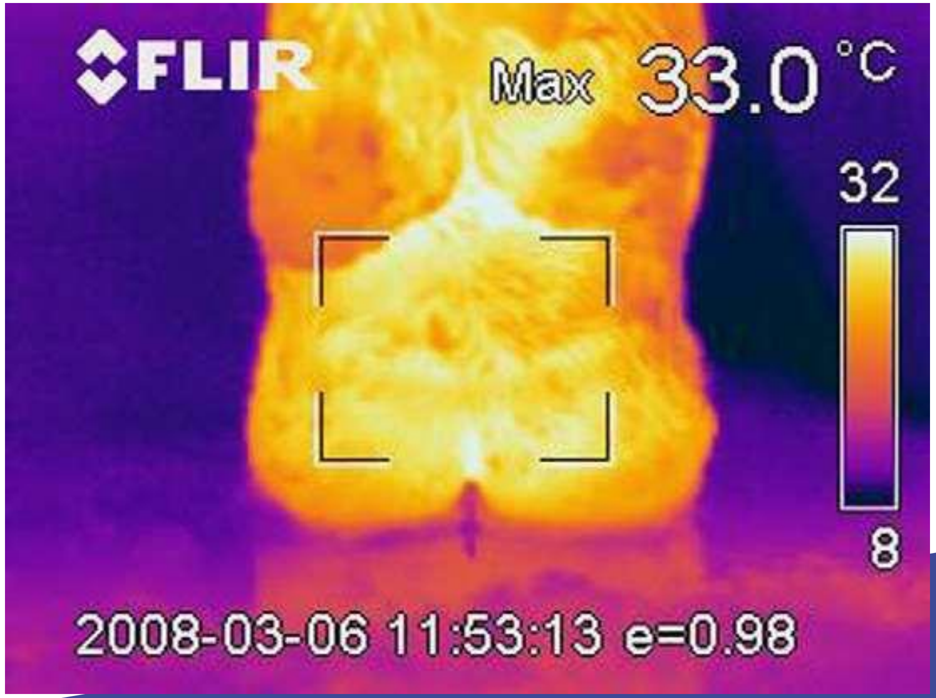
Table 1
Changes of body surface temperature of dairy cows in relation to changes of microclimatic factors (March), mean and S.D. ($N = 12$)

	Cycles	T (°C)	RH (%)	V ($m \cdot s^{-1}$)	CWC ($W \cdot m^{-2}$)	FP (°C)	B (°C)	HP (°C)
1st day	Closed	16.6	48.2	0.08	195	31.02±1.22	30.22±0.97	30.33±0.80
	Open	13.5	53.1	0.12	462	30.90±1.20	30.30±1.21	30.43±0.72
Difference		−3.1	+5.1	+0.04	+267	−0.12	+0.10	+0.10
2nd day	Open	7.6	60	0.92	965	24.55±1.06	24.14±1.35	24.03±1.06
	Closed	10.0	61	0.17	383	27.52±1.23	27.07±1.43	27.51±1.01
Difference		2.4	+1	0.75	−582	+2.97**	+2.93**	+3.48**
	Closed	10.0	61	0.17	383	27.52±1.23	27.07±1.43	27.51±1.01
	Open	8.5	54	0.84	965	24.11±1.09	23.83±1,57	23.61±1.32
Difference		−1.5	−7	+0.67	+582	−3.41**	−3.24**	−3.90**

**, $P < 0.01$. T, air temperature; RH, relative humidity; V, air velocity; CWC, Canadian wind chill; FR, fore part; B, barrel; HP, hind part.

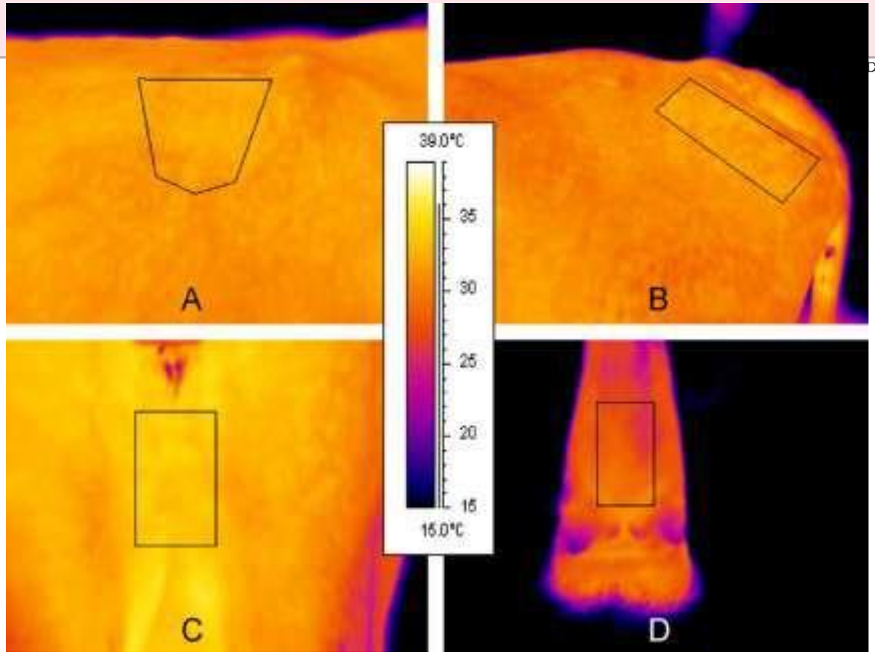
Stokes, J. E. et al (2012): **An investigation into the use of infrared thermography (IRT) as a rapid diagnostic tool for foot lesions in dairy cattle.** *The Veterinary Journal* 193 (3)





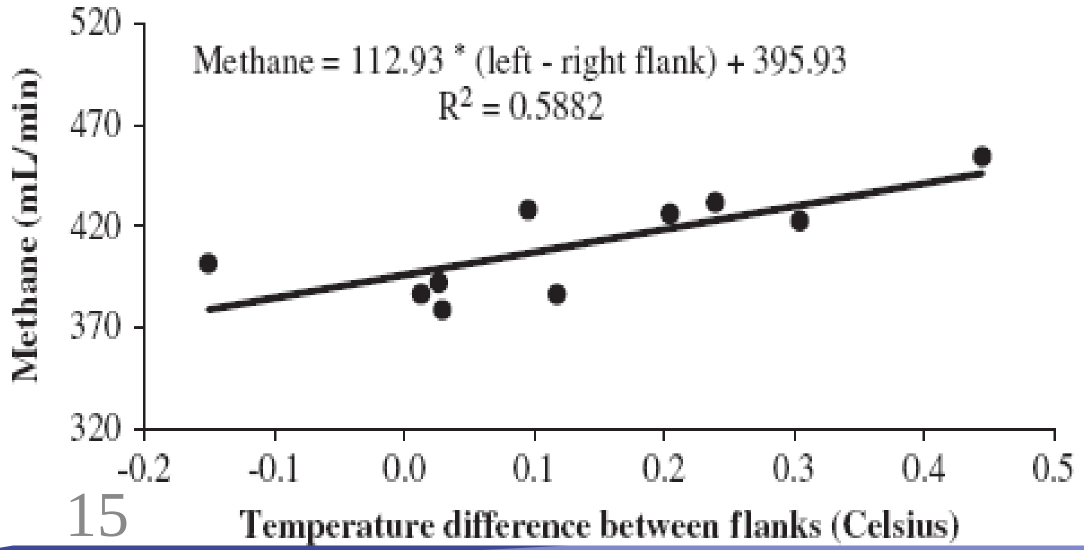
Conclusions: This study established the potential of IRT as a reliable, practical tool for detection of lesions, without having to clean or lift feet but could not be used to differentiate between lesions.

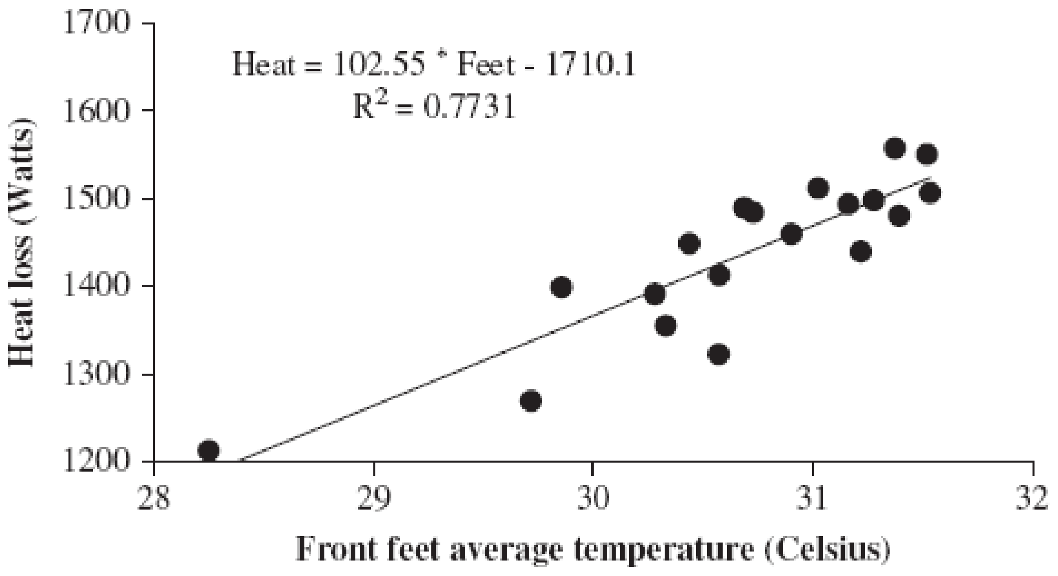
Montanholi, Y. et. al. (2008) Application of infrared thermography as an indicator of heat and methane production and its use in the study of skin temperature in response to physiological events in dairy cattle (Bos taurus). *Journal of Thermal Biology* 33 (8), S. 468–475.



Pearson correlations between infrared traits and heat production and methane production

Infrared traits	Heat production (*P* value)	Methane production (*P* value)
Left flank	0.62 (0.0058)[a]	0.03 (0.8857)
Right flank	0.72 (0.0008)[a]	−0.21 (0.3784)
Left rump	0.71 (0.0010)[a]	−0.01 (0.9607)
Rear area	0.58 (0.0119)[a]	0.03 (0.9155)
Left front foot	0.83 (0.0001)[a]	−0.15 (0.5189)
Right front foot	0.88 (0.0001)[a]	−0.32 (0.1657)
Whole body	0.66 (0.0030)[a]	−0.01 (0.9569)
Trunk	0.66 (0.0028)[a]	−0.05 (0.8235)
Left minus right flank	0.67 (0.0025)[a]	0.53 (0.0165)[a]





Research in Veterinary Science 94 (2013) 722–724

Contents lists available at SciVerse ScienceDirect

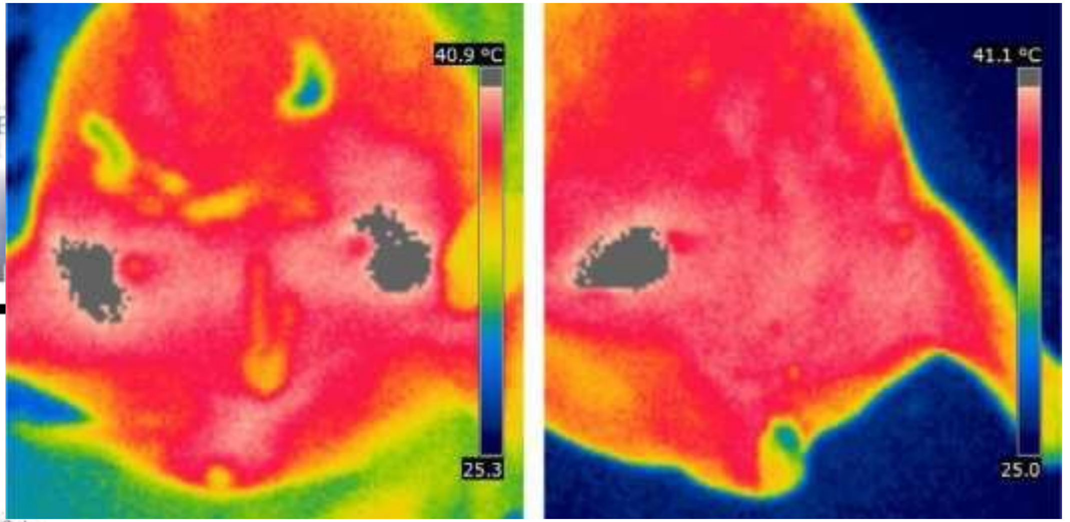
Research in Veterinary Science

journal homepage: www.elsevier.com/locate/rvsc

Mastitis detection in sheep by infrared thermography

Rafhael Felipe Saraiva Martins [a], Tiago do Prado Paim [b], Cyntia de Abreu Cardoso [a], Bruno Stéfano Lima Dallago [a], Cristiano Barros de Melo [a], Helder Louvandini [b], Concepta McManus [c,*]

[a] Faculty of Agronomy and Veterinary Medicine, University of Brasília, CP 04508, CEP 70910-900 Brasília, Distrito Federal, Brazil



Thermographic images of the udder of ewes in this study, showing an udder with mastitis at both sides (left) and an udder with mastitis at one side (right).

Superficial udder temperatures and milk components from ewes classified as Health, Subclinical and Clinical mastitis.

		Healthy	Subclinical mastitis	Clinical mastitis
Total udder (°C)	Max	38.56^{b}	39.02^{a}	38.4^{b}
	Min	33.56^{b}	33.79^{a}	33.35^{b}
	Mean	36.06^{ns}	36.3^{ns}	35.89^{ns}
Left side (°C)	Front	42.21^{ns}	37.33^{ns}	36.45^{ns}
	Intermediate	37.19^{b}	37.50^{a}	36.90^{b}
	Rear	37.17^{a}	37.42^{b}	36.69^{c}
	Mean	37.01^{b}	37.48^{a}	36.60^{b}
Right side (°C)	Front	36.85^{b,a}	37.14^{a}	36.53^{b}
	Intermediate	37.22^{b}	37.72^{a}	36.84^{b}
	Rear	37.16^{a}	37.50^{a}	36.71^{b}
	Mean	37.08^{b}	37.44^{a}	36.74^{b}
TCL (%)	Fat	5.68^{b}	6.17^{b}	7.12^{a}
	Protein	5.40^{b}	5.17^{b}	5.82^{a}
	Lactose	5.00^{a}	4.91^{a}	4.60^{b}
	FFDM	11.25^{a}	10.99^{b}	11.29^{a}
	TDM	17.43^{b}	16.67^{c}	18.41^{a}
SCC (×1000 cells/mL)		167.1^{b}	540.7^{b}	2693.2^{a}

Conclusions: The results demonstrate that infrared udder temperatures can be a good auxiliary diagnostic method to mastitis in sheep, principally to subclinical mastitis.

Applied Animal Behaviour Science 174 (2016) 58–65

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Genetic study of stress assessed with infrared thermography during dressage competitions in the Pura Raza Español horse

María José Sánchez[a], Ester Bartolomé[b,*], Mercedes Valera[a]

General Lineal Model and post-hoc LSM test analysis of the environmental effects in thermography and Dressage performance variables in Pura Raza Español breed.

Traits		Stud	Trip	Training	Rider	Age (LSMean) 4 years	5 years	6 years	Event (LSMean) Event 1	Event 2	Event 3
Temperature traits	ET_B	***	*	*	–	35.4^a	35.2^{ab}	35.0^b	35.4^a	35.5^a	34.9^b
	ET_JA	***	***	***	***	36.6^a	36.4^a	35.9^b	36.9^a	36.6^a	35.5^b
	ET_A	***	***	***	–	36.4^a	35.8^b	35.6^b	36.2^a	36.6^a	35.3^b
	ET_B_JA	***	*	*	***	0.57^a	0.44^a	0.50^a	0.58^{ab}	0.64^a	0.27^b
	ET_JA_A	***	***	*	***	-0.24^a	-0.58^a	-0.32^a	-0.74^a	-0.10^b	-0.12^b
Performance traits	Walk Score	***	***	***	***	6.4^b	6.7^a	6.8^a	6.1^b	6.7^a	6.8^a
	Trot Score	***	***	***	***	6.4^b	6.7^a	6.7^{ab}	6.2^b	6.8^a	6.9^a
	Canter Score	***	***	***	***	6.6^a	6.7^a	6.7^a	6.2^b	6.9^a	6.9^a
	Submission Score	***	***	***	***	6.3^a	6.5^a	6.6^a	6.1^b	6.7^a	6.7^a
	General Impression Score	***	***	***	***	6.4^a	6.7^a	6.6^a	6.1^b	6.7^a	6.8^a
	Total Dressage Score	***	***	***	***	63.5^b	66.5^a	65.9^{ab}	60.4^b	67.3^a	68.2^a

ET_B = eye temperature taken 3 h before the competition; ET_JA = eye temperature taken just after the competition (<5 min after the dressage exercise); ET_A = eye temperature taken 3 h after the competition, when the animal was resting; ET_B_JA = difference between eye temperature taken 3 h before the competition and eye temperature taken just after the competition (<5 min after the dressage exercise) and ET_JA_A = difference between eye temperature taken just after the competition (<5 min after the dressage exercise) and eye temperature taken 3 h after the competition, when the animal was resting. [abc]Values within a row with different superscripts differ significantly at $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Mean (and standard deviation) of the marginal posterior distributions means for heritabilities, repeatability and the rider ratio, for all the traits analyzed.

Trait		Heritabilities	Repeatability	Rider ratio
Temperature traits	ET_B	0.38(0.173)	0.76(0.343)	
	ET_JA	[illegible]	0.25(0.153)	0.45(0.127)
	ET_A	[illegible]	0.77(0.431)	
	ET_B_JA	[illegible]	0.30(0.204)	0.24(0.161)
	ET_JA_A	0.31(0.180)	0.59(0.389)	0.30(0.243)
Performance traits	Walk Score	0.44(0.183)	0.79(0.370)	0.19(0.119)
	Trot Score	0.40(0.187)	0.76(0.370)	0.22(0.117)
	Canter Score	0.43(0.176)	0.78(0.352)	0.20(0.113)
	Submission Score	0.37(0.163)	0.71(0.326)	0.28(0.123)
	General Impression Score	0.40(0.168)	0.73(0.335)	0.26(0.127)
	Total Dressage Score	0.42(0.179)	0.73(0.350)	0.24(0.121)

h^2= 14% to 50%

ET_B = eye temperature taken 3 h before the competition; ET_JA = eye temperature taken just after the competition (<5 min after the dressage exercise); ET_A = eye temperature taken 3 h after the competition, when the animal was resting; ET_B_JA = difference between eye temperature taken 3 h before the competition and eye temperature taken just after the competition (<5 min after the dressage exercise) and ET_JA_A = difference between eye temperature taken just after the competition (<5 min after the dressage exercise) and eye temperature taken 3 h after the competition, when the animal was resting.

Correlations between eye temperature and performance breeding values.

Trait		Breeding value of temperature traits ET_B	ET_JA	ET_A	ET_B_JA	ET_JA_A
Breeding value of performance traits	Walk Score	–0.00	0.07	0.07	–0.10	–0.13
	Trot Score	0.02	0.19^{*}	0.12	0.00	–0.05
	Canter Score	0.07	0.22^{*}	0.14	–0.04	0.02
	Submission Score	0.00	0.22^{*}	0.11	–0.03	–0.00
	General Impression Score	0.02	0.28^{*}	0.10	–0.06	0.02
	Total Dressage Score	–0.00	0.21^{*}	0.09	–0.03	–0.03

ET_B = eye temperature taken 3 h before the competition; ET_JA = eye temperature taken just after the competition (<5 min after the dressage exercise) ET_A = eye temperature taken 3 h after the competition, when the animal was resting; ET_B_JA = Difference between eye temperature taken 3 h before the competition and eye temperature taken just after the competition (<5 min after the dressage exercise) and ET_JA_A = Difference between eye temperature taken just after the competition (<5 min after the dressage exercise) and eye temperature taken 3 h after the competition, when the animal was resting. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Authors **analyzed different factors influencing stress** of horses **during Dressage competitions**, evaluated with IRT. **Correlations with Dressage results** were also assessed.

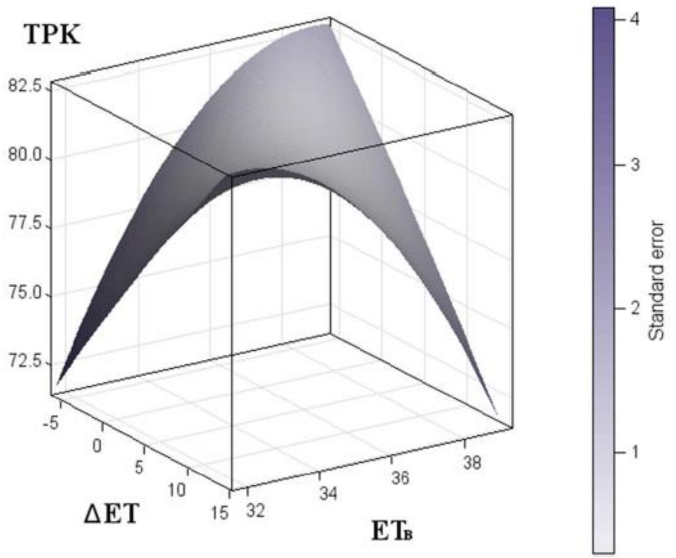
Conclusions: These findings indicate that it is **possible to assess selection for stress** with ET in horses.
The positive medium **correlations** found suggested that **horses with higher ET values were better dressage performers**, appearing to be related with a **more proactive and energetic response** of the horse to the environmental stimuli and hence, to physiological stress rather than emotional stress (or “distress”).

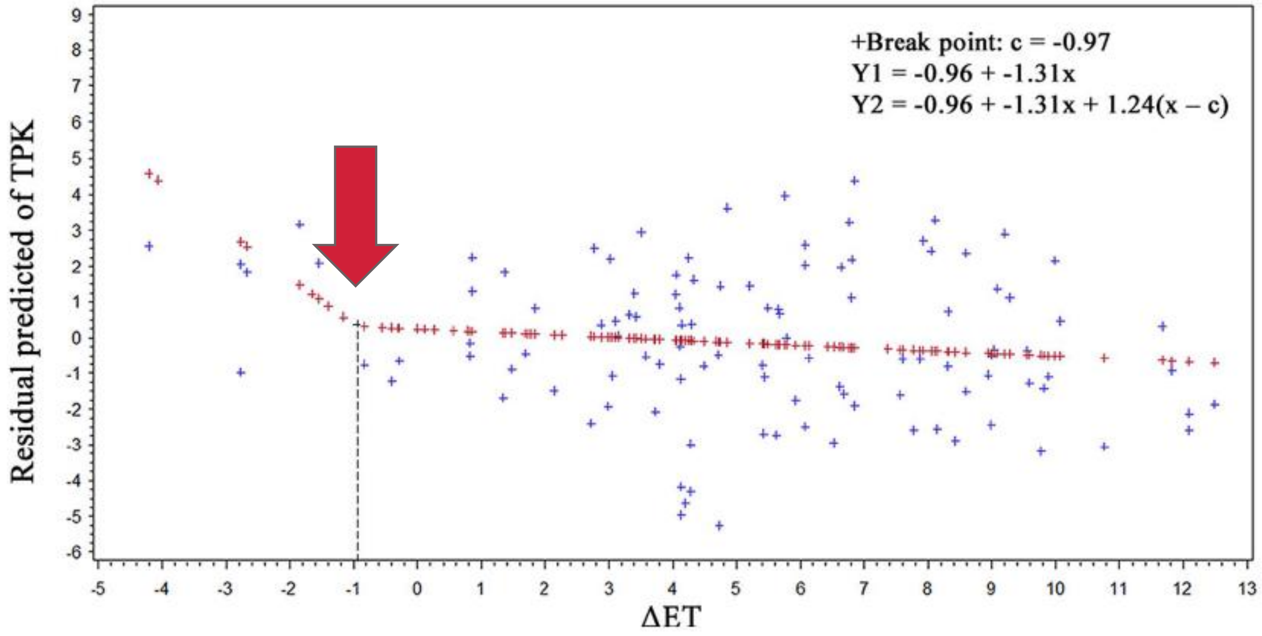
Stress level effects on sport performance during trotting races in Spanish Trotter Horses

Negro S, Bartolomé E, Molina A et al. See more

Research in Veterinary Science (2018) 118 86-90

DOI: 10.1016/j.rvsc.2018.01.017





Segmented regression analysis and break point for the residual predicted of time per kilometre (TPK) according to the eye temperature increase (ΔET) in the Spanish Trotter Horse participating in trotting races.

Conclusions: Results suggest that **racing performance is influenced by the level of physiological stress**, because ET, but not HR, are related to competition results. This study also suggests an **elliptical behaviour of ET during the race which would be incremental to a certain point from which the animals would suffer the consequences of distress**, diminishing its performance and worsening its racing results.

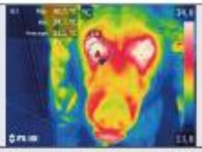
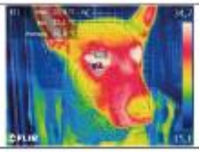
Authors analyzed the stress of Trotter Horses during Trotting Races with IRT and Heart Rate. Developed a regression análisis and a response surface comparing results (TPK) and stress (ET increase and ET before competition).

Dog Behavior, 2-2021, pp. 13-21 • DOI 10.4454/db.v7i2.137

Stress at rest in working dogs assessed with infrared thermography

E. Bartolomé*, D.I. Perdomo-González, M.J. Sánchez-Guerrero, M. Valera

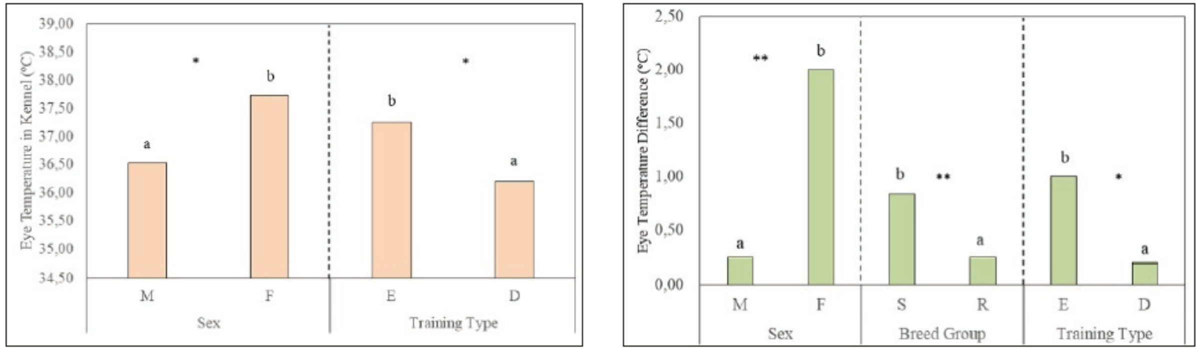
Table 1. Pearson's correlations between eye temperature variables (measured in dog kennels -ETK-, inside the police cars -ETC-, their difference -ETD- and mean value -MET-, including a thermographic photo) and heart rate -HR- variable (measured inside the police car) analyzed. Mean (absolute values), standard deviation and coefficient of variation (in percentage in parentheses), appear in the diagonal.

	ETK	ETC	ETD	HR	MET
					
ETK	36.79±1.09 (2.98%)	$0.38^{n.s.}$	0.61^{**}	$0.23^{n.s.}$	0.85^{***}
ETC		36.14±1.00 (2.78%)	0.50^{*}	$-0.14^{n.s.}$	0.82^{***}
ETD			0.92±0.95 (103.04%)	$0.34^{n.s.}$	$0.09^{n.s.}$
HR				92.33±18.54 (20.08%)	$0.06^{n.s.}$
MET					36.47±0.87 (2.39%)

Where ETD= ETC – ETK; MET = (ETC + ETK)/2; *p<0.05; **p<0.01; *** p<0.001; n.s. not statistically significant.

Figure 2. General Lineal Model and Duncan post-hoc test for variables that resulted statistically significant (eye temperature assessed in kennel and eye temperature difference between kennel and police car) for sex, breed group and training type effects.

2A. *Eye Temperature in Kennel* **2B.** *Eye Temperature Difference*



Where M = male; F = female; S = Shepherd dogs; R = Retriever dogs; E = explosives; D = drugs; *p<0.05; **p<0.01; *** p<0.001. Different letters indicated statistically significant differences between means (p<0.05).

Authors analyzed the stress of Police working dogs trained for drugs and explosives detection at rest, evaluated on their kennels and on the car they used for working purposes. ET and HR were assessed.

Conclusions: Statistically significant **differences were reported between stress perceived in the kennel versus stress perceived in the police car**. The stress of working dogs shown in the kennel and the size of the stress difference recorded between the kennel and the police car was **influenced** by environmental factors such as **sex, breed group or training type.**

Applications in Animal Production

Youtube video: “Infrared Thermogrpahy for Veterinary” – Pass Thermal (3:00min.)

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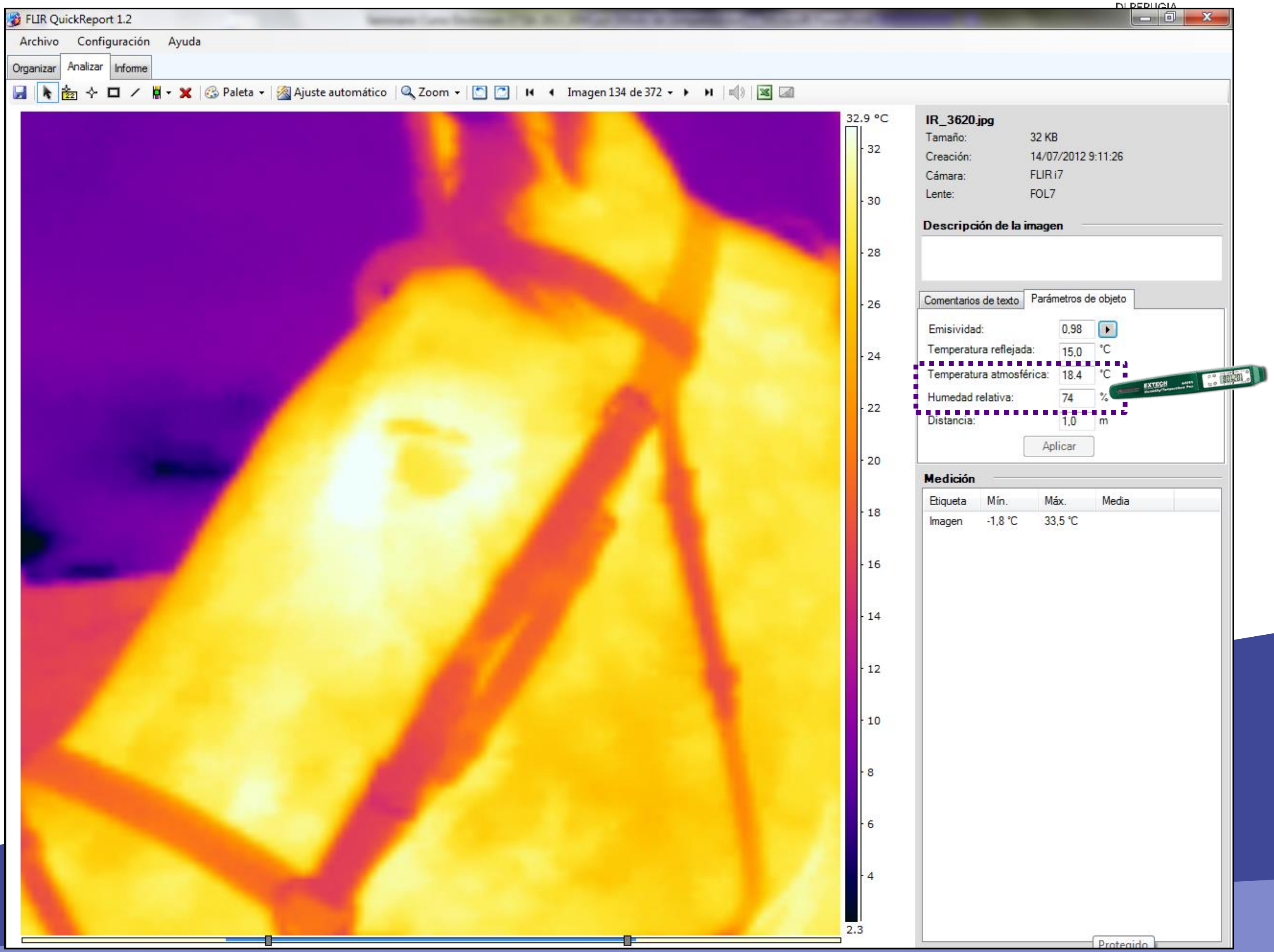
HOW DO WE OBTAIN THE DATA

IRT camera assigns color to the infrared radiation: **different color equals different temperature.**

IRT data has to be **analyzed** with an **external software**, where *Emissivity*, Environmental *Temperature* and Relative Humidity and Area of the image to be measured, have to be settled.



Program used for the analysis of IRT images. (FLIR QuickReport Version 1.2. (1.0.1.173))

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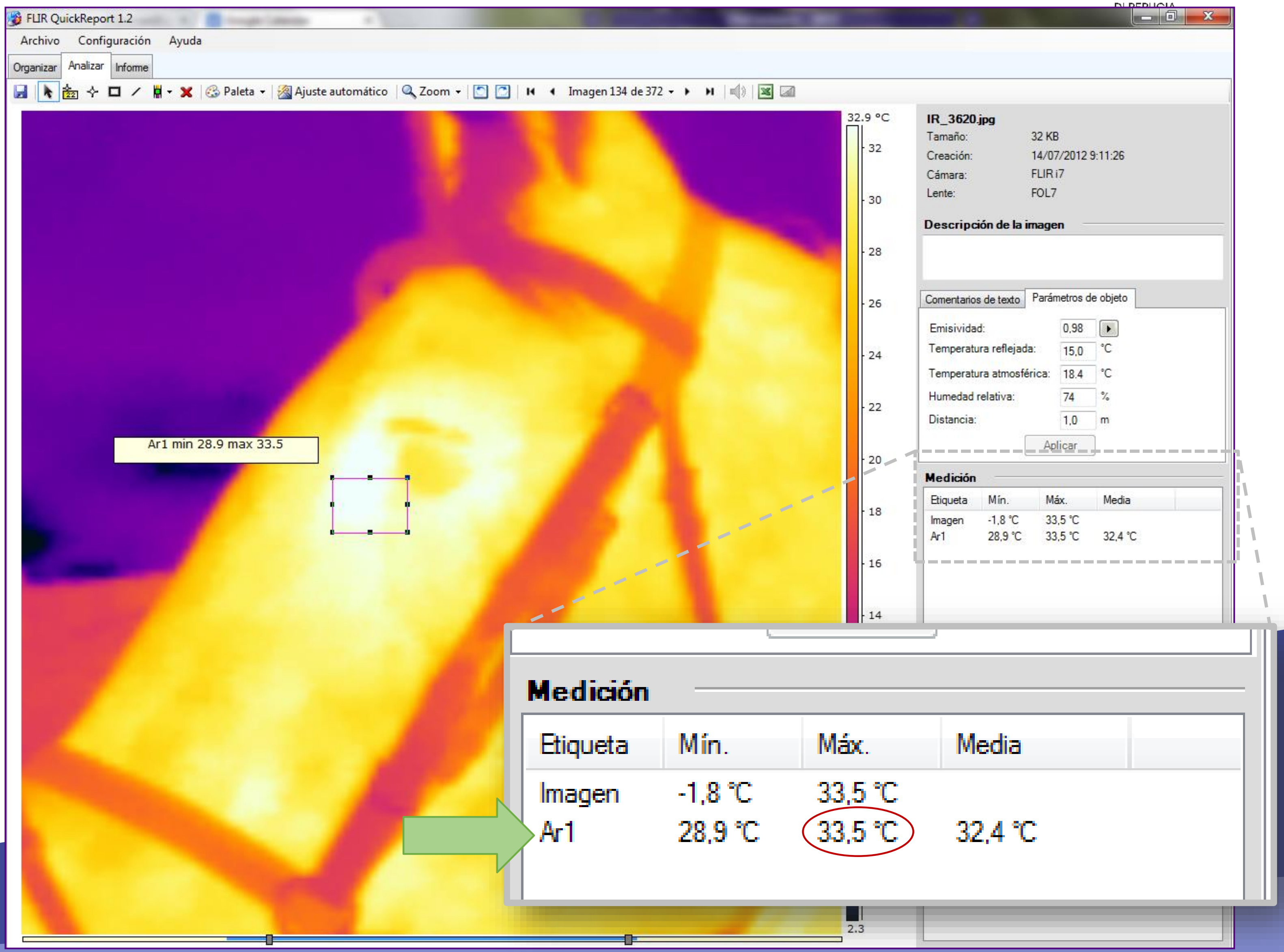
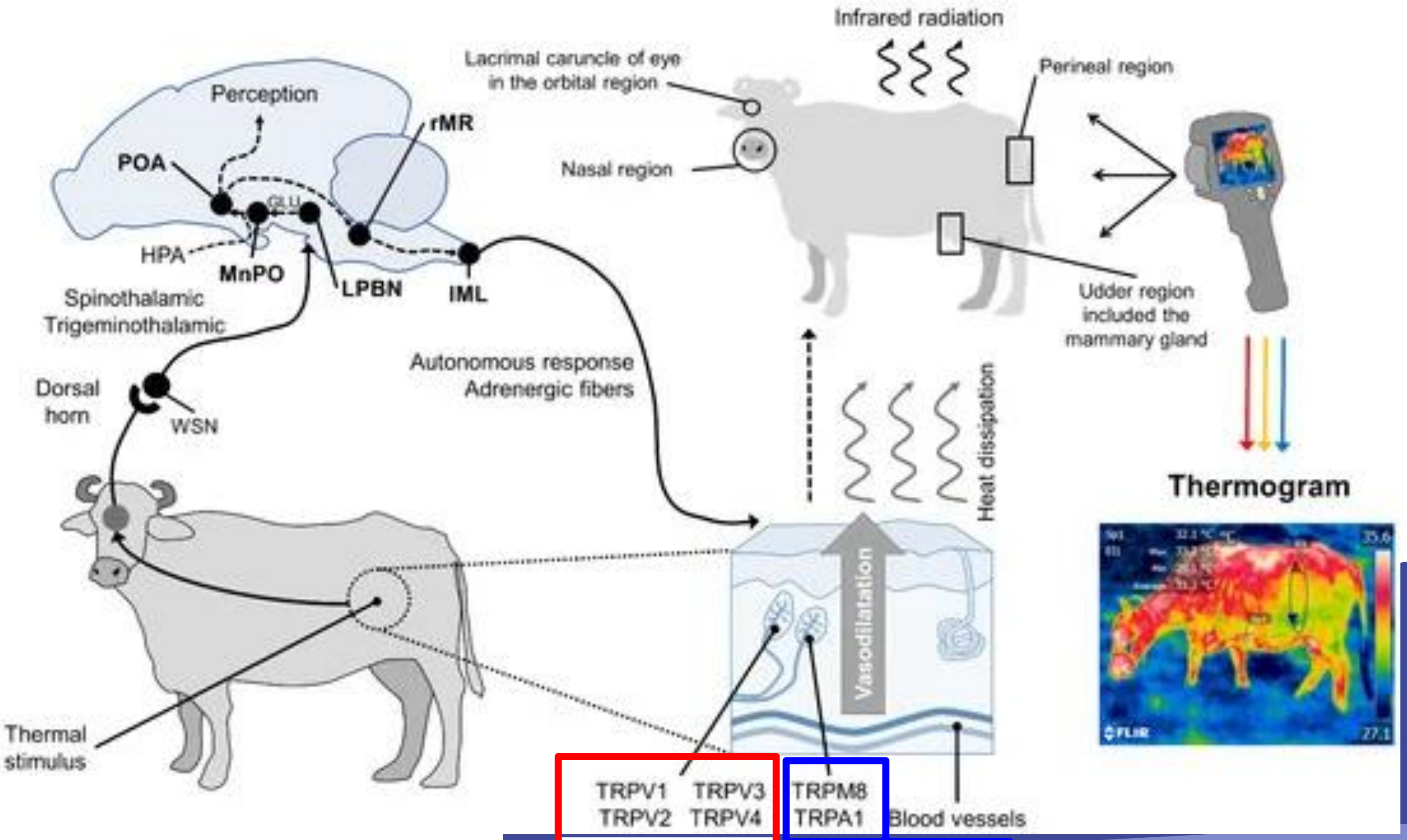


Program used for the analysis of IRT images. (FLIR QuickReport Version 1.2. (1.0.1.173))

WHAT ARE WE MEASURING?

Hypothalamic neuromodulation of thermoregulation and its cutaneous response.

- ✓ The thermoregulatory response **begins** on with **thermoreceptors in the dermis**.
- ✓ These **receive afferent information** from a thermal stimulus and **send the signal** to the laminae of the dorsal horn of the **spinal cord**.
- ✓ The **heat-sensitive (WSN) spinothalamic and trigeminothalamic neurons** in this zone **relay the impulse** to third-order neurons in brain structures.
- ✓ From there, **they are projected to the median preoptic nucleus** (MnPO) in the preoptic area (POA) of the **hypothalamus**.
- ✓ The hypothalamic network is responsible for **integrating behavioral, neuroendocrine** (mediated by the hypothalamic–pituitary–adrenal axis (HPA)), **and autonomic thermoregulatory effector responses**.

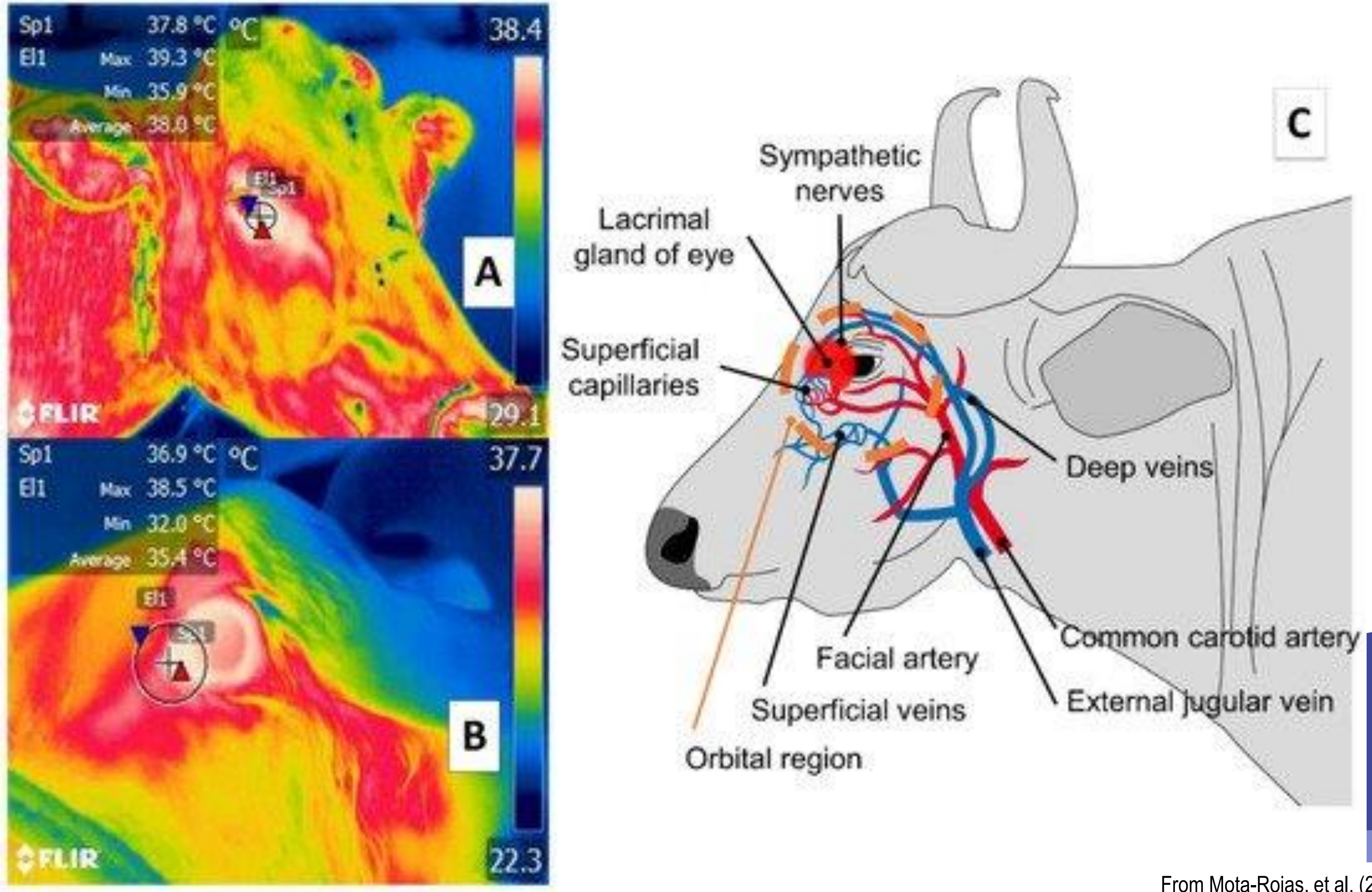


From Mota-Rojas, et al. (2021) *Animals*, *11*, 2247.

Skin Receptors activated by **HEAT**

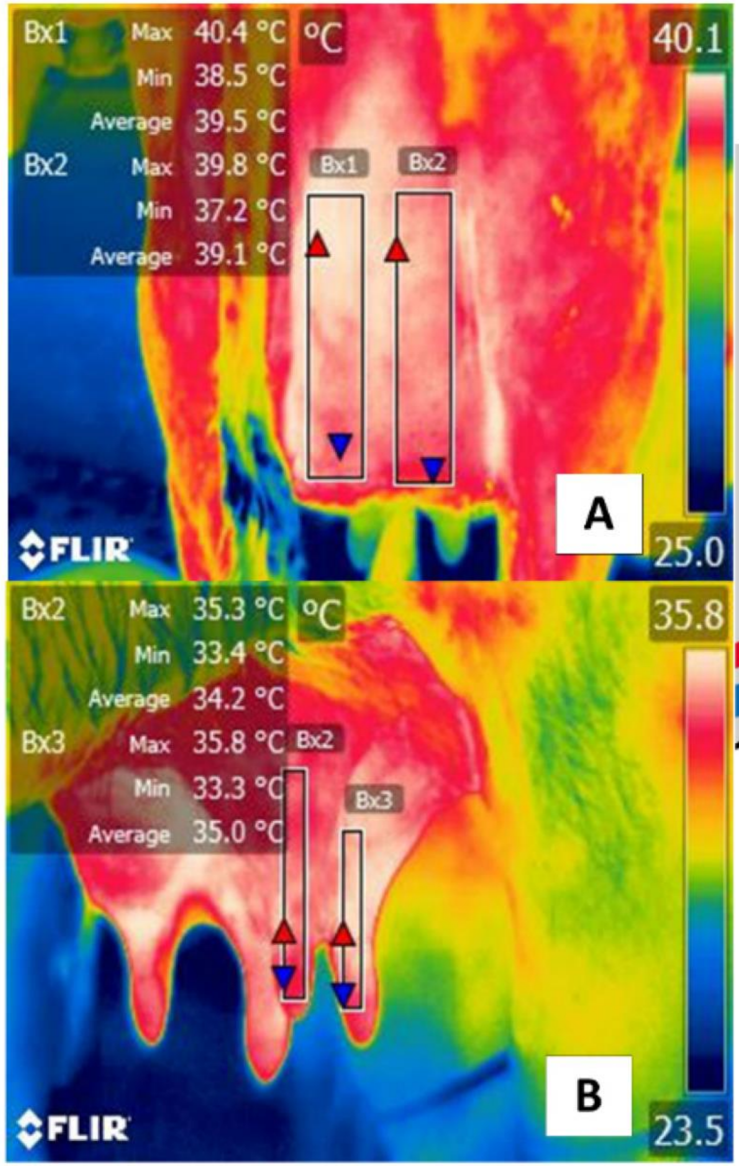
Skin Receptors activated by **COLD**

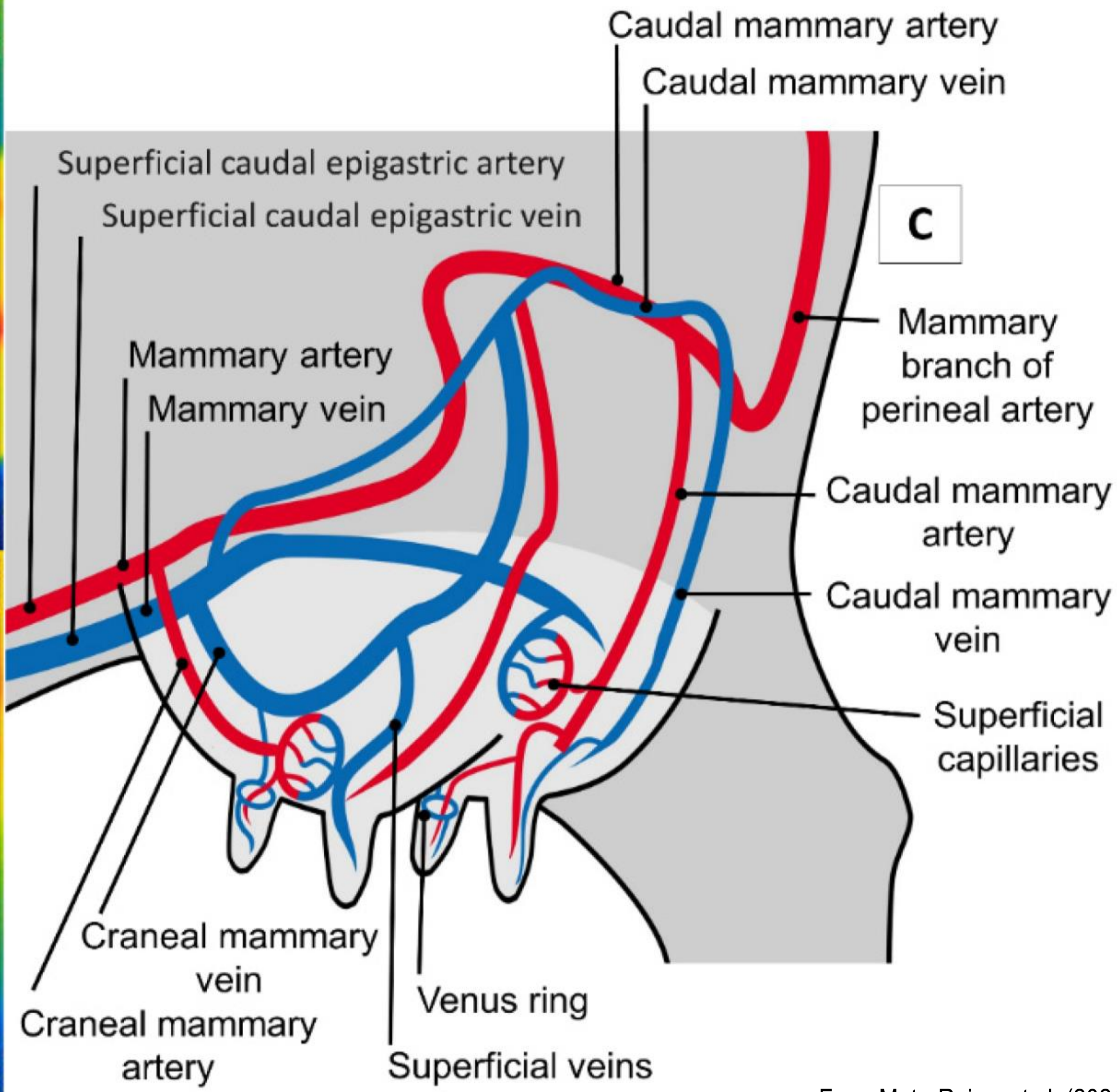
WHAT ARE WE MEASURING?



From Mota-Rojas, et al. (2021) *Animals*, *11*, 2247.

WHAT ARE WE MEASURING?





From Mota-Rojas, et al. (2021) *Animals*, *11*, 2247.

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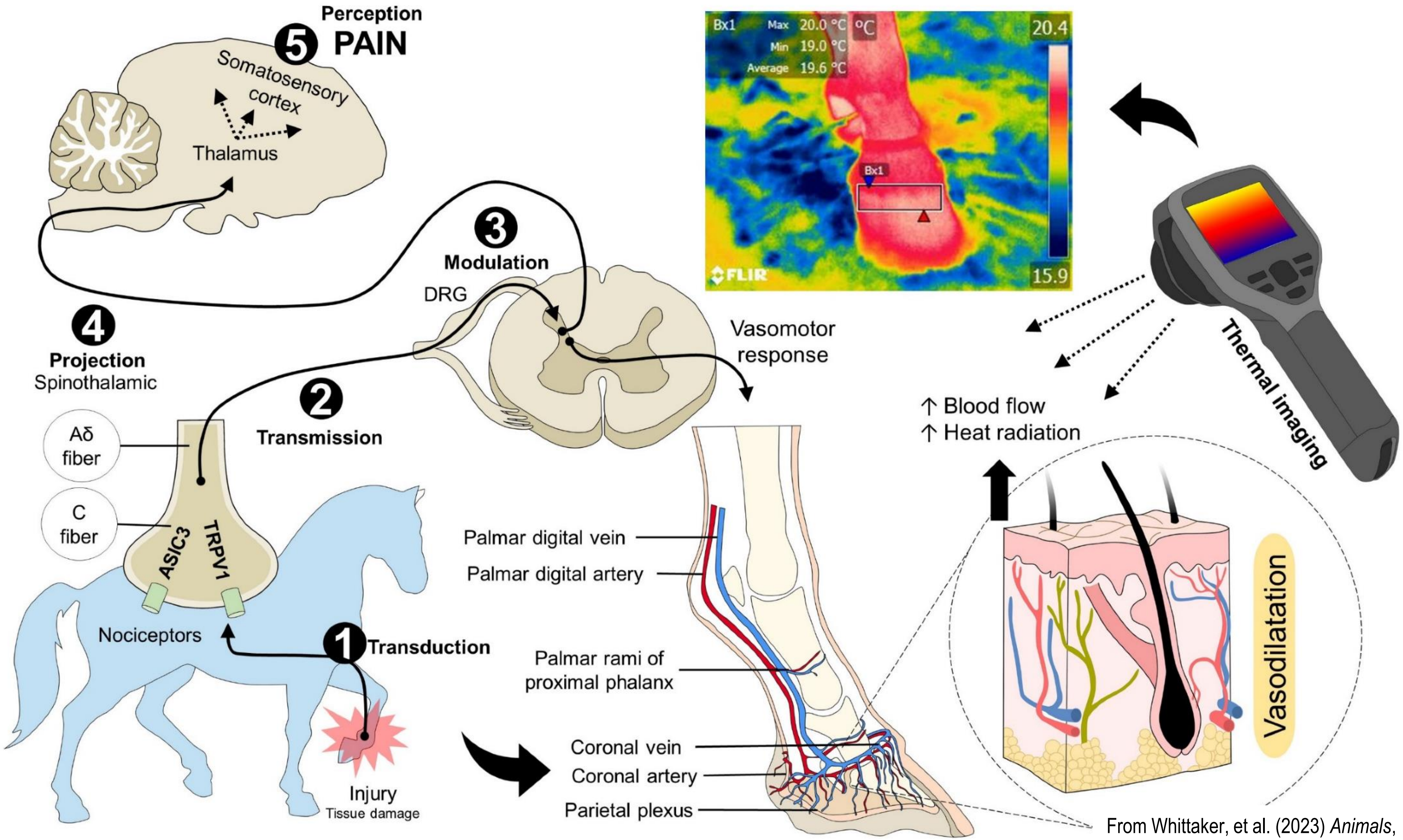

From Whittaker, et al. (2023) *Animals*, *13(13)*, 2065.

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SETOUT

- We are going to divide the big group in **4 working groups (purple, blue, yellow, orange),** with 4-5 students per group**.**
- Each group is going to **analyze a different practical case** from already **published papers**.
- Each group **have to solve** the following **points** for their case:
  - *I. Species and Production System.*
  - *II. Problem/Issue detected/studied on the animal/s.*
  - *III. Proposal to prevent this problem and to collect information regularly.*
- Finnaly, **one student from each group** will comes out and **present their proposal** to the rest of the **students that will give their feed-back** about it.

PURPLE GROUP

Figure from: Zheng, S.; Zhou, C.; Jiang, X.; Huang, J.; Xu, D. Progress on Infrared Imaging Technology in Animal Production: A Review. *Sensors* **2022**, *22*, 705. https://doi.org/10.3390/s22030705

BLUE GROUP

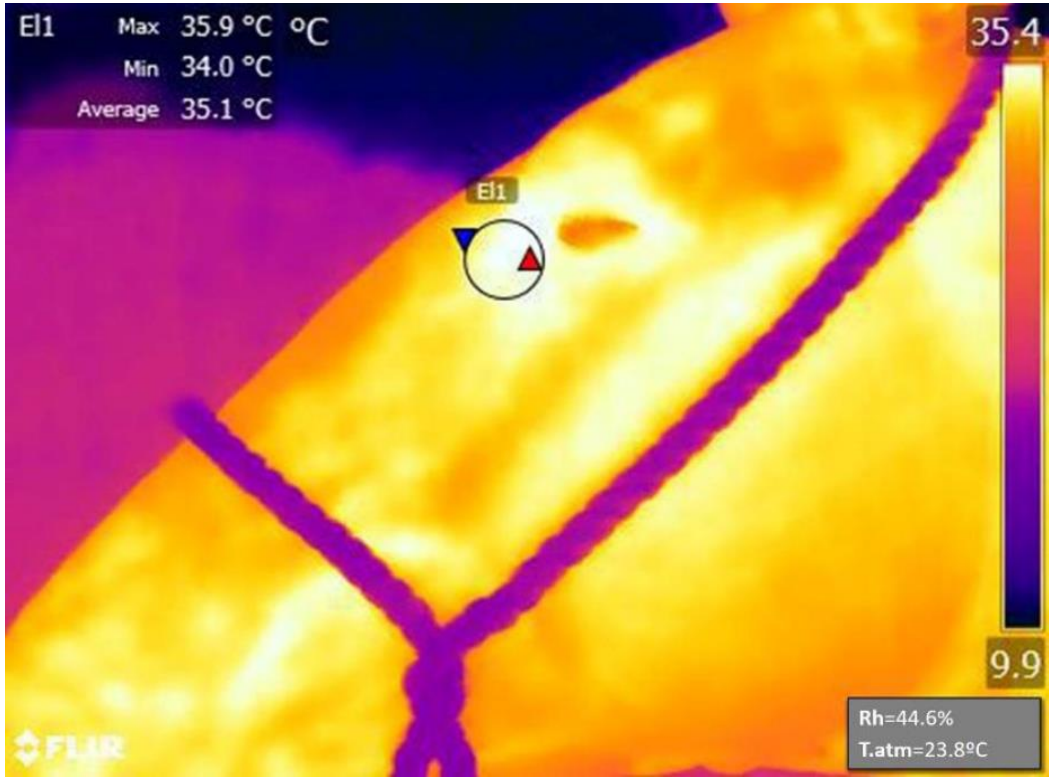

Figure from: Bartolomé, E.; Perdomo-González, D.I.; Ripollés-Lobo, M.; Valera, M. Basal Reactivity Evaluated by Infrared Thermography in the "Caballo de Deporte Español" Horse Breed According to Its Coat Color. *Animals* **2022**, *12*, 2515. https://doi.org/10.3390/ani12192515

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YELLOW GROUP

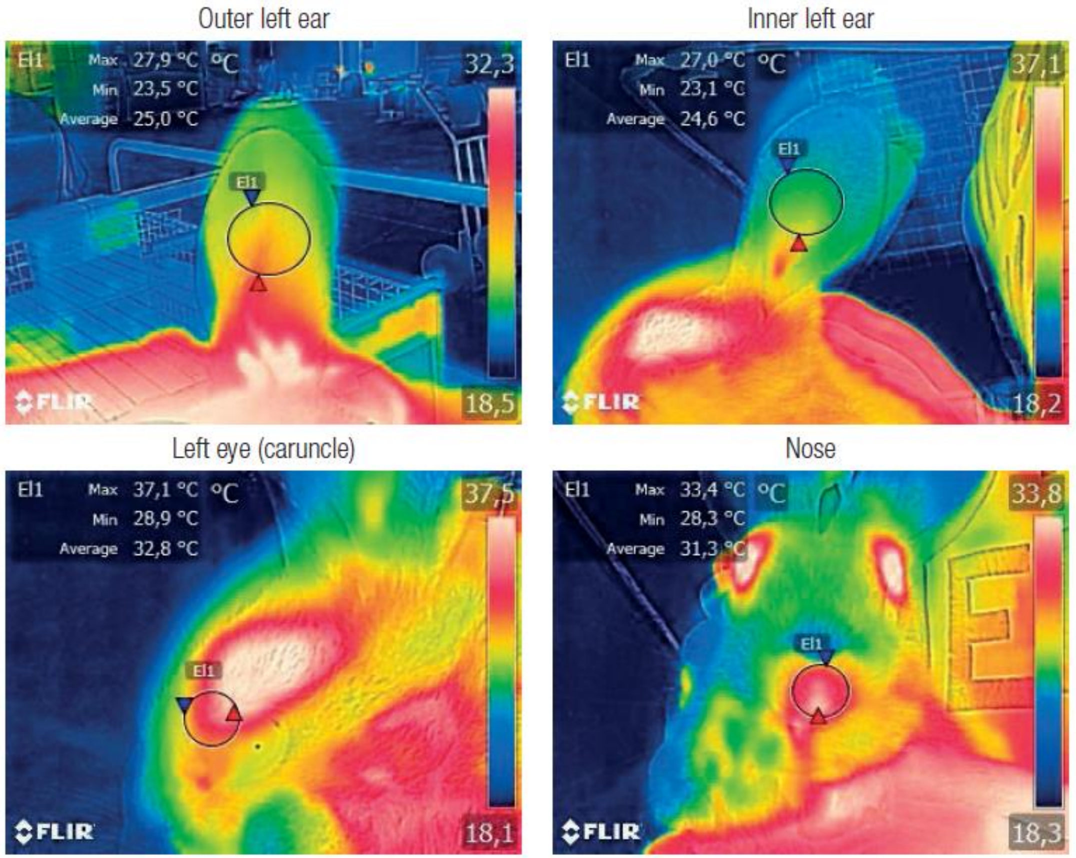

Figure from: Jaén-Téllez J.A., Bartolomé E., Sánchez-Guerrero M.J., Valera M., González-Redondo (2021) Relationship between rectal temperature measured with a conventional thermometer and the temperature of several body regions measured by infrared thermography in fattening rabbits. Influence of different environmental factors. World Rabbit Science, 29 (4), pp. 263 – 273. DOI: 10.4995/wrs.2021.15556.

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ORANGE GROUP

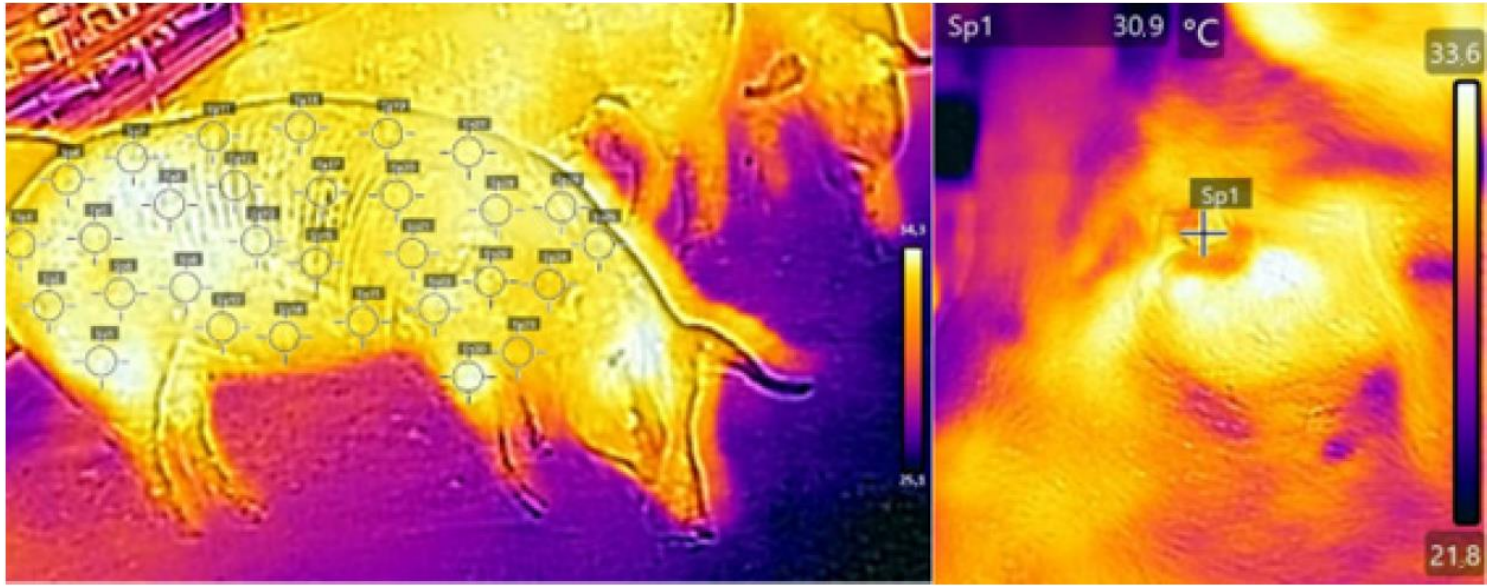

Figure from: Palermo Mendes, J.; Ribeiro Caldara, F.; de Castro Burbarelli, M.F.; Valentim, J.K.; Ferreira de Brito Mandú, D.; Garófallo Garcia, R.; Correia de Lima Almeida-Paz, I.; Markiy Odakura, A.; Lourenço da Silva, M.I. Performance and Welfare of Sows Exposed to Auditory Environmental Enrichment in Mixed or Collective Housing Systems. *Animals* **2023**, *13*, 1226. https://doi.org/10.3390/ani13071226.

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Thank you