European Commission

Better Training for Safer Food

Initiative

Training course on "Animal Welfare during transport"

Title of the presentation:

Predictive modelling of the responses of animals to transportation to assess welfare: the sound scientific basis for improvements in practice and legislation

Author: Malcolm Mitchell

BTSF

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Slovenia/Italy, 24-27 June, 2014

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Predictive modelling

(1)Modelling in relation to this course

(2)<u>Practical considerations: </u>sound theoretical basis

(3) Insight in to the scientific basis of regulations – evidence based

(4) Modelling theory

(5)Applications and outputs

(6) Case studies

(7)Conclusions

The relevant European context

The Commission adopted its report on the impact of Regulation **EC 1/2005** on the protection of animals during transport on 10 Nov. 2011

- **Its impact on animal welfare during transport;**
- Impact of the Regulation on trade within the EU;
- Socio-economic and regional implications;
- Implementation of the navigation systems;
- Enforcement of EU rules on animal welfare during transport.

Specific learning objectives

interpret relevant EU legislation and international framework (as the OIE guidelines);

apply scientific basis for proper transport of the animals (animal **behaviour**, **concept of stress** and its implication in the **quality of the meat, animal physiology** in particular drinking and feeding needs);

check transport conditions and records (fitness for transport, **vehicle standards, space allowances, temperatures, travelling time limits,** tachographs and navigation systems etc.);

manage practical aspects of handling of animals (loading and unloading activities) and emergency care for animals during transport;

Specific learning objectives

assess the design of vehicles facilities (density, drinking devices, headroom, ramps of access, stalls when required, etc…);

identify best solutions to achieve the requirements on control posts;

facilitate the monitoring and proper enforcement of relevant animal welfare requirements during the transport.

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Live animal transport – modelling, evidence and welfare

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Executive Agency

EU Strategy for Protection and Welfare of animals 2011 – 2015

The Commission has prepared the second EU strategy for the protection and welfare of animals adopted in December 2011.

EC/EU, EFSA and Evidence

Science is the foundation of the new Animal Health (and Welfare) policy – and it will be on the basis of solid scientific advice and information that future animal health and welfare rules are developed.

EVIDENCE BASED

EC/EU, EFSA and Evidence

Andrea Gavinelli (EC Commission for Animal Welfare) has stated that:

"changes and amendments to animal welfare Regulations and any new or proposed Regulations must be based on sound and proven scientific principles and research outputs - EVIDENCE"

EC/EU, EFSA and Evidence

The AHAW Panel has performed scientific assessments on the welfare of a number of animal species

Further work will be needed to update those assessments in light of new scientific **evidence** and to develop new assessments in response to risk management demands.

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EC/EU, EFSA and Evidence

Scientific opinions of the AHAW Panel are used as a scientific basis for many of the EU legislative measures on animal welfare. **(EVIDENCE)**

For example, **Council Regulation (EC) No 1/2005** on the protection of animals during transport is essentially based on conclusions and recommendations of the 2004 EFSA opinion on the welfare of animals during transport. This opinion has recently been updated **(AHAW, 2011)** and has contributed to a comprehensive report to the European Parliament proposing additional management options.

Animal transportation is a matter of public and political concern

It receives the largest "ministerial" mailbag of all welfare issues

It is the topic of ever developing European legislation and therefore fierce political debate

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There are many forms and types of animal transport

Animal transport is important because:

- There are major influences on animal welfare
- In slaughter animals product quality may be affected by transportation stress
- In breeding and performance animals there are potential detrimental effects
- There may be long term health consequences
- Losses and mortality may be increased
- Economic effects and considerations

Origins/ sources of stress?

- Transport conditions
- Journey duration
- Stocking density
- Vehicle or container type
- Loading and unloading
- Genetics of the animal/breed/strain/individual

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Stressors in transit

Thermal loads
Motion
Acceleration
Vibration
Impact

Fasting/withdrawal of water
Restriction of behaviour
Social disruption
Noise
Air contaminants

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Live animal transport

How do we approach the study of animal transport?

Transport procedures, practices and environments

Animal responses

- Stress in animal transport*
- Physiology
- Behaviour

"Modelling"?

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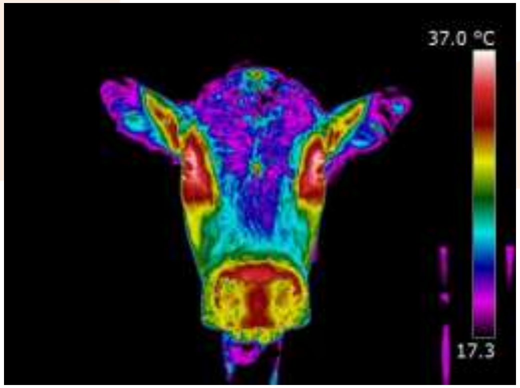
Predictive Modelling – Outcome based

Animal Physiology
Animal Behaviour
Understanding and quantifying the environment, imposed stress and the consequences for animal health, welfare and product quality



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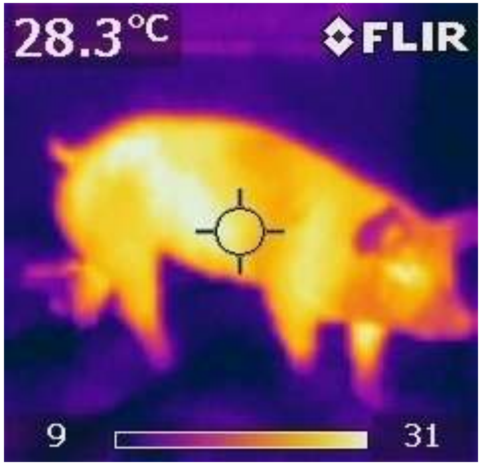
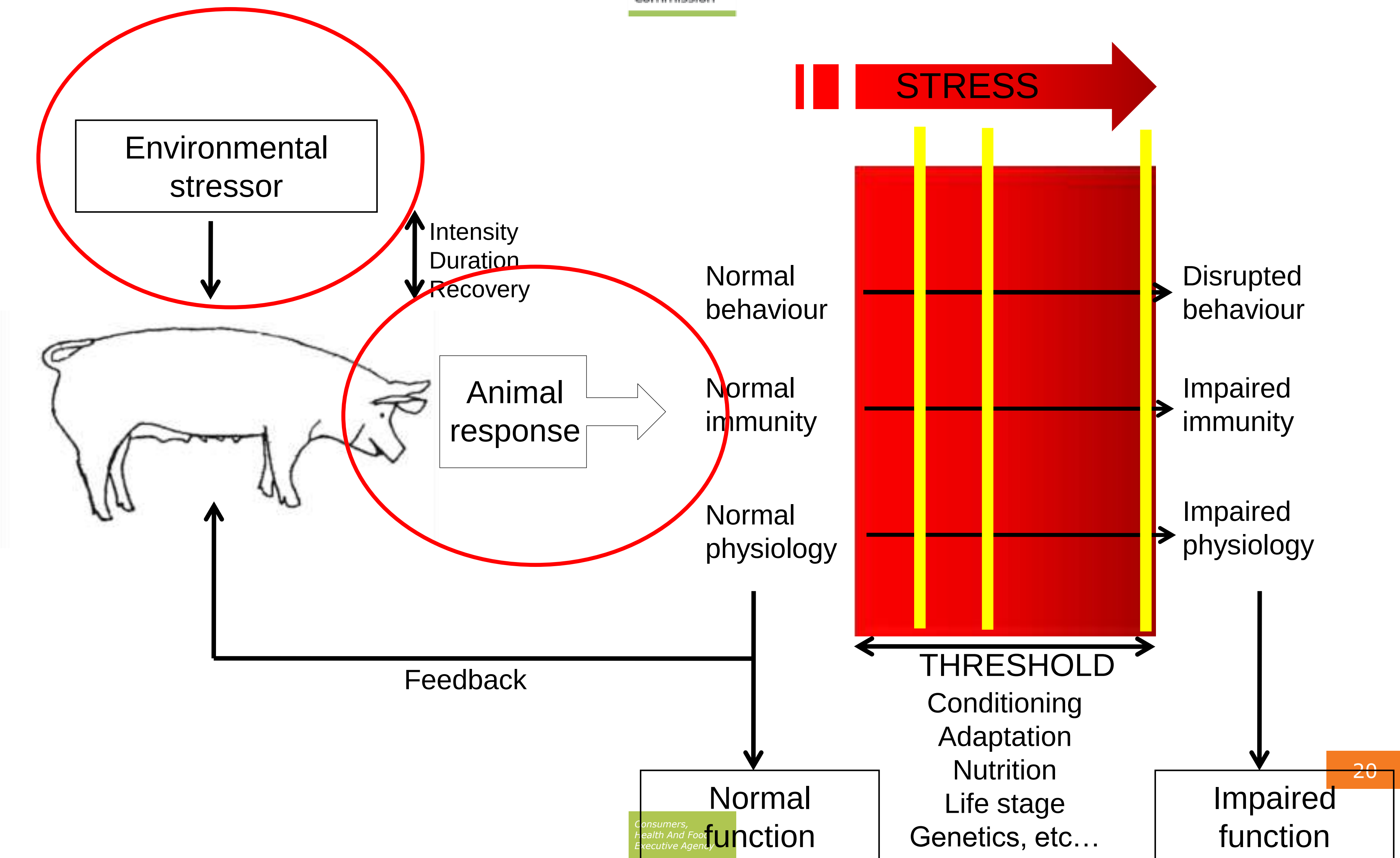
Physiological Response Modelling





STRESS
Environmental stressor
Intensity
Duration
Recovery
Animal response
Normal behaviour
Normal immunity
Normal physiology
Disrupted behaviour
Impaired immunity
Impaired physiology
Feedback
THRESHOLD
Conditioning
Adaptation
Nutrition
Life stage
Genetics, etc…
Normal function
Impaired function

Mild discomfort or distress

↓

Moderate distress

↓

Severe distress (suffering ?)

↓

Overt injury and Mortality

- Control Theory

  - **Controlled variable**
  - **Set Point**

- Homeostatic success
- Homeostatic effort

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Adaptive or Homeostatic responses

Compensation	CV regulated at or close to SP
Inadequate compensation	Perturbation in CV
Decompensation	Catastrophic failure of regulation

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Compensation	**Mild physiological stress**
Inadequate compensation	**Moderate physiological stress**
Decompensation	**Severe physiological stress**

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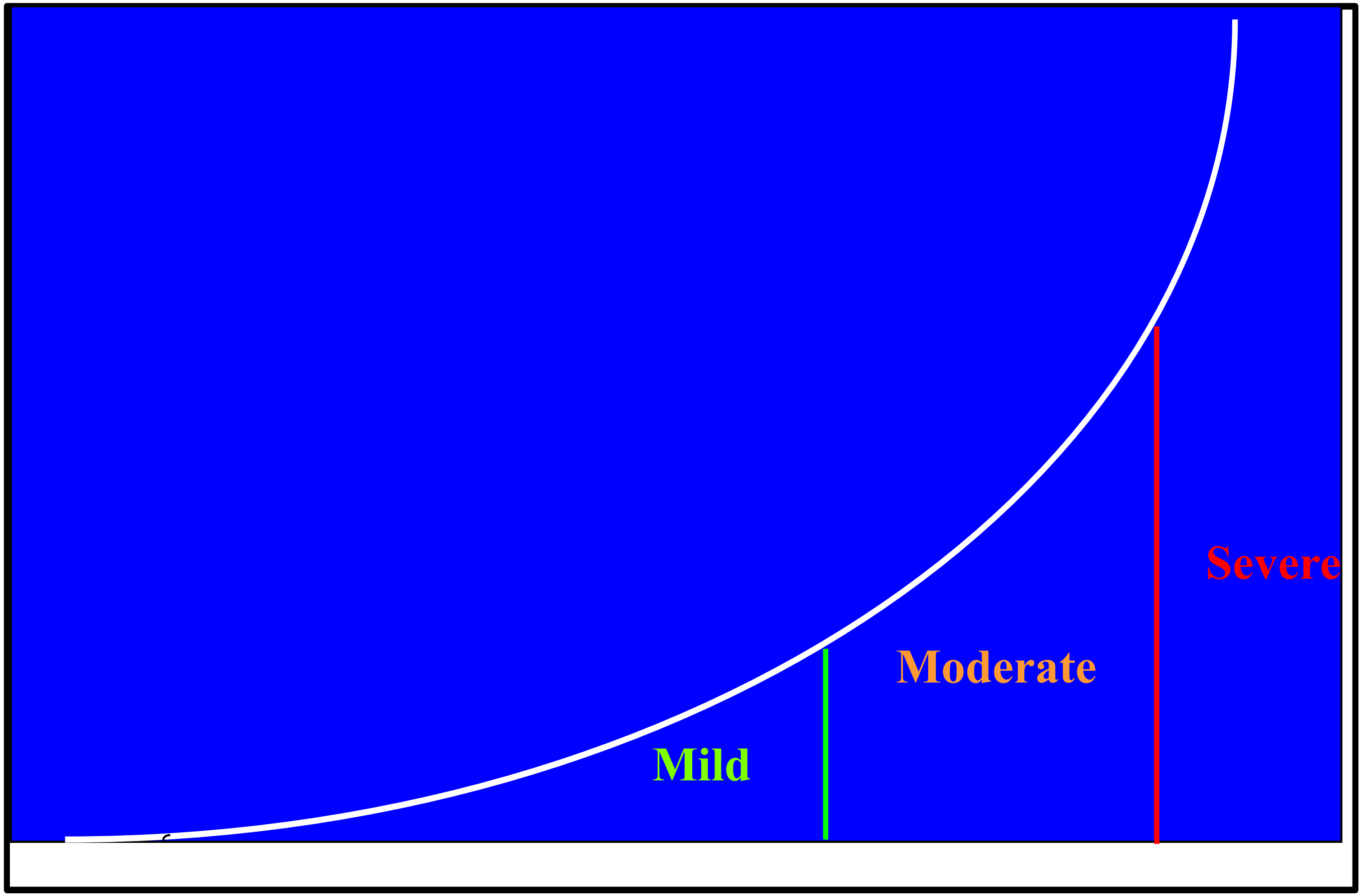

Physiological response

Imposed stress

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- Thermoregulation
- Cardiovascular
- Respiratory
- Blood gas and acid-base status
- Electrolyte balance
- Hydration state
- Plasma hormone concentration
- Circulating metabolites

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- Deep body temperature
- Heart rate
- Respiration rate
- Blood pH, pCO_2,
- Blood sodium and potassium
- Osmolarity
- Plasma protein
- Plasma glucose and lipids

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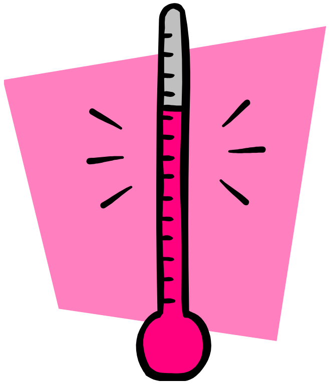
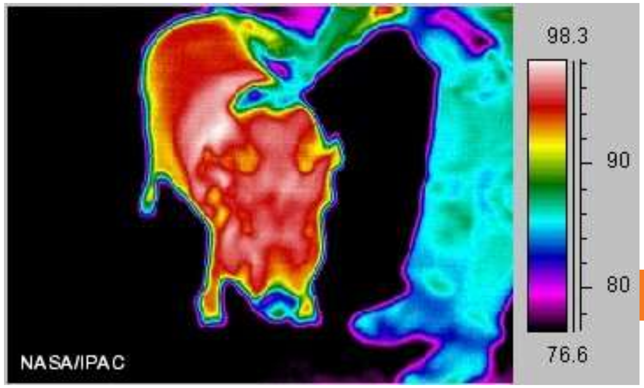
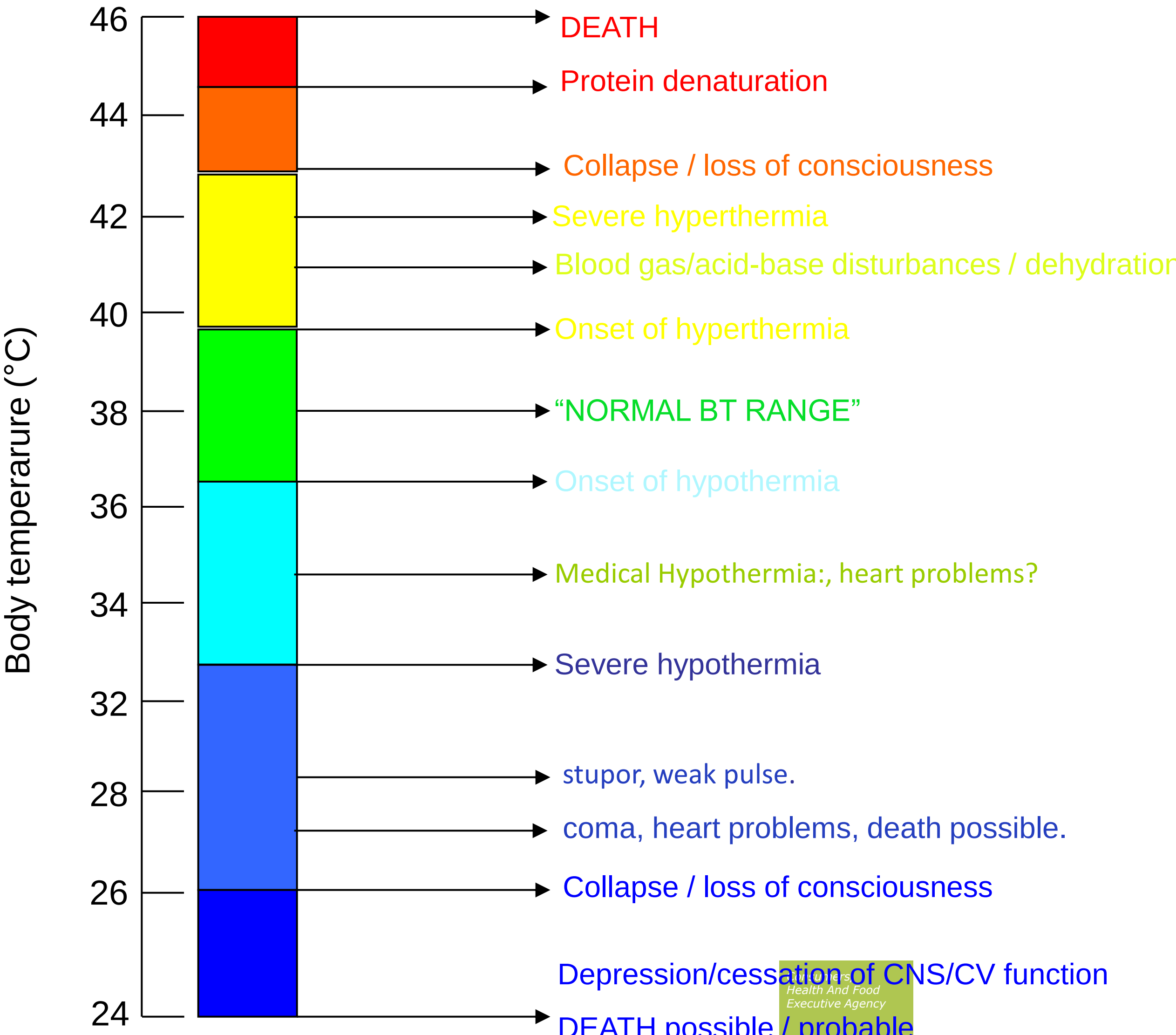
One of the biggest problems in transit is thermal stress



Either ***cold*** or ***heat***




Body temperarure (°C)
46
44
42
40
38
36
34
32
28
26
24
DEATH
Protein denaturation
Collapse / loss of consciousness
Severe hyperthermia
Blood gas/acid-base disturbances / dehydration
Onset of hyperthermia
"NORMAL BT RANGE"
Onset of hypothermia
Medical Hypothermia:, heart problems?
Severe hypothermia
stupor, weak pulse.
coma, heart problems, death possible.
Collapse / loss of consciousness
Depression/cessation of CNS/CV function
DEATH possible / probable


RIP
Corbis.com
RIP

Case studies

Transportation of poultry

Thermal conditions and long distance transport of pigs

Identification and quantification of the main stressors

Modelling or characterisation of the appropriate responses

Recommendations for improvements, measures or control

Poultry Production

Livestock Species (slaughterings – 2011)	European Union	World
Broilers	**6.4 billion**	**58 billion**
Turkeys	**203 million**	**654 million**

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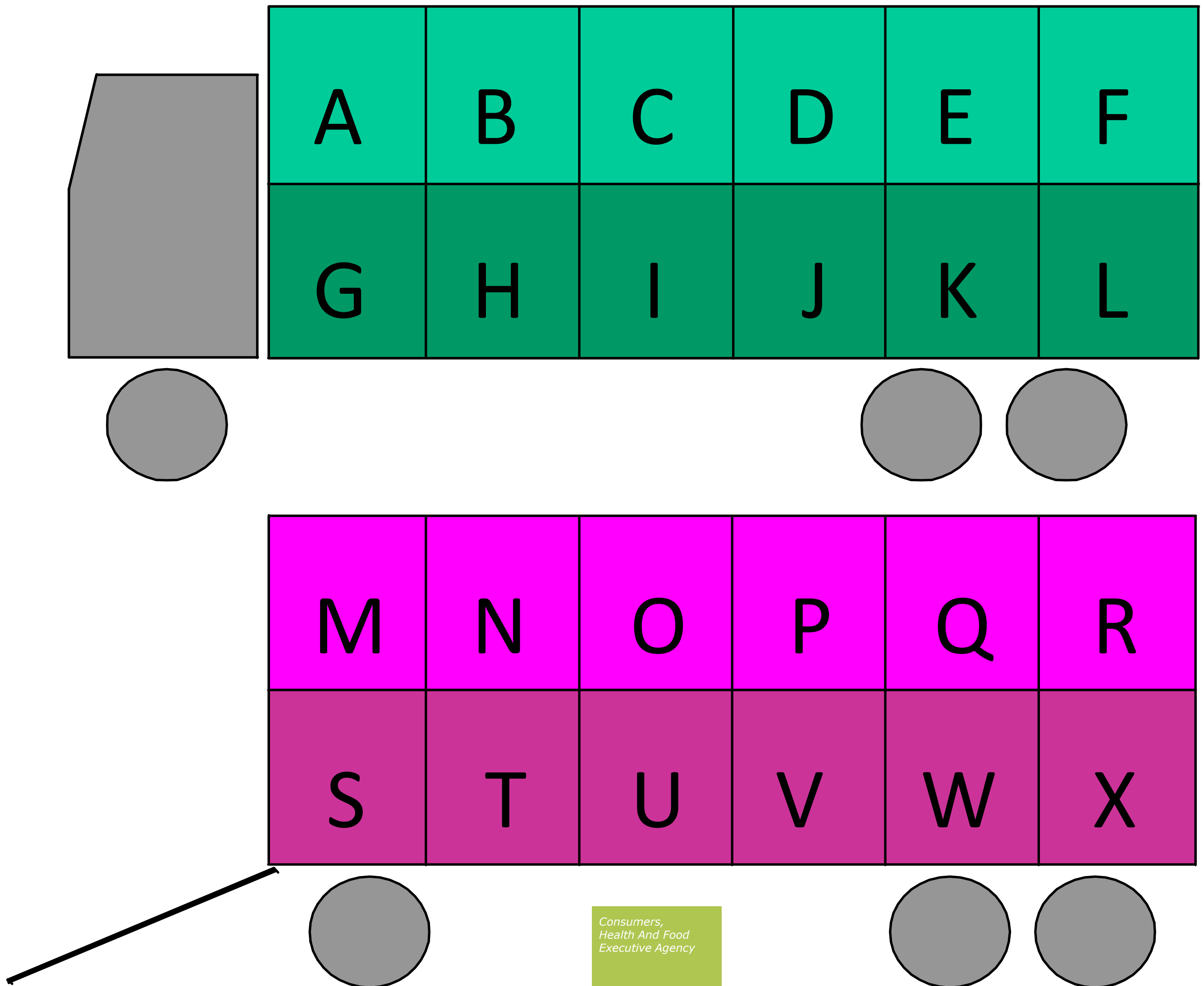
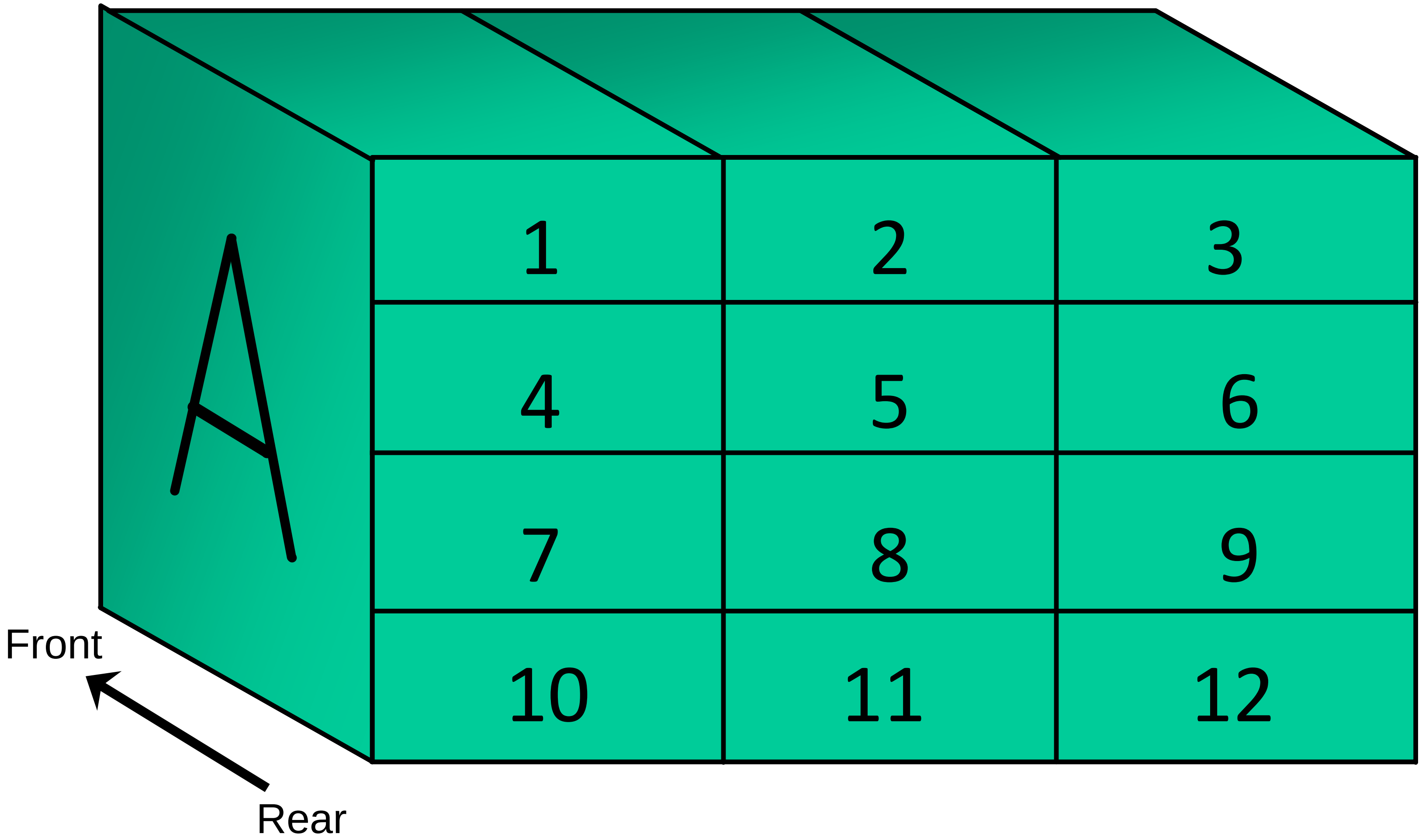
CU = curtains up

CD = curtains down (closed)


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X


A
1
2
3
4
5
6
7
8
9
10
11
12
Front
Rear

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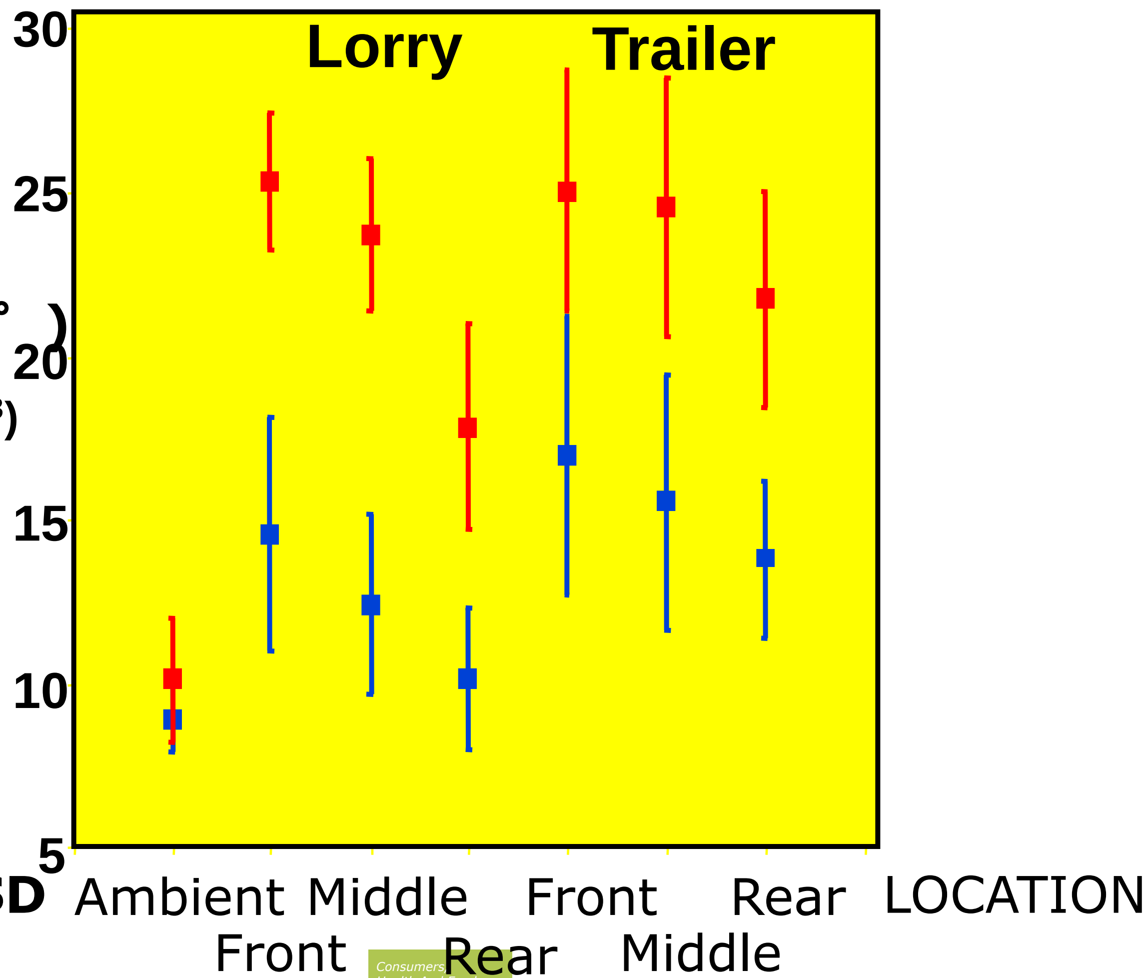
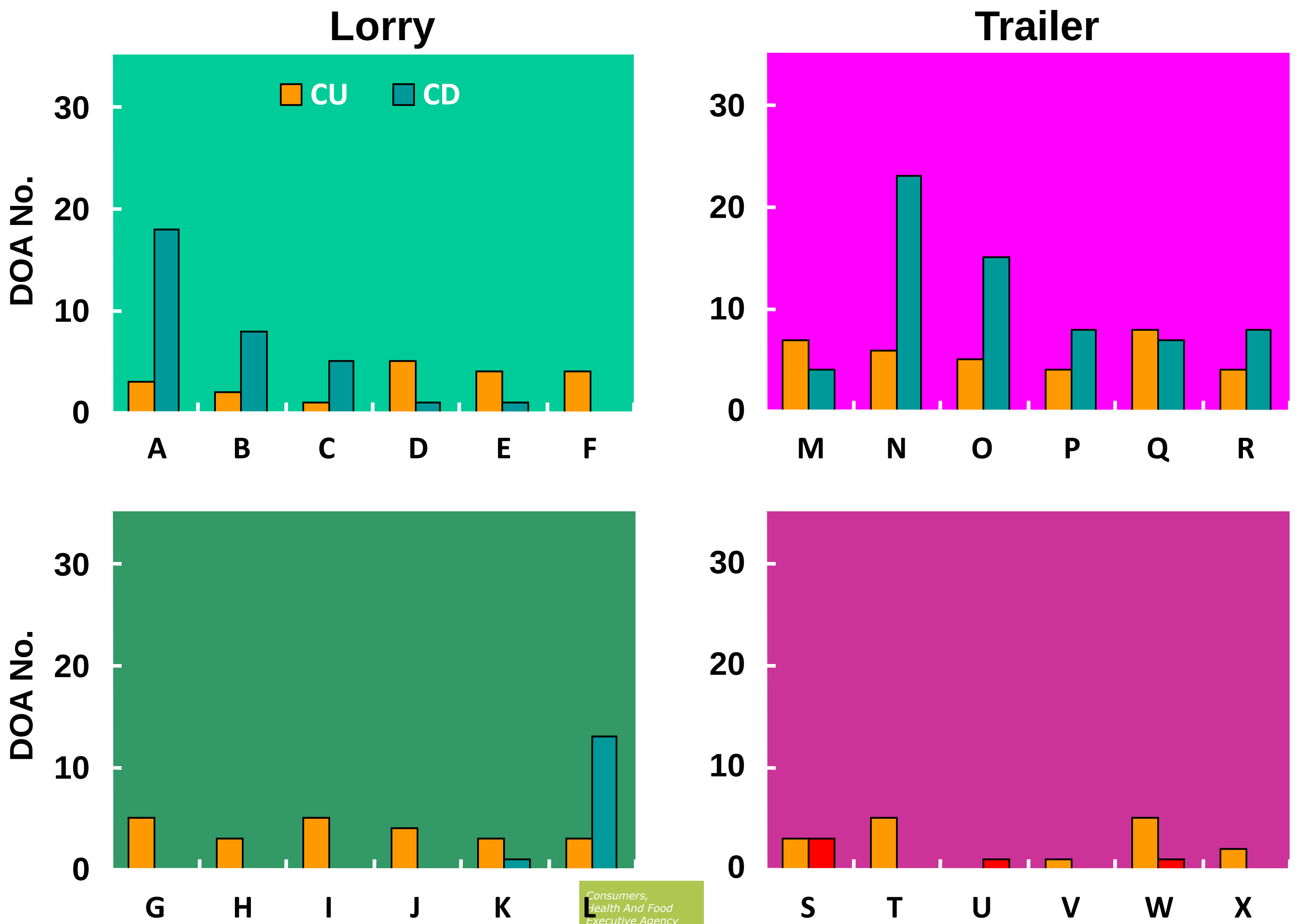
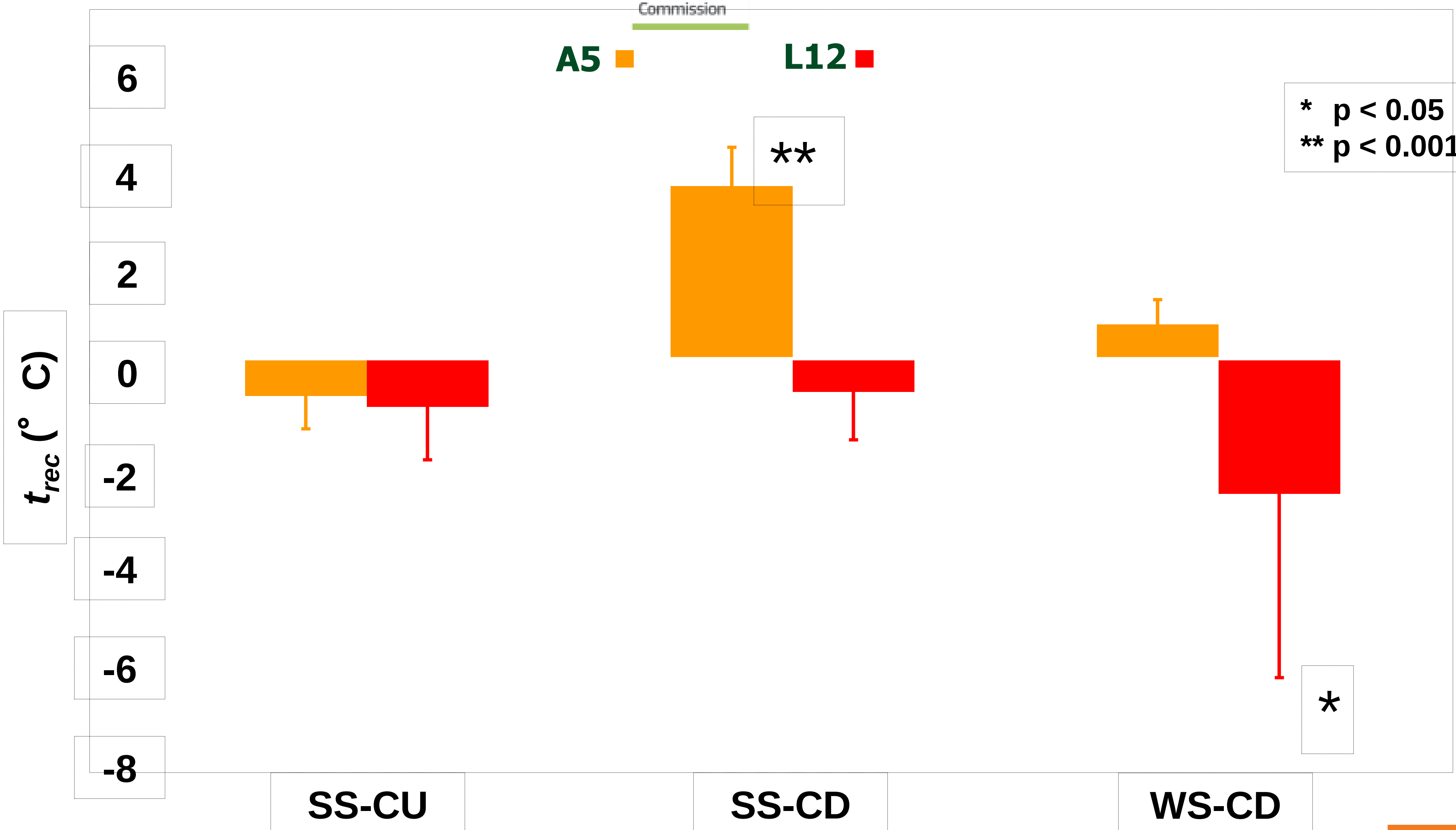
Temperature (C°)

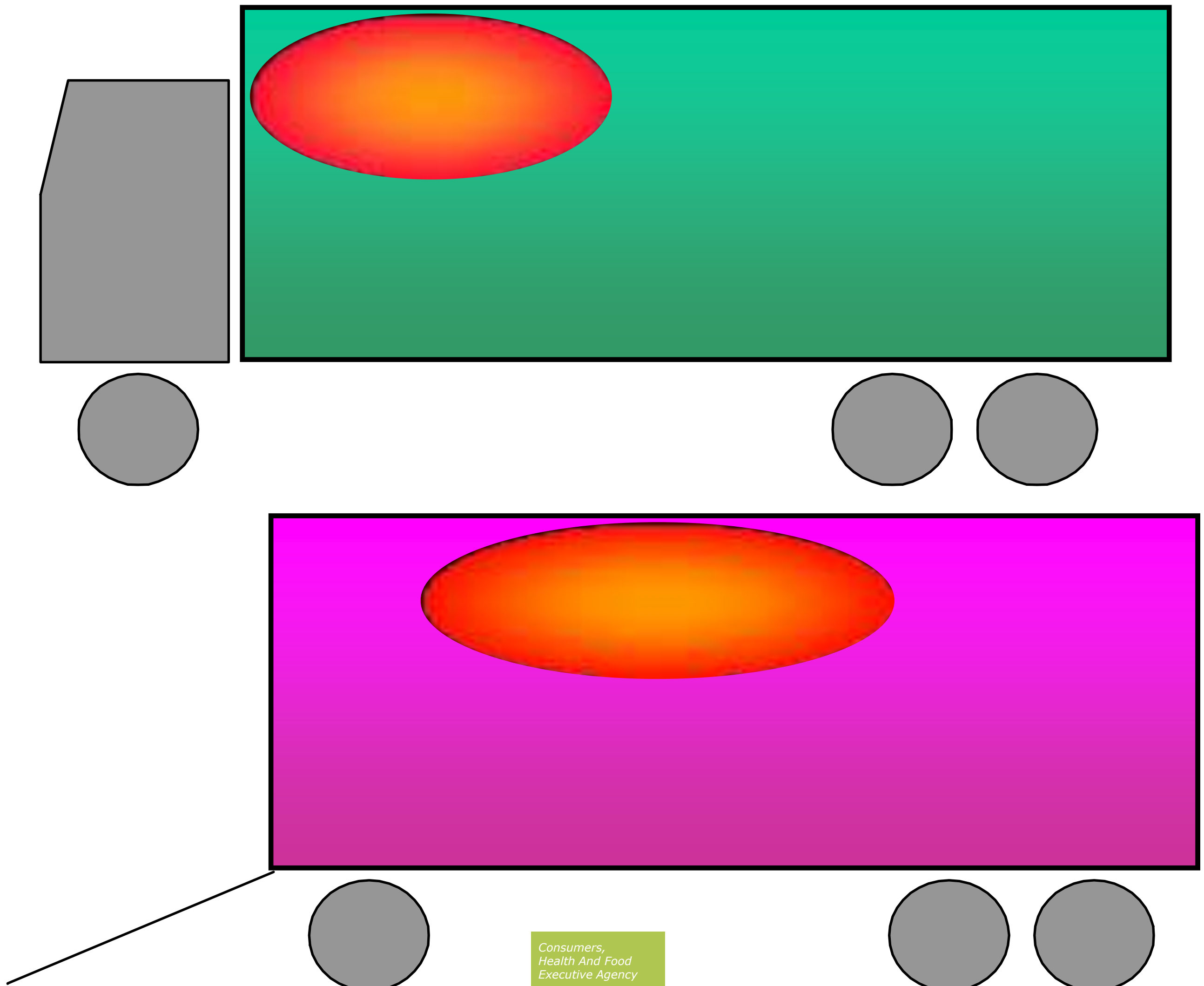
Vapour density (gm^{-3})

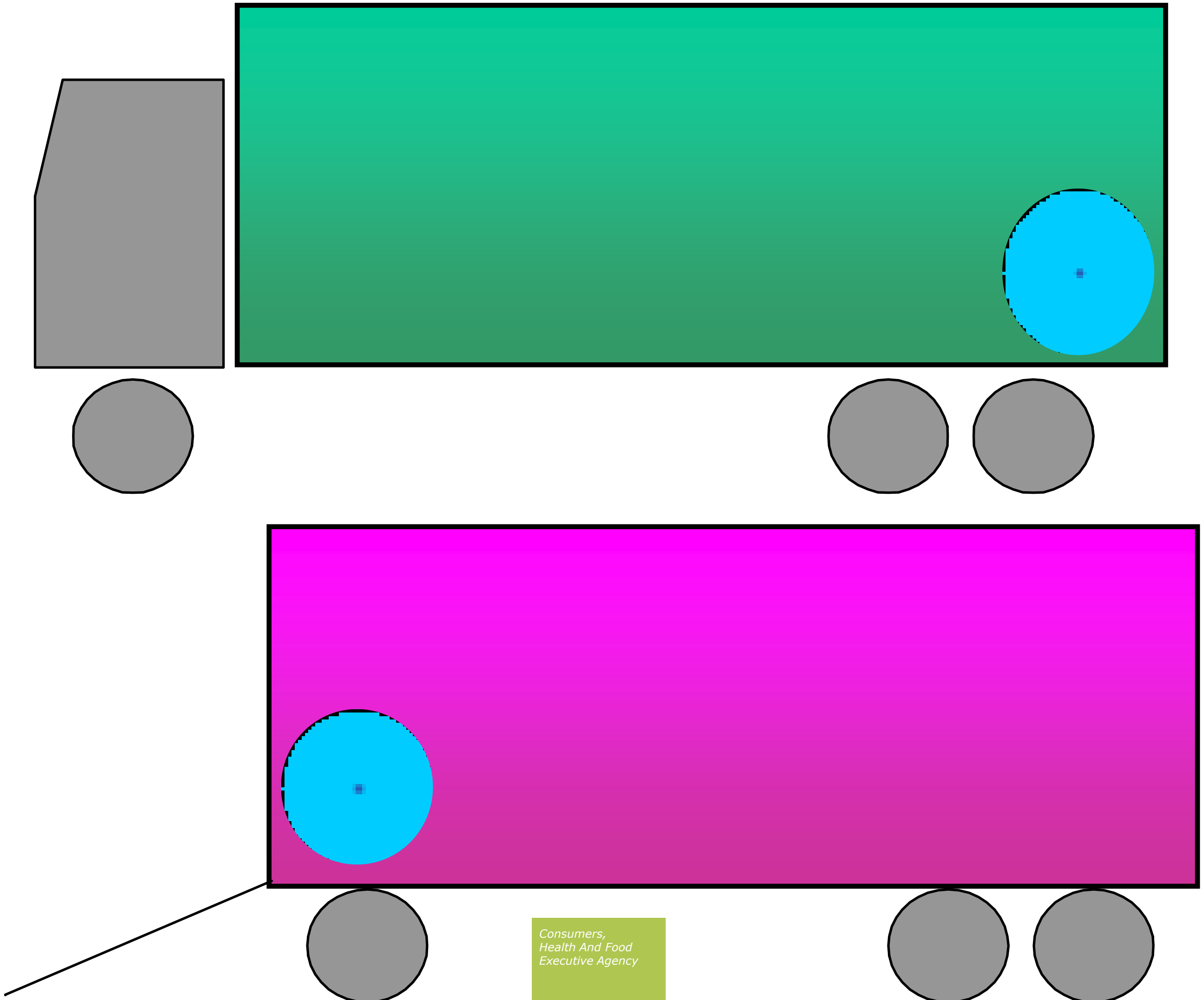


Mean values ± SD


Lorry
Trailer
CU
CD
DOA No.
30
20
10
0
A
B
C
D
E
F
M
N
O
P
Q
R
G
H
I
J
K
L
S
T
U
V
W
X


A5
L12
* p < 0.05
** p < 0.001
6
4
2
0
-2
-4
-6
-8
t_rec (° C)
**
*
SS-CU
SS-CD
WS-CD





Broiler Transport

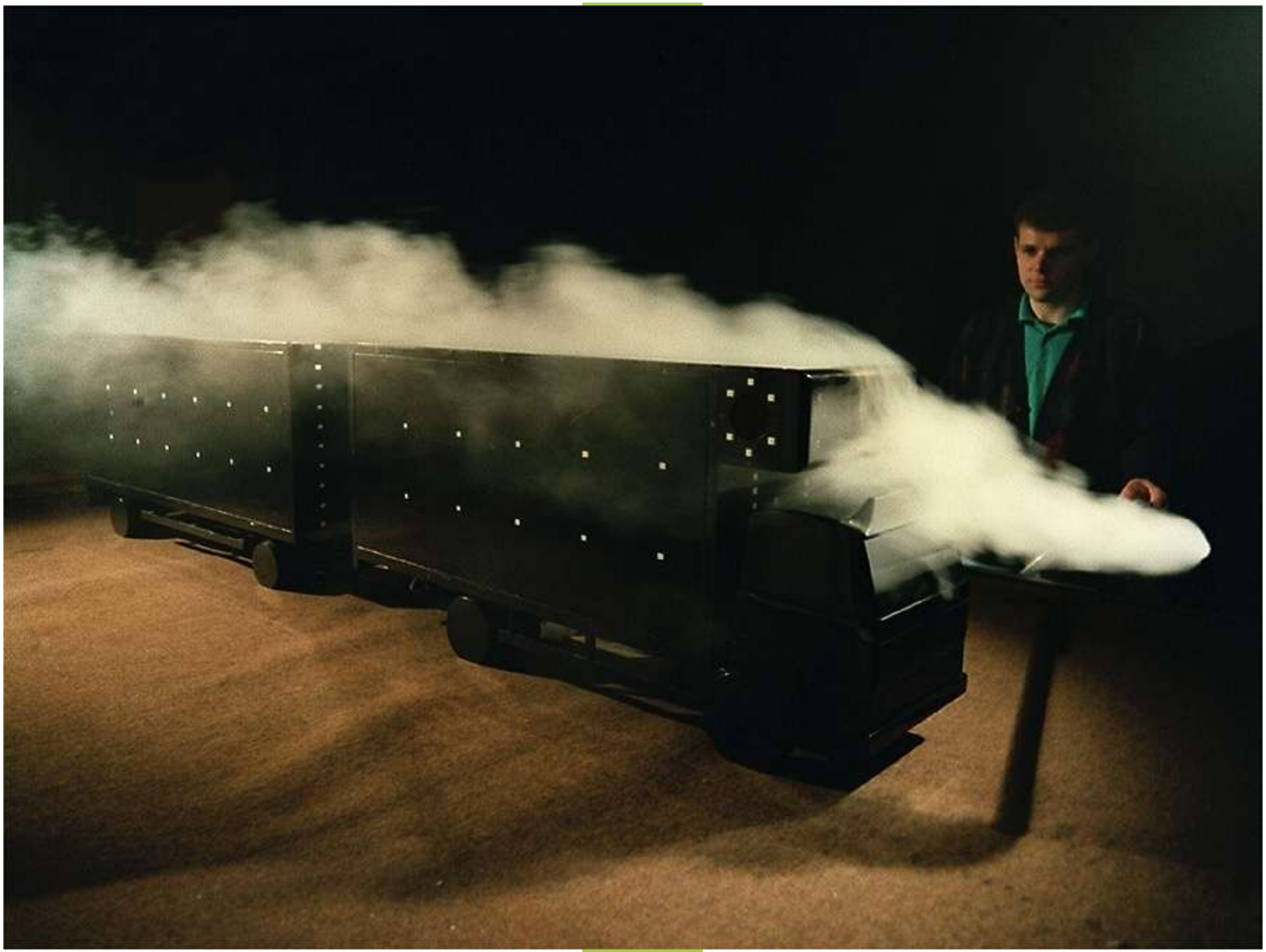
- Heterogeneous distributions of thermal loads

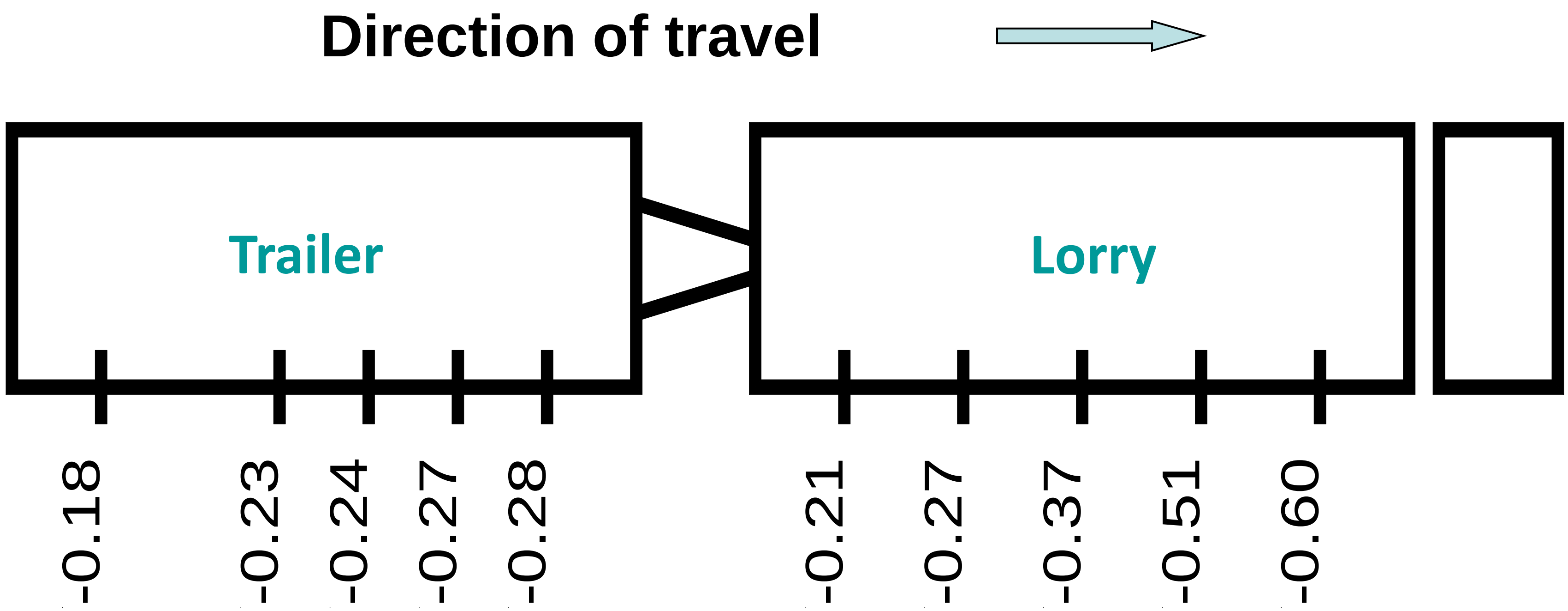
- Heterogeneous distributions of mortality and stress ?

VENTILATION IS THE CULPRIT


HOUGHTONS
2540
ACTROS
W708 XGS

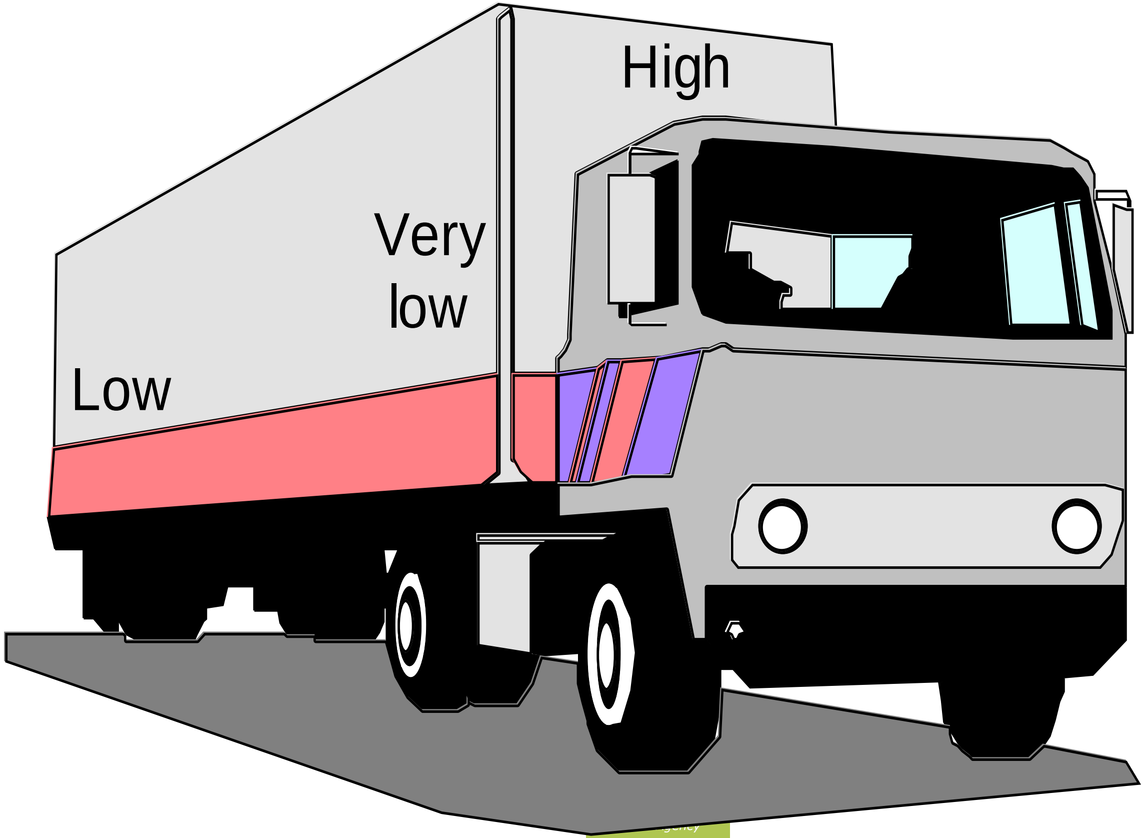
Actual air movement around and within a vehicle





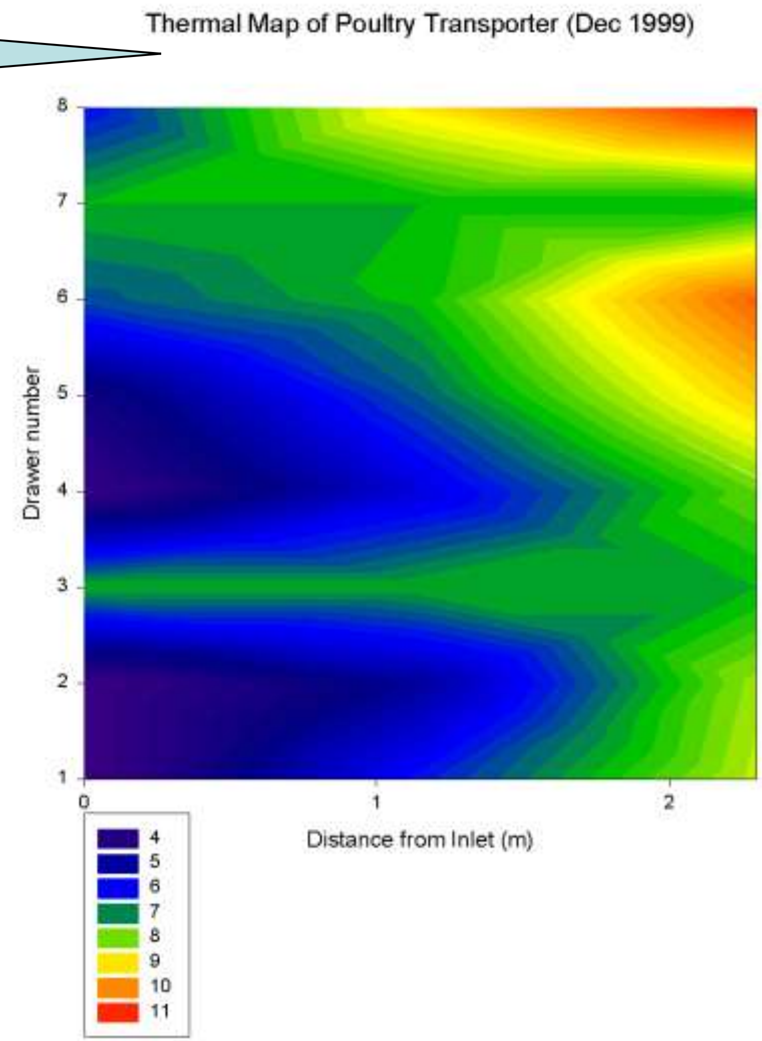
Pressure coefficients

External pressure field around moving vehicle



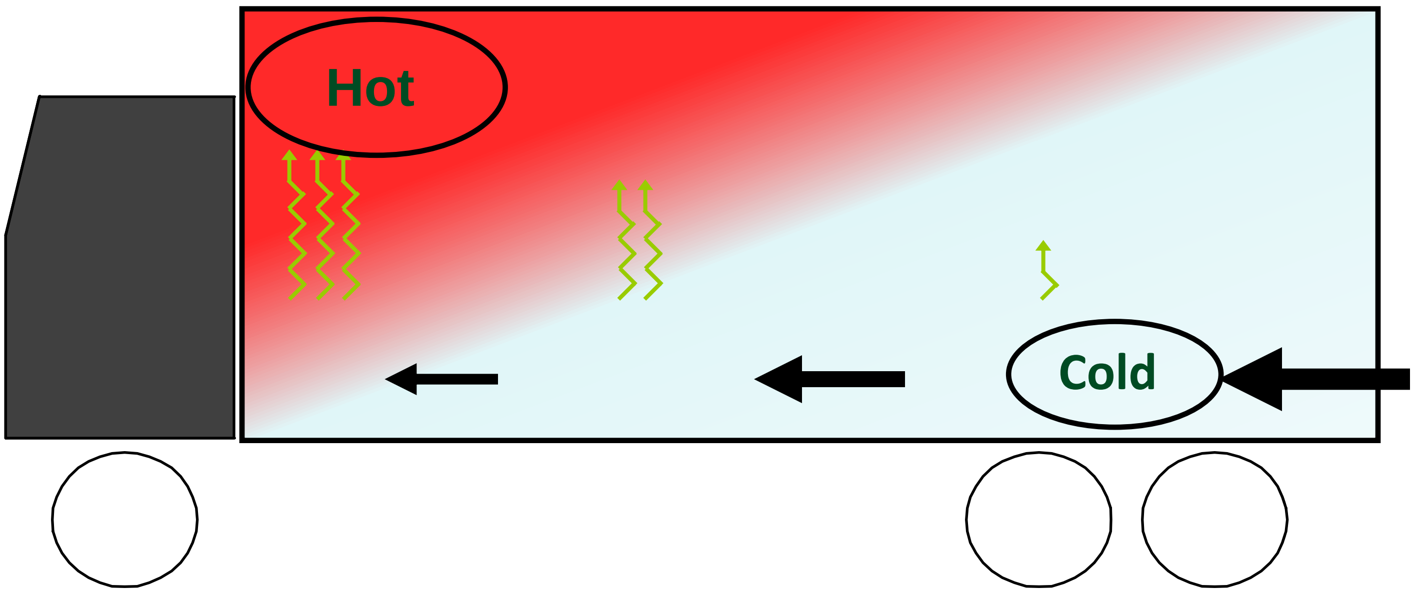
Front

Rear



Inlet at rear

Air movement around and within a vehicle



- Air flow
- Convection

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1) Air tends to move from the rear towards the front on a moving, passively ventilated vehicle.

2) This phenomenon is responsible for the heterogeneous distribution of thermal loads within the vehicle - the “thermal core”.

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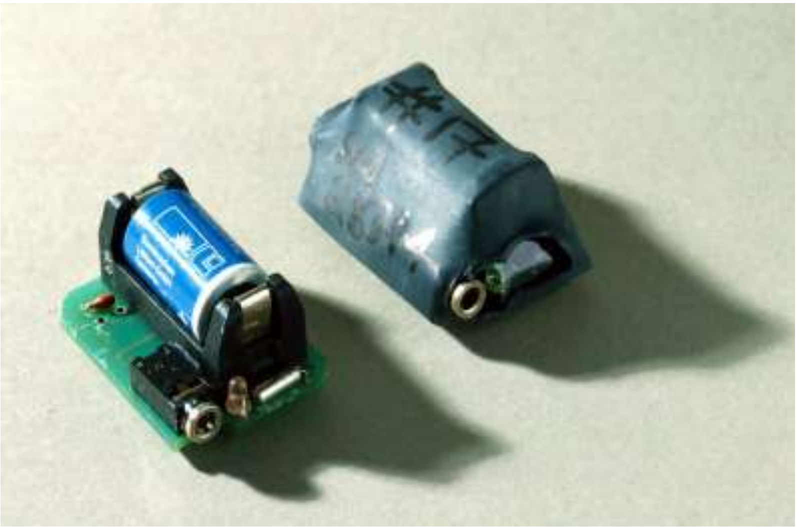
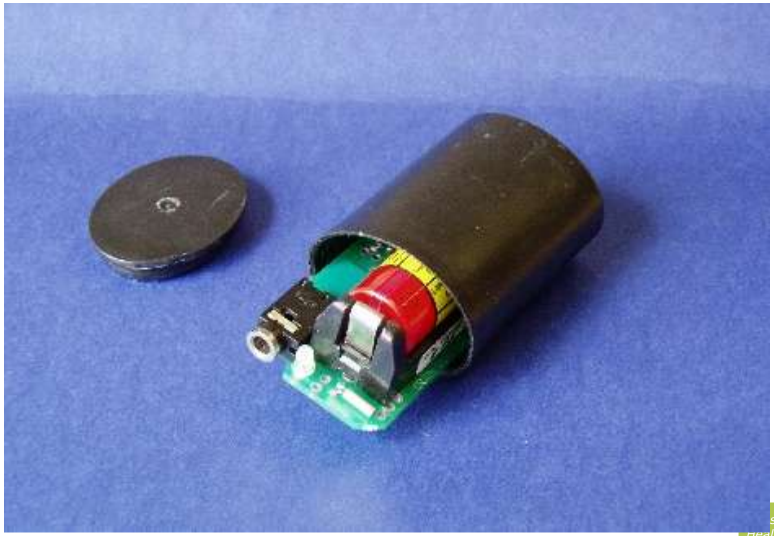
LOADING





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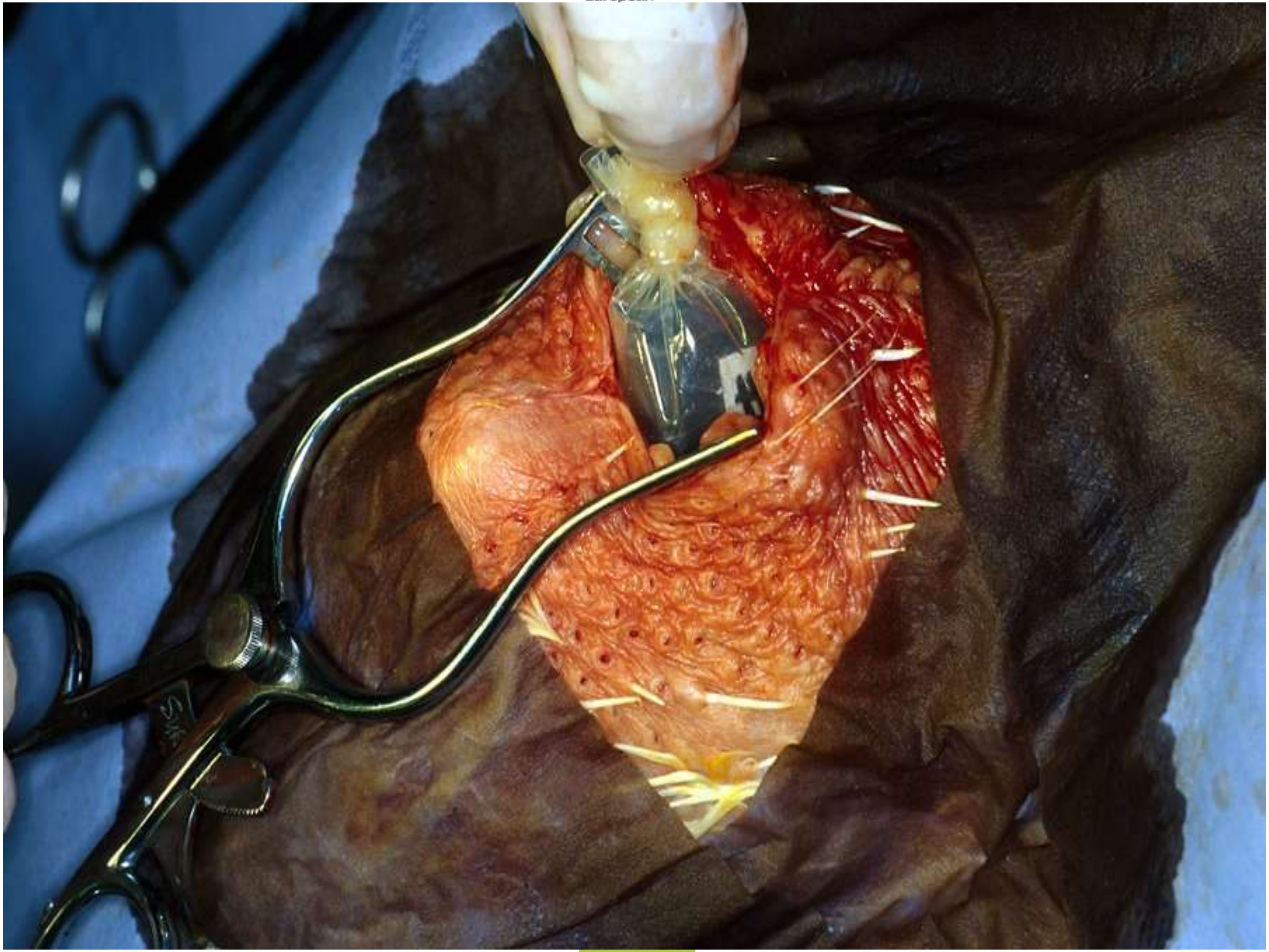
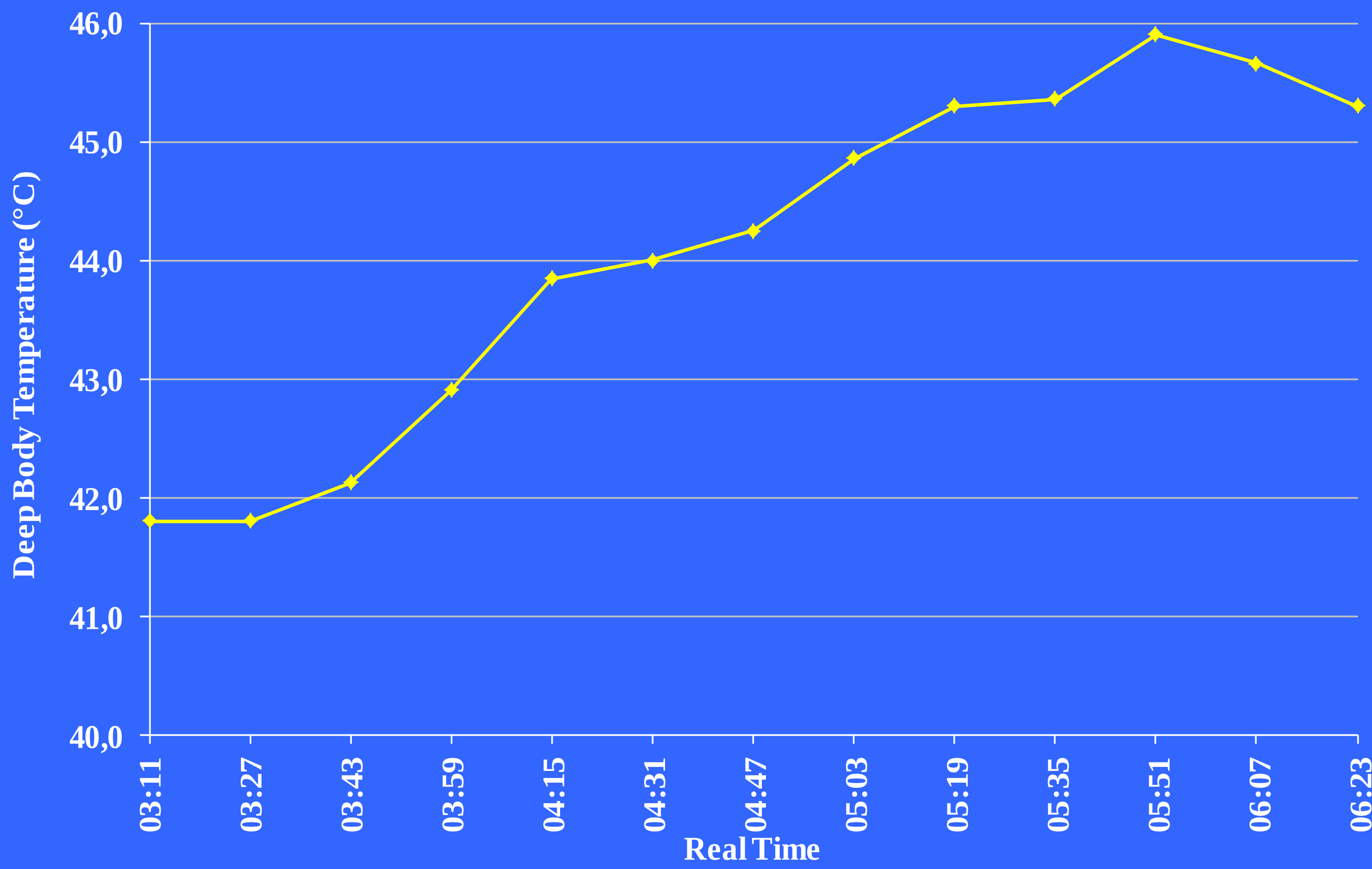


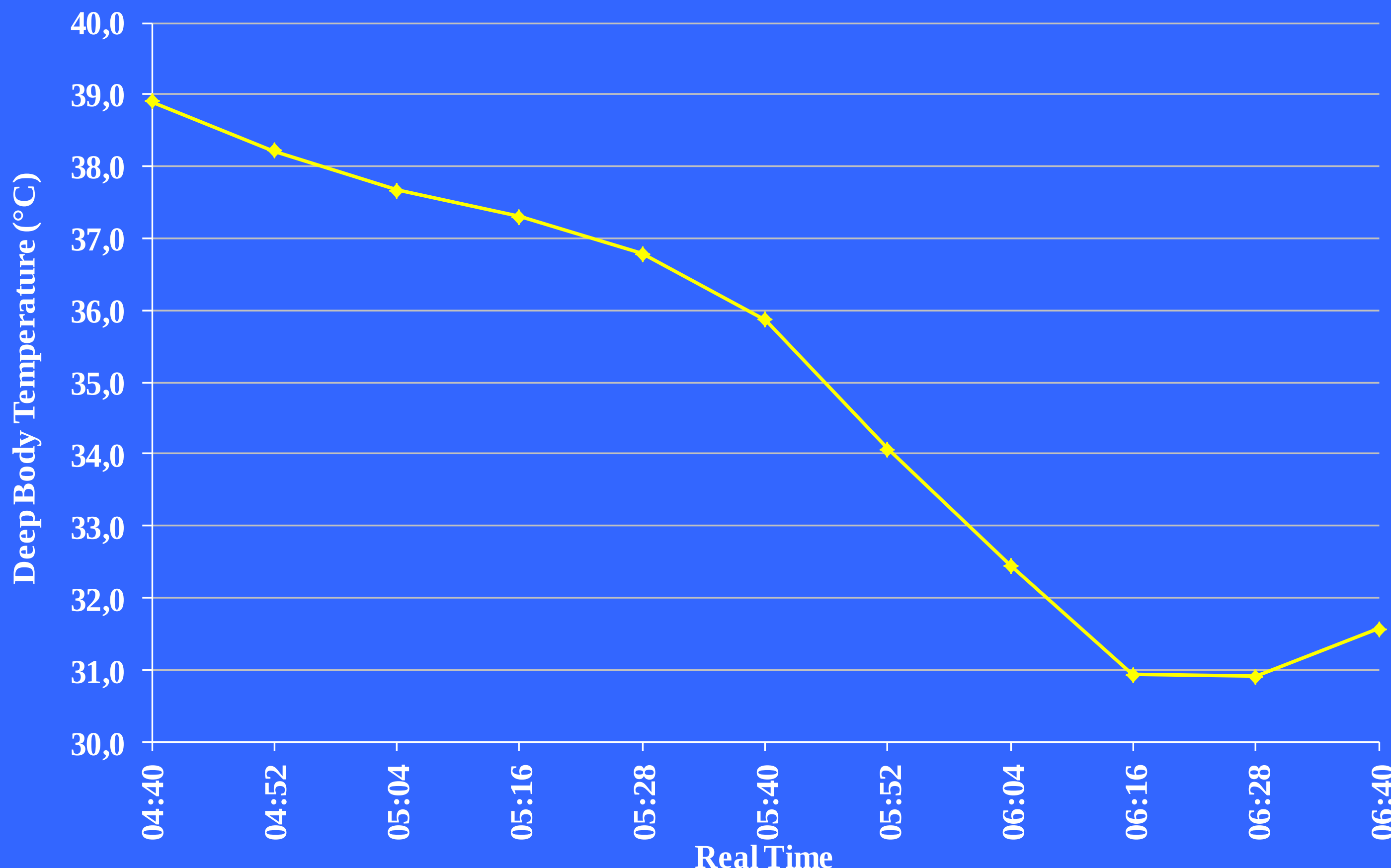
HEAT STRESS

Location – A5 front upper deck

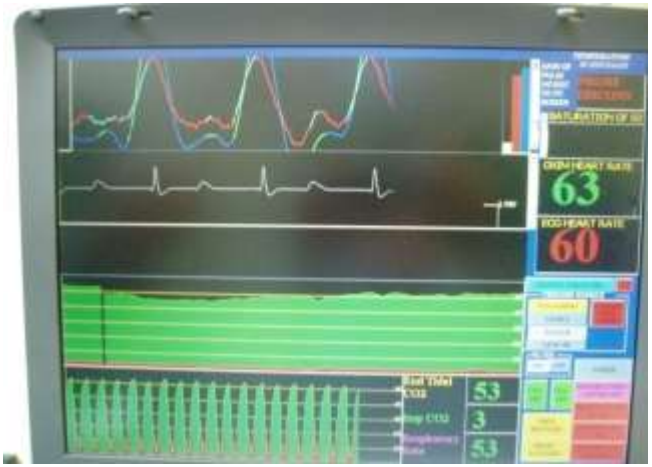


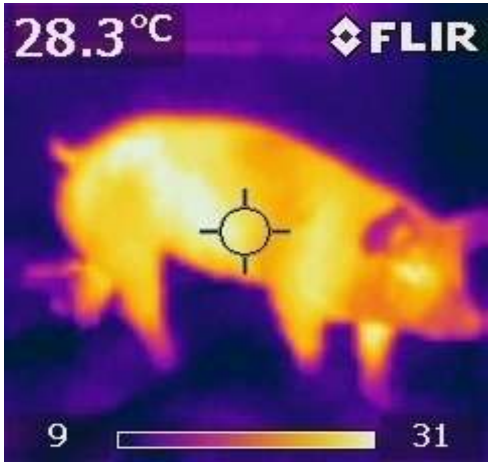
COLD STRESS

Location – L12 rear bottom deck



Physiological Response Modelling





Apparent Equivalent Temperature (AET)

$$\theta^{*}_{app} = T + e/\gamma^{*}$$

θ^{*}_{app} = AET

T = Temperature

e = Water vapour pressure

γ^{*} = corrected psychrometric constant

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Derived from

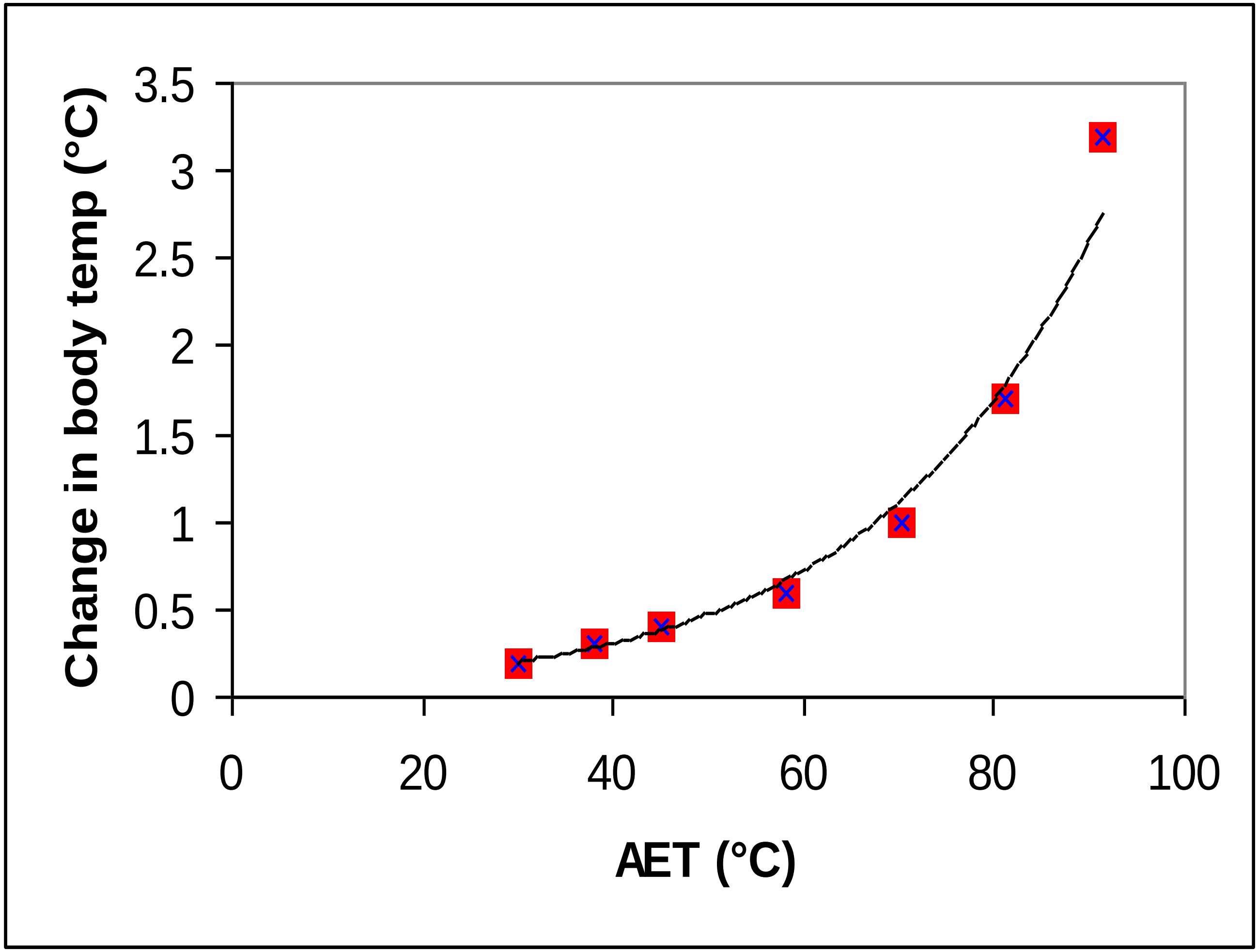
- Temperature
- Water vapour pressure
- Psychrometric constant

Relates to

- Total heat exchange between a wetted surface and the environment

Value

- Integrated index of total thermal load: physiologically valid


3.5
3
2.5
2
1.5
1
0.5
0
Change in body temp (°C)
0
20
40
60
80
100
AET (°C)

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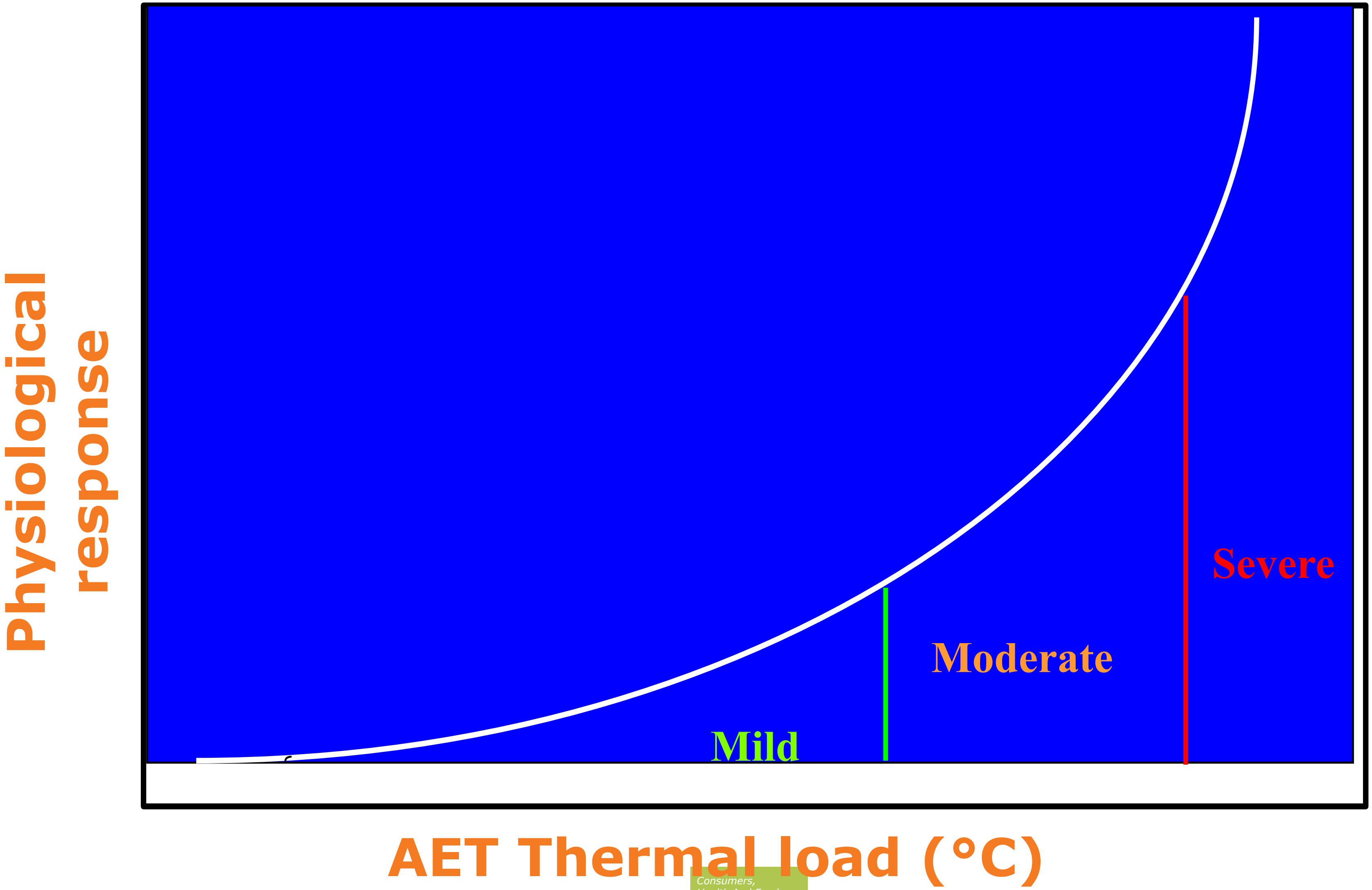

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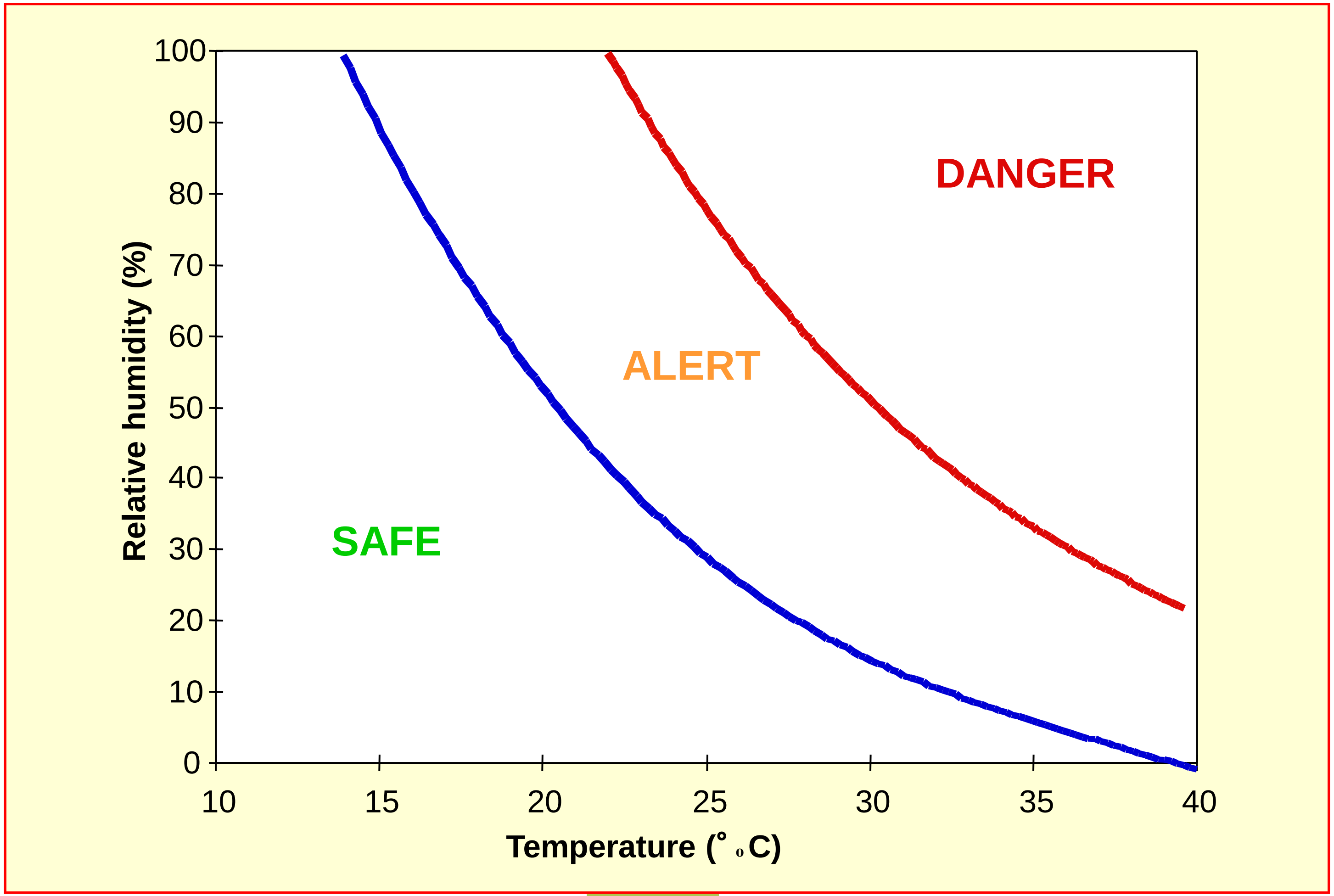
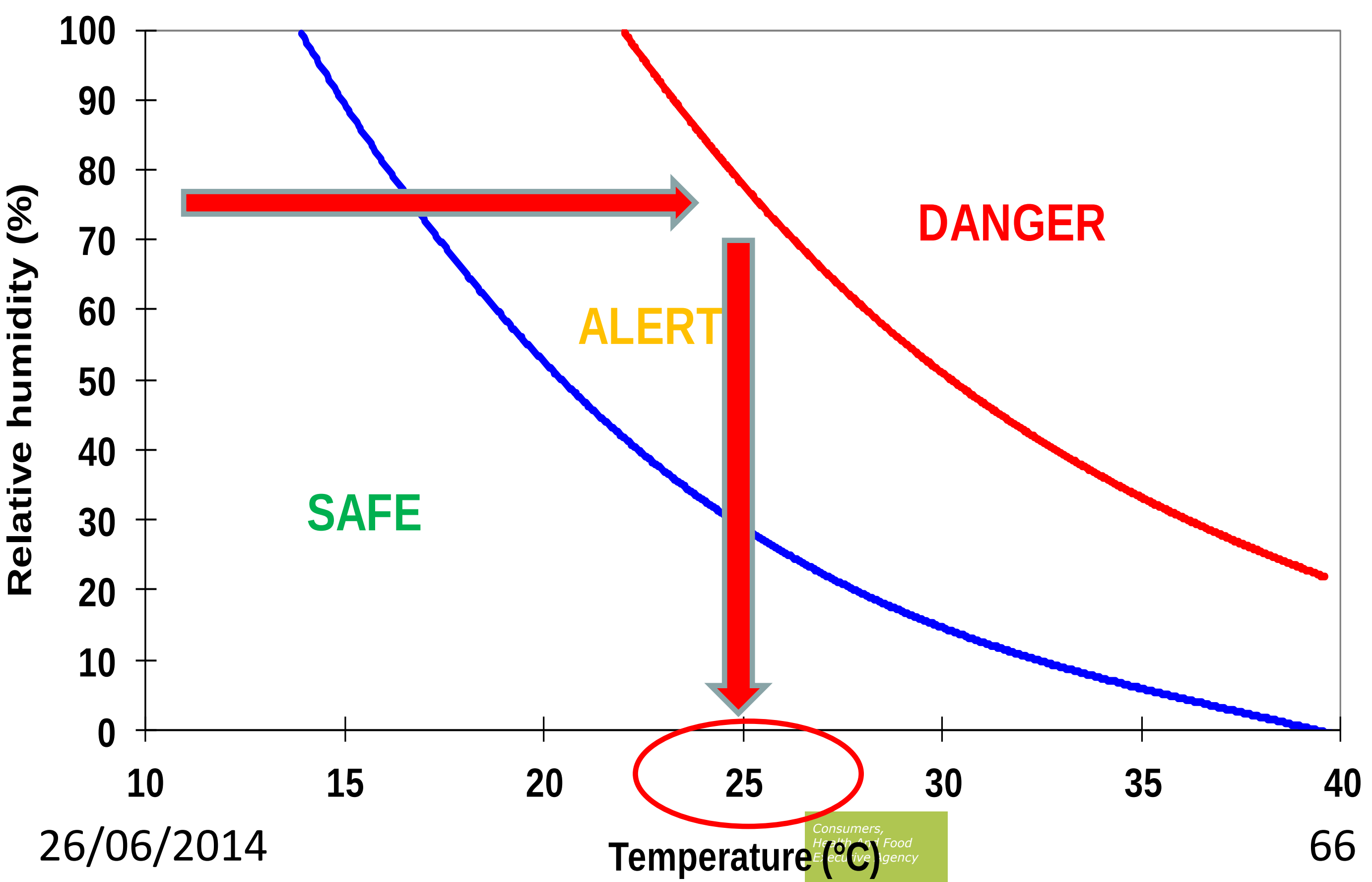

100
90
80
70
60
50
40
30
20
10
0
Relative humidity (%)
10
15
20
25
30
35
40
Temperature (° C)
DANGER
ALERT
SAFE

Thermal comfort zones - in crate conditions



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Poultry transport and EC 1\2005

European Commission

Poultry transport and EC 1\2005

EC 1/2005 "The Transport Regulation"

Journey definitions

First animal on until last animal off (NOT poultry)

Journeys classified as short or long (> 8 hours)

Maximum journey times for species and age

Vehicle standards e.g. mechanical ventilation, temperature recording, feeding/watering apply only to "long journeys

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Poultry transport and EC 1\2005

Previous legislation (e.g. EC 91/628) incorporated with little change

Journey times (effective) 12 hours for most birds (24 hours for ODO)

No standard or long journeys defined so no vehicle specifications other than general!

No temperature limits!

Poultry transport and EC 1\2005

Work of Warriss et al at Bristol has demonstrated that :-

- **Mortality increases with journey times greater than 4 hours**

- **Mortality increase with temperature i.e. season**

So should we be paying attention to longer journeys on warmer days and looking in the vulnerable locations (on specific vehicle / trailer types??!!)

Models

Can be applied to animals in a wide range of situations
Can predict heat exchange
Will describe the degree of “stress” experienced by animals
May help us define what is “acceptable” and what isn’t!

External conditions

Ventilation

Total volume flow

Internal mixing

Heat and moisture addition

Numbers and sizes of birds

Insulation

Water sources

Ventilation

Can be employed to reduce total heat load by removing heat and moisture

Can provide direct convective cooling

Passive ventilation may prove inadequate in adverse weather conditions or if vehicle is stationary

Controlled ventilation system

Flow rate can be adjusted to suit:

- numbers of animals/birds

- prevailing weather conditions

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Appropriate ventilation rates

Objective is to remove metabolic heat and moisture produced by animals on vehicle (birds)

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MECHANICAL VENTILATION

TARGET CONDITIONS (Temp/RH ; acceptable ranges and lifts above ambient) Obtained from physiological modeling.

HEAT AND MOISTURE LOADS ON VEHICLES

REQUIRED VENTILATION RATE

Calculation of ventilation rate

$VFR = TMHP/Cp \times \Delta T$

Where

VFR = flow rate (m3 s-1)

TMHP= Total metabolic heat production(Js-1)

Cp = Sp. Ht Capacity of air (1226 Jm-3 °C-1)

ΔT= Acceptable rise in air temperature (°C)

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MECHANICAL VENTILATION

5000 birds (2kg.) producing
10 W of heat per bird = 50000W

acceptable ΔT = 10°C

Ventilation rate = (50000) / (1226 x 10) = 4 m3/


Premier Poultry

Animal Transport

Case study

Transcontinental transport of breeder pigs in hot weather




EUROPE
Norwegian Sea
ICELAND
NORWAY
SWEDEN
FINLAND
RUSSIA
North Atlantic Ocean
North Sea
UNITED KINGDOM
IRELAND
DENMARK
LATVIA
LITHUANIA
BELARUS
POLAND
GERMANY
UKRAINE
FRANCE
ROMANIA
ITALY
BULGARIA
SPAIN
PORTUGAL
GREECE
TURKEY
Mediterranean Sea
ALGERIA
MOROCCO
TUNISIA
Scale 1: 19,500,000


SPAIN
Road Network

European Commission

Pig Locations

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Temperature-humidity recording

Pre-journey preparations

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Procedures

- Rectal temperature
- Surface temperature
- Saliva
- Blood (plasma)
- PCV (packed cell volume)
- DBT data logger (logger implant)
- RFID chip injection (identification and BT)
- Behavioural analysis (recording)
- Lesion scores

85

Slaughterhouse - Humilladero

86

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Behavioural recording

Quantified durations of and latencies to drink and rest (indicators of transport stress)

Drinking – water balance

Resting - fatigue

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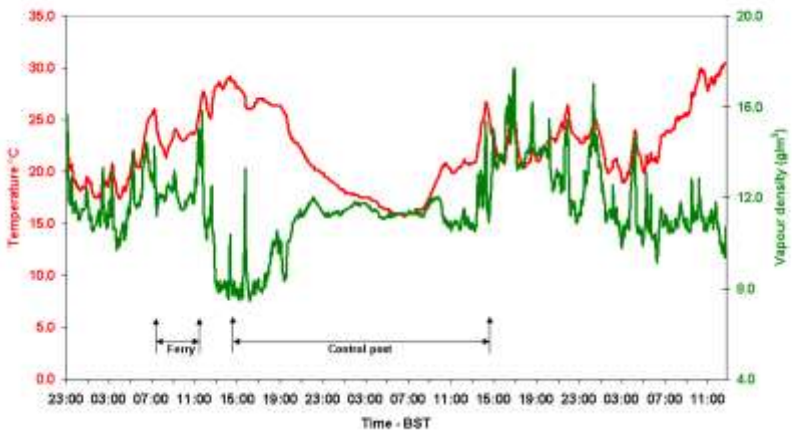
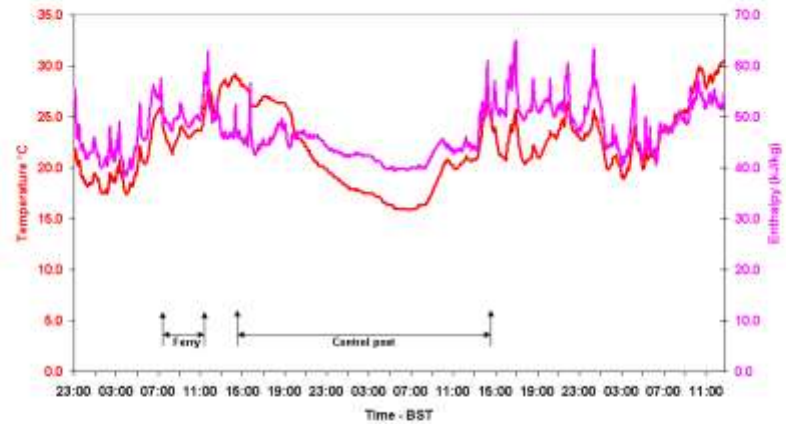
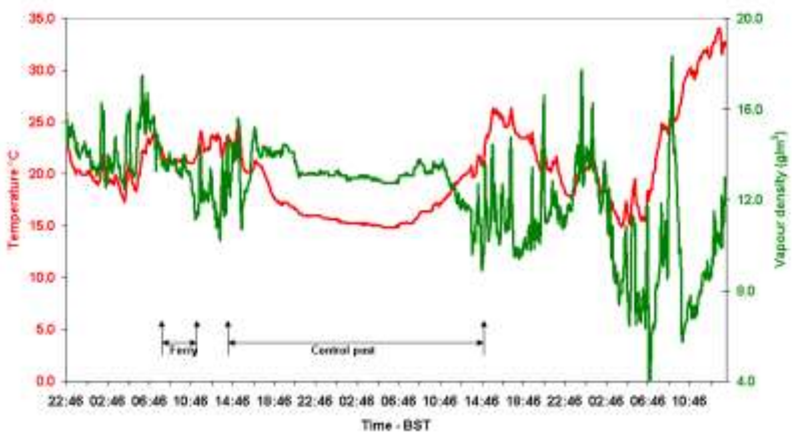
Shipment 23 - In vehicle temperature and vapour density (whole journey)



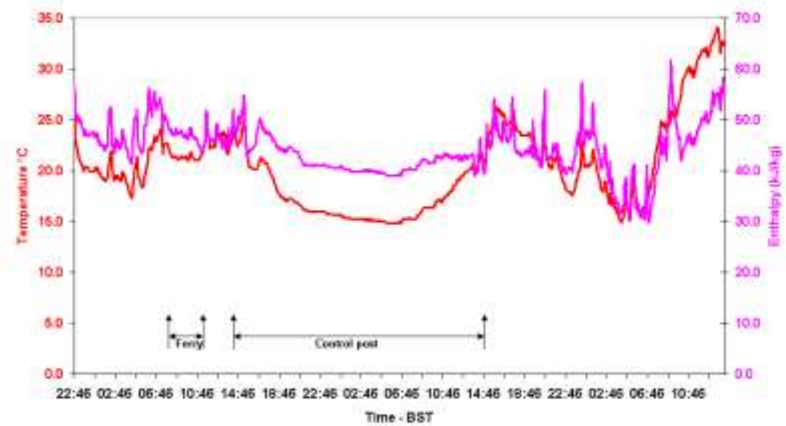
Shipment 23 - In vehicle temperature and enthalpy (whole journey)



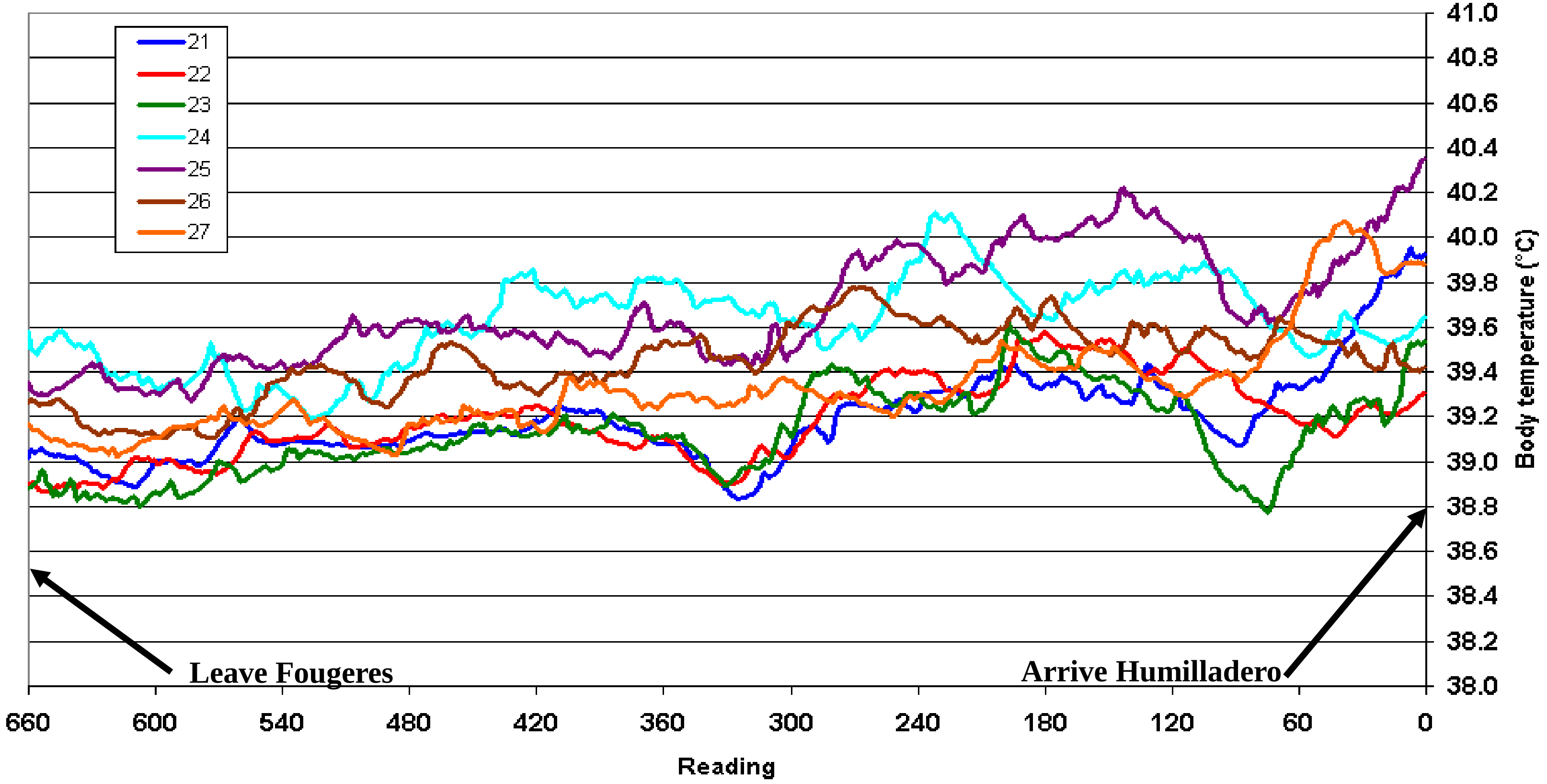
Shipment 24 - In vehicle temperature and vapour density (whole journey)



Shipment 24 - In vehicle temperature and enthalpy (whole journey)



Mean body temperature (°C) during last 22 hours of shipment



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Mean body temperature – last 22 hours

Deep body temperature – final 22 hours of journey							
	Shipment						
	21	22	23	24	25	26	27
Mean	**39.2**	**39.2**	**39.1**	**39.6**	**39.7**	**39.4**	**39.3**
SD	0.2	0.2	0.2	0.2	0.3	0.2	0.2
Maximum	40.0	39.6	39.6	40.1	40.3	39.8	40.1
Minimum	38.8	38.9	38.8	39.2	39.3	39.1	39.0
Range	1.1	0.7	0.9	0.9	1.1	0.7	1.0
Median	39.1	39.2	39.1	39.6	39.6	39.5	39.3

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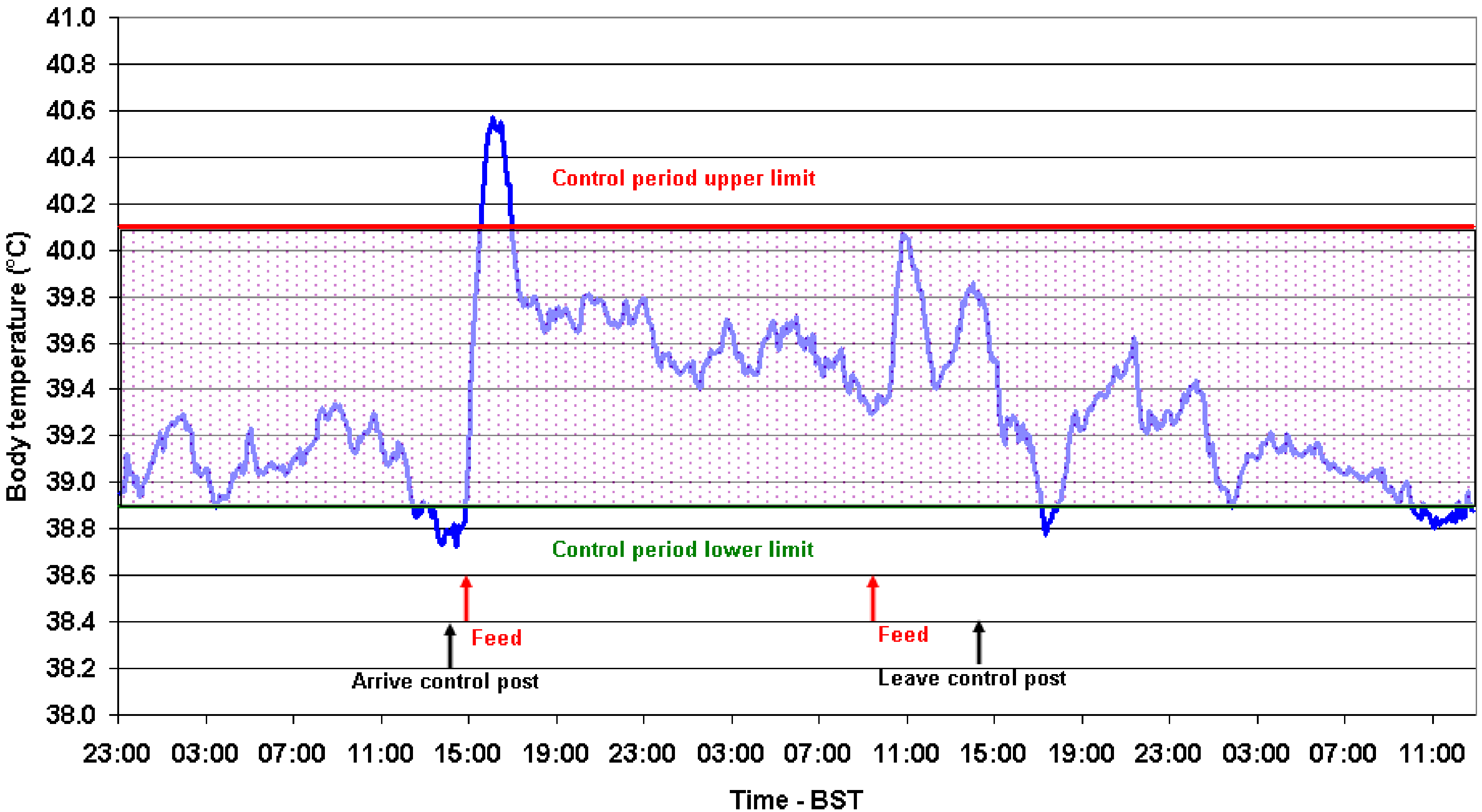
Shipment 23 - mean body temperature (all pigs)



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- Homeostatic Effort
- Homeostatic Success
- Regulation of body temperature
- Panting/water loss/ behaviour

More effort → better control

Less effort → change in DBT

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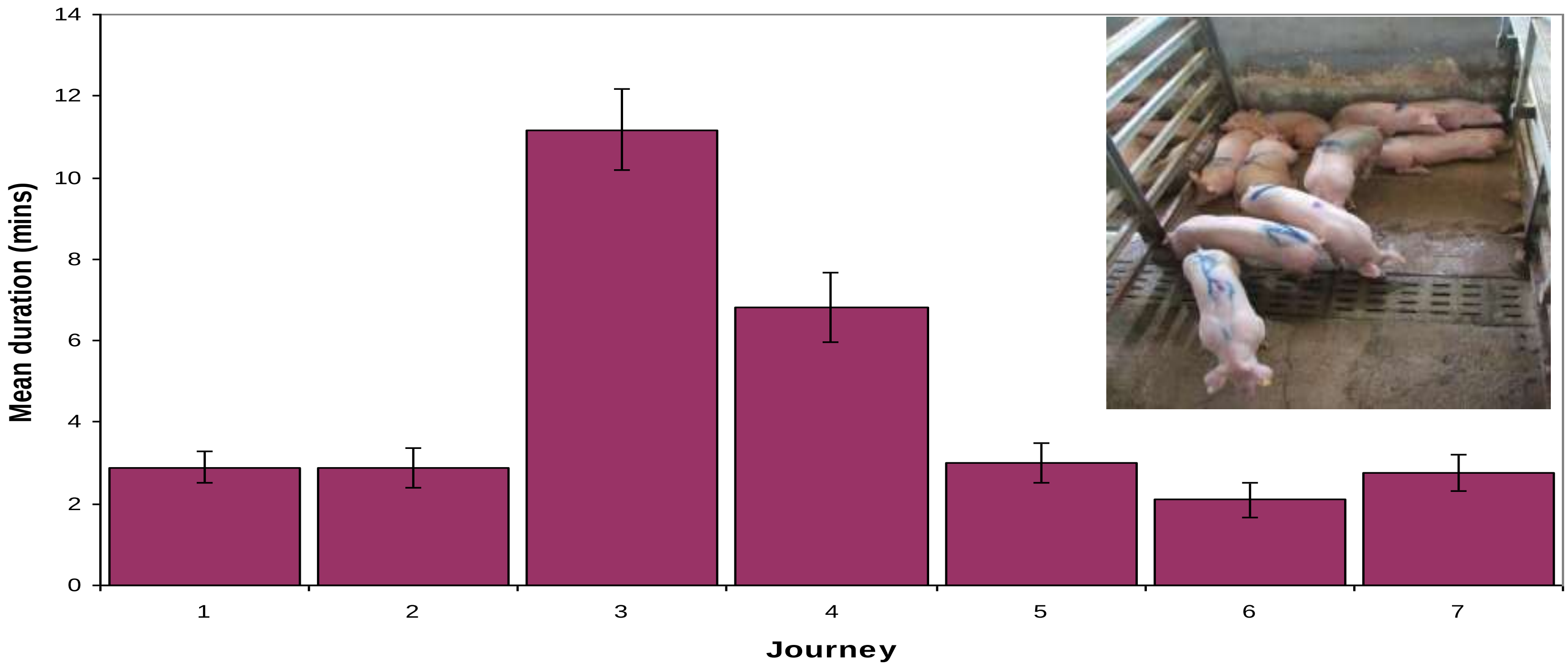
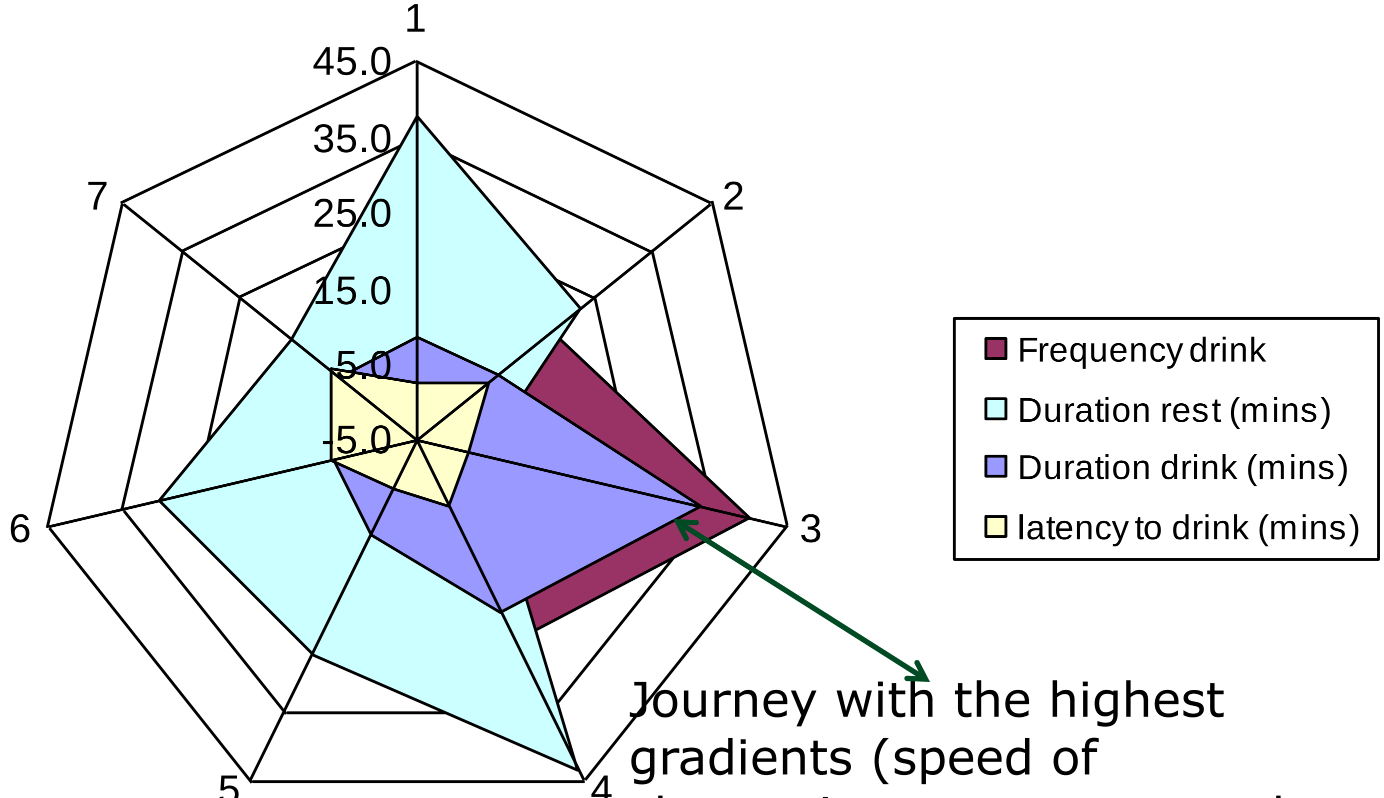
Drinking Behaviour

Mean duration of drinking over three hours post transport



Pig behavioural assessment



Journey with the highest gradients (speed of change in temperature and Enthalpy)

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SUMMARY

The effects of each journey on the animals may be assessed by:

- Body temperature responses
- Drinking behaviour / hydration state
- Resting behaviour / fatigue

Integration of these indices and correlation with thermal classification off each journey

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Whilst journeys undertaken in conditions close to or at the limits of temperature prescribed in the current regulation were associated with some physiological adaptive responses these did not constitute a major threat to welfare of the animals

Consumers, Health And Food Executive Agency

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European Commission

The results suggest that if transportation is undertaken in a manner consistent with current legislation, on appropriate vehicles and with high standards of personnel and practice there is little threat to the welfare of the pigs even in relatively hot conditions.

Consumers, Health And Food Executive Agency

Predictive modelling

So what does modelling tell us?

- ***In relation to the Regulation***
- ***In relation to monitoring***
- ***In relation to enforcement***

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EC 1/2005 and “Modellng”

There are **NOT** going to be any changes to EC 1/2005 in the foreseeable future

However understanding the problems of the current REGULATION may help us to better implement and enforce what we have

The understanding of the origin and mechanisms of transport stress and the regulatory issues should form the basis of improved **TRAINING and EDUCATION (CPD etc)**

Predictive modelling

Modelling tells us where the Regulation is "good" and "bad" – where it protects adequately and where it may not?

Strengths and weaknesses

This enable us to examine the vulnerable components in relation to monitoring and enforcement

European Commission

Predictive modelling

Modelling can provide the "template" for modelling and enforcement

It informs "best practice" and now Network Documents

(Is enforcement / prosecution an index of failure?)

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Predictive modelling

Modelling can inform monitoring and inspection procedures and protocols

What to look for, where, when and how

CAs, OVs, AWOs, Enforcement officers and all those responsible for the welfare of animals in transit

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Predictive modelling

Can provide the basis for:-

Improvements in practices, procedures, vehicle and their operation

Quantifying problems

Improved monitoring

Improved training

Evidence and data gathering

Enforcement

Modelling Outputs

Mechanical ventilation of transporters – design and validation

- **Poultry (broilers, turkeys, chicks)**
- **Red meat (pigs, cattle, sheep)**

Thermal limits for on-board micro-environments

- **Poultry (broilers, turkeys, chicks)**
- **Red meat (pigs, cattle, sheep)**

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Modelling Outputs

Journey times

- **Pigs (sheep)**

Welfare measures

- **physiological (stress) modelling**

Physiological measures, indices and methodologies

- **monitoring / measures and parameters "fit for purpose / integration of behavioural and physiological approaches**

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Modelling Outputs

Methods for “Risk Assessment and Management”

Guidelines and education (CPD) for OVs, TSOs

Evidence for enforcement / prosecutions

QA Schemes / ***Retailer Transport Codes***

EU Working groups (See EFSA opinion 2011)

Defra Expert groups and Working groups

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Thanks to the "team in the field"

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defra
Department for Environment Food and Rural Affairs

SRUC

University of Saskatchewan

ADAS

EH

AATA

A GLOBAL INDUSTRY

University of BRISTOL

University of Zaragoza

CASA DE GANADEROS

DESDE 1218

IRISH EQUINE CENTRE

bbsrc
biotechnology and biological sciences research council

RVA

Escuela Técnica Superior de Ingenieros Agrónomos
UNIVERSIDAD POLITÉCNICA DE MADRID

THE UNIVERSITY OF EDINBURGH

teagasc Irish Agriculture and Food Development Authority

UNIVERSITY of ULSTER

University of Madrid

Consumers, Health And Food Executive Agency

European Commission

Thank you for your attention!

Single slaughterhouse study

Data collection (84 journeys)

On Arrival

- Vehicle and journey information
- Lameness scores
- Injuries
- General health / appearance
- Lorry / pig weights (carcase weights)

Behaviour

- 1 hour
- 51 pigs

Behavioural measures

Instantaneous sampling

- **Behaviour scans are made every five minutes, starting 5 minutes after the last pig enters the pen up to 60 minutes after penning. This means there will be 12 scan intervals starting at 5 minutes and ending at 60 minutes.**

Drinking
Standing
Sitting
Lying down
Fighting

Kill at 1 hour – pigs on line

First 20 pigs of each batch of 51in chiller and labelled

pH_i – 2 muscles (+ meat temp)

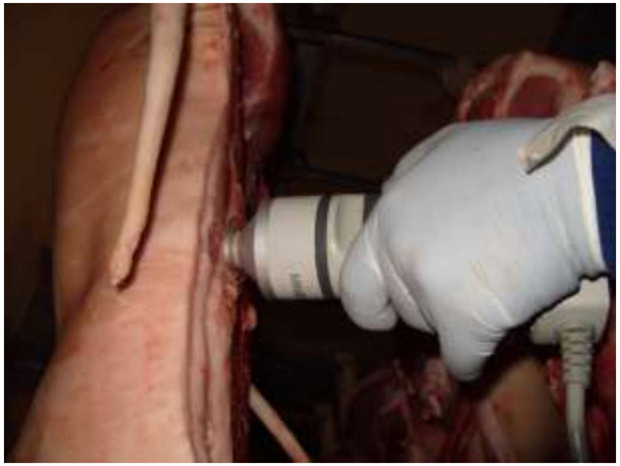
$Colour_{45}$ (L, a, b – Minolta colour meter)

pH_{24} and $Colour_{24}$ (+ meat temp)

Calculate Hue and Chroma

Semimembranosus and longissimus lumborum


TEST PIGS
YD 0985
8




TEST PIGS
TEST PIGS
12-13 PROBE

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Single slaughterhouse study

Data were analysed by:-

GLMM (logit link function)

Logistic regression models

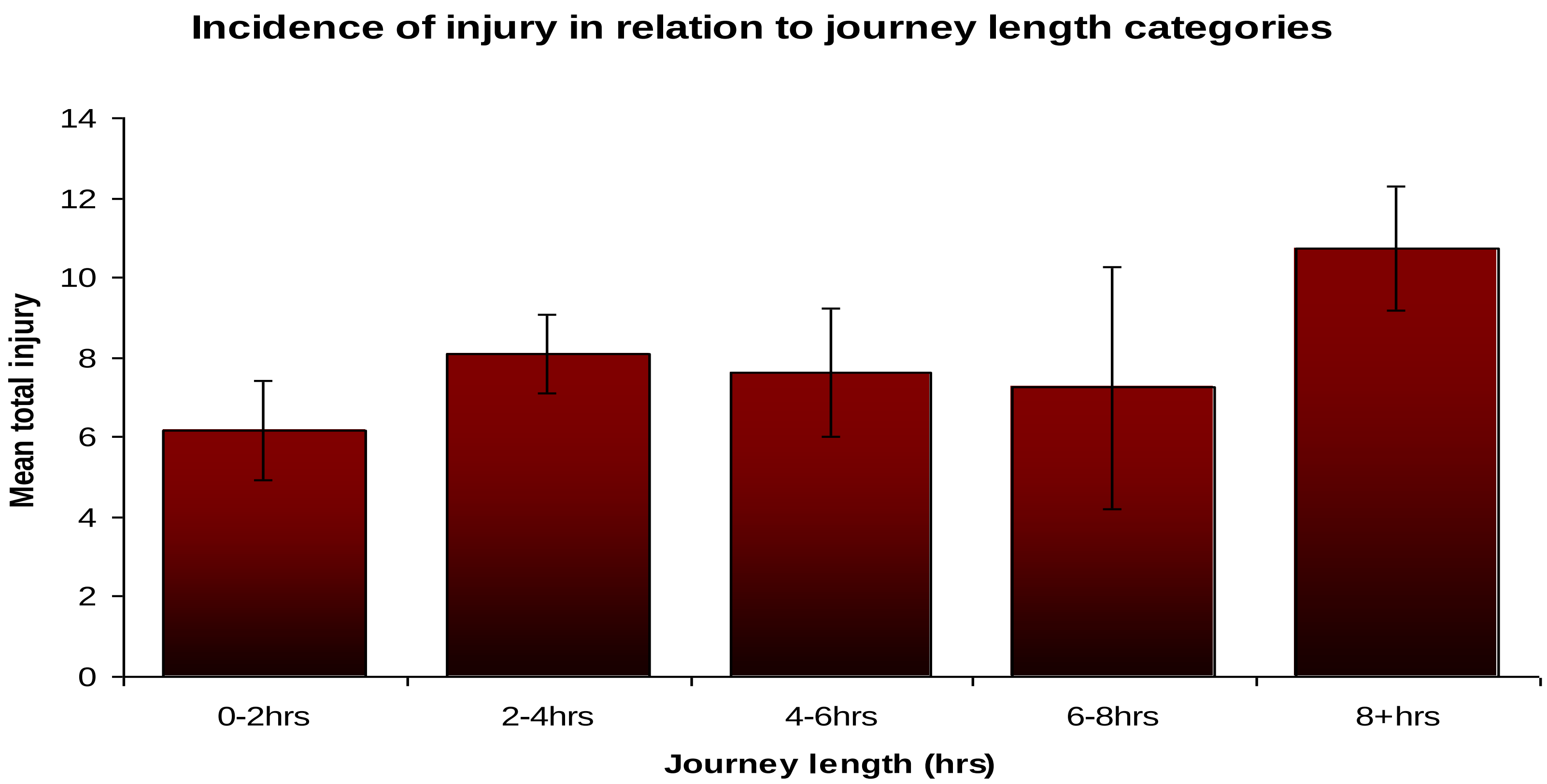
REML

European Commission

Single slaughterhouse study

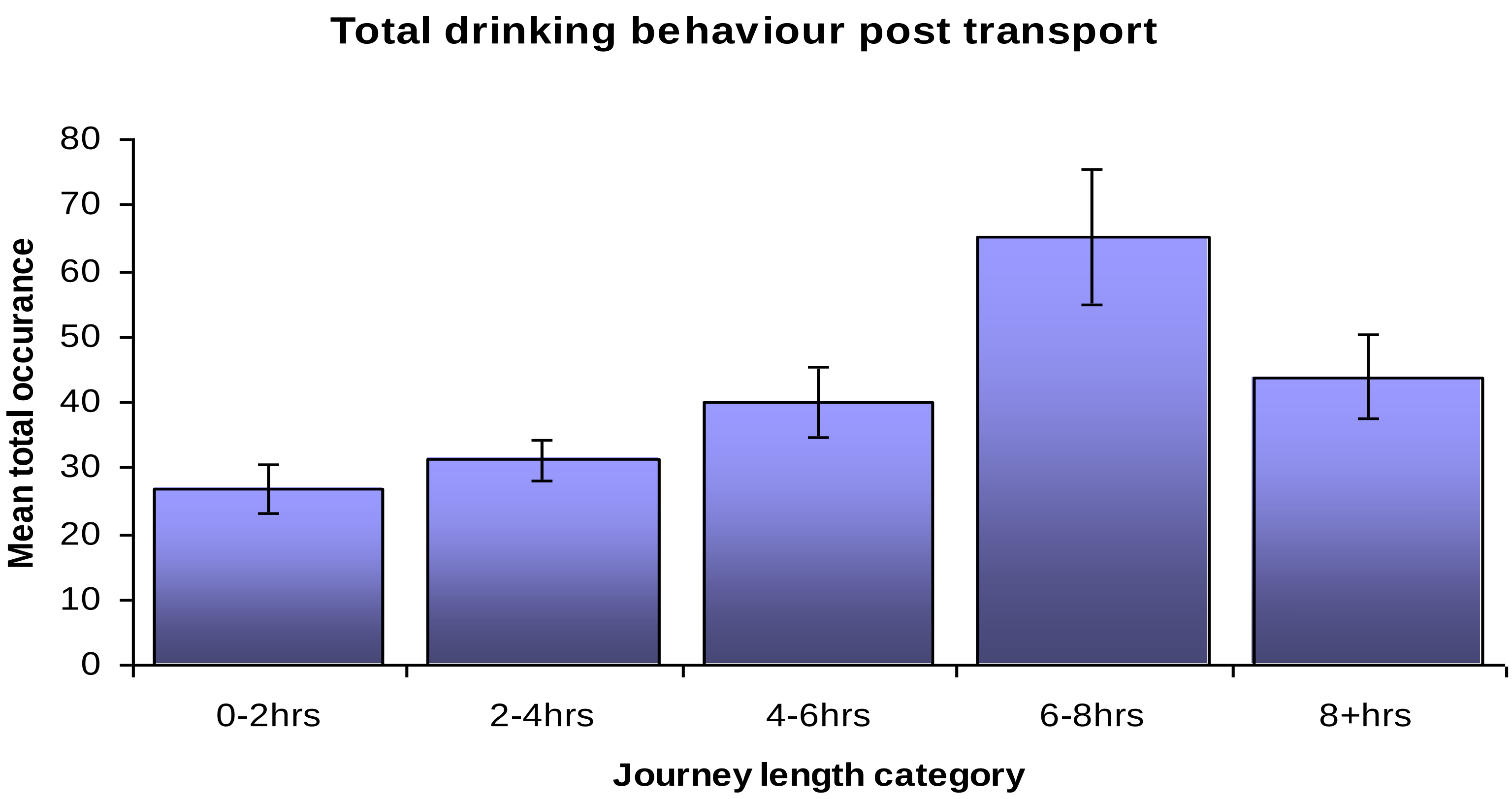
Total 84 journeys – November - August

Injury

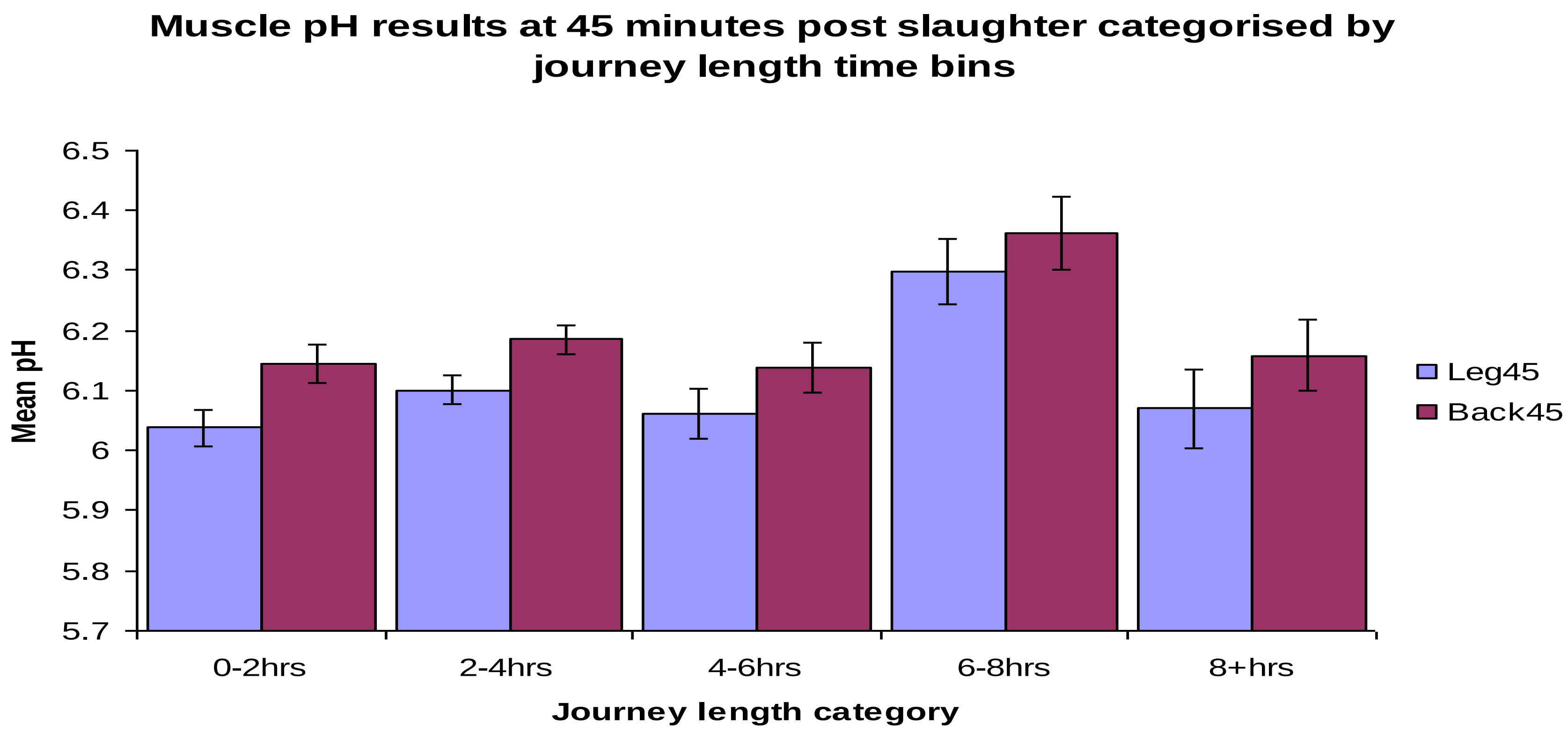


Incidence of injury in relation to journey length categories
Mean total injury
14
12
10
8
6
4
2
0
0-2hrs
2-4hrs
4-6hrs
6-8hrs
8+hrs
Journey length (hrs)

Drinking Behaviour



Meat Quality Measures



Meat Quality Measures

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Other factors examined

Farm type \ production system

Abattoir Standing Time (AST)

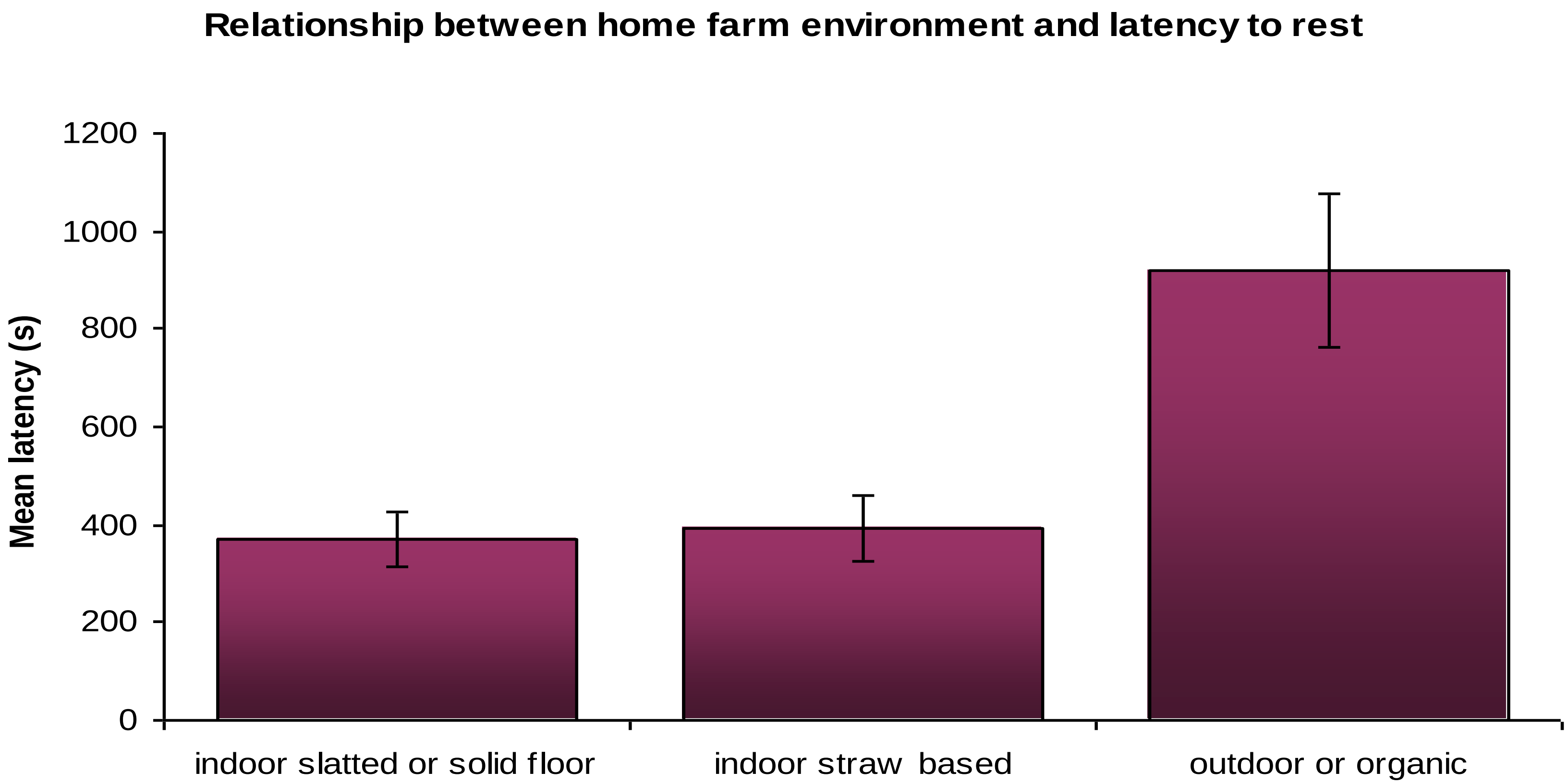
Mean, max and min temperatures on days of travel

Environment	Number of loads monitored
Unknown	2
Slatted/solid floor	49
Straw based (yards, pens, courts)	26
organics/outdoor	7

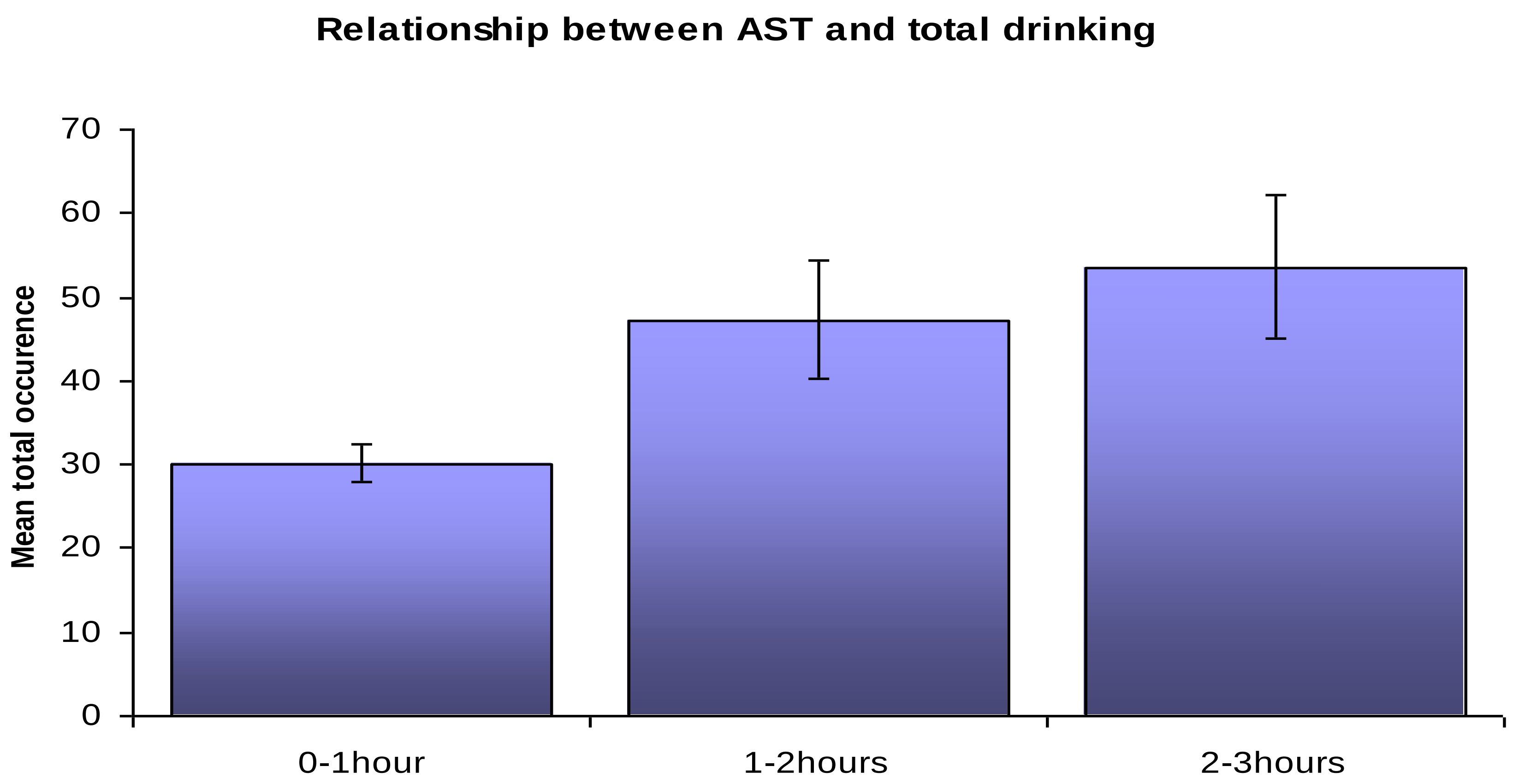
Lameness


Lameness recorded post transport
Mean % of load
0
1
2
3
4
5
6
7
8
Slatted or solid floor
Straw based
FFO/Outdoor
Home farm environment

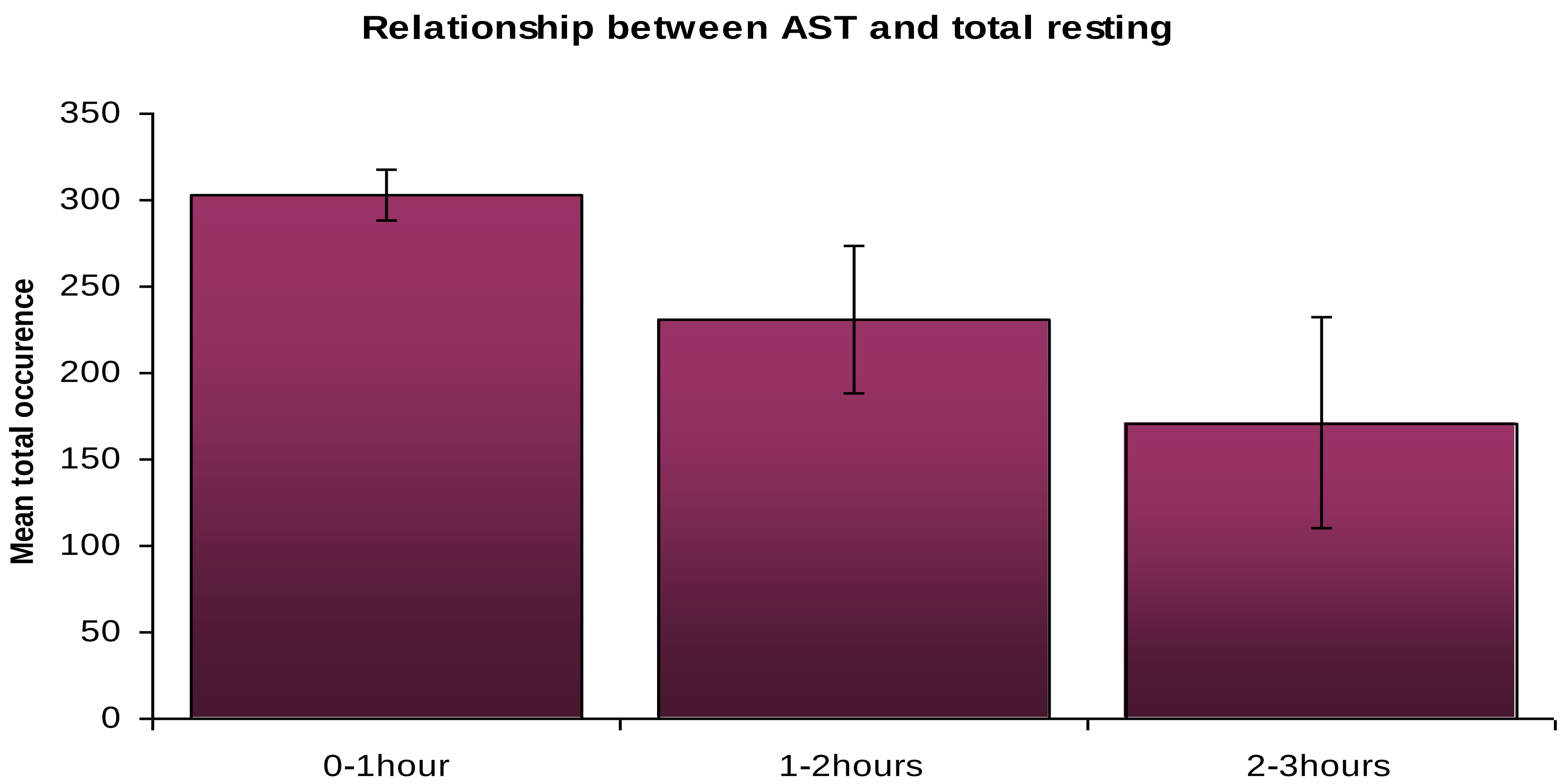
Home farm system



Standing time – Drinking behaviour

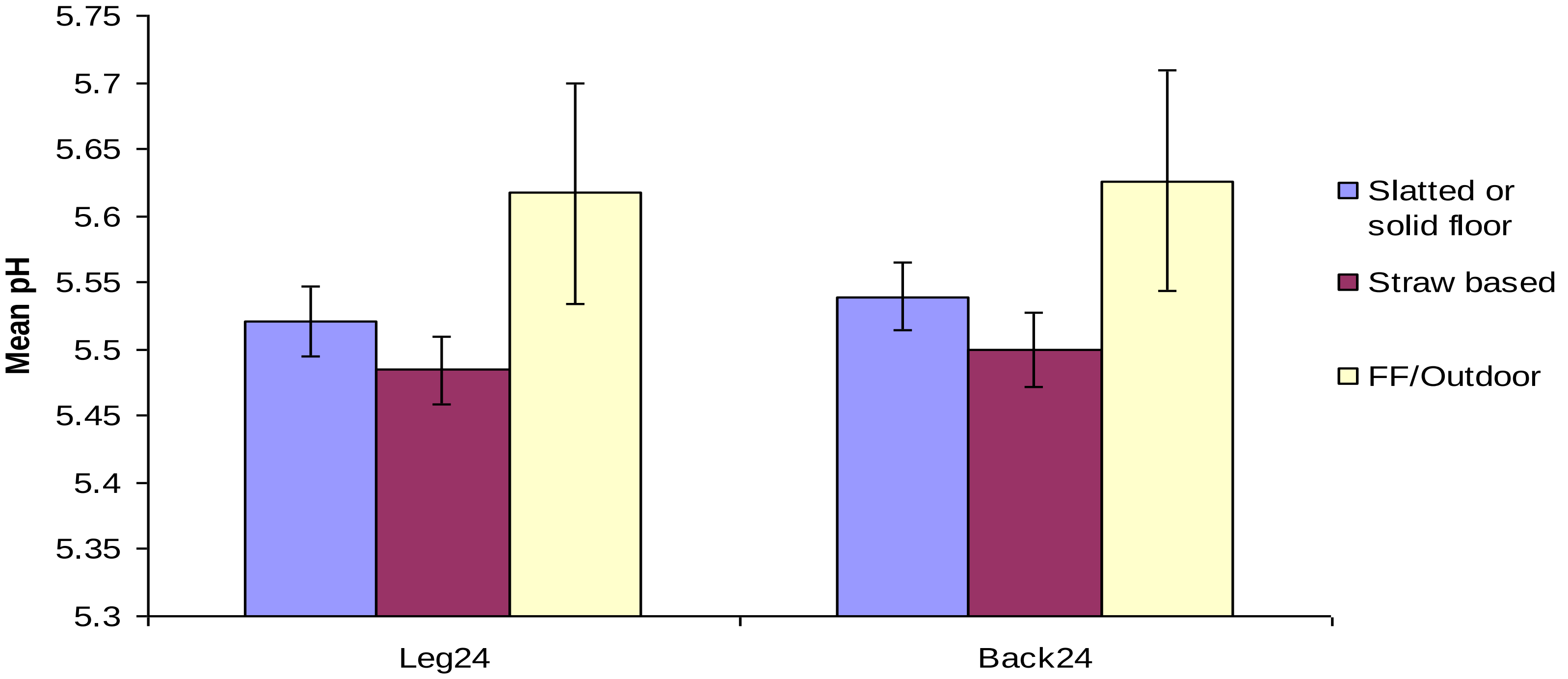


Standing time – Resting Behaviour

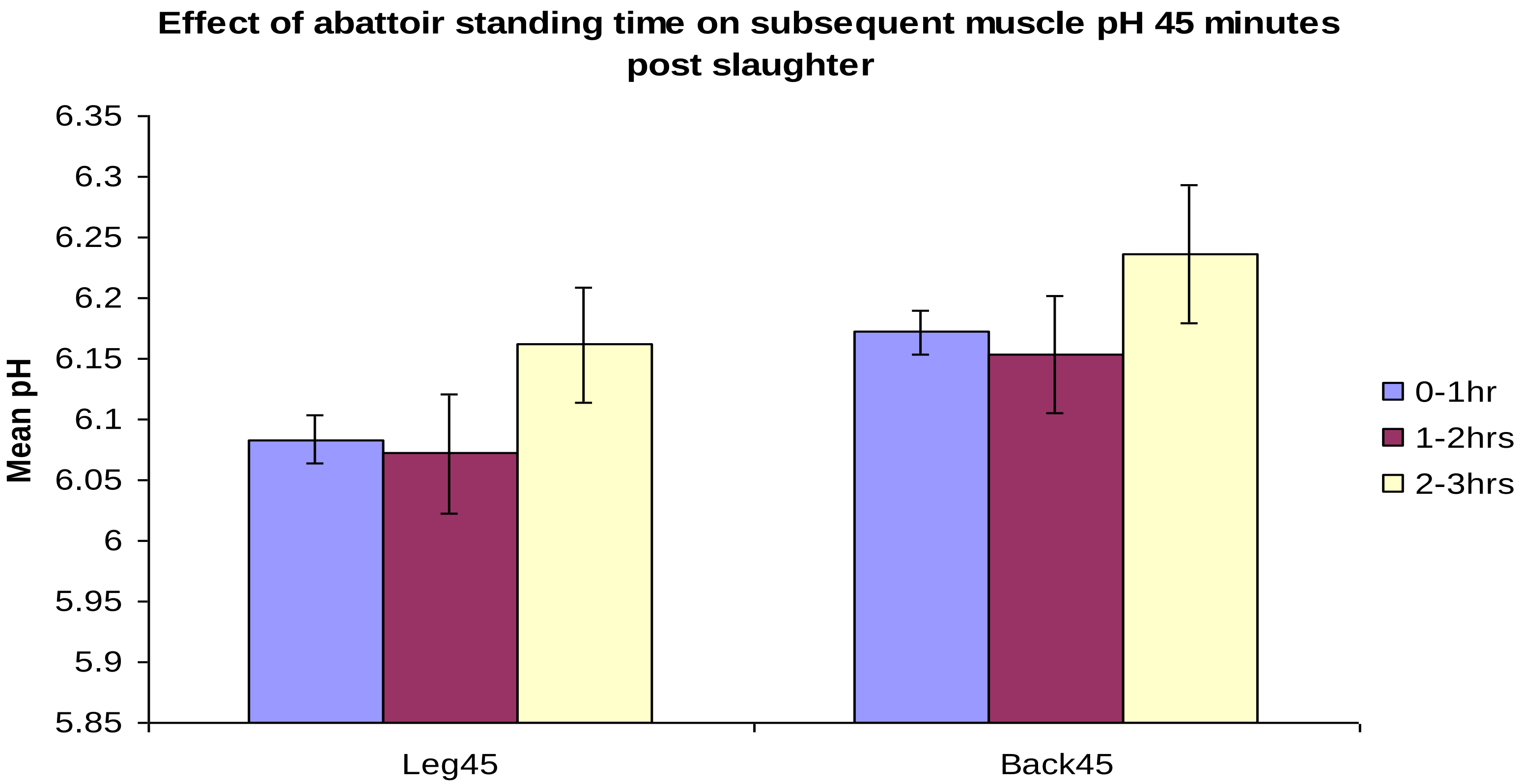


Meat Quality Measures

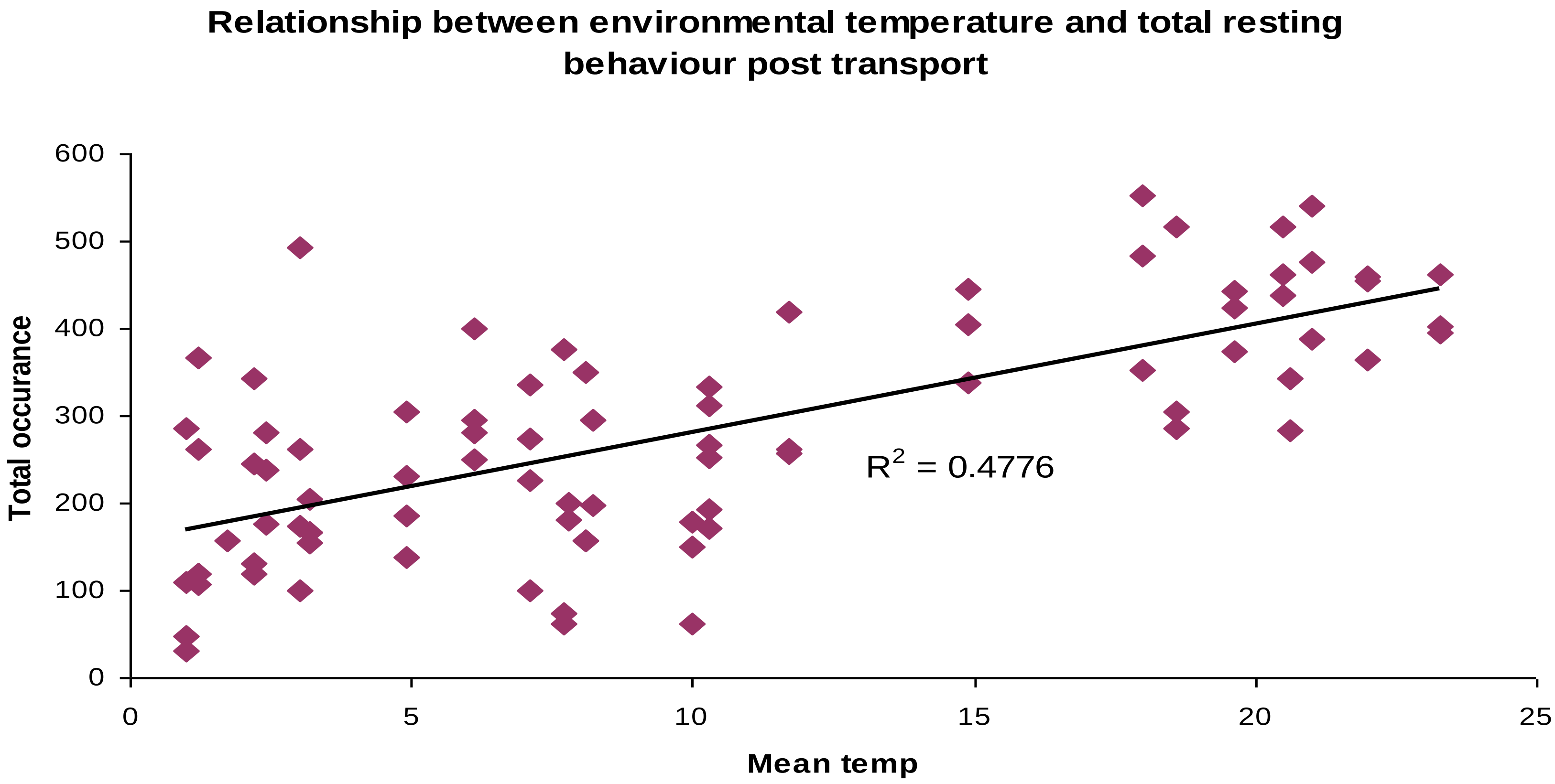
Effect of home farm environment on subsequent muscle pH 24 hours post slaughter



Meat Quality Measures



Thermal conditions



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Correlation matrix

	JLL	TRest	Lat Rest	Lame %	pH45L	pH45B	pH24L	pH24B	Li45L	Li45B	Li24L	Li24B	C45L	C45B	C24L	C24B	H45L	H45B	H24L	H24B
JLL																				
TRest																				
Lat Rest	0.331	**-0.676**																		
Lame%	*-0.232*																			
pH45L		-0.204																		
pH45B		-0.203			**0.893**															
pH24L		**-0.359**	0.204	*-0.221*	0.317	*0.270*														
pH24B		**-0.363**	0.206	*-0.241*	0.342	0.298	**0.986**													
Li45L							*-0.228*	*-0.245*												
Li45B		*0.229*						-0.205	*0.249*											
Li24L							-0.282	-0.281	**0.633**	0.290										
Li24B							*-0.272*	-0.289	0.309	**0.672**	**0.509**									
C45L	*0.244*		*0.214*																	
C45B	0.187						*0.253*	*0.268*	-0.330				**0.432**							
C24L				*0.245*	-0.196	*-0.241*			-0.211				0.208	*0.223*						
C24B		*0.226*			*-0.254*	-0.299								**0.489**	**0.535**					
H45L									*-0.224*											
H45B				*0.246*						0.185		*0.215*								
H24L											**0.636**	**0.415**					*0.271*	*0.240*		
H24B							*-0.275*	-0.294	0.284	0.296	**0.466**	**0.630**			*-0.275*	-0.299			**0.623**	

P < 0.001	P < 0.01	*P < 0.05*	P < 0.1 (trend or tendancy)

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Summary

There were no significant ***correlations/ relationships to support*** the hypothesis that commercial journey time would affect the measures of stress/welfare in ***the sampled journeys***

Several other factors may affect post-journey behaviour and meat quality

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These include:

- Production system
- Abattoir standing time
- Temperature

Clearly the effects of these factors (and their combinations) will be exacerbated by extended journey time

Journey time per se (in the range studied) does not appear to constitute a major threat to welfare or product quality (measured indices – proxy?)

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The assumption that journey time may be studied under “commercial conditions” to detect direct effects upon welfare and production efficiency is confounded by the multiplicity of other factors impinging upon the relevant measures

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In summary

There were no statistically significant indications that journey time had a detrimental effect of the pigs transported under commercial conditions in this study

- ***when all the current regulations and recommendations for practice were adhered to.***