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Loading density and welfare of goat kids during long distance road transport

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Abstract

*Many goat kids (*Capra aegagrus hircus*) are transported live from The Netherlands for slaughter in France or Spain. Current standards indicate that goats (< 35 kg) should have sufficient space at 0.2–0.30 m² per animal (approximately 5 goats per m²). Research was devised to assess behaviour and physiological responses of goat kids transported at different space allowances. After weaning, goat kids were fed milk for six weeks using a lambar-type feeder and then transported to Spain (*circa *1,400 km). These kids (8–10 kg, maximum eight weeks old) were transported at space allowances of 0.2, 0.13 and 0.1 m² per animal (ie loading densities 5, 7.5 or 10 animals per m², respectively) in three journeys. Before loading and upon arrival, six goats per compartment were weighed, blood sampled and had rectal temperature measured. Three goats per compartment were equipped with ECG loggers. On average, kids lost approximately 4% in bodyweight and rectal temperature fell 0.2°C during 20 h transport. Heart rate ranged between 100–190 bpm irrespective of loading density during actual transport. All animals stood at the beginning but were never all recumbent independent of loading density. Kids tended to huddle together at lower loading densities. High loading density restricted movement. Blood concentrations of haemoglobin and haematocrit increased, as did osmolality indicating dehydration. It is recommended that water be supplied using a drinking system to which animals are accustomed. Since movement was restricted it is recommended that kids be transported at nine animals per m² (maximum).*

Keywords: *animal welfare, behaviour, goat kids, live transport, loading density, physiology*

Introduction

Consumers and public organisations across Europe are becoming increasingly concerned about the rearing and handling of human foodchain production animals. These concerns include questions about the need to transport live animals. Policy-makers and various governmental organisations are aware of the fact that something has to be done to address these concerns.

At the same time, demand for Dutch dairy products from goats (*Capra aegagrus hircus*) is growing, which consequently results in surplus numbers of 'Billy' or male goats. In order to avoid the on-farm slaughter of male goats the industry endeavours to fatten male goats and slaughter them nearby. At present, there is insufficient slaughter capacity in The Netherlands, necessitating that a large number of male goats are transported live for slaughter upon arrival in southern Europe (eg Spain or France). This practice is contrary to the intentions of the Dutch ministry to restrict live animal transportation.

Transportation is a source of emotional and physical stress affecting goat welfare (Nwe *et al* 1996; Kannan *et al* 2000; Das *et al* 2001). Different phases of transportation, ie loading, unloading, stopping and starting can be particularly stressful. A recent review of EU Directive 1/2005 recommends maximum journey times for several species including goats of up to 8 h (European Food Safety Authority [EFSA] 2011).

Competent authorities are concerned about the authenticity of present European standards for goats. According to present EU standards, goats weighing up to 35 kg should have sufficient space with an allowance of 0.2–0.3 m² per animal, or approximately five goats per m² (EC Regulation 2004). However, the law remains unclear and allows for differences in interpretation with respect to variation in environmental conditions, ie ambient temperature. Therefore, if the goats weigh between 9–10 kg (< 35 kg) the guideline is five animals per m² to ensure animal welfare standards. According to the Directive on transportation of live animals, the space allowance for goat kids may be less than 0.2 m² per animal depending on age, body size, weather conditions and length of journey. Adjustments, based on the size of the animals to be transported, appear justifiable, but long journey times, physical restraints of young animals and extreme weather conditions in Spain have restricted acceptance of higher stocking densities. These restrictions were made in relation to recommendations made in the report of the EFSA scientific committee on animal health and animal welfare (SCAHAW 2002).

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Table 1 Details of journeys with goat kids.

Journey	Time (h: min)	Compartment			Total freight
		Front	Middle	Rear	
March					684 kids
Journey time	18: 18				
Kids per compartment		32	46	65	
Stocking density (goats per m²)		5	7.5	10	
April					563 kids
Journey time	19: 40				
Kids per compartment		43	68	32	
Stocking density (goats per m²)		7.5	10	5	
May					654 kids
Journey time	18: 25				
Kids per compartment		65	34	43	
Stocking density (goats per m²)		10	5	7.5	

* Departure and arrival times approximately 1100 and 0530h, respectively.

Additionally, a recent EFSA review (EFSA 2011; p 69) emphasises that sufficient space should be provided at each level inside the vehicle to facilitate efficiency of ventilation above the animals standing in their natural posture, without hindering their movement.

An animal's ability to cope is considered to be correlated with its response to transportation and conditions affecting its ability to react to what it perceives to be threatening (von Borell 2000). During transport, goats in particular are subject to social (ie mixing with strange, unknown animals) and other forms of stress (eg rough handling) (EFSA 2011). The response of individual animals to potential stressors, such as herding, loading, mixing with unfamiliar animals and transport, is also influenced by genetic factors and earlier on-farm experiences (von Borell 2000). Stress activates the hormones of the hypothalamic-pituitary-adrenal axis (glucocorticoids) and the autonomic nervous system (ANS) (parasympathetic and sympathetic nervous system; catecholamines). This triggers unusual behaviour (dramatic change in motor behaviour, vocalisation) and clinical changes (increased respiration and heart rate), which can result in exhaustion (Broom & Johnson 1993). Before departure, animals are loaded onto the vehicle with increased risk of injury or wounding. This is mainly due to forcible contact against the sides of the loading runs but, once in the compartment, they can fight or spring up against their contemporaries, causing pre-transport stress. Stress affects energy use and body temperature, resulting in an increase in respiration and evaporation rates. Additionally, defaecation increases resulting in loss of bodyweight. Withholding of feed or dehydration during periods up to 18 h can result in weight losses of 10% in goats (Kannan *et al* 2000).

Space allowance during transportation has been shown to be important to the well-being of various species of farm animals including sheep (*Ovies aries*) (Cockram *et al* 1996). However, little information is available on loading densities for goats. The major concern appears to be provision of sufficient space for most goats to be able to lie down (preferably simultaneously) during transport (Das *et al* 2001).

Present European legislation on acceptable stocking density levels is indistinct and no research has been performed to elucidate the effects of transport over long distances (above 500 km and for longer than 8 h) with such small animals. At present, road transportations with loading densities above ten animals per m² have become common practice. This manuscript documents a study devised to assess behavioural and physiological reactions of male goat kids during long road journeys at three different space allowances (two of which increased space allowance per animal above the accepted standard allowance).

Materials and methods

Experimental design

Transport of live goats was arranged in co-operation with traders and a commercial transport company. However, transportations were not physically pursued. Tachometer data were made available from three commercial journeys with male goat kids from an assembly point in the south of The Netherlands to a slaughter facility in northern Spain, a distance of approximately 1,400 km, expected to take up to 20 h. These journeys were performed in spring (April–May) 2011. The kids were transported in a three-tier vehicle with each deck divided into three compartments. Monitored animals were placed in the three compartments of the lower deck of the trailer and transported at one of the

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Table 2 Study ethogram.

Parameter	Description
Standing	Animal supports its own weight on three or four legs
Lying down	Animal prostrate on belly or side (sometimes on top of a companion animal)
Sitting	Animal sits on rump and supports front half with front legs (rump placed on floor of companion or on top of a companion animal)
Agonistic behaviour	Butting, displacement, threats (noted when observed but not analysed as separate behavioural characteristic)

following stocking densities: 5 (low), 7.5 (medium) or 10 (high) animals per square meter. These stocking densities were rotated per compartment for each journey (Table 1). The floor-space dimensions per compartment varied slightly: front 2.7 × 2.4 m; middle 2.85 × 2.4 m; and rear 2.7 × 2.4 m (length × breadth). All compartments were occupied to complement the commercial load for each journey including a trailer. Compartments were bedded with a good layer of wood-shavings.

Drinking water was available *ad libitum* via a nipple system in lairage (assembly point) and during transportation.

Immediately before loading, 18 goats were selected at random and numbered with a (water-repellent) marker, weighed and blood samples were taken from the jugular vein. Rectal temperature was measured using a standard mercury (Hg) thermometer. Nine (three per compartment) were equipped with ECG electrodes. These animals were then allocated six to each of the three test compartments.

Study animals

Test animals were male Dutch Dairy goat kids (6–8 weeks old) surplus to demand on-farm and reared on a lambar from birth with goats' milk. Milk was withdrawn 2 h prior to transportation from the rearing farm to the assembly point. The kids, from different rearing farms (origins unknown), were housed for 2–6 h at the assembly station and had access only to water.

Behaviour

Animal behaviour was recorded throughout each journey with cameras fitted with wide-angle lenses and stored on digital recorders for analysis at a later date, after completion of all the journeys. Cameras were fitted in the three compartments on the lower deck of the vehicle. The two cameras in each compartment were placed on each side of the compartment directly facing each other in an attempt to record the activity of the animals throughout as much of the compartment as possible.

Video recording started from the moment that the first animals entered the compartment until unloading.

The basis for behavioural analysis was an ethogram (see Table 2).

These parameters were analysed by scan sampling of segments of *circa* 45–60 s at intervals of 15 min from the moment the compartment was closed until unloading. Behavioural characteristics were analysed from the first 15-min period real time until the last 15-min segment real time, ie: as 15-min periods (0, 15, 30, 45 every hour). Activity assessment was based on the following: 1) Count or estimation of numbers of goats standing; 2) Estimation of area occupied as percentage of total compartment area; and 3) Estimation of the area unoccupied as percentage of total compartment area.

Activity and space occupation were recorded with two cameras in each compartment. These were placed opposite each other to eliminate so-called 'blind' areas (ie areas not covered by the other camera). For practical reasons, derivative measure for the area occupied (as percentage of total compartment space) was defined as the smallest imaginary square that could be drawn around all animals, including the corner that was nearest to the animals. The area unoccupied (as percentage of total compartment space) was defined as the largest imaginary rectangle that could be drawn around free space, including the corner furthest away from the animals. Therefore, occupied and unoccupied space, as defined here, do not necessarily add up to 100% of compartment space.

Heart activity, bodyweight, temperature

In order to secure placement of monitoring equipment, a specially designed jacket was used in this experiment. Goat kids had been previously fitted with the jackets in order to establish their reaction to wearing such a garment for longer periods (up to 48 h). A single goat was fitted with a logging device for 24 h in the group with no extreme changes in heart rate, behaviour or display of aversion to wearing the jacket. It was therefore decided to use the jackets. Firstly, the test goats were shaved (area of jacket cover) to allow close fitting of the jacket and ensure good contact between pad electrodes and skin. Before placement of the electrodes the area was rinsed with water, dried and cleaned with 70% alcohol. Surgical glue was applied to secure the pad electrodes to the surface of the skin. Button electrodes were placed caudal to the olecranon on both sides of the breast. The earth electrode being placed dorsally to the electrode on the right side of the breast. The sensor leads were attached to a data logger (Lowe *et al* 2007) which was housed in a stainless steel container and secured in a pouch of the jacket on the back of the goat. Logging started immediately after fitting the data logger and was terminated upon arrival in the reception pen in the slaughterhouse.

After transport, the jackets including electrodes were removed. Rectal body temperature was measured using a hand-held digital veterinary thermometer (type: VT1831,

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Table 3 Allocated stocking density (goats per m²) per transport. Mean (± SD) rectal temperature (°C) and bodyweight (kg) of six goats per compartment prior to loading (Dept) and after unloading (Arr).

Journey/Compartment	Stocking density*	Rectal temperature#		Bodyweight#	
		Dept	Arr	Dept	Arr
March					
Front	5	39.2 (± 0.6)	38.9 (± 0.7)	8.8 (± 1.0)	8.6 (± 1.0)
Middle	7.5	39.4 (± 0.2)	39.2 (± 0.5)	8.4 (± 1.0)	8.1 (± 0.9)
Rear	10	39.4 (± 0.6)	39.1 (± 0.3)	8.4 (± 0.7)	8.2 (± 0.7)
Overall average		39.3 (± 0.5)	39.1 (± 0.5)	8.5 (± 0.8)	8.3 (± 0.8)
April					
Front	7.5	39.8 (± 0.3)	39.5 (± 0.2)	8.1 (± 1.1)	7.5 (± 1.0)
Middle	10	39.6 (± 0.2)	39.6 (± 0.3)	8.4 (± 1.0)	8.0 (± 1.0)
Rear	5	39.8 (± 0.2)	39.6 (± 0.3)	9.0 (± 0.6)	8.5 (± 0.6)
Overall average		39.8 (± 0.3)	39.6 (± 0.3)	8.5 (± 1.0)	8.0 (± 0.9)
May					
Front	10	39.4 (± 0.4)	39.3 (± 0.4)	9.1 (± 1.2)	8.5 (± 1.2)
Middle	5	39.6 (± 0.4)	39.3 (± 0.5)	8.8 (± 1.0)	8.5 (± 0.8)
Rear	7.5	39.6 (± 0.3)	39.3 (± 0.3)	8.9 (± 1.5)	8.6 (± 1.5)
Overall average		39.5 (± 0.4)	39.3 (± 0.4)	8.9 (± 1.2)	8.5 (± 1.1)

* Stocking density of 5, 7.5 and 10 animals per m² equivalent to space allowances of 0.2, 0.13 and 0.1 m² per animal, respectively.
# Rectal temperatures and bodyweight measured prior to departure and after arrival at destination.

Microlife AG, Widnau, Switzerland) in the selected kids prior to loading and after unloading and ECG traces were analysed as heart rate in beats per minute, logged continually during the journey (Labchart7 Pro, V7.1.2, AD Instruments, Cologne, Germany).

All selected goats were weighed using a Sartorirus QA60FEG-S digital balance (Mettler-Toledo BV, 4000 HA, Tiel, The Netherlands) prior to preparation for blood sampling and logger fitting. All test animals were weighed upon arrival in the collection pen at the slaughterhouse.

Blood parameters

The goat kids were hand-held to collect blood samples from the *vena jugularis* in 100 μm heparinised vials prior to fitting of the logging equipment and after arrival at the slaughterhouse prior to removal of the logging device. Analysis of blood samples was performed immediately after sampling using an ABL80 Flex (Radiometer Medical ApS, Brønshøj, Denmark).

Blood samples were analysed for acidity or alkalinity values; expressed as H^+ concentration (pH), pressure of carbon dioxide expressed as mm Hg (pCO$_2$), pressure of oxygen as mm Hg (pO$_2$), saturation levels of oxygen as % (sO$_2$), base excess value as mmol L^{-1} (BE), haemoglobin levels as g dL^{-1} (Hb), haematocrit levels as % (Ht), glucose levels in mmol L^{-1} (Glu), sodium ion concentration in mmol L^{-1} (Na^+), chloride ion concentration in mmol L^{-1} (Cl^-), potassium ion concentration: mmol L^{-1} (K^+) and calcium ion concentration in mmol L^{-1} (Ca^{2+}).

During the second journey, analysis of blood samples taken on arrival was aborted due to equipment failure.

Compartment temperature and humidity

Ambient temperature and relative humidity were recorded for each compartment. Hotdog (thermohygrometer; ATV-11a, ATAL BV, Purmerend, The Netherlands) digital logging devices were suspended from the ceiling in the centre of each compartment enabling continual measurement of temperature and relative humidity throughout the journey.

Ethics

Use of a limited number of goats for measurement and observation during commercial journeys from a collection point in The Netherlands to the slaughterhouse in Spain was approved beforehand by the Ethics Committee on use of Animals for Experiments (DEC) of Wageningen UR, Livestock Research (Lelystad, The Netherlands).

Statistical analysis

Changes in rectal temperature and bodyweight were analysed using the ANOVA option in the statistical package GenStat for Windows (GenStat 2011). According to the basic model:

$$y = a + b + a*b + e$$

Where: y = difference in rectal temperature or difference in blood parameter; a = effect of journey; b = effect of loading density; $a*b$ = interactive effect of journey and loading density; and e = residual.

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Since blood sample data from the second journey were incomplete, the dataset is imbalanced and does not allow a complete analysis of variation. Therefore, available data from two completed journeys were analysed as a paired student's *t*-test of variables within each journey from samples taken prior to departure and after arrival at the slaughter plant.

Results

Temperature and humidity

Conditions at departure were within seasonal ranges for the area. Temperature at departure averaged 15 (± 2)°C and relative humidity averaged between 63–73% over the three journeys monitored. Conditions upon arrival were between 10–15°C and relative humidity was 50–60%.

Study animals

All animals arrived safely at the destination, ie no deaths occurred during transportation (Table 1). Bodyweight (Table 3) fluctuated during successive journeys by 2.4, 5.9 and 4.5%, respectively. Rectal temperature (Table 3) decreased in all journeys by 0.5% .

Behaviour

It was only at the beginning of each transport (between 1000–1100h) that all kids were standing simultaneously. On average, at the first stop (after ± 6 h), approximately 58, 42 and 42% of kids were standing at loading densities 5, 7.5 and 10 per m^2, respectively. An hour later, 22, 70 and 63% were standing in the respective loading densities. At no loading density were all kids observed to be recumbent at the same time. However, occupation of the compartment differed with loading density, the available area is fully utilised at a loading density of ten goats per m^2 (Figure 1[c]), standing or recumbent. Kids were only occasionally observed with their rump on the floor. Goats transported at a low density tended to group to the front or rear of their compartment in close proximity to adjacent groups. Goats transported in the high density group filled the compartment and those in the medium density group were evenly distributed making full use of the available space (Figure 2).

Due to the height restriction (low ceiling), positioning of the cameras restricted animal observation and agonistic behaviour could only be observed occasionally.

Heart rate

Figure 3 shows the trends, based on 10-min moving averages in heart rate measured with the ECG data loggers. Heart rate trends, illustrated for kids at the different loading densities per compartment, did not differ between treatments.

Blood parameters

Table 4 provides an overview of the results from the blood sample analyses taken during the first and last journey. Results indicate significant ($P < 0.001$) increases in Hb, Ht, Na^+ and Cl^- measurements and BE ($P = 0.002$) and a significant decrease in sO_2 ($P = 0.007$) levels.

Discussion

Various changes in physiological factors including bodyweight, body temperature, blood parameters and heart function have been advocated as reliable indicators of animal welfare status during transportation (EFSA 2011). Weight loss during transportation can indicate compromised animal welfare conditions often seen in relation to dehydration (Warriss 1998). In the past, bodyweight losses of up to 10% have been indicated in goats transported under warm conditions (Kannan *et al* 2000). Changes in bodyweight observed during this study could not be associated with effects from treatment densities or placement in the vehicle (Table 3). Most of the goats monitored lost between 0.1–0.6 kg during the journeys, with one outstanding exception (loss of almost 2.5 kg) in April. There were also two animals that actually displayed a slight gain in weight (0.1 kg), for which the reason is unclear. Overall, average bodyweight loss (± 0.4 kg) was approximately 4% which is lower than the 10% reduction advocated as critical by Kannan *et al* (2000) or the 11.9% bodyweight loss reported by Minka and Ayo (2007). However, both of these studies were performed under extremely warm ambient conditions in Africa. Our observation of a 4% loss in bodyweight is similar to weight losses of 0.5% per hour predicted from other European studies (Plyaschenko & Sidorov 1987). Rectal temperature is considered a reliable, relatively accurate on-the-spot diagnostic parameter alongside blood parameters, providing insight into the adaptability of domestic livestock to various environmental factors but particularly to transportation stress (Vihan & Sahni 1981; Ayo *et al* 1998; Minka & Ayo 2007). In our study, rectal temperature decreased slightly (± 0.2°C) during transportation (Table 3) yet remained within an acceptable physiological range (38.5–40.0°C; van Zutphen *et al* 1991) similar to previous investigations (Minka & Ayo 2007).

Mortality rates are also considered to be influenced by transport conditions (More & Brightling 2003), losses being reported at 1.4% under certain circumstances. However, no fatalities were registered during any of our journeys. Deaths during transit have been reported during earlier studies and are often linked to the capability or fitness of the animals to travel. Fitness is often associated with preceding treatment (rearing and husbandry). In our study, the goats (6–8 weeks old) were weaned at birth on-farm and transferred to be milk reared (lambar) until transported to an assembly point for onward transportation to slaughter. These animals were all considered fit to travel.

Conditions within the vehicle are also of importance. Compartment temperature, relative humidity and ventilation (automated or not) are critical to animal comfort. In goats, the thermoneutral zone is 12–24ºC (Nikitchenko *et al* 1988) and the upper limit of heat tolerance is between 35 to 40ºC (Appleman & Delouche 1958). Transportation during thermally stressful hot-dry seasons may overtax their homeostatic control mechanisms (Igono *et al* 1982; Minka & Ayo

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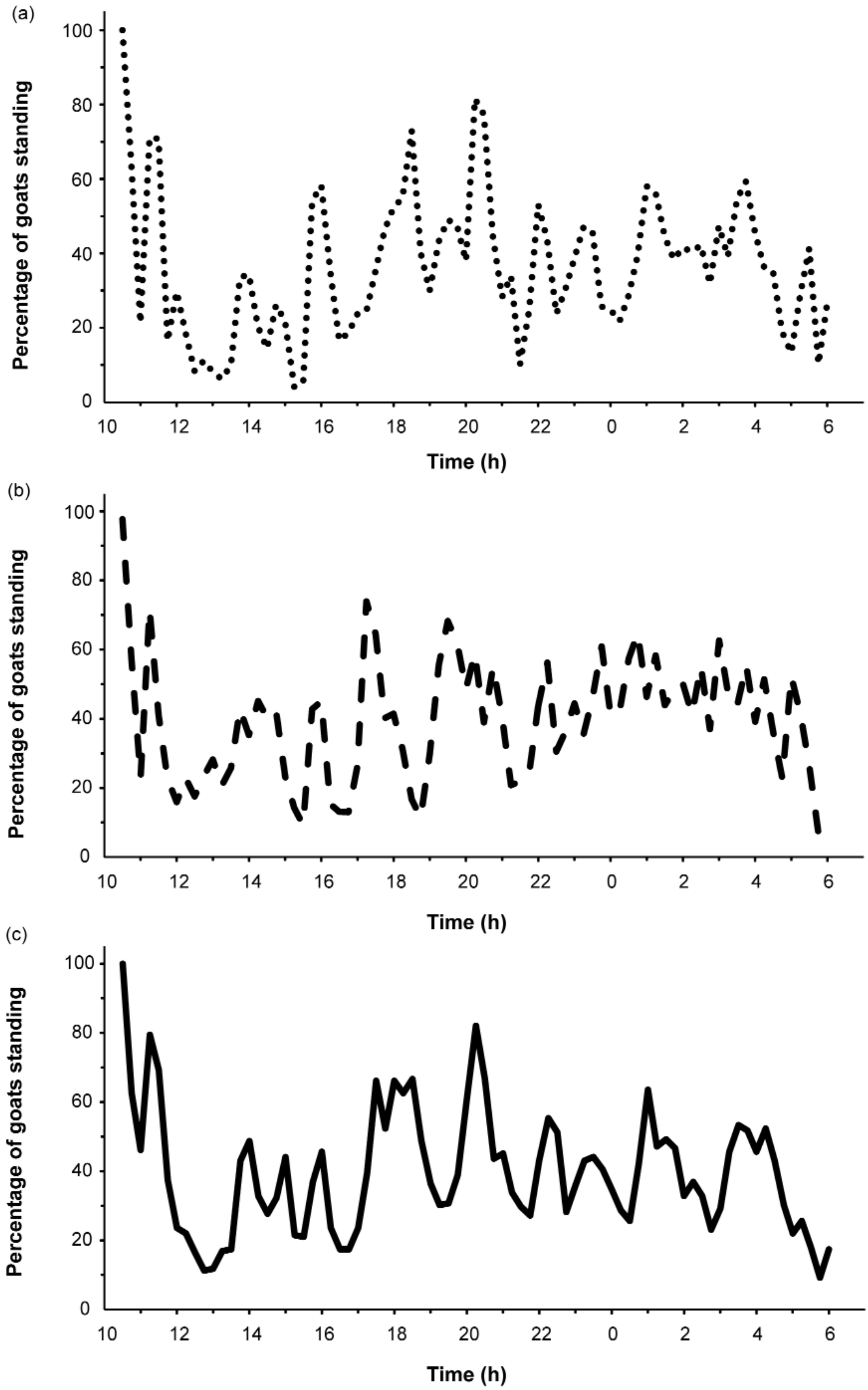
Figure 1



Percentage of goats standing during transportation (average of three journeys) showing (a) low (5 per m²), (b) medium (7.5 per m²) and (c) high density (10 per m²).

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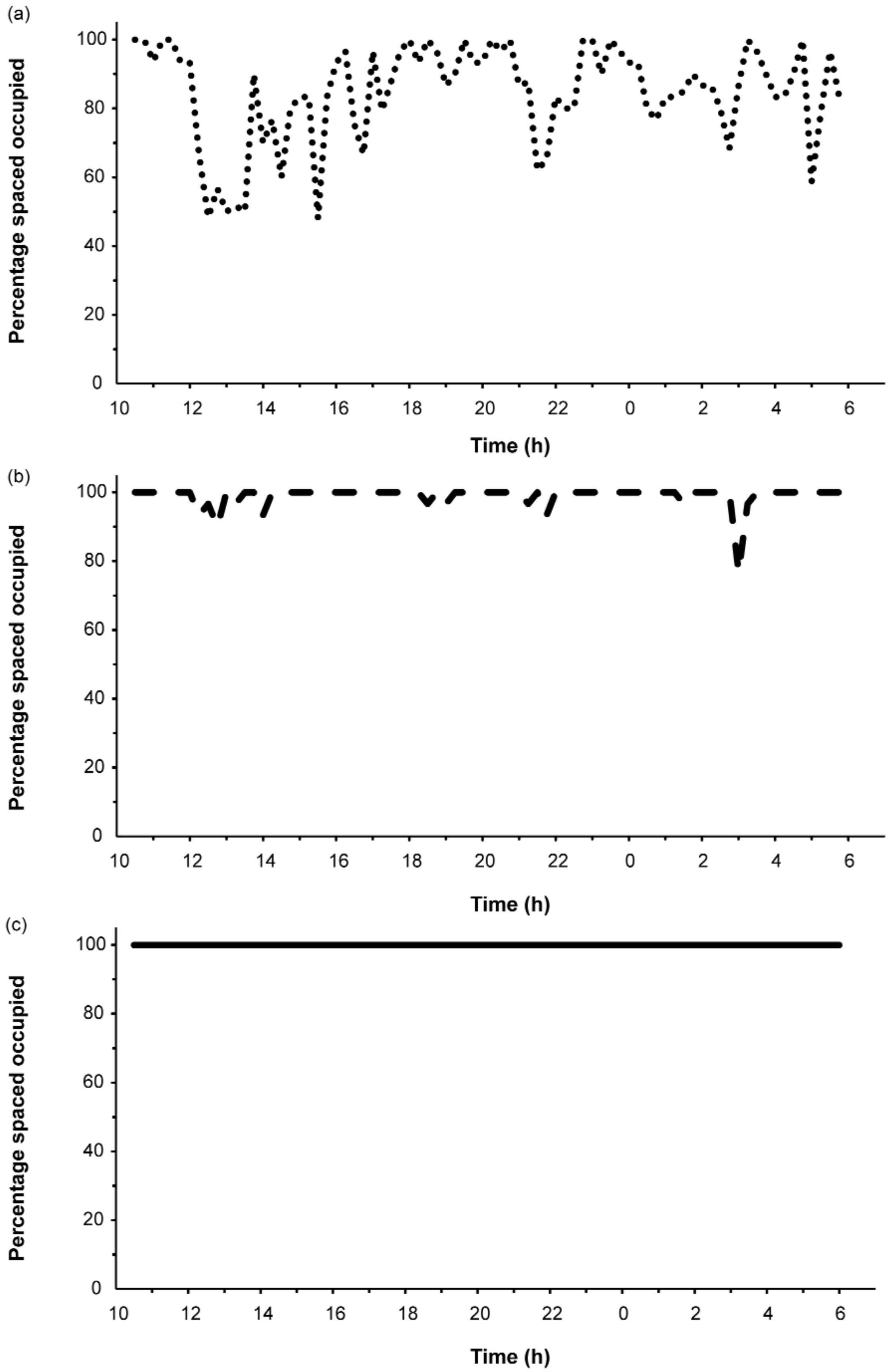
Figure 2



Percentage space occupied during transportation (average of three journeys) for (a) low (5 per m^2); (b) medium (7.5 per m^2) and (c) high density (10 per m^2).

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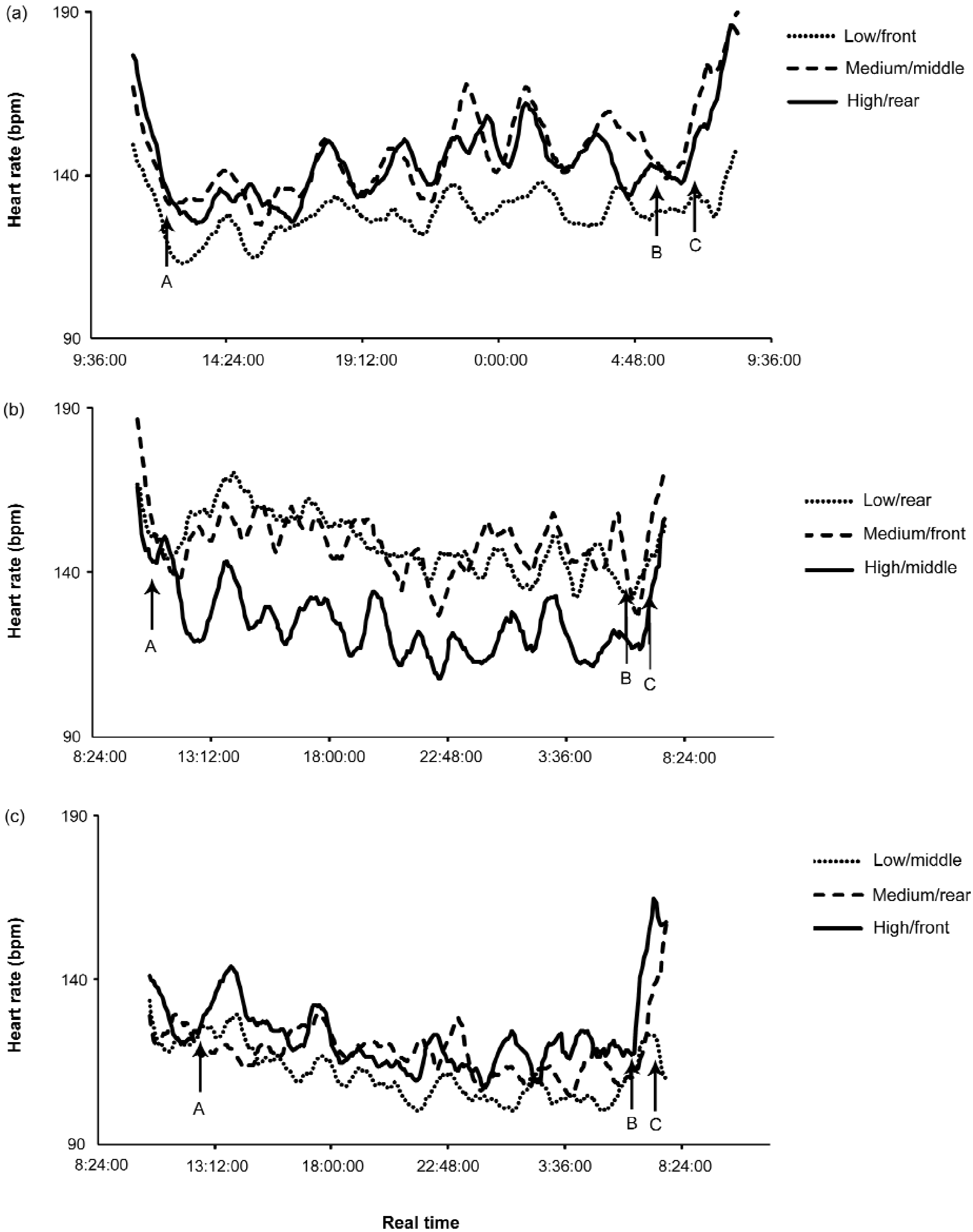
Figure 3



Heart rate (bpm) trends of young goats measured at different loading densities (low, medium, high) or compartment (front, middle, rear) during each journey. Where A = departure, B = arrival and C = at unloading for the months (a) March, (b) April and (c) May.

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Table 4 Mean (± SD) blood variables* (measured in samples taken before departure and after unloading.

		Journey: March			Journey: May					
Stocking density (n per m²)		10	7.5	5	10	7.5	5			
Goats monitored (n)		6	6	6	6	6	6	Average all journeys prior to departure	Average all journeys after arrival	*P*-value[†]
Compartment		Rear	Middle	Front	Front	Rear	Middle			
pH	Departure[‡]	7.36 (± 0.04)	7.37 (± 0.05)	7.35 (± 0.02)	7.40 (± 0.02)	7.42 (± 0.03)	7.38 (± 0.04)			
	Arrival	7.37 (± 0.06)	7.38 (± 0.02)	7.37 (± 0.02)	7.41 (± 0.02)	7.40 (± 0.04)	7.40 (± 0.03)	7.38 (± 0.04)	7.39 (± 0.04)	*P* = 0.229
pCO_2	Departure	44.3 (± 2.25)	41.0 (± 4.73)	43.8 (± 2.86)	40.5 (± 1.38)	38.5 (± 1.76)	41.7 (± 2.16)			
mm Hg	Arrival	49.0 (± 7.97)	44.7 (± 4.27)	44.7 (± 0.82)	40.3 (± 3.33)	39.5 (± 2.88)	41.5 (± 2.59)	41.6 (± 3.24)	43.5 (± 5.12)	*P* = 0.017
pO_2	Departure	29.5 (± 2.59)	36.8 (± 20.43)	33.2 (± 4.31)	28.0 (± 2.97)	26.7 (± 2.66)	28.5 (± 2.59)			
mm Hg	Arrival	26.5 (± 0.84)	27.2 (± 4.26)	29.2 (± 4.79)	27.5 (± 3.02)	26.7 (± 4.55)	27.0 (± 4.73)	30.4 (± 8.89)	27.3 (± 3.77)	*P* = 0.026
sO_2	Departure	53.0 (± 4.99)	58.7 (± 19.85)	59.9 (± 8.62)	52.6 (± 6.60)	51.1 (± 6.52)	52.6 (± 5.21)			
%	Arrival	46.3 (± 3.97)	48.7 (± 10.89)	52.7 (± 8.95)	51.9 (± 9.01)	49.0 (± 11.39)	49.9 (± 12.65)	54.6 (± 9.9)	49.7 (± 9.40)	*P* = 0.007
BE	Departure	–0.65 (± 2.84)	–1.32 (± 1.99)	–1.57 (± 0.83)	0.45 (± 1.35)	0.80 (± 1.37)	0.28 (± 2.55)			
mmol L⁻¹	Arrival	1.98 (± 1.50)	1.12 (± 1.22)	0.60 (± 1.80)	0.67 (± 1.49)	–0.27 (± 3.04)	0.95 (± 0.95)	0.43 (± 2.01)	0.84 (± 1.80)	*P* = 0.002
Haemoglobin	Departure	8.70 (± 0.77)	8.20 (± 0.78)	9.03 (± 0.81)	7.58 (± 0.66)	6.77 (± 1.96)	7.48 (± 1.33)			
g dL⁻¹	Arrival	8.98 (± 0.52)	9.27 (± 0.83)	9.52 (± 0.42)	8.70 (± 0.19)	8.30 (± 2.21)	8.30 (± 0.69)	7.96 (± 1.31)	8.85 (± 1.07)	*P* < 0.001
Haematocrit	Departure	27.0 (± 2.28)	25.5 (± 2.26)	28.0 (± 2.37)	23.7 (± 1.97)	21.2 (± 5.81)	23.3 (± 4.03)			
%	Arrival	27.8 (± 1.60)	28.7 (± 2.42)	29.5 (± 1.22)	27.0 (± 0.63)	25.8 (± 6.59)	25.8 (± 2.04)	24.8 (± 3.94)	27.3 (± 3.19)	*P* < 0.001
Glucose	Departure	3.87 (± 0.93)	4.07 (± 1.13)	3.65 (± 0.33)	3.35 (± 0.79)	3.37 (± 1.00)	3.18 (± 0.87)			
mmol L⁻¹	Arrival	4.22 (± 0.37)	4.13 (± 0.65)	4.5 (± 0.79)	3.28 (± 1.10)	2.52 (± 1.17)	3.47 (± 0.59)	3.6 (± 0.87)	3.7 (± 1.03)	*P* = 0.57
K^+	Departure	4.5 (± 0.3)	4.7 (± 0.3)	4.7 (± 0.6)	5.0 (± 0.6)	4.7 (± 0.4)	4.6 (± 0.3)			
mmol L⁻¹	Arrival	4.9 (± 0.4)	4.9 (± 0.6)	4.8 (± 0.2)	4.7 (± 0.5)	4.8 (± 0.5)	5.1 (± 0.8)	4.7 (± 0.4)	4.8 (± 0.5)	*P* = 0.435
Ca^{2+}	Departure	1.39 (± 0.07)	1.39 (± 0.04)	1.41 (± 0.06)	1.37 (± 0.04)	1.36 (± 0.03)	1.36 (± 0.03)			
mmol L⁻¹	Arrival	1.35 (± 0.07)	1.39 (± 0.03)	1.38 (± 0.05)	1.36 (± 0.10)	1.36 (± 0.03)	1.35 (± 0.04)	1.38 (± 0.05)	1.36 (± 0.05)	*P* = 0.059
Na^+	Departure	145 (± 2.1)	145 (± 1.2)	146 (± 2.0)	142 (± 0.5)	142 (± 1.9)	144 (± 1.0)			
mmol L⁻¹	Arrival	147 (± 2.6)	149 (± 2.1)	148 (± 2.6)	146 (± 1.9)	144 (± 2.5)	145 (± 1.2)	144 (± 2.1)	146 (± 2.7)	*P* < 0.001
Cl^-	Departure	109 (± 2.3)	110 (± 2.8)	110 (± 1.7)	109 (± 2.1)	107 (± 1.4)	109 (± 1.2)			
mmol L⁻¹	Arrival	112 (± 2.3)	113 (± 3.1)	112 (± 2.9)	110 (± 3.6)	109 (± 2.8)	110 (± 2.4)	109 (± 2.0)	111 (± 2.9)	*P* < 0.001
mOsm	Departure	294 (± 4.1)	295 (± 3.1)	296 (± 4.3)	288 (± 1.1)	288 (± 3.8)	291 (± 1.4)			
mmol kg⁻¹	Arrival	299 (± 5.3)	301 (± 4.4)	301 (± 5.5)	294 (± 3.9)	290 (± 4.3)	293 (± 1.9)	292 (± 4.4)	296 (± 5.8)	*P* < 0.001

* Data (not shown) from journey in April were incomplete due to failure of blood analyser at slaughterhouse.

[†] *P* indicates probability statistic for difference in blood values before and after transports.

[‡] 'Departure' indicates blood sample taken prior to departure (assembly station) and 'Arrival' indicates blood sample taken after arrival at final destination (slaughterhouse).

pCO_2: carbon dioxide pressure; pO_2: oxygen pressure; sO_2: oxygen saturation of haemoglobin; BE: actual base excess, measured as concentration of titratable base; mOsm: osmolality.

2007) and may have longer term negative effects on health status and productivity (Ayo *et al* 2006). During our study, conditions of temperature and relative humidity within the compartment remained well within the boundaries of animal comfort (ie compartment temperature: 10–28ºC and relative humidity: 35–75%).

Disruptions to any established group, ie by mixing prior to or during transportation can lead to excessive agonistic behaviour (Addison & Baker 1982; Barosso *et al* 2000; Andersen & Bøe 2007). This may lead to biting, kicking, butting or threatening displays involving interactions of chasing and fleeing (Alvarez *et al* 2007). These activities have been seen to decrease dramatically after 24 h (Alley & Fordham 1994). However, during transportation, the establishment of new hierarchal structures could aggravate behavioural patterns in dominant animals, increasing bouts of aggression and injuries (Ayo *et al* 2006). Observation of the recorded behaviour during our trips was limited to analysis of

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the area occupied and the frequency of standing, or recumbence. Observed incidences of aggression were limited (occasional butting or threatening). Establishment of dominance in goats is influenced by individual characteristics, ie aggressiveness, age, size, bodyweight, breed, sex, parentage, experience, the presence of horns and horn length (Miranda de la Lama *et al* 2010). In situations where individual space is limited, goats have less room to perform butting activity and biting, as observed previously (Tolu & Savas 2007).

Space allowance appeared to influence occupation of floor space. Although similar standing patterns (Figure 1) were observed per loading density. The greatest variation in area occupied (Figure 2) was found in the lightest loading density with more floor space being occupied at the higher densities. The limitation of free floor space at ten young goats per square meter was so restrictive to their freedom of movement that we considered it detrimental to their welfare during transit.

During transportation, goats changed their orientation frequently, apparently to maintain balance, suggesting they are restless. During the journeys performed in this study the goats were observed to huddle together but at the highest loading density there was less free floor space available. Heart rate is also an important physiological indicator of animal health status and adaptability (Minka & Ayo 2009). According to de Jong (2000), heart rate can increase (tachycardia) or decrease (bradycardia) when animals are subjected to stressors, ie frightened. Heart rate is considered a useful measure of welfare for short-term stressors, such as during handling, (un)loading and certain incidences during transportation. Some adverse conditions may prolong the occurrence of elevated levels (van Putton & Elshof 1978). Parrot *et al* (1998a) showed that HR of sheep increased from 100–160 bpm during loading and lasted for at least 15 min. Furthermore, elevations in HR have been shown to last for 9 h during transportation (Parrott *et al* 1998b). The heart rate levels and patterns observed here (Figure 3) were variable, heart rate ranged between 120–190 bpm during the first two journeys while a slightly lower range (100–160 bpm) was observed during the last journey. Patterns were similar with apparently large increases in HR at loading and unloading. The HR pattern was lowest for the high density group during the last journey, transported in the middle compartment. Patterns varied least during the last journey. No determination could be made of the effect of loading density on HR during transportation.

Certain blood parameters can be seen as indicators of (di)stress. Cortisol and glucose responses to stressor treatment are greater in older goats (Kannan *et al* 2003).

Kannan *et al* (2000) reported that plasma glucose concentrations remained elevated for about 3 h in Spanish goats after 2 h transport, whereas Nwe *et al* (1996) observed a similar trend in Japanese native goats after 6 h transportation. When animals are transported they are, to a certain extent, deprived of water. This can be assessed by measurement of the osmolality of blood (Broom *et al* 1996). If food is restricted, body reserves are rapidly exhausted and various changes in metabolites become apparent. Haematocrit (Ht) levels are altered during transport (Broom *et al* 1996), and have been seen to increase during transport (Parrott *et al* 1998b). However, if the animal is challenged for longer periods these levels may decrease dramatically (Broom *et al* 1996). Although the blood analyses during our study were limited there are indications (Table 4) that samples taken upon arrival after travelling for approximately 20 h, displayed significant increases in Hb (± 0.9 g dL^{-1}), Ht (± 2.6%) and BE (also Na^+ and Cl^- concentrations) levels. There was no indication of significant increases in glucose levels. However, these increases in Ht and BE (Na^+ and Cl^-) together with a slight (± 4%) loss in bodyweight would seem to be symptomatic of dehydration. This indication is supported by increases in osmolality levels in all groups during the journey in March and increases in the high density (10 per m^2) group during the May journey.

Any new environment during pre-slaughter holding and social isolation may be a stronger stressor than feed and water deprivation for goats (Richardson 2002). Several studies have confirmed differences between sheep and goats in their water consumption and water conservation capacities. Mutton Merino lambs had a 49% higher water intake per kg mass gain than Boer goats (Ferreira *et al* 2002). Higher water turnover rates were also found in sheep compared with goats kept under tropical conditions in Nigeria (Aganga *et al* 1989). Lower water turnover rates in goats suggest that goats can cope better with dehydration than sheep under dry climatic conditions (Silanikove 2000). Goats very rarely drink water during the pre-slaughter holding period. However, withholding of feed coupled with dehydration can cause live-weight shrinkage as high as 10% in the summer (Richardson 2002). The estimated weight loss (± 4%) during our study was, although not desirable, less excessive than in other reported cases. It is also considered that young animals may have difficulty identifying or using the drinking water supplied via nipple drinkers. Restriction of movement space at the highest stocking density may also have hindered access to the drinking nipples.

Animal welfare implications

There were no indications of obvious differences in behaviour and physiological parameters of goat kids (8–10 kg) when transported at the loading densities applied during this study.

It was evident that when loading at ten animals per m^2 the compartment is full (ie goats were packed in with no room to manoeuvre). We therefore recommend that goat kids should be transported at a slightly lower loading density (ie maximum nine animals per m^2). Although this study did not provide us with a firm basis to establish optimal stocking densities, we consider that a reduction in space allowance would enable the kids more freedom of movement allowing them to express their natural behaviour (ie turning, moving around, standing up and lying down).

Kids displayed signs of dehydration although water was available. It is advised that during transportation of young animals, drinking water be supplied in a manner to which the animals are accustomed (eg lambar system).

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Conclusion

Goat kids huddle together during transportation and especially at the highest loading density when floor space is very restricted, indicating that this loading density was possibly too high.

Goat kids (8–10 kg) lost between 2.4–5.9% (0.2–0.5 kg) in bodyweight and rectal temperature fell by 0.2ºC during transportation by road for approximately 20 h. A proportion of this weight loss is accountable to dehydration, shown by blood analysis, indicating a requirement for easily available drinking water.

Heart-rate levels displayed variable patterns, with high between-animal variability making it difficult to establish whether or not loading density influences this parameter.

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