Effects of graded noise levels on behavior, physiology and production performance of intensively managed lambs

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ABSTRACT

The aim of the experiment was to assess the effects of graded noise levels on behavioral, immune and cortisol responses, and on production performance of forty precocious Merino lambs. The experiment lasted 42 days and was preceded by a two-week adjustment period. The animals were divided into 3 test groups and a control group of 10 each, which were housed in 12 m^2 sound-proof rooms. The lambs in the test groups were exposed to recordings of high-speed motor vehicle traffic noise for 8 hours a day. The frequency range of the recordings was 100 to 6,300 Hz, while the loudness levels were different in the three experimental rooms: group A = 95 dB, group B = 85 dB, and group C = 75 dB. During the same 8 hours the control group was exposed to a background noise of 42-44 dB. For the rest of the day, the ambient noise level in the animal building was 35-40 dB. Behavioral traits of lambs were recorded at the end of the adjustment period and then at 14d, 28d and 42d of the experiment. At the same intervals, the plasma levels of glucose, total cholesterol, triglycerides, total proteins, albumins and cortisol were determined. Cell-mediated immune response to phytohemagglutinin (PHA) was determined at the beginning and at days 21 and 42 of the trial. Live weights of lambs were measured at the beginning of the trial and then at two-week intervals during the trial. After slaughtering, the carcass weights and the dressing percentage were determined. The experimental treatment determined a significant increase in the walking time ($P < 0.01$) and a reduction of plasma cortisol levels ($P < 0.01$) in the samples taken on days 28 and 42 of the trial in groups A and B. The lambs in the test groups exhibited a slower growth rate ($P < 0.01$) than the animals of the control group, whereas a deterioration of feed efficiency was observed only in group A ($P < 0.01$). There were no differences amongst the groups in terms of cell-mediated immunity and blood metabolites. Results suggest that exposure to noise has a detrimental effect on some biological functions in lambs but it does not severely impair animal well-being, at least when there are no concomitant conditions of physical and social discomfort.

Key words: Lambs, Noise, Behavior, Cortisol, Production performance.

RIASSUNTO

EFFETTO DI UNA DIVERSA INTENSITA' DI RUMORE SUL COMPORTAMENTO, SU ALCUNI PARAMETRI FISIOLOGICI E SULLE PRESTAZIONI PRODUTTIVE DELL'AGNELLO ALLEVATO INTENSIVAMENTE

La prova, della durata di 6 settimane, è *stata condotta su 40 agnelli di razza Merinos precoce ed* è *stata preceduta da una fase di adattamento degli agnelli agli ambienti sperimentali della durata di 2 settimane. Gli animali sono stati sud-*

divisi in 3 gruppi sperimentali ed un gruppo di controllo, di 10 soggetti ciascuno, ed alloggiati in ambienti insonorizzati di uguale ampiezza (12 m^2). Gli agnelli dei gruppi sperimentali sono stati esposti per 8 ore/d alla registrazione sonora del rumore prodotto da automezzi in corsa. La registrazione sonora aveva un campo di frequenze compreso tra 100 e 6300 Hz e veniva diffusa con una diversa intensità nei 3 ambienti sperimentali: gruppo A = 95 dB; gruppo B = 85 dB; gruppo C = 75 dB. Il gruppo di controllo era esposto contemporaneamente a un rumore di fondo di 42-44 dB. Per il resto della giornata, la rumorosità ambientale all'interno dello stabulario era pari a 35-40 dB. Le attività comportamentali degli agnelli sono state rilevate al termine del periodo di adattamento e, successivamente, ad intervalli quindicinali (14d, 28d and 42 d). Agli stessi intervalli sono stati rilevati i livelli plasmatici del glucosio, del colesterolo totale, dei trigliceridi, delle proteine totali, dell'albumina e del cortisolo. La risposta immunitaria cellulo-mediata al PHA è stata determinata all'inizio ed a 21 e 42 giorni di prova. I pesi vivi degli agnelli sono stati rilevati ad inizio prova ed ogni 14 giorni nel corso della sperimentazione. Alla macellazione sono stati infine determinati i pesi delle carcasse e le rese di macellazione. Il trattamento sperimentale ha determinato un aumento significativo dei tempi di locomozione (40,4 vs 46,0 vs 39,3 vs 27,5%, rispettivamente nei gruppi A, B, C e di controllo; P < 0,01) e, nei gruppi A e B, una riduzione dei livelli plasmatici di cortisolo (P < 0,01) limitatamente ai campionamenti effettuati a 28 e 42 d di prova. Inoltre, gli agnelli dei gruppi sperimentali hanno evidenziato una riduzione degli accrescimenti (249 vs 252 vs 262 vs 300 g/d; P < 0,01) rispetto al gruppo di controllo e, limitatamente al gruppo A, un peggioramento degli indici di conversione alimentare (4,0 vs 3,4 vs 3,5 vs 3,3, rispettivamente nei gruppi A, B, C e di controllo; P < 0,01). Non sono invece emerse differenze di rilievo, tra i gruppi a confronto, per la risposta immunitaria cellulo-mediata e per i parametri ematochimici. Nel complesso, l'esposizione alle sollecitazioni sonore tipiche del trasporto su automezzo pesante, caratterizzato da un'ampia banda di frequenza sonora (da 100 a 6300 KHz), sembra aver provocato un'azione di disturbo sul sistema uditivo dell'agnello, producendo un progressivo peggioramento del benessere all'aumento dell'intensità di erogazione del rumore. Sarebbe però anche difficile azzardare l'esistenza di uno stato di sofferenza negli agnelli esposti al rumore; è presumibile, invece, che il rumore da noi prodotto, pur avendo determinato delle differenze significative negli accrescimenti e negli indici di conversione, non rappresenti da solo un'elevata fonte di stress o di pericolo per l'animale. Come è noto, gli agnelli sono più sensibili ai rumori forti e improvvisi, variabili e inattesi, che rappresentano un classico segnale di allarme, piuttosto che ai rumori forti ma costanti, ripetuti e prevedibili. Pertanto, i risultati ottenuti evidenziano che l'esposizione al rumore, pur menomando alcune delle funzioni biologiche degli agnelli, non è in grado di creare situazioni di grave compromissione del benessere, almeno in assenza di concomitanti condizioni di discomfort fisico e sociale.

Parole chiave: *Agnello, Rumore, Comportamento, Cortisolo, Prestazioni produttive.*

Introduction

Animal well-being is considered an essential prerequisite for optimal production performance in animal farming. With the widespread use of intensive rearing systems, animals are increasingly exposed to several stressful situations engendered by farm management practices. In particular, greater exposure to noise has been produced by the mechanization of many husbandry procedures.

There are contrasting reports regarding the influence noise may have on the physiological, behavioral and productive traits of animals, especially because response to sound stimulation are species-specific and largely depend on the nature, loudness and familiarness of the noise (Spensley *et al.*, 1995; Talling *et al.*, 1998; Waynert *et al.*, 1998; Sevi *et al.*, 2001). These factors become particularly important where sheep are concerned since they do not seem to easily adapt to intensive management conditions (McNatty *et al.*, 1973; Pearson and Mellor, 1976; Fordham *et al.*; 1991). Noise is also an important component of the stress induced by transport of animals (Knowles *et al.*, 1995) although sheep seem to have better adaptive abilities for this specific stressor than do other livestock species (Knowles *et al.*, 1994). The effects of noise on the productivity parameters of sheep vary according to the age of the animals and to the characteristics of the sound (Ames, 1974; Harbers *et al.*, 1975). Recent investigations by our group on lambs (Sevi *et al.*, 2001) and on pregnant ewes (Quaranta *et al.*, 2001), that had been exposed to noise at a frequency of 2 kHz and at escalating levels of loudness from 45 to 95 dB, showed varying effects on the physiological, behavioral and productive parameters of the animals. In particular, only a transient increase in cortisol secretion was seen in lambs when noise was associated to a slight increase in temperature, while no changes were observed in their behavior or immune response; pregnant ewes exhibited a reduction in the time spent eating and an increase in the time spent inactive together with lower plasma cortisol levels after several days of noise administration. No significant effects on productive traits were registered in either the lambs or the ewes.

On the basis of these findings, we deemed it necessary to gather more information on the effect of noise on some physiological, behavioral and production parameters of intensively managed lambs by exposing them to recordings of high-speed motor vehicle traffic noise in monitored experimental environments to mimick the conditions of animal transportation.

Material and methods

Experimental design and animal management

The experiment lasted 42 days and was performed with 40 precocious Merino lambs aged 56 ±3 days and having a live weight of about 16 kg at the beginning of the trial. Before the investigation, the animals were allowed a two-week period to become accustomed to the experimental rooms. The experimental rooms were 3m x 4m x 4m high and situated inside the same animal building. The rooms were adjacent, provided with 1 m^2 transom windows and had appropriate lighting. After the adjustment period, the animals were divided into four groups that were homogenous in terms of age and live weight. Three groups (A, B, C) were exposed to noise and one group served as a control.

The experimental rooms were soundproofed by insulating the walls and the ceiling with sound-absorbing material. Two loudspeakers were positioned at a 45° angle and at animal height in the corners of each room to ensure maximum uniformity of the sound signals.

The noise, which had been recorded on a heavy-duty vehicle driving at relatively high speed on a road with heavy traffic, was administered for 8 hours a day (from 0800 to 1600). The frequency range was 100 Hz to 6,300 Hz and remained the same for all the test groups, while the loudness levels were 95 dB for group A, 85 dB for group B, and 75 dB for group C. A class 1 precision phonometer (HD 9019, Salmoiraghi) placed at animal level served to monitor noise loudness and frequency throughout the investigation. The phonometric measurements recorded in the room lodging the control group indicated a background noise of 42-44 dB during the time the noise recordings were played in the rooms housing the test animals. For the rest of the day the ambient noise level in the animal building was 35-40 dB.

Thermo-hygrographs TIG-T1 (LSI, 20090 Settala Premenugo, Italy) were placed in each room to monitor the ambient temperature and relative humidity throughout the trial. Averages of ambient temperatures and relative humidities ranged from 16.2 °C and 77% during the 0-14 day period to 12.2 °C and 85.1% during the 29-42 day period, being strictly similar in all the experimental rooms.

The lambs were fed *ad libitum* with a pelleted concentrate based on our formulation; the chemical composition of the dry matter was: 18.63% crude protein, 3.12 % fat (by ether-extraction), 9.62% crude fibre and 9.66 % ash. The feed was given to the animals by the same operator three times a day, at 0800, 1300 and 1800. Small amounts of pelleted hay were also offered to the lambs and drinking water was provided in self-filling bowls. The straw litter bed was changed twice a week.

Behavior

The behavior patterns of all the animals were observed in four sessions of two consecutive days each; the first session took place before the animals were exposed to noise, in order to assess the absence of anomalous behavior in each individual lamb. The other three sessions were conducted at 14-day intervals during the trial (days 13 and 14, days 27 and 28, and days 41 and 42). During each session, behavioral observations were conducted continuously from 0800 to 1800 with the scan sampling technique, i.e. 10-minute observation periods per room rotating systematically among the experimental groups without disturbing the animals. Posturing, lying or standing, were noted. Activities such as feeding, drinking, ruminating, walking, exploration, i.e. sniffing peers and the litter, directing the head, ears, eyes, or nose towards the room, and other activities (grooming, self-grooming, biting objects, aggressive or playful behavior) were also recorded. The number of animals involved in each behavior item during each sampling period was noted down and this was then expressed as a percentage of the total number of animals in the groups.

Plasma metabolites and cortisol

Blood samples were taken from all the animals. The first samples were collected at the end of the two-week adjustment period and provided the baseline values, while the others were taken every two weeks during the trial (on days 14, 28 and 42). Blood was collected in vacuum tubes from the jugular vein by the same operator at 0830, i.e. 30 minutes after noise administration began. The blood samples were immediately centrifuged and the plasma analyzed to determine glucose, total cholesterol and triglyceride concentrations enzymatically, total proteins and albumins colorimetrically. Plasma metabolites were analyzed using commercial kits and an ARCO automatic analyzer (Biotecnica Instruments, Rome, Italy). Plasma cortisol concentrations were determined using a specific RIA kit for sheep (DiaSorin-Italia, 13040 Saluggia, Italy).

Cell-mediated immune response in vivo

Skin-tests were performed on all the animals by injecting 0.5 ml of phytohemagglutinin (PHA) dissolved in sterile saline solution (1 mg/ml) into shaven spots on each shoulder to evaluate the effect of noise on their cell-mediated immunity. A total of three skin-tests were performed, one at the beginning, one at the end and one at mid-trial (21 d). Responses were evaluated by measuring the animals' skinfold thickness with a calliper before PHA injection and 24 hours after.

Production performance

The performance measurements *in vivo* were based on individual live weights and group feed intake. Live weights were measured at the beginning of the trial and every 14 days during the trial. At the end of the experiment and before slaughtering, the animals were weighed after 24 h food and water deprivation. Before being transported to the slaughterhouse, the animals were allowed access to the drinking bowls to restore body fluids. After slaughtering, the carcass, skin and coat, head and liver, heart, spleen, lungs and trachea of each subject were immediately weighed to reckon the dressing percentage.

Daily intakes of concentrate were measured by weighing the feed administered following the timetable indicated above and what was left over on the following morning. The feed rations administered *ad libitum* were appropriately adjusted to the nutritional requirements of the lambs on the basis of the feed intakes measured each day.

All procedures were conducted according to the guidelines of the Council Directive 86/609/EEC of 24 November 1986 on the protection of animals used for experimental and other scientific purposes. In particular, for blood sampling each lamb was swiftly caught to minimize any excitement due to chasing and catching. There were always two trained persons involved in taking jugular blood samples. One person held the animal and securely pulled the lamb's head to the side to stretch his neck gently. The second person obstructed jugular blood flow by applying some pressure with the thumb in order to engorge the vein before puncturing it with a sterile needle.

Statistical analysis

All the variables were tested for normal distribution using the Shapiro-Wilk test (Shapiro and Wilk, 1965). Behavioral data were transformed into logarithmic form to normalize their frequency distributions before performing statistical analysis. Behavioral, blood and immune data were processed using ANOVA for repeated measures, using the SAS/STAT, release 6.04, package (SAS Institute Inc., Cary, NC, USA). The following method was adopted:

$$y_{ijk}=\mu+N_i+L_{ij}+T_k+(NT)_{ik}+E_{ijk}$$

where y_{ijk} = experimental observation;
μ = overall mean;
N_i = effect of the experimental treatment (i= 1, 2, 3, 4);
L_{ij} = lamb effect within the experimental treatment;

T_k = effect of behavioral observation session or skin testing (k = 1, 2, 3) and of day of blood sampling (k = 1, 2, 3, 4);

$(NT)_{ik}$ = interaction between treatment and observation session or between treatment and day of sampling;

E_{ijk} = residual error.

Where significant effects were found, the Student's T-test was used to locate significant differences between means.

The live weights and weight gains of the lambs were analyzed using ANOVA with one factor (treatment). Results are presented as the least squares means of the lambs in each treatment, and variability of the data is expressed as the SE of the mean response over the whole experimental period. $P < 0.05$ was considered significant, unless otherwise noted.

Results and discussion

Behavior

Exposure to noise did not influence the observed parameters in any significant way, with the sole exception of walking times. In fact, the control group walked for shorter periods than the test groups, both on day 14 and day 28 of the experiment (Table 1). As a consequence of this, motor activity in the control group was on average lower by 40% than that of the group exposed to 85 dB of noise ($P < 0.01$) and by approximately 30% compared to those exposed to noise levels of 75 and 95 dB ($P< 0.05$). It should furthermore be noted that times spent lying, feeding and ruminating were - even without significant differences - consistently longer in the control group as compared to the groups of animals exposed to noise, which is in line with prior observations carried out on pregnant sheep (Quaranta *et al.*, 2001). This behavioral pattern is consistent with the hypothesis that the lower noise level of the control group promoted harmonious routine behavior patterns as compared to the test groups; exposure to stress in the form of noise may have created a nervous condition in the animals which in turn was the cause of greater motor activity. Indeed, it is well known that various stressors may cause hyperactivity, both in cattle and in lambs (Moberg and Wood, 1982; Baldi *et al.*, 1990).

The greater degree of motor activity observed in the test groups confirms our previous findings in a similar test carried out on lambs exposed to 95 dB of 2 kHz noise (Sevi *et al.*, 2001), whereby the animals subjected to relocation and regrouping as compared to those with no change in their physical and social environment. Knowles *et al.* (1995) also reported that sheep subjected to stress induced by transport showed signs of increased nervousness during the initial period of the trip by standing for longer periods of time and exhibiting greater motor activity. This increased motor activity has also been observed in cattle subjected to metallic noises and to human voices (Waynert *et al.*, 1998).

Plasma metabolites and cortisol

There were no significant differences amongst the groups in the blood parameters, which remained well within the normal range for lambs of that age (Table 2). A significant effect of the treatment x time ($P < 0.05$) was observed only for the plasma cortisol levels subsequent to significant variations observed when samples were taken on days 28 and 42. On those days, the cortisol levels were notably higher in the control group and the C group ($P < 0.01$ and $P < 0.05$, respectively) as compared to groups A and B. As the test proceeded, there was a drop in the plasma cortisol levels in the groups which had been exposed to noise as compared to the control groups, and the reduction grew with the loudness of the noise.

Given this unusual trend in plasma cortisol levels, it could be hypothesized that exposure to noise for weeks could be considered a chronic source of stress capable of causing a reduction in adrenal activity which in turn causes a drop in the production of cortisol. This hypothesis would appear to be borne out by our prior study carried out on pregnant ewes where cortisol levels proved to be significantly lower in animals exposed to loud noise (95 dB) for 120 days than in the control group (Quaranta *et al.*, 2001).

Other researchers (Warriss *et al.*, 1989, 1990; Knowles *et al.*, 1993; Sevi *et al.*, 1999) have shown that high plasma cortisol levels are observed in

Table 1. Least squares means ± SE of time spent in each of behavioral categories by Control lambs and lambs subjected to noise of 95 dB (group A), 85 dB (group B) and 75 dB (group C). Data are presented as % of animals in a group involved in the activity.

	Day of observation	Groups				SE	Levels of significance		
		A 95 dB	B 85 dB	C 75 dB	Control		Noise	Day of observation	Noise x day of observation
Feeding	14 d	18.1	25.6	23.2	32.7				
	28 d	13.5	21.5	22.7	21.2				
	42 d	13.3	10.5	11.7	18.5				
	Mean	15.0	19.2	19.2	24.1	2.21	ns	**	ns
Drinking	14 d	1.0	1.7	3.2	1.2				
	28 d	1.3	1.7	1.7	0.7				
	42 d	2.0	0.7	1.7	1.0				
	Mean	1.4	1.4	2.2	1.0	0.38	ns	ns	ns
Exploration	14 d	0.8	0	0	0				
	28 d	0.3	0	0.2	0.2				
	42 d	0.2	0.5	0.2	0				
	Mean	0.4	0.2	0.2	0.1	0.09	ns	ns	ns
Walking	14 d	36.8 A	41.0 A	33.4 A	17.6 B				
	28 d	44.4 a	52.0 Aa	41.0 ABa	28.6 Bb				
	42 d	39.8	45.1	43.7	36.3				
	Mean	40.4 ABb	46.0 Aa	39.3 ABb	27.5 Bb	2.41	**	**	ns
Ruminating	14 d	8.8	5.9	6.8	8.8				
	28 d	4.7	2.9	2.9	8.8				
	42 d	4.9	2.9	4.1	4.4				
	Mean	6.1	3.9	4.6	7.3	0.92	ns	ns	ns
Lying	14 d	31.8	22.7	32.9	38.8				
	28 d	35.1	20.0	29.0	38.5				
	42 d	38.7	39.0	36.8	38.5				
	Mean	35.2	27.2	32.9	38.6	3.28	ns	ns	ns
Other activities	14 d	2.7	3.2	0.5	1.0				
	28 d	0.7	2.0	0.7	2.0				
	42 d	1.1	1.2	1.7	1.2				
	Mean	1.5	2.1	1.0	1.4	0.53	ns	ns	ns

*A, B = P <0.01; a, b = P <0.05. ns = not significant; * = P <0.05; ** = P <0,01.*
In the same row, means followed by different letters are significantly different at P<0.01 (A, B) and at P<0.05 (a, b).

lambs only when the stressful situations are of short duration. It would thus appear that prolonged stress may induce a reduction in plasma cortisol (Terlow *et al.*, 1997).

It cannot be ruled out, moreover, that the particular stock-farming conditions of the test animals might cause an increase in their reaction thresholds. The animals' rooms tended to be rather bare, free of any risks and stimuli. The animals had very little opportunity to explore and to come into contact with humans, no contact with the outside world and very little exposure to weather changes, and it is thus possible that their reaction thresholds increased and the reactivity of the hypothalamus-pituitary-adrenal axis decreased (Fraser and Broom, 1990).

Immune response

No significant effects of the experimental treatment were observed on the cell-mediated immune response of the lambs (Figure 1). The increase in skin thickness after injecting PHA ranged, on average, from 3.5 mm in group B to 2.8 mm in the control group. The results confirm our previous observations of lambs and pregnant sheep after prolonged exposure to noise (Sevi *et al.*, 2001a; Quaranta *et al.*, 2001). Indeed, it is a well-known fact that T lymphocytes are sensitive only to soluble immune-modulating factors (Napolitano *et al.*, 1998). In particular, corticosteroids are considered to have a depressing effect specifically on T lymphocytes (Harbuz and Lightman, 1992), even though the immunosuppressive effects observed in rats subjected to removal of the adrenal glands would suggest that there might well be other factors involved in regulating the cell-mediated immune response system besides cortisol (Keller *et al.*, 1983). Thus, the fact that no increase in cortisol secretion in the groups exposed to the greatest noise levels was observed might help explain, at least in part, the lack of difference between the skin thicknesses after PHA administration.

Apart from the experimental treatment, the immune response to PHA injection dropped ($P < 0.01$) as the trial proceeded (3.68, 3.44 and 2.58 mm on days 14, 28, and 42, respectively), probably due to the fact that the lambs became progressively inured to the procedure which was used. It is a well-known fact that sheep are timorous animals and it is in their nature to be frightened of novelties; any unusual event might scare them (Gray, 1987), though through repeated exposure to these events, they become progressively accustomed to them.

Production performance

Exposure to noise had a negative impact on the production performance of the lambs, notwithstanding the fact that growth rates, even in the

Figure 1. Least square means ± SE of skinfold thickness after PHA injection in Control lambs and lambs subjected to noise of 95 db (group A), 85 dB (group B) and 75 dB (group C).

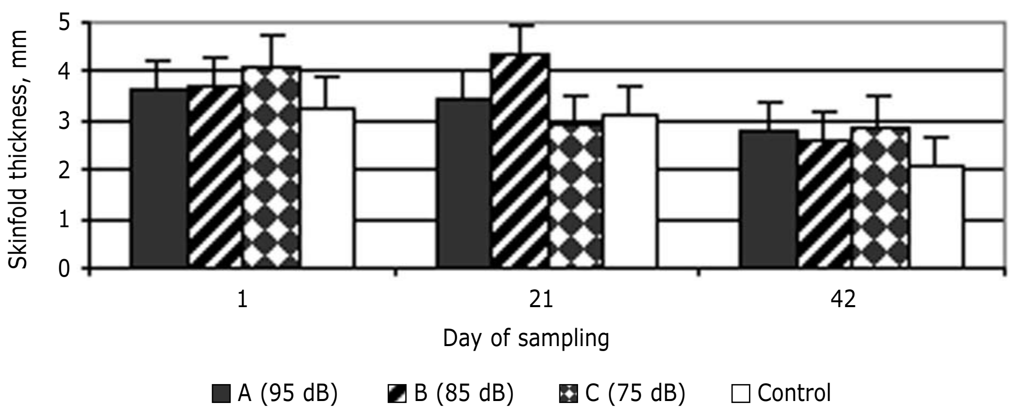

Table 2. Least squares means ± SE of plasma metabolites and cortisol in Control lambs and lambs subjected to noise of 95 dB (group A), 85 dB (group B) and 75 dB (group C).

		Groups					Levels of significance		
	Day of sampling	A 95 dB	B 85 dB	C 75 dB	Control	SE	Noise	Day of sampling	Noise x day of sampling
Glucose, mmol/l	0 d	3.46	3.61	3.46	3.37				
	14 d	3.40	3.73	3.63	3.73				
	28 d	4.53	4.28	4.21	4.12				
	42 d	4.11	4.15	4.03	3.91				
	Media	3.88	3.94	3.83	3.78	0.54	ns	ns	ns
Total protein, g/l	0 d	69.3	64.2	63.2	65.3				
	14 d	66.9	65.0	62.0	63.7				
	28 d	66.5	63.7	63.1	64.6				
	42 d	69.5	63.4	66.3	66.0				
	Media	68.0	64.1	63.7	64.9	8.11	ns	ns	ns
Albumin, g/l	0 d	36.4	33.6	39.1	38.7				
	14 d	36.7	35.8	38.9	38.5				
	28 d	36.1	35.8	38.2	37.7				
	42 d	36.4	35.2	38.3	37.8				
	Media	36.4	35.1	38.6	38.1	5.93	ns	ns	ns
Triglycerides, g/l	0 d	0.18	0.16	0.21	0.15				
	14 d	0.15	0.19	0.21	0.19				
	28 d	0.25	0.18	0.17	0.17				
	42 d	0.32	0.20	0.19	0.18				
	Media	0.22	0.18	0.19	0.17	0.02	ns	ns	ns
Total cholesterol, mmol/l	0 d	1.15	1.12	1.09	1.22				
	14 d	1.08	1.21	1.21	1.27				
	28 d	0.99	0.75	0.82	0.71				
	42 d	1.03	0.97	0.92	0.89				
	Media	1.06	1.01	1.01	1.02	0.05	ns	**	ns
Cortisol, ng/ml	0 d	22.8	19.0	14.7	16.9				
	14 d	17.8	16.1	16.4	17.6				
	28 d	13.4 Bb	19.5	25.7 a	27.3 A				
	42 d	15.0 Bb	17.2 Bb	26.4 a	30.4 A				
	Media	17.3	18.0	20.8	23.1	1.70	ns	ns	*

*A, B = P <0.01; a, b = P <0.05. ns = not significant; * = P <0.05; ** = P <0,01.*
In the same row, means followed by different letters are significantly different at P<0.01 (A, B) and at P<0.05 (a, b).

test groups, remained satisfactory and well within the bounds of the breed's average.

Throughout the trial, the live weights and growth rates (Table 3) were higher in the control group than in groups A, B and C (28.72 kg vs 26.45 kg, 26.51 kg and 27.01 kg, respectively; P < 0.01; 300 g/d vs 249 g/d, 252 g/d and 262 g/d, respectively; P < 0.01). In particular, the live weights and relative daily growth showed no differences between the compared groups during the 0-14 day period, whereas later (15-28 d and 29-42 d) there was a progressive increase in live weights and in growth in the control group as compared to the test groups. This suggests that the effects of noise were progressively cumulative and that the longer the exposure time, the greater the decline in the growth rate of the lambs exposed to noise.

The lambs in group A also showed, overall, a

Table 3. Least squares means ± SE of live weights, weight changes, feed efficiency, carcass weights and dressing percentage of Control lambs and lambs subjected to noise of 95 dB (group A), 85dB (group B), and 75 dB (group C).

		Groups					Significance
		A 95 dB	B 85 dB	C 75 dB	Control	SE	Noise
Live weights, kg	initial	15.97	15.94	16.01	16.10	0.18	ns
	at 14 d	19.15	19.31	19.49	19.66	0.21	ns
	at 28 d	22.66 Bb	22.59 Bb	22.99 ABb	23.90 Aa	0.28	**
	at 42 d	26.45 B	26.51 B	27.01 B	28.72 A	0.35	**
Weight gains, g/d	0-14d	227	241	248	254	7.7	ns
	15-28d	251 B	234 B	250 B	303 A	9.4	**
	29-42d	271 B	280 B	287 B	344 A	11.7	**
	0-42d	249 B	252 B	262 B	300 A	7.7	**
DM intake from concentrate, g/d	0-14d	877	847	835	877		___
	15-28d	1005	826	880	927		___
	29-42d	1117	870	1014	1111		___
	0-42d	1000	848	909	971		___
Feed efficiency, g DM/g weight gain	0-14d	3.9 Bb	3.5 ABa	3.4 Aa	3.5 Aa	0.11	*
	15-28d	4.0 Bb	3.6 ABa	3.6 Aa	3.1 Aa	0.13	**
	29-42d	4.2 Bc	3.1 Aa	3.6 Ab	3.3 Aab	0.14	**
	0-42d	4.0 B	3.4 A	3.5 A	3.3 A	0.10	**
Slaughter weights after 24 h fasting, kg		25.13 B	24.97 B	25.36 b	26.44 Aa	0.33	*
Warm carcass weights, kg [1]		14.67	14.55	14.66	15.27	0.22	ns
Warm dressing percentage, %		58.4	58.3	57.8	57.7	0.47	ns

[1] Including head, liver, heart, spleen, lungs and trachea.
*A, B = P <0.01; a, b = P <0.05; ns = not significant; * = P <0.05; ** = P <0,01.*
In the same row, means followed by different letters are significantly different at P<0.01 (A, B) and at P<0.05 (a, b).

significant deterioration of feed efficiency as compared both to the control group and as compared to groups C and B (4.0 vs 3.3, 3.5 and 3.4 respectively; P < 0.01). The deterioration of feed efficiency might perhaps be due to the higher stress placed on the body's homeostatic regulatory mechanisms, given the need to adapt to non-optimal environmental conditions. This gives rise to a waste of energy, which might otherwise be available for growth (Bauman and Currie, 1980).

As far as slaughtering data is concerned, the only statistically significant differences observed were in slaughter weights (26.44 kg for the control group vs 25.13, 24.97 and 25.36 kg for groups A, B and C, respectively; P < 0.05). Dressing percentage was unaffected by noise treatment; the values were on average around 58%.

In previous experiments carried out by other researchers (Arehart and Ames, 1972; Ames, 1974), there was no evidence of any particularly damaging effect of noise on the productive performance of lambs. Indeed, in one of our earlier studies (Sevi *et al.*, 2001), we observed no significant differences in the growth performance of lambs exposed to an increasingly high noise level, ranging from 54 dB to 95 dB, with a constant frequency band of 2 kHz.

The discrepancy between these results and the results of prior investigations is in all likelihood due to the type of noise that was produced. In particular, in the current experiment, the animals were exposed to sound stresses that are typical of the sounds of a heavy-duty transport vehicle with a broad frequency band (from 100 to 6,300 Hz). This probably created greater stress for the lamb's hearing system and in turn may have caused a progressive deterioration of well-being when the loudness levels increased. However, it seems unlikely that the lambs subjected to noise were in a state of distress. On the contrary, it could be assumed that, though the noise we generated caused significant differences in growth and in feed efficiency, it was not per se a sufficiently strong source of stress and danger for the animal. As is well known, lambs are very sensitive to sudden, loud noises which vary in intensity and are unexpected. This type of noise is the classic alarm signal, as opposed to loud but constant, repeated and predictable noise, which is not an alarm signal (Komersaroff *et al.*, 1998; Colthorpe *et al.*, 1998). In line with our observations, Knowles *et al.* (1995) observed a drop in body weight in lambs transported by trucks with a noise level of 90 dB; the weight loss was greater when the trips were longer, but the animals showed no clear signs of distress, and their behavior patterns were completely normal.

Conclusions

The aim of the experiment was to simulate noise conditions which apply during the transport of animals; the test treatment had a clear effect on lamb growth, irrespective of the intensity of the noise, and produced a change in feed efficiency and plasma cortisol levels, but only in the groups exposed to the highest degree of noise. These effects became evident as of the third week of exposure of the lambs to noise. Conversely, behavior patterns changed very little and there were no effects on the immune response or on blood parameters. These results suggest that noise alone is not enough to cause serious changes in the well-being of lambs, unless noise exposure lasts much longer than the period in which, under normal circumstances, a lamb would be transported in a vehicle. Thus, special monitoring of other potential stress factors is necessary, such as overcrowding, high temperatures and long periods without food and water, in order to minimize the negative impact of transport on the well-being of lambs.

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