



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

ARCHIVIO ISTITUZIONALE DELLA RICERCA

Alma Mater Studiorum Università di Bologna Archivio istituzionale della ricerca

Changes in cortisol and glucose concentrations in rabbits transported to the slaughterhouse

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

Published Version:

Accorsi, P., Biscotto, A., Viggiani, R., Prodan, C., Bucci, D., Beghelli, V., et al. (2017). Changes in cortisol and glucose concentrations in rabbits transported to the slaughterhouse. *LIVESTOCK SCIENCE*, 204(Ottobre), 47-51 [10.1016/j.livsci.2017.07.013].

Availability:

This version is available at: <https://hdl.handle.net/11585/622652> since: 2021-12-03

Published:

DOI: <http://doi.org/10.1016/j.livsci.2017.07.013>

Terms of use:

Some rights reserved. The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

This item was downloaded from IRIS Università di Bologna (<https://cris.unibo.it/>).
When citing, please refer to the published version.

(Article begins on next page)

This is the final peer-reviewed accepted manuscript of:

P.A. Accorsi, A. Biscotto, R. Viggiani, C. Prodan, D. Bucci, V. Beghelli, M. Mattioli, C.A. Petrulli, G. Postiglione, C. Milandri, Changes in cortisol and glucose concentrations in rabbits transported to the slaughterhouse, *Livestock Science*, Volume 204, 2017, Pages 47-51

The final published version is available online at:

<https://doi.org/10.1016/j.livsci.2017.07.013>

Rights / License:

The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

This item was downloaded from IRIS Università di Bologna (<https://cris.unibo.it/>)

When citing, please refer to the published version.

Changes in cortisol and glucose concentrations in rabbits transported to the slaughterhouse

P.A. Accorsi^a, A. Biscotto^b, R. Viggiani^a, C. Prodan^b, D. Bucci^a, V. Beghelli^a, M. Mattioli^a,
C.A. Petrulli^{a,*}, G. Postiglione^a, C. Milandri^b

^a *Dipartimento di Scienze Mediche Veterinarie - Università di Bologna, Via Tolara di Sopra 50, 40064 Ozzano Emilia, BO, Italy*

^b *Azienda Unità Sanitaria Locale, Via Carlo Forlanini, 34, 47121 Forlì, BO,*

ABSTRACT

The effect of transport on Cortisol and Glucose serum concentrations were assessed in rabbits during summer and winter. Animals were divided into high (HSA, 307 cm²/rabbit), medium (MSA, 373 cm²/rabbit) and low space allowance (LSA, 475 cm²/rabbit) transport groups, and rabbits slaughtered directly in the farm were used as control group (C). During summer, cortisol and glucose concentrations were significantly higher in HSA (high space allowance), MSA and LSA than in C rabbits ($P < 0.01$). LSA cortisol concentrations were significantly lower than MSA and HSA samples and MSA rabbits' glycaemia was significantly higher ($P < 0.01$) compared with HSA animals. During winter, cortisol concentrations in group C were significantly lower than in MSA and HSA groups. Glycaemia in group C was lower than in LSA ($P < 0.01$) and HSA ($P < 0.02$) groups. Cortisol and glucose levels in summer were significantly higher than in winter. Our data clearly show that some stress-related physiological parameters are significantly modified by transport, in particular in the case of overcrowded transport crates.

Keywords: Rabbits transport Space allowance Cortisol Glycaemia Animal welfare

1. Introduction

In the last two decades, public awareness regarding farm animal welfare has spread all over the world (Maria, 2006; Blokhuis et al., 2008; You et al., 2014) and is now considered a central legislative goal by the Organization of the United Nations FAO (2010). Such interest is guiding and influencing trade trends, not only to guarantee animal welfare but also to ensure food quality. Animal welfare in breeding and slaughtering influences the characteristics, quality, commercial lifespan of the final product and sanitary features of food, making the different tissues variably sensitive to microbial attack (Dalle Zotte et al., 1995; Jolley, 1990; Lambertini et al., 2004).

Transport represents a considerable stressor for animals and in particular stocking density condition, trip duration and waiting time at the slaughterhouse are the most effective factors that increase stress (Jolley, 1990; De La Fuente et al., 2004; Corese, 2005). Transport space allowance could also have an important impact on animal conditions when arriving to the slaughterhouse and consequently on the quality of the carcasses and meat with possible economic damages (Weeks et al., 1997).

To date, European laws (Council Regulation (EC) No 1/2005) do not establish space allowance limitations for rabbit transport, while for other species the optimal, or good conditions for animal space allowance are dictated. Therefore, for rabbit transportation, it is necessary to refer to laws concerning transport conditions of other species. (De La Fuente et al., 2004).

Few studies concerning rabbit welfare during transport are available in literature. Many Authors considered this subject, but they focused on carcass quality rather than trying to state which densities could be better to guarantee transport welfare (Coppings et al., 1989; Jolley, 1990; Kola et al., 1994; Batchelor

47 and Giddins, 1995; Trocino et al., 2003; Corese, 2005). The aim of the present study was to identify
48 parameters that could represent an objective measurement of the rabbits physiological response to
49 different transport conditions. We decided to focus on cortisol and glucose blood concentration, as they
50 represent the most indicative and easiest parameters to be studied for the assessment of stress levels
51 (Fordham et al., 1989; Broom et al., 1996; Broom, 2000; Ibañez et al., 2002; Teke et al., 2014).
52
53

54 **2. Materials and methods**

55 *2.1. Animals and farm*

56 364 meat rabbits (Hycote commercial hybrid) of both sexes were used, approximately weighted 2.50–
57 3.00 kg and aged 80–100 days. The animals were bred in a home-managed farm with the complete pro-
58 duction cycle (reproduction and growth/fat) composed of about 500–700 breeding does and about 20,000
59 to 30,000 fattened rabbits per year. The space available for the animal was about 600 cm²/head; the
60 mortality varied from 5% to 7%. The mean temperature in the rabbits crates was 18.7 °C in winter and
61 27.8 °C in summer. The farm was located approximately 220 km from the slaughterhouse.
62
63
64

65 *2.2. Transport*

66 Rabbits were loaded in groups corresponding to three different stocking densities: high space allowance
67 (HSA), mean space allowance (MSA) and low space allowance (LSA). The rabbits were randomly as-
68 signed to three groups and the animals transported together always came from the same crate on the farm.
69

70 MSA group arrangement was obtained from Biscotto et al. (2007) and it consisted in 350 cm²/rabbit (for
71 fat rabbits with an average weight of 2.6–2.9 kg) as the minimum limit to safeguard the animals welfare
72 during transport. Transport crates were 5225 cm² in area. Crates for MSA group were loaded with 14
73 rabbits each (373 cm²/ rabbit). To obtain the HSA and LSA stocking densities, crates were loaded with a
74 difference of 3 animals each (17 rabbits, 307 cm²/rabbit, HSA; 11 rabbits, 475 cm²/rabbit, LSA). In
75 summer (July) and winter (January) trials, transport was carried out in the same manner.

76 Rabbits were transferred from breeding to transport crates manually by the farm staff.

77 Transport crates were made of rigid plastic with a rectangular base (96.40 × 54.20 × 25.00 cm) and
78 rounded corners; a plastic grid would allow for proper air circulation from floor, ceiling and walls.
79 During transport, crates were arranged in columns of 10 each in the central part of the lorry.

80 For each journey, the same lorry driven by the same operator was used and the procedures of charge,
81 transport and discharge were identical. Crates charge and discharge were carried out by the lorry driver.

82 Animals were transported during the night (between 1:00 and 2:00 a.m.) and they reached the
83 slaughterhouse in about 3 h. The travel from farm to slaughterhouse was carried out on normal roads,
84 avoiding highways and rabbits did not have access to food or water.

85 The ambient temperature at the arrival to the slaughterhouse was 17 °C in summer and 1 °C in winter.
86

87 *2.3. Slaughtering*

88 Rabbits were slaughtered in summer (n = 148) and in winter (n = 177). In particular, in summer
89 were slaughtered 50 rabbits for MSA group and 49 rabbits both in HAS and in LSA group, whereas in
90 winter were slaughtered 59 rabbits in each treatment.
91

92 The slaughtering of rabbits was performed with standardized procedures as described by Regulations
93 ((EC) N° 852/2004, N° 853/2004, N° 854/2004) (hygiene of foodstuffs) and N° 1099/2009 (protection of
94 animals at the time of killing). Animals were manually extracted from the crates and stunned with specific
95 electric rabbit stunner by trained personnel. The current intensity applied to each rabbit was of 150 mA
96 with a voltage of 250 Hz and the time of application was 0,3 s. Subsequently, rabbits were hung on the
97 slaughter line and jugular ex-sanguination performed. Afterwards, rabbits were skinned and eviscerated
98 and the health inspection was carried out by the Veterinary Officer. Subsequently, carcasses were
99 transferred to the local refrigerator for cooling.

100 Before they were killed rabbits waited in the slaughter from 5 a.m. to 6:30 a.m. and the slaughtering
101 process ended 1 h later; during this period environmental conditions did not change.

102 On the same day of slaughtering, between 01:00 and 02:00 a.m., 39 rabbits (19 in summer and 20 in
103 winter – control group, C) were slaughtered directly in the farm following the same slaughtering
104 procedures used in the slaughterhouse.

106 **2.4. Blood sampling and analysis**

107
108 Blood samples were obtained from the jugular vein wound made at the time of slaughtering in all
109 groups (C, HSA, MSA, LSA groups).

110 All blood samples were collected in tubes without anticoagulant, thus using serum for analysis. Serum
111 was divided into aliquots, immediately stored at -20°C until determination of cortisol and glucose.

112 C rabbit blood samples were used as reference values to evaluate changes in cortisol and glucose blood
113 concentrations.

114 Cortisol serum concentration was determined by radioimmunoassay (RIA), glucose was quantified by
115 enzyme-colorimetric methods using a commercial kit (Far, Verona, Italy).

116 Cortisol extraction from serum was performed as described by Tamanini et al. (1983): briefly, 100 μL
117 of serum were added with 5 mL of diethyl ether (BDH Italia, Milan, Italy). Samples were placed on a
118 multivortex for 30 min, then centrifuged at 2000g for 4 min at 4°C . The ethereal part, separated from the
119 serum component by suction, was evaporated under aspiration hood in current of air at 37°C . The dry
120 residue containing the steroid hormone was dissolved in 0.5 mL of 0.05 M phosphate buffer (PBS).

121 Cortisol serum concentration was determined as described by Tamanini et al. (1983). Analysis was
122 performed in duplicate. 100 μL of 3H-cortisol (specific activity 100 Ci/mmol, amount 30 pg/tube vial,
123 $\approx 12,771$ dpm/100 μL) and 100 μL of an anti-cortisol antibody (dilution 1:20,000) were added to 100
124 μL of the solution obtained with the serum extraction. After incubation at $+4^{\circ}\text{C}$ for 18 h, the free
125 steroid was separated with the addition of 1 mL of 1% charcoal solution (Sigma Chemical Co.) +
126 0.025% dextran (Sigma Chemical Co.), and incubation at $+4^{\circ}\text{C}$ for 15 min followed by centrifugation
127 (4000g) for 4 min at $+4^{\circ}\text{C}$. The supernatant containing the hormone bound to its antibody was
128 decanted into scintillation vials and measured in a liquid scintillation β -counter (Perkin-Elmer Life
129 Science Inc.).

130 Parameters for the analysis validation were: sensibility 0.78 pg/mg, assay variability 6.8%, variability
131 between assays 9.3%, specificity (%): cortisol 100, corticosterone 9.5, 11α -hydroxy-progesterone 8.3,
132 cortisone 5.3, 11α -desossicortisol 5.0, progesterone 0.6, desossicorticosterone 0.5, 20α -
133 dihydrocortisone 0.4, testosterone 0.3, aldosterone 0.1, dehydroepiandrosterone, 5β -pregnenolone,
134 17β -estradiolo, cholesterol < 0.0001 .

135 Readings of radioactive counting by liquid phase β counter were treated to construct linear standard
136 curves and eventually processed to calculate corresponding concentrations using an ad hoc designed soft-

137 ware program.

138 Glucose levels in serum were determined by enzymatic colorimetric glucose oxidase/peroxidase assay.

139 The principle is: $\text{glucose} + \text{O}_2 + \text{H}_2\text{O} \xrightarrow{\text{glucose oxidase}} \text{gluconate} + \text{H}_2\text{O}_2$. The last step is a reaction
140 between

141 $\text{H}_2\text{O}_2 + \text{o-dianisidine}$ with peroxidase to produce a detectable brown colour. Samples' absorbance was
142 measured in a spectrophotometer (Biotek instrument Inc. - mod. ELX 808 IU) at a wavelength of 450 nm.

143

144 *2.5. Statistical analysis*

145

146 Normal distribution was tested using the Kolmogorov–Smirnov test. Data were subjected to ANOVA
147 by GLM using space allowance, season and interaction in the model. The following model was adopted:

148 $Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$ where: Y_{ij} = elements, μ = overall mean, α_j = treatment (HSA, MSA and LSA), β_j =
149 season (summer and winter), $(\alpha\beta)_{ij}$ = interaction, ε_{ij} = experimental error.

150 Since the ANOVA test revealed a significant effect, Tukey post-hoc test was performed to identify
151 differences between groups.

152 The differences were considered significant with $P \leq 0.05$ ($\alpha = P \leq 0.05$). All results are
153 expressed as means \pm SE.

154

155 **3. Results**

156

157 Serum cortisol concentrations were significantly modified by the different space allowance (F_{3357}
158 = 18.12, $P < 0.01$) and season ($F_{1357} = 30.47$, $P < 0.01$). During summer, cortisol concentrations in
159 trans-ported animals were significantly higher ($P < 0.01$) than those observed in group C. Cortisol
160 concentrations detected in LSA rabbits were significantly lower ($P < 0.01$) when compared to those of
161 MSA and HSA groups, while the differences between MSA and HSA groups were not significant (Fig. 1).
162 In winter, cortisol levels in group C rabbits were significantly lower ($P < 0.02$) than those observed in
163 MSA and HSA animals (Fig. 1). Whereas seasonality modulates cortisol secretion, to compare results
164 between seasons (summer vs winter), variations of this hormone were compared to the C group value
165 (considering C = 100%). The comparison between cortisol concentration in percentage (referred to the C
166 group concentrations) showed that summer levels were significantly ($P < 0.01$) higher than winter ones in
167 all the groups: LSA 667.91% vs 160.75%; MSA 1336.57% vs 198.26%; HSA 1041.79% vs
168 202.14% (Fig. 2).

169 Serum glucose concentrations were significantly influenced by the different space allowance (F_{3357}
170 = 31.11, $P < 0.01$), season ($F_{1357} = 31.42$, $P < 0.01$) and by the interaction on two main factors
171 ($F_{3357} = 18.50$, $P < 0.01$). Glycemia during summer varied depending on the different stocking
172 density condition: HSA, MSA, LSA conditions influenced serum glucose values ($P < 0.01$) from
173 those of the C group. In addition, rabbits glycemia in the MSA group was significantly higher ($P < 0.01$)
174 than that of HSA animals, but no significant difference was noticed between the LSA group compared
175 respectively to the MSA and HSA group (Fig. 3). In winter, C group glucose concentration was
176 significantly lower than LSA and HSA groups, while no differences were evident with the MSA group
177 (Fig. 3). As with cortisol, comparing the percentage changes of the glucose concentration in summer and
178 winter in the C group (set 100%) to those in all the other groups, it resulted that HSA, MSA and LSA group
179 values in summer were significantly higher ($P < 0.01$) than those detected in winter (LSA 173.70% vs
180 122.47%; MSA 198.01% vs 106.51%; HSA 160.12% vs 115.34%)(Fig. 4).

181

182 **4. Discussion**

183

184 Transport represents a considerable stressor for animals; in particular, stocking density condition, trip
185 duration and waiting time at the slaughterhouse are considered among the most effective factors that
186 increase stress and consequently influence carcasses and meat quality (Jolley, 1990; Weeks et al., 1997,
187 De La Fuente et al., 2004; Corese, 2005).

188 Animal welfare is also an important topic, because it should be taken into account when assessing law
189 requirements. Moreover, the sensibility of the public opinion on animal rights is increasing. It is a specific
190 due for the slaughterhouse-holder as well as for the official veterinary to verify rabbits welfare condition
191 after travel.

192 There are a few publications and articles that discuss common practices for the transportation of research
193 animals (National Research Council, 2006), including the *AATA Manual for the Transportation of Live*
194 *Animals* (AATA, 2001), the *IATA Live Animals Regulations* (IATA, 2005), and a Report of the Transport
195 Working Group Established by the Laboratory Animal Science Association (Swallow et al., 2005). Very
196 few studies concern rabbit transport and the available literature focus on carcass quality after slaughtering
197 instead of animal well-being during transport (Coppings et al., 1989; Jolley, 1990; Kola et al., 1994;
198 Batchelor and Giddins, 1995; Trocino et al., 2003; Corese, 2005).

199 The present study was carried out to clarify density at transport effects in rabbits after the transport by
200 measuring cortisol and glucose serum concentrations. Results demonstrate that stocking density can induce
201 significant differences in the cortisol and glucose response. In fact, both in summer and winter, the two
202 parameters studied, were significantly higher in rabbits transported with a lower area avail- ability.

203 HSA group rabbits, in spite of the predictability, presented similar cortisol levels as compared to those in
204 MSA group, both in summer and winter. These results seem to contradict the hypothesis that the increase of
205 stress level (measured by animals space allowance) induces an in- crease in serum cortisol concentrations. It
206 is possible to argue that the animal adaptation to stressors is possible into certain limits: outside these
207 physiological limits, the animal does not have the resources to contrast further requests (vibration, shock,
208 noises, temperature, fasting, dehydration, etc.). Therefore, we could hypothesize that there is a “maximal
209 load level” beyond which the organism uses up its resources and is not able to produce more cortisol and
210 thereby mobilize glucose. De la Fuente et al. (2004) studied the effects of different stocking density in
211 rabbits of an average age of 60 days and an average weight of 1.85 kg. Those animals were transported in
212 normal crates at different densities (515 cm²/rabbit or 340 cm²/rabbit) and with different temperatures
213 (winter, 12 °C, summer 27 °C). Those authors evaluated some haematic parameters and/or activity (cortisol,
214 creatinin-kinase, lactdehydrogenase, lactate, glucose, osmolarity, albumins and globulins) but they found no
215 differences related with stocking density condition or temperature. The discrepancy between our results and
216 those data could be found in the relative short travel time in De la Fuente's work (1 h.20 min) as well
217 as to the different weight of the rabbits and the space allowance per kg of body weight, which were way
218 higher in this study. Furthermore, our results confirm this trend, as there is no significant difference between
219 HSA and MSA group.

220 Cortisol and glucose serum concentrations of all the experimental groups (HSA, MSA, LSA) were
221 similar in their trends, but presented a lower variation (increase) in winter rather than in summer when
222 compared with the C group. These results agree with those by De la Fuente et al. (2004): they found that
223 plasma concentration of cortisol and glucose was significantly higher in rabbits transported in summer than
224 those transported in winter. These seasonal differences in cortisol and glucose serum concentrations
225 probably depend on the higher transport temperature in summer. This could also suggest that besides
226 stocking density, in particular when the external temperature is high, rabbit welfare during transport should

227 be achieved with other strategies, such as good ventilation or air conditioning. In fact, as the outside and
228 inside lorry temperatures correlated highly (Lambooy, 1988), an adequate ventilation can maintain the
229 internal temperature close to the thermo-neutral zone (Collins, 1993).

230 Cortisol is a hyperglycemic inductor but, unlike glucagon, it acts not only on hepatic glycogen, but also
231 on muscular glycogen, accelerating protein catabolism. Its final effect lies in a loss of protein, particularly
232 from muscle, to give hepatic cells some substrates for glucose synthesis (gluconeogenesis). In fact, it
233 should be remembered that glycogen stores last for a short period that, in human, is almost 15 h. Rabbits
234 were fasted for 12 h before slaughtering, leading to two different consequences: the effective possibility of
235 the exhaustion of the body reserves, as hypothesized in our work, and a reduction in muscular protein
236 quality, in particular due to the meat acidification level that could be reached as a consequence of
237 biochemical post mortem phenomena (Jolley, 1990; Hulot and Ouhayoun, 1999). Another cause of
238 reduction in hepatic and muscular glycogen content could be the increase of energy demand in stressful
239 situations (Hulot and Ouhayoun, 1999; Warriss et al., 1999).

240

241 **5. Conclusions**

242

243 These observations lead to link transport welfare, as an ethic responsibility, to investigations on meat
244 quality and durability. Furthermore, the increase in stress levels evidenced by objective measurement of
245 blood parameters, demonstrates that animals welfare condition decreases with space availability.
246 Considering that we studied only 3 different space allowance levels, it is not possible to state which is the
247 limit not to be exceeded to avoid a state of distress in the animals. In medium space allowance level group
248 (MSA group), animals had an increment in cortisol and glucose (except for glucose during winter) that
249 seems to indicate that this level is beyond the limit of adaptation of the rabbits.

250 These results endorse those of a previous work of our group (Biscotto et al., 2007) on data reported in
251 animal welfare laws and results from other investigations.

252 In conclusion, our data indicate that different space allowance levels correspond to different stress
253 levels: a higher space availability reduces stress levels, that tend to increase with the space reduction. The
254 adaptation to the different conditions increases until a maximum level is reached; over this limit the
255 animal does not react because of the exhaustion of all resources. Finally, even if our data are not
256 exhaustive, we suggest not reducing the space availability for rabbits of 2,6-2,7 kg under 350 cm²/rabbit
257 for travels lasting more than 2 h.

258

259 **Disclosure statement**

260 No potential conflict of interest was reported by the authors.

261

262 **Funding information**

263 This study was supported by Università di Bologna (Galeati 2015–2016) (RFO).

264

265 **Ethical approval**

266 All applicable international, national, and/or institutional guidelines for the care and use of animals
267 were followed

268

269 **Acknowledgements**

270 We are grateful to Danilo Matteuzzi and Antonio Volgarino for their support in biological sample analysis.

271 We are grateful to Eleonora Petrucci for the English language check.

272 **References**

- 273 AATA, 2001. AATA Animal Transportation Association Manual for the Transportation of Live Animals
274 by Road, 2 ed. Animal Transportation Association, Surrey, England.
- 275 Batchelor, G.R., Giddins, G., 1995. Bodyweight changes in laboratory rabbits subjected to transport and
276 difference housing conditions. *Anim. Technol.* 46, 89–95.
- 277 Blokhuis, H.J., Keeling, L.J., Gavinelli, A., Serratos, J., 2008. Animal welfare's impact on the food chain.
278 A review. *Trends Food Sci. Technol.* 19, S79–S87.
- 279 Biscotto, A., Prodan, C., Milandri, C., 2007. Trasporto dei conigli, una proposta per il benessere. *Riv.*
280 *Coniglicoltura* 2, 10–14.
- 281 Broom, D.M., Goode, J.A., Hall, S.J.G., Lloyd, D.M., Parrott, R.F., 1996. Hormonal and physiological
282 effects of 15 h journey in sheep: comparison with the responses to loading, handling and penning in the
283 absence of transport. *Br. Vet. J.* 152, 593–604.
- 284 Broom, D.M., 2000. Welfare assessment and welfare problem areas during handling and transport. *Livest.*
285 *Handl. Transp.* 2, 43–61.
- 286 Collins, J.R., 1993. Welfare in transit. *Pig Vet. J.* 30, 23–29.
- 287 Coppings, R.J., Ekhaton, N., Ghodrati, A., 1989. Effects of antemortem treatment and transport on
288 slaughter characteristics of fryer rabbits. *J. Anim.* 67, 872–880.
- 289 Corese, M., 2005. Rapporto tra benessere animale e qualità della carne di coniglio. *Webzine Sanità*
290 *Pubblica Vet.* 33.
- 291 Dalle Zotte, A., Parigi Bini, R., Xiccato, G., Simionato, S., 1995. Proprietà tecnologiche e sensoriali della
292 carne di coniglio. *Riv. Coniglicoltura* 6, 33–39.
- 293 De La Fuente, J., Salazar, M.I., Ibanez, M., Gonzalez de Chavarri, E., 2004. Effects of season and stocking
294 density during transport on live weight and biochemical measurements of stress, dehydration and injury of
295 rabbits at time of slaughter. *Anim. Sci.* 78, pp. 285–292.
- 296 Fordham, D.P., Lincoln, G.A., Seswanyana, E., Rodway, R.G., 1989. Plasma β -endorphin and cortisol
297 concentrations in lambs after handling transport and slaughter. *Anim. Prod.* 49, 103–107.
- 298 Hulot, F., Ouhayoun, J., 1999. Muscular pH and related traits in rabbits: a review. *WorLSA Rabbit Sci.* 7,
299 15–36.
- 300 International Air Transport Association (IATA), 2005. *Live Anim.s Regulations*. 32nd ed.
- 301 Ibañez, M., De La Fuente, J., Thos, J., Gonzalez de Chavarri, E., 2002. Behavioural and physiological
302 responses of suckling lambs to transport and Lairage. *Anim. Welf.* 11, 223–230.
- 303 Jolley, P.D., 1990. Rabbit transport and its effects on meat quality. *Appl. Anim. Behav. Sci.* 28, 119–134.
- 304 Kola, J., Awosanya, B., Adebua, B.A., 1994. The effects of preslaughter withholding of feed and water
305 from rabbits on their carcass yield and meat quality. *Niger. J. Anim. Prod.* 21, pp. 164–169.
- 306 Lambertini, L., Giammarco, M., Vignola, G., 2004. Effetti dei trattamenti ante-mortem sulla qualità della

- 307 carne cunicola. Riv. Coniglicoltura 4, 18–21.
- 308 Lambooy, E., 1988. Road transport of pigs over a long distance: some aspects of behaviour, temperature
309 and humidity during transport and some effects of the last two factors. Anim. Prod. 46, 257–263.
- 310 María, G.A., 2006. Public perception of farm animal welfare in Spain. Livest. Sci. 103, 250–256.
- 311 National Research Council (US) Committee on Guidelines for the Humane Transportation of Laboratory
312 Animals, 2006. Guidelines for the Humane Transportation of Research Animals. Nat. Academies Press,
313 Washington (DC).
- 314 Regulation (EC) No 1/2005 of 22 December 2004, on the protection of animals during transport and related
315 operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97.
- 316 Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the
317 hygiene of foodstuffs.
- 318 Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down
319 specific hygiene rules for food of animal origin.
- 320 Regulation (EC) No 854/2004 of the European Parliament and of the Council of 29 April 2004 laying down
321 specific rules for the organisation of official controls on products of animal origin intended for human
322 consumption.
- 323 Swallow, J., Anderson, D., Buckwell, A., Harris, T., Hawkins, P., Kirkwood, J., Lomas, M., Meacham, S.,
324 Peters, A., Prescott, M., Owen, S., Quest, R., Sutcliffe, R., Thompson, K., 2005. Guidance on the transport
325 of laboratory animals. Lab. Anim. 39, 1–39.
- 326 Tamanini, C., Giordano, N., Chiesa, F., Seren, E., 1983. Plasma cortisol variations induced in the stallion
327 by mating. Acta Endocrinol. 102, 447–450.
- 328 Teke, B., Ekiz, B., Akdag, F., Ugurlu, M., Ciftci, G., Senturk, B., 2014. Effects of stocking density of
329 lambs on biochemical stress parameters and meat quality related to commercial transportation. Ann. Anim.
330 Sci. 14, 611–621.
- 331 Trocino, A., Xiccato, G., Queaque, P.I., Sartori, A., 2003. Effect of transport duration and gender on rabbit
332 carcass on meat quality. WorLSA Rabbit Sci. 11, 23–32.
- 333 Warriss, P.D., Knowles, T.G., Brown, S.N., Edwards, J.E., Kettlewell, P.J., Mitchell, M.A., Baxter, C.A.,
334 1999. Effect of lairage time on body temperature and glycogen reserves of broiler chickens heLSA in
335 transport modules. Vet. Rec. 145, 218–222.
- 336 Weeks, C.A., Webster, J., WyLSA, H.M., 1997. Vehicle design and thermal comfort of poultry in transit.
337 Br. Poult. Sci. 38, 464–474.
- 338 You, X., Li, Y., Zhang, M., Yan, H., Zhao, R., 2014. A survey of Chinese citizens' perceptions on farm
339 animal welfare. PLoS One 9, e109177.
- 340

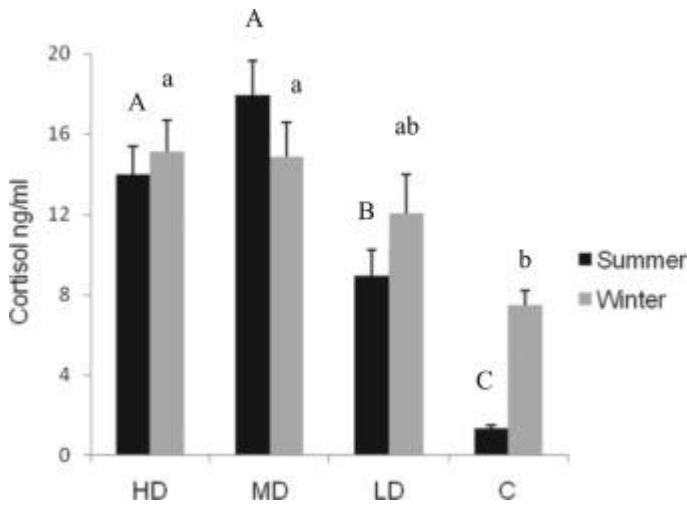


Fig. 1. Serum cortisol concentration (mean \pm SE) in control rabbits (C) and in animals transported at different densities: HD (high density), MD (mean density) and LD (low density) during summer (July) and winter (January). A, B = $P < 0.01$; a, b = $P < 0.05$ between groups in the same season.

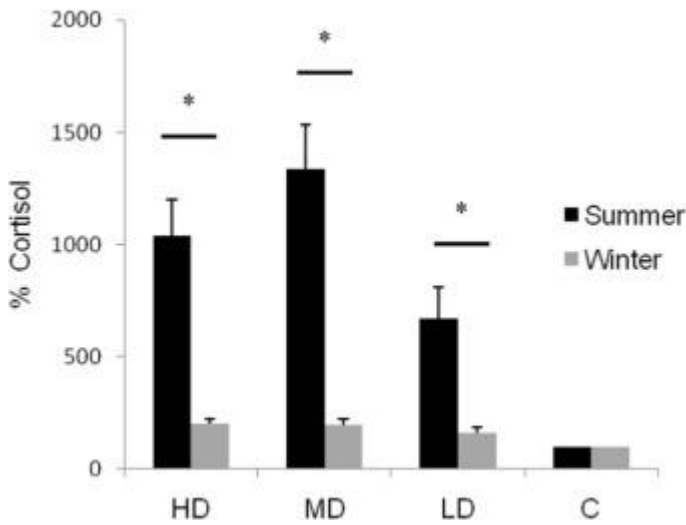


Fig. 2. Percentage changes of serum cortisol concentrations (means \pm SE) between control rabbits (C) (set equal to 100%) and those transported to slaughter at different densities (high density (HD), mean density (MD) and low density (LD)) during summer (July) and winter (January). * = $P < 0.01$.

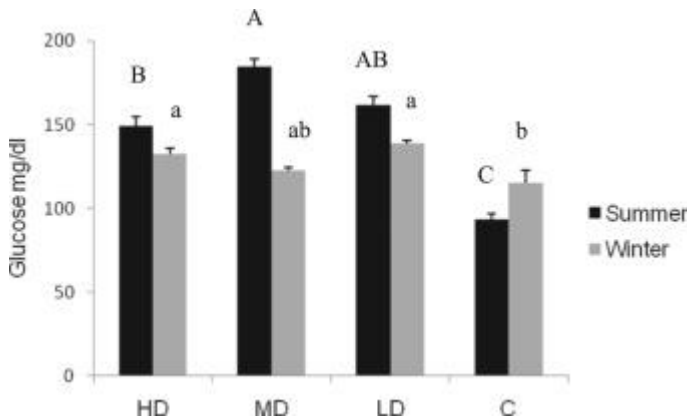


Fig. 3. Serum glucose concentration (mean \pm SE) in control rabbits (C) and in animals transported at different densities: HD (high density), MD (mean density) and LD (low density) during summer (July) and winter (January). A, B = $P < 0.01$; a, b = $P < 0.05$ between groups in the same season.

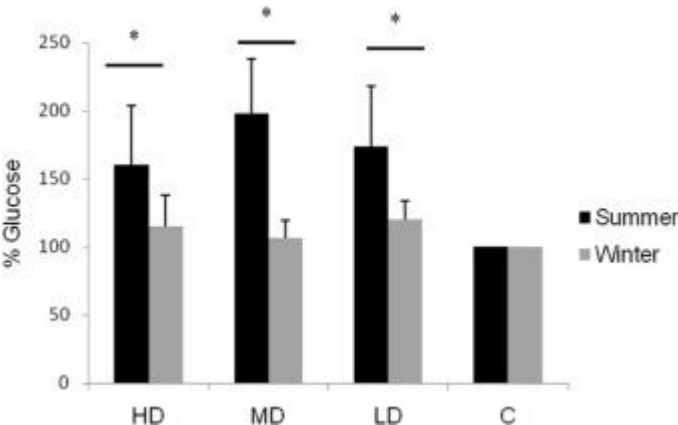


Fig. 4. Percentage changes of serum glucose concentrations (means \pm SE) between control rabbits (C) (set equal to 100%) and those transported to slaughter at different densities (high density (HD), mean density (MD) and low density (LD)) during summer (July) and winter (January). * = $P < 0.01$.