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EFFECT OF HOUSING SYSTEM (WIRE CAGE *VERSUS* GROUP-HOUSING) AND IN-HOUSE AIR QUALITY PARAMETERS ON THE BEHAVIOUR OF FATTENING RABBITS

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Abstract: In the same room of an experimental rabbit house 2 housing systems were compared, namely three pens to keep rabbits on bedding and six wire cages for unbedded rabbit keeping. In total, 69 New Zealand White crossbred rabbits 8-12 wk old were used in the study. The rabbits were kept in groups with 0.6 m^2 floor area per animal in pens with thinly scattered straw. Wire cages had no bedding and there were 4 rabbits in each cage and 0.4 m^2 floor area per rabbit. The study lasted for 8 wk. Rabbit behaviour was observed once 1 wk for 24 h. Behaviour was recorded using a scan sampling every hour. Results were analysed by calculating the percentage frequency of each behaviour. Behaviour analysis according to the keeping method indicated that rabbits kept on bedding spent on average less time resting and grooming (41.53 % and 5.18 % *vs*. 53.60 % and 8.48 %) and more time eating (29.86 % *vs*. 18.03 %, respectively) in comparison with those kept in wire cages. There was a statistically significant positive correlation between environmental temperature, illumination, ammonia and carbon dioxide gas concentrations and activity of rabbits.

Key Words: rabbits, behaviour, air quality, housing system.

INTRODUCTION

Mankind may have only minimal influence on the inborn behaviour of rabbits, as domestication had no significant effect on the species' evolution, and the behaviour of domestic rabbits is quite similar to that in the wild (Lebas *et al*., 1997). Nevertheless, most of the environmental factors can be controlled in many ways.

There are two conventional housing methods in rabbit breeding – rabbits are either kept in cages without (or with) bedding or group housed and bedded. Wire cage housing for rabbits is considered most economical and is more widespread (Morton *et al*., 1993), although each housing method has its advantages and disadvantages. When cage keeping without bedding is applied, rabbit excrements falls thought the bars without heaping, so the risk of coccidiosis is reduced. However, this housing method is most suitable for keeping specialised breeds such as New Zealand White and Californian rabbits, as heavier breeds rub their feet sore on the bars. When kept on straw bedding, rabbits have a warmer lying area, there is a lower influence of outside temperatures, yet constant contact with the manure increases the risk of coccidiosis. This housing method requires manure removal at least once a week.

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In addition to physiological, biochemical, biophysical and pathological factors that are important to animals, ethological or behavioural factors are also used to assess domestic animal welfare. However, there are no unanimous standards in the evaluation of different housing systems for farming animals.

As housing standards become stricter, it is important to estimate rabbit welfare factors and compare various housing systems by investigating rabbit behaviour and examining several factors that influence it. Animal behaviour studies allow an estimation of the quality of rabbit growing conditions, while investigating indirect environmental effects on the production quality. Currently used rabbit housing technologies should be revised by paying greater attention to animal welfare – space requirements per rabbit, cage height requirements and environment enrichment, such as platforms or hiding places for rabbits. Old housing methods might be reviewed (T-AP, 2008) as they could be affecting the behaviour specific to the species. One of the solutions to the problem is changing of the cage design by making all or part of the cages higher. Rabbit behaviour studies (Hansen and Berthelsen, 2000) indicated that cages improved in this way are more favourable as regards welfare than those of the ordinary design. However, the most favourable husbandry method could be group rabbit keeping in bedded spacious cages. It is possible that rabbit behaviour in group cages is close to rabbit behaviour under natural conditions. This is not always beneficial from an economic viewpoint (rabbits might become more sensitive to the environment changes and more fearful), yet positive aspects of this technology should completely compensate these as well as other drawbacks. In general, there is a dearth of scientific information on alternative rabbit housing technologies because these technologies are not yet widespread. Moreover, most rabbit behaviour studies were carried out with laboratory rabbits that are kept for purposes other than farming.

The aims of the study were to investigate the behaviour of rabbits in wire cages and in groups in bedded pens and determine relationships between rabbit behaviour and in-house air quality.

MATERIAL AND METHODS

The 69 rabbits used in the experiment were a crossbreed of New Zealand White and French Lop and were between 55 and 85 d old at the beginning of the observations. The rabbits were housed at the experimental rabbit house where in 1 room 2 housing systems were set up, comprising 3 pens to keep rabbits on bedding (total 45 animals, 15 animals per pen) and 6 wire cages for unbedded rabbit keeping (total 24 animals, 4 animals in each cage). Rabbits were kept in groups in the thinly scattered straw pens with 0.6 m^2 floor area per rabbit. Wire cages had no bedding. The floor area was 0.4 m^2 per rabbit. The wire cages were 50 cm in height, 130 cm width and 120 cm deep. The whole area of the rabbit house was 34.51 m^2. The room had natural ventilation through two openings of the windows. Rabbits were held under natural light/dark cycle (app. 16/8 h). Manure from wire cages was collected into metal trays placed below them and trays were cleaned every 7 d. Bedding from pens was removed every 7 d and clean bedding was added every day. Rabbits were held under natural light/dark cycle (app. 16/8 h). The animals were fed a pelleted diets to their needs based on their body weight and age. Hay and tap water were available *ad libitum*.

Rabbit activity during the 24 h period was recorded in relationship with in-house air quality. The study was carried out in July and August and lasted for 8 wk. Rabbit behaviour was observed once a week for 24 h. Behaviour was recorded using a scan sampling every hour. Video recording was performed using black and white video cameras FCH-25C with infrared searchlights IR-015. Video recorder was manufactured on 4-channel Framegrabber Euresys Picolo Diligent basis. The following behavioural elements were scored: sitting, resting, self-grooming, locomotion, eating, drinking. The amount of water consumed was recorded twice a day by weighing the water remaining in every pen and cage.

The total amount of microorganisms and the quantity of mould fungi and *E.coli* in air were determined by SAS Super 100 air sampling device (INTERNATIONAL PBI S.P.A., Italy) by cultivating the samples on

Meat Peptone, Levine and Sabouraud agar respectively. To define the total amount of bacteria and E.coli, samples were incubated for 24 h at 37ºC, for mould detection −48 h at 25ºC. The ammonia concentration was determined by Drager x-am 7000 device, CO_2 concentration, and temperature and air humidity by Almemo 2890-9 device. Dust concentration was determined by drawing measured volume of air (200 liters) through a paper filter (65 mm diameter, dried 24 h at 80ºC) mounted in a sampler. The mass of dust collected was determined by weighing the substrate before and after sampling, by the gravimetric method. Air velocity indoors was measured by kata-thermometer (an alcohol thermometer, with a wet bulb, which measures how quickly air is cooled) and outdoors by Almemo wing anemometer. In-house air measurements were taken once a week. Ammonia, carbon dioxide concentrations, temperature and humidity were recorded every hour in the 24 h period while concentrations of microorganisms and dust – every 6 h.

The behaviour and other data were analysed by TTEST two sample unpaired variance analysis. The significance of the correlation coefficient was determined from t-statistic and given as percentage point for the Student t-distribution.

RESULTS AND DISCUSSION

The 24-hour rabbit activity studies indicated that on average 62.58% of time was spent sitting and resting (inactive behaviour), with 22.0% for eating, 7.7% for self-body care, 5.5% for locomotion and 2.3% for drinking (Table 1). This is in agreement with the studies of Jordan *et al*. (2004) who found similar rabbit inactivity, drinking and comfort behaviour time, although the eating time in our study was higher (22% *vs*. 6.9-8.5%).

The highest number of eating rabbits was found at 7-10 p.m. Eating frequency registered at 4 p.m. was significantly different to those observed in the period 2 a.m. to 3 p.m., and at 5 p.m., 6 p.m., 11 p.m. and 0 a.m. The highest number of eating rabbits (45%) was determined at 8 p.m. and differences were statistically significant if compared with the other times, except for 1 a.m., 4 p.m., 7 p.m., 9 p.m. The highest number of drinking rabbits was also found at 8 p.m. (10%) although there were no significant differences in comparison with other periods. It is natural for rabbits to feed in the evening and at night, as this is the natural behaviour of wild rabbits (Hansen and Berthelsen, 2000). Domestic rabbits adjust themselves to the feeding regime, but if fed *ad libitum* they revert to the natural and specific 24 h feeding rhythm of wild rabbits (Gunn and Morton, 1995).

The largest number of rabbits resting was recorded at 3 a.m. (63.1%); later, the number decreased ($P<0.05$) and subsequently began to increase at 9 a.m. ($P<0.025$) until it reached the second highest number of 61.3% resting rabbits at 5 p.m. The lowest number of resting rabbits was recorded at 8 p.m. as at this time most of the rabbits were eating and drinking (54.7%). It can be seen that the rabbits were more active in the second half of the day or in the evening (from 6 p.m. till 2 a.m.). This is in agreement with the studies of Siloto *et al*. (2008).

Some of the rabbits were kept in pens on bedding and the others in wire cages. The behaviour analysis according to the keeping method (Table 1) indicated that rabbits kept on bedding spent on average less time resting and grooming and more time eating compared with those kept in the wire cages. These results partly coincide with the findings of Jekkel *et al*. (2008), who found that rabbits kept in wire cages used to rest and groom significantly more often than those kept on bedding, although there were no significant differences regarding locomotion and drinking.

In accordance with Jekkel *et al*. (2007), Silva *et al*. (2007), Siloto *et al*. (2008), the activity of the rabbits kept on bedding was higher than that of the rabbits kept on a wire net and this is in agreement with our findings. Other authors have also found that in enriched and more spacious cages, rabbits spent less time

Table 1: Behaviour of rabbits every 24 h and effects of floor type, percentage±standard error.

Activity	Sitting	Resting	Self-rooming	Locomotion	Eating	Drinking
Hours						
1	12.39±4.64	49.21±8.59	0.69±0.69	6.01±3.66	24.27±7.29	7.42±4.03
2	27.79±8.28	43.78±7.93	6.90±6.65	3.89±2.68	17.24±4.71	0.40±0.40
3	17.32±7.06	63.07±8.13	9.52±6.72	0.61±0.61	7.82±4.14	1.67±1.67
4	22.16±5.94	40.66±7.23	9.02±6.73	12.40±5.11	15.76±4.20	0.00
5	20.59±5.22	55.48±8.53	7.13±6.65	6.81±4.58	9.36±3.20	0.63±0.45
6	32.93±7.79	36.49±8.03	3.86±2.39	5.96±3.69	17.93±6.38	2.83±2.26
7	24.68±5.56	43.11±8.18	3.63±2.35	10.19±4.19	15.33±5.53	3.06±2.25
8	24.99±4.03	35.33±4.90	12.72±3.31	10.57±3.14	14.96±2.86	1.43±0.71
9	8.47±2.31	52.00±4.99	8.69±2.15	7.76±3.42	22.65±4.83	0.43±0.22
10	5.98±1.60	44.07±4.68	20.72±4.23	1.16±0.67	24.47±4.61	3.60±1.61
11	9.87±3.47	58.52±4.65	11.03±2.53	3.94±1.83	15.94±3.28	0.70±0.35
12	7.08±1.67	61.51±4.51	6.80±1.82	5.38±1.89	17.63±3.69	1.60±0.74
13	13.17±2.85	53.95±4.19	6.37±1.97	2.73±1.29	20.91±3.85	2.88±0.98
14	11.55±3.46	53.75±4.85	3.18±1.28	2.93±0.99	25.43±3.57	3.17±1.46
15	7.64±2.56	58.75±4.98	8.09±2.50	4.80±2.40	19.36±3.78	1.37±0.78
16	6.16±1.73	39.91±5.18	5.42±1.85	4.24±2.31	41.72±5.30	2.56±1.34
17	13.13±7.17	61.25±8.81	1.92±1.67	4.20±2.07	17.83±5.82	1.66±1.14
18	12.93±6.83	59.77±9.44	2.44±1.97	4.90±3.43	19.47±7.41	0.49±0.33
19	15.55±6.76	37.99±8.01	7.72±2.75	5.69±3.62	30.04±7.06	3.02±1.75
20	10.39±4.04	23.98±6.13	2.21±1.19	8.71±6.62	44.72±7.47	10.00±6.81
21	16.82±5.59	32.49±8.74	5.30±3.38	6.02±3.64	36.04±10.45	3.33±3.33
22	16.84±7.61	36.87±9.08	1.56±1.09	2.76±1.77	38.17±10.21	3.79±2.27
23	15.71±6.84	57.88±9.82	6.15±3.63	9.06±6.66	10.97±5.55	0.23±0.23
24	22.30±7.58	46.10±7.37	5.95±3.65	11.92±7.25	10.40±4.19	3.33±2.27
Total	13.49±0.87	49.09±1.32	7.66±0.67	5.46±0.61	22.03±1.10	2.27±0.33
Floor type[1]						
Wire net	12.60±1.15	53.60±1.70*	8.48±0.92*	4.92±0.80	18.03±1.35*	2.36±0.45
Litter	14.87±1.02	41.53±1.65	5.18±0.57	6.53±0.76	29.86±1.60	2.03±0.29

[1] Floor type: Wire net (No=24) and litter (No:45).
* Differences between housing (floor type) in the column P<0.05.

on comfort behaviours than in conventional cages (Hansen and Berhelsen, 2000, Siloto *et al*., 2008). However, contrary to our findings, Jekkel *et al*. (2007, 2008) recorded higher eating frequency for the rabbits kept on a wire net than on bedding. These opposite findings are partly due to the fact that eating frequency did not include bedding eating. In our study, bedding eating was recorded together with food eating. However, even knowing the fact that rabbits willingly eat the bedding, it is only logical to assume that higher activity of the rabbits kept on bedding required more energy and, consequently, resulted in more frequent eating. Moreover, bedding seems to be insufficient for improvement of rabbit welfare and

Table 2: Air quality parameters in the rabbit house

	9 a.m.		3 p.m.		9 p.m.		3 a.m.	
	Indoors	Outdoors	Indoors	Outdoors	Indoors	Outdoors	Indoors	Outdoors
Air temperature, ºC	21.58±0.08	20.56±0.16	21.94 ±0.07	22.88±0.13	21.68 ±0.06	19.36±0.11	21.30±0.06	15.83±0.08
Relative air humidity, %	72.16±0.28	72.09±0.65	67.26±0.39	60.27±0.64	73.07±0.29	70.32±0.60	75.70±0.18	79.75±0.41
NH3 concentration, ppm	6.38±0.53	-	6.44±0.63	-	4.00±0.41	-	4.00±0.41	-
CO2 concentration, ppm	550±27	324±8	659±34	312±12	498±56	352±22	487±60	331±31
Air velocity, m s^{-1}	0.04±0.002	1.86±0.27	0.072±0.015	2.15±0.33	0.040±0.000	1.11±0.53	0.057±0.008	0.63±0.56
Light, l×	204±46	29358±791	59±46	29408±741	30±3	2672±1144	33±6	0
Dust concentration, mg m^{-3}	18.05±5.12	10.92±1.88	15.66±5.03	16.00±4.98	8.47±1.83	10.04±2.00	9.63±2.04	7.84±1.72
TBC concentration, thous. CFU m^{-3}	35.30±8.01	0.65±0.20	49.22±7.32	2.21±1.25	26.63±8.07	1.55±1.05	28.45±8.73	1.38±0.94
E.coli concentration, CFU m^{-3}	230.00±34.99	50.00±0.02	289.00±87.06	51.00±14.56	292.50±43.08	10.00±4.08	278.60±41.23	41.00±6.13
Mould concentration, 10^3. CFU m^{-3}	2.99±0.86	1.32±0.41	3.98±2.67	1.12±0.37	1.09±0.28	0.57±0.34	1.24±0.32	0.58±0.39

more measures such as increased space, equipment with wooden constructions, heightened platforms, etc. could be important. More frequent grooming or other stereotypical behaviours also lower total activity of the rabbits kept in conventional wire cages, which is considered to be an indication of stress (Morton *et al*., 2003). In our study, the space allowance per rabbit kept on a bedding was higher (0.6 *vs*. 0.4 m^2) and the total area was greater than that in wire cages. Both higher functional space and space per rabbit could have resulted in higher rabbit activity and this is consistent with the findings of Verga *et al*. (2004) and Zucca *et al*. (2008).

The amount of water consumed daily per rabbit was on average 213.1±7.21 g. The rabbits kept in cages on wire net drank a daily average of 250.65±8.90 g water each, while those kept in bedded pens drank 130.85±4.93 g water each daily on average. The difference was statistically significant ($P<0.001$). It is unclear why water consumption led to a distinction between research groups. Since the rabbits were watered from an open dish-type drinkers, it may be that the rabbits kept in the cage and having little space simply spilled more water out. Besides, the drinking frequency of caged rabbits was slightly higher compared to rabbits kept in the scattered straw pens. The average water consumption recorded in our study is in agreement with the literature data indicating that water consumption by 6 to 18 wk old New Zealand rabbits amounts to 153-297 g daily (Lebas *et al*., 1997).

The analysis of the in-house air quality data (Table 2) indicates that all the environmental parameters were within standard limits (Marai and Rashwan, 2004) and typical of the warm season.

Statistically significant correlation was determined only between the level of mould concentration in the rabbit house air and air temperature (0.76; $P=0.001$) and humidity (−0.73; $P=0.002$). Positive correlation with the temperature is natural and coincides with the results of other studies (Ribikauskas and Vaičionis, 2008). However, negative correlation with the air humidity does not look typical, as it is expected that the higher the humidity in the premises, the higher the level of mould concentration will be (Singh, 2005). In our study, this discrepancy may have been due to the higher influence of indirect factors. For example, higher air velocity reduces air humidity, yet relatively more intensive air streams raise more dust from the floor, feed and bedding. At the same time, mould concentration in the air increases with the dust flow. This is partly confirmed by a positive (though statistically insignificant) correlation between mould concentration and dust level in the air (0.49; $P=0.07$). Similar correlation between air humidity and mould concentration (−0.75; $P<0.05$) was obtained in the other studies with ducks (Ribikauskas *et al*., 2008). Thus, a natural trend can be observed – the higher the level of dust in the air, the higher the mould concentration.

There was another, even higher positive correlation between total bacterial count and *E.coli* (0.43; $P=0.11$). This is also natural because total bacterial count includes, among other bacteria, *E.coli*. The proportion of *E.coli* bacteria compared to the total bacterial count was 0.65%. All the other correlations were low and no significance was found. Low correlation values between various air quality parameters might have been the results of comparatively small room for rabbit keeping where the microenvironment most probably was not as stale as in more spacious stables.

The correlation between air quality parameters and rabbit activity is shown in Table 3. There was a statistically significant positive correlation between ambient temperature, illumination, ammonia and carbon dioxide gas concentrations and rabbit activity. The influence of temperatures and illumination on rabbit behaviour was shown in the study by Sility *et al*. (2008). In our study, they were influenced by external factors and corresponded to the daily rhythm. In the daytime, both temperature and natural illumination change regularly, and these results therefore illustrate the fact that the rabbits' behaviour follows the diurnal rhythm. Meanwhile, ammonia and carbon dioxide emission is the result of rabbit

Table 3: Correlations (r) between air quality parameters and rabbit behaviour activities (number between brackets).

	Sitting		Resting		Eating		Self-grooming		Locomotion	
	r	*P-value*	r	*P-value*	r	*P-value*	r	*P-value*	r	*P-value*
Temperature (24)	0.60	0.00	0.27	0.20	−0.22	0.30	−0.80	0.00	0.70	0.00
Humidity (24)	−0.20	0.36	−0.15	0.49	0.45	0.03	−0.17	0.42	0.11	0.60
Dust (6)	0.29	0.57	0.32	0.53	−0.65	0.16	0.45	0.37	0.66	0.15
Air velocity (6)	−0.27	0.61	0.57	0.24	−0.30	0.56	0.31	0.25	−0.68	0.14
Light (24)	0.59	0.00	−0.11	0.61	−0.72	0.00	0.18	0.40	−0.04	0.85
NH_3 (24)	0.74	0.00	0.25	0.23	−0.60	0.00	−0.50	0.01	0.47	0.02
CO_2 (24)	0.25	0.24	0.24	0.25	−0.10	0.63	−0.49	0.02	0.53	0.00
TBC (6)	0.14	0.80	0.38	0.46	−0.53	0.28	0.05	0.93	0.29	0.57
E. coli (6)	0.25	0.63	−0.36	0.48	0.14	0.79	0.37	0.46	0.78	0.07
Mould (6)	0.02	0.97	0.33	0.52	−0.19	0.72	−0.43	0.39	−0.54	0.27

physiological activity, and the higher it is, the higher the parameters are, especially for carbon dioxide. The negative correlation between temperature and grooming can be explained as the stress indicator of worse conditions (Morton *et al*., 1993). In our study, it is difficult to explain the negative correlation between ammonia and carbon dioxide and grooming.

CONCLUSIONS

Housing significantly affected the behaviour of some rabbits. Housing in pens resulted in higher rabbit activity in comparison with keeping in wire cages. This might indicate a better satisfaction of rabbit behavioural needs when they are on bedding. Rabbit activity changed in the course of 24 h – it was higher in the second half of the day and lower at night.

Air temperature, carbon dioxide concentration were higher at 9 a.m. 3 p.m. and 9 p.m. than at 3 a.m., while ammonia, dust, mould concentrations, total bacterial count in the air, air velocity were higher at 9 a.m. and 3 p.m. than at 9 p.m. The correlation between mould concentration in the air and air temperature and humidity in the rabbit house was determined. There was a statistically significant positive correlation between environmental temperature, illumination, ammonia and carbon dioxide gas concentrations and rabbit activity.

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