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Effect of type of housing on veal calf growth performance, behaviour and meat quality

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Abstract

A study compared the traditional housing of veal calves in individual crates (IC) with group pen housing (GP). Thirty-four pure Holstein male calves (67.6±4.9 kg LW) imported from Poland were used, of which 16 were kept tethered in IC while the remaining animals were housed in six pens of three calves each. The growth trial lasted 142 days during which the calves were fed only a milk replacer diet. Calves health, average daily gain (ADG) and feed efficiency (FE) were similar between types of housing throughout the trial. However, GP calves had higher ADG (1387 vs. 1317 g/day; $P<0.05$) and better FE (1.83 vs. 1.94; $P<0.05$) than IC calves in the last 72 days of the trial. Behavioural measurements were taken at the 10th week of the study. The GP calves were allowed to adopt more comfortable resting postures and displayed increased social behaviour than the IC calves. Haemoglobin in samples taken at the end of the growing cycle was higher in GP than in IC calves (10.9 vs. 7.7 g/100 ml; $P<0.01$). At slaughter, the dressing percentage was unaffected by the housing system, but GP calves showed a better carcass conformation than IC calves. Meat quality evaluation was carried out on the *Longissimus thoracis* muscle. The meat of GP calves had lower intramuscular fat content (3.92 vs. 6.85% DM; $P<0.01$) and showed a better tenderness and flavour than that of the IC calves. Consistent with the haemoglobin data, the calves reared in group pens produced carcasses and meat with a darker colour than calves in individual crates.

Keywords: Veal calves; Housing system; Behaviour; Weight gain; Meat quality

1. Introduction

In the traditional veal calf rearing system, the animals are kept in individual, narrow and short crates, and receive a liquid milk replacer with low iron content up to 6 months of age. Isolation and reduced space allowance are considered the main constraints of this housing system on calf behaviour and welfare (Ketelaar-de Lauwere and Smits, 1991; Le Neindre, 1993).

Veal calf behaviour is improved by housing in group pens (Broom, 1991). However, keeping calves together can increase the possibility of cross contamination and the spreading of diseases (Steenkamer, 1982), as shown in many studies where group pen calves had a higher mortality rate and incidence of diseases than control animals kept in individual crates (de Wilt, 1985; Tomkins, 1991; Webster, 1991).

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The adoption of group pen housing should also consider the quality control of production. With regard to this, the literature is mainly focused on growth performance (de Wilt, 1985; Smits and de Wilt, 1991) whereas limited information are available on slaughter traits and meat quality.

In the present study, behaviour, growth, slaughter performance and meat quality of veal calves housed in group pens were compared with those of animals reared in the traditional individual crates.

2. Materials and methods

Thirty-four pure Holstein male calves imported from Poland were used in the study. The animals arrived at the experimental unit at 8–10 days of age and for an adaptation period of 30 days were housed in individual crates to allow more careful control by the stockman. During adaptation and the following experimental period, the calves were fed a milk replacer based on sprayed skimmed milk powder (Table 1), without receiving any other feed or supplement. The daily dose of the milk replacer was delivered in two equal meals, at 07:00 and 17:00 h and, based on the age of the calves, the daily amount and powder concentration of the milk were increased throughout the fattening period.

Table 1
Feed and chemical composition of the milk replacer

Feed composition (% as fed):	
Skimmed milk powder	45.0
Fat[a]	22.0
Whey powder	11.0
Cereals	8.0
Whey albumin	6.5
Soybean protein concentrate	6.0
Mineral-vitamin supplement[b]	1.5
Chemical composition:	
Dry matter (%)	94.4±0.1
Crude protein (% of DM)	24.4±0.5
Ether extract (% of DM)	21.5±1.5
Crude fibre (% of DM)	0.4±0.1
Ash (% of DM)	6.4±0.2
Iron (ppm)	15.2±1.0

[a]Tallow, coconut oil and lard.
[b]Supplementation per kg: vit. A 23 000 UI; vit. D_3 6000 UI; vit. E 32 mg; vit. C 100 mg; vit. B_1 2 mg; vit. B_6 3 mg; vit. B_{12} 0.01 mg; vit. PP 50 mg; Cu 10 mg; Mn 13 mg; Zn 15 mg; Co 0.2 mg.

2.1. Growth measurements

At the end of the adaptation period, the calves were weighed and assigned to two experimental groups of the same average body weight (Table 2). Sixteen calves were housed in 0.6 × 1.4 m individual wooden crates tethered to the feeding gate. The crates had wooden slatted floors and slatted partitions which allowed visual contact between neighbouring calves. Eighteen animals were confined to six pens of three calves each, with 1.5 m^2/calf of space allowance. The pens were made of wood with a slatted floor, and they were located in front of the crates in a single closed barn.

The animals were weighed at the beginning, after 70 days and at the end of the experimental period, which began at about 40 days of calves age and lasted 142 days. Individual intake of milk replacer DM was recorded daily and the feed efficiency was calculated as DM intake/daily gain ratio. The day before slaughter, all calves were bled by jugular vein puncture before the morning meal and blood samples were analyzed for haemoglobin and packed cell volume (PCV) according to the procedure of the International Committee for Standardization in Haematology (1967).

2.2. Behavioural measurements

Calf behaviour was recorded at the 10th week of the experimental period by video cameras mounted on the ceiling and connected to a time lapse video cassette recorder. Behavioural observations were carried out simultaneously on eight calves housed in crates and on six calves of two group pens randomly chosen within each treatment. The calf behaviour was video-recorded for 2 consecutive days from 08:00 to 20:00 h. The videotapes were then replayed in the lab and individual behavioural measurements were taken every 15 min with the Scan Sampling recording method (Martin and Bateson, 1993) excluding the 30 min of the afternoon milk delivery (17:00–17:30 h).

The data collected at each scan considered three behavioural categories: (1) head position, (2) body and legs position, and (3) type of activity. Prior to data collection, specific behavioural patterns were defined for each category referring to the veal calf ethogram reported by Gottardo et al. (1997).

Head positions were recorded as follows:

- head turned back while the calf is standing or lying down;
- head laid on the partition with recumbent calf;
- head laid forwards on the floor with recumbent calf;
- head up, turned to another calf while the animal is standing or lying down;
- head up, turned to a specific object while the animal is standing or lying down;
- head up, without specific occupation while the animal is standing or lying down.

Body and legs positions considered:

- standing still;
- standing and moving;
- lying with all legs bent;
- lying with all legs outstretched;
- lying with one fore and two hindlegs outstretched;
- lying with the hindlegs outstretched;
- lying with one or two forelegs outstretched;
- lying with one foreleg and one hindleg outstretched;
- lying with one hindleg outstretched.

The type of activity was recorded as follows:

- licking and/or smelling;
- touching another calf;
- sham ruminating;
- tongue playing;
- self-grooming;
- scraping an object;
- totally inactive.

2.3. Slaughter measurements and meat quality evaluation

At slaughter, individual dressing percentage was measured and all carcasses were graded for conformation (EUROP) and fatness adopting for both evaluations a 15-point scale as suggested by the Italian Scientific Association for Animal Production (Associazione Scientifica di Produzione Animale, 1989). The scales were obtained by subdividing in three subclasses each of the five main classes of conformation (P–E) and fatness (1–5). An evaluation of carcass colour was made by observing the visible external muscular tissue, adopting the following three-point scale: 1 = white, 2 = pink and 3 = red.

The right half-carcass of all calves was dissected 48 h after slaughtering to separate lean, fat and bones. A sample joint of *Longissimus thoracis* muscle, taken between the 5th and 9th rib of each carcass, was vacuum packed and stored at 2°C for 5 days to assess veal meat quality.

Meat chemical analysis considered pH, moisture and the intramuscular fat extracted in Soxhlet apparatus (Association of Official Analytical Chemists, 1990). Meat colour was measured by CR 100 Chromameter (Minolta, Camera Co. Ltd, Japan) equipped with C illuminant on samples exposed for 1 h to air at 2°C. Colour data were expressed in the Hunter-Lab system (Boccard et al., 1981). Cooking weight losses were determined on 2.5-cm-thick steaks after the heating procedure suggested by Boccard et al. (1981). The instrumental measurement of veal meat tenderness was done using a Warner–Bratzler shear meter on cylindrical cores of cooked meat (Joseph, 1979).

Sensory assessment of meat quality was carried out by a taste panel according to the guidelines of the American Meat Science Association (1978). A steak, 1.9-cm thick, was cooked in an electric oven at 165°C until the meat core reached the temperature of 70°C and then cut into 1.3 cm^2 pieces, which were immediately offered to the panellists. Sensory evaluation of meat tenderness, juiciness and flavour was assessed adopting a five-point scale: 1: undesirable–5: extremely desirable.

2.4. Statistical analysis

Live weight, growth performance, feed efficiency, blood parameters, slaughter measurements and meat quality experimental data were submitted to one-way ANOVA (SAS, 1991) adopting the following model:

$$Y_{ij} = \mu + H_i + e_{ij}$$

where Y_{ij} = single observation on the jth calf under ith housing system, μ = population mean, H_i = effect of housing system (i = 1,2), e_{ij} = random residual.

Behavioural data were expressed as frequency by dividing the number of occurrences of each behavioural pattern by the total number of occurrences recorded within the category on the 2 observation days. The normal distribution of the dataset was verified with the Shapiro–Wilk test (SAS, 1991), which showed satisfactory values ($W > 0.9$) for all the behavioural patterns considered. Data were then subjected to one-way ANOVA using the same statistical model previously described.

3. Results and discussion

3.1. Growth performance

None of the calves was culled during the experimental period and the animals of both housing systems did not receive any treatment for gastrointestinal disorders and respiratory diseases.

In agreement with previous studies (de Wilt, 1985; Smits and de Wilt, 1991), calves daily gain throughout the experimental period was not significantly affected by the housing system and resulted as 1211 g/day on average (Table 2). However, a higher daily gain was measured for group pen calves in the second part of the experimental period (1387 vs. 1317 g/day; $P < 0.05$) as a result of better feed efficiency (Table 2). Blood haemoglobin and PCV, measured at the end of the experimental period, were higher in group pen calves (Table 3) and this result could explain the better feed efficiency and thus the better growth performance shown by these animals. Previous studies (Roy et al., 1964; Bremner et al., 1976) showed reduced growth rates for veal calves with haemoglobin levels below 7.0 g/100 ml. In the present research, four calves all kept in individual crates had haemoglobin levels below this threshold at the end of the fattening period. The restriction of movement forced by the individual crates could have caused the lower haemoglobin and PCV levels observed for calves reared with this housing system. The stimulus for erythropoiesis is reduced by persistent locomotory inactivity (Guyton, 1974) whereas, according to Reece and Hotchkiss (1987), the freedom of movement allowed by an increased space allowance may be sufficient for stimulating erythropoiesis in the calf. The same authors reported anaemia and reduced daily gains only in calves that

Table 2
Effect of the housing system on veal calves growth performance during the experimental period

	Housing system		R.S.D.	Stat.
	Individual crate	Group pen		
Live weight (kg):				
Beginning of the trial	68.3	67.0	5.0	n.s.
At 70 days	143.6	140.9	8.0	n.s.
End of the trial	238.4	240.7	12.4	n.s.
Average daily gain (g/day):				
0–70 days	1076	1055	73	n.s.
71–142 days	1317	1387	102	*
Whole trial	1198	1223	78	n.s.
Dry matter intake (g/day):				
0–70 days	1587	1584	24	n.s.
71–142 days	2531	2524	35	n.s.
Whole trial	2066	2060	25	n.s.
Feed efficiency (g of DM/g of gain):				
0–70 days	1.49	1.51	0.10	n.s.
71–142 days	1.94	1.83	0.13	*
Whole trial	1.73	1.69	0.10	n.s.

n.s., $P > 0.10$, $*P < 0.05$.

Table 3
Effect of the housing system on veal calves haemoglobin and packed cell volume

	Housing system		R.S.D.	Stat.
	Individual crate	Group pen		
Haemoglobin (g/100 ml)	7.7	10.9	1.4	**
Packed cell volume (%)	23.6	32.9	4.0	**

**$P<0.01$.

were housed in narrow crates and not in calves with freedom of movement in more spacious pens. Fisher et al. (1985) reported lower daily gains and less favourable feed efficiency for post-weaned calves housed in narrow individual pens (0.66×1.48 m) than for animals kept in wider individual pens (1.36×1.48 m).

3.2. Behavioural observations

Behavioural differences between individual crate and group pen calves were observed from the measurements taken at the 10th week of the experimental period (Table 4).

The calves housed in group pen had an increased

Table 4
Effect of the housing system on veal calves behaviour (percentage frequency of each behavioural pattern within category)

	Housing system		R.S.D.	Stat.
	Individual crate	Group pen		
1. Head positions:				
Head turned back[a]	16.4	17.7	11.2	n.s.
Head laid on the partition[b]	1.0	4.5	3.3	*
Head laid forwards on the floor[b]	1.0	2.3	3.3	n.s.
Head up, turned to another calf[a]	0.2	10.2	3.4	**
Head up, turned to a specific object[a]	28.5	22.1	6.3	†
Head up, without specific occupation[a]	52.9	43.2	13.0	n.s.
2. Body and legs positions:				
Standing still	26.8	28.9	4.4	n.s.
Standing and moving	1.0	0.5	1.3	n.s.
Lying with all legs bent	41.8	26.6	13.1	**
Lying with all legs outstretched	0.0	1.3	1.1	**
Lying with one fore and two hindlegs outstretched	1.8	4.7	4.2	*
Lying with the hindlegs outstretched	3.3	2.9	4.6	n.s.
Lying with one or two forelegs outstretched	2.3	4.7	5.1	n.s.
Lying with one foreleg and one hindleg outstretched	2.3	4.7	4.5	n.s.
Lying with one hindleg outstretched	20.7	25.8	8.8	*
3. Type of activity:				
Licking and/or smelling	20.7	17.5	4.9	n.s.
Touching another calf	0.2	12.2	3.2	**
Sham ruminating	1.9	5.1	3.2	*
Tongue playing	5.1	2.6	1.9	*
Self-grooming	6.5	2.9	2.5	*
Scraping an object	0.0	0.3	0.6	n.s.
Totally inactive	65.6	59.4	7.2	n.s.

n.s. $P>0.10$, †$P<0.10$, *$P<0.05$, **$P<0.01$.
[a]Calf is standing or lying down.
[b]Calf is lying down.

opportunity to perform some social behaviour as shown by their head position, which was more frequently turned towards other animals. On the contrary, the calves in crates spent more time with their head turned towards specific objects such as the floor slats or the feeding gate. These animals were tethered but this did not limit their head positions and their possible contacts with the neighbouring animals.

According to previous studies by Dellmeier et al. (1985) and Albright et al. (1991), there was no difference between the two housing systems in the time spent standing or lying down. However, the calves in crates spent more time lying with all legs bent (Table 4). The calves kept in group pens more frequently adopted resting postures with one or more legs outstretched, which are considered more 'natural' and therefore comfortable (Ketelaar-de Lauwere and Smits, 1991). Regarding the group pen, it must be pointed out that the space allowance used in the present study was still below the recommended limit of the most recent European Council Directive (97/2/CE) which suggests a space allowance of 1.8 m^2 for calves weighing more than 220 kg.

Comparisons among crates of different sizes carried out in previous studies on veal calf housing (de Wilt, 1985; Le Neindre, 1993) reported a significant decrease in time spent lying with legs stretched away from the body when animals were kept in crates less than 0.75 m wide. The present study, where crate width was 0.60 m, confirmed this previous finding.

There were significant differences between crate and group pen animals in the frequency of certain activities carried out during the observation period, as shown in Table 4. In comparison with the individual crate, group pen calves had more opportunities for social interactions touching each other with more frequency. Tethered calves in crates tended to address their attention more to the surrounding environment or to themselves (Table 4).

Rushen (1994) considers oral stereotypies in veal calves more a reflection of the feeding plan than of the housing system. However, the results of the present study suggest that the type of housing can modify the oral behaviour of calves fed only a milk replacer. When space allowance and freedom of movement were not limiting factors, as in the group pen housing, the oral activity showed the increase of the sham rumination (Table 4), as a likely indicator of the absence of roughage in the diet. In comparison with the group pen, tethering, isolation and other restrictions caused by the use of narrow crates increased tongue playing, which is certainly a more abnormal oral behaviour in the bovine species and, according to Fraser and Broom (1990), it could be controlled by the provision of freedom of movement.

3.3. Slaughter measurements and meat quality evaluation

At slaughter, carcass weight and dressing percentage were not affected by the housing system, whereas a significant difference was found for the carcass evaluation (Table 5). Carcass EUROP score was higher in calves housed in group pen than for those in individual crates but this result was not confirmed by an increased proportion of muscle tissue on total carcass composition. Despite the limited number of animals used in the study, it is likely that the better conformation of group pen carcasses may have arisen from a more pronounced hypertrophy of the muscle directly involved in locomotion. This hypothesis is supported by the results of a previous study by Aalhus and Price (1990b) on the effects of locomotion on carcass growth and development in sheep. In comparison to the control animals, exercised sheep did not show any change in the proportion of muscle, fat and bone on total carcass composition, but they increased significantly the proportion of muscle in the proximal pelvic limb.

The carcass colour of the group pen calves was classified as 'pink' while that of the animals in crates was paler (Table 5). In agreement with this evaluation and with the blood haemoglobin (Table 3), colour measurements taken on the *Longissimus thoracis* muscle showed less redness and yellowness and greater lightness in the meat produced by the calves reared in individual crates (Table 6). Therefore, based on colour characteristics, this meat was considered more acceptable for the market.

Carcass separable fat was similar between housing systems (Table 5), while the chemical determination of intramuscular fat on *Longissimus thoracis* muscle showed a lower content in the group pen calves. Intramuscular fat is classified as one of the late

Table 5
Effect of the housing system on veal calves slaughter traits

	Housing system		R.S.D.	Stat.
	Individual crate	Group pen		
Slaughter live weight (kg)	240.1	242.2	11.6	n.s.
Warm carcass weight (kg)	143.1	145.6	8.0	n.s.
Dressing percentage (% live weight)	59.6	60.1	1.7	n.s.
Carcass evaluation (scores):				
EUROP[a]	6.6	8.2	2.2	*
Fatness[b]	6.1	5.8	1.2	n.s.
Colour[c]	1.1	1.9	0.6	**
Half carcass composition (%):				
Meat	67.7	68.0	1.6	n.s.
Fat	14.2	13.6	1.3	n.s.
Bone	18.1	18.4	0.9	n.s.

n.s. $P>0.10$, *$P<0.05$, **$P<0.01$.
[a]15-point EUROP scale: 1 = P− (minimum) . . . 15 = E+ (maximum).
[b]15-point fatness scale: 1 = 1− (minimum) . . . 15 = 5+ (maximum).
[c]Three-point scale: 1 = white; 2 = pink; 3 = red.

Table 6
Effect of the housing system on veal calves meat quality

	Housing system		R.S.D.	Stat.
	Individual crate	Group pen		
Chemical traits:				
pH	5.49	5.50	0.04	n.s.
Moisture (%)	75.8	75.3	0.8	n.s.
Ether extract (%DM)	6.85	3.92	1.85	**
Colour:				
Lightness (L)	56.4	54.5	3.5	n.s.
Redness (aL)	10.3	12.4	1.9	**
Yellowness (bL)	8.1	9.2	1.1	**
Cooking weight losses (%)	32.0	29.9	1.7	**
Shear force (kg/cm^2)	3.47	3.02	0.76	†
Sensorial measurements (scores)[a]:				
Tenderness	3.56	3.99	0.49	*
Juiciness	2.94	2.90	0.32	n.s.
Flavour	3.04	3.34	0.30	**

n.s. $P>0.10$, †$P<0.10$, *$P<0.05$, **$P<0.01$.
[a]Five-point scale: 1 = undesirable; 2 = little desirable; 3 = medium desirable; 4 = highly desirable; 5 = extremely desirable.

developing fat deposits in bovine species (Cianzio et al., 1985). Its lower deposition in calves with freedom of movement might be explained by the increased energy demand for locomotion and for the higher gain (Table 2). In the animals reared in crates, factors limiting muscle growth such as the haemoglobin level and the lack of locomotion likely shifted the available energy for growth towards an earlier intramuscular fat deposition. The energy content of the unit of gain in the last part of the growing cycle was therefore lower for calves in group pens than that of calves in crates. This would justify the more favourable feed efficiency measured for group pen animals in the second half of the experimental period (Table 2).

The meat of the group pen calves showed reduced cooking losses (Table 6) and despite its lower marbling was considered more tender and tasty by the panel. Low correlation between intramuscular fat content and meat flavour ($r=0.20$) and tenderness ($r=0.06$) were reported by Andreoli et al. (1994) in a previous study on veal meat quality. Johnson et al. (1992) found a higher correlation ($r=0.44$) between muscle pigment and flavour, suggesting that, as total pigment of veal meat increases, the flavour becomes more intense.

Regarding tenderness, the positive judgement of the panel on the meat produced by the calves in group pen was confirmed by the results of the shear force (Table 6). The positive effect of the group pen housing on veal meat tenderness should arise from the locomotion allowed by this housing system. Results of previous studies carried out on sheep (Aalhus and Price, 1990a) and pigs (Essén-Gustavsson et al., 1988) support this hypothesis without giving a clear explanation of how locomotion can improve meat tenderness. However, muscle hypertrophy and collagen properties were considered as the major factors involved.

4. Conclusions

The results of the present study advise the adoption of the group pen as an interesting alternative for the individual narrow crate in the housing of the veal calves from about 40 days of age. The increased space allowance and freedom of movement allowed by the group pen improved veal calf welfare as shown by both behavioural measurements and growth performance.

Group pen calves had the opportunity for locomotion and social behaviour and were allowed to adopt more comfortable resting postures. The improved welfare of the calves kept in group pens was confirmed by the higher haemoglobin levels at the end of the growing cycle. However, the consequent darker colour of the meat did not meet consumer preference, despite the better tenderness and flavour.

The results obtained in the present study with the individual crates were not satisfactory from an ethological and productive point of view and supported their future substitution with group pens.

Further studies on group pen housing are required to discover suitable rearing techniques which are able to reduce the negative effect on veal meat colour.

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