Archiv Tierzucht 56 (2013) 49, 509-517

Open Access

Original study

The effect of the design of housing systems for calves on the microclimatic conditions of the rearing environment

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Abstract

The objective of this study was to compare microclimatic conditions in three different housing systems designed for calf rearing – individual wooden hutches, individual tarpaulin hutches and individual pens under shelter – and to evaluate the thermal comfort of calves reared in these systems. Air temperature, relative air humidity and the rectal temperature of calves (n=324) were measured in the hutches and pens during three consecutive years. The hypothesis that the climatic conditions of different housing system designs used in calf rearing affect the thermal comfort of calves was confirmed, as the design of the individual housing systems affected microclimatic conditions and subsequently the rectal temperature of the housed calves as well. Statistically significant differences ($P<0.05$) were found between the shelter and individual outdoor calf hutches in relation to the measured parameters. In the summer, the shelter showed a significantly ($P<0.05$) lower air temperature and significantly higher level of both relative air humidity and calf rectal temperature. These significantly higher rectal temperatures in both summer and in transitional periods (from March to June and from September to December) can be explained by microclimatic conditions and specifically by the combination of air temperature and the highest relative humidity that caused less comfortable microclimatic conditions for calves. The high relative humidity is probably caused by inadequate ventilation under the shelter. Therefore, new technology of calf housing under shelter could be recommended as suitable housing only if adequate ventilation is provided.

Archiv Tierzucht 56 (2013) 49, 509-517
doi: 10.7482/0003-9438-56-049

Received: 13 July 2012
Accepted: 19 February 2013
Online: 26 April 2013

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Keywords: housing system design, calves, microclimatic conditions, rectal temperature, thermal comfort

Abbreviations: OT: outdoor tarpaulin calf hutch, OW: outdoor wooden calf hutch, SH: shelter

Introduction

Calves should be housed individually in facilities that are draft-free but provide good ventilation to prevent the spread of disease from one calf to another (Amaral *et al.* 2006). European Union regulations now set a maximal age limit (eight weeks) for raising calves in individual pens and the necessity for calves to have social contact with other animals (Council Directive 91/629/EEC and Council Directive 97/2/EC) (Marcé *et al.* 2010). Individual outdoor hutches should provide good health, growth and gain for the reared calves. They are generally made out of wood or plastic (Coleman *et al.* 1996) or from tarpaulin (Doležal *et al.* 2003). Calves housed outside, however, may be exposed to significant heat stress during the summer (Brouček *et al.* 1990, Maltz *et al.* 2000), because they are more exposed to direct sunlight than those kept in a shaded environment (Spain & Spiers 1996). Shading reduces deaths from heatstroke (Blackshaw & Blackshaw 1994). The disadvantages of hutches are that the operator is not protected from the weather and the amount of space required on larger farms. Pens placed under shelter provide more weather protection for the caretaker (McFarland 1996, Curt & Gooch 2005).

Calf shelters should be built to allow the prevailing wind to pass directly through the shelter onto the animals to avoid conditions of high temperature and relative humidity (Margerison 2011) and should ideally be sloped to allow liquids to run out (Curt & Gooch 2005). Structures with an open ridge and adjustable sidewall openings are the best places. Solid panels on three sides of the resting area help to minimise drafts and reduce heat loss during cold weather (McFarland 1996). Microclimatic conditions generally influence the health status, fertility and performance of cattle (Marai *et al.* 2010, Sawa & Bogucki 2011).

Calves are born with extremely good functional thermoregulatory mechanisms (Davis & Drackley 1998). The lower critical temperature ranges from 9 to 15 °C at birth and during the first two weeks of life (Phillips 2010, Davis & Drackley 1998) and declines to range from 0 °C (Phillips 2010) to 10 °C in older calves (Davis & Drackley 1998). The thermoneutral zone for calves lies in a range of 15-25 °C (Scanes 2011, Schrama *et al.* 1992, 1993). Davis & Drackley (1998) stated a temperature of 26 °C as the upper limit of the thermoneutral zone for calves.

The environmental temperature is closely associated with body temperature, for which reason rectal temperature is often used as the evaluation parameter of physiological adaptation to the environment. Any rise in rectal temperature shows that the mechanisms for maintaining homeostasis can no longer release sufficient heat from the organism (Mota 1997). The physiological range of rectal temperature in calves is 37.5-39.5 °C (Scanes 2011).

The aim of this work was to compare microclimatic conditions (air temperature and relative air humidity) in individual outdoor wooden hutches, individual outdoor tarpaulin hutches and shelters for calf rearing on the milk diet and to assess the thermal comfort of the animals on the basis of their rectal temperature. The aim was based upon the following hypothesis, that differing values of microclimatic parameters, which would have differing effects on the parameters of thermal comfort among calves, would be discovered in various housing systems.

Material and methods

Housing

Individual outdoor wooden calf hutch (OW)
The hutch, made of spruce wood, is of a size of 1 200×1 200×1 200 mm (length, width, depth) with an entry opening of 440-600×1 000 mm and a removable roof. A paddock of a size of 1 200×1 200×1 200 mm adjoins the hutch. There is a sheltered feeding area with two pails for water and a calf starter at the front of the paddock.

Individual outdoor tarpaulin calf hutch (OT)
The hutch is 1 500×1 200×1 300 mm in size. Its frame is made of Jäckl thin-walled steel profiles. The hutch is sheathed in a blue tarpaulin. There is an entry opening for the calf (600×1 300 mm) at the front of the hutch. A ventilation opening may be created at the back of the hutch as necessary. A tarpaulin is also used as roofing.

Shelter
The shelter is made of two rows of individual pens connected by an uncovered resting area with a solid partition wall, to which mobile paddock structures are fixed. A feed alley leads through the middle of the shelter with dung and operating alleys to the sides. The walls of the shelter are covered with roller curtains and nets. Part of the roof can also be opened.

Air ventilation in the area beneath the shelter is based on automatic regulation of the rolling of side and roof draft prevention tarpaulins depending on the outdoor air currents. The tarpaulins roll out, thereby closing the shelter, if the air current exceeds 1 ms^{-1} in the summer period and 0.25 ms^{-1} in the winter period. After total closing of the shelter the ventilation is ensured by natural ventilation.

Animals

Each year, calves (n=108) aged from 1 to 56 days of the Holstein (n=72) and Czech Fleckvieh (n=36) breeds were included in the study. A total of 324 calves, 216 Holstein and 108 Czech Fleckvieh, were reared during the three years of the study. Always 36 calves (24 Holstein and 12 Czech Fleckvieh) were housed in individual outdoor wooden hutches, 36 calves (24 Holstein and 12 Czech Fleckvieh) in individual outdoor tarpaulin hutches and 36 calves (24 Holstein and 12 Czech Fleckvieh) in shelter a year. The calves were examined after birth and moved to a hutch or pen for calf rearing within 24 h. In all housing systems calves had only visual, not physical contact. All calves were continuously under veterinary supervision and diseased calves were excluded from the experiment. The calves were fed with maternal colostrum during days 1 to 3, with mixed colostrum during days 3 to 6 and with untreated native milk during days 6 to 56. Water and a starter based on oats, maize and a protein supplement (at a ratio of 1:4:5) were available for the calves *ad libitum*. Weaning occurred when the calves reached the age of 56 days, when the calves were able to accept 1 kg of the starter.

Measurements

Measurements were taken on a dairy farm in a lowland area. Six OW, six OT and six shelter pens for calf rearing on the milk diet were included in the study. Measurements were taken on a regular basis in transitional periods (March to June, September to December), in the summer (June to September) and in the winter (December to March) over the course of three subsequent years. Measurements were taken twice a week (on Tuesday and Thursday), always on the same days, between 9.00 and 12.00. Total number of measurements was 5 616. The values of air temperature and relative air humidity in the housed calf's living zone (300-500 mm above the ground) and the calf's rectal temperature were recorded.

Equipment

A Testo 615 digital thermometer (TESTO, Lenzkirch, Germany) was used to measure air temperature (°C). A Testo 615 digital hygrometer (TESTO, Lenzkirch, Germany) was used to measure relative air humidity (%). The rectal temperature (°C) of the studied calves was monitored with the use of a digital medical thermometer accurate to hundredths of a degree.

Statistical analysis

The methodology of statistical evaluation was based on the analytical processing of the values measured and their synthesis. Basic descriptive statistics on the selected group that fully characterise the data obtained were selected. The ANOVA procedure and, subsequently, a POST-HOC Tukey test were used for statistical calculations. An analysis of the dependence of the measured values with the following intervals of dependence was then drawn up:

$0 < |r| \le 0.3$ – small dependence, $0.3 < |r| \le 0.8$ – medium dependence, $0.8 < |r| \le 1$ – large dependence.

All mathematical and statistical processing of the values obtained was performed in the statistical computer program Statistica komplet CZ (StatSoft CR s.r.o., Praha, Czech Republic).

Results and discussion

Air temperature

The lowest air temperature (Table 1) in all the seasons monitored was found in the shelter housing. Statistical data processing showed that the difference in the air temperatures between the housing types was significant only in the summer period. In the shelter, there were significantly ($P<0.05$) lower air temperature for 3.87 °C than in the wooden hutch and for 4.38 °C lower than in the tarpaulin hutch. Other differences were statistically insignificant ($P>0.05$).

The thermoneutral zone for calves ranges from 15 to 25 °C (Scanes 2011, Schrama *et al.* 1992, 1993). Davis & Drackley (1998) stipulated the upper limit of the thermoneutral zone at 26 °C, while Nardone *et al.* (2006) consider 30 °C as the critical temperature for calves. Stull *et al.* (2008) observed lower calf mortality at temperatures of between 14 and 25 °C. The average air temperature in the summer in our study fell within the range of temperatures favourable for calves recommended by the above authors in their studies. Neither the upper limit of the thermoneutral zone of 26 °C recommended by Davis & Drackley (1998) nor critical temperatures above 30 °C, as given by Nardone *et al.* (2006), were reached. The average air temperatures recorded in the transitional period in all the types of housing studied are below the limit of the thermoneutral zone from the viewpoint of the requirements of the calves, though above the limit of the minimal recommended air temperature of 0 °C given by Phillips (2010). It can then be stated that the air temperatures recorded can be considered suitable in all types of housing, even in the winter period.

Table 1
Average air temperature (°C) in different housing technologies for calves during year seasons observed

	Transition period	Summer period	Winter period
OT	12.62±7.30	24.36±5.64^{A}	1.96±5.42
OW	12.92±7.04	23.85±5.41^{B}	1.44±5.13
SH	9.90±3.02	19.98±4.10^{A,B}	1.26±3.49

^{A,B}statistical significant differences between shelter and hutches (*P*<0.05) in given periods, transition period: March to June, September to December, summer period: June to September, winter period: December to March

Malá *et al.* (2010) discovered that calves reared under SH and in OW were exposed to lower air temperatures than calves reared in OT and plastic hutches. The higher average air temperature in plastic hutches compared to wooden hutches has also been confirmed by Lammers *et al.* (1996) and Macaulay *et al.* (1995) and also by Spain & Spiers (1996) in comparison with shelters. The SH, we studied also, showed a significantly lower air temperature in the summer than OT, though in contrast to Malá *et al.* (2010) it also showed a lower air temperature than OW. Brouček *et al.* (1990) also recorded a higher average air temperature in the summer in OW (24.4 °C) in comparison with SH (23.3 °C). The average air temperatures given by Brouček *et al.* (1990) were higher than those we recorded in our study. The differences between OT and OW in our study did not confirm statistically significant difference in air temperature.

Relative air humidity

The highest relative air humidity (Table 2) was recorded in the shelter in all the seasons monitored. The relative air humidity under SH in the summer was statistically significantly (*P*<0.05) higher by 19.59 % than under OT and OW. Differences in other seasons were not statistically significant (*P*>0.05).

Table 2
Average relative air humidity (%) in different housing technologies for calves during year seasons observed

	Transition period	Summer period	Winter period
OT	64.27±15.15	48.42±12.13^{A}	64.09±15.25
OW	62.94±16.22	48.42±12.13^{B}	64.56±15.27
SH	64.69±2.95	68.01±15.94^{A,B}	69.34±6.60

^{A,B}statistical significant differences between shelter and hutches (*P*<0.05) in given periods, transition period: March to June, September to December, summer period: June to September, winter period: December to March

The average relative air humidity discovered in the transitional and winter periods was optimal for calves in all types of housing, as Blom *et al.* (1984) and Davis & Drackley (1998) state 85 % as the maximum value for calves and heifers. In the summer, the relative air humidity under SH reached significantly higher values than in both types of hutch and was almost 10 % higher than that measured by Nonnecke *et al.* (2009), who also housed calves under SH. Although the relative air humidity under SH did not exceed the maximal value given by Blom *et al.* (1984) and Davis & Drackley (1998), it is clear that more humidity accumulates here, particularly in the summer, than in hutches. This phenomenon is caused by the regulation technology used for rolling tarpaulins in dependence on the speed of the outdoor air current. This regulation prevents the natural removal of humidity by an increased airflow. The solid side walls of the bedding area also prevent the flowing air from penetrating into the housed calf's living zone. McFarland (1996) recommends installing solid side walls in the winter months to prevent hypothermia in calves. However, in accordance with our findings, these could cause increased relative air humidity during summer months.

Margerison (2011) states that SH must ensure an adequate flow of fresh air in the housed calf's living zone to remove excess humidity. To reduce the air humidity it is necessary to ensure adequate ventilation of the shelter to spread dry litter regularly and to avoid the excessive accumulation of water that occurs during the cleaning of pails and hutches as a result of a failure to observe the correct working procedure (McFarland 1996).

According to Malá *et al.* (2010), the lowest value of relative air humidity was measured in OT compared with the plastic hutch, OW and SH. The relative air humidity recorded in the plastic hutch was higher than in the other hutches and in the SH. A higher relative air humidity in a plastic hutch is also confirmed by Lammers *et al.* (1996). Our results document an insignificantly (P>0.05) higher air humidity when comparing OT with OW only in the transitional period.

Rectal temperature

The rectal temperature (Table 3) of calves housed in the shelter showed values significantly different from calves housed in OT and OW. The highest values were recorded in the transitional period and in the summer, while the lowest rectal temperature was recorded in the winter in calves under SH. The rectal temperature of calves housed in SH was significantly (P<0.05) higher, by 0.23 °C in the transitional period than in OW, by 0.19 °C than in OT and by 0.27 °C than in OW in the summer period. In contrast, a significantly (P<0.05) lower rectal temperature was recorded in SH in the winter, this was by 0.26 °C lower than in OT and by 0.27 °C lower than in OW.

Table 3
Average rectal temperature (°C) in different housing technologies for calves during year seasons observed

	Transition period	Summer period	Winter period
OT	38.77±0.24	$38.71{\pm}0.10^{A}$	$38.82{\pm}0.23^{A}$
OW	$38.75{\pm}0.27^{B}$	$38.63{\pm}0.92^{B,b}$	$38.83{\pm}0.20^{B,b}$
SH	$38.98{\pm}0.47^{B,a}$	$38.90{\pm}0.39^{A,B,b}$	$38.56{\pm}0.56^{A,B,a,b}$

^{A,B}statistical significant differences between shelter and hutches (P<0.05) in given periods, ^{a,b}statistical significant differences between periods (P<0.05) in selected types of housing, transition period: March to June, September to December, summer period: June to September, winter period: December to March

The physiological range of rectal temperature in calves is 37.5-39.5 °C (Scanes 2011). According to Robinson (1999), the rectal temperature measured in our study therefore can be considered as physiological. In contrast to Malá *et al.* (2010) and Matarazzo *et al.* (2010), a statistically significant difference in rectal temperature was discovered between various types of housing in all the seasons studied. Coleman *et al.* (1996), who placed calves in individual outdoor hutches and individual pens under shelter and who also discovered that SH reduces the air temperature while increasing the relative air humidity, achieved results similar to those found in our study. Calves housed under SH had a demonstrably higher rectal temperature in the summer than calves housed in outdoor hutches. Bray *et al.* (1997), however, discovered that calves housed under SH showed a lower rectal temperature in the summer than calves housed in hutches.

The dependency of rectal temperature on the air temperature was assessed in OT and OW, according to the correlation index r (−0.01) as extremely small, although a statistically significant difference (P<0.05) was found in rectal temperature (Table 3) in OW between the summer and winter seasons. In SH, in view of the significant unfavourable effect of the combination of air temperature and high relative air humidity, the dependence of rectal temperature on air temperature was small (r=0.3), although the dependence of rectal temperature on relative air humidity was extremely small (r=0.05). A significant difference in rectal temperature (P<0.05) was found here between the transitional periods and both the summer and the winter seasons.

Ferreira *et al.* (2006) also noticed a fall in rectal temperature in the winter compared to the summer. In our study, the rectal temperature was also significantly lower in the SH during the winter compared to the transitional and summer seasons. In contrast, the rectal temperature fell with increasing air temperature in OW. Similar results have been produced in the work by Maia *et al.* (2005).

The tested hypothesis has been confirmed. Demonstrable differences in the values of microclimatic parameters, which affected parameters of thermal comfort of calves in various ways, were discovered in observed types of housing.

The lowest overall air temperature and highest average relative air humidity were found in the shelter housing in all the studied seasons.

The air temperatures measured in the summer in all the types of housing studied can be generally considered optimal, falling within the range of temperatures comprising the calves' thermoneutral zone. The temperatures measured in the transitional and winter seasons are also satisfactory, as they did not fall beneath the minimal temperature acceptable for calves.

The average relative air humidity fell within the optimal humidity range recommended for calves during the entire study in all types of housing.

The average rectal temperature did not exceed physiological values. The rectal temperature attained demonstrably differing values in the shelter housing than in the other types of housing. Its significantly higher values in the summer and the transitional period can be explained by the microclimatic conditions with a combination of air temperature and higher relative air humidity creating less favourable conditions for calves than the other types of housing and similarly in the winter, when the calves' rectal temperature was the lowest.

On the basis of our findings determined, the shelter may be recommended as suitable housing for the quality rearing of calves only under the condition that adequate ventilation is assured and the optimal working procedures, such as prevention of the accumulation of excessive humidity, which has an unfavourable effect on the thermal comfort of calves in both the summer and the winter, are observed.

Acknowledgements

This research was funded by Projects. MZE 0002701404 and S grant of MSMT Czech Republic.

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