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THE EFFECT OF AIR TEMPERATURE AND TIME OF DAY ON DISTRIBUTION OF CZECH FLECKVIEH COWS WITHIN THE BARN

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Abstract

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The effect of air temperature and time of day on distribution of Czech Fleckvieh cows within the barn was studied on a dairy farm located in the south of Moravia, CR, (49°12'31.875"N, 16°23'43.146"E). The cows were loose-housed in a barn with stalls. The floor surface was made of separated manure. The observation was carried out in one of the four sections (100 cows) of the barn (total 400 cows). The observed section was visually divided into two parts – left L (situated centrally) and right R (situated peripherally). Video camera images (the total of 5304 images were evaluated) revealed the distribution of cows within the barn and the presence of cows in parts A or B. The air temperature was monitored by temperature sensors. At lower temperatures (up to 19.00 °C), the distribution of cows within the barn was even, at higher temperatures, the cows had a distinct tendency to crowd in L side of the barn (up to 100% of them). The cows were scattered evenly around the barn up to 10.00 in the morning and after 19:01 in the evening. During the day between 10.00 and 19.01, the cows tended to group in L part (up to 100% of them). They never grouped in R part. It was found out that changes in distribution of cows within the barn were associated with both air temperature and time of day. The changes in mean air temperature during the day were defined as $y = 0.000002x^4 - 0.0005x^3 + 0.0412x^2 - 0.8876x + 18.515$ (where y = air temperature and x time of day in hours) with $R^2 = 0.957$.

Keywords: crowding, grouping of cows, air temperature, time of day, Czech Fleckvieh

INTRODUCTION

Loose housing systems for dairy cows offer opportunities to perform natural behaviour and exercise. A stable social hierarchy helps to reduce the impact of general stressors on cows' organisms (Bouissou *et al.*, 2001). Therefore, social behaviour of loose-housed cows is an important aspect of their welfare (Rousing and Wemelsfelder, 2006). The distribution of cows within the barn is not always even and cows tend to crowed in certain places. Erbez *et al.* (2010) studied this crowding phenomenon and they believe it was associated with greater occurrence of flies in summer time.

Hurnik *et al.* (1995) defined crowding as an unusually high density of animals within a certain area which can cause discomfort of some or all of the animals in the group but is not associated with serious suffering or injuries. Crowding can also have a thermoregulatory function reducing the heat loss in cold temperatures. This has been known in pigs (Andersen *et al.*, 2000) and sheep (Bøe, 1990). Grant and Albright (2001) and Huzzey *et al.* (2006) observed that overcrowding in a certain place leads to reduction of food intake, resting time and rumination. Huddling closely together increases body temperature and leads to heat stress.

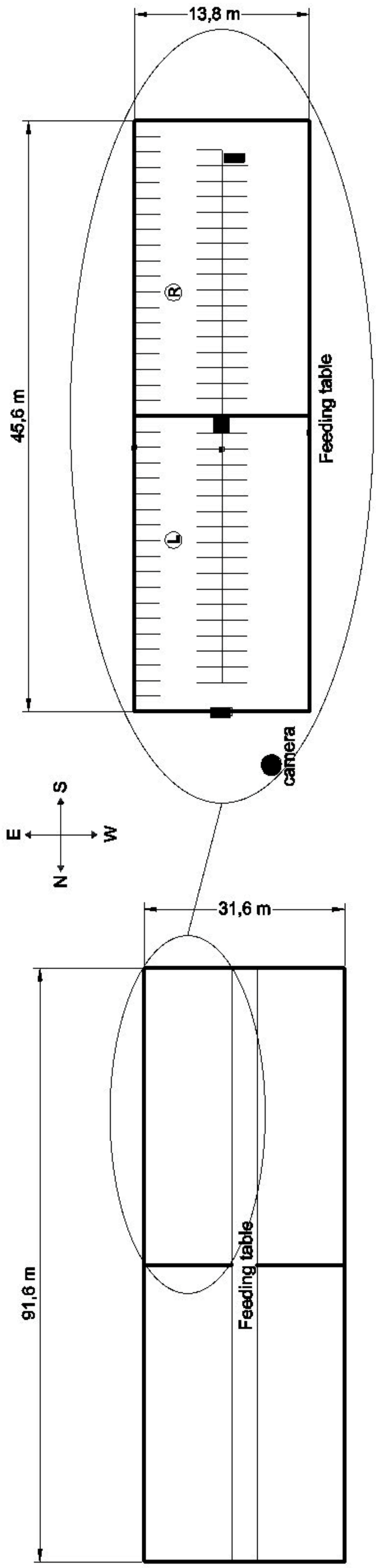
Cattle are more sensitive to high temperatures than humans. High environmental temperatures and humidity elicit heat stress in dairy cows. Cattle dispose of excessive heat through respiration rather than perspiration. Heat tolerance is affected by a number of factors: age, colour and length of hair, nutritional status, interaction with environmental factors such as air temperature, humidity and air velocity (Osborne, 2003). Bovine thermoneutral zone ranges from 10 to 16 °C (Chládek, 2004). Bach *et al.* (2008); Metcalf *et al.* (1992) found out that a high stocking density has also a negative impact on milk performance. If the stocking density is too high, the cows spent more time standing in an alley waiting for their chance to lie down and less time feeding. About 28% of cows were observed to chew the cud in overcrowded facilities, whereas in adequately occupied places it was about 37% of cows. It has been proved that the time spent ruminating is not only affected by a fibre content but also by housing conditions (Grant and Albright, 2001). Grant (2010) claims that overcrowding can reduce rumination time by 10 to 20%.

Beside the milk production, several health aspects are also affected by the time spent lying down. Firstly, if the cows are forced to stand on concrete floors for prolonged periods, the pressure on hooves is much greater (Cook, 2002). Long periods of standing may increase the incidence of hoof infections. These circumstances often lead to greater incidence of lameness (Guard, 2002). Secondly, the cows prevented from lying down showed higher concentrations of cortisol (a stress indicator) compared to the cows whose resting time was unrestricted. Higher levels of cortisol are usually associated with immunosuppression (Munksgaard and Simonsen, 1996). Thirdly, longer lying down periods are potentially beneficial for the growth of a foetus (Nishida *et al.*, 2004). In summary, overcrowding can have the following consequences: reduced resting time, increased time spent standing in an alley, reduced feeding time and impaired comfort of cows (Krawczel and Grant, 2009).

The aim of this study was to examine the distribution of Czech Fleckvieh cows within the barn in relation to the changing air temperature and time of day.

MATERIAL AND METHODS

The observation was carried out on GenAgro Říčany farm, PLC, located in the south of Moravia, CR (49°12'31.875"N, 16°23'43.146"E) in the herd of Czech Fleckvieh cows. The cows were loose-housed in a barn with individual stalls (412). The floor surface was made of separated manure. Delivery of fresh feed was twice a day around 4:30 and 16:30. Pushing of feed was 1 or 2 hours after its setting (or as needed). Bedding process took place 9.8. (from 7:00 to 11:15) and 15.9. (from 9:00 to 10:00). There were four sections in the barn, each of which housed 100 cows. The observation took place in one of the



1: *The observed section*

sections. The observed section was visually divided into two parts – left L (situated centrally) and right R (situated peripherally), see Fig. 1. The cows were in various stages of lactation and they were milked twice a day; in the morning between 7:15 and 9:00 and in the evening between 19:00 and 20:30. They were fed the total mixed ration (TMR) ad libitum.

The observation continued from 1st July to 30th September 2011. The distribution of cows within the barn (i.e. their presence in the left L or right R half of the barn) was checked in 15-minute intervals, 24 hours non-stop. The images captured at the time of the morning and evening milking (and at the time of bedding process) were excluded from the evaluation, because the numbers of cows were biased. The images unclear due to poor visibility (darkness) were eliminated, too. The total of 5304 images were evaluated. The air temperature in the barn was monitored in 15-minute intervals by three sensors, and the resulting value was calculated as the arithmetic mean. The smallest temperature unit used for statistical analysis was 0.99 °C and the time unit was one hour.

Each observation (image) was assigned into one of five groups, based on the number of cows present in L or R part of the barn.

Group 1 L part of observed section – 0 to 20 cows; R part of observed section – 100 to 80 cows.
Group 2 L part of observed section – 21 to 40 cows; R part of observed section – 79 to 30 cows.
Group 3 L part of observed section – 41 to 60 cows; R part of observed section – 59 to 40 cows.
Group 4 L part of observed section – 61 to 80 cows; R part of observed section – 39 to 20 cows.
Group 5 L part of observed section – 81 to 100 cows; R part of observed section – 19 to 0 cows.

The distribution of cows within the barn was described as a proportion of images in one of the groups out of the total number of images in a particular air temperature or time interval. The same section of the barn had previously been subjected to observation in the work of Erbez *et al.* (2010).

RESULTS AND DISCUSSION

Tab. I describes the effect of air temperature on distribution of cows within the barn. When the temperature ranged between 5.01 °C and 19.00 °C, the cows were distributed evenly over both parts of the section, i.e. they were in group 3 (L – 41 to 60 cows and R – 59 to 40 cows,), especially at temperatures up to 11.00 °C (in 93.2% to 100% of observations). Then, up to 15.00 °C, the number of observations was mildly dropping (90.3% to 80.6%). At temperatures of 15.00 °C and higher, the number of cows in group 3 dropped severely (53.3% to 66.8%) while the number of cows in group 5 (L – 81 to 100 cows and R – 19 to 0 cows) increased up to 24.5%. From temperature 19.01 °C up to 35.00 °C, the greatest number of cows were found in group 5 (L – 81 to 100 cows and R – 19 to 0 cows) ranging from 44.1% to 94.4%. In some observations, all of the cows (100%) were seen in L part. On the contrary, all of the observed cows were never seen in part R at one time.

Brouček (2009) found out that the number of cows standing up was growing with the growing air temperature. Zahrádková *et al.* (2009) pointed out that standing has a cooling effect, because it enhances evaporation from the body surface. Our results are comparable to those of Erbez *et al.* (2012), who found out that the cows in loose housing with stalls tend to form groups and crowd during the summer months. Crowding of the cows exposed to high air temperatures is thought to be unusual. The cows tend to crowd in the centre of the barn where the microclimate is generally most adverse and consequently, central crowding increases the heat stress of the animals and naturally, seems unfavourable. Therefore, there must be a significant reason why the animals do it. Gerry *et al.* (2007) and Osborne (2003) explained the cows' tendency to form tight groups by the presence on an enormous number of flies. The cows on the outside of the group are attacked by the insect as much as solitary animals, while the cows in the centre of the group are fully protected. However, this behaviour is likely to increase the heat stress (poor air circulation) and may lead to injuries. Nevertheless, the cows fight for the central position in order to escape painful bites. Flies are typically most active at air temperatures above 20 °C. Our study proved, that the cows start to crowd at air temperatures around 19 °C, which most farmers consider adequate for the animals. It was found a clear borderline between the even distribution of cows within the barn and the onset of crowding at the temperature of 19 °C. The change was quite sudden, there was no prior "transition" period. Fig. 2 illustrates the situation when all of the cows are crowded in the central (L) part of the barn and none is in the peripheral part (P).

Tab. II shows the effect of time of day on distribution of cows within the barn. The cows were distributed quite evenly throughout the barn up until 10:00, i.e. they were in group 3 (L – 41 to 60 cows and R – 59 to 40 cows), especially until 5:00 (99.3% to 100% of observations). Then the number was gradually decreasing until 10:00 (46% observations) with the exception of the period between 8:01 to 9:00 when the greatest number of observations (49.8%) was in group 4 (L – 61 to 80 cows and R 39 to 20 cows). From 10:01 to 19:00, the greatest number of observations (40.2% to 78.4%) was constantly in group 5 (L – 81 to 100 cows and R – 19 to 0 cows). From 19:01 to 20:00, most observations were in group 4 (L – 61 to 80 cows and R 39 to 20 cows). Since 20:01, the cows once again distributed themselves evenly throughout the barn and the greatest number of cows (66.7% to 86.4%) were in group 3 (L – 41 to 60 cows and R – 59 to 40 cows).

Erbez *et al.* (2010) noted that the cows gathered in a particular part of the barn every day at 14.00. Erbez

I: *The effect of air temperature on distribution of cows within the barn*

Number of observations in temperature intervals		**Number of cows in L or R part of the barn**				
Air temperature intervals (°C)	**Total number of observations (n)**	**Group 1 (L – 0 to 20 cows and R – 100 to 80 cows)**	**Group 2 (L – 21 to 40 cows and R – 79 to 60 cows)**	**Group 3 (L – 41 to 60 cows and R – 59 to 40 cows)**	**Group 4 (L – 61 to 80 cows and R – 39 to 20 cows)**	**Group 5 (L – 81 to 100 cows and R – 19 to 0 cows)**
		Proportion out of the total number of observations (n = 100%)				
5.01–6.00	**2**	0.0	0.0	**100.0**	0.0	0.0
6.01–7.00	**34**	0.0	5.9	**94.1**	0.0	0.0
7.01–8.00	**44**	0.0	6.8	**93.2**	0.0	0.0
8.01–9.00	**62**	0.0	0.0	**96.8**	3.2	0.0
9.01–10.00	**107**	0.0	0.9	**97.2**	1.9	0.0
10.01–11.00	**178**	0.0	1.1	**96.1**	1.7	1.1
11.01–12.00	**182**	0.0	11.0	**86.8**	2.2	0.0
12.01–13.00	**207**	0.0	5.8	**90.3**	2.9	1.0
13.01–14.00	**294**	0.0	5.8	**82.3**	3.4	8.5
14.01–15.00	**381**	0.0	3.7	**80.6**	8.4	7.3
15.01–16.00	**265**	0.0	1.9	**66.8**	15.1	16.2
16.01–17.00	**288**	0.0	0.7	**64.9**	18.4	16.0
17.01–18.00	**330**	0.0	3.9	**53.3**	18.2	24.5
18.01–19.00	**243**	0.0	1.2	**59.7**	15.6	23.5
19.01–20.00	**347**	0.0	1.4	36.9	17.6	**44.1**
20.01–21.00	**302**	0.0	0.0	30.8	24.8	**44.4**
21.01–22.00	**179**	0.0	1.1	25.7	23.5	**49.7**
22.01–23.00	**322**	0.0	1.2	15.8	16.5	**66.5**
23.01–24.00	**209**	0.0	0.0	8.1	14.4	**77.5**
24.01–25.00	**276**	0.0	0.0	12.0	14.9	**73.2**
25.01–26.00	**271**	0.0	0.0	6.3	13.7	**80.1**
26.01–27.00	**155**	0.0	0.0	4.5	15.5	**80.0**
27.01–28.00	**189**	0.0	0.5	5.3	13.2	**81.0**
28.01–29.00	**90**	0.0	0.0	12.2	8.9	**78.9**
29.01–30.00	**94**	0.0	0.0	2.1	16.0	**81.9**
30.01–31.00	**72**	0.0	0.0	1.4	22.2	**76.4**
31.01–32.00	**87**	0.0	0.0	2.3	14.9	**82.8**
32.01–33.00	**25**	0.0	0.0	4.0	20.0	**76.0**
33.01–34.00	**33**	0.0	0.0	0.0	6.0	**93.9**
34.01–35.00	**36**	0.0	0.0	0.0	5.6	**94.4**
Σ	5304	0.0	2.0	**45.4**	13.2	39.4

L – left part of the barn, situated centrally (see Figure 1)
R – right part of the barn, situated peripherally (see Figure 1)
■ – maximum value within the temperature interval

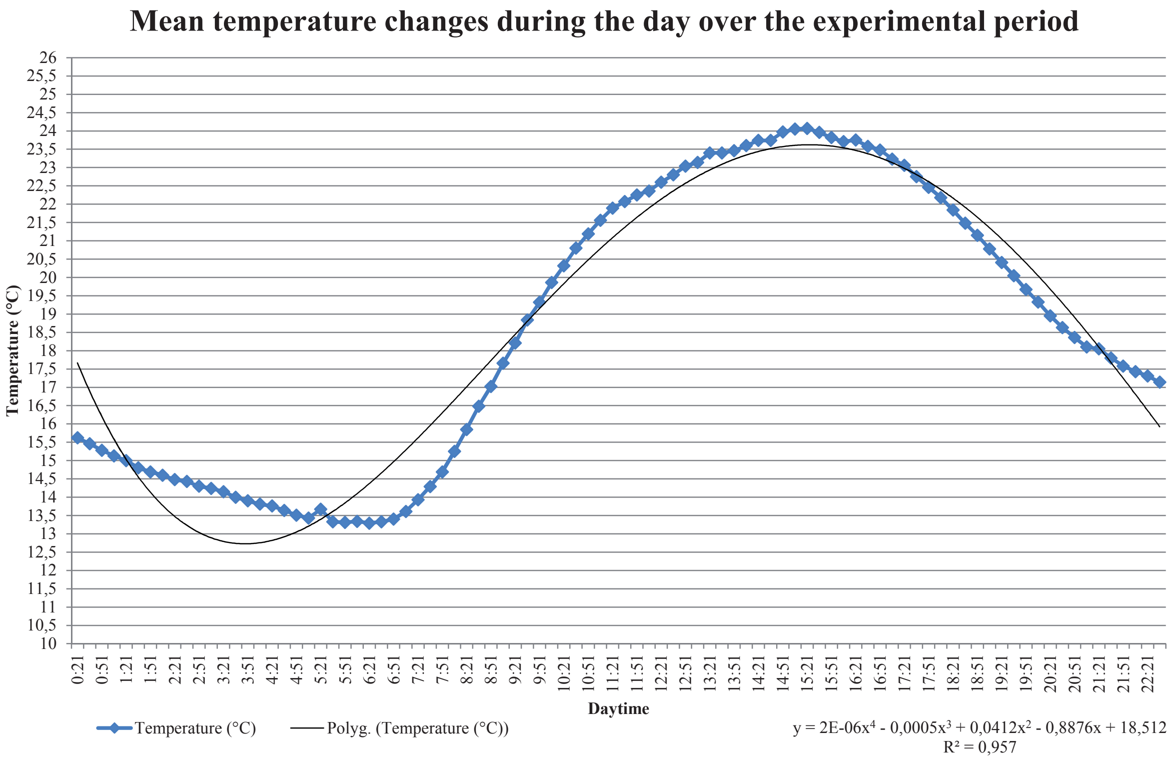
II: *The effect of time of day on distribution of cows within the barn*

Number of observations in time intervals		**Number of cows in L or R part of the barn**				
Time intervals (hours: minutes)	**Total number of observations (n)**	**Group 1 (L – 0 to 20 cows and R – 100 to 80 cows)**	**Group 2 (L – 21 to 40 cows and R – 79 to 60 cows)**	**Group 3 (L – 41 to 60 cows and R – 59 to 40 cows)**	**Group 4 (L – 61 to 80 cows and R – 39 to 20 cows)**	**Group 5 (L – 81 to 100 cows and R – 19 to 0 cows)**
		Proportion out of the total number of observations (n = 100%)				
0:01–1:00	71	0.0	0.0	**100.0**	0.0	0.0
1:01–2:00	164	0.0	0.0	**100.0**	0.0	0.0
2:01–3:00	193	0.0	0.0	**100.0**	0.0	0.0
3:01–4:00	248	0.0	0.0	**100.0**	0.0	0.0
4:01–5:00	289	0.0	0.4	**99.3**	0.3	0.0
5:01–6:00	324	0.0	10.8	**87.4**	0.9	0.9
6:01–7:00	320	0.0	9.0	**87.6**	2.5	0.9

Number of observations in time intervals		Number of cows in L or R part of the barn				
Time intervals (hours: minutes)	Total number of observations (n)	Group 1 (L – 0 to 20 cows and R – 100 to 80 cows)	Group 2 (L – 21 to 40 cows and R – 79 to 60 cows)	Group 3 (L – 41 to 60 cows and R – 59 to 40 cows)	Group 4 (L – 61 to 80 cows and R – 39 to 20 cows)	Group 5 (L – 81 to 100 cows and R – 19 to 0 cows)
		Proportion out of the total number of observations (n = 100%)				
7:01–8:00	125	0.0	1.1	**74.4**	19.9	4.6
8:01–9:00	80	0.0	0.5	46.4	**49.8**	3.3
9:01–10:00	318	0.0	1.0	**46.0**	33.3	19.7
10:01–11:00	329	0.0	0.0	30.7	29.1	**40.2**
11:01–12:00	326	0.0	0.6	17.5	17.2	**64.7**
12:01–13:00	329	0.0	0.3	14.0	16.1	**69.6**
13:01–14:00	333	0.0	0.3	9.0	13.5	**77.2**
14:01–15:00	329	0.0	0.6	7.9	13.1	**78.4**
15:01–16:00	329	0.0	1.2	5.8	24.3	**68.7**
16:01–17:00	334	0.0	1.8	8.0	16.3	**73.9**
17:01–18:00	328	0.0	0.3	14.9	13.4	**71.4**
18:01–19:00	330	0.0	3.0	37.3	13.0	**46.7**
19:01–20:00	91	0.0	0.0	28.0	**55.4**	16.6
20:01–21:00	52	0.0	4.3	**82.1**	8.3	5.3
21:01–22:00	55	0.0	11.6	**86.4**	0.0	2.0
22:01–23:00	7	0.0	22.2	**66.7**	11.1	0.0
Σ	5304	0.0	2.0	**45.4**	13.2	39.4

L – left part of the barn, situated centrally (see Fig. 1)
R – right part of the barn, situated peripherally (see Fig. 1)
[grey box] – maximum value within the temperature interval

2: *Crowding – uneven distribution of cows within the barn*



3: *Average temperatures during the reporting period, depending on the time of day*

et al. (2012) observed that the cows tended to group together from 10:00 to 19:30 in the summer, which basically corresponds with our results and supports the hypothesis that crowding is a long-termed and repetitive phenomenon of cows' behaviour. Naturally, the air temperature is closely related to the time of day when it was measured. This relation is depicted in Figure 3, which shows that the mean air temperature was growing since 7:00 (the minimum of 13.29 °C was found in 6:21) and reached its peak at 15:21 (24.07 °C), then the temperature started to decline. The relationship between these two parameters ($y = 0.00002x^4 - 0.0005x^3 + 0.0412x^2 - 0.8876x + 18.515$ with $R^2 = 0.957$, where y is temperature and x time) corresponds with our findings that distribution of cows within the barn depends on both the air temperature and time of day.

CONCLUSIONS

We can conclude that distribution of cows within the barn was closely associated with both the air temperature and time of day. The cows were scattered around the barn evenly in air temperatures up to 19.00 °C. With growing air temperature, they clearly preferred L part of the barn (up to 100% of cows) which was situated centrally. During the day, the cows were distributed around the barn quite evenly until 10:00 in the morning and again after 19:01 in the evening. Between 10:00 and 19:01, the cows tended to group in the left part of the section (up to 100%) while no grouping and crowding was noted in the right part of the section. The cows scattered evenly around the barn started to form groups in certain parts of the barn abruptly, it was not a gradual process.

SUMMARY

The effect of air temperature and time of day on the distribution of Czech Fleckvieh cows within the barn was studied on GenAgro Říčany dairy farm, PLC, situated in the south of Moravia, CR, (49°12'31.875"N, 16°23'43.146"E). The cows were loose-housed in a barn with stalls. The floor surface was made of separated manure. The observation took place in one of the four sections (100 cows) of the barn; it continued from 1st July to 30th September 2011. The cows were milked twice a day; in the morning between 7:15 and 9:00 and in the evening between 19:00 and 20:30. They were in various stages of lactation and were fed the total mixed ration (TMR) ad libitum.

The observed section was visually divided into two parts – left L (situated centrally) and right R (situated peripherally). The images of the section were captured in 15-minute intervals, showing the presence of the cows in both parts of the section. The total of 5304 images were evaluated. The images captured at the time of the morning and evening milking were excluded from the evaluation because the numbers of cows were biased. The images unclear due to poor visibility (darkness) were eliminated, too. The air temperature in the barn was monitored in 15-minute intervals by three sensors, and the resulting value was calculated as the arithmetic mean. The smallest temperature unit used for statistical analysis was 0.99 °C and time unit was one hour. It was found out that at lower temperatures (up to 19.00 °C) distribution of cows within the barn was even, at higher temperatures, the cows had a distinct tendency to crowd in L side of the barn (up to 100% of them). They tended to form groups.

The cows were evenly scattered over the section in the morning until 10.00 and then in the evening after 19.01. In between, the cows preferred left side of the section (up to 100%).

On the contrary, no grouping and crowding was noted in R part of the section. The distribution of cows within the barn was affected by both the air temperature and time of day. It was observed that the cows scattered around the barn started to form groups in certain parts of the barn abruptly, it was no a gradual process.

The mean daily air temperature in the barn was described as:

$y = 0.000002x^4 – 0.0005x^3 + 0.0412x^2 – 0.8876x + 18.515$ with $R^2 = 0.957$.

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