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Impact of shelter on daylight in the stables for dairy cows

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Abstract

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The aim of the measurement was to assess the illuminance values and values of daylight factor in two stables for dairy cows that have the same technology layout. The difference between the stables was a shelter on the side of one of them. Measurements were made halfway through the stables including edge portions with cubicle and central parts with feed passage, above which is skylight. From the measured values of illuminance and calculated values of daylight factor, it can be seen that the effect of roof skylight is significant in terms of daylight. At the same time, they show how shelter affects daylight in the stable. The difference in values in the section under the roof skylight and in parts where the external walls are open is considerable. In the sheltered part, illuminance values are even lower than those with other external walls. This implies that the shelter sufficiently shades the cubicle, which is especially useful during summer.

Keywords: daylight factor; illuminance; lighting measurement; stable for dairy cows; shelter

One of the important parameters in the stables for dairy cows is lighting. It is an important parameter, not only in terms of working environment but also in terms of animal accommodation. According to the standard STN EN 12464-1:2012, the required maintained illuminance in stables for livestock should be 50 lx. In the barns for dairy cows the required illuminance in the area of animal movements 50 lx and in the feeding spot 100 lx (Hutla et al. 2013). Breeders are encouraged to light intensity at the level of the living area that would not be less than 200 lx (Doležal, Černá 2006). According to Chastian et al. (1994) proper lighting is an environmental factor that is often overlooked, or given little attention during the planning, construction, and maintenance of livestock facilities. However, it is just as important to the efficient operation of a livestock as ventilation, heating, or cooling. Doležal and Černá (2006) and Peters (1994) present the results of the research work, under which cows which are moved daily in good light conditions during 16 to 18 h have about 5–16% higher usefulness. Aharoni et al. (2000) analysed the lighting and the effects of day length, the daily change in day length, and heat load prevailing on test days, and on milk yield and composition of dairy cows in hot weather. The difference of 4 h between the shortest and the longest day, plus the seasonal change in day length, accounted for the addition of 1.9 kg of milk/day for cow calving after the shortest day compared with cow calving after the longest day. In cattle, as in other species, increasing exposure to light reduces the duration of melatonin secretion. A long day pattern of melatonin secretion increases circulating prolactin and insulin-like growth factor I (IGF-I) concentrations and these endocrine shifts are consistent with the observed effects on lactation and body growth and composition in cattle (Dahl et al. 2002). Photoperiod management and increased milking frequency

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in early lactation offer non-invasive methods to improve production and health of dairy cows (Dahl et al. 2004). A very important parameter especially in the box housing system is the uniformity of daylight (U_o), which is determined as a proportion of the min. and max. values of daylight factor (D_{min} and D_{max}), found in the network control points on a horizontal comparative plane within the entire indoor premises or in a functionally defined part (Chloupek, Suchý 2008). The aim of the study was to characterize the daylight by daylight factor (D) and daylight uniformity (U_o) in standardized buildings after reconstruction and to compare the change in daily lighting after completion of shielding shelter in one stable.

MATERIAL AND METHODS

Measurements of daylight were performed in two stables for dairy cows with the same technology layout. Plan dimensions of stables were 66 × 28 m. Headroom of the stables at the external walls was 2.8 m and 4.7 m below the roof skylight. The animals were placed by the external walls of the stable in two rows of cubicles, between which was a manure corridor. The feed passage along with food mangers was under the roof skylight in the middle part of the stable.

Daylight entered the stable through the open external walls of the stable, open barn doors in the front walls and roof skylights. The external walls of the stable had a parapet at the bottom, which was at a height 830 mm above the floor. Opening, which was supplied by the original small windows on the side wall in the height of 1.8 m, was almost continuous – in length of 66 m (11 modules by 6 m). In the front and backside of the stable were six gates, of which two barn doors had dimensions 2.7 × 3.0 m, two 3 × 3 m and in the middle were two, having dimensions 2.7 × 2.9 m. In the summer period, all the doors were open, with the exception of wind storms or heavy rain. Dimensions of the skylight opening were 2.4 × 54 m.

After three years of use of these facilities, it was necessary to add a shelter to the eastern side of the stable 3.5 m wide, all over the length of the building (66.96 m). The shelter was used to partially shade the cubicle where the animals were placed and protect them thus from overheating.

For measurement of daylight, two same luxmeters Testo 545 (Testo AG, Lenzkirch, Germany) were used. The daylight was measured in the ex-

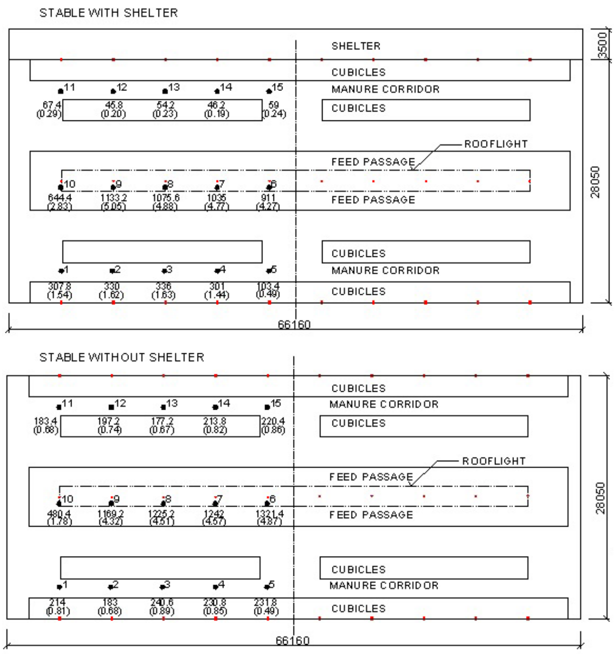

Fig. 1. Layout of measuring points in the stables
■[1] – measurement point; 307.8 – illuminace (lx); (1.54) – daylight factor (%)

ternal and internal environment at the same time. Before the measurement of illuminance, a network of measuring points was determined in the buildings. Illuminance was measured halfway through the stable in the manure corridors and feed passage with 5 repetitions. The other half of the stable was symmetric. Measuring points with the values of illuminance and daylight factor are shown in Fig. 1. The measurement was performed in accuracy class 3. The outdoors measurement location was designated so that it was not shielded by anything.

Daylight level was evaluated using the daylight factor (D).

$$D = (\bar{E}/\bar{E}_h) \times 100\ (\%) \qquad (1)$$

where: $\bar{E}$ – the average illuminance at the point of the given plane of indoor premises (lx); $\bar{E}_h$ – the average value of outside comparative illuminance (lx)

According to STN 73 0580:1986 for humans, the minimal value of daylight factor should be D_{min} = 1.5% and mean value of daylight factor D_{mean} at least 3%. For free dairy housing with cubicle the minimal value of daylight factor should be D_{min} = 1.0% (STN 36 0088:1973).

Physiological illuminance of the stables for dairy cows should be 60 lx as well as working illuminance.

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Table 1. Values of internal and external illuminance and daylight factor in the stable with shelter on one side and without shelter

Area	No.	Stall with shelter on one side			Stall without shelter		
		E_h (lx) average	E (lx) average	D (%)	E_h (lx) average	E (lx) average	D (%)
Manure corridor	1	20,042	308	1.54	26,446	214	0.81
	2	20,380	330	1.62	26,751	183	0.68
	3	20,604	336	1.63	26,955	241	0.89
	4	20,837	301	1.44	27,303	231	0.85
	5	21,079	103	0.49	27,143	232	0.85
Feed passage	6	21,349	911	4.27	27,139	1,321	4.87
	7	21,711	1,035	4.77	27,164	1,242	4.57
	8	22,044	1,076	4.88	27,175	1,225	4.51
	9	22,426	1,133	5.05	27,072	1,169	4.32
	10	22,741	644	2.83	26,967	480	1.78
Manure corridor by the shelter	11	23,042	67	0.29	26,824	183	0.68
	12	23,235	46	0.20	26,590	197	0.74
	13	23,484	54	0.23	26,343	177	0.67
	14	23,896	46	0.19	26,121	214	0.82
	15	24,365	59	0.24	25,772	220	0.86

No. – number of measurement; E_h – outside comparative illuminance; E – illuminance in the point of the given plane of indoor premises; D – daylight factor

For uniformity of daylight (U_o) indoor with the upper or combined lighting applies (Chloupek, Suchý 2008):

$$U_o = D_{min}/D_m \quad (2)$$

where: U_o – uniformity of daylight; D_{min} – minimum daylight factor value (%); D_{mean} – mean daylight factor value (%)

Required value U_o in housing with the upper or combined lighting is ≥ 0.30. For humans the value is $U_o > 0.2$ at a moderately precise class of visual activity (Chloupek, Suchý 2008).

RESULTS AND DISCUSSION

The average values of internal illumination at a point of the plane, external comparative illuminance and calculated daylight factor values are given in Table 1and in Figs 2 and 3.

The highest values of illuminance and daylight factor in both stables were obtained in the middle section under the roof skylight. These values exceeded standard set values for the daylight factor values and for illuminance values as well. In the stable with shelter, the values of illuminance (E) under the roof skylight ranged from 644 lx to

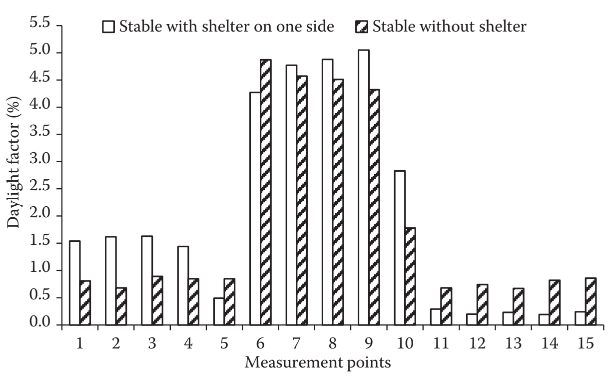

Fig. 2. Illuminance values in the stables

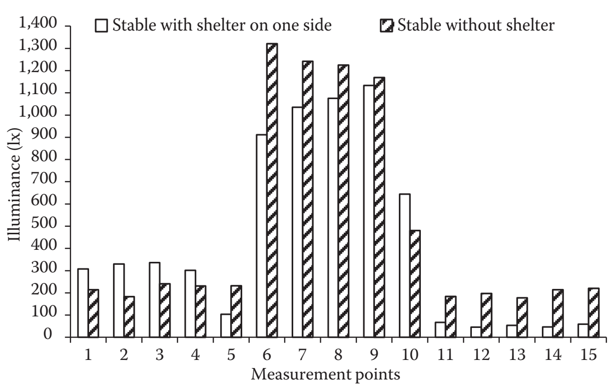

Fig. 3. Daylight factor values in the stables

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Table 2. Uniformity of daylight

Service	$\bar{E}$ (lx)	$\bar{E}_h$ (lx)	D_{mean} (%)	D_{min} (%)	D_{max} (%)	U_o (–)
Stall with shelter on one side	22,082	430	1.98	0.19	5.05	0.1
Stall without shelter	26,784	502	1.86	0.67	4.87	0.36

$\bar{E}$ – average illuminance in the point of the given plane of indoor premises; $\bar{E}_h$ – the average value of outside comparative illuminance; D_{max} – the maximum value of daylight factor; D_{min} – the lowest value of daylight factor; D_{mean} – the average value of daylight factor; U_o – uniformity of daylight

1,133 lx, values of daylight factor (*D*) from 2.08% to 5.05%. In the stable without shelter, the values of *E* under the skylights ranged from 480 to 1,321 lx, values D from 1.78% to 4.78%. Values were significantly lower in places by the external walls, where the cubicles are placed.

In the stable that has a shelter on one side, the values were satisfactory on the side without the shelter (values *E* ranged from 301 to 336 lx, values *D* were from 1.44% to 1.63%), except places in the middle part if the stable doors were closed (*E* = 103 lx, *D* = 0.49%). On the east side where the shelter was situated, these values were significantly lower and did not meet the minimum requirements. Values *E* were from 45.8 to 67.4 lx, values *D* from 0.19% to 0.29%. In the cubicle located beside the shelter, daylight factor values were approximately 7 times lower than in the cubicles that were beside the wall without shelter.

In the stable without shelter the values at the external walls, where the cubicles are situated, were approximately the same, but they did not satisfy the given conditions in terms of daylight factor; this value was lower than 1%. Illuminance was sufficient in these parts. The lowest value of illuminance in all of stable was 183 lx.

The value for uniformity of daylight in the stable with shelter was lower than the set point of the interior spaces with combined lighting (Table 2). This is caused by lower daylight in cubicles that are placed in the section by the shelter. In the stable without shelter, this value was satisfactory.

Stables for cattle must be constructed to ensure healthy indoor environment and not to threaten housing and animal breeding (Pogran 2011). Therefore, it is necessary to monitor microclimatic characteristics of the environment (Karandušovská 2012), as well as lighting in stable (Reksen et al. 1999; Philips et al. 2000).

Several studies have shown benefits of longer photoperiod in lactating dairy cows; however, it is known that the locomotion pattern of dairy cows is altered at low light intensities. This may result in reduced cow traffic and milking frequency, which would have a negative impact on system productivity (Hjalmarsson et al. 2014).

It can be seen from the values measured in our experimental farm that the illuminance values are lower in a place where the shelter is than in other parts of the stable. According to STN EN 12464-1:2012 these values are only a little lower, which is negligible. However, based on the original standard STN 36 00 88:1993, illuminance for free housing of dairy cows should be at least 60 lx. Daylight factor values are not satisfactory in the livings in either stable. In the place of feeding these values are high. The results show that in the sheltered place (Fig. 4), the values of daylight factor are lower, even though there is enough daylight. The problem of not-lying of 56 cows during the entire morning in summer was solved, too (Lendelová et al. 2011). In Fig. 5 is the inner part of the stable with shelter. In summer, shelter is a very good solution for dairy cows, because it protects them from direct sunlight and thus against overheating. In winter, the sail that covers the shelter is rolled up and thus it does not affect the daylight in the stable. Feeding animals is

Fig. 4. Shelter of stable in Oponice

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Fig. 5. The inner part of the stable by the shelter

Fig. 6. Middle part of the stable with roof skylight

very well designed, too. The roof skylight above the feeding manger provides good daylight, but the sun in the midday hours is not shining directly on the animals (Fig. 6).

CONCLUSION

The work deals with influence of shelter on stable daylight. In the first stable, daylight was compared at the side with and without shelter. On the east side, where the shelter was, values of daylight factor ranged from 0.19% to 0.29%, which is only 14% of the values on the west side without shelter. These values do not satisfy the requirements for dairy cows. In the stable without shelter, illuminance values were compared at the both sides, too. Differences in values of daylight factor on the east and west side of the stable were minimal and were caused mainly by illuminance changes in the external environment during measurement. It follows that the shelter shades the stable enough. It has a positive impact on protection of this part of stable against overheating. Given that the sail is used as a shelter only in summertime, it does not affect the daylight in wintertime, when there is a lack of light. The disadvantage of shelter in this type of stable is the deterioration of uniformity of daylight; hence, it is important to address how to ensure the differences in the daylight inside the stables as small as possible. An appropriate solution is the use of such sail for roofing of shelter that enables light pass through but prevents overheating. Second solution that is more difficult is a reconstruction of roof and ceiling structure using translucent light elements. Another possibility to improve the illuminance is artificial lighting, which is important especially in winter. A suitable arrangement would be adding a light sensor device to the lighting system, which would switch on the system automatically if the lighting levels got worse (Šístková et al. 2010). The artificial lighting should be divided into sections, because the light in the stable is unevenly distributed. The light should be switched only in that part of the stable, where illuminance values would be insufficient.

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