RELATION BETWEEN THE INDOOR AND OUTDOOR CLIMATE IN UNINSULATED COWSHEDS

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ABSTRACT. *In Estonia, there are about fifty farms with uninsulated and loose housing cowsheds where the outdoor climate has big impact on the indoor climate of the cowsheds. It is known that cows can put up with lower temperatures much better than with higher ones, so we can say that these buildings are well suited for animals, although there are problems with workers and working environment in uninsulated cowsheds in extreme cases, during very low and high outside temperatures.*

The goal of this study was to find out the outdoor climate impact on indoor climate in cowsheds with 500, 420 and 250 cow places during winter and summertime. For that, indoor temperature, relative humidity and ammonia content were measured, using measuring device ALMEMO Data Logger 2690-8 with respective sensors and computer programme AMR WinControl. At the same time, outdoor temperature and relative humidity were measured, using measuring device HygroLog with sensor HygroClip S.

The data about empiric dependence of indoor temperature, relative humidity and ammonia content upon outdoor climate are given. The processed results are well applicable when designing new cattle housing or improving the indoor climate of already existing uninsulated cowsheds.

Keywords: *uninsulated cowshed with cubicles, outdoor climate, indoor climate, air temperature, relative humidity, ammonia content, Data Logger, computer programme.*

Introduction

The construction of uninsulated cowsheds is becoming increasingly popular. Old light structures are taken into use and also new livestock buildings are built for greater stock, considering relatively inexpensive construction costs. In recent years, the reconstruction possibilities (Miljan, J., Leola, 2000) and cost-effectiveness (Miljan, J., Miljan, R., 1999) of former large farms have been studied. In such cowsheds, animals may be kept both in deep litter free stalls and in cubicles.

The indoor climate of uninsulated cowshed is to a great extent affected by outdoor climate (Neste Air–IX).

Properly functioning ventilation (air ducting) is required in order to ensure favourable indoor climate. Constant ventilation is necessary for maintaining air temperature, humidity and cleanliness of the room. Intensive ventilation in winter causes the room to cool down (Mikson, 2000). Natural ventilation is the best solution because it is noiseless, cheap and easily built and requires very little maintenance.

No standards have been provided for daily change in temperatures, but daily differences of temperature in cowsheds should not exceed 5 °C (Neste Air–IX, 1990). The recommended highest, lowest and optimum temperatures for animals are provided in Table 1.

Cows tolerate low temperature better than high temperature. It should be pointed out that the temperatures which are quite acceptable for humans, may cause negative response in cattle. An increase in breathing frequency and emission of humidity has been observed (Vutt, 1983) at temperatures exceeding +15 °C and a decrease in appetite, productivity and body mass of animals has been observed at temperatures exceeding +21 °C.

Table 1. Recommended temperatures for animals (Neste Air–IX, 1990*)*

Animal category	Critical temperatures		Optimum
	lowest	highest	
Dairy cow	(–25…)–15	23…27	5…15
Young cattle	(–15…) 0	25…30	10…20
Calves	(0…) 10	30	15…25
Beef-cattle, over 3 months of age	(–35…)–15	25…30	–10…15

When compared to insulated cowshed, the uninsulated cowshed has more intensive ventilation. It is best manifested by the difference in indoor and outdoor air temperatures. In case of major difference the ventilation is insufficient, causing excessive increase in relative humidity and carbon dioxide content of indoor air and the formation of condensation on walls (Antelmann, 1992; Hilty *et al.*, 2002; Kavolelis, 2003; Rannamäe, 1985).

The working environment in cowsheds has been studied mostly in small cowsheds, but there is a growing tendency towards building larger farms.

The objective of this research was to study the impact of outdoor climate of uninsulated cowsheds with cubicles on indoor climate of these premises in winter and in summer. For that purpose, indoor air temperature, relative humidity and ammonia contents were measured in cowsheds. Outdoor air temperature and relative humidity were measured at the same time (Mikson *et al.,* 2004; Reppo *et al.,* 2003).

Material and methods

Indoor air temperature, relative humidity and ammonia content were measured in the middle of the premises at the height of 1.5 m in uninsulated cowsheds for 500, 420 and 250 cows (hereinafter referred to as Cowshed 1, 2 and 3, respectively) (http… 25048, Karhunen, 1992). Simultaneously, the outdoor air temperature and relative humidity were measured at the distance of ca 10 m from the cowshed in a shadowy place.

The number of dairy cows kept in cubicles in Cowsheds 1, 2 and 3 during the study was 475, 352 and 220 respectively (Table 2). Cowshed 1 is a new woodframe building and Cowshed 2 is new metalframe building. Cowshed 3 represents reconstructed building of former collective farm cowshed, where windows have been replaced with construction net (Mikson *et al.,* 2004). They can be covered with plastic frames when necessary. All cowsheds have covered ventilation slot along the ridge. The slot could not be adjusted at the time of measurement. Cowsheds 1 and 2 have adjustable curtains on the walls. In Cowshed 3, no litter was used, whereas in Cowsheds 1 and 2 animals were kept on sawdust and straw litter, respectively.

In Cowsheds 1 and 2, manure was removed with tractors T-25 and T-40, respectively, in Cowshed 3 manure was removed constantly by using wing scrapers and a manure pump. Attached mixer-distributors of various manufacturers were used in all cowsheds (Table 2).

Table 2. Information on cowsheds

Cowshed	Cowshed 1	Cowshed 2	Cowshed 3
Cowshed	Uninsulated	Uninsulated	Uninsulated
Cowshed volume, m^3	26 390	20 625	8141
Dairy cows	475	352	220
Cowshed volume per dairy cow, m^3/cow	55.6	58.6	37.0
Method of keeping	In cubicles	In cubicles	In cubicles
Milking	DeLaval 2×20	Stranko 2×20	DeLaval 2 x 14
Feed distribution	DeLaval attached mixer-distributor	Eurocomp attached mixer-distributor	DeLaval attached mixer-distributor
Manure removal	T-25+front loader+ drainage + pump	T-40+front loader	Constant, wing scrapers, manure pump
Litter	Sawdust	Straw	–
Ventilation	Natural	Natural	Natural

ALMEMO Data Logger 8990-8 equipment with computer programme AMR WinControl was used for studying the parameters of indoor climate. Indoor air temperature and relative humidity were measured with AMR company sensor FH646-1 with measurement area –20…+80°C (measuring accuracy 0.01°C) and 5…98% (measuring accuracy 0.1%), respectively. Ammonia content was measured with sensor ZA 3601-FS2 (Bacarach EIT Co), measurement area 0…100 ppm and measuring accuracy 0.01 ppm. HygroLog device with HygroClip S sensor (measurement area –40…+85°C and 0…100%, measurement accuracy ±0.3°C and ±1.5%, respectively) were used for measuring the temperature and relative humidity of outdoor air. In winter the numerical values of the climate parameters were determined at the interval of 1 and 2 minutes in Cowshed 1 and 2 respectively and at the interval of 10 minutes in Cowshed 3. In summer the measurements were taken at the interval of 60 sec in all cowsheds. Measurement results were analysed by using computer programmes AMR WinControl, HW3 and MS Excel (Kiviste, 1999).

Results

The study revealed that in case of outdoor temperature –14.70…+8.81 °C measured in winter, the indoor air temperature of cowsheds was –7.45…+13.76 °C, which constituted average of –0.31 and 2.01 °C, respectively (Table 3, Figure 1a and Figure 2). Measurement results of climate parameters in Cowsheds 1, 2 and 3 in winter are shown in Table 3 and Figure 2. According to the results, the indoor air temperature was the lowest in Cowshed 3, the average temperature being –2.79 °C. Similar results were seen in the relative humidity of indoor air, 99.61%. During the measuring period, the outdoor temperature was also low and relative humidity was high (–9.17°C and 96.48%, respectively). The average indoor air temperature and humidity in Cowsheds 1

and 2 were 3.17 and 77.77% and 0.65 and 95.02%, respectively. Simultaneously, the outdoor temperature and humidity were measured with the results of 2.2°C and 85.19% and –3.49°C and 92.50% respectively.

In case of outdoor temperature 8.38…23.19 °C measured in summer, the indoor air temperature of cowsheds was 9.81…22.07 °C, which constituted the average of 16.33 and 17.12 °C, respectively (Table 3, Figure 1b and Figure 2). Table 3 reveals that in summer the highest numerical values of indoor temperature and relative humidity were measured in Cowshed 2, the average values being 22.07 °C and 100.00%, respectively, whereas the relevant average numerical values of outdoor air were 20.44°C and 96.25%.

The relation between indoor temperature in winter t_{iw} and in summer t_{is} and outdoor temperature t_{ow}, t_{os} can be expressed by using functions in Table 4, which apply to the cowshed volume and the number of dairy cows.

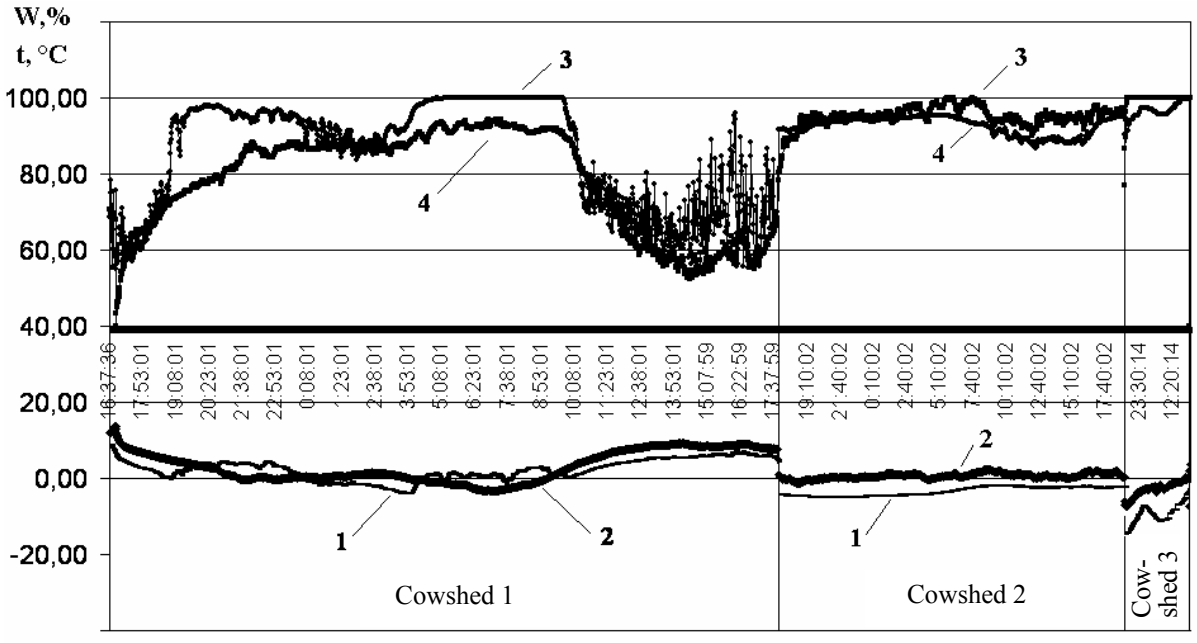
In winter the difference in average indoor and outdoor temperatures of Cowsheds 1, 2 and 3 was 0.97, 4.14 and 2.31 °C, respectively; average tabular data value (Table 3) was 2.32°C. Relevant numerical values in summer were 0.06, 1.63 and 0.90 °C, respectively; the average tabular data value was 0.79°C. Despite higher indoor temperature in summer, the humidity was higher indoors than outdoors, due to wet surfaces covered with manure.

Table 3. Indoor and outdoor climate parameters in Cowsheds 1, 2 and 3 in winter and in summer (numerical values)

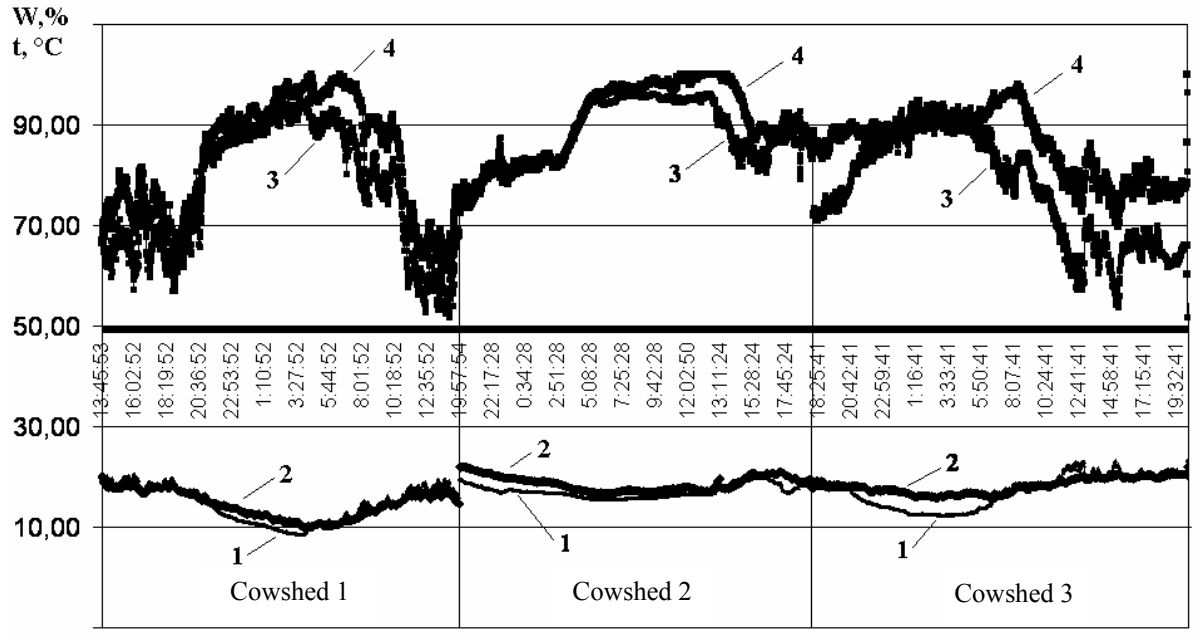
Parameters	Winter					Summer				
	indoors			outdoors		indoors			outdoors	
	t, °C	W, %	NH_3, ppm	t, °C	W, %	t, °C	W, %	NH_3, ppm	t, °C	W, %
	Cowshed 1									
Min	–3.43	40.1	0.58	–4.06	55.1	9.81	60.2	0.58	8.38	51.8
Average	3.17	77.77	1.69	2.20	85.19	14.48	83.20	3.04	14.54	76.85
Max	13.76	94.4	3.40	8.81	100.0	20.29	100.0	5.58	20.50	96.4
σ_x	4.1	13.32	0.52	2.73	14.18	2.69	11.71	0.76	3.65	12.43
S_x	0.11	0.34	0.01	0.07	0.36	0.07	0.30	0.02	0.09	0.32
	Cowshed 2									
Min	–1.27	78.5	0.43	–5.00	86.6	16.59	73.1	0.63	15.50	72.4
Average	0.65	95.02	2.21	–3.49	92.50	22.07	100.00	4.20	20.44	96.25
Max	2.42	100.0	3.20	–1.94	95.5	18.70	90.4	7.68	17.15	88.2
σ_x	0.71	2.75	0.31	1.14	2.38	1.47	7.68	1.28	1.28	6.47
S_x	0.03	0.10	0.01	0.04	0.09	0.04	0.20	0.03	0.03	0.17
	Cowshed 3									
Min	–7.45	77.0	0.58	–14.70	90.4	15.76	69.7	0.63	12.25	53.8
Average	–2.79	99.61	2.35	–9.17	96.48	18.16	85.65	7.45	17.26	77.16
Max	0.46	100.0	3.39	–2.90	99.8	20.62	98.1	10.34	23.19	95.0
σ_x	1.94	2.40	0.27	2.69	2.10	1.47	6.33	1.54	3.31	10.83
S_x	0.16	0.20	0.01	0.22	0.17	0.04	0.16	0.04	0.08	0.27
	Tabular data									
Min	–7.45	40.1	0.43	–14.70	55.1	9.81	60.2	0.58	8.38	51.8
Average	2.01	84.61	1.92	–0.31	88.21	17.12	86.38	4.88	16.33	80.66
Max	13.76	100.0	3.40	8.81	100.0	22.07	100.0	10.34	23.19	96.4
σ_x	3.69	13.78	0.53	4.16	11.92	2.70	9.32	2.24	3.20	11.51
S_x	0.07	0.28	0.01	0.08	0.24	0.04	0.14	0.03	0.05	0.17

Ammonia content did not exceed the allowed limits (20 ppm) neither in winter nor in summer (http://...73153). While the ammonia content measured in winter remained within the range of 0.43…3.40 ppm, the ammonia emission at elevated indoor temperatures of cowshed was higher in summer (measured within the range of 0.58…10.34 ppm) (Table 3 and Figure 3). In winter the highest average numerical value of ammonia content was observed in Cowshed 3 (2.35 ppm). In summer the highest average numerical value of ammonia content 7.68 ppm was observed in Cowshed 2. Manure was removed with tractor during milking.

The impact of indoor air temperature in summer t_{iS} (°C) on ammonia content P_{NH_3} (ppm) is represented in Figure 3.



a.



b.

Figure 1. Outdoor and indoor temperature and relative humidity in Cowsheds 1, 2 and 3 in winter (a) and in summer (b). 1 and 2 – outdoor and indoor temperature; 3 and 4 – outdoor and indoor relative humidity

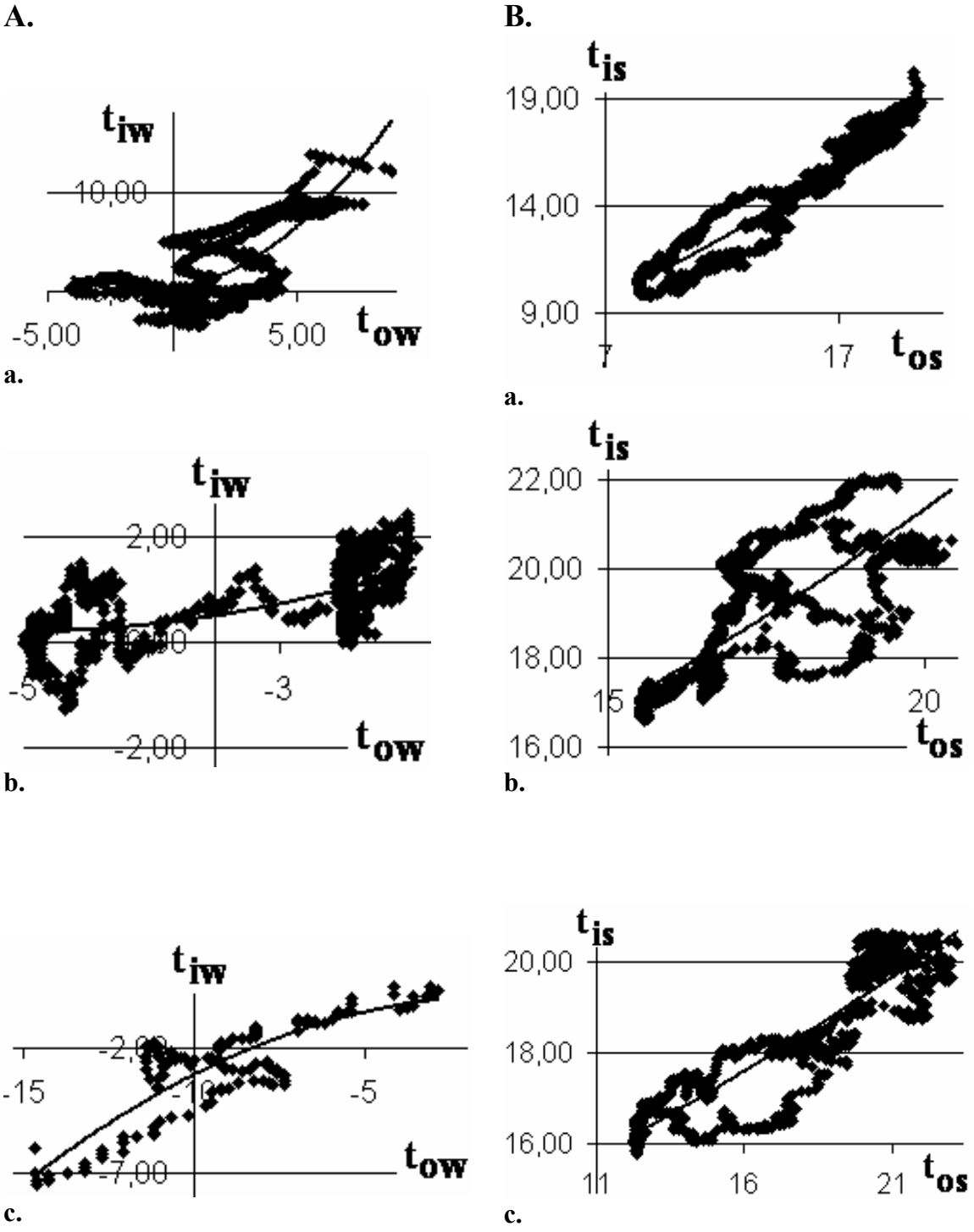


Figure 2. Relation between indoor (t_{iw}) and outdoor (t_{ow}) temperatures of Cowsheds 1 (a), 2 (b) and 3 (c) in winter (A) and in summer (B)

Table 4. Relation between indoor (t_{iw}, t_{is}) and outdoor (t_{ow}, t_{os}) temperatures in cowsheds

	In winter	In summer
Cowshed 1	$t_{iw} = 0{,}1749\ t^2_{ow} + 0{,}4038\ t_{ow} + 0{,}1409$	$t_{is} = 6{,}8407e^{\ 0{,}0476\ t_{os}}$
475 dairy cows	$R^2 = 0{,}6186$	$R^2 = 0{,}9109$
Cowshed 2	$t_{iw} = 0{,}1226\ t^2_{ow} + 1{,}2462\ t_{ow} + 3{,}347$	$t_{is} = 8{,}2434e^{0{,}0476\ t_{os}}$
352 dairy cows	$R^2 = 0{,}3826$	$R^2 = 0{,}6152$
Cowshed 3	$t_{iw} = -0{,}0377\ t^2_{ow} - 0{,}0678\ t_{ow} + 0{,}0263$	$t_{is} = 12{,}328e^{0{,}0476\ t_{os}}$
220 dairy cows	$R^2 = 0{,}7332$	$R^2 = 0{,}8266$

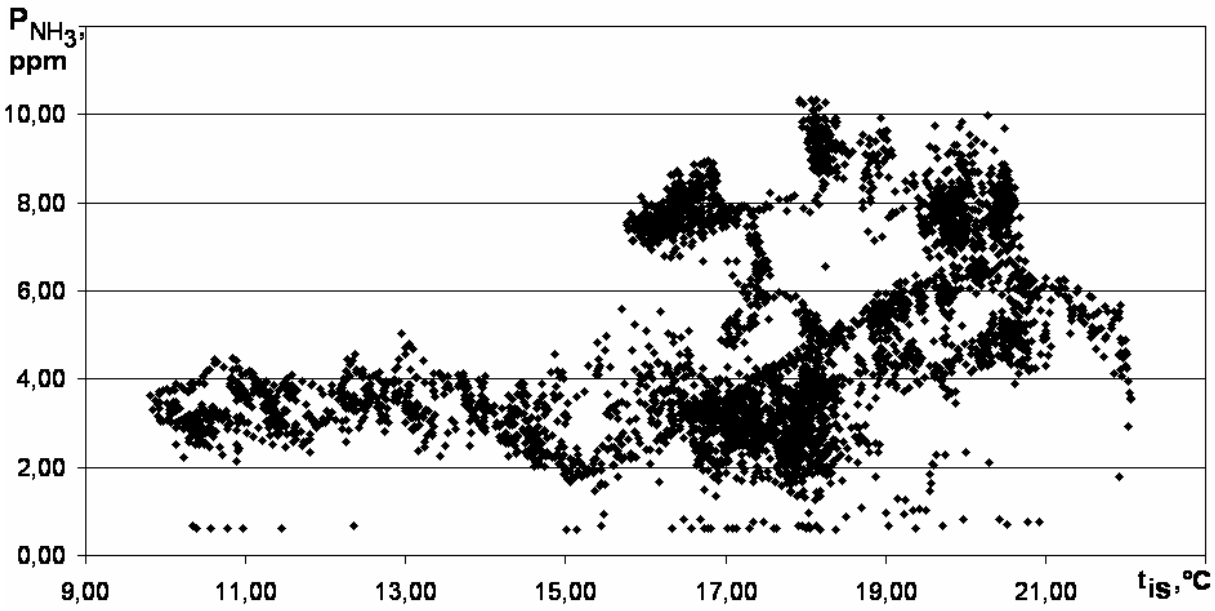


Figure 3. The impact of indoor air temperature on ammonia content in summer

Conclusions

The research measured indoor temperature, relative humidity and ammonia content in three uninsulated cowsheds of different size and number of cows in winter and in summer. Simultaneously, outdoor air temperature and relative humidity were measured.

Indoor temperature measured in winter was on average 2.32°C higher than outdoor temperature; relevant parameter in summer was 0.79°C. In summer the air humidity was higher indoors than outdoors, caused by humidity emission from animals and floor surface.

Ammonia content in winter was relatively low, remaining in the range of 0.43…3.40 ppm, but in summer the measured values of ammonia content were higher, ranging from 0.58 to 10.34, still remaining within the recommended limits.

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