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MICROCLIMATE IN CATTLE BARNS WITH FUNCTIONAL ATTIC AND ROOF RIDGE GAP

Summary

The aim of this article to present of research results of microclimate parameters in barns with different gravitational ventilation systems and comparison of efficiency of these systems. Two tied-up and three loose-housing barns for dairy cows and one for beef cattle were researched. Tied-up barns had functional attic and duct ventilation, in barns with loose housing systems there were skylights with roof ridge gap. In stalls with ventilation by vertical channels there was not sufficient area of air inflow and outflow. The negative consequence of this was overcoming of recommended internal relative humidity of air (80%) in these stalls. In non-littered barns, with roof- ridge gap ventilation, temperature of air exceeded recommended values of 25°C. The luminance of daily light in stalls with functional attic was below of minimal level, which was described by standards (100 lx).
***Key words**: microclimate, natural ventilation, air temperature, relative humidity, ammonia, animal welfare, vertical ventilation channels*

MIKROKLIMAT OBÓR Z PODDASZEM UŻYTKOWYM I SZCZELINĄ KALENICOWĄ

Streszczenie

Celem niniejszego artykułu jest przedstawienie wyników badań parametrów mikroklimatu w oborach z dwoma różnymi systemami wentylacji grawitacyjnej i porównanie skuteczności tych systemów. Zbadano po dwie obory stanowiskowe i wolnostanowiskowe dla krów mlecznych oraz jedną dla bydła mięsnego. Obory stanowiskowe posiadały poddasze użytkowe z wentylacją kanałową, natomiast w pozostałych oborach był świetlik ze szczeliną kalenicową. W oborach z wentylacją pionowymi kanałami nie była zapewniona odpowiednia powierzchnia nawiewu i wywiewu. Negatywnym tego skutkiem było przekroczenie zalecanych wartości wilgotności względnej powietrza (80%) w tych oborach. Temperatura w oborach bezściółkowych z wentylacją kalenicową przekraczała zalecane standardami wartości (25°C). Natężenie oświetlenia dziennego, w oborach z poddaszem użytkowym było poniżej minimalnego poziomu określonego standardami (100 lx).
***Słowa kluczowe**: mikroklimat, wentylacja naturalna, temperatura powietrza, wilgotność względna powietrza, amoniak, dobrostan zwierząt, pionowe kanały wentylacyjne*

1. Introduction

The progressive intensification of animal production and increase in concentration of cattle herds goes together with increase in production costs. One way of increase in milk production's effectiveness is ensuring of proper microclimatic conditions in new buildings as well as improvement of them in existing one.

In last years almost 50 thousands of tied-up cattle barns were rebuilt for free-stall barns [7]. Modernization, although expensive, should lead to creating of proper animal welfare conditions. The reconstruction is connected most frequently with liquidation of functional attic, which in significant range limits the cubage and amount of air necessarily to normal functioning of alive animals organisms. However, even in cattle barns with roof-ridge gap ventilation, especially without litter, it is very difficult to ensure proper microclimatic conditions due to releasing of large amounts of ammonia from liquid manure. Especially in autumn season , even in barns from which natural manure is removed every day such difficulties occur. According to Witkowska and other's research, relative humidity in such season in loose housing systems with litter and mechanical ventilation ranged even up to 99,9%. The high humidity with proper air temperature could lead, first of all, to expansion of dangerous pathogenic bacteria and fungi *Fusarium*, *Penicillium*, *Alternaria* [11, 12]. Spring and autumn are the most difficult periods due to oft and significant changes in temperature, humidity and of air movement velocity [2, 14].

Thermoneutral zone for cattle ranges from -5 to +25°C, while temperature for human beings is recommended at higher ranges. It explains the existence of differences with respect to ventilation management patterns, creating an unfavorable environment for animals [5].

As Teye's research shows, in cattle barns with partially insulation , by external temperature ranged -20°C the relative humidity of air ranged up to 80%, with air movement velocity 0,2 $m \cdot s^{-1}$ and carbon dioxide concentration 2925 ppm. In summer the highest ammonia concentration (19 ppm) was together with internal temperature of 28°C and relative humidity 48%, with air velocity amounting 0,6 $m \cdot s^{-1}$ [13].

2. Research aim and scope

The aim of the study was to evaluate microclimate parameters in barns with different technical solutions of natural ventilation. The research scope covered 5 cattle barns with herd's size from 83 to 170 LU. Among chosen barns were 3 with roof ridge gap (free-stall, non-littered cattle barns) and 2 barns with functional attic (littered stalls). In four from this barns dairy cows were kept, in one were beef cattle.

3. Methods of research

The research of microclimate parameters was conducted, according to elaborated methodic, which based on the following literature and formal-legal regulations: Romaniuk and Overby [8], Kośla [3], Winnicki et al. [10], Instytut Zootechniki [1], Regulation of Ministry of Agriculture and Rural Development MRiRW [9] and industry standard [6].

The research was realized by using of following apparatus:

– termo-, higro-meters – (marked on drawings TH-5, TH-6, TH-7 and Th-8) continuously registration to concentration's memory 487 and/or LB 731,

– termo-, higro-barometers LB-417, LB- 418, LB-419 and LB-420 – continuously registration to internal memory,

– dry cathatermometer – measurement of cathathermometric cooling,

– 4 double, portable gas detectors (MX6 No. 1, 2, 3, 4) for measurement of CO_2 and NH_3 concentration – continuously registration to internal memory,

– luxmeter Lx-100.

The technical data of measuring apparatus were described in PhD thesis of Mazur [4].

4. Research results

Technological- functional schemes of barns together with location of measuring equipment for microclimate is shown on figures 1-5.

Characteristics of researched barns were shown in table 1, whilst in table 2. – measured microclimate parameters.

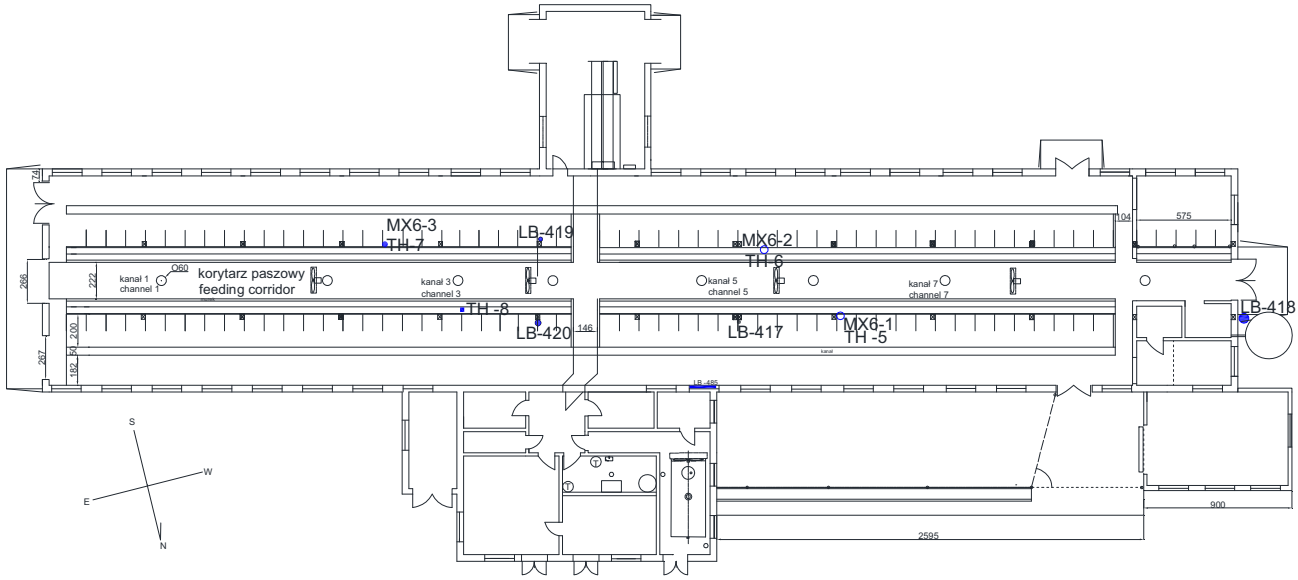

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Fig. 1. Scheme of tied-up housing barn in farm 1 with location of measuring equipment

Rys. 1. Schemat rzutu przyziemia obory stanowiskowej w gospodarstwie nr1 z rozmieszczeniem aparatury pomiarowej

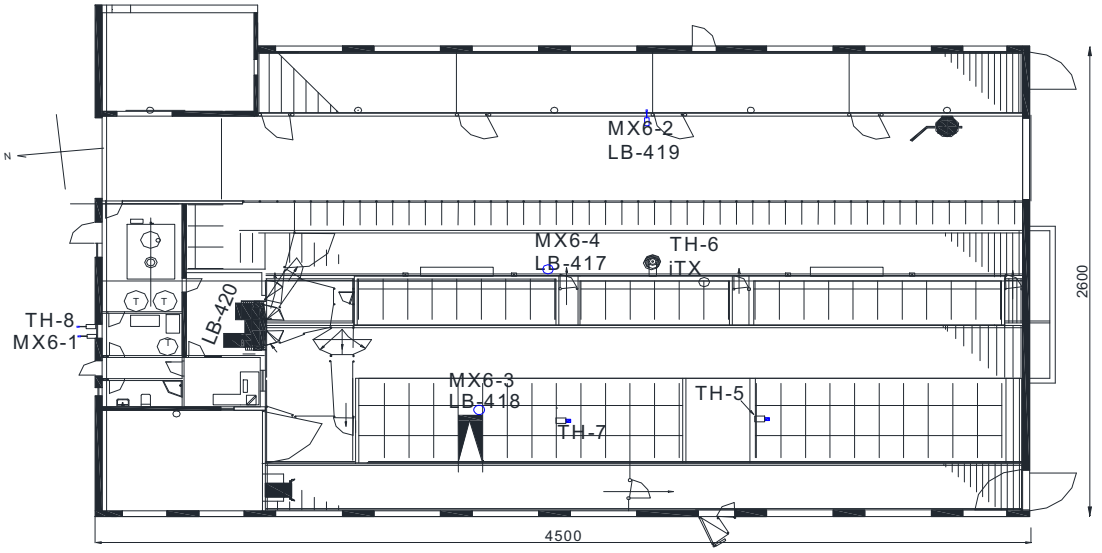

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Fig. 2. Scheme of non-littered loose housing barn in farm 2 with location of measuring equipment

Rys. 2. Schemat rzutu przyziemia obory bezściółkowej w gospodarstwie nr 2 z rozmieszczeniem aparatury pomiarowej

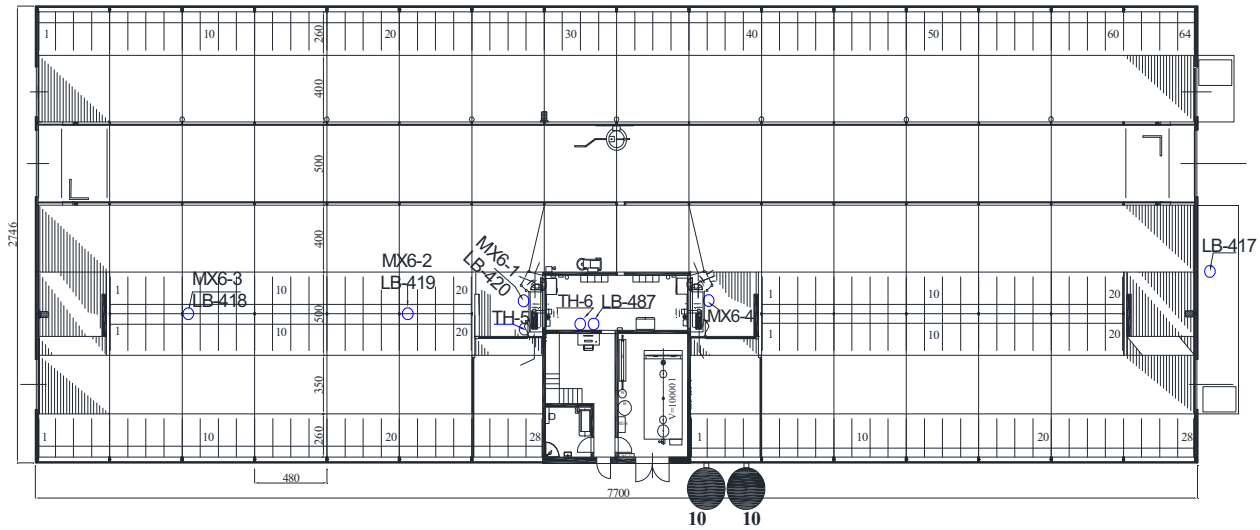

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Fig. 3. Scheme of non-littered loose housing barn in farm no.3 with location of measuring equipment
Rys. 3. Schemat rzutu przyziemia obory bezściółkowej w gospodarstwie nr 3 z rozmieszczeniem aparatury pomiarowej

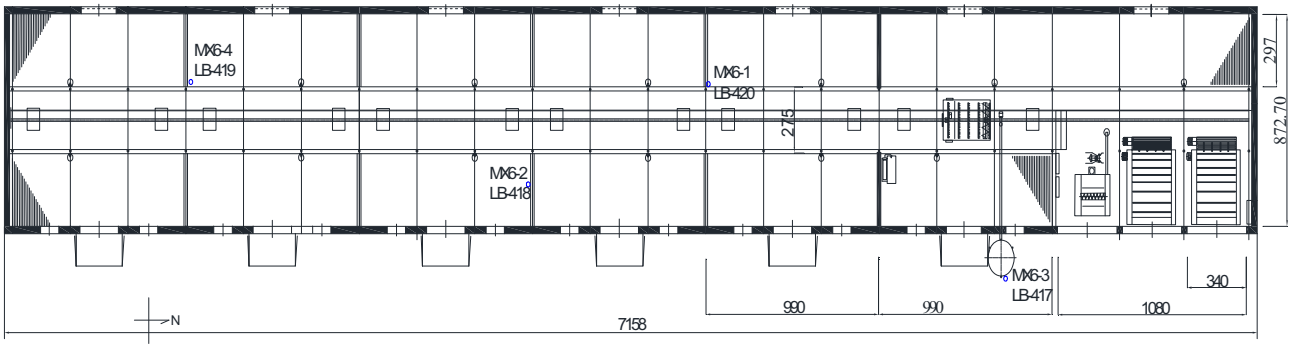

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Fig. 4. Scheme of non-littered loose housing barn for beef cattle in farm no. 4. with location of measuring equipment
Rys. 4. Schemat rzutu przyziemia obory bezściółkowej dla bydła mięsnego w gospodarstwie nr 4 z rozmieszczeniem aparatury pomiarowej

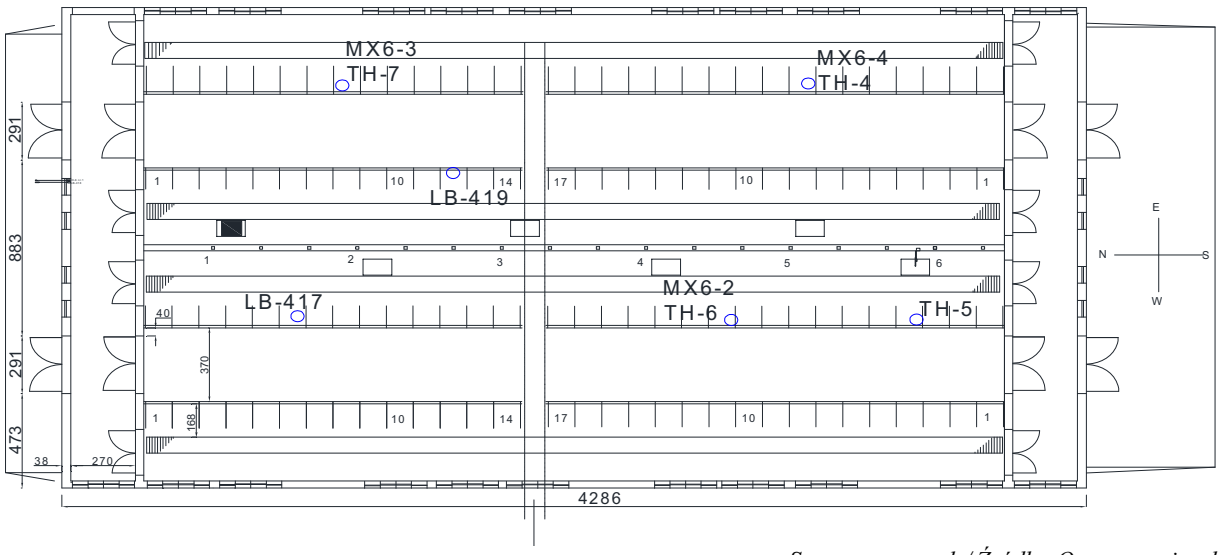

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Fig. 5. Scheme of tied-up housing barn in farm no. 5 with location of measuring equipment
Rys. 5. Schemat rzutu przyziemia obory stanowiskowej w gospodarstwie nr 5 z rozmieszczeniem aparatury pomiarowej

Table 1. Characteristics of researched barns including forming of microclimate
Tab. 1. Charakterystyka badanych obór z uwzględnieniem kształtowania mikroklimatu

No of farm	Breed Herd size LU [Livestock unit]	Housing system	Ventilation inflow/outflow of air	Light	Resting area Litter material floors of walking- manure channel	Manure removing - frequency	Cubage $m^3 \cdot DJP^{-1}$
1	Polish Holstein-Friesian black-white 109	tied-up, littered	gravitational, air inflow: gaps under windows / otflow:4 channels with vertical circular section Ø 60 and height 6,5 m, damaged moving ventilation shutter; additionally axial fan	windows 0,8 x 1,80 m, incandescent lamp with lack of regulation of luminance	stalls littered with straw 2,6 kg·animal^{-1}·day^{-1}	manure scraper in shallow channel – 2 times per day	28,5
2	Polish Holstein-Friesian black-white 83	loose housing, boxed, non-littered with slatted floor	gravitational, inflow: windows/ outflow – roof ridge gap	windows, skylight ridge 2,6 x 28,8 m; halogen lamps without regulation of luminance	boxes with mattresses from elastic gum, without litter	manure channels – few times per year, depending on level of channels filling	74,43
3	Polish Holstein-Friesian black-white 170	loose housing, boxed, non-littered with slatted floor	gravitational, inflow: mobile curtains made from polycarbonate, lack of inflow channel for fresh air in milk room, which is too small for cooling aggregate/ outflow: roof ridge gap, throttles with electrical engines	curtains (polycarbonate) on the whole length of side walls – height 1,4 m (when abandoned – gaps 1,4 m height), skylight; metal halide lamps 400 W	boxes with gum mats LELY Compedes littered with short cut straw 0,3 kg·animal^{-1}·day^{-1}	slurry channels – few times per year depending on level of channels filling	70,64
4	Aberdeen Angus Piemontese Limousine 100	loose housing, non-littered joint pens for weight-age groups	gravitational, roof: Eurofala inflow: PVC windows with net/ outflow: roof ridge gap	7 windows: 2 x 0,6 m^2 skylight 1,5 x 57 m^2, fluorescent lamps	slatted floor without litter	slurry channels, – few times a year depending on level of channels filling	19,79
5	Polish Holstein-Friesian black-white 150	tied-up, littered	gravitational, inflow: windows/outflow: vertical ventilation channels with rectangular section 1,2 x 1,2 m	natural: windows, artificial: fluorescent lamps	stalls, littered twice a day with straw 2,6 kg·animal^{-1}·day^{-1}	channels with slatted floor, removing of slurry once a day, slurry spreader + tractor	22,8

Source: own work / Źródło: Opracowanie własne

Table 2. Microclimate parameters from researched barns
Tab. 2. Parametry mikroklimatu w badanych oborach

No of barn	Temperature [°C]		Relative humidity of air [%]		Gas concentration		Cathatermo metric cooling [W/dm^2]	Air velocity [m·s^{-1}]		Lumination [Lx]
					CO_2 [ppm]	NH_3 [ppm]				
	external average	iternal average	internal average	internal average	average	average				
	variations from - to	variations from - to	variations from - to	variations from- to	variations from - to	variations from - to	average	average		average
1	20,8	21,9	68,1	73,03	1143,5	4,9	3,07	0,17		68
	18,9-22,1	19,2-23,6	48,7-95,2	53,4-84,6	500-2200	1-10				
2	18,32	17,60	59,25	66,5	665,5	6,1	2,7	0,2		124,25
	12-23	13,0-21,03	38,1-91	46,97-83,5	300-1500	1-19				
3	23,07	23,6	48,14	58,31	845,5	11,9	2,85	1,55		1193,5
	16,8-38,8	18,5-30,6	18,4-67,6	21,28-77,32	472-1380	0,6-20				
4	23,2	27,6	68,7	66,4	869,2	14,5	1,347	0,26		530
	15,2-33,8	20,3-37,4	34,4-99,7	37,7-93,1	500-1550	5-22				
5	17,54 13-23	21,64 17,4-26,4	67,8 26,6-84,7	73,58 56,4-89,1	1105,88 300-2800	2,96 1-5	3,02	0,15		76
Recom-mendation	-	optimal 8-16	-	optimal 60 max. 80	max. 3000	max. 20	optimal 2,9-4,0	0,3 winter	0,5 summer	100

Source: own work / Źródło: Opracowanie własne

The conducted research indicated many abnormalities in designing of ventilation system, as well as in its exploitation. It concerns, in particular, the barns with functional attic, where there wasn't proper air inflow and outflow area ensured. In many barns were exceeded the highest permissible air temperature 25°C, relative air humidity 80% and recommended ammonia concentration of 20 ppm.

- Temperature inside barns with functional attic was lower and relative air humidity was higher than in barns without such attic.
- Only in non-littered barn with the highest unitary cubage the relative air humidity did not exceed boundary value of 80% recommended by standards. In barn with roof ridge slit and the lowest cubage, microclimatic conditions did not fulfill the recommended standards. While it was raining (night) there was very high relative air humidity in this barn – from 80 to 93,1%, by air temperature from 21 to 24°C.
- The average air temperature inside barns was from 17,6 to 27,6°C with variations from 13 to 37,4°C. Relative air humidity was from 58,31 to 73,58%, with variations of single values from 37,7 to 93,1%. In non-littered barn for dairy cattle with higher herd size and in barn for beef cattle, temperature inside barns in momentary measurements exceeded the value recommended by standards 25°C.
- The illumination of daily light was above minimal level recommended by standards (100 lx), in exception of barns with functional attics.
- In all barns researched the artificial light was used, but it was insufficient in barns with functional attic. The incandescent lamps should be replaced by fluorescent lamps, due to their low efficiency. Also halide lamps are improper, because they do not allow to obtain scattered light.
- In tied-up barn with lower herd size the inflow of air area as well as outflow area are insufficient. The inflow gaps are unnecessarily clogged with various materials by staff. There is too low number of outflow channels (4 pcs). The operating range of outflow channel equals 10 diameters of cross section, so by length of building of 66 m there should be 6 such channels. The thermal insulation of outflow channels, necessary to proper functioning of ventilation, were destroyed during exploitation. These channels should be insulated.
- In boxed, non-littered barn (no 2) the improper solution were slatted floor on the whole area of joint pen for heifers and dried cows. Too large area of slatted floor, in relation to the needs, could be the reason of high ammonia emission. Anyway the ventilation system in this barn was designed properly. The roof slope 24° guarantees effective air movement. The height of roof ridge gap equals 0,25 m, what gives 14,4 m^2 of outflow area, whereas inflow area equals 51,2 m^2.
- The air velocity in three barns did not exceed the maximum value in summer season permitted by standards (0,5 $m \cdot s^{-1}$), however, in one barn with the highest cubage – amounted its three times.
- The average carbon dioxide concentration in barns was from 665,5 to 1143,5 ppm with variations from 500 to 2800 ppm. The higher concentrations of this gas were in barns with vertical ventilation channels. The highest carbon dioxide concentration was in tied-up barn with higher herd size and it was 93% of norm 3000 ppm, which is permitted by standards.
- Average ammonia concentration in barns was from 4,9 to 14,5 ppm with variations from 1 ppm in barn with the highest unitary cubage (no 2) to 22 ppm in barn with the lowest cubage (no 4), with the fact that in barns with functional attic, in variations did not exceed 10 ppm – the half of level permitted by standards. The NH_3 concentration was higher in non-littered barns.
- In particular, unfavourable ammonia concentration was in barn for beef cattle (calves over 3 months and older cattle) with housing on a slatted floor. During research slurry channels were overflowing. The cubage of this barn and its height also were definitely insufficient. The precondition for effective ventilation is the difference 5°C between internal and external temperature of air, what did not take place in this time. Air temperature inside this barn was high, what proves improper working of ventilation. The ammonia concentration above permitted level was remaining in continues mode through eight-hour periods and few nights, from about 21st hour to 6th hour in the morning. It is alarming phenomenon, whereas according to Regulation of Ministry of Agriculture and Rural Development from 2010 year, ammonia concentration in rooms for calves should not exceed 20 ppm.

5. References

[1] Instytut Zootechniki. Karty informacyjne dla założeń technologicznych produkcji zwierzęcej, 1977.

[2] Knížková I. Kunc P., Koubková, Flusser J., Dolezal O.: Evaluation of naturally ventilated dairy barn management by a thermographic method. Livestock Production Science, 2002, 77, 349-353.

[3] Kośla T.: Przewodnik do ćwiczeń z higieny zwierząt. Warszawa: SGGW, 2001.

[4] Mazur K.: Ocena wielokryterialna obór wolnostanowiskowych dla krów mlecznych, rozprawa doktorska, ITP O/ Warszawa, 2012.

[5] Meschner T.M., Veenhuizen M.A.: Livestock housing ventilation: natural ventilation design and management for dairy housing, , Ohio State University Ext, Columbus, Ohio, 1998, p. 113-119.

[6] Norma Branżowa „Mikroklimat w budynkach inwentarskich" BN-86/880-03 zgłoszona przez IBMER w 1986 r.

[7] Powszechny Spis Rolny 2010, Główny Urząd Statystyczny.

[8] Romaniuk W., Overby T.: „Praca zbiorowa: Systemy utrzymania bydła. Poradnik" Skejby, Duńskie Służby Doradztwa Rolniczego, Warszawa IBMER, 2005.

[9] Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 28 czerwca 2010 r. w sprawie minimalnych warunków utrzymywania gatunków zwierząt gospodarskich innych niż te, dla których normy ochrony zostały określone w przepisach Unii Europejskiej. Dz.U. 2010 nr 116 poz. 778.

[10] Winnicki S., Woyke, Pleskot: Kodeks zaleceń i praktyk. IBMER 2003.

[11] Witkowska D., Chorąży Ł., Sowińska J., Iwańczuk-Czernik K., Wójcik A., Mituniewicz T.: Mikrobiologiczne zanieczyszczenia powietrza w oborze krów mlecznych przy zastosowaniu różnych rodzajów wymiany powietrza, Ekologia i Technika, 2008, vol. XVI, nr 5A, s. 186-189.

[12] Wójcik A., Chorąży Ł., Polichť Ł., Mituniewicz T., Witkowska D., Iwańczuk-Czernik K., Sowińska J.: Zanieczyszczenie mikrobiologiczne powietrza w oborze krów mlecznych utrzymywanych w systemie wolnostanowiskowym na głębokiej ściółce. Ekologia i Technika, 2010, 4(107): 220-226.

[13] Teye, F.K., Hautala M., Pastell M., Praks J., Veermäe, I.; Poikalainen V. Pajumägic A., Kivinend T., Ahokas J. 2008, Microclimate and ventilation in Estonian and Finnish dairy buildings, Energy & Buildings, 2008, Vol. 40, Issue 7, pp. 1194-1201.

[14] Zähner M., Schrader L., Hauser R., Keck M., Langhans W., Wechsler B.: The influence of climatic conditions on physiological and behavioural parameters in dairy cows kept in open stables, Animal Science 2004, 78, 139-147.