INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

Nr IV/3/2015, POLSKA AKADEMIA NAUK, Oddział w Krakowie, s. 1399–1408
Komisja Technicznej Infrastruktury Wsi

DOI: http://dx.medra.org/10.14597/infraeco.2015.4.3.101

CHARACTERISTICS OF THE TEMPERATURE AND HUMIDITY CONDITIONS IN A DEEP-LITTER BARN IN A SUMMER SEASON

Grzegorz Nawalany, Paweł Sokołowski
University of Agriculture in Krakow

Summary

Preliminary results of the investigations conducted in a deep-litter barn were presented in the paper. The research was carried out during the summer season, from June till August 2014. Results of continuous measurements of the indoor temperature and air humidity revealed considerable diversification of the temperature and humidity conditions in the barn. Exceeded limit indoor temperature was registered, particularly in July when the ambient temperatures were high. The most unfavourable indoor conditions in the building occurred in July during 24 days of animal rearing. In the other analysed months (June and August) the recommended value of the indoor air temperature was noted during 13 days of animal rearing. The indoor air relative humidity also exceeded the maximum permissible values, although the animals remained on the pasture for a major part of the day.

Keywords: temperature and humidity in a barn, deep litter, animal welfare

INTRODUCTION

Ensuring comfortable temperature and humidity conditions in a barn is crucial for the animal welfare and milk performance of cows. The microclimate trend in a barn in the first place depends of the outline, shape and volume of the building, on the efficiency of its ventilation system (Herbut *et al.* 2015, Angrecka 2014), as well as on the animal farming system (Marciniak and Romaniuk 2005). The indoor microclimate in the barn is also greatly shaped by the material solutions applied for the building external walls. One of the walls, which crucially affects the changes of the temperature conditions in a barn is the roof. During a summer period the indoor air temperature is often exceeded. The risk of an excessive increase in the temperature inside the building raises depending on the material of which the roof has been constructed. The investigations of farm buildings conducted in the area of the Świętokrzyskie voivodship revealed considerable diversifications concerning the materials applied as roofing (Nawalany *et al.* 2015, Herbut and Nawalany 2014).

Maintaining the appropriate temperature and humidity in a barn is crucially important for of thermal comfort of the animals, which directly translates itself into the herd productivity. The building should be properly designed and equipped in the necessary active systems, so that the permissible indoor air temperature and relative air humidity would not be exceeded (Romaniuk *et al*. 2009). Tolerance of thermal conditions by dairy cattle, under which a slight risk of disturbing production effectiveness and disease occurrence hazard occur, ranges from – 10 to +20°C (Jaśkowski *et al.* 2005, Angrecka 2014). The most optimal conditions are when the air temperature oscillates about 10°C, while the relative air humidity does not exceed 75%, assuming that constant air exchange is ensured on the level of 15 $m^3 \cdot h^{-1}$ per 100 kg of cow weight (Chodanowicz *et al.* 2009, Chodanowicz and Woliński 2007, Gordeev 2006). A considerable risk of exceeding the recommended maximum values of the indoor temperature and relative indoor air humidity appear in the summer period. Especially during this period unfavourable thermal conditions may directly influence the heightened risk of a decreased milk performance of cows (Daniel 2008, Herbut *et al*. 2013). The problem becomes particularly apparent for high productive dairy herds, in open type barns, where thermal stress in animals may appear in result of the abnormal temperatures.

The ground under the building floor plays a key role in the stabilization and optimization of the temperature and humidity conditions in a barn. In a summer season it is the only receiver of heat excess, whereas in winter it returns the accumulated energy to the building. On the other hand, during the transitional periods it considerably affects decreased fluctuations of the indoor air temperature amplitudes (Bieda *et al.* 2013).

Biothermal phenomena and raised temperature may occur in deep litter animal housing systems. In such situation, there is a risk of indoor air temperature increase in the barn. The phenomenon is unfavourable during the summer season, but may prove positive in the wintertime where low temperatures occur outside the building.

Deep litter animal housing also makes possible decreasing or totally eliminating the manure plates on farms. The investigations conducted in the Świętokrzyskie voivodship, in Kazimierza Wielka district demonstrated that 74% of farms did not own appropriate infrastructure, such as manure storage facilities, so it was stored directly on the ground (Herbut *et al*. 2015). It poses a serious hazard for the local environment, particularly for the groundwaters, which may be contaminated.

AIM AND SCOPE OF RESEARCH

The research aimed at an analysis of the temperature and humidity conditions in a deep litter barn during the summer period.

The investigations comprised constant measurement of the indoor temperature and relative humidity in five measurement points, as well as the ambient air temperature and relative humidity. The investigations included also measurements of the litter bedding thickness.

MATERIAL AND METHODS

The analysed object was a deep-litter barn for 50 dairy cows (Fig.1). The building is situated in Kuchary village in the Świętokrzyskie voivodship.

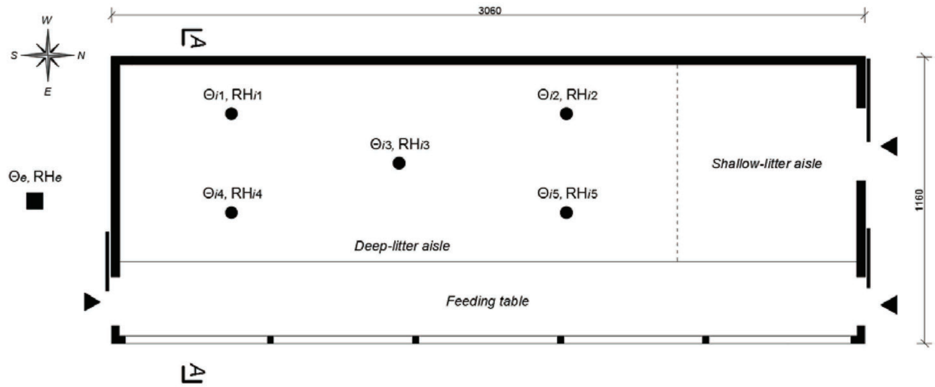
The analysed building is north-south oriented with its longitudinal axis. It has been constructed using traditional technology. Its concrete foundations are at the depth of 120 cm below the ground level, the barn external walls are made of perforated ceramic bricks (MAX type), the queen post truss roof is covered with troughed sheet. The ventilation system with ridge apertures has been applied in the building and a parallel milking parlour adjoins the barn.

Figure 1. The inside of the analysed object (Photo P.Sokołowski)

The research covered the period from 1 June to 31 August 2014. During this time constant measurements of the indoor and ambient air temperature and air humidity were conducted every 5 minutes using five USB Voltcraft DL-121TH recorders of the following technical specification: measuring range from – 40 to 70^{o}C, temperature measurement resolution 0.1^{o}C, humidity measuring range from 0 to 100% and humidity measurement resolution 0.1%.

The measurement of indoor temperature and relative humidity was conducted in 5 measurement points, whereas the measurement of the ambient temperature and relative humidity was made in one point (Fig.2).

a)



b)

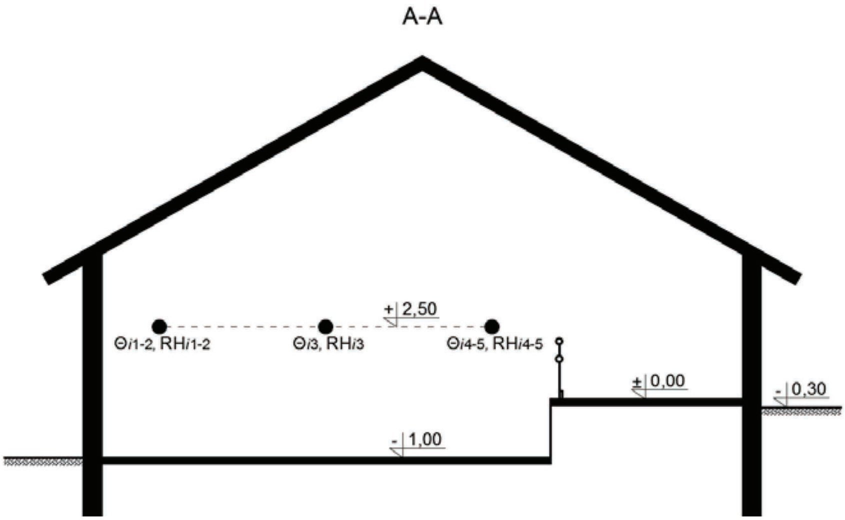
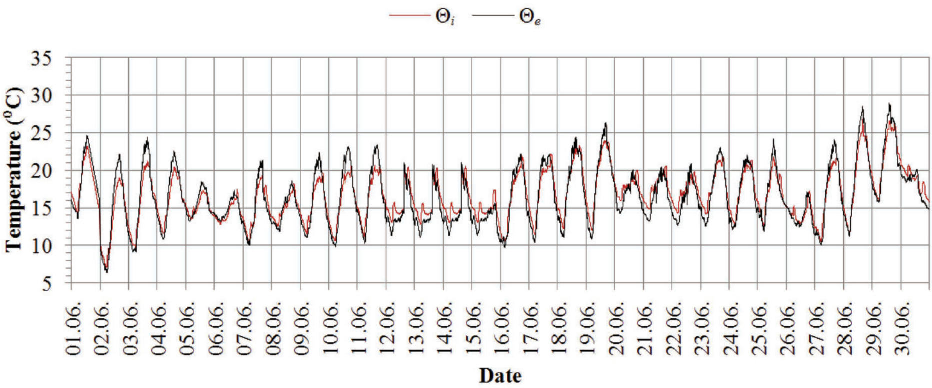
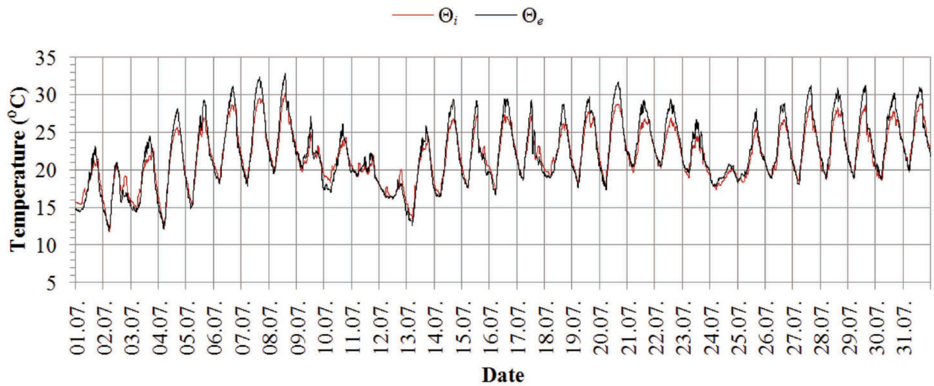


Figure 2. Location of the measurement points of: indoor air temperature ($\Theta_{i\,1\text{-}5}$), relative indoor humidity ($RH_{i\,1\text{-}5}$) and the ambient air temperature(Θ_e) and relative humidity (RH_e); a)projection, b)cross-section

a)



b)



c)

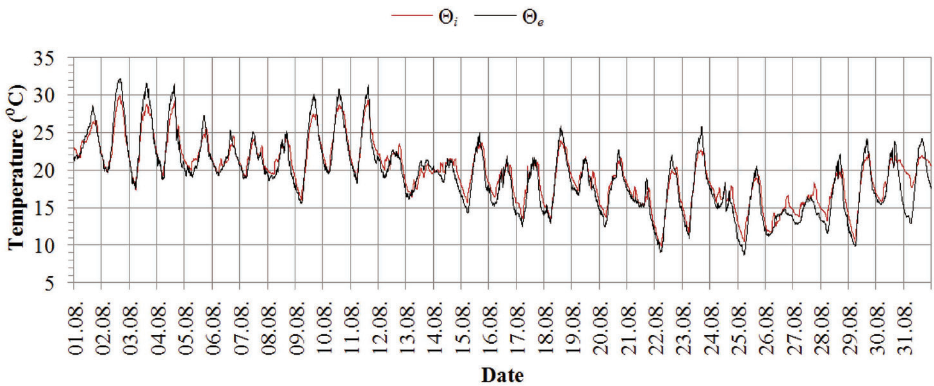


Figure 3. The course of indoor air temperature (Θ_i) and the ambient temperature (Θ_e) in the months of: a) June, b) July, c) August

RESULTS AND ANALYSIS

The course of the indoor air temperature (Θ_i) and ambient air temperature (Θ_e) were presented in Figure 3. At the initial stage of the investigations (June) the indoor temperature oscillated within the range between 17 and 18°C at night and 22-23°C during the day. The indoor air relative humidity was on the level of about 75%. 30 cm thick litter was spread in the barn (June) and supplemented in the subsequent months. In August its thickness was about 45 cm. Free-range dairy herd husbandry was conducted in the barn, which denoted that for a major part of the day the animals remained outside the barn – on the pasture. During the investigated summer periods cows were in the building only during the morning milking (ca. 7:00) or under unfavourable weather conditions. The building remained open all the time to allow the animals a free movement. This solution caused that the barn was well aired and the indoor temperature Θ_i was approximate to the ambient temperature Θ_e.

Despite intensive ventilation of the barn, on hot days it was impossible to lower the indoor air temperature below the thermal stress temperature. In June the recommended maximum indoor air temperature (>25°C) was exceeded only for three days. However, these were only brief raises in the temperature, totally constituting only about 1% of the whole month. In July raised temperatures were registered on as many as 24 days (total period with elevated temperature was 23% per month), whereas in August for 10 days (9% in the scale of the month).

Figure 4 shows the course of the relative indoor air humidity and relative ambient air humidity in the summer months of animal rearing.

The research revealed that during the summer period the maximum value of relative indoor air humidity (RH_i) was also exceeded in the researched barn. The period when the permissible value of exceeded indoor air relative humidity was registered in each of the analysed months. The most unfavourable conditions occurred in August, when the indoor air relative humidity reached even 90%.

The course of the temperature and relative humidity of the indoor and ambient air for the selected period were presented in Figure 5.

Analysis of the daily course of the temperature and indoor air relative humidity demonstrated that such brief stay of the animals in the building has a slight effect on the indoor temperature changes in the barn. During the morning milking (ca. 7:00), cow entering the barn caused a raise in the air temperature by ca. 2.5°C, whereas during the evening milking the temperature inside the barn increased by ca. 1.5%. A definitely greater dynamics of changes was observed in case of the indoor air relative humidity, which in result of cows entering the barn raised by ca. 10%.

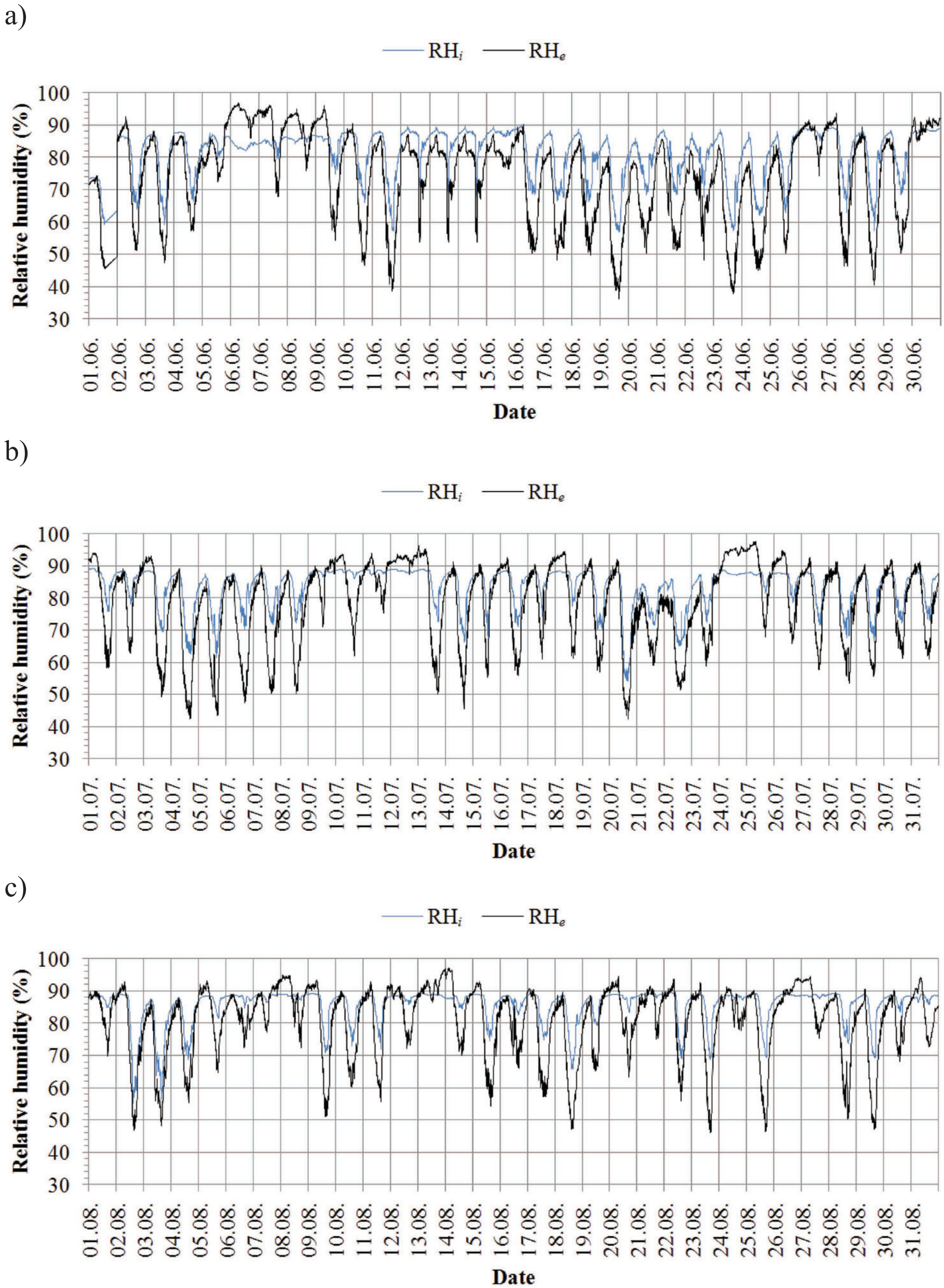


Figure 4. The curse of indoor air humidity (RH_i) and ambient air humidity (RH_e) in the months of: a) June, b) July and c) August

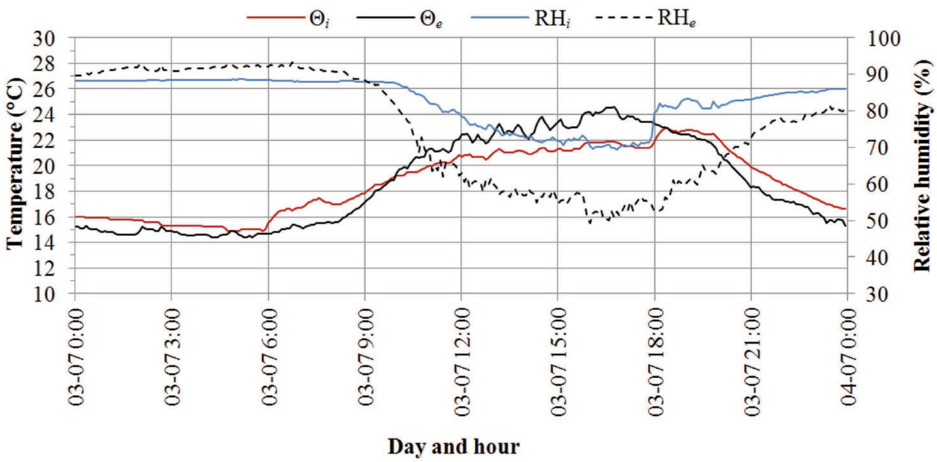


Figure 5. The course of temperature and relative humidity of indoor and ambient air on 3rd July, 2014.

Table 1 presents the compilation of results of the conducted statistical analysis of the temperature and relative humidity of the indoor and ambient air.

Table 1. Basic statistics of the temperature and relative humidity of the indoor and ambient air

	June				July				August			
	Θ_i	Θ_e	RH_i	RH_e	Θ_i	Θ_e	RH_i	RH_e	Θ_i	Θ_e	RH_i	RH_e
	(°C)		(%)		(°C)		(%)		(°C)		(%)	
min	7.1	6.4	56.9	36.3	11.8	11.9	54.0	42.3	9.8	8.7	55.0	46.0
max	26.8	29.0	89.7	96.8	30.3	32.9	89.1	97.7	30.0	32.2	89.5	97.1
mean	16.7	16.5	81.4	74.4	21.9	22.2	83.7	78.6	19.7	19.3	85.8	80.9
median	16.4	15.9	84.5	77.9	21.6	21.7	86.7	82.2	19.8	19.4	88.1	84.6
stand.dev.	3.3	3.9	7.7	14.0	3.5	4.3	6.2	12.5	3.9	4.6	5.3	11.0

During the research period the highest temperatures of the indoor air were registered in July (30.3°C), whereas the lowest in June (7.1°C). Mean indoor air temperature was 16.7°C for June, 21.9°C for July and 19.7°C for August. Mean value of the relative indoor air humidity exceeded the permissible values in each of the investigated months and was around of 80-90%.

SUMMARY AND CONCLUSIONS

The study showed high variability of hygrothermal conditions in the analysed deep-litter barn. In June the recommended maximum indoor air temperature was exceeded (>25°C) during 3 days. In July the exceedance of the permissible indoor air temperature was noted on 24 days, whereas the total period with this temperature constituted 23% in the scale of the month. In August, exceeded allowable indoor air temperature was registered during 10 days (9% in the scale of the month).

Results of the relative indoor air humidity showed that it ranged from about 55 to 90%. Exceeding the maximum value of 80% occurred over the whole research period.

Cow stay in the barn while waiting for milking raised the indoor temperature by about 2.5°C and the relative air humidity by about 10%.

REFERENCES

Angrecka, S. (2014). *Wpływ wiatru na prędkość ruchu powietrza w oborze podczas lata*. Infrastruktura i Ekologia Terenów Wiejskich, Nr I/I/2014, PAN, Oddział w Krakowie, s. 89-101

Bieda, W., Radoń, J., Nawalany, G. (2013). *Wymiana ciepła między nieizolowaną termicznie oborą a gruntem w badaniach eksperymentalnych*. Budownictwo i Architektura 12(3) (2013), s. 35-38

Chodanowicz, B., Woliński, J. (2007). *Problemy chowu bydła w oborach bez izolacji termicznej*. Problemy intensyfikacji produkcji zwierzęcej z uwzględnieniem ochrony środowiska i przepisów UE. IBMER. Warszawa. s. 285-290.

Chodanowicz, B., Woliński, J., Wolińska, J. (2009). *Wentylacja w oborach bez izolacji termicznej*. Inżynieria Rolnicza, 6(115)/2009, s. 17-21

Daniel, Z. (2008). *Wpływ mikroklimatu obory na mleczność krów*. Inżynieria Rolnicza, 9(107)/2008, s. 67-73

Gordeev, A. (2006). *Uveliczenie proizvodstva moloka na osnove sovremennych technologii – vaznieisze napravlenie realizacji proritetnogo proekta.* „Razvitie APK" MSX RF. Moskwa. s. 158-169.

Herbut, P., Angrecka, S. (2015). *Skuteczność działania wentylacji kalenicowej obory wolnostanowiskowej typu „Fermbet" w okresie letnim*. Rocz. Nauk. Zoot., T.39, z. 2 (2012), 319-329

Herbut, P., Angrecka, S., Nawalany, G. (2013). *Influence of wind on air movement in a free stall barn during the summer period*. Annals of Animal Science, Vol. 13, No. 1, s. 109–119

Herbut, P., Angrecka, S., Nawalany, G., Adamczyk, K. (2015). *Spatial and Temporal Distribution of Temperature, Relative Humidity and Air Velocity in a Parallel Milking Parlour During Summer Period.* Annals of Animal Science, 04/2015, 15(2), s. 517-526

Herbut, P., Nawalany, G. (2014). *Analiza istniejących azbestowych pokryć dachowych budynków w gospodarstwach rolnych na wybranym przykładzie*. Infrastruktura i Ekologia Terenów Wiejskich. Nr 2014/ I (1 (Mar 2014))

Herbut, P., Angrecka, S., Nawalany, G., Sokołowski, P. (2015). *Analiza sposobów magazynowania nawozów naturalnych na przykładzie wybranych gospodarstw rolnych we wsi Paśmiechy*. Infrastruktura i Ekologia Terenów Wiejskich, Nr IV/1/2015, s. 899-908

Jaśkowski, J.M., Urbaniak, K., Olechnowicz, J. (2005). *Stres cieplny u krów – zaburzenia płodności i ich profilaktyka*. Życie weterynaryjne, Nr 80(1), s. 18-21

Marciniak, A. M., Romaniuk, W. (2005). *Wpływ systemu chowu na koncentrację zanieczyszczeń gazowych (NH_3, CO_2, H_2S) w oborach wolnostanowiskowych*. Problemy Inżynierii Rolniczej, Nr 4/2005, s. 71-77

Nawalany, G., Herbut, P., Sokołowski, P., Gryc, A. (2015). *Analysis of existing concrete tiles roofing in agricultural holdings on a selected example.* Infrastruktura i Ekologia Terenów Wiejskich. Nr 2015/ II, s. 385-392

Romaniuk, W., Domasiewicz, T., Karbowy, A., Wardal, W. (2009). *Ograniczenie wpływu produkcji zwierzęcej na środowisko.* Inżynieria Rolnicza, (1(110)/2009, s. 233-242

dr hab. inż. Grzegorz Nawalany
mgr inż. Paweł Sokołowski
University of Agriculture in Krakow
Department of Rural Building
al. Mickiewicza 24/28, 30-059 Kraków
kbw@ur.krakow.pl
tel. (12) 662 40 09

Received: 23.09.2015
Accepted: 23.11.2015