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Original article

Preliminary studies on the reaction of growing geese (*Anser anser f. domestica*) to the proximity of wind turbines

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Abstract

Wind farms produce electricity without causing air pollution and environmental degradation. Unfortunately, wind turbines are a source of infrasound, which may cause a number of physiological effects, such as an increase in cortisol and catecholamine secretion. The impact of infrasound noise, emitted by wind turbines, on the health of geese and other farm animals has not previously been evaluated. Therefore, the aim of this study was to determine the effect of noise, generated by wind turbines, on the stress parameters (cortisol) and the weight gain of geese kept in surrounding areas. The study consisted of 40 individuals of 5- week- old domestic geese *Anser anser f domestica*, divided into 2 equal groups. The first experimental gaggle (I) remained within 50 m from turbine and the second one (II) within 500 m. During the 12 weeks of the study, noise measurements were also taken. Weight gain and the concentration of cortisol in blood were assessed and significant differences in both cases were found. Geese from gaggle I gained less weight and had a higher concentration of cortisol in blood, compared to individuals from gaggle II. Lower activity and some disturbing changes in behavior of animals from group I were noted. Results of the study suggest a negative effect of the immediate vicinity of a wind turbine on the stress parameters of geese and their productivity.

Key words: wind turbine, domestic goose, anser anser, noise, cortisol

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Introduction

Sound waves are divided into infrasound, audible sounds and ultrasounds (Pawlas 2009). Infrasound is a sound or noise with a frequency spectrum ranging from 1 to 20 Hz (Augustyńska 2009), and is perceived not as a "normal" tone, but rather as a pounding and the feeling of "tightness" in the ears (Pawlas 2009).

Continuous sounds (both audible and infrasound noise) may be produced by wind turbines. The level of noise emitted by wind turbines, ranges from 100-107 dB and decreases as the distance from the turbine increases (Pawlas 2009).

Currently, there is no European and international legislation concerning the exposure limit values for infrasound (Augustyńska 2009). The results of animal studies suggest considerable nuisance and harmfulness of infrasound, and therefore indicate the need to determine the safe level of noise.

The effect of infrasound on animals under laboratory conditions, has often been studied (Nekhoroshev and Glinchikov 1992, Bohne and Harding 2000). During such studies the adverse effects of infrasound were noted in animals such as mice, rats, guinea pigs, chinchillas, dogs, monkeys and other mammals. Changes may be observed in the cardiovascular system (narrowing of arteries and coronary vessels) (Alekseev 1985), in the brain (Nekhoroshev and Glinchikov 1992) and in the lungs (thickening of alveoli and filling of the pulmonary acinus with erythrocytes, the partial destruction of the acinus and the disruption of blood vessel walls) (Svidovyi and Glinchikov 1987). Infrasound with a very high intensity may cause serious damage to ear structures (Johnson 1980). Continuous exposure may cause significant changes in comparison to intermittent exposure. In chinchillas constantly exposed to infrasound at a frequency of 0.5 Hz and a level of 95 dB, damage to hearing may occur after 2 days up to 432 days of exposure (Bohne and Harding 2000). In humans exposed to infrasound some psychological and physiological changes such as fatigue and wakefulness disorders, related to changes in the central nervous system, have been reported (Landström et al. 1983).

Under natural conditions, infrasound generated by wind turbines reduces species diversity during nesting (Francis et al. 2009) and may have negative effects on the behavior, communication skills, health and survival ability of birds (Barber et al. 2010), and also on squirrels' ability to recognize predators (Rabin et al. 2006). In the case of animals living fenced in, held without the possibility of free movement, noise can lead to an increasing level of stress (Flydal et al. 2004). In domestic animals, such as sheep and horses, the noise from wind turbines at a level of 60-75 dB may cause acceleration of breath, rapid heart rate, increased alertness and reduced grazing time (Ames and Arehart 1972). Increased cortisol secretion in sheep was observed as a response to stress caused by exposure to the noise emitted during the shearing procedure (Hargreaves and Hutson 1990). However, more research showing the impact of noise emitted by wind turbines on farm animals is needed.

Glucocorticoids (GCs): cortisol and corticosterone, are the front-line hormones in overcoming stressful situations (Palme et al. 2005). Although corticosterone is considered to be the dominant avian glucocorticoid and is well known as a stress hormone in birds (Koren et al. 2012), there are some papers demonstrating that birds also produce cortisol (Walsh et al. 1985, Schmidt and Soma 2008, Sohail et al. 2010, Swathi et al. 2012, Jadhaw et al. 2013). We, therefore, examined the changes of cortisol concentration in blood of geese as a response to the possible stress caused by infrasound generated by a wind turbine.

Materials and methods

The study included 40 individuals of 5-week-old domestic geese *Anser anser f. domestica*, divided into two groups of 20 individuals each. The first gaggle (group I) remained within 50 m from the turbine (with a capacity of 2 MW) in Rapałki near Rypin (Kuyavian-Pomeranian Voivodeship, Poland), the second one (group II) within 500 m. Animals from both groups had continuous access to feed and water and were fed identically, with a commercial mixture of complete feed. The composition of the mixture is presented in Table 1. The birds were kept on a covered surface with paddock (1 m^2 per individual). The study lasted for 12 weeks, and during that time, in order to analyze the concentration of cortisol, blood was collected between 9:00 to 10:00 a.m. from 20 randomly selected animals (10 individuals from

Table 1. Composition of commercial mixture of complete feed.

Component	%
Crude protein	19.00
Crude fiber	4.50
Oils and fats	3.80
Crude ash	5.30
Calcium	0.80
Organic phosphorus	0.56
Sodium	0.17
Lysine	0.93
Methionine	0.38

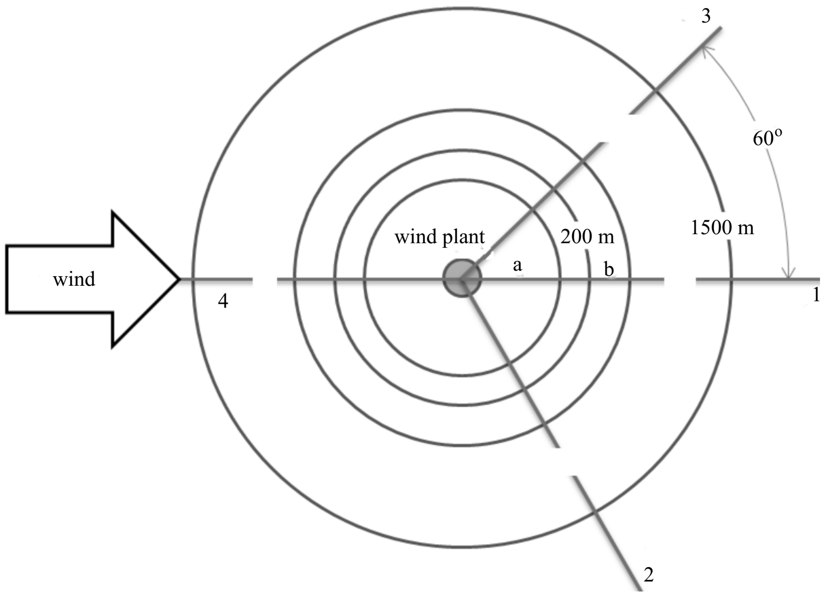

Fig. 1. Scheme of vibration, noise and infrasound measurements around the wind plant: 1, 2, 3, 4 – measuring directions; a – the diameter of the first circle resulting from PN-EN 61400-11; b – distance between following circles (100 m).

each group, 5 males and 5 females). The procedure was performed three times, in the 5th, 10th and 17th week of rearing. Venous blood was collected in order to obtain serum which, until assessment, was stored deep-frozen (-80°C) in small aliquots. The cortisol concentration in the serum of birds from both gaggles was measured by using the ELISA method with the use of the R & D System diagnostic kit. Reproducibility of the method for intra-assay precision was CV < 9.3%, and for inter-assay precision CV < 12%.

The geese were weighed during the 5th, 10th and 17th weeks. The results were statistically analyzed using Statistica 8.0 PL.

In the course of the experiment the measurements of noise were taken as follows: 10 times at 4 designated measuring points situated 140 m away from the turbine and 5 times within 50 m from the turbine, at the place where the geese were kept. In addition, measurements (in four directions) at a distance of 200 m from the plant and at every subsequent 100 m, up to 1500 m, were made. Both audible sound and infrasound were measured using a class I sound and vibration analyzer (Svantek SVAN 912 AE). Measurements of noise generated by the wind turbine were assessed according to marker points designated in accordance with PN- EN 61400-11 (Fig. 1). A microphone located on a special plate was used to measure noise. The results were adjusted based on the reference wind speed and roughness of the terrain.

Results

Noise measurements

Noise emission in the audible range

During the experiment, ten measurements of noise generated by the Vestas wind turbine (2 MW) were performed. Declarations of the wind turbine manufacturer, concerning acceptable noise emission, are presented in Table 2. The measurements were performed at 4 measuring points, in accordance with PN- EN 61400-11 and at the location of geese gaggles (within a distance of 50 m from the turbine), at a distance of 200 m from the plant and at every subsequent 100 m, up to 1500 m. During measurements the wind speed and its direction were observed. The speed was 5.9 m/s and the wind was blowing in the direction of 12 degrees N-E.

Table 2. Declarations of the manufacturer concerning levels of maximum noise emission.

Wind speed [m/s]	Noise level [dB(A)]
4	94.4
5	99.4
6	102.5
7	103.6
>8	104.0

Table 3. Results for measuring site 1 [dB(A)].

Measure-ment	1	2	3	4	5	6	7	8	9	10	Average value
Value	87.0	87.0	83.0	79.1	81.0	79.8	79.6	79.5	79.3	82.0	81.73

Table 4. Results for measuring site 2 [dB(A)].

Measure-ment	1	2	3	4	5	6	7	8	9	10	Average value
Value	105.0	105.0	104.0	103.5	103.0	101.5	101.0	98.0	97.5	97.0	101.55

Table 5. Results for measuring site 3[dB(A)].

Measure-ment	1	2	3	4	5	6	7	8	9	10	Average value
Value	99.0	99.0	98.5	98.0	92.0	87.0	90.0	89.0	91.0	85.0	92.85

Table 6. Results for measuring site 4 [dB(A)].

Measure-ment	1	2	3	4	5	6	7	8	9	10	Average value
Value	102.0	102.0	104.0	103.5	104.0	101.5	101.0	100.0	99.5	97.0	101.45

Measurements of noise emitted by the wind turbine, which is audible for humans (A scale), gave the value of the sound intensity at the distance of 140 m from the turbine. At site 1 the average value was 81.73 dB, at site 2 – 101.55 dB, site 3 – 92.85 dB and site 4 – 101.45 dB. Detailed results of measurements for each point are summarized in Tables 3-6.

At the site where the geese of group I were kept (50 m from the turbine), the average sound intensity, obtained from 5 measurements, was 56.3 dB, while at the place where the second gaggle was kept the mean volume was 58.33 dB.

Noise emission in the infrasound range

Noise measurements in the infrasound range (Lin scale) generated by the wind turbine in Rypałki allowed determination of the intensity of sound at the point 50 meters from the turbine (the location of geese), where the average value was 94.5 dB, while the average value in site 1 was 99 dB, site 2- 105 dB, site 3- 96.23 dB and site 4- 98.63 dB. When the distance from the turbine was greater, the intensity of recorded infrasound was significantly lower. At a distance of 300 m the intensity was less than 100 dB, at 500 m – 80 dB, while at 1000 m it was approximately 40 dB.

Cortisol

Steroid hormones function as mediators of essential metabolic and energy-allocation processes. GCs, cortisol and corticosterone, mobilize energy storage in response to a crisis (Koren et al. 2012). Although corticosterone is considered to be the dominant avian glucocorticoid and is well known as a stress hormone in birds (Koren et al. 2012), there are some papers demonstrating that birds may also produce cortisol (Walsh et al. 1985, Schmidt and Soma 2008, Sohail et al. 2010, Swathi et al. 2012, Jadhaw et al. 2013). Cortisol is secreted by the adrenal cortex in response to the adrenocorticotrophic hormone produced by the pituary gland (Kerr 2002) and has a multidirectional mode of action. The best known is its effect on the metabolism and the immune system (Lisurek and Bernhardt 2004) and is associated with the stress response. During stress it acts as a neuroendocrine mediator in organs and tissues such as the brain, cardiovascular system, immune system, adipose tissue and muscle (De Kloet et al. 1998).

Table 7. Concentration of cortisol in blood of geese from both groups [ng /mL].

Age	5th week		10th week		17th week	
Group	I	II	I	II	I	II
♂	x – 12.40	x – 6.14	x – 31.3	x – 9.64	x – 34.08	x – 11.23
♀	x – 11.24	x – 6.72	x – 34.12	x – 8.58	x – 34.35	x – 13.99
x for whole group	11.92*	6.43*	32.71*	9.11*	34.12*	12.61*
SD for whole group	1.63	2.13	6.3	1.65	8.9	9.10

* highly statistically significant differences between average values ($p < 0.001$)

Table 8. Body weight of geese from both groups [kg].

Age	5th week		10th week		17th week	
Group	I	II	I	II	I	II
♂	x – 3.10	x – 2.99	x – 4.55	x – 4.80	x – 7.8	x – 8.98
♀	x – 2.67	x – 2.82	x – 4.31	x – 4.52	x – 7.1	x – 7.65
x for whole group	2.89	2.91	4.43	4.66	7.45*	8.31*
SD for whole group	260.18	104.74	173.61	153.83	0.59	0.84

* statistically significant differences between average values ($p < 0.05$)

During the 5th, 10th and 17th week of rearing, in order to determine the concentration of cortisol in the serum of birds, blood samples were collected from 10 geese selected randomly from each experimental group. The results are summarized in Table 7.

The first measurement of cortisol concentration in blood was performed 48 hours after transport and placement of the birds at the sites located at a distance of 50 and 500 meters from the wind turbine. In the 5th week, the average concentration of cortisol in the geese blood from group I was 11.92 ng/mL, while in group II – 6.43 ng/mL. In the 10th week the average cortisol concentrations for group I and II were 32.71 ng/mL and 9.11 ng/mL, respectively. In the 17th week, the cortisol concentration in group I was 34.12 ng/mL, and in group II – 12.61 ng/mL.

The differences in the cortisol concentration in the blood of animals from both gaggles, in the 5th, 10th and 17th week of rearing, were found to be highly significant ($p < 0.001$).

Body weight

In the 5th, 10th and 17th week of rearing geese were weighed, each time 10 geese from both groups were chosen. The result of body weight measurements, obtained in the subsequent weeks, are presented in Table 8.

In the 5th week, the body weight of birds from both gaggles were similar. In the 10th week, the average body weight of animals in group I was approximately 230 g lower than the average weight of birds from the second gaggle. In the 17th week, the difference in average body weight between the two groups was greater (860 g) and was statistically significant ($p < 0.05$). Geese from gaggle I tended to eat less feed. The daily feed intakes are presented in Table 9.

Table 9. Daily feed intake by geese of both groups [g].

Week of rearing	Group I	Group II
5	305	340
10	730	780
17	800	1030

The results obtained in the 10th week of rearing showed sexual dimorphism. The body weights of males from both groups were higher by 280 g in group I and 240 g in group II, than the weight of females. Sexual dimorphism in 17-week-old birds was even more noticeable. The body weights of males were higher (by 700 g in group I and 1330 g in group II) than the body weight of females.

Discussion

Noise measurements

The lowest level of noise in the audible range was recorded at measuring site 1 and the highest at site 2. Mean values of sound intensity at sites 2 and 4 are in accordance with the noise intensity value specified by van den Berg (2004) for Dutch turbines, and was 103 dB(A). According to Pawlas (2009), the level of noise around the turbine is within the range of 100 to 107 dB(A). This information is in accordance with results obtained from sites 2 and 4. The noise levels measured at sites 1 and 3, were lower than the noise levels at 2 and 4; since these sites were located opposite each other, different levels of noise may be associated with wind direction. Sites 1 and 3 were located on the leeward side, which explains the lower average noise value, while sites 2 and 4 were located on the windward side, and therefore the mean values of sound intensity were higher.

Results of measurements of the noise level, with an average wind speed of 5.9 m/s, ranged up to 103.6 dB(A), and therefore were within the acceptable range specified by the manufacturer. However, in the case of measurements of infrasound, results were higher than those reported by Golec et al. (2006).

Cortisol

48 hours after transportation and placement of the birds at the sites, located at a distance of 50 and 500 meters from the wind turbine, the cortisol concentration in the blood of geese from group I was significantly higher than the concentration of cortisol in animals from group II. In addition, the geese of gaggle I exhibited reduced adaptability and their behavior (reduced physical activity and feed intake) indicated exposure to stress.

In the 10th week the average concentration of cortisol in the blood of birds from group I was significantly higher than the concentration of cortisol in geese from group II. Also in the 17th week of rearing the concentration of cortisol in the blood of birds kept in the immediate vicinity of the wind turbine was noticeably higher than in the geese that lived at a distance of 500 m from the turbine. The differences in cortisol concentration recorded during all three measurements, between the two groups of birds, were found to be highly statistically significant ($p < 0.001$).

After 48 hours, geese from group I had twice the cortisol concentration in blood compared to group II. In the 10 week of the experiment, the concentration of cortisol in the blood from group I was 3.5 times higher than the concentration of cortisol in the blood from group II. In the 17th week, the cortisol concentration in the blood of birds from group I, compared to geese from the group II, was 2.7 times higher, so it is possible to assume that even though there are some significant differences in the cortisol concentration in the blood of animals from both groups, there is a tendency which suggests that geese may become accustomed to a stressor.

In the 5th week, males from gaggle I had a higher cortisol concentration in blood than female geese; in gaggle II the result was opposite. In the 10th week, a higher concentration of cortisol in the blood of females from group I was noted, but in group II the result was opposite. At the end of the study in both gaggles females had a higher concentration of cortisol in blood than males, however, the difference was not sufficiently significant to claim that gender influences sensitivity to infrasound.

Moreover, the concentration of cortisol in the blood of geese increased with the time of exposure to the immediate vicinity of the wind plant.

All three successive measurements of cortisol concentration showed a higher concentration of "stress hormones" in birds kept at a distance of 50 m from the turbine. The lower cortisol concentration in animals kept at a distance of 500 m may indicate that this distance is safer for animals but still not safe enough, as mentioned below.

In birds, due to their endocrine dissimilarity, the corticosterone concentration during the stress response is commonly tested, and there are few publications on the change in the cortisol concentration in the blood of birds that are influenced by a stressor. Sohail et al. (2010) examined the impact of cyclic heat stress on serum cortisol concentration in broilers. Tokarzewski et al. (2006) studied the impact of the stress caused by transportation on the changes in the cortisol concentration in broiler blood. In the studies mentioned above, the results for control groups were as follows: 1.04 ng/mL (mean) (Sohail et al. 2010) and 1.55 ng/mL (mean) (Tokarzewski et al. 2006), whereas in the experimental groups the results were: 1.91 ng/mL (mean) and 9.26 ng/mL (mean), respectively. In the present study, all results of the cortisol concentration were higher than the control values outlined above. The concentration of cortisol, determined in both gaggles, in every week of rearing (except for the concentration of cortisol in geese from group II in the 5th week), was also higher than concentrations of "stress hormones" obtained in the experimental groups by Tokarzewski et al. (2006) and Sohail et al. (2010). This information suggests that infrasound noise may be a very serious source of stress. In addition, it was noted that the cortisol concentration in the animals from group II was higher than the control concentration, which may therefore suggest that the distance of 500 m from the turbine is still not a safe distance.

The reaction of the birds confirmed that geese have a sensitive sense of hearing and are responding to both audible sounds and infrasound.

Furthermore, a change in the animals' behavior was observed. Birds of group I, for the most part, remained in a compact group and showed less physical activity, while individuals from gaggle II moved freely. This change is likely to result from the exposure of the animals to chronic stress and may be associated with a higher concentration of cortisol, as was shown for birds from group I.

The literature review indicates that any stress, particularly mental, is accompanied by an excessive secretion of the adrenocorticotropic hormone (De Jong et al. 2001). The effect of the stress source on cortisol secretion has been confirmed in other species, including sheep (Hargreaves and Hutson 1990). The increased secretion of cortisol may be harmful to the health of geese, as steroid hormones suppress the immune system, resulting in increased susceptibility to infections with bacteria of endogenous origin (De Jong et al. 2001).

Body weight

In the 5th week, the body weights of birds from both groups were similar. In the 10th week, the average body weight of animals in group I was lower than the mean weight of individuals from gaggle II. Seven weeks later, the difference was even greater and was statistically significant ($p < 0.05$). The mean body weight of both groups of animals, in 10 weeks of rearing, was lower than in the studies of Biesiada-Drzazga et al. (2006). Depending on the experimental group, the authors reported that the male's body weight was from 5.29 to 5.61 kg and for females from 4.88 to 5.11 kg.

In the 17th week the body weight of geese from group I was much lower, but achieved weights in both groups were satisfactory and higher than those found in the literature. During 17 weeks of rearing, Kłos et al. (2010) obtained a weight of 5.74-6.00 kg for males and from 5.18 kg to 5.38 kg for females. Similarly, Łukaszewicz et al. (2008) reported lower body weights – 7.09 kg for males to 6.30 kg for females. Moreover, in our experiment, sexual dimorphism was observed. The greatest differences in body weight between the sexes were found in the 17th week of rearing.

At the end of the study, the differences in the body weights between birds from both groups were found to be statistically significant ($p < 0.05$). Animals kept near the wind turbine had about 10 percent lower body weight than those kept at a distance of 500 m from the turbine. The lower body weight of group I was caused by reduced feed intake. Animals ate less willingly, which could have resulted from the stress caused by infrasound noise emitted by the wind turbine.

To sum up, the results of measuring noise generated by the wind turbine are in accordance with the results obtained by other research (van der Berg 2004). When the distance from the turbine increased, the intensity of infrasound decreased greatly, and at a distance of 1000 m the intensity was 40 dB. Geese from the gaggle which was kept at a distance of 50 m from the turbine, grew slower, gained less body weight (by 10 %) and had a higher concentration of cortisol in blood, compared to birds reared 500 meters away from the wind plant. It was also noted that even the distance of 500 meters cannot be considered a safe one; this was confirmed by the results of infrasound measurement and cortisol concentration in blood, which exceeded the control values.

In addition, cortisol concentration increased with the residence time in the vicinity of the wind turbine. Differences in both weight and cortisol concentration were proven to be statistically significant. The cortisol concentration in both groups, which was higher than the concentration in the control groups, could have resulted from stress caused by the noise generated by the wind plant. Stress may have caused the disturbing changes in behavior.

The results indicate the negative impact of the immediate vicinity of wind turbines on feed consumption, weight gain and cortisol concentration in blood. Nevertheless, further studies, with a larger number of animals and with a variety of distances, are needed, so that the safe distance appropriate for keeping animals can be determined.

References

Alekseev SV (**1985**) Myocardial ischemia in rats exposed to infrasound. Gigiena Truda i Prof. Zabolewania 8: 34-38.

Ames DR, Arehart LA (**1972**) Physiological response of lambs to auditory stimuli. J Anim Sci 34: 994-998.

Augustyńska D (**2009**) Wartości graniczne ekspozycji na infradźwięki – przegląd piśmiennictwa. Podstawy i Metody Oceny 1rodowiska Pracy 2: 5-15.

Barber JR, Crooks KR, Fristrup KM (**2010**) The costs of chronic noise exposure for terrestrial organisms. Trends Ecol Evol 25: 180-189.

Biesiada-Drzazga B, Górski J, Górska A (**2006**) Analysis of slaughter value and muscle fibre thickness of selected muscles in geese broilers as related to feeding applied during the rearing period. Anim Sci Pap Rep 24 (S-2): 37-44.

Bohne BA, Harding GW (**2000**) Degeneration in the cochlea after noise damage: primary versus secondary events. Am J Otol 21: 505-509.

Cited by Pawlas K (**2009**) Wpływ infradźwięków i hałasu o niskich częstotliwościach na człowieka- przegląd piśmiennictwa. Podstawy i Metody Oceny 1rodowiska Pracy 2: 27-64.

De Jong IC, van Voorst AS, Erkens JH, Ehlhardt DA, Blokhuis HJ (**2001**) Determination of the circadian rhythm in plasma corticosterone and catecholamine concentrations in growing broiler breeders using intravenous cannulation. Physiol Behav 74: 299-304.

De Kloet ER, Vreugdenhil E, Oitzl MS, Jolls M (**1998**) Brain corticosteroid receptor balance in health and disease. Endocr Rev 19: 269-301.

Flydal K, Eftestol S, Reimers E, Colman JE (**2004**) Effects of wind turbines on area use and behaviour of semi-domestic reindeer in enclosures. Rangifer 24: 55-66.

Francis CD, Ortega CP, Cruz A (**2009**) Noise Pollution Changes Avian Communities and Species Interactions. Curr Biol 19: 1415-1419.

Golec M, Golec Z, Cempel C (**2006**) Hałas turbiny wiatrowej VESTAS V80 podczas eksploatacji. Diagnostyka 1: 115-120.

Hargreaves AL, Hutson GD (**1990**) Changes in heart rate, plasma cortisol and haematocrit of sheep during a shearing procedure. Appl Anim Behav Sci 26: 91-101.

Jadhav NV, Awati B, Kulkarni S, Waghmare PG, Suranagi MD, Saxena MJ, Ravikanth K, Dandale M, Shivi Maini (**2013**) Performance of Layer Birds Supplemented with Herbal Antistress Product Ayucee and Synthetic Vitamin C under Physiological Heat Stress. Mal J Anim Sci 16: 67-78.

Johnson DL (**1980**) The effects of high level infrasound. Porceed of Conference on Low Fre-quency Noise, Moller H, Rubak P Aaalbork: 1-14. Cited by Pawlas K (2009) Wpływ infradźwięków i hałasu o niskich częstotliwościach na człowieka- przegląd piśmiennictwa. Podstawy i Metody Oceny 1rodowiska Pracy 2: 27-64.

Kerr MG (**2002**) Veterinary Laboratory Medicine, 2nd ed., Blackwell Science, Oxford.

Kłos K, Sokołowicz Z, Badowski J, Bielińska H (**2010**) Określenie możliwości szacowania umięśnienia nóg gęsi *Białych Kołudzkich* na podstawie pomiarów przyżyciowych. Roczniki Naukowe Zootechniki 37: 55-62.

Koren L, Nakagawa S, Burke T, Soma KK, Wynne- Edwards KE, Geffen E (**2012**) Non-breeding feather concentrations of testosterone, corticosterone and cortisol are associated with subsequent survival in wild house sparrows. Proc Biol Sci 279: 1560-1566.

Landström U, Lundström R, Byström M (**1983**) Exposure to infrasound – Perception and changes in wakefulness. J Low Freq Noise Vib 2: 1-11.

Lisurek M, Bernhardt R (**2004**) Modulation of aldosterone and cortisol synthesis on the molecular level. Mol Cell Endocrinol 215: 149-159.

Łukaszewicz E, Adamski M, Kowalczyk A (**2008**) Correlations between body measurements and tissue composition of oat-fattened *White Kołuda* geese at 17 weeks of age. Br Poult Sci 49: 21-27.

Nekhoroshev AS, Glinchikov VV (**1992**) Effect of infrasound on change in the auditory cortex. Gig Sanit 7-8: 62-64.

Palme R, Rettenbacher S, Touma C, El- Bahr SM, Mostl E (**2005**) Stress Hormones in Mammals and Birds: Comparative Aspects Regarding Metabolism, Excretion, and Noninvasive Measurement in Fecal Samples. Ann N Y Acad Sci 1040: 162-171.

Pawlas K (**2009**) Wpływ infradźwięków i hałasu o niskich częstotliwościach na człowieka- przegląd piśmiennictwa. Podstawy i Metody Oceny Środowiska Pracy 2: 27-64.

PN-EN 61400-11 (**2001**) Turbozespoły wiatrowe. Część 11: Procedury pomiaru hałasu. In: Normalizacyjna Komisja Problemowa nr 137 ds. Urządzeń Cieplno-Mechanicznych w Energetyce.

Rabin LA, Coss RG, Owings DH (**2006**) The effects of wind turbines on antipredator behavior in California ground squirrels (*Spermophilus beecheyi*). Biol Conserv 131: 410-420.

Schmidt KL, Soma KK (**2008**) Cortisol and corticosterone in the songbird immune and nervous systems: local vs. systemic levels during development. Am J Physiol Regul Integr Comp Physiol 295: 103-110.

Sohail MU, Ijaz A, Yousaf MS, Ashraf K, Zaneb H, Aleem M, Rehman H (**2010**) Alleviation of cyclic heat stress in broilers by dietary supplementation of mannan-oligosaccharide and *Lactobacillus*-based probiotic: dynamics of cortisol, thyroid hormones, cholesterol, C-reactive protein, and humoral immunity. Poult Sci 89: 1934-1938.

Statistica (**2008**) StatSoft Poland (data analysis software system), Version 8.0 PL. Kraków, Poland.

Svidovyi VI, Glinchikov VV (**1987**) Action of infrasound on the lung structure. Noise and Vibration Bulletin: 153-154. Cited by Pawlas K (2009) Wpływ infradźwięków i hałasu o niskich częstotliwościach na człowieka- przegląd piśmiennictwa. Podstawy i Metody Oceny 1rodowiska Pracy 2: 27-64.

Swathi B, Gupta PS, Nagalakshmi D, Reddy AR (**2012**) Effect of Herbals Tulsi and Turmeric on Cortisol, Enzymatic and Biochemical Constituents in Serum of Heat Stressed Broilers. Indian J Anim Nutr 29: 284-286.

Tokarzewski S, Wernicki A, Kankofer M, Urban- Chmiel R, Arciszewski M (**2006)** Transport jako czynnik wzmagający reakcje stresowe u brojlerów kurzych. Annales Universitatis Mariae Curie Skłodowska LXI: 127-134.

van den Berg GP (**2004**) Effects of the wind profile at night on wind turbine sound. J Sound Vib 277: 955-970.

Walsh MT, Beldegreen RA, Clubb SL, Chen CL (**1985**) Effect of exogenous ACTH on serum corticosterone and cortisol concentrations in the Moluccan cockatoo (*Cacatua moluccensis*). Am J Vet Res 46: 1584-1588.