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Effect of sex on the meat quality of European wild boar (*Sus scrofa scrofa*)

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Abstract: *Effect of sex on the meat quality of European wild boar* (Sus scrofa scrofa). Forty carcasses (38.6–45.9 kg) from male and female (1 : 1) wild boar, which were shot in one hunting area during the 2014/2015 season, were studied. Samples of MLD were analysed for proximate chemical composition and fatty acid content of IMF as well as shear force and WHC. Values of AI and TI index were calculated. Statistical analysis confirmed a significant ($P \leq 0.05$) effect of sex on the water content of MLD, which was higher in males than in females. Protein content of MLD was high and averaged 24%. Meat was lean with IMF below 2%. The PUFA to SFA ratio was similar in both groups of sex, and the dietetically beneficial n-6 to n-3 PUFA ratio was less than 4 : 1 because the proportion of n-3 PUFA was high at 4.7–5.1 g per 100 g of fat. The effect of sex of wild boar on AI was significantly ($P \leq 0.05$) higher in males than in females. The results obtained show that the meat of wild boar of both groups of sex would be a rich source of protein in the human diet as well as a source of long-chain n-3 PUFA. The high level of long-chain n-3 PUFA is in line with dietary recommendations for the low n-6/n-3 PUFA. Due to its health-promoting benefits, wild boar meat may provide an alternative to the meat of farm animals.

Key words: wild boar, sex, meat quality

INTRODUCTION

In Poland, the size of the wild boar population has consistently increased from 173,500 in 2005 to 250,000–285,000 at present. The number of wild boar shot in the 2014/2015 season was 291,450 and encompassed all sex and age classes (GUS 2015).

The annually increasing harvesting of wild boar meat and its more availability led consumers to show greater interest in game meat and believe that animals living in their natural habitats are a source of healthy food (Popczyk 2012, Skorupski and Wierzbicka 2014, Kasprzyk 2015).

The quality of wild boar meat is an important factor as regards the consumers' choice of this type of meat. The living conditions of wild boar and the specific biodiversity of their natural feeding grounds contribute to the content of basic nutrients in their meat (including the level of protein and fat), the unsaturated

to saturated fatty acids ratio (which is particularly beneficial compared to that in pork), and the flavour and aroma of the meat (Quaresma et al. 2011, Guzek et al. 2013, Skobrák Bodnár and Bodnár 2014).

The aim of the study was to determine if the sex of wild boar has a significant effect on the quality of their meat.

MATERIAL AND METHODS

Carcasses obtained from 40 male and female (1 : 1) wild boar, which were shot in one hunting area of central Poland between December 2014 and January 2015, were investigated. Carcass weight averaged 45.9 kg for females and 38.6 kg for males. The animals were hunted at night. After shooting and bleeding out wild boar were eviscerated and transported within 48 h to a slaughterhouse, where the carcasses were weighed, removed skin and samples (300 g) of *m. longissimus dorsi* (MLD, part of *musculus lumborum*) were collected.

The samples of MLD were analysed to determine proximate chemical composition, fatty acid content of intramuscular fat (IMF), water holding capacity (WHC) and shear force. The chemical composition (water, protein, fat, collagen) was determined by near-infrared transmission (NIT) spectroscopy with calibration using artificial neural networks (ANN) and FoodScan™ meat analyser (PN-A-82109:2010).

Water holding capacity was determined in a 300 mg sample of meat, which was placed on a filter paper (Whatman 1) and held under 2 kg pressure between glass plates for a period of 5 min (Grau and Hamm 1953). An electronic planimeter was used to calculate the area of the pressed meat sample and the area of expressed water. The free water was calculated as the quotient of the difference between the areas of expressed water and pressed meat sample, and sample weight.

Shear force value was measured using a Zwick 1120 tester. Samples of MLD were boiled in water for 30 s and, after placing into an oven at 180°C, roasted to an internal temperature of 76°C. The sample was cooled at room temperature (24 h). A 20 mm cube was excised from the sample and cut with a Warner-Bratzler blade with a speed of 30 mm/min to reach a shear force of 2 N and with a speed of 50 mm/min during the test.

Lipid extraction of meat samples was performed according to the Folch procedure (AOAC 2005) at room temperature. Fatty acid methylation was performed according to the transesterification method EN ISO 5509:2000. Identification with fatty acid standards and quantitative determination of individual fatty acids in crude fat were conducted using a Agilent Technologies 7890A GC (Agilent, Waldbronn, Germany) with HP ChemStation software, a flame–ionization detector and a Varian Select FAME column (100 m length, 0.25 mm diameter, 0.25 μm film thickness; Varian/Agilent Technologies, Waldbronn, Germany). The analysis involved a programmed run with temperature ramps under the conditions and temperatures

described by Puppel (2011). Each peak was identified and quantified using pure methyl ester standards (PUFA 1, Lot LB 75066; PUFA 2, Lot LB 83491; FAME Mix RM-6, Lot LB 68242; Supelco 37 Comp. FAME Mix, Lot LB 68887; Supelco, Bellefonte, PA, USA).

Atherogenic (AI) and thrombogenic (TI) index were calculated according to the formula given by Ulbricht and Southgate (1991).

$$AI = [C12:0 + (4 \times C14:0) + C16:0] / [MUFA + PUFAn\text{-}6 + PUFAn\text{-}3]$$

$$TI = (C14:0 + C16:0 + C18:0) / [(0.5 \times MUFA) + (0.5 \times PUFAn\text{-}6) + (3 \times PUFAn\text{-}3) + (PUFAn\text{-}3 / PUFAn\text{-}6)]$$

The results were statistically elaborated. The differences between the groups were determined by the U Mann–Whitney test (IBM SPSS Statisics 23). The table contain the means of the traits together with the standard deviation.

RESULTS AND DISCUSSION

Statistical analysis confirmed a significant ($P \leq 0.05$) effect of sex on the water content of MLD (Table 1). These differences can also result from the mass of carcass. Female carcasses were heavier than male carcasses. Protein content of MLD was high and averaged 24%. Meat was lean with IMF below 2%. A similarly high protein content (23.1–24.1%) of MLD obtained from wild boar of both sexes was determined by Dannenberger et al. (2013), who also showed a significant difference in IMF level between males and females older than 1 year. In the study by Postolache et al. (2011), IMF content of *m. longissimus dorsi* exceeded 2% (2.48% in males and 2.57% in females), but the carcasses were heavier than in our study. In turn, Quaresma et al. (2011) reported IMF content to be twice as high but in *m. psoas major*. The Feder number, being the ratio of water to protein content in the meat (index of protein hydration), was similar in both groups of sex ($P > 0.05$), less than 3.5,

TABLE 1. Chemical composition, water holding capacity and shear force of MLD from wild boar

Item	Sex				*P*
	female		male		
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	
Number of animal	20		20		
Moisture (%)	71.62^{a}	1.06	72.37^{b}	0.76	0.042
Protein (%)	24.19	1.08	23.90	0.62	0.371
Fat (%)	1.94	0.67	1.63	0.48	0.154
Collagen (%)	1.39	0.19	1.53	0.37	0.284
Feder number	2.97	0.17	3.03	0.10	0.319
WHC (g/cm^2)	9.91	2.76	12.43	5.11	0.081
Force shear (N)	68.94^{A}	17.72	51.44^{B}	16.94	0.012

A, B – differences $P \leq 0.01$; a, b – differences $P \leq 0.05$.

which is characteristic for raw ham meat of pigs (Olkiewicz 2009).

Collagen is a major structural protein of muscle that largely determines meat tenderness and sensory characteristics. Sex had no effect on the collagen content of MLD and its level did not exceed 2%. That sex has no effect on collagen level in different muscles is confirmed by Postalache et al. (2011) and Lazar et al. (2014). Research results regarding the impact of gender on collagen concentrations in wild game meat are ambiguous, probably due to the combined effects of other factors including the age, diet, species and motor activity of animals (Daszkiewicz et al. 2012).

The meat from females showed a slightly higher water holding capacity compared to the meat of males ($P > 0.05$). With a slightly higher protein content and more favourable WHC, the meat from females was harder than the meat of males ($P \leq 0.01$).

Sex had no effect on SFA content and only a significantly ($P \leq 0.01$) higher C17:0 and C24:0 content of fat was found in males compared to females (Table 2). Quaresma et al. (2011) observed no significant effect of sex on the fatty acid composition of IMF. The same authors reported that the main fatty acids in *m. psoas major* are C18:1*c*9, C18:2n-6, C16:0 and C18:0. Likewise in our study, these fatty acids were most abundant in the MLD of wild boar. The most abundant acids were palmitic (C16:0) and stearic acids (C18:0) in SFA, oleic acid (C18:1*c*9) in MUFA, and linolenic acid (C18:2n-6) in PUFA, which is consistent with the findings of Quaresma et al. (2011) and Razmaite et al. (2011, 2012).

In our study, the proportion of n-3 PUFA in IMF was high at 4.7–5.1 g per 100 g of fat. Dannenberger et al. (2013) noted an equally high content of n-3 PUFA in the meat of female and

TABLE 2. Fatty acids composition (g per 100 g of total fatty acids) in MLD of wild boar

Item	Sex				*P*
	female		male		
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	
SFA	36.76	2.65	39.24	4.85	0.068
C14:0	1.39	0.28	1.64	0.44	0.076
C15:0	0.33	0.12	0.39	0.19	0.611
C16:0	23.39	3.94	25.55	3.48	0.137
C17:0	0.26^{A}	0.13	0.44^{B}	0.22	0.004
C18:0	10.79	2.63	10.08	1.93	0.481
C20:0	0.04	0.02	0.05	0.02	0.076
C24:0	0.56^{A}	0.50	1.09^{B}	0.63	0.008
MUFA	36.29	6.03	34.61	4.19	0.251
C14:1	0.66^{A}	0.30	0.91^{B}	0.25	0.002
C16:1	5.21	1.70	5.84	1.43	0.090
C17:1	0.30	0.23	0.47	0.30	0.100
C18:1 *t*9	0.22^{A}	0.10	0.50^{B}	0.21	0.000
C18:1 *c*9	29.73^{a}	6.06	26.52^{b}	5.30	0.047
C20:1	0.16^{A}	0.07	0.36^{B}	0.18	0.000
PUFA	22.23	1.93	23.21	1.67	0.050
PUFA n-6	17.54	1.99	18.00	0.68	0.297
C18:2 n-6	15.65	2.04	15.21	1.11	0.794
C18:3 n-6	0.02^{A}	0.02	0.04^{B}	0.01	0.000
C20:4 n-6	1.87^{A}	0.76	2.75^{B}	0.84	0.002
C22:2 n-6	0.17^{A}	0.17	0.43^{B}	0.24	0.262
PUFA n-3	4.69	0.67	5.21	1.31	0.151
C18:3 n-3	1.89	0.45	1.75	0.36	0.130
C18:4 n-3	0.48	0.12	0.54	0.14	0.100
C20:3 n-3	0.34^{a}	0.14	0.44^{b}	0.15	0.033
C20:5 n-3	0.22	0.06	0.22	0.07	0.938
C22:5 n-3	1.08	0.33	1.44	0.66	0.085
C22:6 n-3	0.68	0.50	0.82	0.55	0.262

A, B – differences $P \leq 0.01$; a, b – differences $P \leq 0.05$.

male wild boar from north-eastern region of Mecklenburg-Western Pomerania. A much lower n-3 PUFA was characteristic of the meat of wild boar from the north-western region of Mecklenburg-Western Pomerania, which shows that the content of these acids depends on abundance of the food base.

The PUFA to SFA ratio was similar in both sexes (Table 3). The dietetically beneficial n-6/n-3 PUFA was less than 4 : 1 (Wood et al. 2003). In the studies by Razmaite et al. (2012) and Quaresma et al. (2011), the n-6/n-3 PUFA was much greater: 10 : 1 in females and 9 : 1 in males for MLD, and 15 : 1 in females and 17 : 1 in males for *m. psoas major*.

TABLE 3. Fatty acids ratio, atherogenic index (AI) and thrombogenicity index (TI) in the MLD from wild boar

Item	Female		Male		*P*
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	
Number of animal	20		20		
PUFA/SFA	0.61	0.06	0.60	0.11	0.814
n-6/n-3	3.83	0.81	3.69	1.01	0.375
AI	0.50[a]	0.06	0.56[b]	0.09	0.027
TI	0.87	0.08	0.89	0.17	0.602

PUFA n-6 = C18:2n-6 + C18:3n-6 + C20:4n-6 + + C22:2n-6.
PUFA n-3 = C18:3n-3 + C18:4n-3 + C20:3n-3 + + C20:5n-3 + C22:5n-3 + C22:6n-3.
AI = [(4 × C14:0) + C16:0] / [n-6PUFA + + n-3PUFA + MUFA].
TI = [C14:0 + C16:0 + C18:0] / [(0.5 × MUFA) + + (0.5 × PUFA n-6) + (3 × PUFA n-3) + + PUFA n-3 / n-6].
a, b – differences $P \leq 0.05$.

Statistical analysis confirmed the effect of sex of wild boar on AI, which was significantly ($P \leq 0.05$) higher in males than in females. Similar results were obtained by Razmaite et al. (2012), who demonstrated more beneficial AI and TI values in the intramuscular fat of females (0.43 and 0.97) compared to males (0.48 and 1.09). The atherogenic and thrombogenic index inform about the dietetic value of lipids and their potential effects on the development of coronary artery disease (the lower the values, the lower the risk for the incidence of arteriosclerosis in humans).

CONCLUSION

Our results suggest that the meat from male and female wild boar is a rich source of protein in the human diet. Wild boar meat is a good source of long-chain n-3 PUFA, which are beneficial in human diets. The high level of long-chain n-3 PUFA is in line with dietary recommendations for the low n-6/n-3 PUFA. Due to its health-promoting benefits, wild boar meat may provide an alternative to the meat of farm animals.

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Streszczenie: *Wpływ płci na jakość mięsa dzika europejskiego* (Sus scrofa scrofa). Badania przeprowadzono na 40 tuszach (38,6–45,9 kg) pozyskanych od dzików obu płci (1 : 1) odstrzelonych w jednym rejonie łowieckim centralnej Polski w sezonie 2014/2015. W próbkach MLD określono podstawowy skład chemiczny i zawartość kwasów tłuszczowych w IMF oraz siłę cięcia i całkowitą pojemność wodną (WHC), a także obliczono wartość indeksów AI i TI. Analiza statystyczna potwierdziła istotny ($P \leq 0,05$) wpływ płci na zawartość wody w MLD, która była większa u samców niż u samic. Zawar-

tość białka w MLD była duża i wynosiła średnio 24%. Mięso było chude – poziom IMF wynosił poniżej 2%. Stosunek PUFA do SFA był zbliżony u obu płci. Korzystna ze względów dietetycznych relacja PUFA n-6 do PUFA n-3 wynosiła mniej niż 4 : 1, ponieważ udział kwasów PUFA n-3 w IMF był duży i wynosił 4,7–5,1 g na 100 g tłuszczu. Potwierdzono wpływ płci dzików na wartość indeksu AI, który był istotnie ($P \leq 0,05$) większy u samców niż u samic. Uzyskane wyniki wskazują, że mięso dzików obu płci może być bogatym źródłem białka w diecie człowieka, a także źródłem długołańcuchowych kwasów PUFA n-3. Wysoki poziom długołańcuchowych PUFA n-3 koresponduje z zaleceniami dietetyków odnośnie małego stosunku PUFA n-6 do PUFA n-3. Ze względu na swoje walory prozdrowotne mięso dzika może stanowić alternatywę mięsa zwierząt gospodarskich.

Słowa kluczowe: dzik, płeć, jakość mięsa

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Effects of performance test of Polish Large White and Polish Landrace gilts in relation to their subsequent reproductive performance

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Abstract: *Effects of performance test of Polish Large White and Polish Landrace gilts in relation to their subsequent reproductive performance.* The analysis covered performance test results and reproductive performance of 198 Polish Large White (PLW) sows and 96 Polish Landrace (PL) sows from a pedigree-breeding farm of the region of Pomerania and Kujawy. 1,188 litters produced from the PLW sows and 576 litters produced from the PL sows were tested (six consecutive litters). Reproductive performance of the PLW and PL sows in the subsequent six litters taken as a life reproductive efficiency demonstrated higher indicators of reproductive traits than national data. The PLW sows were characterized by the highest number of piglets at first and 21st day in the third and fifth litter ($P \leq 0.01$) and a ca seven-day lower farrowing interval (second and third litter) in comparison with the PL sows. The analysis demonstrated a negative correlation between the age of the first farrowing and the standardized daily gains ($P \leq 0.01$) in the PLW sows and a positive correlation with the body lean percentage ($P \leq 0.05$), as well as a lower number of young boars in the litters of those sows which were characterized by a higher meat content ($P \leq 0.01$) and a higher selection index value ($P \leq 0.05$). When it comes to the PL sows, the age of the first farrowing was positively correlated with the standardized backfat thickness ($P \leq 0.01$).

Key words: pigs, sows, performance test, reproductive performance

INTRODUCTION

Intensive genetic progress of pigs aims at improving their fattening and slaughtering performance, which is certain to affect the profitability of pork production. In the opinion of some researchers (Gaughan et al. 1997, Hool and Robison 2003), in gilts intended for breeding, there is a lack of balance when it comes to simultaneous reaching of a high slaughter value and a high reproductive ability. Presumably, this is the effect of different influence of various hormone groups (somatic and reproductive) on cell metabolism during growth and development of animals (Booth et al. 1994, Klindt et al. 1999). Therefore, it seems to be a well-grounded opinion on lower reproductive performance traits of sows from herds characterized by a high slaughter value. The most frequent problems observed in the reproduction of gilts and sows with a high meat content include: a less intense and shorter estrus cycle, a lower litter size and a lower number of piglets reared, delayed estrus cycle after

weaning, as well as an increased culling (Flisar et al. 2012).

It seems that among the tested traits of gilts' breeding value (so-called performance test), the gain rate, backfat thickness and carcass meat content are very important in forecasting their reproductive performance (Rekiel and Więcek 2002, Matysiak et al. 2010a, 2010b, Flisar et al. 2012).

Therefore, it seems purposeful to carry out an analysis and assessment of relationships between the results of performance test and the reproductive performance of sows of the maternal breeds PLW and PL.

MATERIAL AND METHODS

The analysis covered performance test results and reproductive performance of 198 Polish Large White (PLW) sows and 96 Polish Landrace (PL) sows from a pedigree-breeding farm of the region of Pomerania and Kujawy. The animals were maintained in accordance with animal welfare requirements and fed in compliance with recommended standards (Grela and Skomiał 2014). 1188 litters from the PLW sows and 576 litters from the PL sows were tested (six consecutive litters). All the litters were born and reared between 2009 and 2014.

The test results obtained were statistically processed. An arithmetic mean and standard deviation were calculated. In order to compare the reproductive performances of the PLW and PL sows in consecutive six litters, a two-way analysis of variance and interaction was carried out. For groups created as a result of dividing the study material according to factors included in the model of the variance analysis, a least significant difference test (LSD) was conducted for pairs of means for items.

Pearson correlation coefficients between the traits of performance test and reproduction were calculated within the PLW and PL sows populations. For statistical calculations, the Statistica software (StatSoft ver. 8) was used.

RESULTS AND DISCUSSION

The characteristics of the tested group of sows along with their performance test results are presented in Table 1. No statistically significant differences between the PLW and PL breeds of the tested gilts were demonstrated when it comes to the tested indicators. The values of the standardized daily gains, thickness of fat cover and carcass lean percentage corresponded to national mean data (Eckert et al. 2015). The selection index value was slightly higher (118 points for the PLW sows and 119 points for the PL sows) than the one obtained previously in own studies (Bocian et al. 2010) and the values provided by other authors (Eckert et al. 2015). Number of teats in both groups of sows were even and amounted to 14 on average. In the opinion of Rekiel et al. (2013), the higher is the number of teats in the PL sows, the higher litter size and the less losses as they are reared. This paper does not confirm this relationship. The age of the first farrowing in sows of both breeds were equal and amounted to 357 days.

TABLE 1. Results of Polish Large White (PLW) and Polish Landrace (PL) gilts' life performance (mean and standard deviation)

Trait	Breed	
	PLW	PL
Body weight of gilts (kg)	82.50 ±7.52	83.59 ±7.46
Standardized daily gains (g)	659 ±69	670 ±60
Standardized backfat thickness (mm)	10.75 ±2.11	10.95 ±2.21
Body lean percentage (%)	59.01 ±2.72	58.87 ±2.30
Selection index value (pts)	117.84 ±11.16	119.11 ±7.79
Number of teats (n)	14.37 ±0.63	14.29 ±0.60
Age at first farrowing (days)	357.3 ±33.03	357.16 ±31.77

Table 2 contains a detailed characteristics of the reproductive value of the tested sows. In two-way variance analysis the significant interaction between consecutive litters and breed of sows was not indicated. The analysed reproductive period of sows covered the first six litters and was suitable for the assessment of the life reproductive efficiency of the sows (Serenius et al. 2008, Schwarz et al. 2009). The number of piglets from the PLW sows at first and 21st day of life was the highest in the third and the fifth litter ($P \leq 0.01$); however, when it comes to litters from the PL sows, there was no significant differences. The results of reproductive performance of the tested PLW and PL sows related to the number of piglets born (NPB) and the number of piglets reared at 21st day (NPR) were clearly higher than the national data obtained for 2014 (Mucha 2015). Subsequent more, piglet mortality until the 21st day was lower than shown in the national data.

In the present study, both PLW and PL sows gave birth to 10% more gilts than young boars (56% of gilts and 44% of young boars) in each of the six consecutive litters and in total (Table 2). The fact that gilts outnumbered young boars in a litter may indicate less favourable conditions for prenatal development of male embryos which show a greater susceptibility to embryonic death when there is a high density of embryos or too low intrauterine space of the sows' reproductive system (Vallet 2000, Foxcroft et al. 2009, Rekiel et al. 2013).

The study demonstrated a significantly shorter farrowing interval in the PLW sows in comparison with the PL sows, especially in the first two reproductive cycles ($P \leq 0.01$). The length of a farrowing interval is determined by the point in time when the estrus cycle occurs after weaning, the efficiency of insemination indirectly related to the intensity and length of the estrus cycle, the length of pregnancy, and other factors (Eliasson et al. 1991, Sterning et al. 1998).

Table 3 presents a correlation between the performance test and reproductive value of the PLW and PL sows.

Significant relationships only regarded the number of young boars in a litter and the age of the first farrowing. A lower number of young boars in

TABLE 2. The results of sows' reproductive performance in subsequent litters (mean and standard deviation)

Trait	Breed	Subsequent litters						Mean
		I	II	III	IV	V	VI	
Number of alive piglets born (n)	PLW	12.17^{ABab} ±1.40	12.58^{a} ±1.69	12.75^{A} ±1.69	12.61^{b} ±1.89	12.72^{B} ±1.78	12.44 ±1.91	12.54 ±1.74
	PL	12.33 ±1.24	12.51 ±1.53	12.72 ±1.70	12.59 ±1.84	12.53 ±1.86	12.32 ±1.87	12.50 ±1.69
Number of piglets reared until 21st day (n)	PLW	11.73^{Aa} ±1.28	11.99 ±1.48	12.15^{Aa} ±1.65	11.96 ±1.72	12.07^{a} ±1.48	11.80^{a} ±1.60	11.95 ±1.55
	PL	11.86 ±1.14	11.87 ±1.32	12.01 ±1.49	11.87 ±1.65	11.91 ±1.44	11.74 ±1.80	11.88 ±1.48
Mortality piglets of from 1st to 21st day (%)	PLW	3.61	4.69	4.70	5.15	5.11	5.14	4.70
	PL	3.81	5.11	5.58	5.72	4.95	4.71	4.96
Number of gilts at 21st day (%)	PLW	56.86	54.30	55.97	56.35	55.34	55.68	55.73
	PL	55.56	53.75	55.62	54.93	57.09	56.90	55.64
Number of boars at 21st day (%)	PLW	43.14	45.70	44.03	43.65	44.66	44.32	44.27
	PL	44.44	46.25	44.38	45.07	42.91	43.10	44.36
Farrowing interval (days)	PLW	–	167.76^{X} ±23.73	164.12^{X} ±17.25	163.93 ±18.99	164.32 ±18.45	166.31 ±20.20	165.28^{X} ±9.36
	PL	–	175.71^{AX} ±26.37	171.21^{aX} ±23.12	164.20^{ABa} ±19.57	166.78^{AC} ±22.00	164.95^{AD} ±22.97	168.57^{X} ±10.81

I, II, III, IV, V, VI – subsequent litters.

$^{a, a}$ and $^{b, b}$ – in line the means marked with the same small letters differ statistically significantly at $P \leq 0.05$.

$^{A, A}$ and $^{B, B}$ – in line the means marked with the same capital letters differ statistically significantly at $P \leq 0.01$.

$^{X, X}$ – values in the columns with the same capital letters differ significantly at $P \leq 0.01$.

TABLE 3. Coefficients of correlation between live performance and reproductive performance traits of PLW and PL sows

Reproductive performance		Life performance test			
	breed	standardized daily gains	standardized backfat thickness	body lean percentage	selection index value
Number of piglets born	PLW	0.010	0.127	–0.115	–0.077
	PL	0.053	–0.045	0.027	0.089
Number of piglets reared until 21st day	PLW	–0.020	–0.056	0.044	0.014
	PL	–0.099	–0.069	0.009	–0.111
Number of gilts at 21st days	PLW	–0.020	–0.089	0.091	0.050
	PL	–0.111	–0.066	0.029	–0.107
Number of boars at 21st days	PLW	0.001	0.180**	–0.254**	–0.191**
	PL	0.104	–0.029	–0.166	–0.027
Age at first farrowing	PLW	–0.221**	–0.036	0.148*	–0.100
	PL	–0.044	0.278**	–0.050	–0.060

* coefficients of correlation significant at $P \leq 0.05$.
** coefficients of correlation significant at $P \leq 0.01$.

a litter was reared by those PLW sows which were characterized by thinner backfat, higher meat content and a higher selection index value ($P \leq 0.01$). The age of the first farrowing of the PLW gilts was negatively correlated with the standardized daily gains ($P \leq 0.01$) and positively correlated with the meat content of the gilts ($P \leq 0.05$). In the PL sows, on the other hand, all the correlated relationships between the traits of performance test and reproductive performance were insignificant, except for the standardized backfat thickness ($P \leq 0.01$).

CONCLUSIONS

This paper demonstrated a relatively high level of the breeding value of the tested gilts and their subsequent productivity. No noticeable differences were observed between the results of both breeds. Relationships between the performance test of the sows and their reproductive efficiency turned out to be quite low – not statistically significant in most cases. A lower number of young boars in a litter occurred in those PLW sows which were characterized by thinner backfat, higher meat content and a higher selection index value as determined by the performance test.

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Streszczenie: *Wyniki oceny przyżyciowej loszek rasy wielkiej białej polskiej i polskiej białej zwisłouchej a efekty ich późniejszego użytkowania rozrodczego*. Analizie poddano wyniki oceny przyżyciowej i użytkowości rozpłodowej 198 loch rasy wielkiej białej polskiej (PLW) i 96 loch polskiej białej zwisłouchej (PL) użytkowanych w gospodarstwie hodowli zarodowej regionu Pomorza i Kujaw. Oceniono 1188 miotów pozyskanych od loch rasy PLW i 576 miotów od loch PL (sześć kolejnych miotów). Ocena użytkowości rozpłodowej loch PLW i PL w kolejnych sześciu miotach przyjęta za życiową wydajność rozrodczą loch wykazała większe wartości wskaźników cech rozpłodowych od danych krajowych. Lochy PLW cechowały się największą liczbą prosiąt w pierwszym i 21. dniu w trzecim i piątym miocie ($P \leq 0{,}01$), a także krótszym o ok. 7 dni okresem międzymiotu (drugi i trzeci miot) w porównaniu do loch PL. Wykazano u loch PLW ujemną ko-

relację między wiekiem pierwszego oproszenia a standaryzowanymi przyrostami dobowymi ($P \leq 0,01$) oraz dodatnią z procentową zawartością mięsa w ciele ($P \leq 0,05$), a także mniejszą liczbę knurków w miotach loch o większej mięsności ($P \leq 0,01$) i większej wartości indeksu selekcyjnego ($P \leq 0,05$). U loch PL wiek pierwszego oproszenia był natomiast dodatnio skorelowany ze standaryzowaną grubością słoniny ($P \leq 0,01$).

Słowa kluczowe: świnie, lochy, ocena przyżyciowa, użytkowość rozpłodowa

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The Influence of the extensification of porker feeding on the slaughter value, quality of meat products and fattening economics

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Abstract: *The influence of the extensification of porker feeding on the slaughter value, quality of meat products and fattening economics.* Sixty four pigs were examined and divided into two groups: group A, fed with feed mixtures, which were poorer in protein and metabolic energy and group B, fed with a mixture richer in those components (a difference of 0.5–1% in the content of protein and from 0.5 to 0.8 MJ/kg in metabolic energy). The fattening of the pigs was done indoors until the pigs gained a body weight of 120 kg. The daily growth, slaughter value and the organoleptic quality of meat products were investigated. The reduced level of protein and energy in the feed was found to result in daily growth to be reduced by 130 g and the fattening period to be lengthened by 9 days. The pigs which were fed less intensively had a higher content of meat in the carcass by 1.86 pp, less fatback in the half-carcass and a higher dressing percentage by 1.33 pp. The feeding was not found to influence the organoleptic quality of dry cured ham (except of the juiciness which was better in group A) and ham sausage (except for the compensation of colour which was better in group B).

Key words: feeding, slaughter value, meat products quality, fattening economics

INTRODUCTION

As Webb and Erasmus (2013) stress there has been a shift from extensive farming systems to more intensive systems and in some species like pigs typical factory farms became more prevalent. At present, when noble breeds are used an extensive system is not economically justified except when the production of pork has a particular sensory value, which is used for the production of brand-name products with adequately high prices. An example of such production is the extensive breeding of the native local Italian breed Nero Siciliano, whose meat is mainly used to make dry cured products, e.g. Parma ham. Research by Pugliese et al. (2003, 2004) proved that the extensive feeding of those pigs in a free-range farming system caused a lower growth rate, a higher meat content and lower content of fat in ham as well as a lighter colour and worse water absorp-

tion of the *longissimus dorsi* muscle than in pigs fattened indoors. According to Italian researchers, the extensive free--range fattening system of the Cinta Senese native breed of pigs caused a lower daily growth and worse physical traits of meat, but it improved the dietary value of fat in comparison to indoor breeding (Franci et al. 2001, Acciaioli et al. 2002, Pugliese et al. 2012).

The slaughter value of pigs and the quality of their meat is very strongly influenced by nutrition (Rekiel et al. 2005). The pigs which are currently fattened, especially those of high-meat breeds, are capable of the effective depositing of protein in the daily gain, which becomes reduced when the body weight of a pig reaches about 90 kg, and the fat deposit increases. The application of appropriate nutrition may reduce the fatness and at the moment simultaneously it may contribute to a reduction of the fattening costs. A maintenance of the desirable traits of meat quality is an important problem in this case.

The aim of the study is to investigate the influence of the intensity of feeding pigs bred indoors on slaughter value, the quality of meat products and the economics of pig production.

MATERIAL AND METHODS

The experiment was carried out on 64 pigs (half of them were gilts and the other half were hogs) divided into two groups: a group fed extensively (n = 26) and a group fed intensively (n = 38). The material for the research was hybrids obtained from the crossbreeding of the Polish Large White (PLW) × Polish Landrace (PL) female breeders with boars PL. The pigs were kept indoors in grates. The feed was foraged manually into auto-feeders. The content of the feed components in mixtures for the porkers and fatteners is shown in Table 1. As follows from Table 1, the pigs that were fed intensively received concentrated feed, which was 1% richer in protein during the first period of fattening and 0.5% richer during the second period of fatten-

TABLE 1. Nutrient components content of the feed mixtures for porkers and fatteners

Components	Grover		Finisher	
	group A	group B	group A	group B
Crude protein (%)	16.5	17.5	15.0	15.5
Energy net (kcal)	2 163	2310	2163	2268
Metabolizable energy (MJ/kg)	12.4	13.2	12.4	12.9
Lysine (%)	0.96	1.10	0.82	0.90
Methionine (%)	0.32	0.34	0.25	0.28
Methionine + Cystine (%)	0.65	0.69	0.66	0.61
Threonine (%)	0.64	0.71	0.56	0.60
Tryptophan (%)	0.19	0.21	0.17	0.18
Crude fibre (%)	4–7	3–6	4.5–7	4.5–6.5
Calcium (%)	0.7	0.7	0.65	0.65
Phosphorus (%)	0.6	0.6	0.65	0.6
Sodium (%)	0.15	0.15	0.14	0. 14

ing and which had 0.8 and 0.5 MJ/kg more metabolic energy during the first and second period, respectively. During fattening the pigs had constant access to water (automatic drinking bowls). The fattening started with body weights of about 30 kg and finished with a weight of about 120 kg.

After the pigs had reached the body weight of about 120 kg, they were transported to a nearby slaughterhouse (a distance of about 50 km), where they were rested for about 2 h and then they slaughtered by means of the electric stun device KOMA, with the following stunning parameters: voltage 250 V, electric current 2 A, frequency 50 Hz.

The following measurements were made on warm, hanging half-carcasses (Borzuta 1998): the content of the meat in the carcasses was measured by means of a CGM Sydel apparatus, the thickness of backfat measured with a calliper on the back, over the shoulder and on the cross-section spinal column (points KI, KII, KIII), the weight of a non-skinned carcass measured on an overhead rail scale to the nearest 100 g.

Part of the raw material was used to make meat products, i.e. dry cured ham from the *semimembranosus* muscle and ham sausage from the other ham muscles (group A $n = 10$, group B $n = 13$). The ham was made according to the methodology of the Institute of Meat and Fat Research Institute (Olkiewicz et al. 2000) with the lactic acid bacteria pokelferment (the process was completed when the product reached the yield of about 78%). The ham sausage was made according to the technology established in the meat industry, without additive polyphosphates. The products were subjected to organoleptic assessment in a five-point bonitation (where 5 points being the best and 1 point – unacceptable) with respect to the following traits: consistence, desirability and equal distribution of colour, juiciness, tenderness, flavour. Meat marbling was estimated on the five-point scale (where 5 is for high IMF content and 1 is for lack of the fat) (Baryłko-Pikielna 2014). The evaluation was done in day light at a temperature of 20 ±2° C by five trained persons. The results were given as a mean from these evaluations. The shear force was measured in the products by means of a Zwick/Roell apparatus. Cylinder cores with a round cross-section (2.54 cm in diameter) were manually removed parallel to the predominant muscle fiber orientation. The crosshead speed was set at 200 mm/min. The average shear force of the five results was used for the statistical analyses.

The results were statistically processed, calculating the standard deviations and Student's t-test by means of the Statistica PL ver 9.1 package. The distribution of the traits was checked by the Shapiro–Wilk test.

Cost-effectiveness of the outlay borne by the experimental farm was analysed. It was applied with the calculation methodology developed by Pepliński et al. (2004) and it was assumed that the same method of piglet production was applied in both fattening types and the feeds were diversified only when the piglets weighed about 30 kg.

RESULTS

The total mixture which was richer in nutrients had a significant influence on shortening the fattening period and increase in daily weight gain. The pigs from group B, which were fed with a ration with a higher amount of protein and a higher energy value, gained the final body weight of 120 kg 9 days earlier and on average had 130 g higher daily growth than the pigs from group A, which were fed less intensively (Table 2). On the other hand, the slaughter value of the pigs in group A turned out to be better, because the carcasses had less fat and a higher content of meat by 1.86 pp on average (58.83% in group A and 56.97% in group B, respectively) and their dressing percentage was 1.33 pp higher than that of the pigs in group B. Depending on the place of measurement the thickness of the backfat was 3–6 mm less in the pigs in group A and in comparison with group B the difference turned out to be statistically significant ($P \leq 0.05$).

The results of the fattening value obtained in this study are similar to those reported in the literature. In the research on the crossbreeding of the native spotted Złotnicka breed the authors achieved an average daily weight gain of 590 g for the Złotnicka breed and 640 g for the hybrids of the breed with the Duroc pigs (Szulc et al. 2012). A similar study on the native Spanish Retino Iberian breed revealed an average daily weight gain of 549 g for the breed and 677 g for the Spanish Duroc breed and 701 g for the Danish Duroc breed. The differences between the breeds proved to be statistically significant (Serrano et al. 2008). The Polish Pig Breeders and the Produc-

TABLE 2. The fattening characteristics, slaughter and pH values of extensively (group A) and intensively (group B) fed fatteners

Fattening and slaughter characteristics	Group A		Group B		*P*
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	
Fattening days (n)	113	–	104	–	0.00**
Initial body weight (kg)	43.10	3.55	47.60	3.10	0.17
Final body weight (kg)	118.97	8.55	122.66	8.60	0.13
Life daily gain (kg/day)	0.66	0.09	0.79	0.09	0.00**
Hot carcass weight (kg)	96.53	7.36	97.89	6.63	0.39
Dressing percentage (%)	81.14	1.72	79.81	1.33	0.03*
Meat content in carcass (%)	58.83	2.40	56.97	3.22	0.03*
Backfat thickness (mm)					
above shoulder	38.50	5.44	41.78	5.86	0.02*
on back	20.08	5.30	22.52	5.46	0.08
on cross I	20.03	5.95	26.19	6.43	0.00**
on cross II	11.74	4.71	14.56	4.84	0.02*
on cross III	17.16	6.55	22.70	7.24	0.00**
pH_{24h}	5.77	0.19	5.73	0.15	0.09

* Statistically significant difference, where $P \leq 0.05$; ** statistically significant difference, where $P \leq 0.01$.

ers Association POLSUS observed the highest weight gain in the production of high-meat pigs, e.g. in 2011 the average standardised daily weight gain was 696 g in the Polish Landrace boars, 698 g in the Polish Large White boars and 724 g in the Hampshire × Duroc hybrids (Blicharski et al. 2012).

The differences in the fattening results obtained in this study can be logically explained. The pigs which receive feeds that are richer in protein and energy components grow faster and their fattening period is shorter. However, the abundance of components involves specific consequences, which are not always positive. The fat content of carcases increases and in consequence, the meat content in pigs becomes reduced. This fact is confirmed by other authors. Pugliese et al. (2004) in their research on intensive and extensive fattening of local Italian Nero Siciliano pigs proved that the ham from pigs fattened extensively in the free-range farming system had 58.4% of meat and 31.24% of subcutaneous fat, whereas the ham from pigs fattened intensively in the indoor system had 55.10% of meat and 34.61% of fat. The content of these tissue components in the shoulder was 53.99 and 53.12% of meat and 31.90 and 33.26% of fat, respectively. American studies (Honeyman 2005) also confirm a similar influence of extensive fattening on the slaughter value.

The evaluation of the products made from the ham material of both groups under investigation, shown in Table 3, pointed to the very high quality of both dry cured ham and ham sausage. The average assessment of quality de-

TABLE 3. The results of the organoleptic assessment of meat products made from extensively (group A) and intensively (group B) fed fatteners

Meat product	Quality trait	Group A		Group B		*P*
		$\bar{x}$	*SD*	$\bar{x}$	*SD*	
Dry cured ham	consistence (pts)	4.47	0.25	4.55	0.23	0.43
	compensation colour (pts)	4.40	0.23	4.25	0.36	0.27
	desirable colour (pts)	4.34	0.28	4.32	0.34	0.89
	smell (pts)	4.26	0.30	4.31	0.28	0.75
	juiciness (pts)	4.08	0.21	3.82	0.25	0.02*
	tenderness (pts)	4.16	0.28	3.98	0.27	0.11
	flavour (pts)	4.28	0.27	4.29	0.27	0.93
	marbling (pts)	2.45	0.30	2.43	0.34	0.87
	shear force (N/cm^2)	27.42	6.28	28.33	4.99	0.28
Ham sausage	smell (pts)	4.42	0.29	4.50	0.27	0.65
	juiciness (pts)	4.70	0.20	4.75	0.23	0.70
	tenderness (pts)	4.70	0.28	4.50	0.29	0.10
	flavour (pts)	4.43	0.26	4.38	0.25	0.55
	shear force (N/cm^2)	10.12	4.51	11.82	4.01	0.12

* Statistically significant difference, where $P \leq 0.05$.

terminants ranged between about 4 and 4.7 points and did not statistically differ significantly between the groups except for the juiciness of ham (it was better in group A) as well as the compensation of colour (it was better in group B) in the ham sausage.

The higher value and greater dressing percentage of porkers in group A (Table 2) resulted in average sales prices of the porkers in group A being 2.89% higher (5.34 PLN per kg LW in group A and 5.19 PLN per kg LW in group B, respectively) – Table 4. A longer fattening period with a less concentrated feed resulted in a 9.8% worse conversion of the feed by the porkers in group A (3.36 kg of feed per kg of weight increase in group A and 3.06 kg of feed per kg of weight increase in group B, respectively). The lower cost per unit of feeds for extensively fed porkers (888 PLN per t during the first fattening period and 827 PLN per t during the second fattening period in group A in compare 961 PLN per t during the first fattening period and 894 PLN per t during the second fattening period in group B, respec-

TABLE 4. The technological and economic results of production of extensively fed fatteners (group A) and intensively fed fatteners (group B) in 2014

Specification	2014		Cost of feeds + 15%*	
	group A	group B	group A	group B
Feed consumption (kg feed/kg increase)	3.36	3.06	3.36	3.06
Costs, price (PLN/kg LW)	5.34	5.19	5.34	5.19
Feed cost (PLN/kg LW)	3.11	2.94	3.35	3.19
Purchase of piglets (PLN/kg LW)	0.14	0.45	0.14	0.45
Veterinary care and insemination cost (PLN/kg LW)	0.30	0.26	0.30	0.26
Energy cost (PLN/kg LW)	0.13	0.11	0.13	0.11
Depreciation (PLN/kg LW)	0.22	0.19	0.22	0.19
Repairs cost (PLN/kg LW)	0.14	0.11	0.14	0.11
Labour cost (PLN/kg LW)	0.42	0.35	0.42	0.35
Other direct costs (PLN/kg LW)	0.15	0.12	0.15	0.12
Indirect costs (PLN/kg LW)	0.12	0.10	0.12	0.10
Total costs (PLN/kg LW)	4.72	4.63	4.97	4.88
Secondary production cost (PLN/kg LW)	0.12	0.10	0.12	0.10
Own net cost (PLN/kg LW)	4.60	4.53	4.85	4.78
Profit per unit (PLN/kg LW)	0.74	0.66	0.49	0.41
Profit per unit (PLN/pigs)	89.58	83.16	59.66	51.88
Total profit (PLN/farm)	303 042	323 846	201 812	202 025

* Simulated results of the experiment if the prices of feeds increased by 15%.

tively) did not fully compensate for the worse conversion of feeds. In group A the cost of feed per kg of livestock produced (during the whole production period, from birth to sales) was higher by 0.16 PLN, because the porkers in this group consumed more feed per kg of growth (3.11 PLN per kg of porkers sold in group A in comparison to 2.94 PLN per kg of porkers sold in group B).

The farm could produce 3,894 porkers with feeds for the intensive group. The application of feeds with less concentrated protein and energy extended the experimental fattening by 9 days. Thus, it reduced the production capacity of the farm to about 3,383 porkers a year. Due to the fact that every year the farm under analysis purchased a few hundred piglets to supplement the deficit of its own production, it would be necessary to purchase fewer piglets for the extensive fattening method and this would result in the farm being burdened with lower costs of porkers. In group A it was 0.14 PLN per kg of porkers sold (it would be necessary to purchase 297 piglets); whereas in group B it was 0.45 PLN per kg of porkers sold (it would be necessary to purchase 827 piglets).

The cost of electricity, depreciation of buildings and machinery, costs of repairs and, to a large extent, labour costs are fixed costs if there is a relatively large number of staff employed. Therefore, when we calculated the costs per weight of porkers sold, there were higher costs per unit of the porkers in group A. The total costs of production reduced by the value of secondary production (sows sold) were higher by 0.07 PLN per kg LW when porkers were produced with a less intensive mixture. The costs amounted to 4.60 PLN per kg LW in group A and 4.53 PLN per kg LW in group B. The higher sales prices of the porkers in group A provided a higher profit per unit of 0.74 PLN per kg LW vs 0.66 PLN per kg LW in group B. It amounted to 89.58 PLN per porker and 83.16 PLN per porker, respectively. However, due to the fact that the fattening period is 9 days longer, the production potential of the farm is 13.1% lower. Thus, the profit of the entire farm would be 20,800 PLN greater and it would amount to about 323,800 PLN if the whole herd was fed with mixture B and it would amount to about 303,000 PLN if the herd was fed with mixture A. As results from the simulations, if the prices of feeds increased by 15%, the whole farm would make a similar profit regardless of the fattening type. However, a further increase in the prices of feeds would make extensive production more cost-effective.

The assumption that the pigs fed extensively had a better sensory quality of meat was not proved. This may have been caused by too small a difference in the fattening methods applied in the experiment. There are literature reports on the better organoleptic quality of the meat products of pigs fed extensively, where this system is connected with the choice of local breeds and free-range fattening. This applies e.g. to breeds from southern European countries (Pugliese and Sirtori 2012) and to other native breeds (Szulc et al. 2012).

On the other hand, from the economic point of view, the reduction of the fattening intensity had an influence on the farmers' results, although it also depended on the prices of feeds to a certain extent. In 2014, when the prices of feeds were low, the profit of the whole farm was 6.9% higher in the intensive fattening method. If the prices of feeds increased by 15%, the yearly profit made by the whole farm would be similar regardless of the fattening type.

The experiment showed that under certain economic circumstances it is justified to apply the extensive production of porkers. If we take external benefits into consideration, such as reduced environmental costs, better meat quality, improved animal welfare, etc., they may outweigh the economic loss (lower profit) resulting from the extensive fattening of porkers.

CONCLUSIONS

Applied in this work the reduced level of protein and energy in the feed provided to the pigs caused a decrease in the daily weight gains by 130 g on average. The pigs which were fed less intensively had a higher slaughter value, i.e. on average the content of meat in the carcasses was 1.54 pp higher, the thickness of backfat was 3–6 mm thinner and the dressing percentage was 1.33 pp higher than in the group of pigs fed with the mixture which was richer in protein and energy. The evaluation of the products made from the ham pointed to the very high quality of both dry cured ham and ham sausage and showed no significant differences between both study groups (except for the juiciness of ham which was better in group A and for the colour compensation of ham sausage which was better in group B).

From the economic point of view, reduced fattening intensity combined with the low prices of feeds resulted in a lower profit margin of the whole farm. If the prices of feeds were 15% higher than in 2014, it might result in equal total profits for the farm in both fattening systems.

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Streszczenie: *Wpływ ekstensyfikacji żywienia tuczników na wartość rzeźną, jakość przetworów mięsnych oraz ekonomikę tuczu.* Wykonano badania 64 świń podzielonych na dwie grupy: grupę A żywioną mieszanką pełnoporcjową uboższą w białko i energię metaboliczną oraz grupę B żywioną mieszanką bogatszą w te składniki (różnica o 0,5–0,8% w zawartości białka i 0,5–0,8 MJ/kg w energii metabolicznej). Tucz prowadzono systemem alkierzowym do osiągnięcia masy ciała 120 kg. Badano przyrosty dzienne, wartość rzeźną oraz jakość organoleptyczną wyrobów mięsnych. Stwierdzono, że obniżony poziom białka i energii w paszy spowodował zmniejszenie przyrostów dziennych o 130 g i wydłużenie okresu tuczu o 9 dni. Tuczniki żywione mniej intensywnie charakteryzowały się większą o 1,86 pp. zawartością mięsa w tuszy, cieńszą o 3–6 mm słoniną oraz większą o 1,33 pp. wydajnością rzeźną. Zróżnicowany poziom żywienia nie wpłynął na jakość organoleptyczną szynek surowo-dojrzewających (oprócz soczystości, która była lepsza w grupie A) oraz kiełbasy szynkowej (z wyjątkiem natężenia barwy, która była większa w grupie B).

Słowa kluczowe: żywienie, wartość rzeźna, jakość przetworów mięsnych, ekonomika tuczu

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Pig housing system versus greenhouse gas emissions

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Abstract: *Pig housing system versus greenhouse gas emissions.* Animals emit greenhouse gases (GHG): carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) through respiration and digestion, and also in feces. The emission rate depends on the way animals are fed and housed. The objective of the study was to determine the emission rates of carbon dioxide, methane and nitrous oxide in two pig fattening farms with deep litter or slatted floor systems. The study was carried out on farm I, which raises 7,617 pigs on slatted floor per year, and on farm II, which keeps 1,594 pigs on deep litter. Carbon dioxide equivalents of 25 for CH_4 and 298 for N_2O were used in the calculations. The study estimated GHG emissions from livestock production only. Greenhouse gas emissions in CO_2 equivalent was 374.52 t on farm I and 68.91 t on farm II, corresponding to 49.17 kg (farm I) and 43.23 kg per pig (farm II). The present study showed lower GHG emissions in the deep litter system compared to the slatted floor system.

Key words: fatteners, greenhouse gases, emission, deep litter, slatted floor system

INTRODUCTION

The intensity of the greenhouse effect is controlled by the accumulation of greenhouse gases (GHG), the emissions of which are caused mainly by the burning of fossil fuels, changes in land use, deforestation, and livestock production. Animals emit greenhouse gases such as carbon dioxide (CO_2), which is produced from respiration, as well as methane (CH_4) and nitrous oxide (N_2O), which come from digestion and animal waste (Nalborczyk et al. 1997, IPCC 2006). The emission potential of CH_4 and N_2O is respectively about 25 and 300 times higher than that of CO_2. The consumption of electricity and liquid fuels, which is associated with animal production, is an additional source of CO_2 emissions. If a farm cultivates plants for animal feed, the GHG balance accounts also for energy used to produce fertilizers and pesticides. Greenhouse gas balance in livestock production is estimated using IPCC Tier 1 and Tier 2 (2006), ASABE (USDA 2014) and Nalborczyk et al. (1999) methods, with allowance made for the data on animal production systems and production results. The methane and nitrous oxide emission rates show high amplitudes for both pigs kept on slatted floor and those raised on deep litter (Philippe and Nicks 2014).

The agricultural sector is a significant contributor to greenhouse gas emissions, in particular methane and nitrous oxide, which account for 35 and 73% of total GHG emissions, respectively

(KOBiZE 2012). In looking for ways of reducing GHG emissions, much attention is being paid to animal feeding and housing systems (Cabaraux et al. 2009, Philippe and Nicks 2014). Management of animal manure in various pig housing systems affect the level of GHG emissions. The objective of the study was to determine the emission rates of carbon dioxide, methane and nitrous oxide (in carbon dioxide equivalent) in two pig fattening farms with deep litter or slatted floor systems.

MATERIAL AND METHODS

Data for the balance of emissions were collected in two individual open-cycle pig farms located in Central Poland. Between 1 October 2013 and 30 September 2014, detailed information was gathered concerning the course of different pig production cycles (Table 1) and the consumption of energy sources used in livestock production (Table 2). The fatteners were kept on slatted floor in the first farm (farm I) and on deep litter in the second farm (farm II). The study estimated GHG emissions from livestock production only.

Open-cycle fattening based on purchased feeds was conducted in both farms. Fattening started at a body weight of ca 35 kg and ended at a body weight of ca 122 kg. Four-phase fattening was conducted in farm I and three-phase fattening in farm II. During the analysed period, 7,617 and 1,594 pigs were kept in farms I and II, respectively.

TABLE 1. Production results of pigs raised in the farms under study

Data on pig fattening	Unit	Farm	
		I slatted floor	II deep litter
Number of pigs per production cycle	head	2 539	797
Duration of one production cycle	day	115	110
Number of fattening cycles during the study	–	3	2
Average weight of pig on the first day of fattening	kg	34	35
Average weight of pig on the last day of fattening	kg	122	121
Average feed conversion (kg feed/kg gain)	kg	2.71	2.79
Average dressing percentage	%	79.2	79.5
Average meatiness of pigs sold	%	58.4	59.1

TABLE 2. Amount of energy sources used in the farms under study

Source of emission	Unit	Farm	
		I slatted floor	II deep litter
Electric energy	kWh	48 390	10 800
Diesel fuel	dm^3	6 460	1 870

Emission of CO_2 was estimated according to Nalborczyk et al. (1999) using KOBiZE (2014) coefficients of electric energy and fuel oil consumption (Matin et al. 2004, Ludwicka 2009) as follows: 1 kWh of electric energy – 0.8315 kg CO_2; 1 dm^3 of diesel oil – 2.7631 kg CO_2 equivalent.

Daily amount of CH_4 from digestion was estimated according to IPCC Tier 1 methodology (IPCC 2006):

$$CH_4 = population \cdot 0.00411$$

where:
CH_4 – daily methane emissions (kg);
population – number of swine (head);
0.00411 – daily CH_4 emissions from each animal (kg).

Methane emission from animal manure was estimated according to IPCC Tier 2 methodology (IPCC 2006). Coefficients recommended by IPCC were used based on the data concerning the number of pigs raised and the housing system.

$$E_{CH_4} = VS \cdot B_0 \cdot 0.67 \cdot \frac{MCF}{100}$$

where:
E_{CH_4} – daily CH_4 emissions per animal (kg);
VS – volatile solids (kg *VS*/kg dry manure), $VS = 0.3$;
B_0 – maximum CH_4 producing capacity for manure (m^3/kg *VS*), $B_0 = 0.45$;
MCF – CH_4 conversion factor for the manure management system (%), slatted floor – 10%, deep litter – 2%;
0.67 – conversion factor of m^3 CH_4 to kg CH_4.

Emission of N_2O was estimated according to ASABE methodology (USDA 2014), using data on feed composition, duration of production cycle, pig fattening and slaughter results, and housing system:

$$E_{N_2O} = [n \cdot N_{ex} \cdot (1 - \%NH_3loss/100) \times \times EF_{N_2O} \cdot \frac{44}{28} \cdot d \cdot c] \cdot \frac{1}{1,000}$$

where:
E_{N_2O} – daily nitrous oxide emissions (kg);
n – number of head of livestock species (animal);
N_{ex} – total daily nitrogen excretion per animal (g);
$\%NH_3loss$ – percent of N_{ex} lost as NH_3 in animal housing (USDA 2014, Tables 5–12);
EF_{N_2O} – N_2O emission factor for manure in housing (kg N_2O-N/kg N) (USDA 2014) – deep bedding – 0.01; pit storage – 0.002 kg;
$\frac{44}{28}$ – conversion of N_2O-N emissions to N_2O emissions;
d – days on feed to finish animals (grow-finish phase) (day);
c – number of phases per year;
$\frac{1}{1,000}$ – conversion of g to kg.

$$N_{ex} = N_{\text{intake}} - N_{\text{retention}}$$

where:
N_{ex} – total nitrogen excretion per animal (g);
N_{intake} – nitrogen intake per finished animal (g);
$N_{\text{retention}}$ – nitrogen retained per finished animal (g).

$$N_{\text{intake}} = ADFI_G \cdot C_{CP} \cdot \frac{DOF_G}{625}$$

$$N_{\text{retention}} = \frac{BW_F \cdot DP_F \cdot FFLP_F}{159.4} - BW_I \cdot [DP_F - 0.05 \cdot (BW_F - BW_I)] \cdot \frac{FFLP_F + 0.07 \cdot (BW_F - BW_I)}{159.4}$$

where:

$ADFI_G$ – average daily feed intake over finishing period (g/day);

C_{CP} – concentration of crude protein of total (wet) ration (%);

DOF_G – days on feed to finish animals (grow-finish phase) (day);

BW_F – final (market) body weight (kg);

DP_F – average dressing percent (yield) at final weight (%);

BW_I – initial body weight (kg);

$FFLP_F$ – average fat-free lean percentage at final weight (%).

Carbon dioxide equivalents of 25 for CH_4 and 298 for N_2O were used in the calculations (IPCC 2007).

RESULTS AND DISCUSSION

The carbon dioxide emission was calculated to be 58.09 t in farm I and 14.15 t in farm II (Table 3). The emission due to consumption of electric energy, used for ventilation of livestock buildings, accounted for 69% in the slatted floor system and for 63% in the deep litter system. The remainder of the emission came from diesel oil burned by agricultural machines for the purpose of organic fertilizer management. Carbon dioxide exhaled by animals is not concentrated in the atmosphere (Walczak 2013) and was not included in the calculations (IPCC 2006).

TABLE 3. Volume of greenhouse gas emissions from different sources as tons of CO_2 equivalent

Emitted gas	Source of emission	Farm	
		I slatted floor	II deep litter
Carbon dioxide	electric energy	40.24	8.98
	liquid fuels	17.85	5.17
Methane	enteric fermentation	89.77	17.98
	animal manure	198.08	7.93
Nitrous oxide	animal manure	28.59	28.86

The methane emission as CO_2 equivalent totaled 287.85 t in farm I and 25.91 t in farm II (Table 3). Share of 69 and 31% of total methane emission came from animal manure in farm I and II, respectively. As reported by Zaliwski and Purchała (2007), the primary source of methane emissions from animal production systems is enteric fermentation in ruminants and manure from pigs. Emission of CH_4 from manure results from microbial processes occurring in the manure. Factors that favour methane production are lack of oxygen, high temperature, a high level of degradable organic matter, high moisture content, a neutral pH, and a C/N of between 15 and 30 (Philippe and Nicks 2014). When estimating methane emissions from manure, it is necessary to account for region of the world, climate, technological group of animals, and the manure management method (IPCC 2006, KOBiZE 2012).

The estimated emission of nitrous oxide did not differ to a significant degree in the analysed farms (Table 3), but in terms of 1 animal it was more than four-fold lower in the slatted floor system compared to the deep litter system (Table 4). In livestock buildings N_2O comes exclusively from animal manure (Philippe and Nicks 2014) and is a by product of nitrification and denitrification. Nitrous oxide emission is estimated based on the animal's N (protein) intake during fattening, N retention, and the manure management method. In manure this process is mainly performed by heterotrophic aerobic bacteria. N_2O accumulation in natural fertilizers is favoured by the presence of oxygen and the low availability of degradable carbohydrates. Nitrous oxide may also be produced in other microbial reactions such as anaerobic or aerobic ammonium oxidation, in the processes known as nitrifier denitrification and anammox (anaerobic ammonia oxidation by bacteria). Most nitrification and denitrification organisms aremesophilic bacteria, as a result of which N_2O is generally not produced at temperatures exceeding 40–50°C. Nitrous oxide production from manure has a stochastic nature, especially due to its numerous sources of emission and environmental controls (Philippe and Nicks 2014).

TABLE 4. Greenhouse gas emissions in the analysed farms in terms of 1 pig and 1 kg of live pigs

Emitted gas	Farm			
	I – slatted floor		II – deep litter	
	pure component	CO_2 equivalent	pure component	CO_2 equivalent
In terms of 1 pig (kg)				
CO_2	7.63	7.63	8.88	8.88
CH_4	1.51	37.79	0.65	16.25
N_2O	0.01	3.75	0.06	18.10
Total	–	49.17	–	43.23
In terms of 1 kg of live pigs (g)				
CO_2	62.51	62.51	73.35	73.35
CH_4	12.39	309.76	5.37	134.32
N_2O	0.10	30.76	0.50	149.62
Total	–	403.03	–	357.29

Greenhouse gas emission as CO_2 equivalent per pig and per kg of live pigs was 49.17 and 43.23 kg in farm I and 0.40 and 0.36 kg in farm II, respectively (Table 4). The present research showed that compared to the slatted floor system, the deep litter system, in terms of unit of production (1 pig, 1 kg of live pigs) is characterized by lower CH_4 emission, considerably higher N_2O emission, and the consequently lower GHG emission as CO_2 equivalent. Since the following parameters the pig housing system, feed conversion rate, duration of production cycle, dressing percentage and meatiness were involved in the formulas for CH_4 and N_2O emission, there is a possibility to elaborate the efficient way of substantial reduction of GHG emission on pig farm.

The carbon dioxide emission, estimated in the analyzed farms, constituted ca 16–21% of total emission (Figs 1 and 2), but in farm II the proportion of emissions from diesel oil combustion was 36%, which is 5% higher than in farm I.

From the calculated GHG emission, originating from animal production only

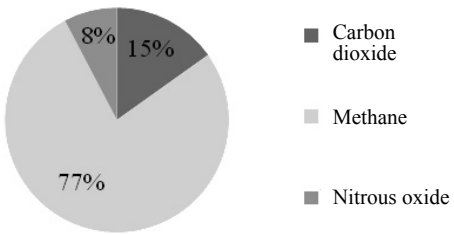

FIGURE 1. Proportion of different greenhouse gases in total emission on farm I

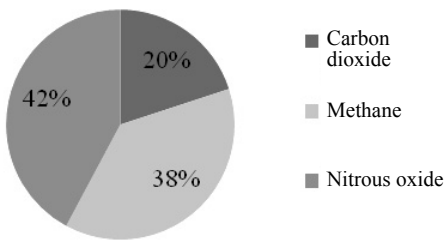

FIGURE 2. Proportion of different greenhouse gases in total emission on farm II

(without consumption of energy and liquid fuels during feed production), it follows that in the slatted floor system 77% of total emissions came from methane, 8% from nitrous oxide, and the remainder from carbon dioxide due to consumption of electric energy and liquid fuels. In farm II, as much as 42% of total emission came from nitrous oxide, a gas with the highest emission potential (IPCC 2007).

CONCLUSIONS

Slatted floor housing of the pigs caused five times lower N_2O and twice higher CH_4 emissions, compared to the deep litter system, which translated into higher total GHG emission as CO_2 equivalent. GHG emission per pig was ca 12% higher in the farm keeping animals on slatted floor compared to deep litter. Comparison of GHG emission from two pig farms belonged to different housing systems speaks for the prevalence of deep litter system over slatted floor one.

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Streszczenie: *System utrzymania tuczników a wielkość emisji gazów cieplarnianych.* Zwierzęta emitują gazy cieplarniane (GHG): dwutlenek węgla (CO_2), metan (CH_4) i podtlenek azotu (N_2O) w procesach oddychania i trawienia oraz w odchodach. Wielkość emisji zależy m.in. od sposobu żywienia i utrzymania zwierząt. Celem pracy było określenie wielkości emisji dwutlenku węgla, metanu i podtlenku azotu w dwóch gospodarstwach prowadzących tucz świń na głębokiej ściółce lub na rusztach. Badania przeprowadzono w gospodarstwie I – utrzymującym rocznie 7617 tuczników w systemie rusztowym i w gospodarstwie II – utrzymującym 1594 tuczniki w systemie głębokiej ściółki. W obliczeniach przyjęto równoważniki na CO_2 dla CH_4 i N_2O wynoszące odpowiednio 25 oraz 298. W pracy oszacowano emisję GHG pochodzącą wyłącznie z produkcji zwierzęcej. Emisja gazów cieplarnianych wyrażona w ekwiwalencie CO_2 w gospodarstwie I wyniosła 374,52 t, w gospodarstwie II 68,91 t, co w przeliczeniu na 1 tucznika stanowiło odpowiednio: 49,17 kg (gospodarstwo I) i 43,23 kg (gospodarstwo II). Na podstawie badań stwierdzono, że w ściołowym systemie utrzymania zwierząt w porównaniu z systemem rusztowym jest mniejsza emisja GHG.

Słowa kluczowe: tuczniki, gazy cieplarniane, emisja, głęboka ściółka, system rusztowy

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The study of domestic cat (*Felis catus*) personality based on survey in Poland

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Abstract: *The study of domestic cat* (Felis catus) *personality based on survey in Poland.* On the basis of Internet survey and using specially structured questionnaire for owners authors obtained data concerning assessment of behaviour of 161 domestic pure breed and mixed breed cats. Working on this data various statistical procedures were applied with Principal Component Analysis (PCA) as a chief method to extract personality dimensions in domestic cat. Authors obtained five dimensions of cat personality: openness, quietness, affiliation, activity and anthroaffiliation. The distinction between affiliation (in cat group context) and anthroaffiliation (in relation between cat and man) was firstly revealed in this study. The data also showed that some specific factors (age, duration of play with caretaker) have effect on cat personality. The comparison of personality of pure breeds and mixed breed cats referred rather to vocal communication than to its affiliation with human being (anthroaffiliation). Results of this study yielded by authors may be applied in shelters procedure of cat adoption.

Key words: cat, personality, behaviour

INTRODUCTION

The concept of animal personality is coined to the great degree on the basis of human psychology and using the meaning of human personality. It is common assumption that like in man, individuals of various species of non-human animals consistently differ from one another in behaviour in such a way that these behaviours can be described as individual traits. These differences should be consistent across time, contexts and situations thus is the meaning of personality in animals (Biffa and Weiss 2010). Personality types are described in the wide array of the animal species from the invertebrates like octopuses to the higher vertebrates like apes. Methods of measurement and construction of personality typology in animals (e.g. so-called Big Five) are also basically adapted from human psychology (Gosling and John 1999).

There is relatively small number of publications (over 20) focused on the personality of felids and domestic cat (*Felis catus*). Bradshaw et al. (2012) summarizing various works claim that in the relation with people three types of cat personality are evident: confident-trusting, timid-nervous and aggressive-active. However, recent review of studies on cat personality shows that there is disagreement among scientists as to methods, drawn conclusions even the terminology (Gartner and Weiss 2013). Therefore, it seems that much more work is needed

to gain reliable information concerning personality in domestic cat. Like in the domestic dog the development of adequate typology of cat personality could be useful not only for cat owners but also for animal shelter staff (e.g. during an adoption procedure).

In the present work authors tried to provide new data concerning cat personality conducting a survey of cat owners. This study is "bottom-up" type (Mehta and Gosling 2008). Authors did not use some established typology, but elaborated own findings to show the personality tendencies in cats. The focus of this study was to analyse presumed difference between the personality characteristics revealed in cat–man relation and the personality characteristics observed in relation of cat with other cats and with other animals.

MATERIAL AND METHODS

The study was carried out in 2015. The authors elaborated Internet survey concerning cat personality. The questionnaire dedicated for cat owners was designed. It was divided into two parts. The first part comprised of questions concerning basic characteristics of animal (sex, age, breed, colour, neutering status etc.) and description of its home environment (e.g. presence of children, outdoor or indoor cat, presence of perching and resting areas, toys, scratching post, toilet, etc). Following main part of questionnaire comprised of 46 questions. They deal with relation with owner, strangers, other cats and other animals. Designing questionnaire various situations were taken into account (play at home, walking with cat, journey by car, presence in veterinary clinic clipping nails, holding cat etc.). Nearly all questions of questionnaire were closed-ended with ordered response choices. Responses were not ranked. However, later they were transformed to numbers using special script (numbers ranged from 0 to 1 with equal intervals). One questionnaire was dedicated to one cat (but not to one household). There was free access for all persons interested in participation in the survey to the electronic version of questionnaire at www.site. In some cases paper version of questionnaire was also used.

Statistical calculations were performed using a statistical software package IBM SPSS version 23. The most important statistical procedure employed was Principal Component Analysis (PCA) which identifying patterns in data and expressing the data in such a way as to highlight similarities and differences (Smith 2002). In the case of psychology and personality studies it enables to search for main personality trait, so-called personality dimensions. The second statistical procedure used by authors was calculation of relationship between cat psychological traits and the other traits. Spearman correlation or t-Student test were used to this end.

RESULTS AND DISCUSSION

A total of 165 questionnaires were submitted by the cat owners: 156 as e-mail questionnaires and nine in the paper version. Reliable data was available for 161 questionnaires. Therefore, the study included a total of 161 cats.

In this group sex ratio was nearly 1 : 1 with 81 tomcats and 80 queens. The age of cats ranged from several months to 21 years but 67% of individuals were kept within the bounds of 5 years of age. Only 11% of cats exceeded 10 years of age. Greater number of individuals (75%) was of mixed breed. Pure breed cats belonged to several breeds but in this study only two of them have some significance: British Shorthair and Maine Coon. Number of individuals in each case contributed to 9% of all animals studied. Over 90% of cats of the whole group were neutered.

Following statistical procedures related to PCA were employed. Firstly, preimage matrix was used to eliminate variables which contributed little to analysis. In this way questions concerning interactions of cat with the other pets were rejected. Secondly, Kaiser–Meyer–Olkin index was calculated to ascertain if it is valid to perform PCA. Authors got satisfactory value of 0.724. Thirdly, scree test was employed to decide how many factors to retain when applying PCA. The obtained graph determined the point at which the last significant drop took place. The break between the steep slope and a levelling off indicates the number of meaningful factors, different from random error. In the authors findings the levelling begin at 4. However, after some considerations concerning contribution to variation authors decided in favour of five factors (Fig. 1).

Finally, on the basis of obtained data authors proposed five broad personality dimensions for the domestic cat: openness, quietness, affiliation, activity and

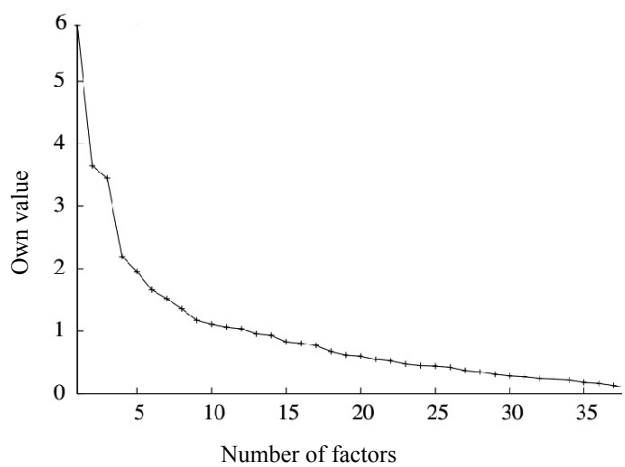

FIGURE 1. Scree test results

anthroaffiliation (Table 1). The short description of these dimensions could be as follows:

1. Openness reflects the high degree of cat favourable attitudes towards new persons and new places. This cat will also show no fear in confrontation with new objects and situations.
2. Quietness is equal to lacking of aggressiveness in the cat either towards caretaker or other persons. This cat is also quiet in veterinary clinic and can put up various unpleasant experiences there.
3. Affiliation in cat means affiliation with other cats, the tendency to socialize with members of its own species. Cat with high degree of affiliation is ready to contact and play with other cats and does not show any sign of aggression. It likes to be amidst its cat companions.
4. Activity means that a cat is physically active and excitable, ready to play with people or with the other cats. Cat is also able to resolve various problem tests. Animal with such personality is very demanding for caretaker, needs frequent physical and psychological stimulation by play or by other interactions.
5. Anthroaffiliation means affiliation of cat with man. Statistical procedure employed in this study allowed to separating this category from factor affiliation. The animal with high anthroaffiliation likes many forms of physical contact with its owner (holding, grooming etc.) but shows negative reaction to harness and walking on lead.

In further analysis of factors their distribution was examined and skewness coefficient was calculated. Skewed left distribution was ascertained in the case of factors quietness and anthroaffiliation. Coefficients values were – 1.352 and – 1.277 respectively. Figures 2A and 2B show histograms for these factors. On the other hand, distributions for remaining factors turned out to be more close to symmetrical. Calculated skewness coefficient values in these case were higher than –1.

Age of cat and duration of play with cat were the most important traits in the matrix of correlations obtained by authors. These findings of emphasized significance are shown in Table 2. It seems that domestic cat coming into age becomes generally less friendly towards strange persons and the other cats as well. It becomes less active, more aggressive towards other cats, also less likely tolerates new place, journey by car and veterinary clinic. Analysis showed also the effect of duration of owner playing with the cat on social behaviour observed in cat group. Individual which played longer with its owner was more friendly in relations with the other cats. It could easily react to non-aggressive contact from the other individuals and is ready to play with them.

Some other correlations are also worth to mention. For example neutered animals became definitively indoor cats, and they retreated from conflicts with other cats over food or over favourite sleeping place. They also frequently avoid contact with strange persons. Pure

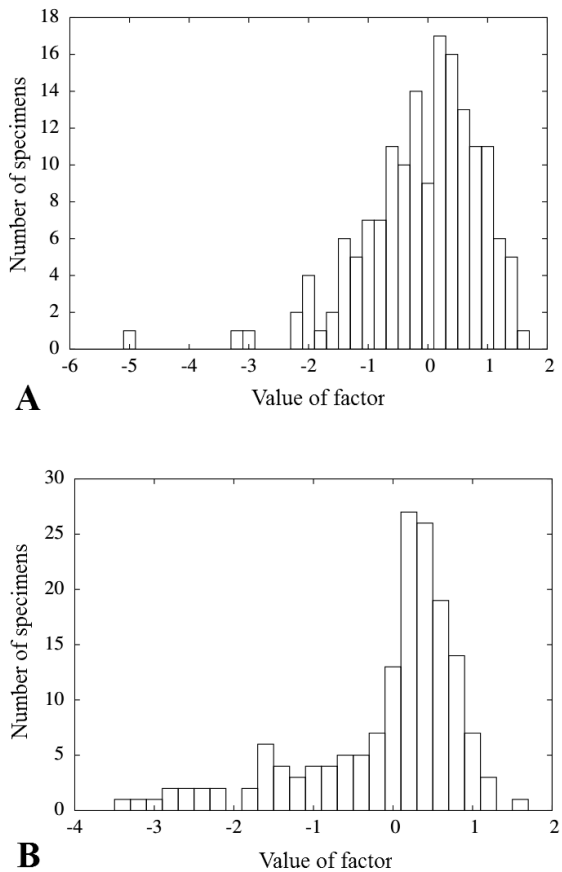

FIGURE 2. Distribution for factors: quietness (A) and anthroaffiliation (B)

breed cats turned out to be shyer and more vocally communicative than mixed breed cats. Both relationships were ascertained using t-Student test for equality of means. It was difficult to compare personality traits in various pure breeds because of relatively small total number of individuals in these groups.

It is important to emphasize that expected natural differences between the sexes were observed only once. Females were more aggressive towards strange persons than males.

These findings may be compared with other works on domestic cat personality (Gosling and John 1999, Bradshaw et al. 2012). Some personality dimension like activity and to some degree affiliation and openness were found in this works.

However, authors of the present study have to distinguish between affiliation (in cat–cat relation) and anthroaffiliation (in cat–man relations). This distinction is absent in other works. Besides contrary to various opinions (e.g. Bradshaw et al. 2000) present results suggest that

TABLE 1. PCA results which demonstrates behaviour characteristic impact (load) on the personality dimension

Code	Question of behaviour in survey	Personality dimensions				
		openness	quietness	affiliation	activity	anthro-affiliation
1	2	3	4	5	6	7
01	Cat is friendly towards familiar people	.352	.126	–.063	.155	**.624**
02	Cat is friendly towards unfamiliar people	**.796**	.077	.064	.008	.288
03	Cat likes to be amidst familiar people	.390	–.019	–.023	.077	**.594**
04	Cat likes to be amidst unfamiliar people	**.798**	.006	.079	.051	.254
05	Cat likes to be amidst cats	.144	.029	**.728**	.153	–.162
06	Cat is active	.68	.38	.237	**.802**	–.014
07	Cat is eager to play independently	.109	.081	.235	**.708**	–.15
08	Cat is eager to play with the caretaker	.198	.172	.167	**.711**	.119
09	Cat is eager to play with other cats	.124	.112	**.677**	**.414**	–.162
10	Reaction to new objects	.285	–.196	.090	.228	.261
11	Reaction to visitors	**.883**	–.087	.064	.020	.039
12	Reaction to new place	**.645**	.052	.104	.192	–.013
13	Solving problem 1	.165	–.084	.059	**.480**	–.070
14	Solving problem 2	–.067	.130	–.155	**.527**	–.009
15	Reaction to commands and tricks	–.109	.054	.058	.033	.284
16	Reaction to petting	.157	.353	.025	.047	**.574**
17	Reaction to holding	.244	.337	.043	.183	**.495**
18	Reaction to grooming	.273	.297	.028	–.102	**.452**
19	Reaction to clipping nails	.109	**.565**	.073	–.085	.185
20	Reaction to action of the other cat	.229	.201	**.671**	.038	–.156
21	Behaviour in a vet clinic	.164	**.484**	.133	.191	.134
22	Reaction to journey by car	.340	.187	.058	.081	–.272
23	Reaction to harness and walking on lead	.275	.069	.048	.210	**–.407**
24	Cat is fearful	**–.505**	–.050	.167	–.058	.198
25	Cat is alert	–.262	–.084	.397	.228	–.008
26	Cat is friendly towards other cats	.213	.118	**.747**	.061	–.182
27	Cat i quiet	.107	.339	.022	–.356	–.041
28	Cat is excitable	.031	–.320	.141	**.505**	.58
29	Cat is aggressive towards caretaker(s)	.33	**–.769**	–.093	.360	–.027

TABLE 1, continued

1	2	3	4	5	6	7
30	Cat is aggressive towards unfamiliar people	.35	**–.625**	–.039	–.124	–.066
31	Cat is aggressive towards other cats	.177	–.113	**–.575**	.018	–.321
32	Cat attacks caretaker(s)	.17	**–.776**	–.040	.075	.070
33	Cat attacks unfamiliar people	.064	**–.726**	–.023	–.035	–.004
34	Cat attacks other cats	.149	–.144	**–.594**	.092	–.301
35	Cat avoids caretaker(s)	.071	.151	.114	.108	**–.447**
36	Cat avoids unfamiliar people	**–.740**	–.016	–.002	–.055	–.030
37	Cat avoids other cats	.086	.116	–.383	–.029	–.091

TABLE 2. Spearman correlations of behaviour related to personality traits with the age of cat (×) and with the duration of play with caretaker (y)

×	Code of behaviour according to list in Table 1								
	03	05	06	07	08	09	10	13	18
CA^{x}	–.179*	–.227**	–.459**	–.498**	–.417**	–.402**	–.637**	– .227**	–.1
DP^{y}	.038	.095	.325**	.221**	.111	.310**	.351**	.195*	.173*
×	21	22	23	24	27	29	31	32	35
CA	–.386**	–.185*	–.268**	–.321*	–.398**	–.285**	.200*	.292**	.278**
DP	.380**	.222**	.259**	–.042	.471**	.137	–.067	–.088	–.135
×	36	37							
CA	–.160*	.207**							
DP	–.043	–.092							

* Significant (P <0.05); ** highly significant (P <0.01).

cat personality may be influenced by some non-psychological factors (like age of animals). Discussing the breed effect authors found only minor differences between pure breed and mixed breed cats. Moreover, these differences did not refer to the cat–man affiliation which was suggested by other authors (Turner and Bateson 2000). It is worth to add that previous works of Polish investigators suggested that mixed breed cats were more aggressive towards their caretakers than pure breed cats (Koziniec 2014).

In this work it was impossible to investigate an effect of human family characteristics on cat behaviour.

CONCLUSIONS

The survey data concerning 161 cats helped to create cat personality dimensions to some degree different from described in literature. Affiliation with

other cats and anthroaffiliation turned out to be distinct dimensions.

Age of cat and duration of its play with caretaker seemed to be important factors which have effect on cat personality.

These personality dimensions of cat have consequences for its owner (e.g. cat active or less affiliative). Therefore, this knowledge concerning cat personality could help in adoption at the animal shelter.

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TURNER D., BATESON P., 2000: The Domestic Cat: The Biology of its Behaviour. Cambridge University Press, Cambridge.

Streszczenie: *Badanie osobowości kota domowego* (Felis catus) *na podstawie ankiety przeprowadzanej w Polsce.* Na podstawie ankiety internetowej i stosując specjalnie rozbudowany kwestionariusz dla właścicieli, autorzy uzyskali dane dotyczące oceny zachowania się 161 kotów rasowych i mieszańców. W opracowaniu danych zastosowano różne procedury statystyczne, z analizą głównych składowych jako główną metodą wyabstrahowania wymiarów osobowości u kota domowego. Autorzy uzyskali pięć takich wymiarów: otwartość, łagodność, afiliacja, aktywność i antroafiliację. Rozróżnienie afiliacji (w kontekście grupy kotów) od antroafiliacji (w relacji między kotem a człowiekiem) ujawniono po raz pierwszy w tym badaniu. Dane pozwoliły stwierdzić, iż pewne specyficzne czynniki (wiek, długość zabawy kota z opiekunem) mają wpływ na osobowość kota. Porównanie osobowości kotów rasowych i nierasowych odnosiło się do raczej do komunikacji głosowej kota niż do jego afiliacji z człowiekiem (antroafiliacji). Wyniki autorskich badań można wykorzystać w procedurze adopcyjnej kotów stosowanej w schroniskach.

Słowa kluczowe: kot, osobowość, zachowanie

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Respecting EU cross-compliance requirements as an indicator of animal welfare in farms with calves

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Abstract: *Respecting EU cross-compliance requirements as an indicator of animal welfare in farms with calves.* The aim of the study was to estimate the level of welfare parameters in calf-rearing holdings and compare them with the cross-compliance requirements. The study was conducted in 46 farms in the winter season. The microclimate measurements, such as: moisture content, concentrations of harmful gases and the brightness of the room, has been taken in calf barns. It has been checked whether the system of calves keeping corresponds with regulations EU. The study allowed assessment of housing conditions of the calves.

Key words: calves, microclimate, EU requirements

INTRODUCTION

Direct payments available to EU farm owners are paid subject to meeting certain standards and requirements, which is called cross-compliance (ARiMR 2012, Nowak 2013). The requirement of conforming to the standards of animal welfare has been in force since 1 January 2013 (Pośniak-Sobczyńska 2011). Farmers keeping calves should ensure that the humidity and concentration of harmful gases in the premises be at an acceptable level; also, adequate lighting should be provided. Moreover, the farmer should pay attention in terms of stocking density, appropriate sizes and technical solutions of the premises, manure removal system, and should also provide for adequate care to animals and a proper arrangement of the technological equipment used in the production cycle. Failure to comply with cross-compliance requirements results in a reduction or withdrawal of direct payments (Pośniak-Sobczyńska 2011, Nowak 2013). Cross-compliance checks in Poland are carried out by the Agency for Restructuring and Modernisation of Agriculture, as well as the Veterinary Inspection. The role of the latter is also to supervise the livestock facilities in terms of animal welfare (ARiMR 2012).

Calves housed indoors should be inspected twice a day and those managed outdoors at least once a day. According to the Regulation of the Minister of Agriculture and Rural from 2010, young cattle of up to 6 months of age can not be confined, except when feeding: in group pens and for 1 h only. Exemptions from these requirements include sick or injured animals, calves under maternal nursing, or farms which manage fewer

than six calves. Nevertheless, all calves under 2 weeks of age, regardless of herd size, must be kept on bedding (www.mrirw.gov.pl). The farmer is obliged to ensure adequate microclimate parameters in calf premises (Rozporządzenie...). Calf barns should be equipped with mechanical ventilation or should be well ventilated naturally (www.mrirw.gov.pl).

The farmer's duty is to ensure that the equipment of the calf barn is constructed of materials which do not affect the animal's health. The equipment and all structures in the calf barn should be in good condition, never causing injuries. The floor should be stable, providing good traction, even and hard, with no bumps or holes. Calf barns should be well lit between 9.00 am and 5.00 pm, with adequate protection against pests, manure and uneaten feed remains being removed once a day (ARiMR 2012).

Calves are to be kept individually or in groups. During the period of milk feeding (until 2 months of age), calves should be kept individually. Council Directive 2008/119/EC states that the width of an individual calf pen shall be at least equal to the calf's height at the withers, while its length shall be at least equal to the body length of the calf, multiplied by 1.1. In such pens, calves may stay until the age of 8 weeks. According to Juszczak and Zalewski (1986), the length of an individual pen for the calf should be 120––150 cm, width 80–110 cm and height 150 cm. Group pens are used for older, 3 to 6 month-old calves, which are fed solid feeds (Juszczak et al. 1982, Lenard 1982). Tethering calves is not recommended (Systemy utrzymania bydła... 2004). Both individual and group pens should be designed to maximally facilitate manure removal, cleaning and disinfection. Calves shall be provided with sufficient air exchange in the barn (Systemy utrzymania bydła... 2008).

Pens should be designed in such a way that the calves may be readily accessible to workers, and the walls should allow the calves to have direct visual and tactile contact with one another. It is recommended that the openings of the drinkers and feeders be placed approximately 20 cm above the floor, so that the calves will not be able to step with their front legs on the containers with water or feed. Appropriate urine drainage should also be provided in order to keep the bedding dry (Systemy utrzymania bydła... 2008). The slope of the floor in the pen should be 5–10%, so as to ensure a good outflow of liquid manure. A good solution is also the hay rack placed in the pen (Romaniuk 1986).

According to Council Directive 2008/119/EC, healthy calves that attained 8 weeks of age should be kept in groups. The space allowance available to each calf kept in group pens shall be as follows: at least 1.5 m^2 for a calf of less than 150 kg live weight, at least 1.7 m^2 for a calf of a live weight of 150–220 kg, and at least 1.8 m^2 for each calf of a live weight of 220 kg or more. According to Juszczak and Zalewski (1986), the floor space in a group pen should be between 2.5 and 3.5 m^2 per calf.

The results reported by Szewczyk and Walczak (2008) show that a high

level of calf welfare may be achieved in group pens with deep bedding and an outdoor run. Individual pens on slatted floor provide a poor level of comfort.

The aim of the study was to estimate the level of welfare parameters in calf-rearing holdings and compare them with the cross-compliance requirements.

MATERIAL AND METHODS

The survey was carried out in calf accommodation facilities in 46 farms. The number of calves held in each farm varied. Since the welfare requirements in terms of calves kept in individual or group pens (Rozporządzenie...) apply to farms that keep more than six calves, the study involved 27 barns housing six calves or more and 19 barns which housed up to six calves.

The measurements were carried out during the winter 2012–2013 in farms managing calves located in Tomaszów Mazowiecki County, Łódź Voivodship, Poland. All measurements were performed between 9.30 am and 3.00 pm. A single measurement of harmful gases concentration, i.e. carbon dioxide, ammonia and hydrogen sulfide, was taken in all the studied calf premises. We used the Gas Hunter IR (Alter, Poland), which allows a simultaneous measurement of three gases (in ppm). Relative air humidity (%) and light intensity (lx) were measured using the DT-8820 multifunctional measuring instrument. Light intensity was measured at the height of a calf's head.

Information on the floor type was collected, whether calves were housed on slatted floor or bedding. The housing conditions of calves were also checked for compliance with the EU regulations. We checked whether: (a) the farm has fewer than six calves; (b) calves are tethered; (c) calves up to 8 weeks of age are kept individually; (d) individual boxes for calves have appropriate dimensions; (e) calves older than 8 weeks are kept in groups; (f) whether calves kept in groups are provided with enough space. The mean values and standard deviations were calculated by using the Microsoft Excell software. The percentage distribution of the analyzed data is depicted on the graphs.

RESULTS AND DISCUSSION

Gas concentrations in calf premises against EU standards

Carbon dioxide inside livestock buildings comes mainly from the air exhaled by animals, but also from the bedding and manure (Kośla 2011). With insufficient ventilation, or lack thereof, the concentration of carbon dioxide may increase considerably (Kołacz and Dobrzański 2006). According to Regulation of the Minister of Agriculture and Rural Development from 2010, CO_2 concentration in the premises for calves should not exceed 3,000 ppm. Our research shows that CO_2 concentrations remained in the range from 530 to 4,000 ppm, with the average 1,983 ppm (Table). In 13% of holdings (six calf barns), the concentration exceeded 3,000 ppm. The remaining 40 holdings kept calves in the atmosphere with the concentrations of carbon dioxide from 530 to 3,000 ppm.

TABLE. Mean gas concentrations in calf barns compared with EU requirements $n = 46$

Gas	Mean gas concentration (ppm)	*SD*	Acceptable concentration (ppm)
CO_2	1 983	814	3 000
NH_3	4.91	4.07	20
H_2S	0.31	0.85	5

Ammonia in livestock premises comes from decaying animal manure. Higher temperatures intensify the decomposition of urea, resulting in a higher concentration of ammonia in the air (Kośla 2011). A high ammonia concentration in livestock houses is linked to insufficient rate of feces and urine removal. High temperature promotes NH_3 production. A high level of ammonia in the air has a significant effect on the respiratory system, leading to of irritation mucous membranes and conjunctiva. At ammonia concentrations of 30–100 ppm, symptoms like tachypnea, excessive mucus secretion and even bronchial swelling. Moreover, with its high content in the air, NH_3 becomes a medium for the bacteria *Pasteurella multocida*, which infect the nostrils and respiratory tracts of the calves. Extremely high concentrations of ammonia affect the nervous system (Kołacz and Dobrzański 2006).

According to Regulation of the Minister of Agriculture and Rural Development from 2010, the concentration of ammonia in the rooms where calves are kept should not exceed 20 ppm. Measurements carried out in 46 calf barns have shown that all the studied holdings comply with this requirement (Table). Ammonia concentrations remained in the range of 0–17 ppm, with the average level 4.9 ppm.

The smell of hydrogen sulphide is described as the odor of rotten eggs. The gas comes is a product of protein decomposition in the feces of animals (Kośla 2011). Hydrogen sulphide is a toxic gas, especially in combination with high air humidity and ammonia. High concentrations of hydrogen sulphide cause respiratory diseases, conjunctivitis, malfunctioning of the digestive system and the nervous system, which results in reduced immunity. Despite its odor, the gas is difficult to detect without a proper instrument, even with high levels of concentration (Kołacz and Dobrzański 2006). According to Regulation of the Minister of Agriculture and Rural Development from 2010, the concentration of hydrogen sulfide in calf premises should not exceed 5 ppm. Our measurements indicate that the concentration of hydrogen sulfide in the studied barns remained within normal limits (Table). The average concentration of hydrogen sulfide in all the calf barns was 0.31 ppm, within the range of 0–5 ppm. No hydrogen sulfide has been detected in 59% of the holdings.

Illumination in calf premises

Sunlight is the best source of illumination when it comes to livestock animals. It kills bacteria, enhances performance of the animals and improves their comfort. Under solar UV radiation, the skin produces vitamin D_3, essential for proper development of young animals. The

recommend window-to-floor area ratio in calf premises is 1 to 18–20 (Kośla 2011). It must be kept in mind that the larger the window-to-floor area ratio, the lower heat insulation parameters of the building. If the windows are not properly cleaned, as much as 50% of the entering sunlight can be lost. Also the walls must be maintained clean, since dirty walls absorb rather than reflect light and, in consequence, the room are darker (Wojciechowski 1984). No trees, silos or other building should be located in the proximity of the windows. Windows are usually placed above the level of the animals. It is recommended that they were mounted as high as possible. Door frames, window frames, roof eaves, or thick walls should not reduce the amount of incoming light. Artificial lighting in cattle premises is complementary to natural light. Adequate power of artificial light must be ensured. Lamps should be spaced along the interior of the building so as to provide equal visibility in every place (Kołacz and Dobrzański 2006).

According to Regulation of the Minister of Agriculture and Rural Development from 2010, the calves must have access to light from 9.00 am to 5.00 pm. The provisions, however, do not specify the parameters of the incoming light. Information cards of the National Research Institute of Animal Production (Karta informacyjna... 1977) recommend that light intensity in calf premises should be at least 15–30 lx. In our study, all the holdings except one (10 lx) provided calves with adequate lighting (Fig. 1).

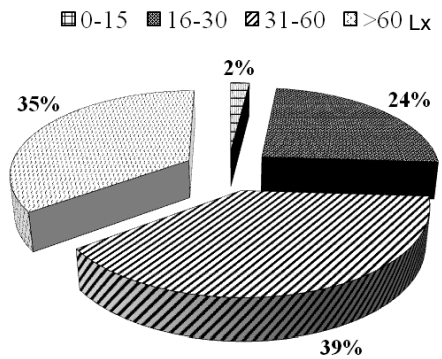

FIGURE 1. Lighting in calf barns

Air humidity in calf premises

Recommendations of the Information cards of the National Research Institute of Animal Production (Karta informacyjna... 1977) state that the optimal level of relative humidity inside buildings for dairy cattle and calves should remain between 60 and 80%.

The level of air humidity in barns depends on the ventilation applied, thermal insulation of the walls, outdoor temperature, the number of animals, manure removal system, the substrate on which the animals are kept, and water content in the feed (Romaniuk 1986). Most humidity in livestock buildings, as much as 75%, come from moisture emitted by animals (Plaszczenko and Chochłowa 1981, Kośla 2011).

In some animal housing facilities air humidity is so high that water vapor may condense on the ceiling and walls. This is the case especially if the building lacks thermal insulation of the walls (Juszczak and Zalewski, 1986). High humidity levels promote the transfer and prolifera-

tion of bacteria, which is dangerous particularly for young cattle. The immune system of calves is not fully developed, which is particularly dangerous in terms of health (Systemy utrzymania bydła... 2004). High humidity, especially in combination with low temperatures, has a negative effect on the animals. In such conditions, animals reveal reduced feed intake, loss of performance and problems with respiration. In winter, this can lead to a common cold, pneumonia, as well as muscular and articular rheumatism. High humidity levels along with high temperatures hamper the body thermoregulation. This in turn results in a general performance decrease, but may also cause digestive tract disorders and lethargy (Plaszczenko and Chochłowa 1981).

Our results (Fig. 2) have shown that relative humidity was to high in 15% of holdings with calf premises, and too low in 4% of the farms. In 81% of the holdings, however, the levels of air relative humidity were at their optimum.

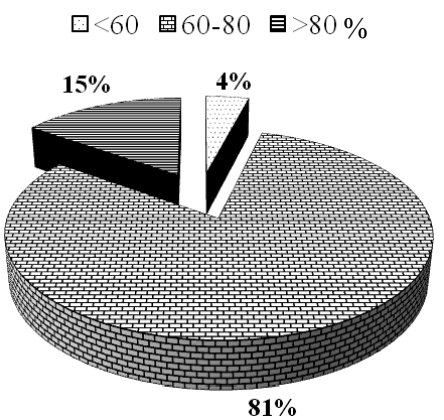

FIGURE 2. Indoor air relative humidity in calf barns

Calf housing systems against EU requirements

According to Regulation of the Minister of Agriculture and Rural Development from 2010, calves must not be tied up, except for feeding, when animals can be kept in groups for 1 h. If the farm operator applies this confinement during feeding, it must be ensured that the tether does not cause injuries of any sort. Calves must not be muzzled (ARIMR 2012). The collected data show that 54% of the studied holdings apply tethering (Fig. 3), which is incompatible with EU requirements.

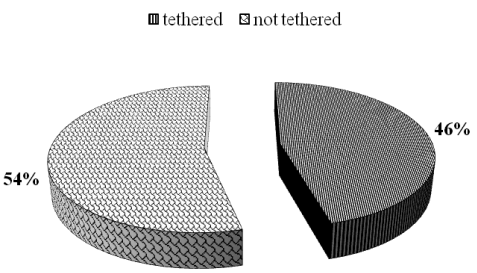

FIGURE 3. Housing systems of calves (tethered and not)

Szewczyk and Walczak (2008) conducted welfare studies on calves at age 7 to 90 days kept in two different housing systems: individually or in groups. A high level of welfare was observed in calves kept in groups on deep bedding, whereas the lowest was found in calves kept individually on slatted floor.

In calf-rearing, the dimensions of the pens are to be adjusted to the age of the calf; recommendations have been provided in a chapter "Introduction". Calves can be kept in individual

pens up to the age of 8 weeks, except for those under maternal nursing, sick, or in the small herds of up to six calves (Rozporządzenie...). In our study, 19 farms managed fewer than six calves. Of 27 farms which were able to keep calves up to 8 weeks of age in individual pens, 30% (eight households) used individual pens (Fig. 4). Other calves were kept confined or in groups (22%). According to Regulation of the Minister of Agriculture and Rural Development

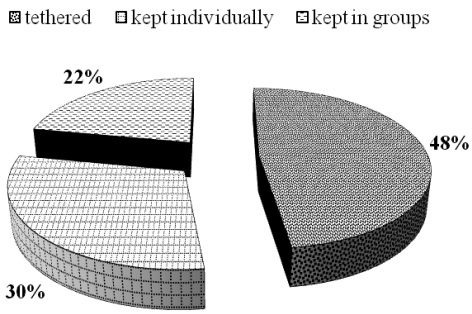

FIGURE 4. Housing systems of calves up to 8 weeks of age

from 2010, an individual calf pen should have appropriate dimensions: the width not lower than calf's height at the withers and the length not less than calf's length multiplied by 1.1. The individual pens for calves in the farms that applied them had dimensions conforming to the regulations.

According to Regulation of the Minister of Agriculture and Rural Development from 2010, calves older than 8 weeks of age – as herd animals – must be kept in groups (Fig. 5). Of all the farms under study, 59% applied group pens, the other used tethering of calves.

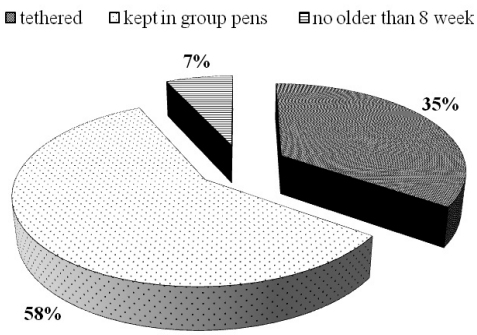

FIGURE 5. Housing systems of calves older than 8 weeks

Three farms did not manage calves in this age range on the day of survey. According to a study by Szewczyk and Walczak (2008), calves kept in groups, especially on deep bedding, reveal a better welfare parameters compared to calves kept on slatted floor and individually.

According to Regulation of the Minister of Agriculture and Rural Development from 2010, calves kept in group pens should have enough space. All the studied farms keeping calves in group pens provided enough space for them.

CONCLUSIONS

The study allowed assessment of housing conditions of the calves.

1. Concentrations of harmful gases in the majority of calf barns were within the recommendations of the Research Institute of Animal Production.
2. Carbon dioxide concentration in 13% of calf barns exceeded EU requirements and animal husbandry standards.
3. The concentration of ammonia and hydrogen sulfide in the calf barns

remained within EU requirements and animal husbandry standards.
4. Air relative humidity in 81% of the calf barns remained within the standards of good animal husbandry practices.
5. In 54% of farms calves were tethered, which was incompatible with EU standards.
6. Only 59% of farms kept calves from 8 weeks of age according to the standards, i.e. in group pens.

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Streszczenie: *Respektowanie unijnych wymogów wzajemnej zgodności jako wskaźnik dobrostanu zwierząt w gospodarstwach utrzymujących cielęta*. Celem pracy było określenie poziomu wskaźników dobrostanu zwierząt i porównanie ich z wymogami wzajemnej zgodności w gospodarstwach utrzymujących cielęta. Badania zostały przeprowadzone w 46 gospodarstwach w okresie zimowym. Przeprowadzono pomiary mikroklimatyczne w cielętnikach, takie jak: wilgotność względna, stężenia szkodliwych gazów, natężenie oświetlenia. Sprawdzono także, czy system utrzymania cieląt odpowiada obowiązującym regulacjom prawnym. Badania pozwoliły na ocenę warunków utrzymania cieląt.

Słowa kluczowe: cielęta, mikroklimat, wymogi unijne

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Control of the lesser mealworm *Alphitobius diaperinus* using entomopathogenic nematodes (EPNs) combined with nanoparticles

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Abstract: *Control of the lesser mealworm* Alphitobius diaperinus *using entomopathogenic nematodes (EPNs) combined with nanoparticles.* We examined the efficacy of entomopathogenic nematodes (EPNs), which were in contact with nanoparticles, in the control of *A. diaperinus*. Treatments were performed in laboratory conditions and consisted of one of the four species and strains of EPNs *Steinernema feltiae* and *Heterorhabditis bacteriophora*, which earlier were exposed to Ag, Au or Cu nanoparticles. All three development stages of the beetle were exposed to different EPNs. The mortality, the extensity, the intensity of infection of beetles were studied for 7 days. Most of nematodes, that survived contact with nanoparticles, developed in *A. diaperinus* larvae, pupae and adults. Significant differences were found in the sensitivity and susceptibility to penetration by parasites to various growth stages of the host. The most studied nematodes and nanoparticles caused a high mortality and the extensity of infection in host larvae, from 12 to 100% and from 8 to 83%, respectively. A negative effect of gold nanoparticles on the mortality was observed in adult insects infected by *S. feltiae* (Owinema). Despite this, in many cases, the addition of nanoparticles may increase efficiency of EPNs, used in the integrated pest control.

Key words: *Steinernema*, *Heterorhabditis*, pest, poultry houses, Ag-NPs, Au-NPs, Cu-NPs

INTRODUCTION

The lesser mealworm (*Alphitobius diaperinus* Panzer, 1797) is a beetle of the family Tenebrionidae. It is a vector of many disease factors like fungi (*Aspergillus* sp., *Fusarium roseum*), viruses causing Mareka, Gumboro and Newcastle disease, bird flu and enteritis, bacteria (mainly of the genera *Escherichia*, *Salmonella*, *Bacillus*, *Streptococcus*), protozoans (*Eimeria* sp.) and tapeworm larvae (*Raillietina* sp., *Choanotaenia* sp.) (De la Casas et al. 1976, Chernaki-Leffer et al. 2010). Pathogen transmission takes place when chickens eat infected insects. Lesser mealworm beetles have shown resistance to many insecticides, for example with pyrethroids (Lambkin and Rice 2006). Increased disease incidence and the mortality and the loss of body weight in chickens is observed during mass appearance of pests in broiler houses. Insects eat their way into the tissues of weakened, ill or dead animals. Chickens are in constant move, do not rest and are exhausted. Adult insects

found in apartments pose a direct risk to humans. The lesser mealworm as a pest of grain stores eats food products and contaminates them with exuvia, dead individuals, excreta and faeces, bacteria and fungi. Feeding beetles affect the quality of food products by making them wet, mouldy, unpleasant in smell and taste (De la Casas et al. 1976, Chernaki-Leffer et al. 2010).

Entomopathogenic nematodes (EPNs) are one of the most promising biological control methods to fight *A. diaperinus*. Infective juveniles (IJs) of the nematodes penetrate body of the insect. Inside, they release mutualistic bacteria that kill the host and after that, they develop and reproduce, giving one to three generations. New IJs return to the soil to find another host (Laznik and Trdan 2013).

More and more nanomaterials are being used in medicine, pharmacy and agriculture. Nanotechnology is a promising discipline which may have a broad application in the pest control. "Nano" dimensions in combination with large active surface area, neutral valence, make nanoparticles biologically active already at very low concentrations. Using nanoparticles one may produce preparations of various biochemical properties. Nanocolloidal silver, gold and copper are used in cosmetics, household, industry, medicine and agriculture (Myczko 2006). They can act as antibacterial and antifungal agents and they are being used in production of plant growth stimulants (Karimi et al. 2010, Kim et al. 2012). Still it is not known if nanoparticles have any synergistic or antagonistic influence on popular biological control agents, such as EPNs (Kucharska et al. 2011).

Although tests have been performed with EPNs on *A. diaperinus* in laboratory conditions (Szalanski et al. 2004, Pezowicz 2005), there are no reports showing influence of both, EPNs and nanoparticles on pests. Our hypothesis was that nanoparticles, used for disinfection in broiler houses, may affect entomopathogenic properties of EPNs.

MATERIAL AND METHODS

The effect of silver, gold and copper nanoparticles on pathogenic properties of entomopathogenic nematodes *Heterorhabditis bacteriophora* (Poinar, 1976) and *Steinernema feltiae* (Filipjev, 1934) were studied in experimental conditions. Analyzed parameters for *A. diaperinus* were: the mortality – percent of dead insects in the last day of experiment, the extensity of infection – percent of dead insects with nematodes discovered after dissection and the intensity of infection – number of nematodes found in dead host.

Colloidal solutions of nanoparticles were from Nano-Tech Polska Sp. z o.o. (Poland). Solutions of nanoparticles suspended in deionised water at concentrations of 0.5, 2 and 5 ppm were used in experiments. *Heterorhabditis bacteriophora* originated from biopreparations: Nematop (E-nema, Germany) and Larvanem (Koppert, The Netherlands), while *Steinernema feltiae* was from biopreparations: Owinema (OWIPLANT,

Poland) and Entonem (Koppert, The Netherlands).

Larvae of EPNs were placed in water solutions containing the respective concentrations of nanosilver, nanogold and nanocopper. Control group consisted of IJs kept in distilled water. After 7 days the nematodes that survived contact with nanocolloids were separated by sedimentation. Multiple sedimentation did not, however, allow for complete removing of chemical compounds from the sample. Particular growth stages of *A. diaperinus* were exposed to the residues of chemical substances and to EPNs that survived seven-day contact with these substances. Experiments involved the analysis of pathogenic properties of IJs whose mortality after the contact with nanoparticles (at concentrations of 0.5, 2 and 5 ppm) was above 90%. So obtained alive nematodes were used to infect three growth stages of the lesser mealworm: four-week larvae, pupae and adult beetles. The experiment was carried out on Petri dishes 9 cm in diameter lined with filter paper where 10 insects in appropriate growth stage were placed. Excluding control group, 900 insects were used in experiment for one insect growth stage. Three repetitions of every variant were made, including: three different nanoparticles (Ag, Au, Cu) in three different concentration (0.5, 2, 5 ppm), four nematode strains. Five hundred IJs of appropriate nematode species were introduced onto Petri dish (50 IJs/1 insect). Because of 100% mortality or low survival (above 90%) of IJs (Nematop, Owinema) after the contact with nano-Ag (2 and 5 ppm), studying their effect on the mortality, the extensity and the intensity of infection of all growth stages of the lesser mealworm was omitted. For the same reason the effect of IJs (Larvanem, Entonem) on *A. diaperinus* after the contact with silver nanoparticles at a concentration of 5 ppm was also not analysed. The mortality was controlled every 24 h for 7 days. Dead insects were transferred to empty dishes and placed in the incubation chamber for 48 h. Later, the insects were sectioned to check whether nematodes and associated mutualistic bacteria were the cause of their death. Experiments were performed at 25°C and 85–90% relative moisture of the substratum. The control consisted of insects of respective growth stage infected by IJs deprived of the contact with nanoparticles. The mortality, the extensity and the intensity of infection of *A. diaperinus* larvae, pupae and adult beetles were studied.

Obtained results were statistically processed with SPSS 15.0 and SAS 9.2 software. ANOVA was used to estimate the significance of differences in: the mortality, the extensity and the intensity of infection of *A. diaperinus*. Statistical significance was tested at $P < 0.05$. Analysis of variance was followed by Tukey post-hoc test to compare the differences between means.

RESULTS DISCUSSION

Based on experiments presented in this paper it was found that nanoparticles of silver, gold and copper in different concentrations may positively increase nematode pathogenicity. The mortality of the lesser mealworm larvae after the contact with EPNs from Owinema preparation and at concentrations of nano-Ag 0.5 ppm, nano-Au 5 ppm and nano-Cu 2 ppm was 83, 100 and 97%, respectively (Table 1). The extensity of infection of insects was lower or equal to the mortality. Only in one case, after using nematodes from the Owinema preparation and nano-Cu at a concentration of 0.5 ppm, the extensity of adults infection was 0% while the mortality was much higher (Table 3). This may be associated with a possibility of killing the host by bacteria released from alimentary tract of only one IJ or with releasing microorganisms and limiting further growth of nematodes. All above mentioned situations made finding the presence of EPNs during the insect dissection impossible. Nematodes of the Owinema biopreparation (at all concentrations of nano-Au and at 2 ppm of nano-Cu) were not pathogenic to adults. Insect mortality was 0% (Table 3). Significant differences were found in the sensitivity and susceptibility to penetration by IJs to various growth stages of the lesser mealworm. The mortality, the extensity and the intensity of infection of larvae (Table 1) and pupae (Table 2) of *A. diaperinus* by pathogenic nematodes *S. feltiae* from Owinema and Entonem previously treated with nano-Au at a concentration of 0.5 ppm may serve as an example. Most studied nematodes and nanoparticles (at all concentrations) caused a high mortality and the extensity of infection in mealworm larvae. At simultaneous application of EPNs and the remains of nano-Ag, nano-Au and nano-Cu, larval mortality was 12–93, 44–100 and 67–100%, respectively, and the extensity of infection was 8–73, 30–69 and 30–83%, respectively (Table 1). A negative effect of nanoparticles on the intensity of infection was observed in adults of *A. diaperinus* infected by *S. feltiae* (Owinema, nano-Cu, 5 ppm). Mean number of nematodes in an adult was 0.1 (Table 3).

Most nematodes were found to preserve their invasive abilities when IJs that survived seven-day contact with various nanoparticles were placed on filter paper in Petri dish with insects. One cannot, however, unambiguously state whether the studied IJs would be able to find a host in the natural environment. This was impossible in view of a direct contact of IJs with insects in a Petri dish. However, despite the action of various chemicals used in broiler houses for disinfection, mutualistic bacteria associated with nematodes survived in their alimentary tract. These microorganisms are food source for EPNs and stimulate their development. This information is very important since it determines the application of EPNs as enemies of *A. diaperinus* in broiler houses. Literature data presents the results of experiments exploring the possibility of this pest control in houses for bird produc-

TABLE 1. Pathogenic properties of entomopathogenic nematodes (percentage mortality, extensity and intensity of infection of *A. diaperinus* larvae) which contacted nanoparticles of silver, gold and copper in various concentrations (n = 30 in every variant of experiment)

Trade name	Active substance	Nematode species	Permanent contact of entomopathogenic nematodes with nanoparticles														
			A. diaperinus larvae														
			mortality (%) ±*SD*					extensity of infection (%) ±*SD*					intensity of infection (nematodes per host) ±*SD*				
			K	A	B	C	ANOVA	K	A	B	C	ANOVA	K	A	B	C	ANOVA
Silver Water	nano-Ag (Ag-NPs)	*H. bacteriophora* (Nematop)	97 ±6	93 ±6			$p = 0.52$	97^{b} ±6	73^{a} ±6			$p = 0.008$	11.0 ±8.9	7.7 ±9.4			$p = 0.16$
		H. bacteriophora (Larvanem)	80 ±35	70 ±44	12 ±11		$p = 0.09$	65 ±42	65 ±49	8 ±11		$p = 0.16$	2.3^{a} ±2.5	8.7^{b} ±7.9	1.2^{a} ±4.9		$p < 0.0001$
		S. feltiae (Owinema)	70 ±26	83±15			$p = 0.49$	67 ±21	67 ±11			$p = 1.00$	13.4^{b} ±18.4	4.2^{a} ±5.3			$p = 0.01$
		S. feltiae (Entonem)	66 ±23	66 ±31	22 ±11		$p = 0.10$	60 ±35	51 ±44	11 ±10		$p = 0.22$	5.3 ±5.9	3.3 ±4.4	2.1 ±6.7		$p = 0.10$
Gold Water	nano-Au (Au-NPs)	*H. bacteriophora* (Nematop)	97 ±6	80 ±10	57 ±30	57 ±15	$p = 0.07$	97^{b} ±6	60^{ab} ±17	43^{a} ±21	37^{a} ±23	$p = 0.01$	11.0^{b} ±8.9	7.5^{ab} ±9.4	4.6^{a} ±8.4	4.6^{a} ±8.7	$p = 0.02$
		H. bacteriophora (Larvanem)	80 ±35	67 ±30	44 ±15	52 ±21	$p = 0.40$	65 ±42	55 ±45	37 ±21	31 ±26	$p = 0.57$	2.3^{a} ±2.5	7.6^{b} ±7.9	4.9^{ab} ±7.6	3.1^{a} ±5.5	$p = 0.007$
		S .feltiae (Owinema)	70 ±26	90 ±10	90 ±0	100 ±0	$p = 0.14$	67 ±21	53 ±6	50 ±10	30 ±20	$p = 0.10$	13.4^{b} ±18.4	6.9^{ab} ±9.2	6.2^{ab} ±9.3	3.9^{a} ±9.4	$p = 0.02$
		S. feltiae (Entonem)	66 ±23	77 ±40	81 ±20	47 ±21	$p = 0.48$	60 ±35	65 ±35	69 ±17	32 ±15	$p = 0.34$	5.3^{a} ±5.9	9.0^{b} ±8.1	4.9^{a} ±4.4	3.8^{a} ±6.3	$p = 0.01$
Copper Water	nano-Cu (Cu-NPs)	*H. bacteriophora* (Nematop)	97 ±6	87 ±6	100 ±0	90 ±10	$p = 0.12$	97^{b} ±6	67^{ab} ±21	83^{ab} ±11	57^{a} ±6	$p = 0.02$	11.0^{b} ±8.9	7.3^{ab} ±7.5	5.8^{a} ±5.6	3.1^{a} ±4.0	$p = 0.0002$
		H. bacteriophora (Larvanem)	80 ±35	92 ±11	77 ±32	80 ±35	$p = 0.90$	65 ±42	68 ±30	67 ±42	35 ±25	$p = 0.67$	2.3 ±2.5	5.3 ±6.0	5.8 ±6.3	3.7 ±6.0	$p = 0.06$
		S. feltiae (Owinema)	70 ±26	80 ±10	97 ±6	90 ±0	$p = 0.20$	67 ±21	30 ±20	70 ±17	70 ±0	$p = 0.05$	13.4^{b} ±18.4	1.6^{a} ±3.4	12.2^{b} ±18.0	5.6^{ab} ±6.5	$p = 0.002$
		S. feltiae (Entonem)	66 ±23	76 ±40	70 ±36	67 ±15	$p = 0.97$	60 ±35	44 ±25	62 ±35	62 ±21	$p = 0.81$	5.3^{a} ±5.9	2.4^{a} ±3.8	11.2^{b} ±11.6	7.2^{ab} ±6.6	$p = 0.0002$

Different small letters denote significant differences at $p < 0.05$ within each nematode species and at various concentrations of nanoparticles – Tukey test. K – control (nematodes from distilled water without nanoparticles). Concentrations of nanoparticles: A – 0.5 ppm, B – 2 ppm, C – 5 ppm. For some concentrations of nano-Ag, study of the mortality, the extensity and the intensity of infection was impossible, due to almost 100% mortality of nematodes.

TABLE 2. Pathogenic properties of entomopathogenic nematodes (percentage mortality, extensity and intensity of infection of *A. diaperinus* pupae) which contacted nanoparticles of silver, gold and copper in various concentrations (n = 30 in every variant of experiment)

Trade name	Active substance	Nematode species	Permanent contact of entomopathogenic nematodes with nanoparticles														
			A. diaperinus pupae														
			mortality (%) ±*SD*					extensity of infection (%) ±*SD*					intensity of infection (nematodes per host) ±*SD*				
			K	A	B	C	ANOVA	K	A	B	C	ANOVA	K	A	B	C	ANOVA
Silver Water	nano-Ag (Ag-NPs)	*H.bacteriophora* (Nematop)	47 ±11	27 ±11			$p = 0.10$	33 ±15	17 ±6			$p = 0.15$	2.7 ±5.0	2.2 ±5.6			$p = 0.70$
		H.bacteriophora (Larvanem)	32 ±25	33 ±15	14 ±15		$p = 0.39$	22 ±15	12 ±11	9 ±10		$p = 0.44$	2.1 ±4.4	1.8 ±4.9	0.7^{a} ±2.3		$p = 0.37$
		S.feltiae (Owinema)	83 ±6	43 ±25			$p = 0.05$	73^{b} ±15	17^{a} ±15			$p = 0.01$	16.4^{b} ±19.7	2.7^{a} ±7.9			$p = 0.0008$
		S. feltiae (Entonem)	67^{B} ±25	30^{A} ±10	11^{A} ±10		$p = 0.01$	56 ±35	11 ±10	10 ±10		$p = 0.06$	14.9^{b} ±16.1	2.7^{a} ±9.2	3.1^{a} ±10.1		$p = 0.0002$
Gold Water	nano-Au (Au-NPs)	*H.bacteriophora* (Nematop)	47^{B} ±11	43^{B} ±6	20^{A} ±10	17^{A} ±6	$p = 0.005$	33^{b} ±15	27^{ab} ±6	13^{ab} ±6	7^{a} ±6	$p = 0.03$	2.7 ±5.0	4.7 ±11.4	1.8 ±6.0	0.2 ±0.6	$p = 0.09$
		H.bacteriophora (Larvanem)	32 ±25	39 ±10	11 ±10	12 ±6	$p = 0.10$	22 ±15	12 ±6	7 ±11	10 ±10	$p = 0.36$	2.1 ±4.4	4.0 ±11.0	1.9 ±7.4	0.7 ±2.1	$p = 0.34$
		S.feltiae (Owinema)	83 ±6	47 ±25	47 ±11	60 ±30	$p = 0.18$	73^{b} ±15	3^{a} ±6	7^{a} ±11	23^{a} ±11	$p = 0.0003$	16.4^{b} ±19.7	0.5^{a} ±2.7	0.3^{a} ±1.0	0.9^{a} ±1.9	$p < 0.0001$
		S. feltiae (Entonem)	67^{B} ±25	33^{AB} ±15	10^{A} ±17	16^{A} ±11	$p = 0.02$	56^{b} ±35	8^{a} ±6	4^{a} ±6	6^{a} ±6	$p = 0.02$	14.9^{b} ±16.1	3.0^{a} ±11.6	3.6^{a} ±19.7	1.2^{a} ±4.7	$p = 0.001$
Copper Water	nano-Cu (Cu-NPs)	*H.bacteriophora* (Nematop)	47 ±11	50 ±10	50 ±26	33 ±15	$p = 0.60$	33 ±15	10 ±10	10 ±0	10 ±10	$p = 0.06$	2.7^{b} ±5.0	0.7^{ab} ±2.2	0.8^{ab} ±3.0	0.4^{a} ±1.2	$p = 0.02$
		H.bacteriophora (Larvanem)	32 ±25	23 ±6	14 ±6	15 ±15	$p = 0.44$	22 ±15	12 ±6	11 ±10	11 ±10	$p = 0.43$	2.1 ±4.4	0.7 ±2.0	0.7 ±2.1	1.9 ±5.9	$p = 0.36$
		S.feltiae (Owinema)	83^{B} ±6	27^{A} ±15	20^{A} ±10	20^{A} ±10	$p = 0.0002$	73^{b} ±15	17^{a} ±11	3^{a} ±6	3^{a} ±6	$p < 0.0001$	16.4^{b} ±19.7	1.4^{a} ±4.1	1.7^{a} ±9.5	0.1^{a} ±0.5	$p < 0.0001$
		S. feltiae (Entonem)	67^{B} ±25	22^{A} ±21	16^{A} ±15	9^{A} ±17	$p = 0.03$	56^{b} ±35	16^{ab} ±15	12^{ab} ±11	4^{a} ±6	$p = 0.05$	14.9^{b} ±16.1	1.9^{a} ±4.9	1.8^{a} ±4.7	1.9^{a} ±10.4	$p < 0.0001$

Different small letters denote significant differences at $p < 0.05$ within each nematode species and at various concentrations of nanoparticles – Tukey test. K – control (nematodes from distilled water without nanoparticles). Concentrations of nanoparticles: A – 0.5 ppm, B – 2 ppm, C – 5 ppm. For some concentrations of nano-Ag, study of the mortality, the extensity and the intensity of infection was impossible, due to almost 100% mortality of nematodes.

TABLE 3. Pathogenic properties of entomopathogenic nematodes (percentage mortality, extensity and intensity of infection of *A. diaperinus* adults) which contacted nanoparticles of silver, gold and copper in various concentrations ($n = 30$ in every variant of experiment)

Trade name	Active substance	Nematode species	Permanent contact of entomopathogenic nematodes with nanoparticles														
			A. diaperinus adults														
			mortality (%) ±*SD*					extensity of infection (%) ±*SD*					intensity of infection (nematodes per host) ±*SD*				
			K	A	B	C	ANOVA	K	A	B	C	ANOVA	K	A	B	C	ANOVA
Silver Water	nano-Ag (Ag-NPs)	*H.bacteriophora* (Nematop)	13 ±6	13 ±15			$p = 1.00$	13 ±6	10 ±10			$p = 0.64$	1.1 ±3.0	1.7 ±6.7			$p = 0.64$
		H.bacteriophora (Larvanem)	11 ±10	10 ±10	5 ±6		$p = 0.87$	10 ±10	9 ±10	3 ±6		$p = 0.59$	1.1 ±3.8	1.9 ±6.0	1.4 ±7.7		$p = 0.87$
		S.feltiae (Owinema)	50^{B} ±10	30^{A} ±0			$p = 0.03$	43 ±15	27 ±6			$p = 0.15$	16.3^{b} ±32.0	3.4^{a} ±8.2			$p = 0.04$
		S. feltiae (Entonem)	45^{B} ±15	9^{A} ±17	12^{A} ±11		$p = 0.04$	9 ±0	7 ±11	8 ±6		$p = 0.82$	14.2 ±46.2	3.4 ±13.0	2.6 ±9.9		$p = 0.21$
Gold Water	nano-Au (Au-NPs)	*H.bacteriophora* (Nematop)	13 ±6	73 ±46	73 ±46	63 ±40	$p = 0.25$	13 ±6	57 ±40	53 ±45	57 ±42	$p = 0.44$	1.1^{a} ±3.0	2.1^{a} ±2.4	4.5^{ab} ±7.5	11.2^{b} ±20.3	$p = 0.002$
		H.bacteriophora (Larvanem)	11^{A} ±10	67^{B} ±6	64^{B} ±25	65^{B} ±35	$p = 0.04$	10^{a} ±10	48^{b} ±15	38^{ab} ±6	54^{b} ±21	$p = 0.02$	1.1^{a} ±3.8	2.4^{a} ±3.0	5.0^{ab} ±7.0	10.9^{b} ±14.9	$p < 0.0001$
		S.feltiae (Owinema)	50 ±10	0 ±0	0 ±0	0 ±0	$p < 0.0001$	43 ±15	–	–	–	–	16.3 ±32.0	–	–	–	–
		S. feltiae (Entonem)	45 ±15	56 ±15	56 ±6	66 ±11	$p = 0.35$	9 ±0	27 ±25	44 ±11	47 ±15	$p = 0.07$	14.2 ±46.2	7.0 ±12.8	8.0 ±11.6	11.1 ±14.2	$p = 0.48$
Copper Water	nano-Cu (Cu-NPs)	*H.bacteriophora* (Nematop)	13^{A} ±6	57^{AB} ±30	100^{B} ±0	17^{A} ±11	$p = 0.0006$	13^{ab} ±6	43^{b} ±21	87^{c} ±11	7^{a} ±6	$p = 0.0002$	1.1^{a} ±3.0	3.1^{a} ±4.6	6.1^{b} ±6.7	0.4^{a} ±1.7	$p < 0.0001$
		H.bacteriophora (Larvanem)	11^{A} ±10	65^{AB} ±21	89^{B} ±17	16^{A} ±11	$p = 0.0006$	10^{a} ±10	48^{b} ±21	67^{b} ±21	9^{a} ±0	$p = 0.005$	1.1^{a} ±3.8	4.4^{a} ±5.6	6.1^{b} ±5.7	1.1^{a} ±3.4	$p < 0.0001$
		S.feltiae (Owinema)	50^{B} ±10	13^{A} ±15	0^{A} ±0	10^{A} ±17	$p = 0.006$	43^{b} ±15	0^{a} ±0	–	7^{a} ±11	$p < 0.001$	16.3^{b} ±32.0	0^{a} ±0	–	0.1^{a} ±0.6	$p < 0.0001$
		S. feltiae (Entonem)	45^{AB} ±15	14^{A} ±6	90^{B} ±17	11^{A} ±10	$p = 0.0002$	9^{a} ±0	10^{a} ±0	88^{b} ±15	8^{a} ±6	$p = 0.001$	14.2 ±46.2	7.7 ±24.7	9.3 ±6.4	3.3 ±12.7	$p = 0.48$

Different small letters denote significant differences at $p < 0.05$ within each nematode species and at various concentrations of nanoparticles – Tukey test. K – control (nematodes from distilled water without nanoparticles). Concentrations of nanoparticles: A – 0.5 ppm, B – 2 ppm, C – 5 ppm. For some concentrations of nano-Ag, study of the mortality, the extensity and the intensity of infection was impossible, due to almost 100% mortality of nematodes. In some cases, caused by zero mortality of insects, extensity and intensity of infection could not be calculated. They were marked with dash sign.

tion and breeding. Fungi and nematodes were used alone as a method of biological control (Gindin et al. 2009). Insect mortality ranged from 63 to 87% and parasites remained in the substratum for ca 7 weeks (Geden et al. 1987). The number of offspring IJs obtained from 16 adults per 1 m^2 decreased the population density of beetles by even 50% (Szalanski et al. 2004). Pezowicz (2005) found a high efficiency of the lesser mealworm control by using nematodes and entomopathogenic fungi simultaneously. The effect was two times more efficient compared with single invasions.

Entomopathogenic nematodes that contacted with various chemical substances developed in all studied growth stages of insects. As those isolated from areas of various industrial pollution, they showed biological activity (Pezowicz et al. 2008). The latter means an ability of IJs to infect an insect (the intensity of infection), its population (the extensity of infection) and to reproduce in the host's body. The activity is affected by many environmental and ecological factors: natural resistance and physiological status of insects, physical, chemical and biotic conditions, and population density of the host. Probably, chemical substances described above may stimulate surviving EPNs which was reflected in high values of studied parameters. Koppenhöfer et al. (2000) also noted the increased number of IJs attached to grubs treated with neonicotinoids preparations. Results of other studies on IJs of *S. carpocapsae* (Weiser, 1955) from areas heavily polluted with SO_2 and NO_x showed that the nematodes caused over 90% mortality in *G. mellonella* (L.) caterpillars on the fifth day of experiment and *H. megidis* (Poinar, Jackson, Klein 1987) was the reason of over 60% mortality in the same insects. Both parasite species developed in the caterpillar's body, the intensity of infection was 4.2 and 6.4, respectively (Pezowicz et al. 2008). Various strains of *S. feltiae* from Polish areas of different lead pollution showed a high mortality and the extensity of infection (from 97 to 100%) of *G. mellonella* caterpillars while the intensity of infection was from 10 to 22 (Matuska and Kamionek 2011).

Species of different insect orders are prone to the infection by EPNs in various ways. The same is true for species that belong to the same family. Most susceptible are the caterpillars of Lepidoptera. Lepidopteran pupae and dipteran maggots are less susceptible to infection. Only 30% of *Ostrinia nubilalis* (Hubner, 1796) pupae were infected by *S. carpocapsae* compared with 100% infection of larvae and adults (Lewis and Raun 1978). Various sheaths and thecae are mechanical barriers hampering penetration of IJs to the host's body. Relatively resistant to infection are also adult beetles. It was found that adult beetles of *A. diaperinus* were not infected by *H. heliothidis* (Poinar, 1979) whereas their larvae and pupae were susceptible (LD_{50} equal 26 and 36, respectively). *Steinernema glaseri* (Steiner, 1929), however, infected only the adult lesser mealworms but all growth stages were susceptible to infection by *S. carpocapsae* (LD_{50} equal 9–56) (Geden et al.

1985). Adult beetles of *Curculio caryae* (Horn, 1873) were more prone to the infection by various strains of *S. carpocapsae* as compared with larvae (Shapiro-Ilan et al. 2003). Ramos-Rodriguez et al. (2006) found that larvae of various species of beetles – pests in corn stores – were more susceptible to infection by *S. feltiae* than adult individuals. Similar observations were made by Kakouli-Duarte et al. (1997) and Rumbos and Athanassiou (2012) in insects *Sphenophorus* spp. (Pallas, 1776), *Otiorhynchus sulcatus* (Fabricius, 1775), *Hylobius abietis* L. and *Tribolium confusum* Jacquelin du Val., 1863. The sensitivity of insects to nematode infection decreased with age, an effect associated with well-developed chitin external skeleton which was a mechanical barrier hampering penetration of EPNs (Rumbos and Athanassiou 2012). Kuźniar (2009) found that nematodes from biopreparations Owinema, Nemasys and Nemaplus which contacted with nano-Cu caused a high mortality in *Tenebrio molitor* L. larvae – from 40% (Owinema, concentration 1 mg/dm^3) to 95% (Nemaplus, concentrations 1 and 10 mg/dm^3). The contact of EPNs (Owinema, Nemasys, Nemaplus and Nematop) with multi-walled carbon nanotubes did not deprive nematodes of their pathogenic properties. The mortality of the yellow mealworm larvae caused by the mentioned above IJs species exceeded 80% (Kuźniar et al. 2011). The extensity of infection of the larvae may be determined by the size and availability of natural body openings like e.g. stigmas, by mobility and the amount of kairomones released to the external environment (Pezowicz 2005).

Despite being used in low doses (50 IJs per insect), the IJs caused the mortality/the extensity of infection at various levels. Pezowicz (2005) did not find mortality in *A. diaperinus* at so low dose of nematodes. The author had to increase the number of IJs from 50 to 2,000 individuals per insect. The extensity and the intensity of infection depend on the defence mechanisms in hosts. Moreover, the intensity of infection is determined by control mechanisms operating within parasite population. The number of nematodes developing in haemocoel determines the number of IJs recovered from an insect. Low intensity of infection may also contribute to a low number of IJs leaving the host's body (Laznik et al. 2010, Laznik and Trdan 2015).

CONCLUSIONS

Use of nanoparticles in agriculture, as antibacterial and antifungal agents, does not affect negatively EPNs pathogenicity under laboratory conditions. Instead of that, addition of nano particles of Ag, Au or Cu may slightly increase the efficacy of nematodes. Further experiments are needed in field trials to verify the observed effects.

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Streszczenie: *Ograniczanie liczebności pleśniakowca lśniącego* Alphitobius diaperinus *nanocząstkami i nicieniami entomopatogenicznymi.* Trzy stadia rozwojowe *Alphitobius diaperinus* (Coleoptera: Tenebrionidae) zostały zarażone czterema gatunkami i szczepami nicieni entomopatogenicznych *Steinernema feltiae* i *Heterorhabditis bacteriophora*, które wcześniej miały kontakt z nanocząstkami srebra, złota i miedzi. Przez 7 dni badano śmiertelność, ekstensywność i intensywność zarażenia chrząszczy. Większość badanych EPNs i nanocząstek powodowała wysoki poziom śmiertelności i dużą ekstensywność zarażenia larw gospodarza, odpowiednio od 12 do 100% oraz od 8 do 83%. Zaobserwowano również negatywny wpływ nicieni *S. feltiae* (Owinema) i nanocząstek złota na śmierelność dorosłych owadów. Mimo to, w wielu przypadkach dodatek nanocząstek może zwiększać skuteczność działania biopreparatów na bazie EPNs. Nanocząstki mogę być również stosowane w integrowanym zwalczaniu szkodników.

Słowa kluczowe: *Steinernema*, *Heterorhabditis*, szkodnik, brojlernia, nanosrebro, nanozłoto, nanomiedź

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Various factors affecting the alpha1-antitrypsin level in Thoroughbred foals

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Abstract: *Various factors affecting the alpha*1*-antitrypsin level in Thoroughbred foals*. Acute phase proteins (APP) are an integral part of the acute phase response. Alpha1-antitrypsin (AAT) is considered to be one of the most important acute-phase protein activated by trauma, stress, or inflammatory processes. The objective of the present study was to estimate the impact of various factors (sex, month of life and sire effect) on concentration of alpha1-antitrypsin in serum of Thoroughbred foals. A total of 624 samples, collected from 39 foals were obtained in monthly intervals from first to 16th month of life and measured by STIC method (specific trypsin inhibitory captivity). The obtained results indicated the significant impact of analyzed age periods on the AAT level. Furthermore, the variation in AAT level in analyzed periods corresponded to significant changes in foals diet and maintaining. Alpha1-antitrypsin concentration was also affected by sire effects and sex of foals. In the most investigated age periods, the impact of sire on alpha1-antitrypsin content in serum of his progeny has been shown. The obtained results might be useful in explanation of differences in serum AAT concentration in foals during early ontogenesis which probably is a critical period that has an influence on racing performance of young horses.

Key words: alpha1-antitrypsin, acute phase proteins, Thoroughbred

INTRODUCTION

The Thoroughbred (TB horses) is one of the most valuable horse breed in the world. As a registered race horse, the stud books trace back up to 18th century (An Introduction... 1791). Since that, TB horses were subjected to artificial selection pressure and planned breeding for superior athletic and racing performance. Furthermore, horse in general has been used as a large animal model for investigation of biochemical, physiological and genetic adaptation to stress factors (McGivney et al. 2009, Fureix et al. 2012). During the growth period important changes in young developing organisms occurred and many studies have been performed to known physiological mechanisms of these modifications (Paltrinieri et al. 2008, Lepeule et al. 2009, Duesterdieck-Zellmer et al. 2014). One of the most important blood proteins are acute phase proteins (APP) which are an

integral part of the acute phase response. Information about changes in the serum APP proteins concentration are used in diagnosis, prognosis and assessment of animal health (Cray et al. 2009). Age related changes in reference values of these biochemical parameters have been described in several equine breeds (Brommer et al. 2001, Čebulj-Kadunc et al. 2002, Muñoz et al. 2012).

The alpha1-antitrypsin enzyme (AAT), known also as alpha1-proteinase inhibitor (A1PI, APi), is a plasma glycoprotein that belongs to SERPIN superfamily. Like in humans, equine AAT is synthesized in liver, in the Islets of Langerhans and it is believed that other immunolocalisation of this protein is similar to humans' (Dagleish et al. 1998). The target proteinase is neutrophil elastase (NE) which is released during the inflammatory response and uncontrolled causes degradation of extracellular matrix (Janof 1985). A genetic disorder of AAT deficiency (AATD) has been widely described in humans. Mutation in gene encoding alpha1-antitrypsin, including single point mutations, insertions and deletions, lead to protein retention in the endoplasmic reticulum and failure of secretion consequently resulting in low level of ATT in plasma and lungs (Stockley and Turner 2014). The equine APi system has been shown to be controlled by four closely linked loci Spi1, Spi2, Spi3, Spi4 which probably derive from the same ancestral gene that encodes human AAT. Further studies described evidence that Spi1 proteins are the equivalent of human APi (Patterson et al. 1991). Isolation of three different functional inhibitors from horse plasma showed that two of them can inactivate horse NE (Potempa et al. 1991). Whereas human APi is a one oxidation sensitive protein, horse APi includes five isoforms and only one of them is oxidation sensitive (Patterson and Bell 1989, Patterson et al. 1991). Study on horse neutrophils provide evidence that synthesis and release of APi also occur in mature equine neutrophils and concurrent extracellular release of neutrophil elastase. The reactive oxidative intermediates from stimulated equine neutrophils would not inactivate all APi, so level of neutrophil elastase inhibition maintain protection from proteolytic damage. This could be an explanation of differences between human and horse neutrophil activity in pulmonary pathology (Dagleish et al. 2003). For the time, the possible hereditary nature of recurrent airway obstruction (RAO) has been indicated due to the stallion which half of descendants have been affected (Schäper 1939). Further studies revealed that risk of RAO appearance is 3.2 higher (p >0.005) when one parent is affected and is 4.6 higher when considering both parents (Marti et al. 1991). To date, there are very limited information about biological significance and deficiency of equine alpha1-antitrypsin during growth and development of foals.

The objective of the present study was to estimate the impact of various factors (sex, month of life and sire effect) on concentration of alpha1-antitrypsin in

the serum of Thoroughbred foals. The obtained results might be useful in explanation of differences in serum AAT concentration in foals during early ontogenesis which probably is a critical period that influence racing performance of young horses.

MATERIAL AND METHODS

Animals and samples collection

Blood samples were obtained from 39 Thoroughbred foals born in the same year, raised in two stud farms with similar agronomic conditions. Study sample of 20 fillies and 19 colts were divided into four groups according to their pedigrees (foals do not have a common mothers). Each group represented foals by one father and the foals sex ratio was 1 : 1. Samples were collected in monthly intervals from the first to 16th month of life (a total of 624 samples were collected). Foals were dewormed and vaccinated at the proper time. They were fed with the diet recommended for foals, accurate to the state of development and season.

Serum alpha1-antitrypsin measurements

Blood samples were collected in to sterile tubes without anticoagulant by jugular venipuncture, then samples were centrifuged at 4,380 g for 5 min, and the serum was used for measurements of ATT.

Concentration of trypsin inhibitory capacity (TIC) serum was measured according to principle of the method by using *N*-benzoyl-DL-arginine-*p*-nitroanilide (BAPNA, Sigma) as substrate primarly described by Dietz and coworkers (Dietz et al. 1976). Reduction in tryptic activity after the addition of plasma to a standard trypsin solution was measured. The standard curve was obtained by the use of scalar concentration of trypsin (bovine pancreas trypsin, Sigma 9300 Unit BAEE). For the determination of TIC (0.02ml), buffer (0.02M $CaCl_2$– 0.1 M Tris, pH 8.2; 3.7 ml) and trypsin (10.0 mg in 50.0 ml 0.0025N HCl; 0.2 ml, about 40 μg of trypsin), were pre-incubated in a water bath. After adding the substrate (4.0 ml) and 10 min of incubation, the reaction was stopped by the addition of 30% acetic acid (1.0 ml). The result of the reaction was read at a photometer (410 nm wavelength). The TIC parameters were calculated according to the reduction of enzyme activity by the serum (1 mg of trypsin per 100 ml of serum). The determined values of AAT level and TIC were used for the calculation of the specific AAT activity (1 mg of trypsin inhibited by 1 mg of AAT).

Statistical analysis

The data were analyzed with the use of GLM procedure (SAS Institute, Cary, NC, USA; ver 9.2). Two different linear models were applied. Model 1 was used for general analysis whereas effect of sex on AAT was tested by means of Model 2:

Model 1:

$$y_{ijk} = o_i + c_j + (o \cdot c)_{ij} + z_{ik} + \varepsilon_{ijk}$$

Model 2:

$$y_{ijk} = p_i + c_j + (p \cdot c)_{ij} + z_{ik} + \varepsilon_{ijk}$$

where:

o – fixed effect of the stallion;

c – fixed effect of the measurement time on j time;

$(o \cdot c)_{ij}$ – interaction between sire and time effect;

z_{ik} – fixed foal effect;

p – fixed sex effect;

ε – random error.

The averages for individual measurement time points were compared using profile, mean and helmert contrasts. Profile contrasts were used to compare adjacent measuring time points, while each data time point with the average of all points were compared using the mean contrasts. Finally, Helmert contrasts were applied to compare each time point with the average points following it. To confirm the significance of impact of the factors on AAT levels in the analyzed periods three orthogonal contrasts have been analyzed:

- Contrast A was sire IV vs all other sires;
- Contrast B was sire III vs sires I and II;
- Contrast C was sire II vs sires I and I.

Differences between sires of every individual measuring time point were tested using orthogonal contrasts, including sire by analyzed periods interaction effect.

RESULTS AND DISCUSSION

Alpha1-antitrypsin is considered to be one of the most important acute-phase protein activated by trauma, stress, or inflammatory processes. Due to inhibition of a wide variety of proteases, alpha1--antitrypsin is also called alpha1-proteinase inhibitor (A1PI; APi). This inhibitor is a critical element which protects lung tissue from uncontrolled, destructive influence of proteolytic enzymes of inflammatory cells, especially neutrophil elastase. The low concentration of AAT protein in the respiratory system can lead to the gradual and irreversible reduction of lungs elasticity. The excessive neutrophil elastase activity results in degradation of elastin, the main component of elastic fiber, and other extracellular matrix components in the lower respiratory tract (Stockley 2000). These changes would be related to respiratory complications characterized by inflammation or chronic obstructive lung disease.

As previously described equine APi are composed of four or five plasma glycoproteins named serine proteinase inhibitor (Spi) 1, 2, 3A, 3B, 4. The Spi1 proteins are the equivalent of human APi (Patterson et al. 1991, Potempa et al. 1991) and Spi1, Spi3A, Spi3B, Spi4 have the ability to inhibit trypsin (Patterson et al. 1991). Whereas human APi is a one oxidation sensitive protein, horse APi includes five isoforms and only one of them is oxidation sensitive (Patterson and Bell 1989, Patterson et al. 1991). Study on horse neutrophils pro-

vide evidence that synthesis and release of APi also occurs in mature equine neutrophils and concurrent extracellular release of neutrophil elastase. The reactive oxidative intermediates from stimulated equine neutrophils would not inactivate all APi, so level of neutrophil elastase inhibition maintain protection from proteolytic damage. This could be an explanation of differences between human and horse neutrophil activity in pulmonary pathology (Dagleish et al. 2003).

In the present study, the statistical analysis showed that all tested effects (sex, month of life and stallion effect) highly significantly affected AAT levels. Mean levels of AAT in serum of fillies and colts in the first 16 months of life were estimated. Concentration of antitrypsin ranges between 1.3 and 1.9 mg/ /ml (Fig. 1). The obtained levels of AAT were lower than previously estimated by different authors: 1 and 2.1–4.0 mg/ml (Patterson et al. 1991, Pellegrini 1994, Dagleish et al. 2000). On the other hand, the presented discrepancies in antitrypsin concentration may result from different methods used to estimation of AAT levels (enzymatic assay and immunoassay). Furthermore, immunoassay method which detects protein level based on the binding with specific antibody, could be influenced by different factors.

In our results, the highest fluctuation in serum AAT concentrations in foals has been observed in the first 6 months of life. Minimum antitrypsin level has been detected in the fifth and a maximum in the third month of life. The observed decrease of AAT concentration is probably a consequence of managing procedures when foals are changing rearing at the stable environment on grazing. Subsequent decrease of AAT content in serum was noted at around eighth month of life which was presumably associated with weaning procedures. Weaning occurs in foals at the eighth month and is the most stressful period (Apter and Housholder 1996). It is associated with the loss

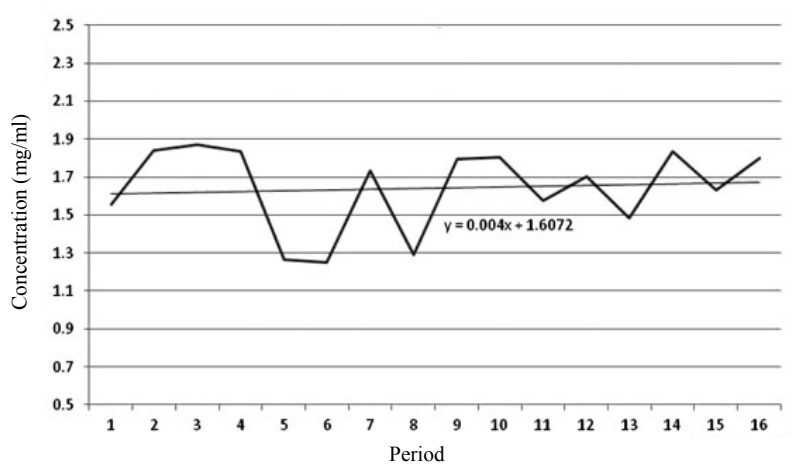

FIGURE 1. Content in serum of alpha1-antitrypsin in foals from first to 16th month

of weight (Waran et al. 2008), increase of immune response and increase of cortisol level (Malinowski et al. 1990). The presented variations in antitrypsin levels in analyzed periods were also confirmed by significance of orthogonal contrasts (p <0.01) (Table 1). In horses, the different acute-phase proteins (APP) manifest a various pathological processes, such as inflammatory process, stress, infections caused by bacteria, viruses, parasites or trauma surgery. In foals, Satué et al. (2013) showed significant impact of the age on another equine APP protein (amyloid type A; SAA), while gender probably does not affect basal levels of this protein. Furthermore, several previous studies confirmed significantly higher level of amyloid A in horses older than 21 months compared to foals at 18 or 12 months (Nunokawa et al. 1993, Satoh et al. 1995). It is proven that SAA concentration was very high in horses with clinical signs of inflammation and also increased after surgery treatment (Eckersall 1995).

TABLE 1. Differences between mean of ATT levels (mg/ml) of foals sired by different stallions in individual measurement points

Point[a]	A[b]		B[c]		C[d]	
	F	*p*	*F*	*p*	*F*	*p*
1	9.510	**	78.880	**	0.350	–
2	16.340	**	6.010	*	0.160	–
3	30.560	**	5.360	*	0.010	–
4	1.390	–	0.380	–	0.360	–
5	2.430	–	19.100	**	1.530	–
6	8.150	**	32.180	**	0.660	–
7	0.410	–	7.290	**	0.430	–
8	51.460	**	23.760	**	0.320	–
9	28.400	**	0.820	–	0.250	–
10	23.300	**	22.150	**	1.410	–
11	8.220	**	0.000	–	1.010	–
12	12.050	**	7.400	**	0.700	–
13	21.340	**	0.830	–	0.250	–
14	9.130	**	0.270	–	0.000	–
15	15.440	**	0.070	–	0.710	–
16	34.230	**	7.180	**	1.150	–

[a]Measurement point which is the month of foals life; [b]A – sire IV vs I, II, III; [c]B – sire III vs I, II, [d]C – sire I vs II; *$p \leq 0.05$; **$p \leq 0.001$.

Basic statistical analysis showed that concentration of alpha1-antitrypsin level was also influenced by sire effects and sex of foals. In the most investigated age periods, the impact of sire on alpha1-antitrypsin content in serum of his progeny has been shown (Fig. 2). Highly significant differences were found between AAT levels in progeny of sire IV vs sires III, II, I, and sire III vs sires II, I (p >0.05). Whereas the AAT mean serum level of progeny of sire IV ranging between 0.7 and 1.7 mg/ml (mean 1.4), for progeny of sire III 0.9––2.1 mg/ml (1.7), for progeny of sire II 1.0–2.1 mg/ml (1.7), for progeny of sire I 0.98–2.20 mg/ml (1.8).

Furthermore, the differences in antitrypsin levels between foals of four stallions in individual months of life were observed. Interesting results were obtained for the offspring of stallion IV which showed highly significant differences in AAT level from the first to third month of life, six month of life and further, from eighth month until end of the experiment. On the other hand, foals of stallion III showed highly significant differences in AAT concentration at the first month of life, fourth to eight month, 10, 12 and 16 months (Table 2). The orthogonal contrasts also illustrated that not

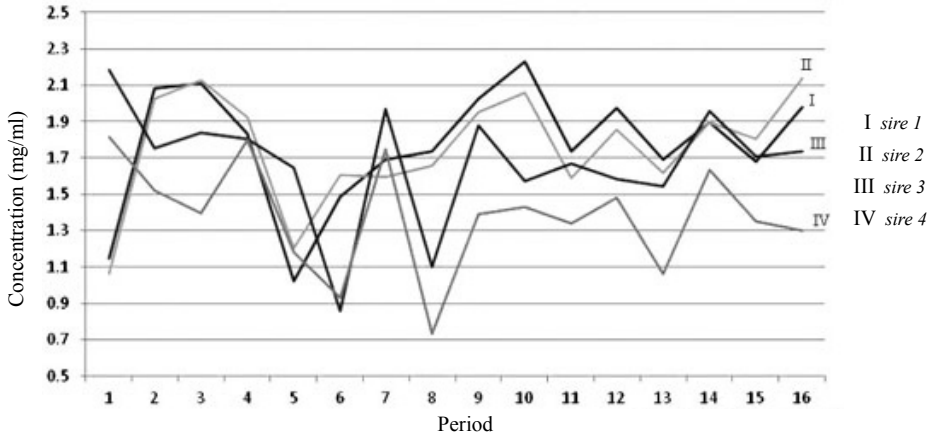

FIGURE 2. Content in serum of alpha1-antitrypsin in sires I–IV from first to 16th month

TABLE 2. Differencies in mean alpha1-antitrypsin levels in foals sired by different stallions

Contrast	*SS*	*MS*	*F*	*p*
A[a]	17.42	17.42	181.57	**
B[b]	0.81	0.81	8.41	**
C[c]	0.01	0.01	0.16	–

[a]A – sire IV vs I, II, III; [b]B – sire III vs I, II; [c]C – sire I vs II; $^{**}p \leq 0.001$.

every sire influences serum antitrypsin content in their progeny. The statistical significance was obtained only for stallions III and IV when compared to the mean AAT concentration of others tested stallions (Table 3). The association of only some stallions with alpha1--antitrypsin levels in offspring indicated the presence of some inheritance factors which may determinate the above feature. It seems important to performed future research on molecular basis of AAT content in horses, what may be useful in breeding selection. In humans, to diagnose the reason of AAT deficiency, few polymorphic sites have been detected and results confirmed the significant association of alpha1-antitrypsin phenotypic isoforms with genetic variation (Wu and Foreman 1991, Bornhorst et al. 2007). To date, there is no data which reported influence of sex on APi concentration in blood serum in horses. In dogs, Hughes et al. (1995) showed that AAT concentration was significantly higher in healthy, sexually inaction females when compared to spread females, sexually inaction males or castrated males. The authors suggested that antitrypsin level may be affected by estrogen hormones. On the other hand, in studies conducted on humans, Bornhorst et al. (2013) indicated that age, race, and sex had only slight effects on the median 95% serum antitrypsin concentration. Furthermore, acute phase proteins are produce due to the stress response. The higher level of AAT in colts is related with stress induced testosterone stimulation on adrenaline. In our study, the GLM procedure confirmed significant effect of gender

TABLE 3. Differences in antitrypsin levels depends on sex in measurement points

Point[a]	Fillies		Colts		Contrast	
	LSM	*SE*	*LSM*	*SE*	*SS*	*p*
1	1.504	0.085	1.588	0.079	0.072	–
2	1.658	0.085	1.981	0.079	1.067	**
3	1.838	0.085	1.886	0.079	0.024	–
4	1.749	0.085	1.892	0.079	0.207	–
5	1.229	0.085	1.284	0.079	0.030	–
6	1.161	0.085	1.311	0.079	0.229	–
7	1.727	0.085	1.723	0.079	0.000	–
8	1.176	0.085	1.372	0.079	0.394	–
9	1.785	0.085	1.792	0.079	0.001	–
10	1.673	0.085	1.905	0.079	0.550	*
11	1.476	0.085	1.650	0.079	0.311	–
12	1.493	0.085	1.865	0.079	1.417	**
13	1.252	0.085	1.670	0.079	1.777	**
14	1.762	0.085	1.882	0.079	0.146	–
15	1.504	0.085	1.725	0.079	0.499	–
16	1.568	0.088	1.975	0.079	1.640	**

[a] Measurement point which is the month of foals life; *$p \leq 0.05$; **$p \leq 0.001$.

on AAT content in foal serum ($p \leq 0.05$) (Fig. 3). Generally, in the most of investigated periods fillies were characterized by lower value of AAT concentration comparing to colts. The increase of differences in antitrypsin levels dependent on sex was observed from the 9th to 10th month of life and the biggest discrepancies between fillies and colts were obtained at 12th, 13th, and 16th month of life (Fig. 3, Table 4). At 12th–13th month, the Thoroughbred horses enter puberty and

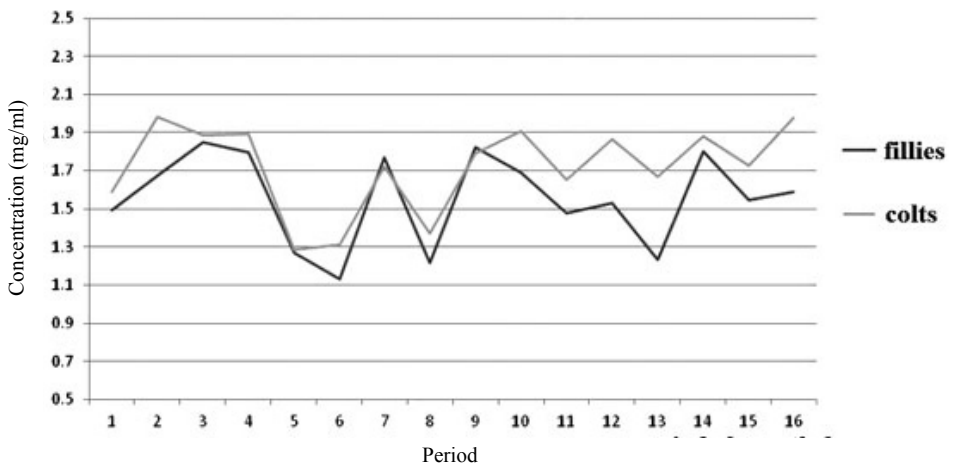

FIGURE 3. Content in serum of alpha1-antitrypsin in fillies and colts from first to 16th month

TABLE 4. Variation in mean alpha1-antitrypsin levels (mg/ml) in analyzed periods

Point[a]	*LSM*	Type of orthogonal contrast[b]					
		Profile[c]		Mean[d]		Helmert[a]	
		SS	*p*	*SS*	*p*	*SS*	*p*
1	1.549	1.695	**	0.354	–	0.354	–
2	1.844	0.018	–	1.708	**	1.613	**
3	1.874	0.053	–	2.251	**	2.429	**
4	1.822	6.397	**	1.356	**	1.809	**
5	1.249	0.002	–	6.399	**	5.169	**
6	1.239	4.761	**	6.737	**	6.540	**
7	1.733	3.622	**	0.349	–	0.181	–
8	1.302	4.930	**	4.789	**	5.661	**
9	1.805	0.004	–	1.112	**	0.434	*
10	1.820	1.064	**	1.323	**	0.740	**
11	1.586	0.293	–	0.127	–	0.335	–
12	1.709	0.924	**	0.189	–	0.021	–
13	1.491	2.274	**	0.941	**	1.904	**
14	1.832	0.863	**	1.519	**	0.432	*
15	1.622	0.510	*	0.015	–	0.510	*
16	1.785	–	–	0.836	**	–	–

[a]Measurement point which is the month of life foals; [b]The averages for individual measurement time points were compared using profile, mean and helmert contrasts; [c] Profile contrasts were used to compare adjacent measuring time points; [d]Mean contrasts were used to compare each data time point with the average of all points; [e]Helmert contrasts were applied to compare each time point with the average points following it.
*$p \leq 0.05$; **$p \leq 0.001$, $SE = 0.05$.

the separation of colts from fillies was performed, which may also explain the greatest variation of serum AAT content between genders at these periods. The obtained results might indicate that hormones involved with sexuality, especially estrogens, play important role in antitrypsin regulation.

CONCLUSIONS

According to very limited information about physiological basis of deficiency of equine alpha1-antitrypsin, the presented results would be helpful in understanding equine AAT regulation. The present study confirmed the significant impact of sex, age and sire effect on concentration of alpha1-antitrypsin in serum in Thoroughbred foals. The variation in AAT level in analyzed periods corresponded to significant changes in foals diet and maintaining. Different effect of investigated stallions on alpha1-antitrypsin level in their offspring indicated the need of future research concerning genetic determinants of AAT concentration.

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Streszczenie: *Wpływ różnych czynników na poziom alfa*1*-antytrypsyny u źrebiąt pełnej krwi angielskiej*. Białka ostrej fazy (APP) są integralną częścią tzw. odpowiedzi ostrej fazy na stan zapalny. Alfa1-antytrypsyna (ATT) jest uważana za jedno z najważniejszych białek ostrej fazy aktywowane przez uraz, stres lub procesy zapalne. W związku z tym celem niniejszego badania była ocena wpływu różnych czynników (płeć, miesiąc życia i ojciec) na stężenia ATT w surowicy krwi źrebiąt pełnej krwi angielskiej. Materiał do badań stanowiły 624 próbki krwi, zebranych od 39 źrebiąt będących potomstwem czterech ogierów, uzyskanych w odstępach miesięcznych od pierwszego do 16. miesiąca życia. Stężenie ATT oznaczono metodą STIC. Uzyskane wyniki wskazały na znaczący wpływ wieku źrebiąt na poziom AAT. Co więcej różnice w poziomie AAT w analizowanych okresach przypadały w okresach znaczących zmian u źrebiąt. Ponadto w większości badanych okresów wykazano wpływ ojca na stężenie ATT u potomstwa. Uzyskane wyniki mogą być przydatne w celu wyjaśnienia różnic w koncentracji AAT w surowicy krwi u źrebiąt w okresie wczesnej ontogenezy, która jest krytycznym okresem mającym wpływ na wyniki użytkowe młodych koni.

Słowa kluczowe: alfa1-antytrypsyna, białka ostrej fazy, pełna krew angielska

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Winter diet of the long-eared owl *Asio otus* in various habitats of central and north-eastern Poland

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Abstract: *Winter diet of the long-eared owl* Asio otus *in various habitats of central and north-eastern Poland.* Variability of the diet of the long-eared owl was studied in selected areas of central and north-eastern Poland. The sites represented three river valleys, two agricultural landscapes and a forest complex. Analysis of pellets collected in the years 1981–2013 provided data on 3,423 prey individuals. Winter food of this owl in study areas was dominated by species of the genus *Microtus* (65.3–95.7% of prey) while typically forest rodents (*Myodes glareolus*, *Apodemus flavicollis*) constituted only 3.9% of total prey. In river valleys the owls often preyed upon *Microtus oeconomus*, which was most frequent prey (87.6%) in the Biebrza river valley. Its share in the owl's diet outside river valleys varied while the dominating prey was *Microtus arvalis* there. Birds were hunted for rather infrequently, most often in the Vistula river valley. The long-eared owl is strongly associated with open areas and the share of two species dominating in its diet (*M. arvalis*, *M. oeconomus*) depends largely on moisture of habitats of these areas.

Key words: owls' diet, pellets, river valley, agricultural landscape, forest

INTRODUCTION

The long-eared owl *Asio otus* belongs to most common and numerous owl species in the country (Ruprecht and Szwagrzak 1988, Grzywaczewski and Szczepaniak 2007). It lives in habitats of variable forest cover but avoids large, dense forests since it preys in open areas of fields and meadows. The diet of this species was analysed in various regions of Poland, in the west (Goszczyński 1981, Jurczyszyn 1990, Żmihorski et al. 2012), south (Pawłowska-Indyk et al. 1998, Zając and Zając 1998, Cichocki et al. 2008, Dziemian et al. 2012, Grzędzicka 2014), north (Hetmański et al. 2008), in the centre (Romanowski 1988, Żmihorski 2005, Romanowski and Żmihorski 2008, Gryz and Krauze-Gryz 2015, Stolarz and Lesiński 2015, Wilniewczyc and Gwardjan 2015) and in the east of Poland (Ruprecht and Szwagrzak 1987, Wiącek et al. 2008, Kitowski 2013, Stasiak et al. 2014). Data on the owl's diet are also available from the neighbouring countries, e.g. from Belarus (Sidorovich et al. 2003) and Lithuania (Balčiauskienė et al. 2006).

Rodents of the subfamily Arvicolinae were found to be the species most frequently preyed upon, though in various types of landscapes the proportion of various species may differ. For example, recent studies carried out in a river valley (Stolarz and Lesiński 2015) showed

a high specificity of the owl's diet compared with that from drier habitats, which was demonstrated by a high percentage share of the root vole *Microtus oeconomus*.

The aim of this study was to determine the differences in winter diet of the long-eared owl in river valleys of different characteristic. It was also aimed to check whether the owl's diet on plateau adjacent to the valley was distinctly different.

MATERIAL AND METHODS

Studies were carried out in four areas in central Poland and in two areas in north-eastern part of the country (Fig.). Fragments of three valleys of the Biebrza, Narew and Vistula rivers were selected. Moreover, the study covered forest complex of the Kampinos Forest situated near the Vistula river valley and two agricultural landscapes with small forests (Suwalszczyzna and southern edges of Płońsk Plateau and Ciechanów Plateau)

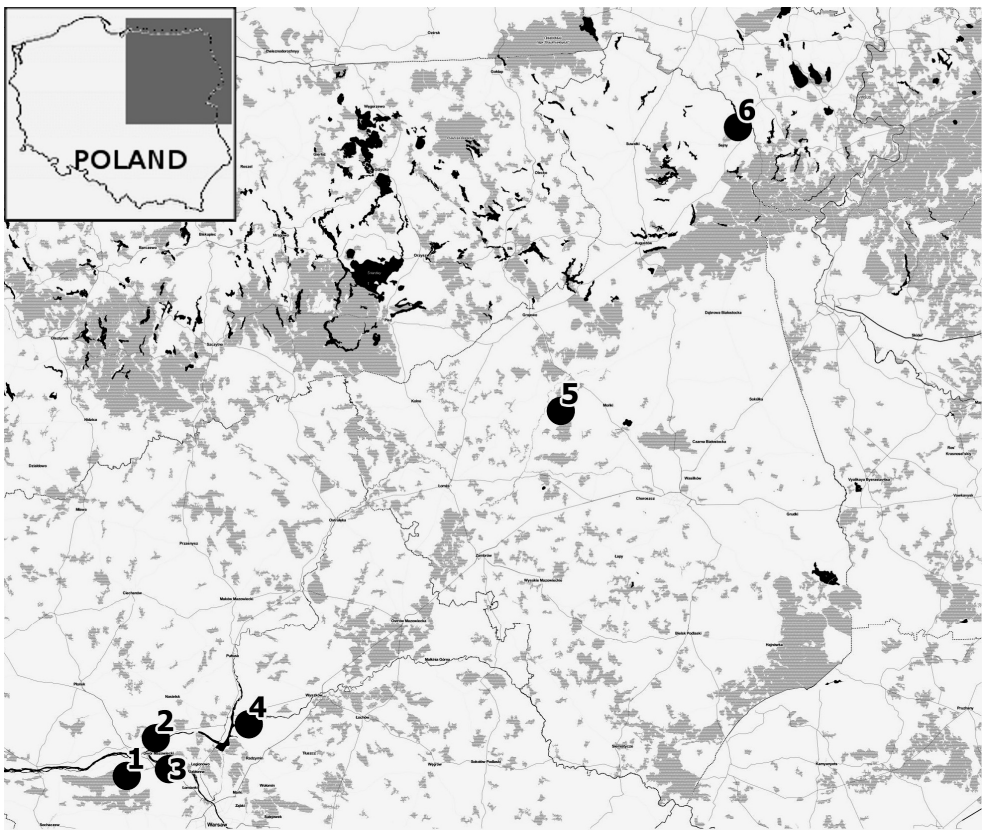

FIGURE. Distribution of study sites (circles): 1 – Kampinos Forest, 2 – Płońsk and Ciechanów Plateaus, 3 – Vistula river valley, 4 – Narew river valley, 5 – Biebrza river valley, 6 – Suwalszczyzna. Forests – grey, waters – black

situated close to the river valleys under study.

The Biebrza river valley – situated in north-eastern Poland it is a boggy valley of a width of several kilometers within the study area. Swamps (alder woods and birch on bogs) and open areas overgrown mainly by sedges may be found in the valley. The area is largely flooded during spring snow melting. At the edge of plateau there are crop fields and oligotrophic pine forests.

The Narew river valley – studies were carried out in a 2–3 km wide fragment of the lower Narew river. There are small oxbow lakes in the flooded areas and open grounds are used as pastures. At the edge of plateau there are village buildings, crop fields and relatively small, mainly pine, forests.

The Vistula river valley – studies were carried out in a 3-km-wide flooded stretch of the valley downstream Warsaw. The dominating form of land use is meadows and crop fields often surrounded by willows *Salix* spp. Riparian forests, midfield woodlots and numerous oxbow lakes are present there. At the edge of the valley there are buildings of Łomianki and of other villages.

The Kampinos Forest – it is the largest forest complex in central Poland protected as the Kampinos National Park. Study area in the eastern part of the park includes forested dunes and boggy belt used by agriculture. Forest cover about 70% of the area. Coniferous forests dominated by pine *Pinus sylvestris* prevail over oak-pine forests and broad-leaved forests. Agricultural lands are used extensively; mown meadows, crop fields and pastures are the dominating forms there.

Suwalszczyzna – a fragment of agricultural landscape close to the border with Lithuania. The area is slightly undulating with crop fields and grasslands. Rather small forest complexes are present in northern and eastern part of the area.

Płońsk Plateau and Ciechanów Plateau – they are morainic plains up to 163 m a.s.l. cut with several small rivers and the Wkra river bordering both areas. Agricultural lands are the dominating element of the landscape while forests and woodlots constitute less than 10% of the area. Forests are fragmented there but some of them show a marked share of deciduous and mixed tree stands.

In the Vistula river valley the study material was collected from five sites along the 40-km-long stretch in the years 1994–2012. One study site in the Narew river valley was selected near Kuligów (years of sampling 2010–2012). Three sites localised along the 30-km-long stretch in the Biebrza river valley were sampled in the years 1981–2005. Study material from the Kampinos Forest was collected from nine sites (years 1983––2013) while that from Suwalszczyzna was collected at one site – Sankury – in the year 2009. Six sites were selected on Płońsk Plateau and Ciechanów Plateau (sampled in the years 1982–2011) situated in relatively small area in southernmost part of both regions.

Composition of the owls' diet was estimated by the analyses of pellets

collected from under trees, where the birds had rested. Material for analyses was from the winter season (November–March). Pellets were prepared after soaking in water, and prey species were determined based mainly on skulls and mandibles, less frequently on skeleton bones (humeral bones of mole *Talpa europaea*, humeral bones and breastbones of birds or on pelvic bones of amphibians). Mammalian species were determined based on skulls and mandibles by adopting the features given in the key edited by Pucek (1984) and those from comparative collection. The minimum number of individuals was determined based on the number of recognizable elements.

To estimate species diversity, Simpson's index was calculated ($S = 1 - \Sigma\, pi^2$, where p is a share of i species within all prey items).

RESULTS AND DISCUSSION

Study material contained remains of 3,423 prey items of the long-eared owl *Asio otus*. Prevailing number of prey animals (98.4%) were mammals; other taxa like birds or anurans were preyed upon very rarely. The number of mammalian species varied from six in the Narew river valley to twelve in the Kampinos Forest (Table).

Rodents of the genus *Microtus* clearly dominated constituting from 65.3% (the Narew river valley) to 95.7% (the Biebrza river valley) of prey. Two most frequent species: *M. arvalis* and *M. oeconomus* contributed to this domination (Table). Their share in the owl's diet varied. *M. arvalis* was less frequent than *M. oeconomus* in the Biebrza river valley while the reverse proportions were found at remaining sites, with relatively slight differences in the Kampinos Forest. The highest differences in proportion of these two voles were noted between the Biebrza river valley (6.0 and 87.6%, respectively) and Płońsk and Ciechanów Plateaus (51.2 and 6.1%, respectively) – Table.

Rodents associated with forested areas (*Myodes glareolus*, *Apodemus flavicollis*) were found less frequently (3.9% of prey on average) but relatively more often in Suwalszczyzna (7.1%). From among species of the genus *Apodemus* most frequently preyed upon was *A. agrarius* (4.3% on average, and 9.8% in the Vistula river valley). Among river valleys only in the Biebrza river valley the diet of the long-eared owl included *Arvicola amphibius*. *Micromys minutus* was the prey of owls in most study areas, and relatively high share of this species (7.9%) was noted in the Kampinos Forest. Birds rarely were the prey of owls; their relative share was highest in the Vistula river valley. Species diversity of owls' prey was very similar at most sites (S values between 0.61 and 0.76), with exception of the Biebrza river valley where it was much lower (Table).

Mikkola (1983) summarizing the results of studies on the long-eared owl's diet in various countries found that small mammals constituted 85–98% of all prey, which was confirmed in our study. Our results show also that species of the

TABLE. Species composition and percentage of the long-eared owls' prey in study areas

Specification	Biebrza river valley	Narew river valley	Vistula river valley	Kampinos Forest	Płońsk and Ciechanów Plateaus	Suwalszczyzna	Total
Talpa europaea	2 (0.5)*	0	2 (0.7)	0	1 (0.5)	0	5 (0.1)
Sorex araneus	3 (0.7)	0	1 (0.4)	4 (0.4)	0	2 (0.2)	10 (0.3)
S. minutus	2 (0.5)	0	0	9 (0.8)	0	0	11 (0.3)
Arvicola amphibius	7 (1.7)	0	0	2 (0.2)	0	1 (0.1)	10 (0.3)
Myodes glareolus	0	5 (1.1)	7 (2.5)	33 (3.0)	7 (3.3)	46 (4.8)	98 (2.9)
Microtus subterraneus	0	0	0	0	6 (2.8)	0	6 (0.2)
M. arvalis	25 (6.0)	242 (53.9)	121 (42.5)	427 (38.5)	109 (51.2)	408 (43.0)	1 332 (38.9)
M. agrestis	9 (2.2)	0	0	8 (0.7)	0	45 (4.7)	62 (1.8)
M. oeconomus	366 (87.6)	143 (31.8)	54 (18.9)	376 (33.9)	13 (6.1)	64 (6.7)	1 016 (30.0)
Microtus sp.	0	14 (3.1)	11 (3.9)	42 (3.8)	16 (7.5)	295 (31.1)	378 (11.0)
Mus musculus	1 (0.2)	0	4 (1.4)	2 (0.2)	6 (2.8)	0	13 (0.4)
Rattus norvegicus	2 (0.5)	0	0	0	0	0	2 (0.1)
Apodemus agrarius	0	8 (1.8)	28 (9.8)	64 (5.8)	6 (2.8)	41 (4.3)	147 (4.3)
A. sylvaticus	0	9 (2.0)	1 (0.4)	2 (0.2)	27 (12.7)	1 (0.1)	40 (1.2)
A. flavicollis	0		2 (0.7)	10 (0.9)	0	22 (2.3)	34 (1.0)
Apodemus sp.	0	11 (2.4)	8 (2.8)	26 (2.3)	14 (6.6)	23 (2.4)	82 (2.4)
Micromys minutus	1 (0.2)	16 (3.6)	4 (1.4)	88 (7.9)	2 (0.9)	0	111 (3.2)
Aves	0	1 (0.2)	35 (12.3)	16 (1.4)	6 (2.8)	1 (0.1)	59 (1.7)
Amphibia (Anura)	0	0	7 (2.5)	0	0	0	7 (0.2)
Total	418 (100.0)	449 (100.0)	285 (100.0)	1 109 (100.0)	213 (100.0)	949 (100.0)	3 423 (100.0)
S	0.23	0.61	0.76	0.72	0.70	0.71	–

* Share of each prey category (%).

genus *Microtus*, especially *M. arvalis* and *M. oeconomus*, dominate in the owl's diet in Poland. Similarly high share of these rodents was noted, for example in Wielkopolska (Goszczyński 1981), Silesia (Pawłowska-Indyk et al. 1998), Małopolska (Grzędzicka 2014), or in the Pilica river valley (Stolarz and Lesiński 2015). Results of most of these studies indicate significant prevalence of

M. arvalis – at some sites its share exceeded 80% of all prey (Goszczyński 1981, Pawłowska-Indyk et al. 1998, Dziemian et al. 2012, Grzędzicka 2014, Gryz and Krauze-Gryz 2015, Wilniewczyc and Gwardjan 2015). This was caused by the fact that studies were usually carried out in areas of a small share of wetlands. In the Pilica river valley, however, *M. oeconomus* predominated over *M. arvalis* in the proportion of 55.3–30.7% (Stolarz and Lesiński 2015), which was confirmed by our data from the Biebrza river valley. In the latter valley covered by large wetland areas the domination of *M. oeconomus* in the diet of the long-eared owl was the highest ever noted in Poland (87.6%). In other river valleys (Narew, Vistula) the share of this species was also high (18.9–31.8%) exceeding those demonstrated at other sites of the country. Domination of two *Microtus* species confirms, that the main hunting grounds of the long-eared owl are open habitats of different moisture from crop fields to meadows and pastures to sedge wetlands.

Common and numerous, typically forest rodents (*M. glareolus*, and particularly *A. flavicollis*) belonged to rare prey species of the long-eared owl (about 4% – Table), which is characteristic for the diet of this owl: about 7% reported by Ruprecht and Szwagrzak (1988), about 5% by Goszczyński (1981), about 3% by Cichocki et al. (2008), about 1% by Dziemian et al. (2012). Small shares of birds, soricomorphs and synanthropic rodents (*Mus musculus*, *Rattus norvegicus*): less than 2% of each group of the prey (Table) confirm results of the studies published so far. For example, in the winter diet of the long-eared owl from Rzeszów (Dziemian et al. 2012) and from Śląska Lowland (Cichocki et al. 2008) birds constituted 0.2 and 1% of prey, respectively, soricomorphs 0.2 and 1.3%, and synanthropic rodents 0.1 and 0.8% of prey, respectively.

CONCLUSIONS

Data on the winter diet of the long-eared owl in central and north-eastern Poland lead to the conclusion that the species selects open areas as hunting grounds in river valleys, agricultural landscapes and a forest complex. However, in particular areas the share of prey, especially of the species being the main components of the owl's diet (*M. arvalis*, *M. oeconomus*), may differ. The factor mostly differentiating the structure of potential prey species can be the moisture of open habitats.

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Streszczenie: *Zimowa dieta uszatki* Asio otus *w różnych środowiskach środkowej i północno-wschodniej Polski*. Zbadano zmienność diety uszatki na wybranych terenach środkowej i północno-wschodniej Polski, które reprezentowały trzy doliny dużych rzek, dwa krajobrazy rolnicze oraz kompleks leśny. Analiza wypluwek zebranych w latach 1981–2013 dostarczyła danych na temat 3423 osobników ofiar. Zimowy pokarm tej sowy na objętych badaniami terenach był zdominowany przez gatunki z rodzaju *Microtus* (65,3–95,7% ofiar), podczas gdy typowo leśne gryzonie (*Myodes glareolus*, *Apodemus flavicollis*) stanowiły łącznie tylko 3,9% ofiar. W dolinach rzecznych stosunkowo często sowy polowały na *Microtus oeconomus*, który w dolinie Biebrzy był najczęstszą ofiarą (87,6%). Poza dolinami rzecznymi jego udział w diecie uszatki był zróżnicowany, a liczebnie zdecydowanie dominował *Microtus arvalis*. *Apodemus agrarius* był łowiony rzadko (średnio 4,3% ofiar). *Micromys minutus* był stosunkowo częstą ofiarą tylko w Puszczy Kampinoskiej (7,9%). W dolinie Biebrzy, na Suwalszczyźnie i w Puszczy Kampinoskiej w diecie uszatki wystąpił *Arvicola amphibius*. Ptaki łowione były rzadko, stosunkowo najczęściej w dolinie Wisły. Uszatka poluje głównie na łowiskach zlokalizowanych na terenach otwartych, gdzie udział w jej diecie dwóch głównych ofiar (*M. arvalis*, *M. oeconomus*) zależy w dużej mierze od wilgotności habitatów tych obszarów.

Słowa kluczowe: dieta sów, wypluwki, dolina rzeczna, krajobraz rolniczy, las

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Influence of housing system on selected quality characteristics of duck meat. Chapter 1. Pekin duck

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Abstract: *Influence of housing system on selected quality characteristics of duck meat. Chapter 1. Pekin duck.* The objective of this study was to determine the effect of housing system on the selected quality characteristic of breast muscles of Pekin (P-44) ducks. The ducks were divided into four experimental groups according to their sex and housing system: intensive system (IS) and outdoor system (OS). Analysis was performed for a total of 48 breast muscle (12 in each experimental group: 2 × gender; 2 × rearing system). For test samples of meat there were determined: chemical composition: moisture, protein, fat, ash and pH_{24}, cooking loss (%), shear force (N), color, flavor, tenderness, juiciness, stringiness and overall consumer acceptance. There was no effect of housing system on the proximate composition of breast muscles of both P-44 ducks. Rearing system of ducks P-44 had significant (P <0.05) effect on cooking loss, L*, tenderness, juiciness and overall acceptation. The meat of males vs females P-44, regardless of the rearing system, was characterized by significantly (P <0.05) higher L* value and lower a*. The Principal Component Analysis (PCA) showed, that meat of P-44 ducks from free range system is better perceived by the consumers than the meat of P-44 ducks from the intensive system, mainly for its greater tenderness and juciness.

Key words: Pekin duck, rearing system, meat quality

INTRODUCTION

Chicken and turkey broilers take the greatest share in the world production of poultry meat. In certain European countries, for instance in France or Czech Republic, similar to Asian market, an increase in the production of slaughter ducks is observed (Huda et al. 2011). Duck meat is highly appreciated as it combines the characteristics of red meat (containing, for example, high levels of phospholipids, precursors of aromas) and the dietetic characteristics of poultry meat (containing, for example, high levels of unsaturated fatty acids). Duck meat has higher fat content and also higher levels of heme pigments (hemoglobin and myoglobin) than chicken and turkey meat (Smith et al. 1993, Baéza 2006a, Witak 2008).

Qualitative properties of duck meat can be developed by the following factors: genotype, age, sex, feeding and keeping conditions (Baéza 2006a, Chartrin et al. 2006, Castellini et al. 2008). In Europe, the ducks most commonly used for the production of broilers are

the Pekin ducks. Rearing period of the Pekin ducks (males and females) lasts 7 weeks.

In Europe the leading housing system of poultry is the intensive system (Baéza 2006b). However, every year poultry production, especially of chicken broilers, increases in both the systems, free range and ecological, which, according to numerous authors (Pietrzak et al. 2006, Mikulski et al. 2011, Zhao et al. 2014), ensures better welfare of the birds and at the same time the meat obtained from them is characterized by higher quality. For consumers the welfare of the birds becomes an increasingly important factor taken into consideration while purchasing meat products (Napolitano et al. 2010, Norwood and Lusk 2011). Aim of the study was to determine the effect of the housing system on selected quality characteristics of Pekin (P-44) duck meat.

MATERIAL AND METHODS

Experimental materials and procedures

The study material consisted of the breast muscles of Polish Pekin ducks of the P-44 line (Kokoszyński et al. 2010). To 3 weeks of age all birds (180 males and 180 females) were kept according to the guidelines for intensive production system on deep litter and at a stocking density of 2.9 birds per 1 m^2. Thereafter, half the ducks and drakes were allowed to use free ranges, at a stock density of 0.08 birds per 1 m^2 (outdoor system – OS). The remaining birds were kept under conditions of intensive production (IS) throughout the rearing period. Production results of ducks related to the growth characteristics, fodder use, mortality and slaughter efficiency have already been published (Damaziak et al. 2014). The P-44 ducks and drakes were kept until 7 weeks of age. After rearing was finished, 12 males and 12 females with body weight similar to the mean for a given sex were selected for slaughter. Slaughter of ducks and post-slaughter processing were conducted using the industrial method, in accordance with the technical sanitary requirements of the poultry industry. Carcasses were chilled with the use of the air chilling method at a temperature of 4°C for 24 h. After cutting breast muscles (*pectoralis major*) from the carcasses, test samples were prepared in accordance with the methodology described by Murawska (2012).

Physico-chemical analysis

Percentage moisture, protein, fat and ash content were determined in meat samples according to the Association of Official Analytical Chemists (AOAC 2005). All chemical analyses were carried out in duplicate. Moisture content by drying a ca 5 g test sample at 105°C (±2°C) until reaching a constant weight; ash content by incinerating a ca 3–5 test sample in a muffle furnace at 550°C until light grey ash results; protein content by the classical marco-Kjeldahl method using Kjeltec System 1026 Distilling Until (Foss Tecator, Höganäs, Sweden); and fat content by petroleum ether ex-

traction using a Büchi Extraction System B-811 (Büchi Labortechnik AG, Flawil, Switzerland).

Ultimate pH (pH_{24}) was measured with a CP-411 pH-meter (Elmetron, Zabrze, Poland), with a glass-calomel electrode, after the homogenization of 10 g raw muscle with 10 mL distilled water. The pH-meter was calibrated in buffers of pH 4.00 and pH 7.00 at 20°C. All results were expressed as the average values obtained from two separate measurements. The L*a*b* color parameters (CIELAB color space; CIE, 1986) were determined on the surface of freshly ground duck meat with a Minolta spectrophotometer CM-2600d (Konica Minolta LTD, Tokyo, Japan: light source D65, observer 10°, a measuring head hole 8 mm) calibrated to the white plate (L* = 99.18, a* = −0.07 and b* = −0.05). The color parameters were represented on the CIE color scales in terms of L* (lightness per darkness), a* (redness per greenness) and b* (yellowness per blueness). Each measurement was performed in five replicates, taking the mean value as the assay result. For the calculation of absolute color difference (between color of breast muscles in IS and OS ducks) the following formula was used:

$$\Delta E = \sqrt{(L^*_1 - L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1 - b^*_2)^2}$$

where:
ΔE – absolute color difference;
L^*_1, a^*_1, b^*_1 – breast muscle color parameters in IS ducks;
L^*_2, a^*_2, b^*_2 – breast muscle color parameters in OS ducks.

In the elaboration of the results the criterion adopted by the International Commission on Illumination was used, according to which absolute color differences (ΔE) are classified as perceived by the human eye. It was assumed that absolute color differences between 0 and 2 are undistinguishable, from 2 to 3.5 distinguishable by an experienced observer, and over 3.5 the clear differences between colors are easily observed (Heidelberg-Anonim 1999).

The cooking loss of intact fillets were determined by weighing the fillets and then cooking in a convection oven on aluminum trays at 180°C to an internal temperature of 75°C. The fillets were drained, allowed to equilibrate to room temperature, and weighed. Cooking loss was determined by expressing cooked sample weight as a percentage of precooked sample weight following the procedure of Bianchi et al. (2005). Twenty-four hours after heat treatment, from each muscle five samples with cross section (1 × 1 cm) were cut out along the muscle fibers. They were used for the measurement of share force with the use of the research device Zwicki 1120 (Zwick, Germany), equipped with the Warner-Bratzler shear device. Maximum share force (F_{max}) was read at the head speed of 0.83 mm/s. The experiment was conducted until the decrease of the share force, after cutting the sample, reached 75% F_{max}. As the result of the determination mean from five measurements was

adopted. Sensory evaluation of the breast muscles was conducted by a 12-member team with the appropriate qualifications. Equal bite size from each treatment was coded, replicated thrice and served in odorless plastic plates. Each sample was evaluated independent of the other. The samples were evaluated on a nine-point hedonic scale for color, flavor, tenderness, juiciness, stringiness and overall acceptability (9 is extremely desirable and 1 is extremely undesirable).

Statistical analysis

Prior to the statistical analysis, data were checked for normality by the Shapiro–Wilk test. The homogeneity of variance across treatments was assessed by Levene test. The statistical analysis was conducted with the Software System Statistica ver. 10 (StatSoft Inc. 2011). For the critical level of significance $P<0.05$ was adopted. Differences of determined characteristics were analyzed with the use of two-way analysis of variance including the housing system and sex, according to the following model:

$$Y_{ij} = \mu + P_i + U_j + (PU)_{ij} + e_{ij}$$

where:
Y – trait;
μ – general mean;
P_i – effect of i-th sex, $i = 1.2$;
U_j – effect of j-th housing system;
$(PU)_{ij}$ – effect of interaction between sex and housing system;
e_{ij} – random error.

To estimate statistical difference between average values the Tukey test was applied. Furthermore the results were developed using the Principal Component Analysis (PCA). This method makes it possible to study the relationships between hierarchical variables and their graphical presentation in the form of data points (retaining a maximum amount of information), whose mutual arrangement is the result of the analysis.

RESULTS AND DISCUSSION

Keeping conditions and gender did not significantly influence the proximate chemical composition of the breast muscles (Table 1). Similar results were obtained by Witak (2008) and Erisir et al. (2009), who studied the effect of housing system and gender on the chemical composition of Pekin Star 52 duck meat.

No significant effect of housing conditions on pH_{24} of breast muscles of P-44 (Table 2) ducks was determined. The mean pH value of duck meat is generally between 5.7 and 5.9 (Larzul et al. 2006, Witak 2008). The amount of cooking loss during heat treatment of breast muscles of P-44 OS ducks was significantly higher ($P<0.05$) than in P-44 IS. No effect of housing conditions on breast muscle texture of P-44 (Table 2) ducks was determined. Breast muscles of P-44 IS ducks were characterized by darker color than in P-44 OS, which is evidenced by significantly ($P<0.05$) lower values of the L* color parameter (Table 2). However, the calculated absolute color differences indicate that these

TABLE 1. Effect of housing system and sex on the chemical composition of the breast muscles of P-44 ducks (each value is presented as mean ±*SD*; *n* = 12)

Specification	Sex	Chemical composition (%)			
		moisture	protein	fat	ash
Intensive system	males	76.5 ±0.2	20.2 ±0.1	1.8 ±0.1	1.5 ±0.1
Outdoor system		76.8 ±0.1	20.0 ±0.1	1.7 ±0.1	1.5 ±0.1
Intensive system	females	76.3 ±0.2	20.3 ±0.4	1.9 ±0.2	1.5 ±0.1
Outdoor system		76.8 ±0.3	19.7 ±0.1	2.0 ±0.1	1.5 ±0.1
Housing system		NS	NS	NS	NS
Sex		NS	NS	NS	NS
Housing system × sex		NS	NS	NS	NS

NS – not significant ($P > 0.05$).

TABLE 2. Effect of housing system and sex on the physico-chemical properties of the breast muscles of P-44 ducks (each value is presented as mean ±*SD*; *n* = 12)

Treatment	Sex	pH_{24}	Cooking loss (%)	Shear force (N)	Color			Δ*E*
					lightness L*	redness a*	yellowness b*	
Intensive system	males	5.9 ±0.0	20.5 ±0.3	30.7 ±1.4	38.6 ±1.1	11.4 ±0.6	13.3 ±0.1	1.4
Outdoor system		5.9 ±0.0	24.3 ±0.7	29.1 ±3.6	39.9 ±0.9	11.3 ±0.2	13.8 ±0.6	
Intensive system	females	5.9 ±0.0	19.9 ±0.7	32.3 ±3.7	34.5 ±1.6	12.0 ±0.5	13.5 ±0.2	3.2
Outdoor system		5.9 ±0.0	24.8 ±0.3	30.6 ±0.9	37.5 ±0.3	12.9 ±0.6	13.4 ±0.3	
Housing system		NS	**	NS	**	NS	NS	×
Sex		NS	NS	NS	**	**	NS	
Housing system × × sex		NS	NS	NS	**	NS	NS	

** Difference significant; NS – not significant ($P > 0.05$).

differences can only be distinguished by an experienced observer (Heidelberg-Anonim 1991). In the sensory evaluation, scores for the color of breast muscles of P-44 IS and P-44 OS ducks were determined at a similar level (Table 3). Regardless of the housing conditions, the breast muscles of P-44 female ducks showed significantly ($P < 0.05$) lower values of the L* color parameter and higher a* color parameter than of the males.

Color is one of the more important meat quality characteristics from the consumer's viewpoint. It is also an important indicator of the technological applicability of meat as a raw material, which can then be directly sold or sent for further processing (Wołoszyn et al. 2009, Mikulski et al. 2011). In the sensory evaluation (Table 3) breast muscles of P-44 OS ducks received significantly ($P < 0.05$) higher scores for such charac-

TABLE 3. Effect of housing system and sex on the sensory attributes of the breast muscles of P-44 ducks (each value is presented as mean ±*SD*; *n* = 12)

Specification	Sex	Color	Flavor	Tenderness	Juiciness	Stringiness	Overall acceptance
Intensive system	males	5.3 ±0.1	5.3 ±0.1	5.8 ±0.1	5.0 ±0.1	5.0 ±0.3	5.6 ±0.1
Outdoor system		5.3 ±0.3	5.3 ±0.1	6.4 ±0.1	5.1 ±0.1	5.4 ±0.3	6.1 ±0.1
Intensive system	females	5.3 ±0.1	5.3 ±0.1	6.2 ±0.2	4.9 ±0.1	5.0 ±0.2	6.0 ±0.1
Outdoor system		5.3 ±0.2	5.4 ±0.2	6.4 ±0.2	5.3 ±0.2	5.1 ±0.3	6.1 ±0.1
Housing system		NS	NS	**	**	NS	**
Sex		NS	NS	**	NS	NS	**
Housing system × sex		NS	NS	**	**	NS	**

** Difference significant; NS – not significant ($P > 0.05$).

teristics as tenderness, juiciness and overall acceptability, compared to P-44 IS.

Table 4 contains the loadings for the first three principal components (PCs) with their variances of the breast muscles of P-44 ducks (male and female). The PC1 explained for 33.12% of the total variance and was associated with tenderness, overall acceptability, cooking loss and stringiness. The PC2 accounted for 25.63% of the total variance and was associated with juiciness and L*. On the other hand, PC3 explains 19.85% of variance and was formed by share force and fat. Distribution of meat samples of P-44 (male and female) ducks kept in intensive and outdoor system is shown on the PCA map (Fig.). Proximate position of the meat samples on the PCA map demonstrates their similarity, the distance demonstrates their differences. P-44 duck meat samples coming from different housing systems were heterogeneous. Breast muscles of male and female P-44 ducks from the OS system formed a cumulative group located on the right side of the PCA map. They were characterized by greater overall acceptability, especially due to greater tenderness than P-44 from the IS system (located on the left side of the PCA map). PCA demonstrated that meat of female P-44 ducks from the IS system was better perceived by consumers than the meat of males, primarily due to greater tenderness and juiciness. The sensory quality of IS ducks' meat was strongly dependent on its stringiness. This trait was the reason of worse (lower) consumer evaluation (Fig.).

TABLE 4. Loadings for the first three PCs of the breast muscles of P-44 ducks (male and female)

Traits	PC1	PC2	PC3
Tenderness	0.261	0.006	0.008
Juiciness	0.021	0.253	0.152
Stringiness	0.189	0.171	0.035
Overall acceptance	0.209	0.068	0.013
Cooking loss (%)	0.261	0.081	0.305
Lightness L*	0.019	0.295	0.001
Fat	0.001	0.053	0.443
Share force	0.037	0.081	0.305

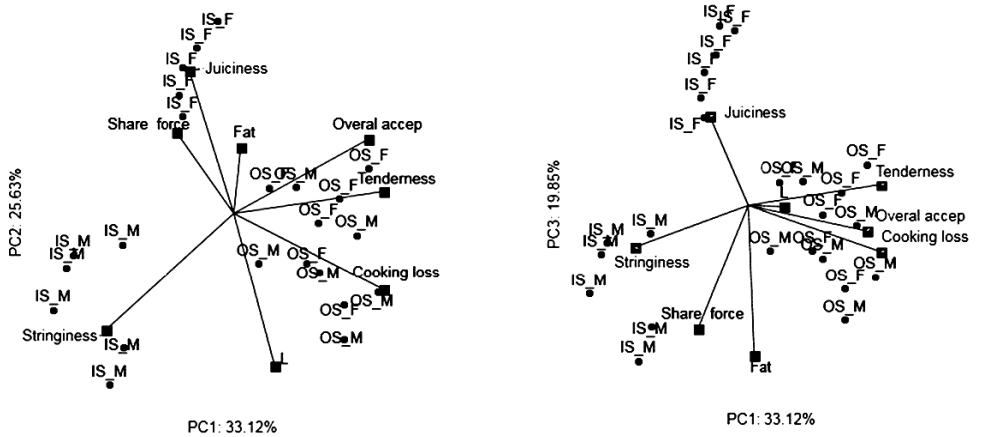

FIGURE. PCA biplot of breast muscle samples of P-44 ducks: IS_F – females, IS_M – males kept in intensive system; OS_F – females, OS_M – males kept in outdoor system

CONCLUSIONS

This study demonstrates that to obtain high quality meat, P-44 ducks can be successfully kept in the outdoor system. Such meat might be an interesting proposition for consumers, who, while purchasing meat products, pay attention not only to their high quality, but also to the welfare of the birds before slaughter. Future research should be broadened to include the interaction of origin, age, sex and housing system of ducks. Rearing system of ducks had no significant effect on chemical composition, pH_{24} and cutting force, but influenced meat color. The meat of ducks from free range rearing system were brighter than the meat from the intensive rearing. Free range rearing system brought a positive effect on the examined traits of P-44 ducks' meat. Better tenderness and juiciness were the features of the meat from the ducks reared in free range system than the ones fed intensively.

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Streszczenie: *Wpływ system utrzymania na wybrane cechy jakościowe mięsa kaczek. Część 1. Kaczki Pekin*. Celem niniejszych badań było określenie wpływu systemu utrzymania na wybrane cech jakościowych mięśni piersiowych kaczek Pekin (P-44). Kaczki podzielono na cztery grupy doświadczalne w zależności od płci i systemu utrzymania: system intensywny (IS) i system z dostępem do wybiegu (OS). Analizy przeprowadzono łącznie dla 48 mięśni piersiowych (po 12 dla każdej grupy doświadczalnej: 2 × płeć; 2 × system utrzymania). Dla badanych prób mięsa oznaczono: skład chemiczny: zawartość wody, białka, tłuszczu i popiołu, pH_{24}, wyciek termiczny (%), siłę cięcia (N), barwę, smak, kruchość, soczystość, sprężystość i ogólną akceptację konsumenta. Nie stwierdzono wpływu systemu utrzymania na skład chemiczny mięśni piersiowych kaczek P-44. System chowu kaczek P-44 miał znaczący (P <0,05) wpływ na straty podczas obróbki cieplnej, L*, kruchość, soczystość i ogólną akceptację konsumenta. Mięso samców w porównaniu z mięsem samic P-44 bez względu na system utrzymania charakteryzowały znacznie (P <0,05) większe wartości L* i mniejsze wartości a*. Statystyczna wielowymiarowa analiza składowych głównych (PCA) wykazała, że mięso kaczek P-44 utrzy-

mywanych w systemie wolno wybiegowym było lepiej postrzegane przez konsumentów w porównaniu z mięsem kaczek P-44 utrzymywanych w systemie intensywnym, głównie ze względu na większą kruchość i soczystość.

Słowa kluczowe: kaczki pekin, system utrzymania, jakość mięsa

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Polymorphism of the *PRNP* gene in Polish Merino and old-type Polish Merino in flock with clinical status of atypical scrapie

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Abstract: *Polymorphism of the* PRNP *gene in Polish Merino and old-type Polish Merino in flock with clinical status of atypical scrapie*. The study was conducted in 2014 in flock located in West Pomerania Province, on 378 ewes and 96 rams of Polish Merino and 416 ewes and 58 rams old-type Polish Merino. All animals were subjected to the identification of the *PRNP* gene polymorphism. Based on the studies, there were no effects of breed and sex within breed on frequency of scrapie alleles and genotypes. In Polish Merino were found five alleles (ALRR, ALRQ, ALHQ, AFRQ, VLRQ), and in old-type Polish Merino six alleles (additional – VLRR allele). There were identified nine genotypes of *PRNP* gene in Polish Merino and 11 in old-type Polish Merino. Very high frequencies of ALRR/ALRR, ALRR/ALRQ, ALRR/ALHQ genotypes were stated in both breeds with low level of genotypes with valine amino acid. In both breeds was found only one allele with phenylalanine amino acid at codon 141 – AFRQ, which appeared in three genotypes (in combination with ALRR, ALRQ, ALHQ), which determined low level of resistant to atypical scrapie. Breeding work assumption, which requires elimination individuals with valine amino acid at codon 136 and phenylalanine amino acid at codon 141, and introduce to sheep population rams with ALRR allele would led to higher frequency of ALRR/ALRR genotype and ALRR allele in sheep population. That indicates the advisability of such breeding work, which is worth to recommend for genetic improvement of all sheep breeds in Poland

Key words: sheep, PRNP, alleles, genotypes, polymorphism

INTRODUCTION

The prevention, control, and eradication of transmissible spongiform encephalopathies are regulated by EU legislation (Regulation EC 999/2001, Regulation EC 260/2003, Commission decision C/2003/498). Among sheep there are two forms of scrapie: classic – which is genetically determined, and atypical. Polymorphisms of prion protein gene located at codons 136, 154, 171 were considered as a genetically responsible for occurrence of classic scrapie (Lühken et al. 2004, Kaal and Windig 2005, Kaam et al. 2005, Palhiere et al. 2008). As a guarantee of lowest sensitivity to scrapie ARR allele was regarded (created as a result of encoding alanine – A, arginine – R and also arginine – R), while VRQ allele (created as a result of encoding valine – V, arginine – R, glutamine – Q) was regarded as responsible for susceptibility to that disease (Kaal and Windig 2005, Kaam et al. 2005, Palhiere et al. 2008, Rejduch et al. 2009). In case of atypical

form of scrapie (Nor98), which first case was described by Benestadt et al. (2003), it concerned alleles located at codon 141 (Goldman 2008, Mcintyre 2008, Mazza et al. 2010) which encoding leucine (L) and phenylalanine (F). Allele F more often accompanied to clinical status of atypical scrapie. Moreover, classical and atypical scrapie could coexist in the same sheep flock (Mazza et al. 2010). So far in Poland, studies were performed to monitor the presence of classic scrapie alleles in many breeds (Palhiere et al. 2008, Rejduch et al. 2009, Wiśniewska and Mroczkowski 2009), despite the fact that in 2009 first case of atypical scrapie was found (Polak et al. 2010). The results of previous studies showed the absence of alleles encoding valine at codon 136 in Wrzosówka sheep and various frequency of its presence in other breeds (Rejduch et al. 2009, Wiśniewska and Mroczkowski 2009, Niżnikowski et al. 2014). Relatively not many papers are related to scrapie alleles located at codon 141 (Niżnikowski et al. 2014). It is worth to conduct breeding work which aims to eliminate VRQ allele from sheep population and also eliminate phenylalanine amino acid encoded at codon 141 in order to improve the genetic resistance to both scrapie forms in sheep population. Therefore, direction of the research aimed to determine the frequency of occurrence of scrapie genetic conditions in both breed kept in the same flock, in which clinical status of atypical scrapie was found.

MATERIAL AND METHODS

The study was conducted in 2014 on Polish Merino and old-type Polish Merino kept in one flock located in West Pomerania Province, in which in 2013 clinical status of atypical scrapie was found. The study was performed on foundation stock ewes (Polish Merino – 378; old-type Polish Merino – 416) and stud rams (Polish Merino – 96; old--type Polish Merino – 58) which were born in 2003–2013. Blood was collected from the jugular vein into tubes containing EDTA. The DNA was isolated from blood leukocytes. In order to obtain high quality DNA suitable for multiple use, blood was purified from the heme compounds, which were erythrocyte lysis products. The DNA was isolated by chromatography on mini-columns of silicate (A&A Biotechnology, Poland), and subsequently served as a template DNA for amplification of polymorphic gene allele fragment. Sample genotyping was performed with KASPar® system (www.kbioscience.co.uk), which uses a single nucleotide polymorphism (SNP) based on primers listed in Table 1. A high reliability of SNP genotyping method compared to the sequencing method was proved by Green et al. (2006). Based on the reading of genotyped DNA samples within the ewes and rams, distribution of alleles and genotype was determined. It was preparatory act to the next stages of research. For statistical calculations SPSS ver. 22 software was used. To compare distribution of alleles and genotypes between breeds and sexes within breeds test χ^2 was used.

TABLE 1. The primers and SNP of the *PRNP* prion protein gene

Locus	Primers 5'-3'	SNP	Changes	Position
PRNP prion protein	CACAGTCAGTG-GAACAAGCC/ /CTTTGCCAGGT-TGGGG	AY909542:g.385A>G	A/G	exon 3
		AY909542:g.386G>T	G/T	exon 3
		AY909542:g.479C>T	C/T	exon 3
		AY909542:g.493C>T	C/T	exon 3
		AY909542:g.534G>A	G/A	exon 3

RESULTS AND DISCUSSION

The distribution of alleles in assessed breeds within sex are presented in Table 2. There were no statistically significant differences in frequencies of alleles and in sexes within breed in both breeds. It was found six alleles (ALRR, ALRQ, ALHQ, AFRQ, VLRQ, VLRR). All alleles were found in old-type Polish Merino whereas in Polish Merino VLRR allele was not observed. Allele with highest frequency was ALRR allele, equally ALRQ allele, whereas allele with the lowest frequency was ALHQ allele. Among alleles, which could cause scrapie, AFRQ allele was found in both

TABLE 2. Frequency of *PRNP* allele occurrence in order to breed and sex

Breed	Sex	Unit	Alleles						Total
			ALRR	ALRQ	ALHQ	AFRQ	VLRR	VLRQ	
Polish Merino	♀	n	194	162	7	6	0	9	378
		%	51.3	42.9	1.9	1.6	0.0	2.4	100.0
	♂	n	51	43	2	0	0	0	96
		%	53.1	44.8	2.1	0.0	0.0	0.0	100.0
Polish Merino Total	×	n	245	205	9	6	0	9	474
		%	51.7	43.2	1.9	1.3	0.0	1.9	100.0
Old-type Polish Merino	♀	n	225	154	4	30	1	2	416
		%	54.1	37.0	1.0	7.2	0.2	0.5	100.0
	♂	n	36	17	0	4	0	1	58
		%	62.1	29.3	0.0	6.9	0.0	1.7	100.0
Old-type Polish Merino Total	×	n	261	171	4	34	1	3	474
		%	55.1	36.1	0.8	7.2	0.2	0.6	100.0
Sex Total	♀	n	419	316	11	36	1	11	794
		%	52.8	39.8	1.4	4.5	0.1	1.4	100.0
	♂	n	87	60	2	4	0	1	154
		%	56.5	39.0	1.3	2.6	0.0	0.6	100.0
Total	×	n	506	376	13	40	1	12	948
		%	53.4	39.7	1.4	4.2	0.1	1.3	100.0

Breed effect – NS; sex effect within breed – NS.

breeds and according to various papers it could indicate susceptibility to atypical scrapie (Goldman 2008, Mcintyre 2008). Moreover VLRQ and VLRR alleles were found which determine genetic susceptibility to classical scrapie (Rejduch et al. 2009, Wiśniewska and Mroczkowski 2009, Niżnikowski et al. 2014). Noticeable is a fact that allele F, which is at codon 141 was state only in AFRQ combination. The rest alleles had leucine amino acid (L) in that place. Frequency of this allele for all animals was 4.2% whereas in each breeds – 1.3% for Polish Merino and 7.2% for old-type Polish Merino. Frequency of scrapie genotypes are presented in Table 3. Similar to alleles, there were no impact of breed and sex within breed on scrapie genotypes distribution. However, it is worth to focus on following results. In old-type Polish Merino 11 genotypes were found and in Polish Merino were found nine genotypes (without ALHQ/AFRQ and VLRR/ALRQ). In both breeds relatively low frequency of the most valuable genotype – ALRR/ALRR was state, whereas heterozygous genotypes of ALRR allele combined with other alleles (with exception AFRQ, VLRQ, VLRR) represented 40% of all. That gives the general opinion that favorable scrapie conditions occurred with a high frequency in both breeds. Interestingly it should be considered configurations in what occurred AFRQ allele. These were ALRR/AFRQ, ALRQ/AFRQ and ALHQ /AFRQ genotypes. ALRQ/AFRQ and ALHQ /AFRQ genotypes occurred only in old-type Polish Merino. AFRQ allele had a high frequency in studied sheep population, completely different from those seen in other herds (Niżnikowski et al. 2014). In national sheep breeds AFRQ allele does not occurred (Żelaźnieńska Sheep and Podlaska Sheep) or occurred in single flocks (Niżnikowski et al. 2014). In this situation there is an urgent need to eliminate animals that has phenylalanine amino acid at codon 141. It could be assumed, that high frequency of this allele favor appearance of clinical forms of atypical scrapie in studied flock (Benestadt 2003). Two alleles which determine genetic susceptibility to classical scrapie were found in tested animals: typical VLRQ allele (Rejduch et al. 2009, Wiśniewska and Mroczkowski 2009, Niżnikowski et al. 2014), and very rare VLRR allele (only in one old-type Polish Merino ewe). Considering alleles frequencies determining susceptibility to classical scrapie, it should be point its extremely low level compared to results from other work carried out on Polish Merino and old-type Polish Merino (Rejduch et al. 2009, Wiśniewska and Mroczkowski 2009). Summing up the results it is need to remove from flock all individuals with AFRQ allele (six Polish Merino ewes and 30 ewes and four trams of old-type Polish Merino) and individuals with VLRR allele (one old-type Polish Merino ewe) and VLRQ allele (nine Polish Merino ewes and two ewes and ram of old-type Polish Merino). Results show to eliminate 53 animals which was 5.59% of all; 3.2% from Polish Merino and 8.0% from old-type Polish Merino. It should be em-

TABLE 3. Frequency of *PRNP* genotypes occurrence in order to breed and sex

Breed	Sex	Unit	Genotypes											Total
			ALRR/ /ALRR	ALRR/ /ALRQ	ALRR/ /ALHQ	ALRR/ /AFRQ	ALRQ/ /ALRQ	ALRQ/ /AFRQ	ALRQ/ /ALHQ	ALHQ/ /AFRQ	VLRR/ /ALRQ	VLRQ/ /ALRR	VLRQ/ /ALRQ	
Polish Merino	♀	n	46	87	6	4	34	2	1	0	0	5	4	189
		%	19.4	36.7	2.5	1.7	14.3	0.8	0.4	0.0	0.0	2.1	1.7	79.7
	♂	n	13	24	1	0	9	0	1	0	0	0	0	48
		%	5.5	10.1	0.4	0.0	3.8	0.0	0.4	0.0	0.0	0.0	0.0	20.3
Polish Merino Total	×	n	59	111	7	4	43	2	2	0	0	5	4	237
		%	24.9	46.8	3.0	1.7	18.1	0.8	0.8	0.0	0.0	2.1	1.7	100.0
Old-type Polish Merino	♀	n	57	92	1	17	23	12	2	1	1	1	1	208
		%	24.1	38.8	0.4	7.2	9.7	5.1	0.8	0.4	0.4	0.4	0.4	87.8
	♂	n	12	9	0	2	3	2	0	0	0	1	0	29
		%	5.1	3.8	0.0	0.8	1.3	0.8	0.0	0.0	0.0	0.4	0.0	12.2
Old-type Polish Merino Total	×	n	69	101	1	19	26	14	2	1	1	2	1	237
		%	29.1	42.6	0.4	8.0	11.0	5.9	0.8	0.4	0.4	0.8	0.4	100.0
Sex Total	♀	n	103	179	7	21	57	14	3	1	1	6	5	397
		%	21.7	37.8	1.5	4.4	12.0	3.0	0.6	0.2	0.2	1.3	1.1	83.8
	♂	n	25	33	1	2	12	2	1	0	0	1	0	77
		%	5.3	7.0	0.2	0.4	2.5	0.4	0.2	0.0	0.0	0.2	0.0	16.2
Total	×	n	128	212	8	23	69	16	4	1	1	7	5	474
		%	27.0	44.7	1.7	4.9	14.6	3.4	0.8	0.2	0.2	1.5	1.1	100.0

Breed effect – NS; Sex effect within breed – NS.

phasized that in old-type Polish Merino was need to eliminate a much larger number of sheep than in Polish Merino. The mere fact of a high frequency of AFRQ allele and reveal clinical status of atypical scrapie fully justified the need for genotyping and elimination animals characterized by a genetic susceptibility to both forms of scrapie, which in the tested flock was done in accordance with the recommendations arising from other research (Goldman 2008, Mcintyre 2008, Rejduch et al. 2009, Wiśniewska and Mroczkowski 2009, Niżnikowski et al. 2014). ALRR/AFRQ genotype is an answer for question, why in various papers genetically resistant conditions for scrapie (ALRR allele) did not protect against atypical form of scrapie (genotypes with AFRQ allele). According to breeding work ALRR/AFRQ and VLRQ/ALRR genotypes should be consider as an unwanted. In both cases resistant conditions for classical scrapie in heterozygous genotypes form was connected with genetically susceptible condition for atypical (AFRQ) and classical (VLRQ) scrapie. Both genotypes should be eliminated from flock, but in case of small populations it may raise doubts. In such cases, all sheep should be used in reproduction and their progeny should be genotype obligatory. That allow to choose animals for further breeding without valine amino acid at codon 136 (Lühken et al. 2004, Palhiere 2008, Rejduch et al. 2009, Niżnikowski et al. 2014) and phenylalanine amino acid at codon 141 (Goldman 2008, Mcintyre 2008). Suggestions appearing in many papers about elimination conditions that encode valine amino acid at codon 136 has been proven to realize through appropriate breeding work (Lühken et al. 2004, Palhiere 2008, Rejduch et al. 2009, Niżnikowski et al. 2014). Applied breeding program has been fully confirmed and worthy to recommend into practice in order to eliminate from the sheep population genetically susceptible to classical scrapie conditions and allow to meet the goals of the EU legislation (Regulation EC 999/2001, Regulation EC 260/2003, Commission decision C/2003/498). The annual introduction to the flock ewes with no valine amino acid at codon 136 and rams with ALRR/ALRR genotype should soon result that whole tested sheep population would have only genetically resistant to classical scrapie alleles. These recommendations should be applied within the breeding work carried out on other sheep breeds. In Poland most cases of atypical form of scrapie were not genotyped; same story was in tested flock. Perhaps this was due to the relatively low frequency of VLRQ and VLRR alleles compared to the much higher frequencies in abroad sheep breeds (Lühken et al. 2004, Kaal and Windig 2005, Kaam et al. 2005, Palhiere et al. 2008). However, in some flocks frequency of genotypes containing the phenylalanine amino acid at codon 141 can reach high level, as it is demonstrated in research

described in other work (Niżnikowski et al. 2014) in which was no atypical scrapie. Moreover, such genotyping in direction to find alleles containing phenylalanine amino acid at codon 141 is justified (Goldman 2008, Mcintyre 2008).

CONCLUSIONS

The obtained results lead up to following statements and conclusions:

1. No statistical significance effect of breed and sex within breed on frequency of occurrence of scrapie alleles and genotypes. In Polish Merino were found five alleles (ALRR, ALRQ, ALHQ, AFRQ, VLRQ), and in old-type Polish Merino six alleles (additional – VLRR allele).
2. Nine genotypes of *PRNP* gene were found in Polish Merino and 11 genotypes were found in old-type Polish Merino.
3. Very high frequency of ALRR/ /ALRR, ALRR/ALRQ, ALRR/ALHQ genotypes were stated in both Merino breeds at low level of genotypes containing valine amino acid.
4. In both breeds, was found only one allele with phenylalanine amino acid at codon 141 – AFRQ, which appeared in three genotypes (in combination with ALRR, ALRQ, ALHQ) and probably determined low level of resistant to atypical scrapie.
5. Breeding work assumption, which requires elimination individuals with valine amino acid at codon 136 and phenylalanine amino acid at codon 141, and introduce to sheep population rams with ALRR allele would led to higher frequency of ALRR/ALRR genotype and ALRR allele in sheep population. That indicates the advisability of such breeding work, which is worth to recommend for genetic improvement of all sheep breeds in Poland. It should also recommend the genotyping of sheep in which clinical status of atypical scrapie was diagnosed.

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Streszczenie: *Polimorfizm genu białka prionowego* PRNP *u owiec ras merynos polski i merynos polski starego typu w gospodarstwie, w którym stwierdzono kliniczny stan trzęsawki atypowej.* Badania przeprowadzono w 2014 roku w jednym gospodarstwie zlokalizowanym w województwie zachodniopomorskim, w którym stwierdzono kliniczną formę trzęsawki atypowej. Badaniami objęto 378 maciorek i 96 tryków rasy merynos polski oraz 416 maciorek i 58 tryków rasy merynos polski starego typu. Wszystkie zwierzęta były poddane identyfikacji polimorfizmu genu białka prionowego *PRNP*. Na podstawie przeprowadzonych prac badawczych stwierdzono nieistotny wpływ rasy owiec oraz płci w obrębie rasy na frekwencje występowania alleli i genotypów trzęsawki. Wykazano występowanie pięciu alleli (ALRR, ALRQ, ALHQ, AFRQ i VLRQ) u merynosa polskiego, sześciu u merynosa polskiego starego typu (dodatkowo VLRR). Zidentyfikowano dziewięć genotypów białka *PRNP* u merynosa polskiego oraz 11 u merynosa polskiego starego typu. Stwierdzono bardzo dużą frekwencję występowania genotypów ALRR/ /ALRR, ALRR/ALRQ i ALRR/ALHQ u ras merynosowych, przy bardzo niskim poziomie występowania genotypów z kodowana waliną u obu ras. Wykazano u obu ras łącznie występowanie uwarunkowania zawierającego w kodonie 141 fenyloalaninę tylko w formie allelu AFRQ, który pojawił się w trzech genotypach (w kombinacji z ALRR, ALRQ i ALHQ), co warunkować może niski poziom oporności genetycznej na trzęsawkę

atypową. Przyjęte założenia pracy hodowlanej polegające na eliminacji nosicieli uwarunkowań kodujących występowanie waliny w kodonie 136 i fenyloalaniny w kodonie 141 oraz wprowadzanie do populacji tryków zawierających w genotypie allel ALRR prowadzić będą do zwiększenia frekwencji występowania w populacji genotypu ALRR/ALRR oraz allelu ALRR. Wskazuje to na zasadność prowadzenia takiej pracy hodowlanej, którą warto zalecić przy doskonaleniu genetycznym innych ras owiec występujących w krajowym pogłowiu.

*Słowa kluczowe***:** owce, *PRNP*, rozkład alleli i genotypów

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Analysis of Angus beef cattle recording results in Poland

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Abstract: *Analysis of Angus beef cattle recording results in Poland.* The aim of the study was to assess the utility of selected results of the British Angus breed with respect to their compliance with the goal of racial breeding and standards adopted by the Polish Association of Breeders and Producers of Beef Cattle (PABPBC). The subject of the analysis were recording results of the British Angus beef cattle breed in Poland. The study was based on data for the years 2002–2014 of PABPBC and the National Center of Animal Breeding (NCAB) for 1996–2001. The data set included:*N* – the number of animals tested, min – minimum values in the studied traits, max – maximum value of the selected features, AVG – average values of the analyzed traits, *SD* – standard deviation. Evaluated properties are: average weight of cows (kg), the average body weight of calves after birth (kg), the average milk yield (kg), the terms of cows and heifers calving aptitude, the distribution of the population according to the order of calving cows. Since 2001 there is a clear, steady decline in the share of population of the breed in the female population of beef cattle. This decrease concern both purebred and crossbred populations. Analysis of the results of evaluation shows that the average body weight of cows did not differ from weights assumed in the breeding goal. The mean body weight of purebred calves at birth did not change significantly in 15 years of assessment. Bulls have demonstrated higher birth weight reaching 37 kg. The difference between bulls and heifers was about 1–2 kg. Calves were characterized by a high average gains during rearing: 763–997 g for heifers and 718––1,032 g for bulls over all years of assessment. In Polish Angus cattle herds 50–60% of cows was calving during the relevant period in recent years. It shows that about half of the calves born at other times of the year only to a small degree can take full advantage of the pasture. Despite a steady decrease in the population of Angus cows primaparous and cows calving for the second time constituted about 40% of the population. In 2001 only four cows was after seventh calving and in 2014 already 94 (22.5%).

Key words: beef cattle, Angus, beef cattle recording

INTRODUCTION

Twenty years of the Programme of Beef Cattle Breeding Development in Poland passed in 2014 (Jasiorowski et al. 1996). Due to the sparse pure-bred female population is difficult to talk about own national breeding program. Therefore, the maintenance of high standards of breed is the main task of the Polish Association of Breeders and Producers of Beef Cattle (PABPBC). Its implementation is, inter alia, usability evaluation conducted in beef cattle herds. The PABPBC breeding goal for Angus cows is maintaining body weight of adult cows on the level of approximately 550–600 kg, and in case of bulls around 900–1000 kg, ease of

calvings, a high level of maternal traits and maintenance of maturity class. Bulls should reach at adulthood the height at sacrum of about 135 cm and cows about 130 cm. In the national beef cattle breeding program there are set out, i.a. the following standards for breeding of Angus cows entered in the introductory part of the book: the minimum weight gain from birth to 210 days of age – 800 g, the minimum weight at first calving 460 kg. The aim of the study was to assess the selected results of the British Angus with respect to their compliance with the breeding goal and standards adopted by the PABPBC.

MATERIAL AND METHODS

The subject of the analysis were beef cattle recording results for the British Angus breed in Poland. with respect to their compliance with the goal of racial breeding and standards adopted by the PABPBC. The subject of the analysis were recording results of the Angus beef cattle breed in Poland. The study was based on data for the years 2002–2014 of the PABPBC and the National Center of Animal Breeding (NCAB) for 1996––2001. The data set included: *N* – number of animals tested, min – minimum values in the studied traits, max – maximum value of the selected features, AVG – average values of the analyzed traits, *SD* – standard deviation. Evaluated properties are: average weight of cows (kg), average body weight of calves after birth (kg), average milk yield (kg), the terms of cows and heifers calving aptitude, the distribution of the population according to the order of calving cows.

The calculation of standardized animal body weight for given day in its life was done according to the following formula:

$$MCS = [(MCB - MCU) / WW] \cdot WS + MCU$$

where:

MCS – standardized animal body weight (kg);
MCB – mean body weight of the animal on the actual weighing (kg);
MCU – actual body weight set for 48 h at birth (kg);
WW – mean age of the animal on the weighing (days);
WS – standardized age of the animal (s).

RESULTS AND DISCUSSION

Table 1 presents the quantitative changes of the female population of Angus cattle in Poland in the years 1996–2014. Since 2006 there is a clear, steady decline in the share of the female population of the breed in beef cattle. This decrease concerned both purebred and crossbred populations.

The average body weight of purebred cows are shown in Table 2. Optimum cow body weight and dimensions depend mainly on cattle production system (Morris and Wilton 1976, Andersen 1978, Dickerson 1978, Fitzhugh 1978, Nogalski et al. 2000). Genotype and weight of cows are always listed among the many factors responsible for normal growth and development of calves.

TABLE 1. Quantitative changes of the female population of Angus cattle in Poland (from 2007 the list includes only the cows)

Year	Beef breed female population			Angus breed (purebred)	Angus breed (crossbred)	Angus breed (purebred + + crossbred)	Angus breed share in the population
	purebred	crossbred	total				
1996	3 939	4 952	8 891	156	245	401	4.5
1997	6 063	5 772	11 835	316	162	478	4.0
1998	7 227	7 601	14 828	455	129	584	3.9
1999	8 375	8 243	16 618	523	161	684	4.1
2000	9 085	9 468	18 553	483	320	803	4.3
2001	9 129	9 748	18 877	487	214	701	3.7
2002	9 735	8 968	18 703	673	136	809	4.3
2003	11 768	9 382	21 150	657	188	845	4.0
2004	13 884	10 925	24 809	742	579	1321	5.3
2005	17 130	11 710	28 840	888	137	1025	3.6
2006	19 597	13 100	32 697	1 001	189	1190	3.6
2007	14 541	11 676	26 217	314	113	427	1.6
2008	17 481	12 097	29 578	351	121	472	1.6
2009	15 435	7 711	23 146	328	94	422	1.8
2010	16 436	7 576	24 012	380	126	506	2.1
2011	16 216	7 459	23 675	291	140	431	1.8
2012	16 724	7 070	23 794	321	97	418	1.8
2013	17 481	6 633	24 114	380	95	475	2.0
2014	18 061	6 302	24 363	403	123	526	2.2

TABLE 2. Body weight of purebred Angus cows

Year	*N*	Cow body weight (kg)			
		min	max	AVG	*SD*
1999	47	400	660	528.3	83.3
2000	72	460	680	561.6	52.5
2001	79	380	750	551.2	71.0
2002	73	460	688	559.2	47.1
2003	112	470	770	552.9	46.7
2004	189	490	700	555.2	35.0
2005*	52	475	588	533.2	29.6
2006*	52	421	625	517.0	43.8

* Body weight after first calving.

Many studies have shown that the weight of the cow has a significant impact on calf birth weight. as well as daily gains during rearing (Przysucha et al. 2002). Cited authors showed that body weight of cows had highly significant impact on calf weight at birth. Cows with the lowest body weight delivered calves lighter by 6.3 kg than calves born to the heaviest cows. Body weight of cows had significant and highly significant influence on weight of calves aged 120 and 210 days. Highly significant effect of cow body weight on calves weight daily

gains for periods from first to 210th and 120th to 210th day of age. The highest daily gains in body weight during the whole period of rearing had calves delivered by cows with the highest weight. Therefore. the weight of a cow in adulthood is an important feature to be considered for breeding programs. According to the breeding goal of the PABPBC, cow body weight in adulthood should be 550–600 kg and for primaparous cows 460 kg. Analysis of the results of usability evaluation shows that the average body weight of cows did not differ from weights assumed to breeding.

Tables 3 and 4 illustrate the average body weight of purebred calves at birth which did not change significantly in 15 years of assessment. Higher birth weight have demonstrated the bulls reaching 37 kg. The difference between bulls and heifers was usually 1–2 kg. Kamieniecki et al. (1998) reported an average birth weight of Angus heifers as 40.82 kg and bulls – 42.85 kg. These are higher weights than shown in the table and those reported by other authors, but they concern calves born to cows from imports. In studies of Trela et al. (1998) the figures were 34.7 and 37.4 kg, respectively. Many authors have shown a significant effect of body weight after giving birth to a calf body weight at weaning at the age of 210 days. The highest weight of calves at birth typically have also the highest body weight at the end of the rearing (Przysucha et al. 2002). Przysucha et al. (2002) showed highly significant influence of calf birth weight for its later body weight and the size of daily gains for periods of from first to 120th and 120th to 210th day of

TABLE 3. Average body weight of purebred heifers at birth

Year	*N*	Body weight (kg)			
		min	max	AVG	*SD*
2000	24	25	38	33.2	3.3
2001	41	20	38	29.4	4.3
2002	30	26	36	30.7	2.7
2003	46	22	45	31.0	5.1
2004	103	20	40	32.3	3.8
2005	115	20	40	29.8	5.1
2006	112	15	46	33.0	3.1
2007	75	18	47	33.6	5.4
2008	97	24	46	33.4	4.4
2009	116	18	47	32.6	5.0
2010	154	13	48	33.1	5.6
2011	132	19	41	30.8	3.9
2012	151	15	48	31.6	5.7
2013	135	22	40	31.5	3.7
2014	147	20	44	32.1	3.9

TABLE 4. Average body weight of purebred bulls at birth

Year	*N*	Body weight (kg)			
		min	max	AVG	*SD*
2000	36	25	50	34.0	5.1
2001	35	20	52	31.2	7.3
2002	35	28	41	33.0	3.2
2003	65	16	45	32.2	5.3
2004	84	25	50	33.5	3.9
2005	118	18	50	31.8	5.9
2006	121	19	45	34.0	2.9
2007	114	20	51	34.7	5.0
2008	90	25	51	34.9	4.7
2009	17	28	47	33.5	4.3
2010	133	20	56	37.0	6.1
2011	144	19	56	33.8	5.0
2012	123	18	50	33.9	5.0
2013	107	24	44	33.5	4.0
2014	128	16	44	34.2	4.6

age. The lightest calves at birth (<30 kg) resolved calves with higher birth weight in later periods of fattening and obtained lowest daily gains.

Table 5 shows the average milk yield of purebred cows in different years of assessment. As can be seen from the following statement. the minimum milk yield of cows of the breed was 1,518 kg

TABLE 5. The average milk yield of purebred cows

Year	*N*	Estimated milk yield of cows (kg)			
		min	max	AVG	*SD*
2000	51	1 643	2 049	1 881.0	93.1
2001	42	1 059	2 845	1 828.4	420.2
2002	28	1 156	2 079	1 517.9	177.1
2003	72	1 052	2 104	1 653.1	180.7
2004	139	991	2 677	1 935.6	251.0
2005	108	1 230	2 001	1 878.0	118.4
2006	198	1 231	2 345	1 893.6	115.3
2009	282	1 144	2 707	1 786.1	242.9

and the maximum 1,894 kg. The data presented should be approached with great caution because milk yield was calculated based on the weight gain of calves. and as we know in the herd calves can always be found that approach to other cows and choke or are additionally fed by the breeder. Przysucha et al. (2002) studied the relationship between milk yield of Angus cows and growth of calves. The highest weight and growth reached calves which mothers had the highest milk yield. The direct relationship of mothers milk yield and calf rearing results indicate many authors. among others (Dobicki 1995, Jasiorowski et al. 1996, Kamieniecki et al. 1998).

Table 6 summarizes the terms of cows and heifers calving aptitude analyzed in the coming months in the years 1999–2014. Season of birth has a significant impact on the vitality and growth pace of reared calves which directly affects the economic effects of the rearing (Przysucha et al. 2005). In studies of Przysucha et al. (2002) Angus calves born in the winter season (November to April) showed a slight weight advantage in body weight in all studied periods of life compared to calves born in the summer, i.e. from May to October. Seasonality in calvings in breeding herds is very important because appropriate term of calving in the future allows to receive breeding material of a very good quality with the least amount of cost of rearing (maximum utilization of pastures). Many authors believe (Dobicki 1996, Jasiorowski 1999, Jasiorowski and Przysucha 2004) that the period of mating and the resulting of calving aptitude time should not be longer than 2–3 months. Beef cows maintained all year round in grazing system should make the best offspring in the winter. Calves born in the period after the completion of the first period of milk drinking are prepared to make full use of the pasture then their growth rate is fast. Calves are healthy and good developed and breeder bear the smallest rearing costs. It should also be noted that in the winter calvings weaning calves moment coincides with the

TABLE 6. Time of purebred cows and heifers calving

Year	Unit	Month												Total
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1999	N	–	4	4	2	2	7	11	8	5	2	2	1	48
	%	–	8.3	8.3	4.2	4.2	14.6	22.9	16.7	10.4	4.2	4.2	2.1	100.0
2000	N	–	21	10	3	15	6	–	–	6	2	4	6	73
	%	–	28.8	13.7	4.1	20.5	8.2	–	–	8.2	2.7	5.5	8.2	100.0
2001	N	11	16	17	6	10	3	1	–	–	8	6	2	80
	%	13.8	20.0	21.3	7.5	12.5	3.8	1.3	–	–	10.0	7.5	2.5	100.0
2002	N	21	11	12	7	6	1	3	1	1	1	9	2	75
	%	28.0	14.7	16.0	9.3	8.0	1.3	4.0	1.3	1.3	1.3	12.0	2.7	100.0
2003	N	28	17	20	13	8	3	9	6	3	55	–	2	114
	%	24.6	14.9	17.5	11.4	7.0	2.6	7.9	5.3	2.6	4.4	–	1.8	100.0
2004	N	35	19	28	19	18	17	11	6	4	1	17	14	189
	%	18.5	10.1	14.8	10.1	9.5	9.0	5.8	3.2	2.1	0.5	9.0	7.4	100.0
2005	N	42	23	32	29	21	19	12	8	4	8	12	14	224
	%	18.8	10.3	14.3	12.9	9.4	8.5	5.4	3.6	1.8	3.6	5.4	6.3	100.0
2006	N	34	24	56	33	43	8	9	8	5	5	3	5	233
	%	14.6	10.3	24.0	14.2	18.5	3.4	3.9	3.4	2.1	2.1	1.3	2.1	100.0
2007	N	23	44	54	39	23	11	9	2	4	7	13	51	280
	%	8.2	15.7	19.3	13.9	8.2	3.9	3.2	0.7	1.4	2.5	4.6	18.2	100.0
2008	N	49	25	53	28	25	12	20	14	5	3	10	43	287
	%	17.1	8.7	18.5	9.8	8.7	4.2	7.0	4.9	1.7	1.0	3.5	15.0	100.0
2009	N	58	46	49	36	28	14	19	5	10	2	9	18	294
	%	19.7	15.6	16.7	12.2	9.5	4.8	6.5	1.7	3.4	0.7	3.1	6.1	100.0
2010	N	46	64	63	54	42	21	26	9	5	5	5	24	364
	%	12.6	17.6	17.3	14.8	11.5	5.8	7.1	2.5	1.4	1.4	1.4	6.6	100.0
2011	N	48	36	80	47	26	19	3	2	1	7	17	6	292
	%	16.4	12.3	27.4	16.1	8.9	6.5	1.0	0.7	0.3	2.4	5.8	2.1	100.0
2012	N	46	57	72	68	28	10	8	12	5	1	16	10	333
	%	13.8	17.1	21.6	20.4	8.4	3.0	2.4	3.6	1.5	0.3	4.8	3.0	100.0
2013	N	45	66	119	53	35	15	20	4	1	1	18	3	380
	%	11.8	17.4	31.3	13.9	9.2	3.9	5.3	1.1	0.3	0.3	4.7	0.8	100.0
2014	N	20	75	18	79	51	29	12	9	–	–	1	23	417
	%	4.8	18.0	28.3	18.9	12.2	7.0	2.9	2.2	–	–	0.2	0.5	100.0

impoverishment of pastures in autumn. The consequence is natural dry-off pregnant cows. With winter calvings cows mostly deliver in the barn so that it is easier to monitor deliveries and possible assistance in the event of complications. Analyzing the obtained results and assuming that the most favorable period of cows calving aptitude is the period from December to March. It should be noted that about 35–60% of the Polish Angus cows delivered in recent years during the

relevant period cows. It follows that about half of the calves born at other times of the year only to a small degree can take full advantage of the pasture.

Table 7 shows the percentage distribution of calving aptitude of Angus cows calving order. It should be noted that despite a steady decrease in the population of Angus primaparous cows and cows calving for the second time constituted about 40% of the population. In 2001 there were only four cows after seventh calvings and in 2014 already 94 (22.5%). It proves that the life of the cow increases. which is of particular economic importance. Long life of cows in herds of beef cattle is one of the main factors allowing for reducing the cost so the breeders should try to use cows as long as possible.

CONCLUSIONS

Analysis of selected results of the evaluation of British Anguses with respect to their compliance with the breeding goal and standards adopted by PABPBC shows

TABLE 7. Distribution of the order of calving

Year	Unit	Number of months												Total
		1	2	3	4	5	6	7	8	9	10	11	≥12	
2000	N	29	13	12	9	6	4	–	–	–	–	–	–	73
	%	39.7	17.8	16.4	12.3	8.2	5.5	–	–	–	–	–	–	100.0
2001	N	21	37	7	3	3	5	3	1	–	–	–	–	80
	%	26.3	46.3	8.8	3.8	3.8	6.3	3.8	1.3	–	–	–	–	100.0
2002	N	14	15	31	7	3	2	2	1	–	–	–	–	75
	%	18.7	20.0	41.3	9.3	4.0	2.7	2.7	1.3	–	–	–	–	100.0
2003	N	37	10	20	31	7	3	2	3	1	–	–	–	114
	%	32.5	8.8	17.5	27.2	6.1	2.6	1.8	2.6	0.9	–	–	–	100.0
2004	N	64	46	16	19	24	9	6	1	3	1	–	–	189
	%	33.9	24.3	8.5	10.1	12.7	4.8	3.2	0.5	1.6	0.5	–	–	100.0
2005	N	52	59	32	26	26	17	8	3	–	1	–	–	224
	%	23.2	26.3	14.3	11.6	11.6	7.6	3.6	1.3	–	0.4	–	–	100.0
2006	N	52	23	15	34	25	43	23	15	3	–	–	–	233
	%	22.3	11.5	8.5	15.2	13.5	19.5	11.5	8.5	1.5	–	–	–	100.0
2010	N	94	32	57	47	41	27	40	8	5	9	4	–	364
	%	25.8	8.7	15.6	12.9	11.2	7.4	10.9	2.1	1.3	2.4	1.0	–	100.0
2011	N	19	75	28	50	37	27	15	28	3	2	5	3	292
	%	6.5	25.6	9.5	17.1	12.6	9.2	5.1	9.5	1.0	0.6	1.7	1.0	100.0
2012	N	62	38	59	29	58	31	27	12	16	6	1	4	333
	%	18.6	11.4	17.7	8.7	14.4	9.3	8.1	3.6	4.8	1.8	0.3	1.2	100.0
2013	N	98	47	42	55	24	39	28	23	10	12	2	–	380
	%	25.8	12.4	11.1	14.5	6.3	10.3	7.4	6.1	2.6	3.2	0.5	0.0	100.0
2014	N	63	98	40	41	54	27	35	26	17	7	8	1	417
	%	15.1	23.5	9.6	9.8	12.9	6.5	8.4	6.2	4.1	1.7	1.9	0.2	100.0

maintenance of high standards despite the systematic reduction of breeding domestic cattle population of the breed.

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Streszczenie: *Analiza wyników oceny użytkowości brytyjskiej rasy angus w Polsce.* Celem pracy była analiza wybranych wyników oceny użytkowości brytyjskiej rasy angus w odniesieniu do ich zgodności z celem hodowlanym i standardami rasowymi przyjętymi przez Polski Związek Hodowców i Producentów Bydła Mięsnego. Przedmiotem analiz były wyniki oceny użytkowości brytyjskiej rasy bydła mięsnego angus w Polsce. Opracowanie powstało na bazie danych PZHiPBM za lata 2002–2014 oraz Krajowego Centrum Hodowli Zwierząt (KCHZ) za lata 1996–2001. Zbiór danych obejmował: *N* – liczbę badanych zwierząt, min. – minimalne wartości w badanej cechy, max. – maksymalne wartości badanej cechy, średnia – uśrednione wartości badanej cech, *SD* – odchylenie standardowe. Oceniane cechy to: średnie masy ciała krów (kg), średnie masy ciała cieląt po urodzeniu (kg), średnia mleczność krów (kg), terminy ocieleń krów i jałowic, rozkład populacji krów według kolejności ocielenia. Od 2001 roku widać wyraźny, systematyczny spadek udziału tej rasy w żeńskiej populacji bydła mięsnego. Spadek ten dotyczy zarówno populacji czystorasowej, jak i mieszańców. Analiza wyników oceny użytkowości przedstawia, iż średnie masy ciała krów nie odbiegają od mas założonych w celu hodowlanym. Średnie masy ciała cieląt czystorasowych

po urodzeniu nie zmieniły się znacząco w ciągu 15 lat prowadzenia oceny. Większą masą urodzeniową wykazały się buhajki, osiągając wagę 357 kg. Różnicą między buhajkami a jałówkami wynosiła 1–2 kg. Cielęta charakteryzowały się dużymi i średnimi przyrostami w okresie odchowu: 763–997 g odpowiednio dla cieliczek i 718–1032 g dla buhajków w ciągu wszystkich lat prowadzenia oceny. W polskich stadach bydła angus cieliło się w ostatnich latach we właściwym okresie 50–60% krów. Wynika z tego, że około połowa cieląt urodzonych w innych okresach roku jedynie w nieznacznym stopniu może w pełni korzystać z pastwiska. Mimo systematycznego zmniejszania populacji krów rasy angus, pierwiastki i krowy cielące się po raz drugi stanowią około 40% populacji. W 2001 roku tylko cztery krowy były po siódmym ocieleniu, a w 2014 roku było ich już 94 (22,5%).

Słowa kluczowe: bydło mięsne, rasa angus, ocena użytkowości bydła mięsnego

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Hormonal stimulation of American mink (*Neovison vison*) females during mating improves reproduction parameters

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Abstract: *Hormonal stimulation of American mink (*Neovison vison*) females during mating improves reproduction parameters.* The aim of the study was to determine the effect of hormonal stimulation during the mating season on reproduction performance in American mink females and a selection of both the hormonal formulation and its dosage. The study involved one-year-old females of American mink (*Neovison vison*) of the pearl color morph. The females received one of two hormonal formulations, F1 or F2, with a single injection administered 24 h before planned mating. The formulations contained: (F1) a pituitary gonadotropin releasing hormone analogue, and (F2) freeze-dried, crystalline serum gonadotropin (PMSG) of a strong FSH- and LH-like effect. Each formulation was administered in three dosage levels. The hormonal stimulation applied 24 h before the planned mating significantly reduced the number of sterile females, also brought a significant increase in the average litter size, from 1.05 to 1.35 kits, and in the average number of live births, from 1.03 to 1.98. Of the two formulations tested, the analogue of pituitary gonadotropin releasing hormone (F1) at a dose of 36 IU proved to be the most effective; its application allowed attaining the highest reproductive parameters. Using hormonal stimulation of the female mink during the mating can be effectively put into practice on the farm and may in consequence improve the profitability of the production cycle.

Key words: American mink, reproduction, hormonal stimulation

INTRODUCTION

Some of the most important elements affecting the efficiency of animal farming, irrespective of the species, include prolificacy, fertility and reproductive performance. In the mink, these traits are highly variable and depending on the individual genotype. Many authors (Franklin 1958, Møller 2000, Bielański et al. 2003, Socha et al. 2003, Święcicka 2004, Kołodziejczyk and Socha 2006, Ślaska et al. 2009, Felska-Błaszczyk et al. 2010, Nieminen et al. 2010) have observed that both gestational length and the outcomes of whelping and nursing vary greatly depending on the color variety of females. As soon as in 1968, this fact was reported by Bowness (1968), who found that new color varieties of mink females had on average 1.15-day longer gestation length in relation to primary-color varieties. Reproduction in mink is a complex, multidimensional trait, and its monoestrous character results in a fact that the breeder only once a year is able to carry out mating and obtain offspring. Taking into account

the above aspects and the fact that, as indicated by Kołodziejczyk and Socha (2006), reproduction is the most difficult step in the whole mink production cycle (Lagerkvist et al. 1993), it seems appropriate to strive to find effective ways to improve its performance.

For many years, research has been carried out on improving fertility in mink. One of the factors used to improve fertility mink is, for example, extending the light regime during their pregnancy (Felska-Błaszczyk et al. 2013), which shortens gestation length and increase fertility. Another factor that may boost the breeding success may be hormonal stimulation of both males and females applied prior to and during the heat. Lasota et al. (2013) administered chorionic gonadotropin, hCG, to American mink males 24 h prior to mating, which increased libido in males and, in consequence, improved conception rates. In experiments by Klotchkov and Eryuchenkov (2000, 2003), hCG was administered to mink females during the pro-estrus, which significantly improved their fertility and fecundity; a higher number of mature graffian follicles were observed in the treated females as compared with the control. On mink farms in Poland, no hormonal treatment, in order to improve the fertility of the females, has been applied during mating so far.

Therefore, the aim of this study was to determine the effect of hormonal stimulation during mating on the reproductive performance of female mink and to select both formulation and its dosage.

MATERIAL AND METHODS

The experiment was carried out on a mink farm located in western Poland during the breeding season. Animals were kept on a farm in multipurpose, double-row sheds, in Danish-type wire cages. Feeding followed best feeding standards and the semi-liquid feed was based on chicken and fish.

The material comprised one-year-old female American mink (*Neovison vison*) of the pearl color morph. The females were treated with a single injection, applied 24 h prior to mating, of one of the following hormonal formulations:

- F1, a pituitary gonadotropin releasing hormone analogue;
- F2, freeze-dried, crystalline serum gonadotropin (PMSG) of a strong FSH-like effect and additional LH-like effect.

The animals were mated according to the scheme 1 + 7 + 8, the numbers being the subsequent days in heat, starting between 5 and 10 March. Due to varied effects of each of the hormones, we applied different doses of the formulations. Table 1 presents six treatment groups (plus control) which were formed for the experiment. The control group was composed of randomly selected females of the same age, which were mated in a similar way as the treatment females.

The following parameters were studied: percent of barren females, mean litter size, mean number of live-born per litter, total gestation length (from the first mating date to delivery).

TABLE 1. Doses of the hormonal treatment by group

Hormonal formulation	Hormonal group	Group	Total number of females	Injection dose (IU)
Formulation 1	F1	A	26	36
	F1	B	23	32
	F1	C	30	28
Formulation 2	F2	A	20	9
	F2	B	35	8
	F2	C	16	7
Control (C)	control	control	71	–

Statistical analysis of data was carried out using the Statistica 10 PL package. The following descriptive statistics were included: arithmetic mean and standard deviation (SD). Testing the differences was accomplished with the non-parametric Mann–Whitney U test for two independent samples (treatment and control groups) and the Kruskal–Wallis test for two or more variables (to compare more than two samples).

RESULTS

In the experiment, we applied three doses of either of the tested hormonal formulations. The analysis showed that the lowest percentage of barren females (7.69%) was found in the group of females that had been administered F1 at the dose A, i.e. 36 IU. In the remaining groups, the percentage was higher, from 8.7%, after application of F1 at the B dose of 32 IU, to as high as nearly 19%, after application of F2 at the dose C, 7 IU (Table 2).

The analysis of female reproduction performance revealed that the lowest rate of barren females, slightly exceeding 10%, was observed in the group that

TABLE 2. Percentage of barren mink females in relation to different hormonal formulations and their doses

Factor	Level of factor	Number of whelping females	Number of barren females	Total number of females	Percentage of barren females
Control (C)		61	10	71	14.08
Hormone	Formulation 1 (F1)	71	8	79	10.13
	Formulation 2 (F2)	62	9	71	12.68
Dose	Formulation 1 36IU (F1, group A)	24	2	26	7.69
	Formulation 1 32IU (F1, group B)	21	2	23	8.70
	Formulation 1 28IU (F1, group C)	26	4	30	13.33
	Formulation 2 9IU (F2, group A)	18	2	20	10.00
	Formulation 2 8IU (F2, group B)	31	4	35	11.43
	Formulation 2 7IU (F2, group C)	13	3	16	18.75

had received F1, whereas the highest rate was found in the control group, in which the value exceeded 14%.

As far as litter sizes are concerned (Table 3), the largest litters, reaching 7.69 kits, were produced by females treated with F1. The value differed significantly (at P <0.01) from those attained in the control group (6.34).

Like in the studies on fertility, the application of the two formulations, F1 and F2, in three different doses revealed superiourity of the formulation F1 at the dose A. The mean numbers of total born and live-born kits per litter, 8.37 and 7.29, respectively, observed in females treated with the F1 at the dose A, were significantly (P <0.01) higher in relation

TABLE 3. Mean litter size at birth and live-born kits in relation to different hormonal formulations and their doses

Factor	Level of factor	Total born kits			Live-born kits		
		n	AVG	*SD*	*n*	AVG	*SD*
Control (C)		61	6.34^{Aa}	1.9	61	4.92^{ABa}	2.62
Hormone	Formulation 1 (F1)	71	7.69^{A}	1.82	71	6.90^{A}	1.99
	Formulation 2 (F2)	62	7.39^{a}	2.59	62	6.5^{B}	2.49
Dose	Formulation 1 36IU (F1, group A)	24	8.37^{A}	1.58	24	7.29^{A}	1.94
	Formulation 1 32IU (F1, group B)	21	7.63	1.98	21	6.84	1.64
	Formulation 1 28IU (F1, group C)	26	7.14	1.76	26	6.61^{a}	2.23
	Formulation 2 9IU (F2, group A)	18	7.06	2.96	18	6.17	2.77
	Formulation 2 8IU (F2, group B)	31	7.39	2.32	31	6.52	2.11
	Formulation 2 7IU (F2, group C)	13	7.85	2.79	13	6.92	3.04

Values in the same row marked with the same letters in columns differ significantly $^{AA, BB}$ at $P \leq 0.01$; ^{aa} at $P \leq 0.05$.

A similar relationship was observed with in the average number of live-born litter size in the first year of the study. Here, too, the highest value of this parameter was attained by females that 24 h before mating had received the formulation F1, 6.9 live-born kits per female on average. This result differed significantly (P <0.01) from the control group, with 4.92 kits per female.

to the control, in which the respective values were 6.34 and 4.92.

Given the type of the administered hormone formulation, the longest average length of gestation (54.82 days) was observed in the group of females treated with an injection of formulation F2. This result was significantly (P <0.01) higher than the value of said characteristic (52.26 days) attained by the females of the control group (Table 4). Gestation

lengths in both treated and control females ranged between 45 and 55 days, and obtained litter sizes, both in terms of total born and live-born kits were satisfactory.

TABLE 4. Gestation length in relation to different hormonal formulations and their doses

Factor	Level of factor	Gestation length		
		n	AVG	*SD*
Control (C)		61	52.26^{AB}	3.20
Hormone	Formulation 1 (F1)	71	53.61	4.01
	Formulation 2 (F2)	62	54.82^{A}	4.33
Dose	Formulation 1 36IU (F1, group A)	24	54.04	4.24
	Formulation 1 32IU (F1, group B)	21	51.95^{a}	2.17
	Formulation 1 28IU (F1, group C)	26	54.36	4.53
	Formulation 2 9IU (F2, group A)	18	54.22	4.19
	Formulation 2 8IU (F2, group B)	31	55.48^{Ba}	4.95
	Formulation 2 7IU (F2, group C)	13	54.08	2.60

Values in the same row marked with the same letters differ significantly $^{AA, BB}$ at $P \leq 0.01$; ^{aa} at $P \leq 0.05$.

An analysis of the effect of treatment on gestation length reveales that the shortest gestations (51.95 days) were characteristic of females receiving F1B, whereas the longest (55.48 days) was observed in those treated with F2B, with the differences significant at $P < 0.05$.

DISCUSSION

Franklin (1958) was probably the first who attempted to improve American mink females reproduction performance by injectable progesterone. Less than a decade later, Holcomb (1967) published the results of his experiments on an application of hCG, which were, however, unsatisfactory. According to the latter author, the control females – which did not receive hCG after mating – whelped in higher numbers and produced larger litters. The author also noticed that most treated females lost their litters within two days from parturition, which probably resulted from lack of lactation in the studied dams.

Positive results of an experiment on female hCG stimulation were attained by Adams (1981), who suggests the possibility of hCG-induced ovulation also in females that failed to mate. These observations, according to the author, may have resulted from a behavioural problem rather than ovary-level malfunctioning. This was later confirmed by Wehrenberg et al. (1992), who attained positive outcomes of eCG and hCG administration to females avoiding mating; by administering a dose of 100 IU of eCG twice, the authors obtained the highest number of pregnant and whelping females, as well as the highest mean litter size. Also Klotchkov and Eryuchenkov (2000, 2003) and Klotchkov et al. (2005) successfully applied hCG.

Application of GnRH, on the other hand, was sudied by, among others, Douglas et al. (1994) and Bäcklin et al.

(1997). Seremak et al. (2010) studied the effects of a synthetic analogue of the hormone in females that were unmated before 19 March. The authors suggest that the effects could be positive, as the fertility after hormonal treatment was at a level of 46.6%, as compared to control (42%).

Desirable outcomes of another stimulus, medroxyprogesterone acetate (MPA), were reported by Concannon et al. (1980). The authors observed that embryonic implantation in the uterine wall of exogenous progesterone-treated female mink took place sooner, and, additionally, the females produced larger litters. Similar studies on skunk, however, did not bring good results (Mead et al. 1981). Also the effects of inhibin (Ireland et al. 1992) and phytoestrogens (Ryökkynen et al. 2005) were studied. Murphy (1983) observed that hormonally treated American mink females had the diapause by 10 days shorter.

CONCLUSIONS

The use of hormonal stimulation 24 h before the planned mating significantly reduced the number of barren females, also resulted in a significant increase in litter sizes, both in the average number of total born and live born kits, from 1.05 to 1.35 and from 1.03 to 1.98 kits, respectively. Of the two formulations tested, the analogue of pituitary gonadotropin releasing hormone (F1) at a dose of 36 IU (A) proved to be the most effective; after its application, the females demonstrated the best reproductive parameters, without gestation length reduced.

Hormonal stimulation of female mink during matings can be successfully applied in the production on the farm, eventually contributing to the success and increased profitability of the production cycle.

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Streszczenie: *Hormonalna stymulacja samic norki amerykańskiej (*Neovison vison*) w trakcie kryć źródłem poprawy parametrów reprodukcyjnych.* Celem podjętych badań było określenie wpływu stymulacji hormonalnej na wyniki rozrodu samic norki amerykańskiej poprzez wybór preparatu i zastosowanej dawki. Materiał do badań stanowiły jednoroczne samice norki amerykańskiej (*Neovison vison*) odmiany barwnej perła. Samicom podawano w postaci jednorazowej iniekcji na 24 h przed planowanym kryciem dwa preparaty hormonalne: (P1) – analog hormonu uwalniającego gonadotropinę przysadkową, (P2) – liofilizowana, krystaliczna substancja zawierającą surowiczą gonadotropinę (PMSG), wykazująca silne działanie głównie o charakterze FSH oraz dodatkowo LH. W doświadczeniu zastosowano trzy różne dawki każdego z dwóch testowanych preparatów hormonalnych. Zastosowanie stymulacji hormonalnej na 24 h przed planowanym kryciem znacząco wpłynęło na spadek liczby jałowych samic, przyniosło także istotny wzrost średniej liczby urodzonych od 1,05 do 1,35 oraz średniej liczby żywo urodzonych od 1,03 do 1,98 norcząt w grupach doświadczalnych. Spośród testowanych dwóch preparatów hormonalnych najskuteczniejszy okazał się preparat P1 w dawce (36 IU), po zastosowaniu którego uzyskano największe z analizowanych parametry rozrodu. Zastosowanie stymulacji hormonalnej samic norki amerykańskiej podczas okresu kryć z powodzeniem można wprowadzić do praktyki hodowlanej w cyklu produkcyjnym na fermie, a w konsekwencji może to realnie wpłynąć na sukces i opłacalność prowadzonej hodowli.

Słowa kluczowe: norka amerykańska, rozród, stymulacja hormonalna

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Accuracy of visual assessment of beef carcasses EUROP performed by the national assessors and assessor from the abattoir

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Abstract: *Accuracy of visual assessment of beef carcasses EUROP performed by the national assessors and assessor from the abattoir.* The EUROP classification system is based on visual assessment of beef carcass conformation and fatness. The aim was to test the accuracy of the trained and certified abattoir EUROP classifier in Poland relative to national assessors. The results of EUROP system, carried on the 3,135 carcasses were analyzed. Assessments were performed in the same conditions on the slaughter line by four independent classifiers. On the basis of the results of beef carcasses evaluations statistical analysis were performed. The results showed that the repeatability and accuracy of the national senior assessors was good. The results of evaluations abattoir assessor are different in comparison to three national assessors (P <0.01). The results show, that fat subclasses are the largest predictors of the differences in EUROP evaluations. The results suggest that visual assessment of beef carcasses might not be objective and is biased with error evaluator.

Key words: beef carcass, classification, EUROP system, conformation, fat class

INTRODUCTION

All over the world the beef carcasses classification systems are differentiated in terms of a particular evaluation technique, but most of them is based on a form of assessment of carcass fatness and conformation. Valid in Europe, EUROP system, based on a visual assessment of carcasses in five classes of conformation and fat, is regulated by the European Union (Commision Regulation 1208/81/EEC). The basic purpose of the system in Europe is the ability to sort carcasses for processing according to their value and quality, and also to ensure fair and adequate gratification for beef producers. This system provides unified guidelines for all EU member states and therefore enables effective operation of carcasses according to common principles of both a domestic and international trade. In EUROP system classification concerns the carcasses of adult bovine animals aged over 12 months weighing more than 300 kg, which were divided into the following categories: A – carcasses not castrated young male aged from 12 months to less than 24 months – bulls, B – carcasses of other not castrated male animals – bulls, C – carcasses of castrated males ages 12 months-bullocks, D – carcasses of cows that have calved, E – carcasses of other female aged 12 months-heifers. The obligation to apply the EUROP

classification system have all slaughterhouses that in the previous year slaughtered more than 3,900 carcasses, or more than 75 bovine carcasses a week on average over the year. Assessment of beef carcasses may provide only those persons who are certified for the EUROP classification (Choroszy and Choroszy 2011). Mostly, classification is furnished by trained slaughterhouse workers who have valid licenses.

Beef carcasses are visually graded in EUROP system by comparison of the carcass with the photographic patterns employed in the EUROP system for each single grade. A qualified assessor sorts carcasses according to their muscle conformation and fatness, taking into account the muscles shape, i.e. the ridge round and shoulder, and the degree of subcutaneous and pelvic fat (Pawelec 2010, Konarska et al. 2012). The EUROP system spreads beef carcasses in six classes of conformation: S – outstanding muscling, E – excellent muscling (with a content of lean meat in the carcasses of more than 55%, but not more than 60%), U – musculature very good, R – good musculature, O – fair musculature, P – poor musculature; and five categories of fatness: 1 – low fatness, 2 – slight fatness, 3 – average fatness, 4 – high fatness, 5 – very high fatness. Additionally, to provide more precise evaluation of carcasses classified as intermediate for both conformation and fatness three subclasses marked with "+", the lack of discriminant or "–" have been introduced (Commission Regulation 1249/2008/EC).

Unfortunately, EUROP system is not free of pitfalls. The main problem with EUROP assessment is its subjectivity, which makes this system not fully accurate and objective. Moreover, the visual EUROP evaluation of the beef carcasses is inappropriate for the measurements of the phenotype for performance recording and breed improvement caused be imprecise nature of the assessment. Modern carcass classification systems do not take into account small differences in carcass quality, which can often be the result of genetic improvement based on cattle conformation (Cegiełka 2013, Wnęk et al. 2014).

Moreover, carcass evaluation, carried out by classifier is far from its true value. This may results from the fact that fat accumulation might be observed not only in the subcutaneous tissue, but also between the muscle fibers, and visual assessment of the carcass is performed only on the basis of its profile. The lack of precision and the accuracy of the classification of carcasses assessments can also be caused by grader fatigue.

The aim of the study was to determine the differences in the assessment of beef carcasses in EUROP based on assessments of independent national and abattoir advisors.

MATERIAL AND METHODS

The animals were slaughtered at ECO--BEEF slaughterhouse in Maków Mazowiecki located in central part of Poland between August 2013 to April 2014. Six independent trials were carried out dur-

ing experiment. The hot carcass weight (HCW) was determined after dressing.

The carcasses were chilled at 4°C for 24 h and graded using EUROP system. Each carcasses was carried out by four professional assessors with valid certificates. The assessors that participated in trials were divided into two groups: first – abattoir assessor (4), and second – national senior assessors (1–3). National senior assessors were a group of three highly skilled assessors representing the Polish Agricultural and Food Quality Inspection. Carcass evaluation was processed independently and under the same conditions – including lightening in slaughterhouses. The carcasses were arranged in random order for each repetition. The unified five-grade scale of carcass assessment involving fat and conformation evaluation, which has been used by classifiers are presented in Table 1. The results of the carcasses classification were written on sheets of paper, and then MS Excel database was created. For each of the EUROP grades and slaughter categories coding system was applied. Fallowing numerical values for the conformation and fatness class E – 1, U – 2, R – 3, O – 4, P – 5 and the subclasses: " = "; –0.75; " – "; –0.5; "+ "; –0.25, were assigned respectively.

TABLE 1. The description of the EUROP conformation and fat evaluation system

Conformation class	Carcasses quality	Fat class	Fat cover
E	excellent	1	low
U	very good	2	slight
R	good	3	average
O	fair	4	high
P	poor	5	very high

The material for the further analysis consisted of 3,135 beef carcasses (breed Polish Holstein-Friesian) classified according to EUROP guidelines contained in the Commission Regulation No 1249/2008, included:

- 1,093 carcasses belonged to A slaughter category – carcasses of castrated males animal aged from 12 to 24 months;
- 473 carcasses belonged to B slaughter category – carcasses of castrated males animal aged above 24 months;
- 947 carcasses belonged to D slaughter category – carcasses of cows;
- 622 carcasses belonged to E slaughter category – carcasses of other male animal aged above 12 months.

Presented average $\bar{x}$ describes the arithmetic average of four independent classifications. The experimental data were evaluated by running ANOVA on IBM SPSS 21 (Statistical Product and Service Solution) according to following statistical model:

$$Y = \mu + A_i + e_{ij}$$

where:
μ – mean;
A_i – assessor (1 –4);
e_{ij} – random error.

After obtaining a significant omnibus of F-test, for the further exploration of the data, post hoc, LSD test in ANOVA procedure has been applied.

RESULTS AND DISCUSSION

The conformation and fatness grade of the beef carcass largely depends on the age and sex of animals at slaughter (Raesa et al. 2003, Bureš et al. 2006, Mach et al. 2008). The differences in assessors' evaluation for conformation and fatness of each slaughter category is presented in Figures 1 and 2. Both conformation and fat scoring in the case of a classifier four significantly differed to scores granted by other classifiers (p <0.01) – Table 2.

Figures 1 and 3 presents the differences in assessors' evaluations for conformation, fatness and hot carcasses weight of each slaughter category. Tables 3, to 5 presents average assessments and standards error (*SE*) in assessors evaluations regarding to conformation, fatness and hot carcasses weight of each slaughter category. There were significant differences (P <0.01) in the EUROP grades granted by abattoir assessor (4) and three national assessors (1–3). For fat subclasses (Fig. 2), a larger difference between mean values was identified, for both within and between assessors, irrespectively to slaughter category. However, the fat subclasses seems to be the largest predictor of the differences in EUROP evaluation (Wnęk et al. 2015). In the case of fat subclasses differences in the grading can rich up to two classes (Wnęk et al. 2014). Figures 1 and 2 show differences in the EUROP classification; the abattoir assessors seemed to overclassify the conformation of the carcass,

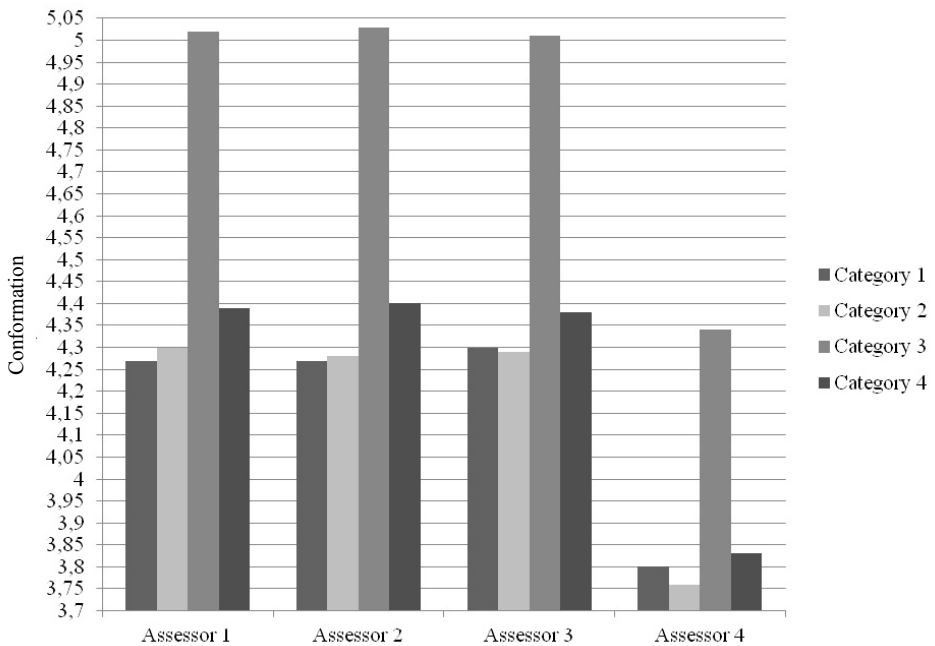

FIGURE 1. Changes in assessors evaluations regarding to carcass conformation

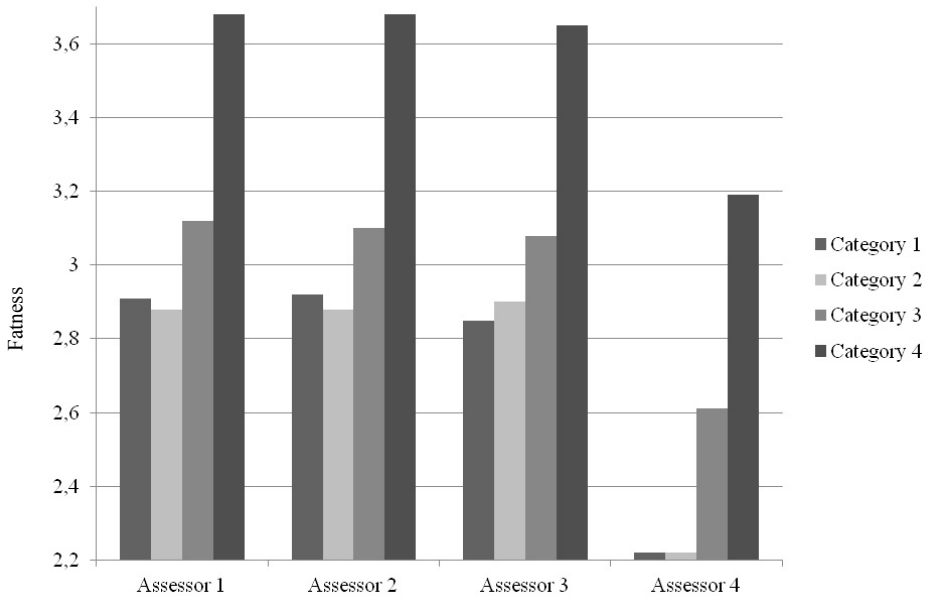

FIGURE 2. Changes in assessors evaluations regarding to carcass fatness

TABLE 2. Average evaluation of four assessors for conformation and fatness slaughter categories

Evaluated feature	Assessor number							
	1		2		3		4	
	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*
Conformation	4.52^{A}	0.77	4.53^{B}	0.76	4.53^{C}	0.77	$3.96A^{BC}$	0.58
Fatness	3.12^{A}	1.00	3.12^{B}	0.99	3.09^{C}	1.02	2.53^{ABC}	0.91

The means marked with the same letters differ significantly at: ^{A,B,C} $P \leq 0.01$.

and under-classify the carcass fatness. The standard deviations for both conformation and fatness grades between national assessors are very similar. Only in the case of carcasses belonged to categories 1 and 2 (old and young uncastrated bulls) small differences in analyzed values were reported. There were no significant differences between sex groups for carcass conformation classes and hot carcass weight. Figure 3 presents only minor differences and high conformity between abattoir and national assessors. The HCW did not influence the visual assessment of the carcass EUROP evaluation.

The assessment depends on human judgment, which can be subjective, and inconsistent (Allen and Finnerty 2000). Carcass evaluation affects its economic value and therefore precision and repeatability of carcass grading (Wnęk et al. 2015). Although EUROP conformation is important, the class of fates also affects the economic value of the carcass. Fat can be deposited not only in the

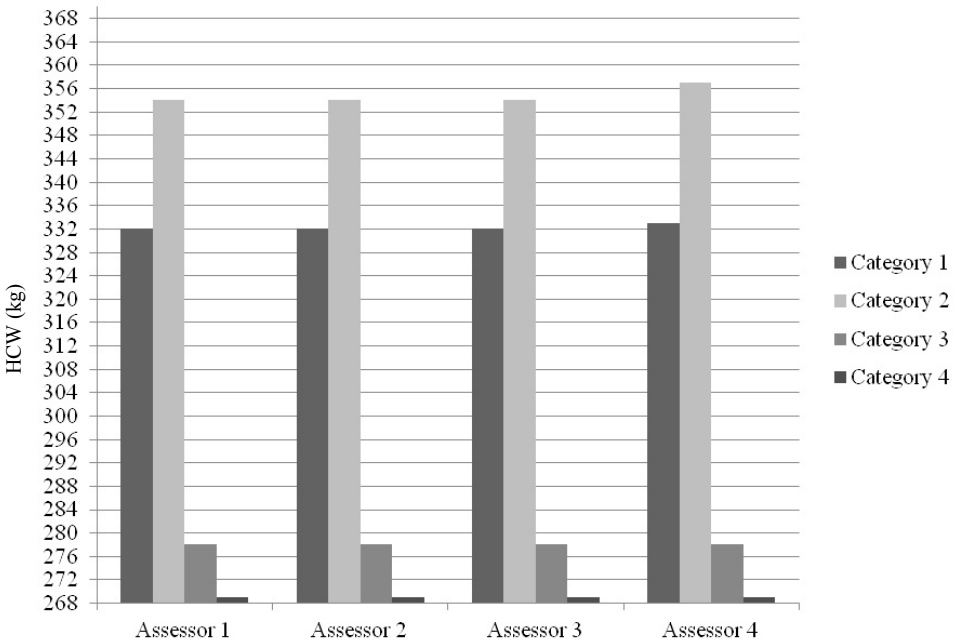

FIGURE 3. Changes in assessors evaluations regarding to hot carcass weight (HCW)

TABLE 3. Average assessments and standards error (*SE*) in assessors evaluations regarding to carcass conformation

Assesor numer	Category A		Category B		Category D		Category E	
	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*
1	4.27	0.2	4.3	0.3	5.02	0.21	4.39	0.26
2	4.27	0.2	4.28	0.3	5.03	0.21	4.40	0.26
3	4.3	0.2	4.29	0.3	5.01	0.21	4.38	0.26
4	3.8	0.2	3.76	0.3	4.34	0.21	3.83	0.26

TABLE 4. Average assessments and standards error (*SE*) in assessors evaluations regarding to carcass fatness

Assesor numer	Category A		Category B		Category D		Category E	
	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*
1	2.91	0.28	2.88	0.43	3.12	0.3	3.68	0.37
2	2.92	0.28	2.88	0.43	3.1	0.3	3.68	0.37
3	2.85	0.28	2.9	0.43	3.08	0.3	3.65	0.37
4	2.22	0.28	2.22	0.42	2.61	0.3	3.19	0.37

TABLE 5. Average assessments and standards error (*SE*) in assessors evaluations regarding to hot carcass weight (HCW)

Assessor numer	Category A		Category B		Category D		Category E	
	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*
1	332	1.73	354	2.63	278	1.87	269	2.3
2	332	1.73	354	2.63	278	1.87	269	2.3
3	332	1.73	354	2.63	278	1.87	269	2.3
4	333	1.72	357	2.61	278	1.87	269	2.3

subcutaneous tissue, but also between muscle fibers – intramuscular fat and carcass evaluation is based on the profiles of the carcass. Therefore, such assessment is usually biased. Lack of precision and accuracy in the classification of carcasses can be also caused by classifier fatigue, abnormal color of fat, or/and fat thickness that accompanies with high percentage of muscle tissue (Craigie et al. 2012, Cegiełka 2013).

CONCLUSIONS

Researches reviled significant differences in EUROP grades between compared assessors, ranged within two classes for carcass fatness and one class for conformation respectively. In average, the abattoirs seemed to under-classify conformation class and over classify carcass fatness. In practice, a visual assessment of the EUROP system performs only one person, so it is not fully representative and is not very accurate. The remuneration for livestock producers strongly depends on the assessment of carcasses and should be improved by increase of precision of the classification in slaughterhouses. An important factor in the growth of consumer satisfaction, as well as the supply of good quality beef would be to improve the precision and accuracy of the evaluation beef carcasses.

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Streszczenie: *Dokładność oceny wizualnej tusz wołowych EUROP wykonywanej przez krajowych ekspertów i eksperta pracującego w ubojni.* Klasyfikacja tusz wołowych w systemie EUROP wykorzystuje ocenę wizualną uformowania i okrywy tłuszczowej. Celem obserwacji było sprawdzenie dokładności ocen w systemie EUROP tusz wołowych certyfikowanego pracownika ubojni z inspektorami/pracownikami IJHARS. Analizowano wyniki w systemie EUROP, przeprowadzone na 3135 tuszach. Ocena przeprowadzona była przez czterech klasyfikatorów niezależnie i w tych samych warunkach panujących na linii ubojowej. Na podstawie wyników ocen tusz wołowych przeprowadzono analizę statystyczną. Wyniki wykazały, że powtarzalność i dokładność klasyfikatorów nadzorujących była dobra, a klasyfikacja pracownika ubojni znacznie odbiegała od reszty ocen (P <0,01). Otrzymane wyniki wskazują, że w klasach tłuszczu jest najwięcej i największych różnic w ocenach. Sugeruje to, że wizualna ocena tusz wołowych nie jest w pełni obiektywna i jest obarczona błędem oceniającego.

Słowa kluczowe: tusza wołowa, klasyfikacja, system EUROP, konformacja, otłuszczenie

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