

Annals of Warsaw University of Life Sciences – SGGW

Animal Science No 55 (2)
Warsaw 2016

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Proper care of dogs from their owner's perspective

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Abstract: *Proper care of dogs from their owner's perspective.* The aim of the study is to examine the level of awareness of dog owners regarding the needs of dogs and ways of providing them with proper care. In order to provide dogs with proper care one needs to consider both the specific requirements of the species, as well as the expectations of the owners. The owner (in Poland) awareness survey was carried out by means of an Internet diagnostic survey. The survey was performed on a group of 424 people currently owning dogs. Surveyed were asked 12 questions. The results of the survey were processed statistically (SPSS 23.0 statistical package). In order to divide the respondents into groups of various awareness of dog welfare, a clustering analysis was performed using *k*-means clustering. In order to estimate the differences in several independent variable samples the Kruskal–Wallis test was used. The respondents attributed the largest weight to medical costs (0.847) and physical activity associated with owning a dog (0.844). They regarded the costs of keep least important (0.548). The differences were confirmed statistically. Already during the phase of making the decision about owning a dog the more aware persons search for information about the animal. Such people declare greater weight of all elements of dog care associated with welfare. This relation is evident in case of grooming and providing the dog with walks. The obtained results of the survey show that the majority of the respondents are people knowing the needs of their dogs.

Key words: dog, welfare, care, health

INTRODUCTION

There is still no certainty as to when the dog was domesticated. The studies of Skoglund et al. (2015) showed that the ancestors of today's dogs separated from wolves probably between 27 and 40 thousand years ago. Initially the relationship between dog and man based mainly on work and the fulfilling of specific tasks by the dog. The basis of this cooperation was the selection of dogs for the ability to beneficially cooperate with man (McGreevy and Nicholas 1999). Fundamental civilization changes of the 20th century caused a change of the dog's role in the life of man. Today people expect dogs to provide them with company and friendship (Boruta et al. 2014).

In order to provide dogs with proper care one needs to consider both the specific requirements of the species, as well as the expectations of the owners. Broom (1997), as well as Lue et al. (2008), proved that the bond between man and dog has an influence on providing welfare to the animal. They proved that caretakers who are more strongly connected with their dog are willing to

provide a higher level of veterinary care, but also follow the recommendations of the veterinarian more often, regardless of the costs.

Depending on the norms in a given society there are various public opinion attitudes towards dogs. The need to provide them with welfare is also understood in various ways. Researchers of this subject found an influence of cultural and social differences (Serpell 2004) and distinct individual differences in attitudes toward pet owners depending on age, sex (McKay et al. 2009), place of residence (Knobel et al. 2008, Acosta-Jamett et al. 2010) and a previous contact with a dog (Hsu et al. 2003). The strength of the bond between man and dog, as well as a social perception of dogs may have an influence on the dog population in a given society. In Poland there are about 7.5 million dogs (FEDIAF 2012), which means we rank second in this respect in Europe (behind Great Britain).

The aim of this study is to determine the level of awareness of dog owners in Poland on the subject of dog needs and ways of providing them with proper care.

MATERIAL AND METHODS

The study of owner awareness regarding the proper care of dogs was carried out by means of an Internet diagnostic survey. The survey was carried out on a group of people currently owning a dog (dogs), who are active on internet forums dedicated to cynology.

The survey was prepared with the use of the "Google Forms" application and distributed on forums and social portals dealing with dog related subjects. The survey collected information characterizing the structure of the respondents, as well as examined the awareness of dog owners regarding dog care (12 questions in the survey). The awareness of the respondents regarding proper care of the dog was assessed by referring to the concept of welfare as a state of physical and mental health achieved in conditions of complete harmony of an organism in its environment (Hughes 1988). Dog owners were asked about how significant to them (to the owners) were vaccinations and dewormings, medical costs, physical activity, the costs of keeping a dog, the place of the dog's residence, the dog's

TABLE 1. The importance of traits for dog owners (% of respondents)

Dog welfare trait	The importance for dog owners				
	very important	important	average important	small important	unimportant
Vaccinations, deworming	56.57	25.12	10.09	4.93	3.29
Medical costs	58.69	27.23	10.09	2.35	1.64
Physical activity	53.05	35.45	8.92	1.41	1.17
Cost of dog keep	14.32	24.88	35.68	15.50	9.62
Place of dog's residence	34.04	37.09	19.48	5.63	3.76
Contact with other animals at home	49.53	29.58	11.03	3.52	6.34
Length of walks	39.20	41.78	12.44	4.23	2.35
Grooming	25.35	35.69	25.35	9.39	4.23

contact with other animals at home, the length of walks and grooming (Table 1).

The results of the survey were processed statistically (SPSS 23.0 statistical package) and presented in the form of tables and figures. In order to divide the respondents into groups of various awareness regarding dog welfare, an analysis was done using *k*-means clustering. In order to estimate the differences in several samples of independent variables the Kruskal–Wallis test was used.

RESULTS AND DISCUSSION

The research consisted of 424 persons (91.5% of them were female and 8.5% were male). In Poland greater activity on internet forums dedicated to cynology is usually exhibited by women. Exactly 64.4% of the respondents had tertiary education, 32.5% secondary or vocational and 2.8% a primary education. In 32.3% of cases the respondents had more than one dog in their life and in 43.4% of cases it was a pedigree dog.

Weights from 1 to 0 were attributed to variables describing the welfare of the dogs (Table 2). All traits achieved the lowest and highest ranks and their

averages were above 0.50. The respondents attributed the highest importance to medical costs (0.847) and physical activity associated with owning a dog (0.844). They considered the costs of keep to be the least significant (0.548).

In order to distinguish groups of respondents with specific preferences regarding dog welfare, an analysis of clusterings was made using the *k*-means method (Fig. 1).

The hierarchies of variables describing dog welfare, pointed out by the respondents, allowed to identify five clusterings (Fig. 1). Detailed data is presented in Table 3. Respondents from clustering 1 ($N = 119$) characterized themselves with the highest rank of the majority of the studied traits. They are the most aware of the responsibility associated with providing welfare to a dog. They stood out among the other groups with a high assessment of the weight of the dog's keep costs (0.83, the other clusterings below 0.53). Similarly to the respondents from this clustering, also the respondents from the clusterings 3 and 4 attributed a very high weight to such traits as vaccination and deworming, medical costs and physical activity. Respondents from clustering 2 ($N = 86$) assessed the analyzed

TABLE 2. Average weights of dog welfare traits

Weight	<i>AVG</i>	<i>SE</i>
Vaccinations, deworming	0.816	0.013
Medical costs	0.847	0.011
Physical activity	0.844	0.010
Cost of dog keep	0.548	0.014
Place of dog's residence	0.731	0.013
Contact with other animals at home	0.780	0.014
Length of walks	0.777	0.011
Grooming	0.670	0.013

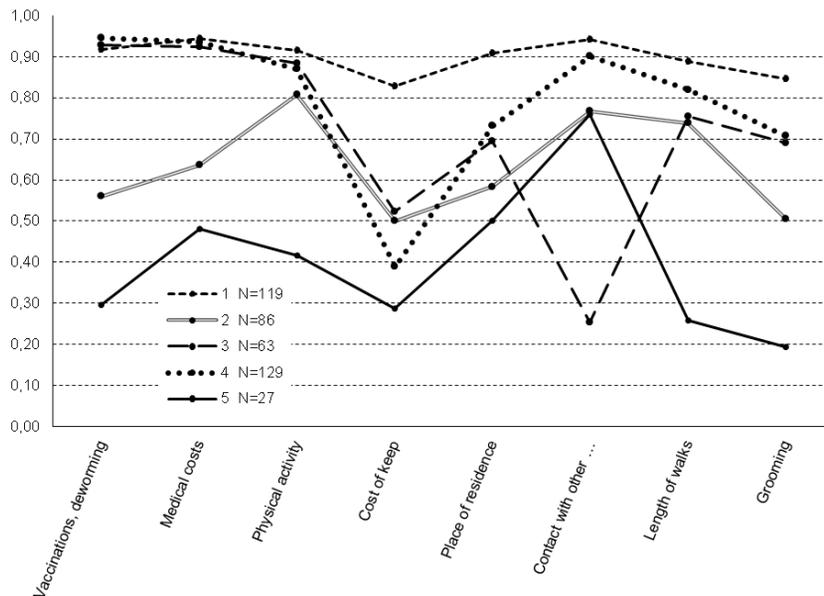


FIGURE 1. Clusters of variables characterizing dog welfare

TABLE 3. Cluster centres of welfare traits in five clusterings

Dog welfare trait	Clustering				
	1	2	3	4	5
Vaccinations, deworming	0.92	0.56	0.93	0.95	0.30
Medical costs	0.94	0.64	0.92	0.94	0.48
Physical activity	0.92	0.81	0.88	0.87	0.42
Cost of dog keep	0.83	0.50	0.52	0.39	0.29
Place of dog's residence	0.91	0.58	0.69	0.73	0.50
Contact with other animals at home	0.94	0.77	0.25	0.90	0.76
Length of walks	0.89	0.74	0.75	0.82	0.26
Grooming	0.85	0.51	0.69	0.71	0.19

traits at an average level. Clustering 3 ($N = 63$) differed from the others in the assessment of the contact with other pets at home, which was regarded as least significant (0.25). Respondents from clustering 4 ($N = 129$) assessed the majority of the traits, apart from the keep costs (0.44 difference) similarly to those from clustering 1. In clustering 5

($N = 27$) were people who attributed the least weight to all studied traits of welfare, apart from contact with other animals already living at home (0.76). The respondents from that clustering regarded the following traits of little significance: grooming of the dogs (0.19), length of walks (0.26), costs of keep (0.29) and preventive procedures (0.30).

An analysis of traits describing dog welfare depending on the information about the owned dog (Fig. 2) showed that beside the costs of keep all traits were assessed high and regarded as very significant or significant and the differences were confirmed statistically.

Already during the phase of making the decision about owning a dog the more aware persons search for information

about the animal. Such people declare a greater weight of all elements of dog care associated with welfare. This relation is especially visible in the case of grooming (Fig. 3) and providing the dog with walks. Exactly 63% of the respondents regularly care about the hygiene of the dog's teeth by giving him cleaning chew toys and care about the dog's coat (depending on the needs). As many as

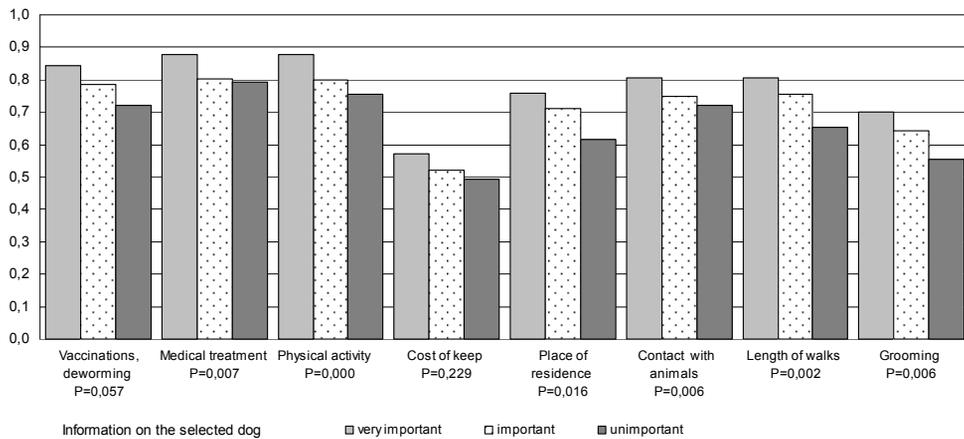


FIGURE 2. Averages of traits characterizing welfare depending on the information about the owned dog

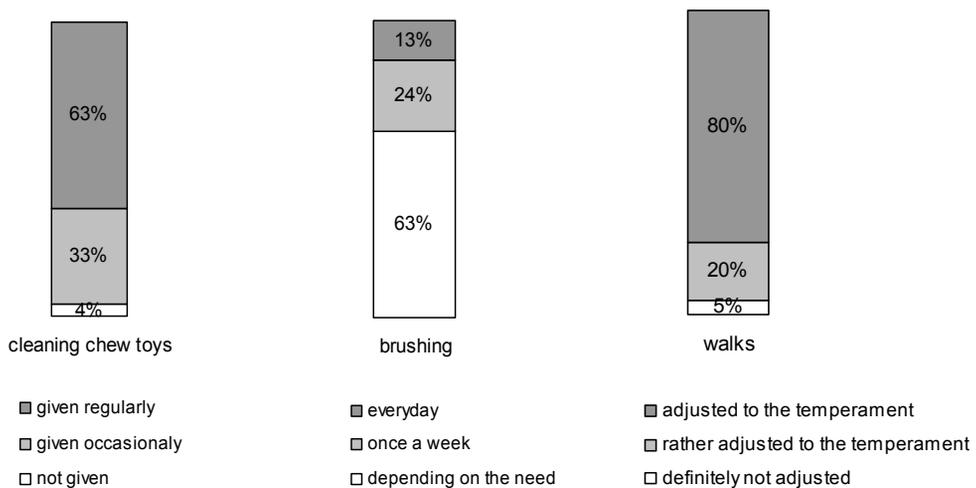


FIGURE 3. Declarations of adhering to dog welfare in respect to selected grooming treatments (teeth and coat care) and walks

80% declare that the dog's walks are adjusted to its temperament. Such a result of the survey analysis places the group of respondents in a group of people that adhere to welfare (Hughes 1988) and principle of the "five freedoms" (Farm Animal Welfare Council 2009). What may cause concern is the fact of undervaluing the role of costs associated with keeping a dog, which may be generated both as part of preventive procedures (vaccinations and deworming), medical treatment, grooming, physical activity and are often associated with the place of the dog's residence.

CONCLUSIONS

An analysis of the level of dog owner awareness regarding the needs of dogs and ways of providing them with welfare showed that:

1. In Poland greater activity on Internet forums dedicated to cynology is exhibited by women (91.5% respondents).
2. Generally respondents attributed the largest weight to medical costs and physical activity associated with owning a dog and regarded the costs of its keep as least significant.
3. The respondents can be divided into five groups (clustering analysis) differing in the understanding of dog needs: first – people most aware of the responsibility associated with providing welfare (the highest rank of the majority of researched traits, a high assessment of the weight of the costs of keeping a dog), second – those assessing the analyzed traits at an average level, third – differed from the

- others by a low assessment of contact with other pets at home, forth – the respondents assessed the majority of the traits, apart from keep costs, similarly to the respondents from clustering 1, fifth – people attributing the lowest weight to all researched welfare traits, apart from contact with other animals already living at home.
4. Already during the phase of making the decision about owning a dog the more aware persons search for information about the animal. Such people declare a greater weight of all elements of dog care associated with its needs and welfare.

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- opieki. Aby zapewnić psom odpowiednią opiekę, należy wziąć pod uwagę zarówno specyficzne wymogi gatunku, jak i oczekiwania właścicieli. Badanie świadomości właścicieli przeprowadzono za pomocą internetowego sondażu diagnostycznego. Ankiety przeprowadzono w Polsce, na grupie 424 osób, aktualnie posiadających psy. Ankietowanym zadano 12 pytań. Wyniki ankiety opracowano statystycznie (pakiet statystyczny SPSS 23.0). W celu podzielenia respondentów na grupy o różnej świadomości w zakresie dobrostanu psów zastosowano analizę skupień metodą *k*-średnich. Do oszacowania różnic w kilku próbach zmiennych niezależnych wykorzystano test Kruskala–Wallisa. Respondenci największą wagę przywiązywali do kosztów leczenia (0,847) i aktywności fizycznej związanej z posiadaniem psa (0,844). Za najmniej istotne uznali koszty utrzymania (0,548). Różnice zostały potwierdzone statystycznie. Już na etapie podejmowania decyzji o posiadaniu psa osoby bardziej świadome poszukują pełnych informacji o zwierzęciu. Takie osoby deklarują większą wagę wszystkich elementów opieki nad psem związanych z dobrostanem. Zależność ta jest wyraźna w przypadku pielęgnacji i zapewnienia psu spacerów. Uzyskane wyniki badania ankietowego wskazują, że większość respondentów to osoby znające potrzeby psów.

Słowa kluczowe: pies, dobrostan, opieka, zdrowie

MS received 04.09.2016

MS accepted 07.11.2016

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Streszczenie: *Właściwa opieka nad psem z perspektywy właścicieli.* Celem pracy jest zbadanie poziomu świadomości właścicieli psów na temat potrzeb psów i sposobu zapewnienia im właściwej

The criteria for choosing a companion dog

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Abstract: *The criteria for choosing a companion dog.* What criteria do people follow in selecting a dog in Poland? By means of a diagnostic survey a study was carried out examining the criteria for selecting a companion dog. The survey was filled out by 424 dog owners (in Poland), representing various ages and education. An analysis of the results allowed to divide the surveyed community into five clusters. The respondents from the 1st cluster preferred pedigree dogs. They regarded the most important criteria of dog selection to be parentage (0.809), size (0.652) and temperament (0.478). The 2nd cluster included people having a good contact with dogs and preferring a specific type of dog temperament. They most highly regarded the temperament of the dog (1.000) and its appearance (0.693). The 3rd cluster included altruists, for whom none of the analyzed criteria of selection were important. For them the most important criteria of dog selection was the temperament of the animal (0.977), less important were sex (0.593), parentage (0.558) and the utility purpose (0.453), whereas age and external appearance were completely irrelevant. The respondents in the 4th cluster (people preferring work and physical activity with the dog) differed from the others by having the highest assessment of the dog's utility purpose (0.906). Their utilitarian attitude towards dog selection confirms regarding temperament as second in the hierarchy of criteria (0.750) and size as the third (0.547). The least traits associated with the utilitarian side of the dog were shown by respondents from the 5th cluster (average dog owners). They regarded the following criteria to be most important: size (0.688), age and appearance (0.656) and sex (0.563).

Key words: dog choosing, conformation, temperament, utility purpose, sex

INTRODUCTION

In the initial phase of building and strengthening mutual relations between man and dog the animal was used solely for utility purposes (Vila et al. 1997). Currently many dogs living in a urban environment serve as companion dogs. The decision to own a dog generates consequences and duties for many years to come. Choosing a method of acquiring a dog, be it by purchase or through adoption, has its good and bad sides. The purchase of a dog from a breeding kennel is synonymous with acquiring information regarding its parentage, needs, and makes one aware of the costs of its future keep. The adoption of a homeless dog is associated with a lack of information about its past, which has a huge influence on the way the animal functions in the environment of man (Salman et al. 2000, Marston et al. 2004, Segurson et al. 2005, King et al. 2009, Boruta et al. 2014).

The aim of the study is to examine the criteria of selecting a companion dog in Poland.

MATERIAL AND METHODS

Based on the results of an anonymous diagnostic survey, an analysis was performed of the criteria by which future

owners make their decision to select a dog. The research material consisted of data from 424 correctly filled out survey forms. Each of the surveyed people was a current dog owner.

The survey was designed basing on the “Google Forms” application and later distributed by means of forums and social portals, which bring together people interested in dog breeding and keep. The aim of the survey was to obtain information on the components that make up the final decision to select a particular dog by its future owners. The following criteria (that are taken into consideration by potential owners when selecting a dog) were analyzed: sex, parentage, utility purpose, age, size, appearance and temperament. The above mentioned variables, depending on the answer given by the respondent, were given the following values: 0 – the respondent does not take this criterion under consideration when selecting a dog, 1 – the respondent considers this criterion when selecting a dog.

The research material was processed statistically by means of the SPSS 23 statistic package. The correlation between the prevalence of particular variables was determined by means of the Fisher test. In order to distinguish groups of respondents characterized by specific preferences when selecting a dog, an analysis using *k*-means clustering (QUICK CLUSTER) was made.

RESULTS AND DISCUSSION

As many as 91.5% of the respondents were female (Table 1). The method of distributing the survey was through forums and social portals, where women

TABLE 1. Profiles of the respondent group

Variable		<i>N</i>	%
Sex	female	388	91.5
	male	36	8.5
Age	18–25 years	150	35.4
	26–40 years	203	47.9
	above 40 years	71	16.7
Education	tertiary	274	64.6
	secondary	120	28.3
	vocational	18	4.3
	primary	12	2.8
Number of owned dogs	one	286	67.5
	two	104	24.5
	three and more	34	8.0
Dog breed	pedigree	184	43.4
	mix-breed	240	56.6

are more active. The respondents were divided into three age groups: I – people on the verge of adulthood (18–25 years), II – people at an age to establish their own families and to build their professional and financial stability (26–40 years) and III – older people, professionally (above 40 years). The majority of respondents had a higher education (64.6%), only 4.2% had a vocational education and just 2.9% had a primary education.

At the time of the carried out survey most people declared that they owned one dog (67.5%) and in 43.4% cases it was a pedigree dog.

Five clusters (groups) of respondents were distinguished, with various hierarchies of values when selecting a dog (Fig. 1, Table 2). Respondents from the 1st cluster considered that the most important criterion when choosing a dog was its parentage (0.809), then its size (0.625) and temperament (0.478). The chosen traits show that the respond-

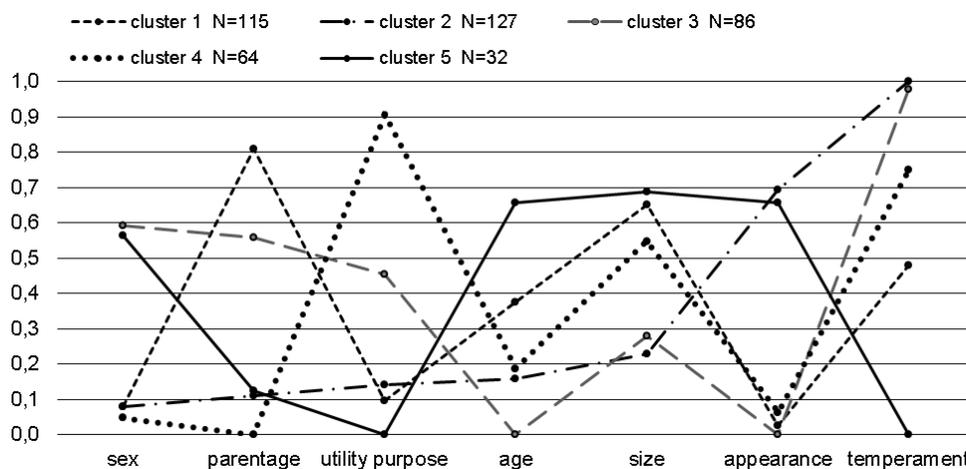


FIGURE 1. Clusters of variables determining the criteria for dog selection

TABLE 2. Cluster centres of variables determining the criteria for dog selection

Selection criteria	N		Cluster				
	significant	insignificant	1 N = 115	2 N = 127	3 N = 86	4 N = 64	5 N = 32
Sex	91	333	0.078	0.079	0.593	0.047	0.563
Parentage	159	265	0.809	0.110	0.558	<0.001	0.125
Utility purpose	126	298	0.096	0.142	0.453	0.906	<0.001
Age	96	328	0.374	0.157	<0.001	0.188	0.656
Size	185	239	0.652	0.228	0.279	0.547	0.688
Appearance	116	308	0.026	0.693	<0.001	0.063	0.656
Temperament	314	110	0.478	1.000	0.977	0.750	<0.001

ents from this cluster probably prefer pedigree dogs. The least important for them, similarly to the respondents from the 3rd and 4th cluster, was the appearance of the dog (0.026), its sex (0.078) and utility purpose – the main reason for which the dog is chosen (0.096). The 2nd cluster included people that valued the temperament of the dog the most (1.000). The external appearance is also of significance to them (0.693), but they assessed the other criteria at less than 0.229. The respondents from that cluster can be characterized as people who

have a good contact with dogs and prefer a specific type of their character. In cluster 3, similarly to cluster 2, the highest criterion was the dog's temperament (0.977). The respondents from that cluster deemed the following less important: sex (0.593), parentage (0.558) and utility purpose of the dog (0.453) and considered the age and external appearance completely irrelevant. The respondents from this cluster can be called altruists, for whom none of the analyzed criteria was important. Those grouped in cluster 4 differed from the others with the high-

est assessment of the utility purpose criterion (0.906). Their utilitarian approach in selecting a dog is confirmed by pointing to temperament as the second in the criteria hierarchy (0.750) and dog size as the third (0.547). These are people preferring work or physical activity with the dog. The least traits associated with the utilitarian side of the dog were shown by respondents from the 5th cluster. None of them pointed to the character and utility purpose of the dog when choosing one. They decided that the most important criteria were: size (0.688), age and appearance (0.656) and sex (0.563). We could define them as interested in the superficiality of the dog.

Reason for owning a dog

The results of the study show that none of the analyzed criteria have a statistically significant influence when selecting a dog for its utility purpose (Fig. 2). The majority of the respondents own

dogs for company (97.4%) and it was in this group that most people deemed the temperament of the dog to be important (75%). The respondents from this group, more often than others, valued the dog's sex (22%) and its appearance (28%). No people that own dogs to guard their homes paid attention to the sex and appearance of the dog (0%). And 60% of them pointed to the age as the criterion in selecting a dog. Among people owning dogs "for children" the most important was the temperament of the dog (67%) and its size (50%). This probably attests to a well-considered decision, as these traits are associated with the safety of children in contact with the dog. A safe behaviour towards children was shown as an important or a very important behavioural element of an ideal dog (Dive-rio et al. 2016).

The results of the study of Wood et al. (2005) show that the company of a dog is conducive to social interactions, while children growing up in the company of

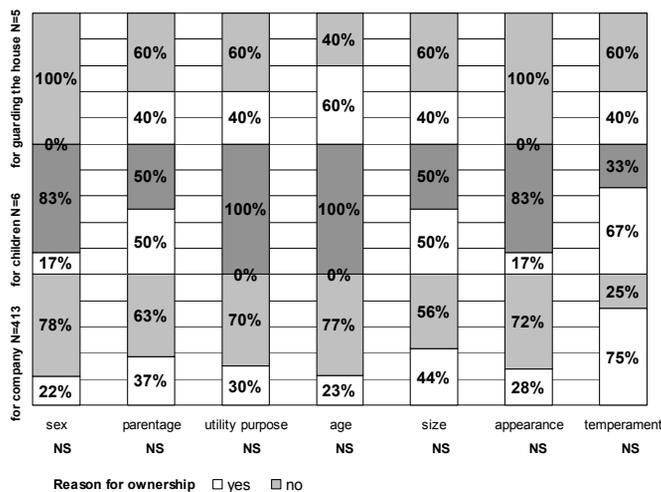


FIGURE 2. Criteria for dog selection depending on reason for ownership

a dog are more emphatic and popular among their peers. The owning of companion animals brings their owners emotional, psychological and physical benefits (Knight and Edwards 2008).

Number of owned dogs

Similarly to the reason for owning a dog, so the number of owned dogs did not have a statistically significant correlation with the criteria for selecting a dog (Fig. 3). Those that owned one dog, regarded utility purpose (31%), size and appearance (29%) to be of more importance during selection. With a larger number of owned dogs grew the significance of parentage (from 34 to 48%) and decreased the utility purpose (from 31 to 24%), size (from 47 to 27%) and appearance (from 15 to 29%). While conducting studies on the perception of an ideal dog Diverio et al. (2016) noticed that the majority of dog owners (60%) had 1–3 dogs.

Owning a dog previously

Respondents which had owned a dog previously differed statistically significantly ($P = 0.031$) from respondents that owned a dog for the first time by prevalence of selecting the appearance criterion (Fig. 4). In other criteria for selecting a dog no statistically significant differences between respondents were found. People owning their first dog were also more focused on its character (78%). Whereas to respondents that owned dogs previously much more important in choosing the next one was its size (44%), parentage (39%), age (24%) and sex (22%).

Breed of dog

The majority of respondents had mixed-breed dogs (Fig. 5). Among the respondents with pedigree dogs only 31% considered the appearance an important criterion of selection. This group

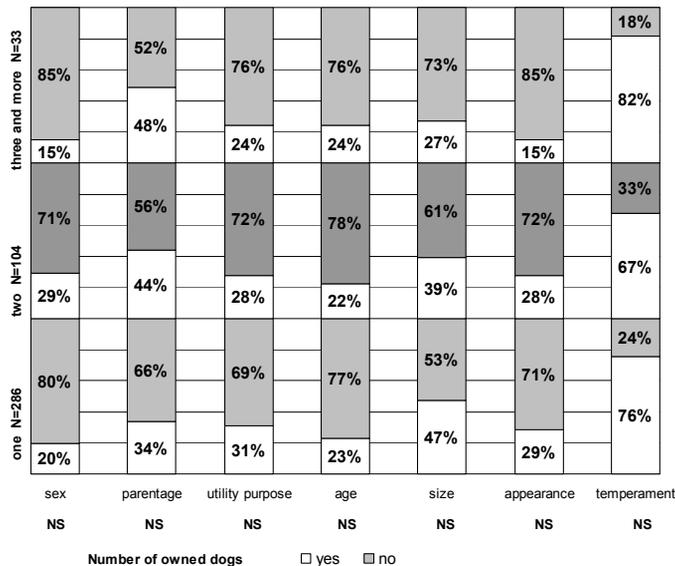


FIGURE 3. Criteria for dog selection depending on the number of owned dogs

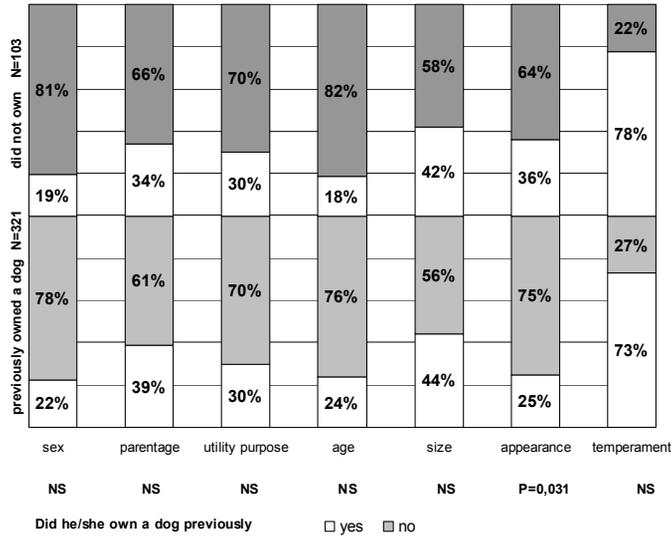


FIGURE 4. Criteria for dog selection depending on earlier dog ownership

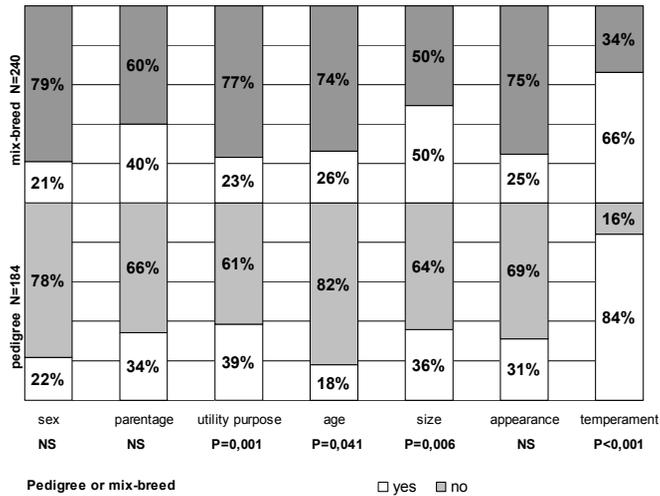


FIGURE 5. Criteria for dog selection depending on the parentage of the dog

did not differ statistically significantly from those owning mix-breeds, analyzing the importance of the parentage and sex criteria. People owning mix-breeds regarded more important the size (50%) and age (26%) of the dog, and those with pedigree dogs the temperament (84%)

and utility purpose (39%). These differences were statistically significant. Di-verio et al. (2016) showed that only in 19.2% of the studied cases of dog owners in Italy the physical attractiveness of the dog had an important or most important significance.

Temperament of the dog

Among people for whom the temperament of the dog is very significant, as many as 13% did not consider it a criterion when selecting a dog (Fig. 6). Whereas 24% of the respondents, for whom temperament is insignificant, pointed to it as an important criterion when selecting. These differences may rise from experiences gained by respondents during their dog ownership. These differences were statistically highly significant ($P < 0.001$). The most important during selection, for respondents not focused on character, was parentage ($P = 0.007$) and the size of the dog ($P = 0.032$). They differed significantly also in regard to the utility purpose of the dog ($P < 0.001$), which only 13% of them regarded as important when selecting a dog. In each group of respondents, on account of their attitude towards the temperament of the dog, a similar number of people regarded sex, age and appearance as an unimportant criterion for selection (from

72 to 79%). Also studies carried out by Diverio et al. (2016) showed that people prefer dogs with desirable temperament traits.

Information about the selected dog

The attitude towards information about the selected dog differentiated respondents in a statistically significant way in the utility purpose ($P < 0.001$) and temperament ($P < 0.001$) criteria. Among people for whom information about the owned dog is insignificant only 2% pointed to the utility purpose of the dog as the criterion for selection (Fig. 7). In the respondent group in which the temperament of the dog was an important trait, 80% regarded information about the dog to be very significant and 72% to be significant. In terms of other criteria of selection the respondents, with various attitude towards information about the dog, did not differ statistically significantly.

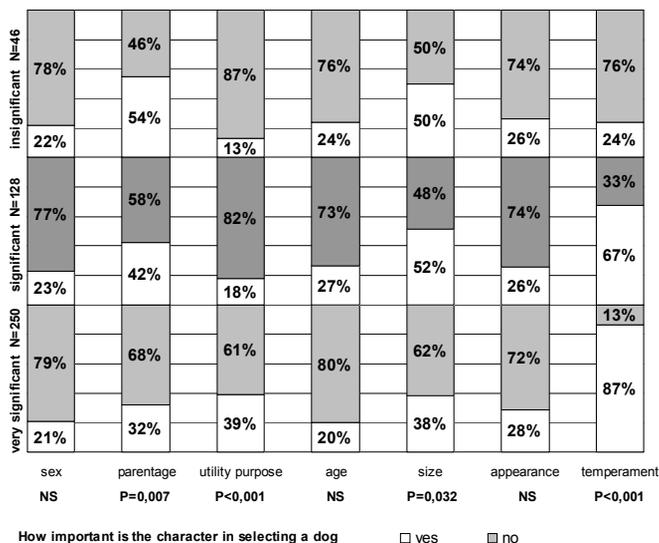


FIGURE 6. Criteria for dog selection depending on the attitude towards the character of the dog

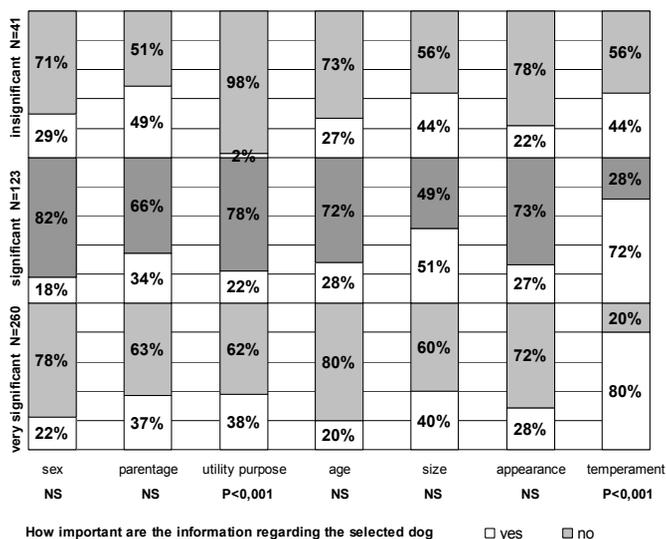


FIGURE 7. Criteria for dog selection depending on the attitude towards information about the dog

Age of the dog owner

Among the respondents the majority of the people were aged from 26 to 40 years old (Fig. 8). The youngest people focused more on the temperament of the dog than older people and this difference was statistically significant ($P < 0.001$). Only 26% respondents from this group regarded the parentage of the dog as a criterion of selection ($P < 0.001$). They regarded the age of the dog to be more important, which for as many as 30% of the respondents was an important criterion in selection ($P = 0.030$). The attitude towards other criteria of selection by people from various age groups was statistically insignificant. The studies of Howell et al. (2016) showed that people above 40 years of age are more conscious dog owners. They admit that despite a conscious decision to own a dog the care of it turned out more difficult than they expected. Together with the increase

of the respondents' age it was observed that they reported problems with destructive behaviour, urinating, defecating and barking as difficult.

Sex of the dog

The sex of the dog is not a significant criterion in selecting a dog, regardless of its utility purpose (from 78 to 100%) (Fig. 2) or the number of dogs already in the house of the person selecting another dog (from 71 to 85%) (Fig. 3). It also has no significance for novices or for experienced dog owners (from 78 to 81%) (Fig. 4). Similar results were obtained in the studies of Boruta et al. (2014). The studies of Žák et al. (2015) showed that though among rehabilitated dogs and those prepared for adoption in Czech shelters males dominate only slightly (56%), they constitute more than 67% of dogs selected by adopting people.

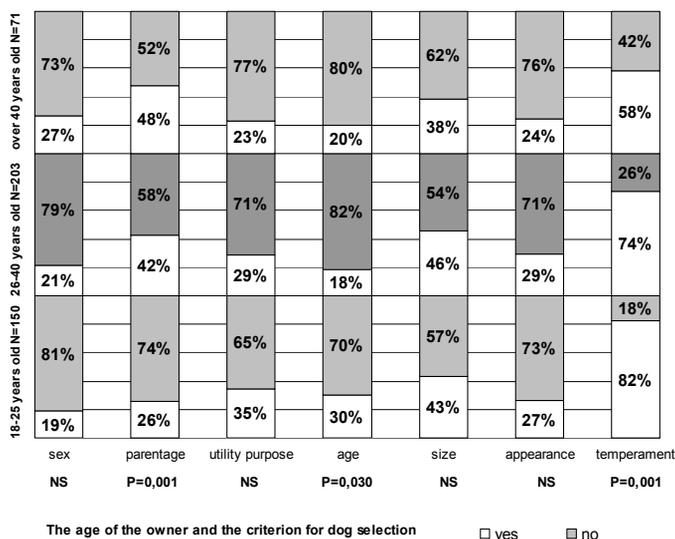


FIGURE 8. Criteria for dog selection depending on the age of the owner

CONCLUSIONS

A person deciding to take in/purchase a dog must be fully aware of the seriousness of his/her decision. A dog is usually a man’s companion for some dozen years, bringing joy and support, but also generating costs that are not so small.

The results of the carried out survey allow to formulate the following conclusions:

1. The most common criterion of dog selection was the animal’s temperament, and the least – its sex and age.
2. Basing on the analysis of the selection criteria, people deciding to own a dog can be qualified into one of five groups:
 - preferring pedigree dogs;
 - having a good contact with dogs and preferring a specific type of temperament;

- altruists – apart from character, none of the suggested criteria has greater significance;
- preferring work or physical activity with the dog;
- interested mainly in the dog’s superficiality.

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- Ankiętę wypełniły 424 osoby, posiadające psy, reprezentujące różny wiek i wykształcenie. Analiza wyników pozwoliła podzielić ankietowaną społeczność na pięć skupień. Respondenci ze skupuienia 1 preferowali psy rasowe. Uznali, że najważniejszym kryterium wyboru psa jest pochodzenie (0,809), wielkość (0,652) i temperament (0,478). W skupieniu 2 znalazły się osoby mające dobry kontakt z psami i preferujące określony typ temperamentu psów. Najwyżej ceniące temperament psa (1,000) oraz jego wygląd (0,693). W skupieniu 3 znaleźli się altruści, dla których żadne z analizowanych kryteriów wyboru nie było ważne. Dla nich najważniejszym kryterium wyboru był temperament (0,977), za mniej ważne uznali płęć (0,593), pochodzenie (0,558) i użytkowość psa (0,453), a za całkiem nieistotne wiek i wygląd zewnętrzny. Badani w skupieniu 4 (osoby preferujące pracę i aktywność fizyczną z psem) różnili się od pozostałych najwyższą oceną użytkowości psa (0,906). Ich użytkowe podejście do wyboru psa potwierdza wskazanie temperamentu jako drugiego w hierarchii kryterium (0,750) i wielkości jako trzeciego (0,547). Najmniej cech związanych ze stroną użytkowa psa wskazali badani ze skupienia 5 (przeciętni właściciele psów). Za najważniejsze kryteria uznali: wielkość (0,688), wiek i wygląd (0,656) oraz płęć (0,563).

Słowa kluczowe: wybór psa, eksterier, temperament, przeznaczenie, płęć

MS received 23.08.2016

MS accepted 13.10.2016

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Streszczenie: Kryteria wyboru psa towarzyszącego. Za pomocą sondażu diagnostycznego przeprowadzono badanie kryteriów wyboru psa towarzyszącego w grupie polskich posiadaczy psów.

Carcass characteristics and meat quality of extensive grazed Polish Heath Sheep

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Abstract: *Carcass characteristics and meat quality of extensive grazed Polish Heath Sheep.* Slaughter value and fatty acid profile from group of rams and castrates, that were kept on fallow lands used for past 15 years only for sheep production were analyzed. Positive impact of extensive grazing on animals production results during grazing season have been shown. Slaughter analysis have shown beneficial effects of this form of grazing on fatty acid profile. Rams castration may be advantageous in case of conducting the production in such areas because number of animals groups is reduced and its affects cost reduction.

Key words: meat quality, extensive grazing, sheep production

INTRODUCTION

In Polish conditions main income from sheep production comes from sale of slaughter lambs for western markets. Knowledge of lamb meat values in Poland is unknown to wider society. There is still a belief that it is a meat having a specific taste and smell, inadequate for fast preparation such as chicken (Głowacz and Niżnikowski 2008). Meanwhile, the lamb meat is considered as a functional and health food characterized with many valuable qualities for a human health (Borys and Pisulewski 2001). In many European countries, lamb meat is considered a luxury product frequently bought by consumers. In

Polish conditions, the average consumption of this meat is about 48 g for the average Pole in year or 0.02% of all meat consumed (<http://faostat.fao.org>). There are many factors that affect the quality and quantity of the received product. An important factor in the meat production is sex of fattened animals. Rams have a better suitability for fattening because of a faster growth rate and carcass weight (Todaro et al. 2004). Despite that fact, there is no need for young rams castration this procedure is used to avoid uncontrolled reproduction when space is limited or animals of both sexes are grazed together, also reduces aggression and sexual activity by lowering testosterone levels, which is particularly important in the period before slaughter, because reduces the depletion of energy resources necessary to lower the pH of muscle (Peinado et al. 2011, Nogalski et al. 2013). The aim of the study is to compare meat quality of two animals groups from extensive livestock production.

MATERIAL AND METHODS

Two groups of animals (rams and castrates) were selected to estimate meat value and the ability to conduct extensive sheep grazing on fallow lands. Af-

ter obtaining a appropriate body weight (33 kg \pm 1%) animals were slaughtered and their carcasses evaluated. Additionally the skin was weighed. In total nine rams and nine castrates were rated. Statistical calculations were done using SPSS software 14 and differences between experimental groups were evaluated with Student's t-test (Ruszczyc 1981).

Carcass quality

Obtained carcasses were weighed, divided into two halves (Nawara et al. 1963) and following measurements were taken on left half part: classification by the EUROP system, estimation of color and texture of carcass fat, length and girth of leg, width of the ankle joint, pH (pH₀ and pH₂₄), slaughter yield (%), surfaces of "eye" loin.

Weight and percentage of parts – neck, middle neck, loin, rib steak, shoulder, hideshow and foreshank, tenderloin and leg, were rated. Share of valuable parts (leg, foreshank and rib steak) of half-carcass was determined. Weight and the percentage of each tissue (meat, bones and fat) of leg were checked.

Meat quality

Samples of meat were taken from *longissimus dorsi* muscle (*musculus longis-*

simus dorsi) and were tested for color (L*a*b* parameters) using Konica Minolta CR-400, where L * parameter meant brightness of meat, and a* – share of red, b* – share of yellow (Strzyżewski at al. 2008, Juarez et al. 2009). Water absorption with Grau–Hamm method (Hamm 1986) and the dry matter according to PN-73/A-82110 were determined (Horoszewicz et al. 2008). Protein and fat content was determined according to standard methods AOAC (1990). From the part of meat sample was taken to analyze fatty acid profile with gas chromatography on a Hewlett–Packard (Radzik–Rant 2005, Nałęcz-Tarwacka 2006).

RESULTS AND DISCUSION

There has been observed a higher weight of the carcass, half-carcass and skin in ram group. Also slaughter yield (%) and daily weight increase (g) were higher in this group, but differences were no statistically significant. Slaughter yield at around 40% were similar to the result which gained by Khidir et al. (1998) and Niżnikowski (2002) but is lower than the results achieved from national population (Table 1).

In terms of EUROP classification and carcass fatness rams showed bet-

TABLE 1. Characteristics of slaughter and fattening

Traits	Rams (A) (N = 9)		Castrates (B) (N = 9)	
	AVG	SE	AVG	SE
Carcass (kg)	12.90	0.44	12.30	0.44
Pelt (kg)	2.77	0.18	2.56	0.18
Daily weight increase (g)	0.29	0.01	0.28	0.01
Half-carcass (kg)	6.45	0.30	6.15	0.30
Slaughter yield (%)	41.50	1.57	38.53	1.57

ter parameters than castrates. Most carcasses for both groups were classified in R category, while two rams were qualified for U category and three castrates to O category. Castrates carcasses had more colored fat and a greater cohesion than other group (Table 2).

TABLE 2. Results comparison of the classification of both groups

Item	Σ	Rams (<i>N</i> = 9)	Castrates (<i>N</i> = 9)
EUROP class (categories)			
E	0	0	0
U	2	2	0
R	13	7	6
O	3	0	3
P	0	0	0
Fat class (categories)			
1	13	8	5
2	5	1	4
3	0	0	0
4	0	0	0
5	0	0	0
Fat colour			
Coloured	10	3	7
White	8	6	2
Fat consistency			
Very	4	0	4
Cohesive	12	7	5
Tender	2	2	0
Very tender	0	0	0

A group of rams was characterized by a higher depth and length of the leg (cm) and the surface of the “eye” loin (cm²). Other analyzed measurements were higher in castrates group. Differences were significant in the case of deep leg (cm) and the thickness of the fat cover on loin eye (mm) – Table 3. Measurements made on loin eye area of tenderloin were varied depending on the experimental group, however similar to the results pre-

sented by Niżnikowski (2002). Animals that were not castrated had greater depth and eye loin area. Other measurements were higher in the second group.

A greater weight of kidney with fat, loin, leg, tenderloin and valuable cuts in half-carcass in ram group was observed but weight of fore- and hideshow, shoulder, neck, middle neck, breast and rib steak was higher in castrated group. In case of leg dissection muscle and bone mass was greater at castrates and the fat in second group. However, these differences were not statistically significant. Only in case of percentage share of middle neck and lean in leg statistically significant differences were observed (Table 4). Cutting carcasses results were similar to the results of research which gained Johnson et al. (2005) for lambs kept on pasture. A similar relationship in relation to the percentage of the most valuable fells (round, loin, steak) in a half-carcass was observed in works of Priolo et al. (2002).

Higher pH after slaughter and after 24 h of cooling was observed in group of castrates, also measurements of meat color showed a higher brightness (L* parameter) and share of yellow spectrum (b* parameter) were higher in this group. Parameter a* (share of red color). Higher value of water absorption and the crude fat content and dry matter was higher in rams group. Only in the case of crude protein content analyzed differences were significant (Table 5). The obtained results of pH immediately after slaughter at level of 5.82 in ram group and 5.87 in castrates were lower than in other authors (Rodriguez et al. 2008, Ekiz et al. 2009, D’Alessandro et al. 2013), where the results oscillated in the range of

TABLE 3. Comparison measurements of rams and castrates carcasses

Traits	Rams (A) (N = 9)		Castrates (B) (N = 9)	
	<i>AVG</i>	<i>SE</i>	<i>AVG</i>	<i>SE</i>
Spread of hock joint (cm)	2.96	0.10	3.03	0.10
Depth of leg (cm)	20.73 ^b	0.44	19.29 ^a	0.44
Length of leg (cm)	25.81	0.50	25.97	0.50
Round of leg (cm)	34.14	0.68	34.92	0.68
Index of leg (%)	132.45	3.03	134.80	3.03
Loin eye area (cm ²)	11.06	0.71	9.38	0.71
Height of the loin eye (cm)	2.52	0.10	2.62	0.10
Spread of the loin eye (cm)	4.61	0.17	5.01	0.17
Fat cover over loin eye (mm)	0.38 ^b	0.13	0.77 ^a	0.13

a, b – $P < 0.05$.

TABLE 4. The results left half-carcass cuttings and leg dissection

Traits	Rams (A) (N = 9)		Castrates (B) (N = 9)	
	<i>AVG</i>	<i>SE</i>	<i>AVG</i>	<i>SE</i>
1	2	3	4	5
Kidney with fat (kg)	0.15	0.02	0.13	0.02
Kidney with fat (%)	2.33	0.40	2.24	0.40
Neck (kg)	0.63	0.04	0.67	0.04
Neck (%)	9.66	0.57	10.72	0.57
Shoulder (kg)	0.92	0.03	0.98	0.03
Shoulder (%)	14.65	0.84	16.12	0.84
Foreshank (kg)	0.19	0.01	0.20	0.01
Foreshank (%)	2.98	0.17	3.35	0.17
Hideshank (kg)	0.24	0.02	0.25	0.02
Hideshank (%)	3.48	0.25	4.15	0.25
Middle neck (kg)	0.47	0.03	0.53	0.03
Middle neck (%)	7.27 ^b	0.36	8.69 ^a	0.36
Breast (kg)	0.75	0.04	0.81	0.04
Breast (%)	11.63	0.58	13.18	0.58
Rib steak (kg)	0.46	0.02	0.49	0.02
Rib steak (%)	7.30	0.35	7.88	0.35
Loin (kg)	0.38	0.03	0.37	0.03
Loin (%)	6.20	0.38	6.38	0.38

TABLE 4 cont.

1	2	3	4	5
Leg (kg)	1.73	0.08	1.72	0.08
Leg (%)	27.02	0.69	28.24	0.69
Tenderloin (kg)	0.11	0.01	0.10	0.01
Tenderloin (%)	1.17	0.13	1.61	0.13
Valuable cuts (kg)	2.57	0.10	2.58	0.10
Valuable cuts (%)	40.52	1.06	42.50	1.06
Tissue composition of leg				
Lean (kg)	1.32	0.07	1.35	0.07
Lean (%)	75.00 ^b	1.06	79.05 ^a	1.06
Fat (kg)	0.17	0.02	0.13	0.02
Fat (%)	9.75	1.21	7.57	1.21
Bone (kg)	0.21	0.01	0.22	0.01
Bone (%)	12.35	0.68	12.55	0.68

a, b – $P < 0.05$.

TABLE 5. Comparison of chemical and physicochemical composition of *musculus longissimus dorsi* (*mld*)

Traits	Rams (A) (N = 9)		Castrats (B) (N = 9)	
	AVG	SE	AVG	SE
Chemical characteristics of <i>mld</i> (%)				
Dry matter	26.72	1.01	25.64	1.01
Crude protein	21.00 ^b	0.28	22.14 ^a	0.28
Fat	3.29	0.48	2.40	0.49
Physical characteristics of <i>mld</i>				
Water holding capacity (cm ²)	14.50	1.18	13.56	1.18
pH ₀	5.82	0.04	5.87	0.04
pH ₂₄	5.59	0.05	5.62	0.05
Meat color				
L* (brightness)	47.78	1.65	48.74	1.65
a* (share of red)	13.72	0.56	12.35	0.56
b* (share of yellow)	6.34	0.86	6.59	0.86

a, b – $P < 0.05$.

5.99–6.49. The same trend was observed with pH level after 24 h after slaughter. Measurements of meat color for a L* parameter (brightness) were similar to results of Ripoll et al. (2008) and Luciano et al. (2009), as well as Ekiz et al. (2009) and D'Alessandro et al. (2013), for lambs kept on pasture without the

addition of nutritive fodder. Parameters a* and b* achieved levels similar to the results obtained by Ádnøy et al. (2005) and Ekiz et al. (2009) for animals kept on mountain pastures and were higher in case of animals kept indoors.

Between both groups of animals highly significant difference in the content of C17:0 and C17:1 acids was observed. This difference was significant for acid: C14:1, C16:1, C18:2n6 and acid group – PUFA_{n6}. In case of other acids such differences were no significant. An acid content

of C10:0, C15:0, C16:0, C16:1, C17:0, C17:1, C18:1c9. MUFACIS was higher in ram meat, however rest were defined in second group (Table 6). Lamb production in Poland currently is the basic section of sheep production, therefore these animals need to obtain the best performance of growth and slaughter capacity, but economic aspect is also very important. Production of good quality lamb meat on wastelands is possible. This meat in Poland is underestimated and even forgotten, characterized by many positive features

TABLE 6. Fatty acids profile in meat

Traits	Rams (A) (N = 9)		Castrates (B) (N = 9)	
	AVG	SE	AVG	SE
1	2	3	4	5
C10:0	0.15	0.01	0.13	0.01
C12:0	0.09	0.02	0.12	0.02
C14:0	2.20	0.20	2.64	0.20
C14:1	0.22 ^b	0.01	0.27 ^a	0.01
C15:0	0.69	0.08	0.49	0.08
C15:1	0.25	0.03	0.26	0.03
C16:0	21.22	0.70	20.90	0.70
C16:1	2.18 ^b	0.19	1.39 ^a	0.19
C17:0	1.91 ^B	0.14	1.33 ^A	0.14
C17:1	1.34 ^B	0.15	0.67 ^A	0.15
C18:0	17.00	0.89	19.61	0.89
C18:1tr11	2.72	0.42	3.55	0.42
C18:1c9	34.79	0.92	34.50	0.92
C18:2n6	2.36 ^b	0.21	3.17 ^a	0.21
C18:3n6	0.10	0.05	0.17	0.05
C18:3n3	0.93	0.13	1.26	0.13
CLA	0.92	0.12	1.09	0.12
C20:1	0.08	0.01	0.10	0.01
C20:3n3	0.05	0.01	0.09	0.01
C20:4n6	0.40	0.11	0.70	0.11
C20:5n3	0.24	0.07	0.35	0.07

TABLE 6 cont.

1	2	3	4	5
C22:5n3	0.25	0.06	0.42	0.06
C22:6n3	0.05	0.02	0.06	0.02
SFA	43.26	1.20	44.85	1.20
MUFA-cis	38.86	0.80	37.19	0.80
MUFA-trans	2.72	0.42	3.55	0.42
PUFAn3	1.52	0.26	2.18	0.26
PUFAn6	2.87 ^b	0.31	4.04 ^a	0.31

a, b – $P < 0.05$; A, B – $P < 0.01$.

among others positive profile of fatty acids (Głowacz and Niznikowski 2008). It characterized by a high content of linoleic acid which protects against cancer, limits the concentration of “bad” cholesterol in the blood, regulates metabolism and affects the growth of muscle mass (Reklewska et al. 2002). The obtained acid levels of the group SFA, MUFA and PUFA were similar to the results received by Radzik-Rant (1996) analyzing the fatty acid profile from Polish heath sheep from RZD Żelazna.

Content of the various fatty acids was different depending on the experimental group. The level of both groups. was similar to the results received by Horoszewicz et al. (2008). Difference of 10% in content of SFA was observed than the results obtained by Juarez et al. (2009) which might have resulted to the feeding system of individual groups of animals.

CONCLUSIONS

1. Results showed that fallow lands can become a good base for livestock production, especially extensive races such as Polish Heath Sheep. Con-

tinuous grazing leads to a reduction of shrubs and trees succession and it is economically feasible.

2. Polish Heath Sheep is predisposed for the such grazing areas. Costs could be reduced because nutrition is based on cheap and ecological feeds.
3. Slaughter analyses showed no contraindications for rams castration and the results of the profile of fatty acids have shown that it is possible to produce good-quality lamb meat based on fallow lands.
4. Animals maintenance on such land can improve the profitability of production and enable production of healthy food.

Acknowledgement

Work has been supported by the Ministry of Science and Higher Education (project 2 P06Z 069 29).

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- Streszczenie:** *Charakterystyka tusz oraz jakość mięsa ekstensywnie wypasanych owiec rasy wrzósówka polska.* Przeanalizowano wartość rzeźną i profil kwasów tłuszczowych od grupy tryczków i kastratów, które utrzymywane były na terenie odłogowanym, na którym od 15 lat prowadzona była produkcja owczarska. Wykazano pozytywny wpływ ekstensywnego wypasu na wyniki produkcyjne zwierząt w trakcie sezonu pastwiskowego. Analizy rzeźne dowiodły korzystnego wpływu takiej formy wypasu na profil kwasów tłuszczowych. Wykazano, iż zabieg kastracji tryczków może okazać się korzystny w przypadku prowadzenia produkcji na takich terenach, gdyż ogranicza liczbę grup zwierząt, a przez to wpływa na ograniczenie kosztów.
- Słowa kluczowe:* jakość mięsa, ekstensywny wypas, produkcja owczarska
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MS accepted 13.10.2016
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The effect of feeding ration, enriched in synthetic and natural β -carotene on the selected indicators of health condition of the cows and on reproduction parameters

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Abstract: *The effect of feeding ration, enriched in synthetic and natural β -carotene on the selected indicators of health condition of the cows and on reproduction parameters.* The studies were conducted on 40 Simmental cows, classified into 4 groups, 10 animals in each group. The experiment was performed since the 4th week before calving until 12th week of lactation. In group I (control), standard nutrition, based on grass silage and maize silage was employed. In group II 400 mg of synthetic β -carotene per cow daily to the ration was introduced. In group III, a part of maize silage was replaced by pumpkin silage in such ratio as to receive by 400 mg higher intake of natural β -carotene per cow daily as compared to group I. The rations in group IV were not balanced in respect of the content of β -carotene; there was only the replacement of 60% d.m. of maize silage by the pumpkin silage in this group. During the studies, blood samples were collected: to 5 h after calving and on 4th and 12th week of lactation. Milk samples were collected on 4th, 8th and 12th week of lactation and on 23rd day after the first insemination. Morphological parameters of blood and concentration of β -hydroxy-butyric acid in blood serum were analysed. In milk, somatic cell count and the level of progesterone on 23rd day after insemination were determined. In group I during the following measurements were found the lowest levels of part of the morphological parameters of blood: after calving the lowest level of RBC (significant difference compared to group II), at 4th week of lactation the lowest level of HCT, and at 12th week of lactation RBC and HCT. The significant differences in somatic cell count in the milk, were recorded in the 8th week of lactation – significantly higher in group

I as compared to group III. The significant differences between the groups in respect of BHM acid concentration was found only after calving. The highest BHM level occurred in the cows from group I and it was significantly higher in relation to groups II and IV. In the cows from groups II, III and IV, the first heat occurred earlier; these animals had also shorter inter-gestation period. Also, the progesterone level, as determined on 23rd day after insemination, was higher in the milk of cows from groups II, III and IV as compared to the animals from group I.

Key words: dairy cows, pumpkin silage, β -carotene, reproduction, blood

INTRODUCTION

In the situation of the presently dominating systems for dairy cow nutrition, based upon the maize silage and grass silage, it may become problematic to supply the important bioactive compounds such as β -carotene to the high-yielding animals. The maize silage, as being the feed universally used in cow nutrition, is poor in the discussed component and in the case of grass silage, or lucerne, we may state big fluctuations in its content (Dunne et al. 2009). There is, therefore, the need of supplementing β -carotene in the rations for the dairy cows. It may be achieved via introduction of synthetic

β -carotene, or employing feeds, rich in the discussed component. Pumpkin silage may be such example. It is characterized by a high content of β -carotene and other carotenoids (Łozicki et al. 2015).

It has been demonstrated that β -carotene affect positively the resistance of animals (Rakes et al. 1985, Krzysik et al. 2007). Beta-carotene demonstrates also antioxidative effect, what is very important in case of high-yielding cows (Akar and Gazioglu 2006). In the studies, a positive effect of β -carotene on changes in rumen, being manifested, i.a. by the improvement of fiber digestibility in the ration (Hino et al. 1993). Beta-carotene is also the compound, having a big influence on the results of animal reproduction (Rakes et al. 1985, Arechiga et al. 1998). In many studies, the relationship between the concentration of β -carotene in blood serum and function of reproduction system was indicated (Graves-Hoagland et al. 1988, Seymour 2001, Kawashima et al. 2009).

The aim of the studies is to evaluate the selected parameters, determining the animal health state and the reproduction results in the case of introducing the synthetic β -carotene additive and of pumpkin silage, as a feed rich in natural β -carotene, to the ration for the cows.

MATERIAL AND METHODS

The studies were conducted with 40 Simmental cows, classified into 4 groups. The differentiating factor in the particular experimental groups was the employed feed ration. The cows were introduced to the experiment 4 weeks before calving. In group I, standard nutrition

based on grass silage and maize silage was employed. In group II, the increased rate of β -carotene in a form of additive of 400 mg synthetic carotene per cow daily was added to the ration. In experimental groups III and IV, pumpkin silage was introduced to the rations for the cows. In group III, a part of the maize silage was replaced by the pumpkin silage as to receive the higher by 400 mg intake of natural β -carotene per cow daily, as compared to group I. It corresponded to the replacement of 40% d.m. of maize silage with the pumpkin silage. The ration in group IV were not balanced in respect of the content of β -carotene; there was replacement of 60% d.m. of maize silage by the pumpkin silage in this group. Chemical composition of the feeds was determined and their energy and protein value was evaluated according to INRA (2009). The rations were formulated according to IZ PIB-INRA system (2009) using INRAtion PrévAlin software. The composition and nutritive value of experimental diets during drying period and during lactation are given in Table 1. The experiment was conducted until 12th week of lactation.

Blood was sampled thrice: to 5 h after calving on 4th week of lactation and on 12th week of lactation. Milk samples were collected on 4th, 8th and 12th week of lactation and also, on 23rd day after insemination. Also, information on the occurrence of the first heat for the cows from particular experimental groups was collected; the length of their inter-gestation period was also determined.

The chemical composition of the feeds was determined according to AOAC (2005). Morphological parameters of blood (elements of white cell

TABLE 1. Composition and nutritive value of rations for the cows during the last drying-off period and at the beginning of lactation

Specification	Experimental group							
	I		II		III		IV	
	D	L	D	L	D	L	D	L
	% of d.m.							
Grass silage	50	38	50	38	55	39	55	40
Maize silage	35	30	35	30	20	19	13	15
Pumpkin silage	–	–	–	–	15	12	22	17
Brewery meal	–	4	–	4	–	4	–	4
Concentrate	15	28	15	28	10	26	10	24
Synthetic β -carotene	–	–	+	+	–	–	–	–
Nutritive value of 1 kg d.m. of ration								
UFL	1.01	1.01	1.01	1.01	1.05	1.05	1.04	1.06
PDIN (g)	89.8	103.4	89.8	103.4	90.7	104.25	91.7	103.78
PDIE (g)	93.64	81.7	93.64	81.7	95.48	83.8	95.6	84.3
Crude protein (g)	155.4	170.19	155.4	170.19	157.8	173.3	158.7	173.9
Crude fibre (g)	226.9	190.2	226.9	190.2	233.8	193.47	234.9	198.4
NDF (g)	388.7	446.8	388.68	446.8	390.0	438.1	395.4	437.5
Crude ash (g)	41.87	47.4	41.87	47.4	47.01	54.6	50.08	56.0
β -carotene (mg)	72.61	66.03	95.9	83.7	95.5	84.4	104.0	92.6
Crude fat (g)	40.6	39.1	40.6	39.1	42.8	40.5	43.3	41.55

D – dry period, L – lactation period, UFL – the feed unit milk production, PDIN – protein digested in the intestines of the nitrogen, PDIE – protein digested in the intestines of energy, NDF – neutral detergent fiber.

and red cell systems) were determined by standard laboratory methods, using haematological analyser ABACUS, Diatron. The level of β -hydroxybutyric acid (BHM) in blood serum of the cows was determined by enzymatic method (Randox reagents). The level of progesterone in milk was determined using radio-immunological kit. Somatic cell count in milk was determined by Somacount 150 of Bentley company for milk evaluation of the Cattle Breeding Division, Warsaw University of Life Sciences – SGGW in Warsaw.

The obtained results were elaborated statistically using a one-way analysis of

variance with the least square method. Account was taken of the effect of feeding on the analyzed parameters. The tables contain mean values of parameters and standard errors of the means. Computations were made with Statgraphics 6.0 Plus Statistical Package.

RESULTS AND DISCUSSION

During the successive measurements the majority of the examined morphological parameters of blood were found within the frames of reference values given for cattle. Only during measurement 3 in con-

trol group the RBC and HCT levels were found below the mentioned values (Winnicka 2015). When analysing the levels of the examined indicators in the particular experimental groups. The differences between the groups were recorded. During measurement 1 in group I the lowest RBC level was stated – the difference was statistically significant in comparison to group II. On 4th week of lactation (measurement 2) in the cows from group I the lowest level of HCT was found in relation to the remaining groups. In the animals from group II higher MCH level was found in relation to the following groups whereas in the cows from group IV the highest MCHC level was recorded (Table 2). During measurement 3 the lowest RBC and HCT levels were found in the cows from group I. Values

TABLE 2. Effect of feed ration on morphological parameters of blood – elements of white cell and red cell systems

Specification	Experimental group				SE	P-value
	I	II	III	IV		
1	2	3	4	5	6	7
Measurement 1 – after calving						
WBC ($10^3/\mu\text{l}$)	7.51	7.03	6.86	7.08	0.421	0.339
RBC ($10^6/\mu\text{l}$)	5.67b	6.26a	5.82	6.15	0.335	0.063
HGB (g/dl)	12.41	11.61	12.06	12.18	0.452	0.631
HCT (%)	31.82	33.04	32.03	30.82	0.937	0.082
PLT ($10^3/\text{mm}^3$)	321.26	295.82	342.33	372.48	41.92	0.231
MCV (μm^3)	52.45	55.26	53.71	56.28	1.021	0.097
MCH (pg)	21.24	20.05	19.93	20.36	0.82	0.142
MCHC (g/dl)	35.71	36.82	37.37	36.84	1.437	0.347
Measurement 2 – 4th week of lactation						
WBC ($10^3/\mu\text{l}$)	7.80	6.68	6.8	7.08	0.477	0.239
RBC ($10^6/\mu\text{l}$)	6.29	6.33	6.77	6.12	0.351	0.753
HGB (g/dl)	10.44	10.03	10.74	10.24	0.483	0.754
HCT (%)	25.46Bb	32.5A	31.03a	29.51a	1.082	0.001
PLT ($10^3/\text{mm}^3$)	339.63	419.88	392.38	472.38	38.39	0.126
MCV (μm^3)	50.38	51.2	50.75	52.38	1.251	0.697
MCH (pg)	17.55B	20.85Aa	16.95B	18.45b	0.77	0.007
MCHC (g/dl)	34.68B	35.13b	33.67B	40.08Aa	1.295	0.008
Measurement 3rd – 12th week of lactation						
WBC ($10^3/\mu\text{l}$)	7.65	6.05	6.56	6.95	0.499	0.165
RBC ($10^6/\mu\text{l}$)	4.52Bd	5.83A	6.45Aa	5.53bc	0.286	0.001
HGB (g/dl)	10.3	9.21	10.43	9.85	0.355	0.092
HCT (%)	23.08Bb	30.11A	31.91A	28.65a	1.364	0.001
PLT ($10^3/\text{mm}^3$)	331.02	400.88	378.45	487.75	46.263	0.135
MCV (μm^3)	51.75	51.13	49.53	52.04	1.107	0.394

TABLE 2 cont.

1	2	3	4	5	6	7
MCH (pg)	16.3B	20.84Aa	17.86b	17.85b	0.751	0.002
MCHC (g/dl)	34.54b	40.19Aa	32.65B	34.28b	1.408	0.002

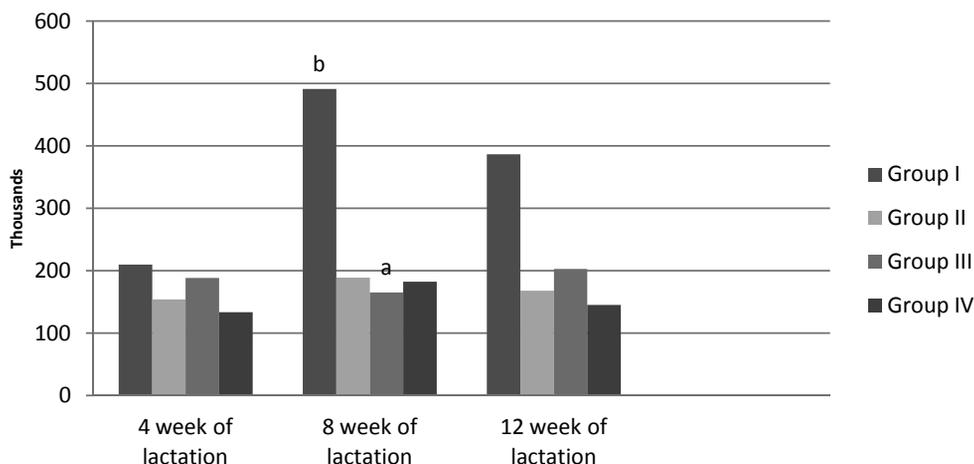
WBC – white cells, RBC – red cells, HGB – haemoglobin, HCT – haematocrite, PLT – blood plates, MCV – mean volume of red cell, MCH – mean weight of haemoglobin in red cell, MCHC – mean concentration of haemoglobin in red cell. Numerical values in the same row marked in pairs with letters AB differ at $P \leq 0.01$, ab, cd – $P \leq 0.05$.

of MCH and MCHC were the highest in case of the groups from group II – the difference was statistically significant in relation to the remaining groups.

Morphological parameters of blood give the possibility of evaluating the health condition of the cows (Radkowska 2015). It is greatly dependent on the conditions of animal management and nutrition. In the case of our studies nutrition in the particular experimental groups was a discriminating factor. It could be observed that in case of the cows receiving synthetic β -carotene and pumpkin silage as a source of natural β -carotene, the level of the analysed indi-

cators was higher compare to the control group. The results do not allow stating univocally that there is a domination of applying pumpkin silage as compared to the synthetic β -carotene additive.

The differences in somatic cell count in milk was found during measurement 2, i.e. 8 weeks after calving: significantly higher in group I in comparison to group III (Fig. 1). During the first (4th week of lactation) and third (12th week of lactation) measurement any significant differences between the groups were not recorded. However the higher somatic cell count in the milk of the cows from group I was observed. The feeding rations in groups



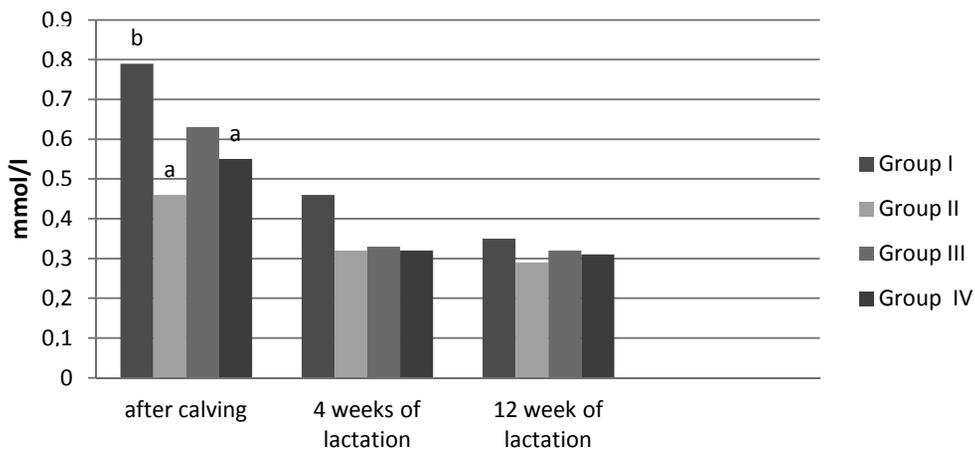
Columns marked with letters ab – $P \leq 0.05$.

FIGURE 1. Somatic cell count in milk

II–IV were characterized by a higher content of β -carotene and in groups II and IV – also of other carotenoids as compared to group I (Table 1). The lower somatic cell count in the groups, receiving β -carotene may result from its effect stimulating immunological system. The immunostimulating effect of β -carotene was reported, i.a. in the studies of other authors (Rakes et al. 1985, Krzysik et al. 2007). Beta-carotene affects the increase of the number and growth of the activity of lymphocytes, monocytes and natural Killers cells, responsible for direct immunological response (Krzysik et al. 2007). The presence of β -carotene has the influence on the improvement of intercellular communication what increases the effectiveness of defence in case of diseases and infections. A positive effect of β -carotene addition to the feeding ration, manifested by a lower somatic cell count in the milk was found in many studies. Rakes et al. (1985) added 300 mg of β -carotene additive to the ration and observed the lowered somatic cell count in the milk of the cows. Also, Michal et al. (1994) introduced 300

or 600 mg of β -carotene to the daily rate for the dairy cows on 4th weeks before calving, and they observed its positive effect on resistance of mammary gland.

When analysing the level of BHM acid in the blood serum of the examined cows, we could state that the differences between the groups were found only after calving (Fig. 2). The highest BHM acid concentration occurred in the cows from group I and it was significantly higher in relation to groups II and IV. Any statistically significant differences between the groups in the content of the mentioned parameter during two remaining measurements on 4th and 8th week after calving were not recorded. However, similarly as during the measurement performed directly after calving, higher level of this parameter in group I was marked. Beta-hydroxybutyric acid is the indicator, informing about release of energy from fat reserves of the cow (loss of condition). The higher is its value, the deeper is energy deficit of a given animal, what may cause ketosis (Jędrzej et al. 2006, Piccione et al. 2012). In our studies, in



Columns marked with letters ab – $P \leq 0.05$.

FIGURE 2. Concentration of β -hydroxybutyric acid (BHM) in blood serum

all experimental groups, feeding rations were characterized by similar energetic value (Table 1). The increased intake of β -carotene in groups II–IV could enhanced bacterial cell yield and improve digestibility of fibre (Hino et al. 1993). Better conversion of feed ration components was reflected in the improvement of energy status of the cows. It should be, however, mentioned that in all groups during the successive measurements, the BMH acid level was found within the limits of reference values presented by Mordak (2008).

The employed feed rations had the influence on reproduction parameters of the cows (Table 3). In the cows from groups II, III and IV, the first oestrus was recorded earlier and they had also the shorter inter-gestation period. Also, on 23rd day after insemination the determined level of progesterone was higher in the milk of the cows from groups II, III and IV in comparison to the cows from group I. A positive effect of feeding rations enriched with β -carotene was found in many studies (Lotthammer 1979, Arechiga et al. 1998, Trojačanec et al. 2012). The addition of carotene accelerates uterus involution, decreases the number of ovulating yellow bodies,

and affects the decrease of ovarian cysts and decrease of foetuses' deaths. In our studies, the effect of the application of synthetic carotene or natural feed, rich in the discussed component, is greatly visible. On the other hand, there are no differences in the examined parameters when comparing the groups, receiving synthetic β -carotene and pumpkin silage as a rich source of natural β -carotene.

CONCLUSION

The conducted studies revealed a positive effect of the increased rate of β -carotene, employed during the last drying-off period and in the initial stage of lactation on the majority of the examined indicators of health condition of the animals and the analysed reproduction parameters. Any significant differences in respect of the influence of synthetic and natural carotene on the examined indicators were not however found. Also, the higher level of β -carotene in the rations for the cows from group IV in relation to groups II and III did not have any distinctly marked, positive effect on the examined parameters.

TABLE 3. Effect of feed ration on reproduction parameters of cows

Specification	Experimental group				SE	P-value
	I	II	III	IV		
Occurrence of the first heat after calving (days)	44.87b	37.65a	34.31a	36.21a	2.733	0.034
Inter-gestation period (days)	81.23b	69.34a	73.54a	64.39a	3.576	0.047
Progesterone level in milk on 23rd day after insemination (ng/ml)	8.67b	11.34a	10.89a	12.63a	0.697	0.049

Numerical values in the same row marked in pairs with ab – $P \leq 0.05$.

Acknowledgement

This study was supported by the Polish National Research Council grants: NCN NN311521740. The paper is a part of the PhD thesis of MSc Gabrieli Halik.

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Streszczenie: *Wpływ dawki pokarmowej wzbogaconej w syntetyczny lub naturalny β -karoten na wybrane wskaźniki stanu zdrowia krów oraz parametry rozrodu.* Badania przeprowadzono na 40 krowach rasy simental, podzielonych na 4 grupy po 10 osobników. Doświadczenie prowadzono od 4. tygodnia przed planowanym wycieleniem do 12. tygodnia laktacji. W grupie I (kontrolnej) stosowano standardowe żywienie, którego podstawą były kiszonki z traw i kukurydzy. W grupie II wprowadzono dodatek do dawki 400 mg syntetycznego β -karotenu na krowę dziennie. W grupie III zastępowano część kisonki z kukurydzy kisonką z dyni, tak aby uzyskać w porównaniu do grupy I większe o 400 mg pobranie naturalnego β -karotenu na krowę dziennie. Dawki w grupie IV nie bilansowano pod kątem zawartości β -karotenu, a przyjęto w niej zastąpienie 60% s.m. kisonki z kukurydzy kisonką z dyni. W trakcie badań od krów pobierano krew: do 5 h po wycieleniu w 4. i 12. tygodniu laktacji. Próbkę mleka pobierano w 4., 8. i 12. tygodniu

laktacji oraz w 23. dniu po pierwszej inseminacji. Analizowano parametry morfologiczne krwi oraz w surowicy stężenie kwasu β -hydroksymasłowego. W mleku oznaczono liczbę komórek somatycznych oraz poziom progesteronu w 23. dniu po inseminacji. W grupie I podczas kolejnych pomiarów stwierdzono najniższe poziomy części parametrów morfologicznych krwi. Po wycieleniu najniższy poziom RBC (istotna różnica w stosunku do grupy II), w 4. tygodniu laktacji najniższy poziom HCT, a w 12. tygodniu laktacji RBC i HCT. Różnice między grupami w zawartości komórek somatycznych w mleku stwierdzono w 8. tygodniu laktacji – istotnie więcej w grupie I w porównaniu do grupy III. Istotne różnice między grupami w stężeniu kwasu BHM w surowicy stwierdzono tylko po wycieleniu. Najwyższy poziom BHM występował u krów z grupy I i był istotnie wyższy w stosunku do grup II i IV. U krów z grup II, III i IV w porównaniu do grupy I wcześniej wystąpiła pierwsza ruja, a także miały one krótszy okres międzyciążowy. W 23. dniu po inseminacji oznaczono również poziom progesteronu – był on wyższy w mleku krów z grup II, III i IV w porównaniu do krów z grupy I.

Słowa kluczowe: krowy mleczne, kisonka z dyni, β -karoten, rozród, krew

MS received 06.10.2016

MS accepted 03.11.2016

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Influence of cow temperament and milking speed on herd life, lifetime milk yield and reasons of cow culling

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Abstract: *Influence of cow temperament and milking speed on herd life, lifetime milk yield and reasons of cow culling.* Importance of functional traits, longevity or reproduction traits increases continuously in present dairy cattle breeding. Effects of milking speed and cow temperament on herd life, lifetime milk yield and reasons of culling were estimated. The highest lifetime yield ($p < 0.01$) of milk, fat and protein as well as life span and herd life had calm animals or slow milking cows. However, cows with normal temperament or fast milking had the highest ($p < 0.01$) yield of milk fat and protein per one day of utilization. The main reason of culling were fertility and reproductive disorders (on average 41.2%), but 15.3% cows were culled because of udder diseases. Results suggest highly significant ($p < 0.01$) influence of temperament and milking speed on life span, herd life, lifetime milk yield. Functional traits, longevity or fertility should be parts of breeding programs to balance dairy cattle selection and compensate negative influence of selection only towards milk yield that took place in the past.

Key words: cow temperament, milking speed, herd life, culling

INTRODUCTION

Nowadays, Holstein-Friesian breed (HF) is the largest worldwide population of dairy cattle. Its potential was already discovered in 19th century. Therefore, in 70s of recent century the aim of displacement crossbreeding of HF cattle with Polish native cows was to improve

milk performance of national population (Litwińczuk and Barłowska 2015).

Proper level of reproduction traits is necessary to achieve appropriate milk yield, which is essential due to economic value of production (Pryce et al. 2004). Unfortunately, because of unfavorable correlation between milk production and reproduction, consequence of animal breeding is e.g. decreased fertility (Lucy 2001). Low fertility traits prolong calving interval, decrease production profitability and number of born calves. They also increase percentage of culled cows, what affects the costs of herd replacement as well as semen and veterinary costs (Roche 2006). Another issue in dairy cattle breeding is short herd life of cows. Culling cows at 2nd or 3rd lactation is undesirable, because it is often happens before they achieve production peak between 2nd and 4th lactation (Grodzki et al. 1998, Frejlach et al. 2015).

Milking speed and temperament are functional traits, and as well as milk yield, can influence profitability of dairy farm. Authors suggest that high positive correlation between temperament and milking speed are due to similar values given to specific animals by assessors. This correlation might have different basis, milking excitable or aggressive cows take more time, e.g. cups are kick off

more frequently (Visscher and Goddard 1995).

Previous studies shown that temperament is constant and doesn't change with age of the animal (Visscher and Goddard 1995). Excitable or aggressive cows are 26% more likely to be culled (Sewalem et al. 2010).

Most cows of Polish native population has normal temperament (84.74%) and number of calm animals increased from 2.98 to 6.85%. According to Neja et al. (2015), it has impact on milk yield in 1st lactation, milk yield per day during 1st lactation, milk yield per day of life and milk yield per day of utilization and also influence lifetime milk yield.

The aim of the study was to estimate the influence of temperament and milking speed on herd life, lifetime milk yield and reasons of culling.

MATERIAL AND METHODS

Analyzed records were taken from SYMLEK database and referred to milk performance and reasons of culling of 1,734 cows. Cattle was maintained on farms from lubelskie and pomorskie regions that participated in "Healthy Cow" program. Database contained animals culled in 2008–2015 with valued temperament, classified milking speed and reason of culling. Statistical analysis were estimated in IBM SPSS 19 software.

Milking speed valued on a scale from 1 to 5 (1 – very slow, 2 – slow, 3 – average, 4 – fast, 5 – very fast), while temperament classified as: calm – 1, normal – 2, excitable or aggressive – 3, accordingly to the Polish Federation of Cattle Breeders and Dairy Farmers (PFHBiPM).

Milking speed and temperament of culled cows were used in one-way analysis of variance to calculate life span, herd life and lifetime milk yield by following model:

$$Y_{ij} = m + A_i + e_{ij}$$

where:

Y_{ij} – value of the trait;

m – average;

A_i – effect of temperament code ($i = 1-3$) or effect of milking speed ($j = 1-5$);

e_{ij} – random error.

Reasons of culling were defined according to SYMLEK database: sold for further breeding, low yield, udder diseases, fertility and reproductive disorders, old age, metabolic and digestive diseases, respiratory diseases, locomotor disorders, accidents, others. Each reason of culling was presented by average and percentage of all reasons.

RESULTS AND DISCUSSION

Considering female temperament, calm animals had higher ($p < 0.01$) lifetime yield of milk (34,951.5 kg), fat (1,472.5 kg) and protein (1,180 kg) than vicious cows (Table 1). Their life span (2,659.6 days) and herd life (1,824 days) differed ($p < 0.01$) from scores of average and excitable or aggressive animals. Similar relationship occurred for milk, fat and protein yield per day of life. Cows classified as calm produced more ($p < 0.01$) milk (12.5 kg), fat (0.52 kg) and protein (0.42 kg). Average animals had higher milk yield per day of utilization (21 kg) than calm ($p < 0.01$) and excitable or aggressive cows ($p < 0.05$) (19.9 kg and 19.6, respectively). They also gained

TABLE 1. Influence of cow temperament on life span, herd life and milk yield per 1 day of life and per 1 day of utilization

Specification	Calm		Average		Excitable or aggressive	
	N = 486		N = 1 177		N = 71	
	LSM	SE	LSM	SE	LSM	SE
Lifetime milk yield (kg)	34 951.5 ^{AB}	909.91	20 758.1 ^A	397.92	2 2613.0 ^B	1 750.2
Lifetime fat yield (kg)	1 472.5 ^{AB}	39.3	875.0 ^A	17.5	979.5 ^B	80.81
Lifetime protein yield (kg)	1 180.0 ^{AB}	30.78	699.7 ^A	13.49	762.6 ^B	60.02
Life span (days)	2 659.6 ^{AB}	43.86	1 820.7 ^A	18.42	1 991.5 ^B	83.31
Herd life (days)	1 824.0 ^{AB}	43.87	989.3 ^{Ac}	17.85	1 167.8 ^{Bc}	80.87
Milk yield per 1 day of life (kg)	12.5 ^{AB}	0.21	10.5 ^A	0.12	10.3 ^B	0.52
Fat yield per 1 day of life (kg)	0.52 ^{AB}	0.009	0.44 ^A	0.005	0.44 ^B	0.024
Protein yield per 1 day of life (kg)	0.42 ^{AB}	0.007	0.35 ^A	0.004	0.35 ^B	0.018
Milk yield per 1 day of utilization (kg)	19.9 ^A	0.27	21.0 ^{Ab}	0.13	19.6 ^b	0.71
Fat yield per 1 day of utilization (kg)	0.82 ^A	0.01	0.88 ^A	0.006	0.83	0.029
Protein yield per 1 day of utilization (kg)	0.67 ^A	0.009	0.70 ^{Ab}	0.004	0.66 ^b	0.024

Differences significant at $p \leq 0.01$ for A, A; $p \leq 0.05$ for b, b.

($p < 0.01$) in fat yield (0.88 kg) and protein yield (0.7 kg) from calm ones.

The major reason of culling were fertility and reproductive disorders (average 41.2%) (Table 2). Among groups they reached 40.5, 41.4, 42.3%, respectively, for calm, average and excitable or aggressive cows (Table 3). Causes of culling calm animals were udder diseases (14%), locomotor disorders (8.2%) and metabolic and digestive diseases (4.9%). In turn, average animals culled because of udder diseases (15.9%), locomotor disorders (9.7%), accidents (8.8%). In the 3rd group cows were culled due to udder diseases (15.5%), accidents (8.5%), locomotor disorders (7.0%). Nevertheless, 13.7% animals culled for other reasons.

Considering milking speed, cows of slow milking speed had higher ($p < 0.01$) lifetime yield of milk (34,992.6 kg), fat (1,503.4 kg) and protein (1,183.5 kg) than animals of average, fast and very fast milking speed. Their life span (2,748 days) and herd life (1,921.5 days) were longer ($p < 0.01$), according to other groups. Although, cows with very slow milking speed had the highest ($p < 0.01$) milk (12.9 kg), fat (0.55 kg) and protein (0.43 kg) yield per day of life. Fast milking cows achieved the highest ($p < 0.01$) production of milk (22.1 kg), fat (0.91 kg) and protein (0.74 kg) per 1 day of utilization (Table 3).

Fertility and reproductive disorders were also the main reason of culling. Per-

TABLE 2. Reasons of dairy cows culling according to cattle temperament

Reason for culling		Temperament			
		calm	average	excitable or aggressive	all
Sold for further breeding	<i>N</i>	19	41	4	64
	%	3.9	3.5	5.6	3.7
Low fertility	<i>N</i>	8	11	3	22
	%	1.6	0.9	4.2	1.3
Udder diseases	<i>N</i>	68	187	11	266
	%	14	15.9	15.5	15.3
Fertility and reproductive disorders	<i>N</i>	197	487	30	714
	%	40.5	41.4	42.3	41.2
Old age	<i>N</i>	21	10	0	31
	%	4.3	0.8	0	1.8
Metabolic and digestive diseases	<i>N</i>	24	72	3	99
	%	4.9	6.1	4.2	5.7
Respiratory diseases	<i>N</i>	3	7	0	10
	%	0.6	0.6	0	0.6
Locomotor disorders	<i>N</i>	40	114	5	159
	%	8.2	9.7	7	9.2
Accidents	<i>N</i>	22	104	6	132
	%	4.5	8.8	8.5	7.6
Others	<i>N</i>	84	144	9	237
	%	17.3	12.2	12.7	13.7
All	<i>N</i>	486	1 177	71	1 734
	%	100	100	100	100

centage of culled animals increased with milking speed, from 30.2% for very slow milking cows to 47.6% for fast milking and 45.5% for very fast (Table 4). However, very slow milking cows were also culled for other reasons, udder diseases and locomotor disorders (34.9, 15.1, 6.6%, respectively). Udder diseases (19.9%), accidents (8.4%) and locomotor disorders (8.1%) were another reasons of culling slow milking cows. For average milking cows the reasons were udder diseases (14.3%), others (13.3%)

and locomotor disorders (10%). Fast milking cows culled because of udder diseases (14%), others (9.5%), locomotor disorders (9.1%) and metabolic and digestive diseases (8.2%). On the other hand, reasons of culling very fast milking cows were metabolic and digestive diseases (15.2%), others (12.1%), accidents (9.1%) and only 3% due to udder diseases.

Importance of functional traits increased in cattle breeding within last years according to their influence on

TABLE 3. Influence of cow milking speed on life span, herd life, milk yield per 1 day of life and milk yield per 1 day of utilization

Specification	Very slow		Slow		Average		Fast		Very fast	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Lifetime milk yield (kg)	3 390.2 ^{0ABC}	1 669.8	34 992.6 ^{DEF}	1 032.17	2 1058.9 ^{AD}	467.82	2 1078.8 ^{BE}	816.39	15 951.4 ^{CF}	1 666.84
Lifetime fat yield (kg)	1 440.9 ^{ABC}	72.05	1 503.4 ^{DEF}	45.46	880.1 ^{AD}	20.11	875.9 ^{BE}	34.72	682.7 ^{CF}	73.79
Lifetime protein yield (kg)	1 126.0 ^{ABC}	55.44	1 183.5 ^{DEF}	34.87	709.7 ^{AD}	15.93	714.4 ^{BE}	27.88	539.2 ^{CF}	56.51
Life span (days)	2 513.6 ^{ABCD}	80.06	2 748.0 ^{DEFG}	48.49	1 825.2 ^{BE}	21.59	1 803.9 ^{CF}	35.18	1 588.4 ^{DG}	80.09
Herd life (days)	1 696.0 ^{ABCD}	77.78	1 921.5 ^{DEFG}	48.35	999.0 ^{BE}	21.12	947.6 ^{CF}	33.52	786.2 ^{DG}	73.73
Milk yield per 1 day of life (kg)	12.9 ^{abcd}	0.37	12.0 ^{abefg}	0.23	10.6 ^{BE}	0.15	10.8 ^{CFh}	0.27	9.0 ^{DGh}	0.58
Fat yield per 1 day of life (kg)	0.55 ^{ABC}	0.016	0.51 ^{DEF}	0.01	0.44 ^{AD}	0.006	0.44 ^{BE}	0.012	0.38 ^{CF}	0.026
Protein yield per 1 day of life (kg)	0.43 ^{ABC}	0.013	0.40 ^{DEF}	0.008	0.36 ^{AD}	0.005	0.36 ^{BEg}	0.009	0.30 ^{CFg}	0.02
Milk yield per 1 day of utilization (kg)	20.7 ^{AB}	0.48	18.3 ^{ACDe}	0.25	21.2 ^{CF}	0.16	22.1 ^{BDFg}	0.29	20.4 ^{eg}	0.87
Fat yield per 1 day of utilization (kg)	0.88 ^A	0.02	0.78 ^{ABcd}	0.011	0.87 ^{Be}	0.007	0.91 ^{Ce}	0.011	0.87 ^d	0.039
Protein yield per 1 day of utilization (kg)	0.69 ^{AB}	0.017	0.62 ^{ACDe}	0.008	0.71 ^{CF}	0.005	0.74 ^{BDF}	0.01	0.68 ^e	0.03

Differences significant at $p \leq 0.01$ for A, A; $p \leq 0.05$ for a, a.

TABLE 4. Reasons of dairy cows culling according to milking speed

Reason for culling		Milking speed					
		very slow	slow	average	fast	very fast	all
Sold for further breeding	<i>N</i>	4	13	38	8	1	64
	%	3.8	3.4	4.3	2.4	3	3.7
Low fertility	<i>N</i>	0	4	11	6	1	22
	%	0	1	1.2	1.8	3	1.3
Udder diseases	<i>N</i>	16	76	127	46	1	266
	%	15.1	19.9	14.3	14	3	15.3
Fertility and reproductive disorders	<i>N</i>	32	142	369	156	15	714
	%	30.2	37.3	41.6	47.6	45.5	41.2
Old age	<i>N</i>	2	21	4	4	0	31
	%	1.9	5.5	0.5	1.2	0	1.8
Metabolic and digestive diseases	<i>N</i>	4	12	51	27	5	99
	%	3.8	3.1	5.8	8.2	15.2	5.7
Respiratory diseases	<i>N</i>	0	3	4	2	1	10
	%	0	0.8	0.5	0.6	3	0.6
Locomotor disorders	<i>N</i>	7	31	89	30	2	159
	%	6.6	8.1	10	9.1	6.1	9.2
Accidents	<i>N</i>	4	32	75	18	3	132
	%	3.8	8.4	8.5	5.5	9.1	7.6
Others	<i>N</i>	37	47	118	31	4	237
	%	34.9	12.3	13.3	9.5	12.1	13.7
All	<i>N</i>	106	381	886	328	33	1734
	%	100	100	100	100	100	100

profitability of production (Visscher and Goddard 1995, Miglior et al. 2005). Recently, as well as traits connected with reproduction, they became element of selection indexes in different countries (e.g. Polish).

Analysis assessing milking speed and temperament show differences in their values within cattle breeds. Average milking speed and temperament of Polish Holstein-Friesian cows (PHF) (black-and-white variety) born in 2012 are 3.17 and 2.01, respectively (compar-

ing to PHF red-and-white variety, average values were 3.19 for milking speed and 1.98 for temperament). Simmental cattle (SM) and Polish Red received, respectively, 3.07 and 3.32 for milking speed, 2.01 and 2.02 for temperament. Genes of HF of have negative effect on milking speed for black-and-white variety and red-and-white variety ($p < 0.01$ or $p < 0.05$, respectively). Some authors point out on influence ($p < 0.05$) of age of 1st calving on temperament and milking speed (Szymik et al. 2015). Unde-

sirable temperament and milking speed can increase percentage of replacement by 2% (Van Doormaal 2009). In addition, Sewalem et al. (2010) suggest that cow temperament and milking speed and probability of culling are connected.

Some authors claim that calm cows have higher production during 1st lactation in compare with average and excitable or aggressive ones – 621 and 329 kg, respectively (Neja et al. 2015). In analysis conducted by Czaplicka et al. (2013) average life span and herd life of HF are 1,809 and 1,338 days, respectively, and their yields per 1 day of life and yields per 1 day of utilization are 12.92 and 17.47 kg, respectively. The same authors provide that lifetime milk yield, fat yield, protein yield for Polish native population are: 23,372, 979.29, 787.64 kg, respectively. However, these results are lower ($p \leq 0.01$) than milk production of imported cows.

Numerous researches keep that variation in milking speed is slight among dairy cattle population (Sewalem et al. 2010, Szymik et al. 2015). Nevertheless, authors from different countries suggest that HF breed is characterized by faster milking speed than Jersey or SM but has more excitable temperament (Dodenhoff et al. 2000, Berry et al. 2005, Sewalem et al. 2010, Szymik et al. 2015). In Canadian dairy cattle population 89.16% of HF and 91.64% of Jersey have more desirable temperament for milk producers (classified as average, calm or very calm). In the same studies, 84.47% of HF and 89.03% of Jersey have average or fast milking speed (Sewalem et al. 2010).

Pokorska et al. (2012) indicate on differences ($p < 0.01$) between reasons

of culling and average herd life or life span, and between calving interval and moment of culling. Authors observed also differences in milk yield and protein yield of animals culled for further reasons.

Obtained results confirm previous studies suggesting fertility and reproductive disorders (including clinical mastitis) are important reasons of dairy cows culling (Pokorska et al. 2012, Sawa et al. 2012, Czaplicka et al. 2013, Neja et al. 2015). Despite the fact, fertility and reproductive disorders were the reason of culling of only 23.4% cows in Pokorska et al. (2012) studies, results presented in this paper are similar to analysis of Sawa et al. (2012) or Czaplicka et al. (2013). Moreover, Sawa et al. (2012) showed that prolonged lactation increase number of cows culled due to infertility. However, percentage of animals culled because of udder diseases is 5.38–16.13% (Pokorska et al. 2012, Sawa et al. 2012, Czaplicka et al. 2013, Neja et al. 2015), but these problems are definitely more seldom if lactations last more than 305 days (Sawa et al. 2012).

Dairy cows are also culled because of: low yield (2.05–11.29%), locomotor disorders (1.88–8.62%), metabolic and digestive diseases (1.75–7.88%), udder defects (6.16%), accidents (5.54–23.22%), stillbirths (5.42%), deaths (4.68%), other reasons (4.31–5.12%) (Pokorska et al. 2012, Sawa et al. 2012, Czaplicka et al. 2013, Neja et al. 2015). Old age is the reason of culling only for 0.51–4.84% of cows (Sawa et al. 2012, Czaplicka et al. 2013, Neja et al. 2015). Results of Polish dairy cattle evaluation system (OWU) for 2015 show that average herd life of PHF (black-and-white variety)

and Jersey breeds last only 3.11 and 3.03 years, respectively. Average herd life of dairy cattle breeds evaluated in OWU is 3.07 years which reflect in culling high number of cows at age 5–6 years (PFHBiPM 2015). Pokorska et al. (2012) suggest that average life span and herd life are shorter. Authors reveal that cows culled because of fertility and reproductive disorders have longer ($p \leq 0.01$) herd life than animals culled for other reasons (days from calving to culling, 473.84 days). Moreover, the amount of protein (3.58%) is the highest ($p \leq 0.01$) among all cows. Cows with metabolic and digestive diseases have the shortest ($p \leq 0.01$) utilization time (60.43 days from calving to culling) in compare to animals culled for other reasons.

Too fast milking can effect in increased somatic cell count (SCC) and udder injuries which can influence on higher mastitis frequency (Rupp and Boichard 1999, Dodenhoff et al. 2000, Berry et al. 2005, Sewalem et al. 2010). On the other hand, slow milking cows extend other animals milking and influence on udder injuries and nervousness in herd. Similar relationship is observed in case of too excitable and too calm cows, because they also prolong milking. Some authors insist that this situation increase reproductive problems in dairy cattle farms (Van Doormaal 2007, Jakobsen et al. 2009). It is clear that proper level of fertility traits is possible to maintain even in high-yield herds. Therefore, herd management and level of nutrition are the key of production in modern dairy farms (Frejlich et al. 2015). Cows with undesirable temperament and slow milking speed are more likely to be culled (Berry et al. 2005). Estimation of the

relationship between temperament and cattle performance should help in defining factors influencing animal welfare in herds (Neja et al. 2015).

Traits connected with fertility, body capacity, longevity or SCC are already parts of PHF selection index, but production traits still are more important in the index. However, more balanced selection strategy shouldn't have negative effect on milk production and can improve neglected parts of cattle breeding.

In conclusion, calm animals or cows with slow milking speed have the highest ($p < 0.01$) lifetime yield of milk, fat and protein and longer life span and herd life. However, the highest ($p < 0.01$) yield of milk, fat and protein per one day of utilization have cows with normal temperament or with fast milking speed. The mayor reason of culling were fertility and reproductive disorders (on average 41.2%), and 15.3% cows culled because of udder diseases. Results suggest influence ($p < 0.01$) of temperament and milking speed on life span, herd life, lifetime milk yield. These traits and also longevity or fertility should be parts of breeding programs to balance dairy cattle selection and compensate negative influence of selection only towards milk yield that took place in the past.

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Streszczenie: *Wpływ temperamentu i szybkości doju na długość użytkowania, wydajność życiową i przyczyny brakowania krów.* Cechy związane z użytkowością, długowiecznością czy rozrodem bydła mlecznego mają coraz większe znaczenie w tworzeniu programów hodowlanych. Oceniono wpływ szybkości doju (bardzo wolne, wolne, przeciętnie, szybko, bardzo szybko) i temperamentu krów (zwierzę powolne, normalnie reagujące, pobudliwe lub agresywne) na długość ich użytkowania, życiową wydajność oraz przyczyny brakowania. Największą wydajnością ($p < 0,01$) życiową mleka, tłuszczu i białka oraz długością życia i użytkowania cechowały się zwierzęta powolne lub te wolno oddające mleko. Krowy normalnie reagujące lub o szybkim tempie oddawania mleka miały z kolei największą ($p < 0,01$) wydajność mleka, tłuszczu i białka na jeden dzień użytkowania. Główną przyczyną brakowania krów była jałowość i choroby układu rozrodczego (średnio 41,2%), jednak 15,3% wszystkich krów wybrakowano z powodu chorób wymienia. Otrzymane wyniki sugerują istotny ($p < 0,01$) wpływ tem-

peramentu oraz szybkości doju na długość życia i użytkowania krów oraz ich wydajność życiową. Cechy użytkowe, długowieczność czy płodność powinny być wykorzystane do tworzenia indeksów selekcyjnych, aby zrównoważyć negatywny wpływ selekcji skoncentrowanej w przeszłości głównie na zwiększaniu wydajności mlecznej.

Słowa kluczowe: temperament krów, szybkość doju, wydajność życiowa, brakowanie

MS received 12.05.2016

MS accepted 12.07.2016

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Effect of herbal mixture in beef cattle diets on fattening performance and nutrient digestibility

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Abstract: *Effect of herbal mixture in beef cattle diets on fattening performance and nutrient digestibility.* The aim of the study is to evaluate the impact of herbal mixture addition in beef cattle diet on daily weight gain, feed utilization and the nutrient digestibility. The study was performed on 16 Limousine bulls during the fattening period from 100 to 650 kg of body weight. The animals were divided into two groups: a control (C) and experimental (E) group. All experimental bulls received the same daily rations composed of basal feeds and a concentrate mixture. The experimental factor was a certified mixture of dried chopped herbs (the author's own elaboration): Echinacea (*Echinacea purpurea* Moench), garlic (*Allium sativum* L.), thyme (*Thymus vulgaris*), caraway (*Carum carvi*), and liquorice (*Glycyrrhiza glabra*), given additionally to the rations, in the amount of 3% of the predicted daily dry matter intake. During the study, the feed intake, animal weight gain, feed utilization per 1 kg of body weight gain, and nutrient digestibility were determined. The digestibility study was performed with the indicator method using acid-insoluble ash (AIA) as internal indicator. The addition of herbs improved animals' performance. Higher daily gains in the experimental group of animals (1,194 g per day animal daily), compared to those fed without the addition of herbs (982 g per animal daily), were found with simultaneous better feed utilization for 1 kg of body weight gain (5.01 kg in the experimental group, 5.94 kg in the control group). Higher apparent protein and fat digestibility coefficients were noted in the animals from the experimental group (by 1.3 and 2.5 percentage points, respectively), compared to the control ones. In conclusion at least a 3% addition of herbal mixture containing Echinacea, garlic, thyme, caraway, and liquorice

can be recommended in beef cattle diet in order to improve the fattening performance. The addition of herbs improves animals' performance. Higher daily gains in the experimental group of animals, with simultaneous better utilization of feed per 1 kg of body weight gain, were found.

Key words: beef cattle, herbs, digestibility, fattening performance

INTRODUCTION

Livestock production has a significant impact on the natural environment. The new legal restrictions regarding environmental standards and increasing awareness of risks and consequences of intensified animal production generate increased interest in this subject. Thus, improved utilization of feed ingredients, including reduction of excretion of biogenic elements from faeces, has become one of the most important issues in terms of environmental and economic aspects.

In ruminants, maintenance of an optimal balance between the particular groups of ruminal microorganisms affects the metabolism and utilization of nutrients and, consequently, influences the productivity of animals (Castillo et al. 2000, Ivan et al. 2000, Łozicki and Dymnicka 2001, Patra and Saxena 2010). The use of phytobiotics as natural stimulants

is one of the methods to improve feed utilization (Klebaniuk et al. 2011).

The aim of the study is to evaluate the impact of herbal mixture addition in beef cattle diet on daily weight gain, feed utilization and the nutrient digestibility.

MATERIAL AND METHODS

The study was conducted on herd of Limousin cattle managed under organic conditions. Materials for the research consisted of 16 animals: 8 in each control (C) and experimental (E) group, were randomly selected to the study (Table 1). The animals were fattened from approx.

requirements according to Strzetelski et al. (2014). The animals had constant access to licks and water. A certified mixture of dried chopped herbs (S): Echinacea (*Echinacea purpurea* Moench), garlic (*Allium sativum* L.), thyme (*Thymus vulgaris*), caraway (*Carum carvi*), and liquorice (*Glycyrrhiza glabra*) (35, 20, 15, 15, and 15%, respectively) was the experimental factor (Klebaniuk et al. 2012). It was added to the rations in the amount of 3% of the predicted daily dry matter intake according to Strzetelski et al. (2014). The concentrate mixtures and herbal supplements were given to the feeders, which were set on the quarters in the pastures or in the boxes.

TABLE 1. Experiment design

Body weight	Control group (C)	Experimental group (E)
100–650 kg	roughages and concentrate mixture	roughages and concentrate mixture and ecological herbal mixture (S)*
<i>n</i>	8 (4 mini-quarters × 2 animals)	8 (4 mini-quarters × 2 animals)

*S – ecological herbal mixture (the author's own elaboration): Echinacea (*Echinacea purpurea* Moench.), garlic (*Allium sativum* L.), thyme (*Thymus vulgaris*), caraway (*Carum carvi*), and liquorice (*Glycyrrhiza glabra*).

100 kg to min. 650 kg body weight. In each group, 8 animals were assigned to 4 mini-quarters in a pasture, and during the winter season the animals were divided into 4 boxes, 2 animals in each. During the study, the animals received green forage (replaced with haylage during winter period) and meadow hay given *ad libitum*, and concentrate mixture (barley, oats, triticale, and fodder peas in the proportion of 25, 35, 25, and 13%, respectively), and a 2% mineral-vitamin mixture given in amounts to cover animal

During the study, the feed intake, animal weight gain, feed utilization per 1 kg of body weight gain, and nutrient digestibility were determined. The assessment of the amount of green forage was evaluated with the Różycki method (Skomial 1997), and other roughages were monitored every two months in three-day cycles. The intake of the concentrate mixture was monitored daily by weighing the amount of feed given to the animals and the leftover feed in each pen. The animals were weighed every two

months. Feed samples were collected for chemical analysis (the green forage green – on a monthly basis, whereas the remaining feeds each time when the faeces were taken for apparent digestibility determination). The contents of basic nutrients, i.e. dry matter (d.m.), crude protein, crude fibre, ether extract, and crude ash in roughages, concentrate mixtures, herbs, and faeces were analysed according to the AOAC (2012) standards. The nutritive value of feed ration components was calculated on the basis of their chemical composition using programme Winwar, ver. 2.1.3.13. Apparent digestibility of nutrients was determined for each mini-quarters or box four times: at the beginning of the experiment, when the animals reached body weight approx. 250, 450, and 650 kg. Collection of representative samples of faecal was conducted in accordance with the instructions given by Rogulski (1997). Briefly, faecal samples containing approx. 200 g of pooled fresh faeces in each mini-quarter or box were taken twice a day at the end of each observation period. Fresh faecal samples were mixed thoroughly, dried at 55°C for 48 h, and then subjected to further analysis. The digestibility coefficients were estimated using the indicator method using the naturally occurring indigestible internal indicator AIA (acid-insoluble ash) according to the Regulation of the Polish Minister of Agriculture and Rural Development of 2 December 2004 on methods of determining the content of nutrients and feed additives in feedstuffs, premixes, feed mixtures and medical feeds. Apparent digestibility coefficients (ADC) were calculated using the following equation:

$$ADC = 100 - 100 \times \frac{I_{feed}}{I_{faeces}} \times \frac{N_{faeces}}{N_{feed}}$$

where:

ADC – apparent digestibility coefficient;

I_{feed} – indicator content in the feed;

I_{faeces} – indicator content in the faeces;

N_{feed} – nutrient content in the feed;

N_{faeces} – nutrient content in the faeces.

The results were subjected to analysis using Statistica ver. 6.0, while the significances of differences between mean values of the analysed parameters were set with the Tukey test ($P \leq 0.05$).

RESULTS AND DISCUSSION

The chemical composition and nutritional value of ration components (Table 2) were typical for cattle feeds (Strzetelski et al. 2014). Similarly, the chemical composition of the herbal mixture used as the experimental factor was not significantly different from the values reported in the literature (Klebaniuk et al. 2013).

Previous studies on cattle (Klebaniuk et al. 2012) or lambs (Krusiński et al. 2004) proved the positive impact of herbal mixtures on daily body weight gains and feed utilization. Animals of group E receiving 3% addition of herbs to the ration were characterized by significantly higher ($P \leq 0.05$) daily gains; at the same time, a lower average concentrate utilization per 1 kg of body weight gain ($P \leq 0.05$) was noted (Table 3). There was a trend ($P = 0.089$) towards lower utilization of roughages per 1 kg of body weight gain.

TABLE 2. The chemical composition and nutritional value of ration components

Specification	Feed				
	green forage	haylage	concentrate mixture	ecological herbal mixture (S)*	
Dry matter (%)	17.84	46.40	87.96	87.12	
In 1 kg of dry matter					
Crude protein (g)	203.56	154.74	170.30	142.10	
Crude fiber (g)	235.33	315.73	54.34	248.74	
Ether extract (g)	37.83	26.51	18.53	19.97	
Nitrogen-free extract (g)	429.05	400.86	704.75	476.70	
PDI (g)**	PDIE (g)	79	72	138	91
	PDIN (g)	74	91	164	87
UFV**	0.75	0.77	1.21	0.76	
LFU**	0.99	1.06	–	–	

*S – ecological herbal mixture (the author's own elaboration): Echinacea (*Echinacea purpurea* Moench), garlic (*Allium sativum* L.), thyme (*Thymus vulgaris*), caraway (*Carum carvi*), and liquorice (*Glycyrrhiza glabra*).

**PDI – protein truly digestible in the small intestine (PDIE – when energy limits microbial protein synthesis, PDIN – when N limits microbial protein synthesis), UFV – feed unit for maintenance and meat production, LFU – fill units for cows.

TABLE 3. Fattening performance

Item	Control group (C)	Experimental group (E)	SEM
The average body weight at the beginning of the experiment (kg/animal)	128	126	0.789
The average body weight at the end of the experiment (kg/animal)	510	537	5.271
Body weight gains (g)	982 ^b	1 194 ^a	43.66
Roughages intake (kg d.m./day/animal)	9.27 ^b	10.93 ^a	0.317
Concentrate mixture intake (kg d.m./day/animal)	5.83	5.98	0.034
Utilization of roughages for body weight gain (kg d.m./kg body weight)	9.44	9.15	0.067
Utilization of concentrate mixture for body weight gain (kg d.m./kg body weight)	5.94 ^a	5.01 ^b	0.179

^{a, b} – values with different letters differ significantly between the groups ($P \leq 0.05$).

Herbal mixtures used in cattle diets have many positive properties (Łozicki et al. 2006). Biologically active substances contained in herbs (i.e. alkaloids,

glycosides, phenols, saponins, tannins, coumarins, essential oils, bitterness, and locks) or preparations produced on the basis of herbs affect a number of

physiological aspects that contribute to improvement of rumen microflora and the function of the rumen or stimulate metabolism in the organism (Klebaniuk 2011). The animals of group E utilized the feed nutrients more efficiently than group C. This was confirmed in the apparent digestibility coefficients of nutrients (Table 4).

Protein is the most expensive and one of the most important nutrients in animal nutrition. Due to the presence of microflora in the rumen, ruminants have an ability to use not only the protein supplied in the feed, but also microbial protein. Efficient microbial protein synthesis in the rumen can proceed while maintaining the optimal conditions in the ru-

TABLE 4. Apparent digestibility coefficients of nutrients (%)

Ingredient	Average body weight of animals during samples collection (kg)	Control group (C)	Experimental group (E)	SEM
Organic matter	100	74.2	73.8	0.603
	250	73.2	74.0	0.721
	450	76.2	76.8	0.507
	650	77.1	76.3	0.613
	mean	75.1	75.2	0,589
Crude protein	100	73.1	73.5	0.608
	250	72.7	73.9	0.593
	450	74.2	75.1	0.615
	650	73.6 ^b	76.3 ^a	0.624
	mean	73.4	74.7	0.492
Crude fibre	100	60.2	61.3	0.443
	250	61.4	60.8	0.492
	450	64.1 ^a	60.4 ^b	0.420
	650	63.7	62.2	0.395
	mean	62.4	61.2	0.376
Ether extract	100	71.8	72.1	0.524
	250	72.5	74.8	0.591
	450	73.1 ^b	76.7 ^a	0.449
	650	74.0 ^b	77.8 ^a	0.502
	mean	72.8 ^b	75.3 ^a	0.487
Nitrogen free extracts	100	81.8	82.7	0.671
	250	83.4	85.2	0.634
	450	85.4	85.7	0.693
	650	84.9	86.3	0.612
	mean	83.9	85.0	0.530

^{a, b} – values in the rows with different letters differ significantly ($P < 0.05$).

men, among others the appropriate level and type of ruminal available energy and the structure of feed rations (Winnicki et al. 2012). Improved utilization of feed and microbial protein in the intestines of ruminants leads to reduction of the amount of nitrogen excreted in faeces, thereby decreasing emission of this element to the environment. In this study, the protein apparent digestibility coefficients were higher in the experimental animal group than in the control (from 0.4 to 3.3 percentage points) – Table 4. This finding confirms the investigations carried out by Wanapat et al. (2008), where higher protein digestibility was reported in a group of ruminants treated with herbal supplements, compared to the control group. However, in our study, the differences between the groups were found to be statistically significant only in the last period of fattening.

Due to stimulation of saliva secretion as well as enhancement of the synthesis of bile acids in the liver and excretion thereof in bile, herbs may have a beneficial effect on the digestion and absorption of lipids. Many active substances in herbs stimulate the function of pancreatic enzymes (lipases, amylases, and proteases) and some increase the activity of digestive enzymes of the gastric mucosa (Srinivasan 2005). In ruminants, also rumen activity is affected by modifying the numbers and species of microorganisms in the rumen (Busquet et al. 2005, Patra and Saxena 2010). The herbal mixtures tested in our trial elevated the digestibility of dietary fat determined as ether extract (Table 4). Comparable results, i.e. a significant increase in the digestibility of dietary fat, were also noted in studies

on ruminants (Mirzaei et al. 2012, Hassan and Abdel-Raheem 2013, Wang and Wang 2016) in which analogical herbal mixtures were applied.

No effect of the herbal treatment was found in either crude fibre (CF) or nitrogen-free extracts (NFE) digestibility throughout the experimental period. This result is consistent with the previous findings described by Castillejos et al. (2006), Hosoda et al. (2006) and Wanapat et al. (2008, 2013), who reported that nutrient digestibility did not change when animals were supplemented with plant herbs. Contrary to these results, other authors (Benchaar et al. 2006, Hassan and Abdel-Raheem 2013, Wang and Wang 2016) reported improved crude fibre digestibility. Herbal additives rich in essential oils or pure essential oils supplemented in ruminant rations may stimulate cellulose-degrading bacteria; thus, increased crude fibre digestibility is observed (Benchaar et al. 2006). Naturally, the major impact on nutrient digestibility is exerted by the composition of herbs supplemented in feed rations. However, the contrasting results between various studies may reflect the basic differences in the feed ration composition, especially the content of structural and non-structural carbohydrates.

An increasing trend in nutrient digestibility, particularly crude protein and fat, was observed along with the growth of animals. The differences obtained in the experimental group of animals with enhanced protein utilization seem to have quite small values. However, when applied to highly productive animal herds, they become relevant.

CONCLUSIONS

Based on the results of the study, at least a 3% addition of herbal mixture containing Echinacea, garlic, thyme, caraway, and liquorice can be recommended in beef cattle diet in order to improve the utilization of nutrients of the diet. The addition of herbs improves animals' performance. Higher daily gains in the experimental group of animals, with simultaneous better utilization of feed per 1 kg of body weight gain, were found.

Acknowledgment

The study partly financed by appropriations under the decision of the Minister of Agriculture and Rural Development: RRre-029-19-16/11, PKRE-029-5-4/12, PKRE-029-31-31/13.

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Streszczenie: *Wpływ mieszanki ziołowej w dawkach bydła mięsnego na wskaźniki wydajności opasu oraz strawność składników pokarmowych.* Celem badań jest ocena wpływu stosowania mieszanki ziół w dawkach pokarmowych dla opasów na przyrosty masy ciała, zużycie paszy na 1 kg przyrostu masy ciała oraz strawność składników pokarmowych. Badania przeprowadzono na 16 cielętach rasy limousine utrzymywanych od około 100 kg do 650 kg masy ciała. Zwierzęta podzielono na dwie grupy: kontrolną (C) i doświadczalną (E). Zwierzęta obydwu grup otrzymywały w dawce te same pasze objętościowe i mieszan-

kę treściwą. Czynnikiem doświadczalnym była mieszanka suszonych, krojonych ziół (receptura własna): jeżówka (*Echinacea purpurea* Moench), czosnek (*Allium sativum* L.), tymianek (*Thymus vulgaris*), kminek (*Carum carvi*), i lukrecja (*Glycyrrhiza glabra*) dodawana do dawki w ilości 3% przewidywanego dziennego pobrania suchej masy dawki. W trakcie badań oceniono spożycie paszy, przyrost masy ciała zwierząt, zużycie paszy na 1 kg masy ciała przyrostu oraz strawność składników odżywczych. Badanie strawności przeprowadzono metodą wskaźnikową przy wykorzystaniu popiołu nierozpuszczalnego w HCl (AIA). Dodatek ziół do dawek pokarmowych poprawił wskaźniki odchowu bydła. U zwierząt grupy eksperymentalnej obserwowano większe dzienne przyrosty masy ciała (1194 g na głowę dziennie), w odniesieniu do tych żywionych bez dodatku ziół (982 g na głowę dziennie), przy jednoczesnym mniejszym średnim zużyciu paszy treściwej na 1 kg przyrostu masy ciała (5,01 kg w grupie eksperymentalnej; 5,94 kg w grupie kontrolnej). Większe wartości współczynników strawności pozornej białka i tłuszczu odnotowano w grupie zwierząt otrzymujących zioła (odpowiednio o 1,3 oraz 2,5 punktu procentowego), w porównaniu do zwierząt grupy kontrolnej. Pod-

sumowując, co najmniej 3% dodatek mieszanki ziołowej zawierającej jeżówkę, czosnek, tymianek, kminek i lukrecję może być zalecany w celu poprawy wskaźników odchowu bydła mięsnego. Dodatek ziół poprawia wydajność zwierząt. W grupie zwierząt doświadczalnych stwierdzono większe dzienne przyrosty zwierząt, z jednoczesnym lepszym wykorzystaniem paszy na 1 kg przyrostu masy ciała.

Słowa kluczowe: bydło mięsne, zioła, strawność, wskaźniki odchowu

MS received 18.07.2016

MS accepted 14.11.2016

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Analysis of stakeholders' implementation of the National Strategy for sustainable utilisation and conservation of animal genetic resources in Poland

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Abstract: *Analysis of stakeholders' implementation of the National Strategy for sustainable utilisation and conservation of animal genetic resources in Poland.* The study, based on the customised questionnaire, is aimed at evaluating the contribution of relevant stakeholder groups in the implementation of Strategic Priorities and specific tasks identified in the Action Plan to the National Strategy. The analysis shows that breeders associations and other organizations entrusted with herd book keeping, as well as agricultural universities, are significantly contributing to the implementation of the National Strategy. In addition, significant involvement in implementation was reported by regional authorities (Marshal's Offices in voivodships) and extension services. Public administration and governmental agencies proved to be heavily engaged in implementation and enforcement of specific areas of the Action Plan.

Key words: National Strategy, animal genetic resources conservation, stakeholders

INTRODUCTION

In September 2007, during the international technical conference in Interlaken, the international community adopted the first ever global framework to enhance management of animal genetic resources worldwide – the Global Plan of Action for Animal Genetic Resources (FAO 2007). The Global Plan of Action (GPA)

includes 23 strategic priorities under four priority areas, namely: Characterization, Inventory and Monitoring of Trends and Associated Risks (2 Strategic Priorities); Sustainable Use and Development (4); Conservation (5); and Policies, Institutions and Capacity-building (12). In July 2016, the 9th session of the Intergovernmental Technical Working Group on Animal Genetic Resources, in the lights of the findings of the Second Report on the State of the World's Animal Genetic Resources (FAO 2015), decided that the GPA is still the most relevant international framework for the management of animal genetic resources, and renewed commitment to its further and full implementation (FAO 2016a, b).

Country implementation of this global framework was foreseen through development of National Strategies and Action Plans (NSAPs) that should include strategic priorities of the GPA relevant for each country and additional priorities as identified by countries themselves. FAO has provided guidelines to support national efforts in developing NSAPs (FAO 2009). These guidelines were closely followed in Poland in the process of preparation of the National Strategy

for sustainable utilisation and conservation of animal genetic resources.

Development of the National Strategy was carried out within the Multi-Year Programme of Work of the National Research Institute of Animal Production 2011–2015, and financed by the Ministry of Agriculture and Rural Development (MARD). The National Strategy provides amplification to the Strategy of Sustainable Development of Countryside, Agriculture and Fishery 2012–2020 (MRiRW 2012) in the area of livestock production. A preparatory process was initiated in 2011 and completed in 2013. The process involved broad participation of stakeholders in animal breeding

and research, MARD officials and representatives of NGOs. Participant provided both technical inputs to the final document as well as contributed to discussions and priority setting during three conferences organized by the Institute (Martyniuk and Krupiński 2013).

The overall objective of the National Strategy is to promote and support the effective utilisation and conservation of genetic resources of farm animals as a contribution to sustainable agriculture (MRiRW 2013a). The National Strategy includes 15 strategic Priorities (SP), clustered within the same priority areas as adopted in the GPA (Table 1). The National Strategy was supplemented by a detailed Plan of Action

TABLE 1. Strategic Priorities and tasks contained in the National Strategy for sustainable utilisation and conservation of animal genetic resources (MRiRW 2013a, b)

Priority area	Strategic Priorities (SP)	Number of tasks
I	1. Monitoring of breeds structure of the population of key farm animal species	2
	2. Establishment and development of central data bases for relevant farm animal species	4
	3. Establishment of the cooperative procedure regarding exchange of information on animal genetic resources	2
	4. Enhancement of phenotypic and genetic characterisation of breeds/varieties/lines of farm animals	2
II	5. Performance recording and breeding value evaluation and publication of results	4
	6. Review and updating of breeding programmes	4
	7. Enhancement of profitability of livestock production and broader utilisation of species of lower economic importance	3
	8. Utilisation of farm animals, including native breeds in nature conservation and landscape management	2
III	9. Continuation, improvement and enhancement of <i>in-situ</i> conservation measures	5
	10. Initiation and implementation of <i>ex-situ</i> conservation activities on a routine basis	5
	11. Monitoring of trends and risk for animal genetic resources and establishment of early warning	2
IV	12. Development of cooperation between breeders, producers and consumers	3
	13. Development of human capital involved in livestock production	3
	14. Building public awareness on roles and importance of livestock production	5
	15. Assessment and improvement of legislation in the area of livestock breeding	4

(MRIRW 2013b), with each Strategic Priority complemented by specific actions/tasks, necessary for its implementation.

The Plan of Action to the National Strategy identified stakeholders within and outside animal breeding and research community that should be involved in implementation of specific tasks within agreed priorities (MRiRW 2013b). To report on progress in the implementation of the National Strategy, it was necessary to understand what activities were undertaken by these stakeholders and extent of such activities. The objective of this study was to analyse and evaluate the scope and level of activities undertaken by relevant stakeholders' groups during the first two years of the implementation of the National Strategy.

MATERIAL AND METHODS

The study was based on customised surveys prepared for each group of stakeholders. Every questionnaire included a set of tasks that are contained in the Plan of Action, and were assigned to given group of stakeholders. In total, the National Strategy and Plan of Action contains 15 strategic priorities and

50 tasks. The customised surveys included between a few up to 20 questions representing tasks relevant for a given group of stakeholders. Each task included in every questionnaire required answer if given organization was involved in implementation of this task, and in such a case the respondent was invited to provide an extensive description of activities undertaken in this field.

The survey included the following groups: Ministries and governmental agencies; Marshal's offices in voivodships; breeding organizations, extension services, agricultural universities, research institutions and non-governmental organizations.

The National Research Institute of Animal Production, as organization entrusted by Minister of Agriculture with coordination of animal genetic resources conservation programmes in Poland, is directly responsible for implementation of a number of tasks, and accordingly information was collected directly from coordinators responsible for implementation of conservation programmes within each livestock species.

In total, questionnaires were sent to 65 organizations and institutions, including governmental agencies (Table 2).

TABLE 2. The distribution of surveys among stakeholder groups and the return rate

Stakeholder's group	Number of entities	Number of responses	Return rate (%)
Breeding organizations/organizations in charge of herdbooks	9	7	77
Research institutions	4	3	75
Agricultural universities	10	7	72
Extension services	17	17	100
Voivodship's Marshal offices	16	16 + 1	100
Non-governmental organizations	3	1	33
Public administration and governmental agencies	6	6	100
Total	65	58	89

RESULTS AND DISCUSSION

The survey resulted in a high overall return rate (89%). Only one response was obtained from the NGO sector and information provided was not related to the issues covered by the questionnaire. Two research institutions responded that they do not carry-out any relevant activities. In spite of repeated efforts, two breeders' organizations entrusted by Minister with responsibility of carrying out breeding work did not respond.

In general, the completeness of responses to all questions included in questionnaires was high. In some cases, the reported activities were related to implementation of only part of tasks foreseen for implementation by the given stakeholder group, or responses indicated involvement in given tasks, but have not provided any details on the scope of their activities.

Public administration and governmental agencies

The Ministry of Agriculture and Rural Development (MARD), through its role in overseeing all activities related to livestock production in general, indirectly contributes to the implementation of the National Strategy. However, it also is directly involved in implementation, mostly related to SP 7, 12 and 14 (Table 1). The MARD is conducting activities aimed at dissemination of knowledge on high quality food, in particular traditional and regional products. Since 2013, the Ministry of Agriculture and Rural Development, in cooperation with the Agricultural Market Agency, is conducting an information campaign "Three labels of taste" to promote the EU system

for identification of products: protected designation of origin (PDO), protected geographical indication (PGI), and traditional specialities guaranteed (TSG).

The Ministry is keeping a Register of traditional products that includes many local or regional dairy and meat products (<http://www.minrol.gov.pl/Jakosczywnosci/Produkty-regionalne-i-tradycyjne/Lista-produktow-tradycyjnych>), some of them based on a raw material obtained from local breeds. The Ministry is also supporting development of food system "Quality tradition". The participants (breeders, producers) involved in implementation of this programme have been entitled to benefits from measures provided through the Rural Development Programme 2007–2013 and 2014–2020.

The Ministry of Agriculture and Rural Development is directly involved in implementation of seven tasks, while specific governmental agencies: Central Statistical Office of Poland (GUS), the Agency for Restructuring and Modernisation of Agriculture (ARMA), and the Central Veterinary Inspectorate Office, were expected to contribute to implementation of four very specific tasks aimed mainly at improving monitoring of animal genetic resources. However, progress in the area of data transmission/sharing was not achieved due to legal considerations; a discussion on this matter is ongoing.

The Ministry of Environment reported on a broad scope of activities, mainly related to implementation of the SP 8 (Utilisation of farm animals, including native breeds, in nature conservation and landscape management). The most important activities were undertaken by the National Parks. Out of our 23 National

Parks, eight (35%) reported using grazing (mainly by sheep and goats, horses and cattle) as landscape management service. The National Parks benefiting from grazing services include: Biebrza, Gorce, Magura, Narew, Ojców, Roztocze, Słowiński and Wolin National Parks. Livestock are playing an important role in these Parks, contributing to active conservation of nature and specific habitats and landscapes.

One of the main aims of the controlled grazing in the National Parks is the reduction of secondary succession and maintaining a balance in valuable ecosystems. The continuation of extensive agriculture practices supports conservation of plant communities with high nature values that are not found any longer in most European countries, for example *Molinia* meadows and peat bogs.

An important initiative to reconstitute populations of various species of pollinators, including honey bees, is being undertaken at Stołowe Mountains National Park. This initiative aims both to conserve pollinators and enhance public awareness and education on the importance of pollinators.

Utilisation of grazing in vegetation control and landscape management was also reported by seven regional Directorates for Environmental Protection (RDOŚ) in Bydgoszcz, Katowice, Kraków, Lublin, Rzeszów, Szczecin and Warszawa. The overall objective of these projects is active nature conservation. In the majority of projects animals belong to native breeds of sheep (Olkuska, Uhruska, Świniarka and Polish Heath Sheep), horses (Polish Konik) and cattle (Polish Red) are providing grazing services. It was reported that highest number

of local grazing projects are in Lubelskie, Podkarpackie, Małopolskie and Śląskie voivodships. In the Podkarpackie region, an additional important goal is to increase the population sizes of native breeds, especially cattle breeds.

Research institutions and agricultural universities

Seven agricultural/life sciences universities and the Institute of Genetics and Animal Breeding responded to the questionnaire. Research institutions and agricultural universities were expected to contribute to 10 tasks included in the Plan of Action; it was reported that all these activities were undertaken and are ongoing. The contribution of research sector to implementation of the National Strategy is based on research projects, resulting scientific publications and preparation of a number of MSc thesis and PhD thesis. The research projects are contributing mainly to SP 2, 4 and 9.

As regards to SP 2 (Establishment and development of central data bases for relevant farm animal species), implementation of task 2.3, related to estimation of phenotypic and genetic trends in performance recording and publication such trends in yearbooks was reported by all universities, and task 2.2 related to utilization of national databases for monitoring genetic diversity in breed populations of farm animals was reported by five out of seven universities.

In implementation of SP 4 (Enhancement of phenotypic and genetic characterisation of breeds/varieties/lines of farm animals), task 4.1, related to initiation and continuation of research on phenotypic and genetic characterization of livestock populations was carried out

by all universities, while task 4.2 on providing information about research projects carried out on breed populations included in genetic resources conservation programmes was reported by one university only. As a result, steps were taken to close this gap.

In regard to SP 9 (Continuation, improvement and enhancement of *in-situ* conservation measures), task 9.4 on monitoring and control of inbreeding in populations under conservation programs was reported by five universities that maintain *in-situ* herds of native breeds. As regards *ex-situ* measures, carrying out task 10.5 (Implementation of innovative biotechnological methods to *ex-situ* conservation) was reported by two universities only: the University of Warmia and Mazury in Olsztyn and Warsaw University of Life Sciences. However, the work in this field carried out in the Department of Animal Genetic and Animal Breeding in Warsaw is focused on conservation of the European bison population and establishment of a genebank of biological material of this species. The extensive research is aimed on improvement of methods to obtain and handle bison's semen before and during freezing, as well as in the course of its thawing.

Another important contribution of Agricultural universities was related to implementation of SP 14 (Building public awareness about the role and importance of farming and animal husbandry), especially tasks 14.2–14.4, that are related, respectively, to promotion and popularisation of non-agricultural functions of farm animals; popularisation of good husbandry practices and principles of animal welfare; and promotion of native breeds including building aware-

ness on the need for their conservation. Six out of seven universities reported undertaking such activities beyond providing formal education. This included for example, radio programmes, articles in the press and participation in various exhibitions and festivals. The Institute of Genetics and Animal Breeding reported contribution to one task only, 4.1 related to undertaking and carrying out research on the phenotypic and genetic characteristics of livestock populations.

Breeding organizations/organizations in charge of herdbooks

The Plan of Action assigned 32 tasks to breeders associations and other organizations in charge of herd book keeping. Responses to questionnaires were obtained from seven subjects, one of them only indicating that given activities are carried out or not carried out, without any detailed description. Due to the high number of tasks, the analysis concentrated on implementation of on Strategic Priorities.

Implementation of SP1 (Monitoring of breeds structure of the population of key farm animal species), based on continuous monitoring of the size of purebred and crossbred populations was reported by five out of seven organizations. However, in some cases these activities were carried out on routine basis and *de facto* have not provided any clear understanding of the breed structure of commercial population of a given species.

In case of the SP2 (Establishment and development of central data bases for relevant farm animal species) there are three tasks to be implemented. In general, implementation of these tasks by all

responders was very satisfactory, only in the case of publishing phenotypic and genetic trends there were some insufficiencies reported by four organizations and one organization reported no activities on monitoring inbreeding level in active populations of individual breeds.

Five out of seven organizations were working on improvement of performance recording and breeding value evaluation methods (SP5), while all organizations were trying to enhance participation of breeders in these activities to increase active populations of individual breeds. Also, all organizations were involved in the publication of yearbooks with summary of the results of breeding work.

In case of SP6 (Review and updating of breeding programmes) all four tasks were fully implemented. However, implementation of the genomic breeding value estimation into selection programme at present is carried out only for dairy cattle.

SP7 (Enhancement of profitability of livestock production and broader utilisation of species of lower economic importance) is implemented thorough three tasks. The first one is related to promotion of regional products and was implemented by five organizations through their participation in projects utilizing so called "Promotion funds", provided by the Ministry (e.g. promotion of pork or horse meat) as well as in regional animal shows and exhibitions. Other activities, focusing on promotion of low-input production systems and popularization of keeping livestock in agro-tourism farms were not fully implemented by breeders' organizations. In general, their involvement in activities in this area was about 50% of their potential contribution.

Tasks to be implemented within the SP8 (Utilisation of farm animals, including native breeds in nature conservation and landscape management) were carried out only by breeders associations in charge of herd book keeping for dairy cattle and horses. Unfortunately, in spite of repeated requests, organization in charge of flock books keeping for sheep and goats did not participate in the survey.

All responding breeding organizations reported on implementation of SP9 (Continuation, improvement and enhancement of *in-situ* conservation measures); and within it on the task 9.4 related to monitoring and control of inbreeding in populations included in genetic resources conservation programmes. It is an important contribution to maintain genetic diversity, especially in native breeds of small population sizes.

The SP12 (Development of cooperation between breeders, producers and consumers) should be implemented though three tasks. However, only in the case of 12.1 (Support for establishment of trade unions, breeders' societies and producer groups) four organizations reported on some activities in this field. Extensive activities regarding Task 12.2 (Promoting branding products of animal origin, safe for the consumers) and 12.3 (Promoting participation in quality assurance systems for products of animal origin) were carried out only by two organizations, both in charge of breeding work in pigs.

The SP13 (Development of a human capital involved in livestock production) has been fulfilled by provision of training (six out of seven organizations), while other tasks such as support for local

initiatives on sustainable management of animal genetic resources and support for local communities for maintaining local traditions and products were undertaken by 35% of respondents of this group.

Implementation of the task on promotion and popularisation of non-agricultural functions of farm animals within SP14 (Building public awareness on roles and importance of livestock production) has been reported only by two organizations, while other promotion and popularization activities related to promotion of animal welfare, promotion and popularisation of native breeds and their products, were extensively carried out by 71% of respondents, through training, exhibitions, web portals and promotion funds.

The last SP15 (Assessment and improvement of legislation in the area of livestock breeding) encompassing four tasks, was implemented at a rather low level, only 39% of respondents reported on such activities. The highest involvement in this area was related to analysis of procedures for participation in implementation of the Rural Development Programme 2014–2020 as well as analysis of the impact of laws in effect on ensuring effective conservation of animal genetic resources.

Voivodship's Marshal offices

The Marshal's offices in the majority of voivodships reported on a broad scope of activities related to promotion of regional food products. All of them were involved in implementation of task 7.1 (Promotion of niche and traditional raw materials and products of animal origin, including high quality products). Activities undertaken in this field cover co-organisation of training workshops,

conferences, open markets, fairs, exhibitions and contests, as well as evaluation of applications to enter "Register of regional products" kept by the Ministry of Agriculture and Rural Development.

Eleven Marshal's offices (out of 16) actively supported establishment of producer groups that contributes to the implementation of task 12.1 (Support for establishment of trade unions, breeders' societies and producer groups), while 10 facilitated and supported participation of farmers in quality assurance schemes (12.3). However, very little was done to implement task 13.2 (Support for local initiatives on sustainable management and conservation of animals genetic resources); only the Mazowieckie voivodship Marshal's office reported on cooperation with the Civil Ecological Institute on this matter. Also, only two respondents in this group contributed to implementation of the task 5.3 on development of mechanisms to ensure broader participation of breeders in performance recording schemes. This is not satisfactory, taking into account substantial needs to enhance this area.

Nine Marshal's offices, usually in cooperation with extension services carried out training in regard to animal welfare, contributing to implementation of the task 14.3 on popularisation of knowledge on animal welfare and good husbandry practices. An excellent example of implementation of this task is work of the Lubuski voivodship Marshal office, which organized 48 two-day training workshops that involved 960 participants.

Contribution to task 14.4 related to promotion and popularisation of native breeds and the need for their conservation

was reported by seven respondents, and the task was carried out mainly through facilitation of participation of farmers/breeders keeping native breeds in various local and regional events, including animal shows, fairs and open markets.

In the Plan of Action to the National Strategy, in total 15 tasks were assigned to the Marshal's offices, out of these, six were implemented by all of them, four by at least half of them and only five were implemented by less than half of the Marshal's offices.

Extension services

Both Agricultural Advisory Centre in Brwinów and the 16 extension centres in voivodships are substantially contributing to the implementation of the National Strategy. Out of 16 task assigned in the Plan of Action to this group of stakeholders, only one, 13.2, related to support for local initiatives on sustainable management and conservation of animals genetic resources, was carried out by less than a half of the centres. Four tasks were implemented by 14 or more centres, and one task, 7.1 as in the case of Marshal's offices, by all of them. Workshops, trainings, culinary contest, and also study trips and individual consulting were carried out in this field. Other tasks that were implemented by the majority of centres include 7.2 on promotion of native breeds in agro-tourism, ecological and extensive farms, 14.3 on dissemination of knowledge on animal welfare and good husbandry practices and 14.4 on promotion of native breeds and their conservation. The task 8.1 on promotion of landscape management services provided by livestock was implemented by 13 centres, mainly through training and

consulting, as well as by using videos and study tours to enhance understanding of the roles of grazing and implementation of such services.

Three tasks were carried-out by 12 out of 17 centres include 7.3 on promotion of low-input production systems and less popular directions of utilisation, 13.1 on specialised training of breeders, producers and extension staff, and 14.5 regarding promotion of traditional products from native breeds. The Małopolski extension centre is maintaining a homepage of traditional and regional products and contributes to organization of fairs to promote regional food and other products in the country and abroad.

CONCLUSIONS

The survey provided a wealth of material, impossible to fully present in this paper. There were substantial differences in the scope and quality of responses, especially in the level of detail that were provided regarding ways and means to implement specific tasks. Many of the initiatives reported at regional and local level, were not known before, and it is clear they deserve recognition and appreciation, and some may serve as model examples.

Both Marshal's Offices and extension services indicated they are implementing a broad scope of activities for the promotion and popularisation of utilisation of native breeds in farming.

Regional Directorates for Environmental Protection provided detailed descriptions of many projects where grazing was used as a tool in active nature conservation. Agricultural universities reported on a wide scope of research

studies that are contributing to implementation of the National Strategy both through specific research projects and through development of MSc and PhD thesis. Valuable contributions are being provided by voivodships' extension services as well as the Agricultural Advisory Centre in Brwinów. The extension services were instrumental in implementation of tasks related to improvement of profitability of livestock production and introduction of underutilised species to farming (SP 7), as well as in building public awareness of the roles and importance of livestock husbandry (SP 14).

It seems that breeders' societies and other organizations in charge of herd book keeping, although substantially contributing to the implementation of the National Strategy could enhance their involvement, as some tasks assigned to this group of stakeholders within the scope of their responsibilities and competence were not yet undertaken.

The contribution of the non-governmental organizations is difficult to evaluate with only one response to the questionnaire.

Acknowledgement

The study was conducted within the Multi-Year Programme of Work of the National Research Institute for Animal Production, task 17-1.40.9, financed by the Ministry of Agriculture and Rural Development.

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Streszczenie: *Analiza wdrażania Krajowej strategii zrównoważonego użytkowania i ochrony zasobów genetycznych zwierząt w Polsce.* Badania opracowane na podstawie ankiet przygotowanych indywidualnie dla wybranych grup organizacji miały za zadanie ocenić, w jakim zakresie te grupy przyczyniają się do realizacji strategicznych priorytetów i specyficznych zadań przyjętych w planie działań do Krajowej strategii. Analiza wykazała, że związki hodowców i inne organizacje, którym powierzono prowadzenie ksiąg hodowlanych, jak też uczelnie rolnicze mają znaczący wkład we wdrażaniu Krajowej strategii. Ponadto duże zaangażowanie wykazały wojewódzkie urzędy marszałkowskie i służby doradztwa rolniczego. Administracja publiczna i agencje

rządowe były zaangażowane w wysokim stopniu we wdrażanie i w nadzorowanie działań w zakresie swoich kompetencji.

MS received 23.08.2016

MS accepted 13.10.2016

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The influence of the types of cross-breeding of the parental generation on the final results of stationary performance tests of Polish half-bred mares

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Abstract: *The influence of the types of cross-breeding of the parental generation on the final results of stationary performance tests of Polish half-bred mares.* An analysis was made of the pedigrees of Polish half-bred mares that underwent a stationary performance test in Polish training stations in order to isolate the types of applied cross-breeding schemes of the parental generation. An attempt was made to determine the influence of particular cross-breeding schemes on the diversity of the value of the final results of the performance test, which is an indicator of the utility value of the mare. The research material consisted of the results of stationary saddle performance tests of 994 mares, obtained at training stations between a period of 2007–2012. The highest least squares means of the final results of the test were achieved by mares whose parents were representatives of foreign breeds, and the lowest by mares deriving from Małopolska breed parents. The largest group among mares taking the stationary saddle test consisted of daughters of one foreign breed parent and the second a Polish Warmblood. The greatest diversity among the schemes for selecting pairs for reproduction was found in the Polish Warmblood mare group. Mares deriving from both parents of the Małopolska breed, as well as from one parent of the Małopolska breed refined with Thoroughbred blood, showed the largest variability of the achieved results in the performance test.

Key words: half-bred mares, performance tests, parentage, utility value

INTRODUCTION

Many authors (Nowicka-Posłuszna 1998, Cuber 2008) emphasize the importance and significance of the influence of the

female material on the utility value of the offspring, and at the same time on the growth of progress and the improvement of breeding. Breeding programs focus their selection and breeding goal on the obtaining of horses for modern equestrian sport. Intended for reproduction purposes should be such individuals, both stallions and mares, with the highest utility potential assessed during performance tests at training stations (Lawin 2008). The selection of parents is dictated by their having certain traits, which their offspring should also exhibit. This aspect justifies the carrying out of an evaluation of mares, equivalent to the evaluation of stallions, and the need to test their potential in terms of “rideability”. Rideability, being a very highly heritable trait, reflects the suitability of a horse for saddle use and the possessing of traits which allow the animal to cooperate with the rider.

The performance control of mares became obligatory starting from 2010 and a condition for obtaining registration in the stud book of a given breed. This was particularly significant in view of the changes in Polish breeding trends, which moved away from a multipurpose type of horse in favor of a sport and saddle horse. A change of the breeding goal is obviously carried out by mares as producers and this fact indicates that they should

absolutely be evaluated in performance tests (Byszewski 2009). A breeding which is mainly “led” by the evaluation of the utility value of stallions, excluding the results of mare performance tests, does not bode well for quick breeding progress (Jończyk 2001). If one observes an incorrect technique in a mare already while clearing short fences, then the increasing of their height will definitely not stimulate a spontaneous reduction of the problem and cause an improvement in the jumping technique. The covering of a poorly talented mare even with an excellent stallion in terms of performance rarely results in a jumping-talented foal (Wiszwoty 2004).

According to Barry et al. (2002a, 2002b), performance tests facilitate the selection of mares for breeding, because they create an opportunity to compare the future dams with each other.

The aim of the study is to evaluate the influence of the types of cross-breeding of the parental generation in the population of Polish half-bred mares on the diversity of the value of the final results of the performance tests, which are a reflection of the utility value of the mares.

MATERIAL AND METHODS

The research material consisted of the results of stationary saddle performance tests of 994 mares obtained in training stations during a period of 2007–2012. The source of the numerical data to conduct the statistic calculations were materials made available by the Polish Horse Breeding Association (PZHK).

An analysis of the construction of the pedigrees was made, based on which

each of the mares of the study was assigned to one of 14 groups, according to the type of cross-breeding that occurred in the parental generation. The number of individuals forming each group was determined with the use of the MEANS procedure of the SAS package. The possessed data were statistically analyzed with the use of the GLM procedure of the SAS package. Levels of LSM were determined for the end result achieved by a mare in the training station. Significances of differences between results achieved by mares forming each of the 14 isolated groups were evaluated according to the following formula:

$$y_n = \mu + \text{Mating}_n + e_n$$

where:

y_n – value of the result for horse n ($n = 1, \dots, 994$);

μ – average result;

Mating_n – fixed effect of mating horse n ;

e_n – sampling error.

The main aim of carrying out stationary saddle tests is to obtain an evaluation of the mare’s suitability for this type of use, as well as an analysis of her excitability and stability of her nervous system. Stationary saddle performance tests were carried out in accordance with the rules of the PZHK, which is that after a 60 day training period each mare was evaluated by the director of the training station, together with a group of mares which underwent training in the same conditions. This created the opportunity to evaluate the individual in comparison to the rest of the group. The traits that underwent evaluation were: character, temperament and suitability for training. In the next phase the committee assessed the mare’s behaviour under a rider in walk, trot and

canter, as well as the technique of clearing fences in the corridor (in free jumping): the style and readiness of clearing the fence, courage and respecting the fences, self-control and determination in moving forward. In order to increase the objectiveness of the evaluation and to eliminate the so-called “effect of the rider”, a test of outside riders was used, which is an anonymous evaluation of all horses by experienced competitors. The test rider assessed the riding level of the horse, its reaction towards riding aids and the ability to quickly establish contact with the horse. The summing up of points awarded by the committee, the director and the outside rider together formed the value of the final evaluation of the mare (Świstowska 2011).

RESULTS AND DISCUSSION

The most numerous group among the 994 mares undergoing the stationary saddle performance test in the researched period were females deriving from one foreign breed parent and the second a Polish Warmblood (Table 1). The size of this group amounted to 183 individuals, which made up 18.41% of the analyzed population. In Poland a tendency can be observed in the increase of the Polish Warmblood population, which resulted from the cross-breeding of Polish breeds with foreign breed individuals. Łojek (2003), as well as Łojek and Nowak (2003) consider this breed to be predestined to obtain horses used in various equestrian disciplines. The results of the junior horse championships show that horses of the Polish Half-Bred and Wielkopolska breeds are among the

TABLE 1. Isolated types of cross-breeding of the parental generation of 994 mares undergoing the stationary performance test in training stations during 2007–2012

No	Type of cross-breeding	<i>n</i>	%
1	imp × imp*	23	2.31
2	imp × wlkp	141	14.19
3	imp × sp	183	18.41
4	imp × xx	19	1.91
5	imp × m	60	6.04
6	sp × sp	113	11.37
7	sp × xx	20	2.01
8	sp × wlkp	113	11.37
9	m × m	164	16.5
10	m × sp	24	2.41
11	m × xx	18	1.81
12	m × wlkp	36	3.63
13	wlkp × wlkp	57	5.73
14	wlkp × xx	23	2.31

*imp – imported foreign breeds, wlkp – Wielkopolska breed, sp – Polish Warmblood, xx – Thoroughbred, m – Małopolska breed.

leading competitors in both show jumping and dressage (Pikuła et al. 2006).

The next two groups dominant in terms of size (164 individuals – 16.5% and 141 individuals – 14.19%, respectively), consisted of mares deriving from both parents of the Małopolska breed, as well as one parent of a foreign breed and the other of the Wielkopolska breed.

Among mares of the Małopolska breed the largest percentage (72.77%) consisted of individuals whose both parents were also representatives of this breed (Table 2). A small number of Małopolska breed mares had in their parental generation, apart from representatives of the Małopolska breed, individuals of foreign breeds (14.73%) and Thoroughbreds

TABLE 2. Distribution of cross-breedings from which mares of Polish breeds, that underwent the stationary saddle test in training stations during 2007–2012 (%), derived

Type of cross-breeding	Małopolska breed	Polish Warmblood breed	Wielkopolska breed
imp × imp*	–	4.69	0.32
imp × wlkp	–	3.41	39.81
imp × sp	–	38.81	0.32
imp × xx	–	4.05	–
imp × m	14.73	5.76	–
sp × sp	–	24.09	–
sp × xx	–	4.05	0.32
sp × wlkp	–	7.89	24.2
m × m	72.77	0.21	–
m × xx	8.04	–	–
m × sp	0.89	4.69	–
m × wlkp	–	1.07	9.87
wlkp × wlkp	–	–	18.15
wlkp × xx	–	0.21	7.01
other × m	3.57	–	–
other × sp	–	0.64	–
other × wlkp	–	0.43	–

*imp – imported foreign breeds, wlkp – Wielkopolska breed, sp – Polish Warmblood, xx – Thoroughbred, m – Małopolska breed.

(8.04%), allowed by the rules of their breeding program. The largest diversity of schemes used for selecting pairs for reproduction was observed in the group of Polish Warmbloods. The largest percentage of Polish Warmblood mares in the evaluated population derived from parents of foreign breeds and Polish Warmbloods (38.81%), as well as from both parents of the Polish Warmblood breed (24.09%). Exactly 39.81% mares of the Wielkopolska breed were the offspring of one parent of the Wielkopolska breed and the other of a foreign breed, whereas in the case of 24.2% of mares of this breed one of the parents was a representative of the Wielkopolska breed and the other of the Polish Warmblood breed.

Stallions of the Małopolska breed were present in the father generation both in the case of Polish Warmblood mares and Wielkopolska breed mares.

The highest level of performance ability during the evaluated period of 2007–2012 belonged to mares deriving from both parents of foreign breeds (Table 3), which is confirmed by results achieved during stationary performance tests in training stations. The results of this group were significantly better than the results of mares deriving from other types of parental generation cross-breeding. The significant influence of foreign breed sires on the state of Polish breeding has been visible for years. The advantage of using foreign breed sires

TABLE 3. Least squares means of the final results of mares undergoing stationary performance tests in training stations in 2007–2012 for the isolated types of cross-breedings of the parental generation from which they derived

No	Type of cross-breeding	<i>n</i>	<i>LSM</i> **	<i>SD</i>
1	imp × imp*	23	60.80 ^A	4.96
2	imp × sp	183	57.88 ^B	4.97
3	imp × wlkp	141	57.33 ^{BC}	4.52
4	imp × xx	19	56.64 ^{BCDF}	4.98
5	imp × m	60	55.93 ^{CD}	4.65
6	sp × sp	113	56.14 ^{CD}	4.75
7	sp × xx	20	56.45 ^{BCDE}	4.65
8	sp × wlkp	113	55.38 ^{DE}	4.59
9	m × m	164	54.33 ^E	5.27
10	m × xx	18	53.75 ^{DE}	5.54
11	m × sp	24	55.70 ^{CDE}	4.09
12	m × wlkp	36	54.98 ^{DE}	5.17
13	wlkp × wlkp	57	54.36 ^{EF}	3.82
14	wlkp × xx	23	54.42 ^{DE}	4.58

*imp – imported foreign breeds, wlkp – Wielkopolska breed, sp – Polish Warmblood, xx – Thoroughbred, m – Małopolska breed.

**Means in columns marked with the same big letters are not significantly different.

compared to domestic breed sires is confirmed by the studies of Pietrzak (2003). Chrzanowski et al. (1997) claim that the need for using imported sires stems from the small suitability of Polish breeds for the production of sport horses. Kaproń (2007) points out the large diversity of performance predispositions of the Polish half-bred population, in which he sees the reason for trying to improve them by cross-breeding with horses of foreign origin. Drewka (2012), as well as Geringer et al. (2004) emphasize the decisive dominance of the performance ability of offspring of foreign breed sires in comparison to the offspring of Polish sires.

Slightly lower least squares means were achieved by the largest group of

mares (183 individuals), being the offspring of parents of foreign breeds and Polish Warmbloods. Its results were significantly higher than those of mares deriving from the following cross-breedings: sp × sp (Polish Warmblood × Polish Warmblood), all types of cross-breedings in which there were both or one parent of the Małopolska breed and all (except imp × wlkp – imported foreign breed × Wielkopolska breed) types of cross-breedings in which both parents or one of the parents was of the Wielkopolska breed. Mares from groups that had representatives of foreign breeds or Polish Warmbloods in their parental generation achieved better results of their evaluation in comparison to mares by both parents of Polish half-bred breeds.

The lowest LSM values were achieved by the second in terms of size (164 individuals) group of mares deriving from both parents of the Małopolska breed and Małopolska mares deriving from a parent of the Małopolska breed refined with Thoroughbred blood. For mares of both of the above mentioned groups also the largest variability of the achieved performance test results was determined, expressed as standard deviation value.

The achieved results point to the justness of using imported breeding material in reproduction, which in a significant manner influences the increase of the utility value of Polish half-bred mares. Lower average results of mares without foreign breed individuals in their parental generation attest to the small effectiveness of carried out breeding programs and the fact of achieving breeding progress in terms of improving saddle traits in the Polish half-bred population only by using sires from abroad for reproduction. The existence of this tendency is confirmed by the results of Chrzanowski and Maśko (2012, 2013), as well as Chrzanowski et al. (2012).

Stachurska et al. (2006) suggest the justness of using sires of German breeds in Polish breeding in order to improve the jumping and movement predispositions of our population. As stated by Borowska (2011), the parameters of the majority of the analyzed traits evaluated during the performance test were the highest in horses of foreign breeds, especially the Dutch Warmblood breed (KWPN), characterizing itself with the highest suitability for show jumping. The studies of Lewczuk (2004) also point to a greater suitability for sport use and therefore a greater performance ability of horses of

foreign breeds or deriving from sires of imported breeds.

As stated by Jończyk (2002) the basic factors in horse selection are the utility value and correct conformation (assessed both during field and stationary tests), whose appropriately high level results in achieving breeding progress from generation to generation. According to Geringer et al. (2006) the general variability of sport horses is influenced in a significant manner by such factors as: the breed of the horse, the breed of the sire and the trainer. The author suggests the improvement of utility traits both by breeding procedures, as well as environmental factors, for example the individualization of training methods.

Similar tendencies to the ones described in the study, referring to the influence of the mares' parentage on the results achieved in stationary performance tests, are described by authors analyzing the influence of stallion parentage on the results achieved in training stations. As Kamieniak et al. (2016) states, sires of foreign breeding statistically had a significantly higher score of almost all traits evaluated during the performance test in comparison to sires of Polish breeding. The author had also proven the existence of statistically significant differences between average scores achieved by stallions of Polish half-bred breeds regarding marks awarded by the director of the training station and outside riders. Polish Warmblood stallions received higher scores than Małopolska and Wielkopolska breed stallions for a majority of traits evaluated at the training station. Małopolska breed stallions received the lowest evaluation during the test with outside riders. Also Lew-

czuk (2005) determined that the highest marks during performance tests were received by stallions deriving from sires of foreign breeds.

Pietrzak et al. (2001 and 2006), having analyzed the predispositions of young stallions for use in sport as part of the independent rider test, showed the existence of statistically significant differences between the results of Wielkopolska and Małopolska breed stallions compared to stallions of the Polish Half-Bred breed. The Polish Half-Bred horses dominated not only in the assessment of their predisposition for use in sport, but also in possessing a potential allowing to specialize in show jumping.

The high utility value of stallions of foreign breeds, confirmed by results achieved in training stations, translates to their popularity as breeding sires.

The developing of a modern system of carrying out performance tests is one of the priority tasks necessary to be implemented by Polish breeding organizations. This procedure is vital if the goal of Polish breeding is to match world standards in terms of producing horses that are able to meet the requirements currently posed by professional disciplines of equestrian sports (Kapron et al. 1996, Kapron 2001).

CONCLUSIONS

1. The analysis of the construction of pedigrees of Polish half-bred mares, undergoing stationary performance tests, has proven the existence of a numerical superiority of mares deriving from one or two parents of foreign breeds or one or two parents of the Polish Warmblood breed.

2. Mares deriving from both parents of foreign breeds, as well as from one parent of foreign breed and the second of the Polish Warmblood breed achieved significantly higher least square means of final results of stationary tests in comparison to the other mares. This fact indicates the justness of using imported breeding material in reproduction.
3. The small suitability of Polish breeds for the production of sport horses and the large diversity of their performance predispositions creates the need to improve the domestic population by way of cross-breeding with horses of foreign breeds.
4. Significantly lower mean values of final results of performance tests of Polish half-bred mares suggest the small effectiveness of the carried out breeding programs and that the improvement of saddle traits is mainly achieved by using foreign breeding material in reproduction.
5. A complete reorganization of the rules of carrying out stationary tests seems to be the basis of all future actions aimed at matching world standards in terms of producing horses for professional equestrian sports.

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- Streszczenie:** *Wpływ typu krzyżowania pokolenia rodzicielskiego na wyniki końcowe stacjonarnych prób dzielności klaczy polskich ras półkrwi.* Dokonano analizy rodowodów klaczy polskich ras półkrwi zdających stacjonarną próbę dzielności w zakładach treningowych pod kątem wyodrębnienia typów zastosowanych schematów krzyżowań pokolenia rodzicielskiego. Podjęto próbę określenia wpływu poszczególnych schematów krzyżowań na zróżnicowanie wartości wyniku końcowego próby dzielności, będącego miarą wartości użytkowej klaczy. Materiał badawczy stanowiły wyniki stacjonarnych wierzchowych prób dzielności 994 klaczy, uzyskane w zakładach treningowych (SPW) w latach 2007–2012. Największe średnie najmniejszych kwadratów wyniku końcowego próby uzyskały klacze, których rodzice byli przedstawicielami ras zagranicznych, a najmniejsze klacze pochodzące po rodzicach rasy małopolskiej. Najliczniejszą grupę spośród klaczy zdających stacjonarną próbę wierzchową tworzyły córki jednego z rodziców rasy zagranicznej i drugiego szlachetnego półkrwi. Największe zróżnicowanie zastosowanych schematów doboru par do rozrodu stwierdzono w grupie klaczy rasy polski koń szlachetny półkrwi. Zarówno klacze mające oboje rodziców rasy małopolskiej, jak i te, które miały jednego z rodziców rasy małopolskiej uszlachetnionego rasą pełnej krwi angielskiej, charakteryzowały się największą zmiennością uzyskanych wyników próby dzielności.
- Słowa kluczowe:* klacze ras półkrwi, próby dzielności, pochodzenie, wartość użytkowa
- MS received* 08.07.2016
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Safe and effective anaesthesiological protocols in domestic pig

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Abstract: *Safe and effective anaesthesiological protocols in domestic pig.* The aim of this study is to establish a neuroleptanalgesic protocol and a general anaesthetic protocol in domestic pigs. The study was approved by approved by the Local Ethical Commission of the University of Warmia and Mazury in Olsztyn (the permit 73/2015). Fifteen juvenile female crossbred gilts were used. The drugs used in intramuscularly injection were: atropine (0.035 mg/kg b.w.), ketamine (7.0 mg/kg b.w.), medetomidine (0.063 mg/kg b.w.). The main anaesthetic drug, propofol, was given intravenously for induction and maintenance of general anaesthesia. To achieve the adequate neuroleptanalgesia the animals required in intramuscular injection atropine, ketamine and medetomidine mixing in the same syringe. The average time from muscular injection to the point at which pigs remained laterally recumbent was 1.95 ± 0.72 min. The average time from muscular injection to the point at which pigs managed to stand in recovery was 75.80 ± 13.14 min. To achieve the general anaesthesia the pigs required atropine, ketamine, medetomidine and propofol. Premedication with mixture of atropine, ketamine and medetomidine was achieved rapidly after intramuscular injection. All pigs became recumbent within 1.20 ± 0.19 min without any signs of excitement. The average time from muscular injection to the point at which pigs remained laterally recumbent was 2.06 ± 0.67 min. The induction dose of propofol was 4.5 mg/kg b.w. Anaesthesia was maintained with propofol 2.0 mg/kg b.w. During the surgery no complications occurred intraoperatively concerning. Concluding the findings demonstrate that the proposed protocols permits to obtain a safe and an effective neuroleptanalgesia and general anaesthesia in swine and can be useful in biomedical investigations. A short-lasting time for recumbency after intramuscularly injection

of atropine, ketamine and medetomidine mixture injection can allow optimizing the workflow of clinical practice in a laboratory animal farm.

Key words: anaesthesia, ketamine, medetomidine, propofol, pig

INTRODUCTION

The pig is an important biomedical model and provides an important resource for further research studies on many diseases of animals and humans. In addition the pigs are still a preferred animal in surgical research for development of new surgical techniques (Kaiser et al. 2006). The porcine models are of interest, as they will allow detailed characterization in an experimental model organism whose physiology is very similar to that of human. One obvious reason why the pigs are so good biomedical models is that they are phylogenetically closer to humans than rodents.

A disproportionate amount of research efforts have focused on rodent biomedical models as opposed to porcine models, despite the advantages of using porcine models, that more closely represent the natural underlying disease in humans. The network connectivity of the central nervous system is different in mammals than in rodents. Sometimes it may not be possible to identify com-

pounds that have identical or even similar affinity for the human versus rodent variants, e.g. calcitonin gene-related peptide (CGRP) receptor antagonists (Salvatore et al. 2008). Analyses of the pig genome extend the potential of using the pig as a biomedical model (Groenen et al. 2012).

The humane and ethical use of animal models plays a critical role both in understanding the physiological and pathophysiological processes in the human body as well as in the development of therapeutic treatments. To achieve these goals it is very important to minimize prevalent pain conditions of experimental animals. That is why animal anaesthesia and analgesia are crucial components of guides of using animals in experiments and selection of the most appropriate anaesthesiological protocol is very important. Therefore, the aim of this study is to establish a neuroleptanalgesic protocol and a general anaesthetic protocol which have proven to be safe and easy to perform in domestic pigs.

MATERIAL AND METHODS

The study was approved by approved by the Local Ethical Commission of the University of Warmia and Mazury in Olsztyn (the permit 73/2015). All animals received humane care in compliance with the Guide for the Care and Use of Laboratory Animals prepared by the National Academy of Sciences and published by the National Institutes of Health (NIH publication 86–23, revised 1985, Washington, DC, US Government Printing Office). All animal procedures were carried out under licence in accordance with the European Communities (Amendment of Cruelty to Animals Act

1876), Regulations 2002 and Directive 2010/63/EU on the protection of animals used for scientific purposes.

Fifteen juvenile female crossbred gilts (Pietrain × Duroc) were used. Pigs were maintained in individual pens under standard laboratory conditions for 2 weeks prior to the experiment in order to allow adaptation to the new environment. All animals were allowed *ad libitum* access to food and water. The experiments took place when pigs were 8–9 weeks of age with body weight 16–18 kg.

All animals, which were judged to be healthy on the basis of physical examination, normal appetite, expected weight gain were used in two experiments. All procedures and the drugs have been managed and administered by a veterinary doctor (DVM, PhD). The drugs used in the study were: atropine (1 mg/ml, Atropinum Sulfuricum Polfa Warszawa S.A., Poland), ketamine (100 mg/ml, Bioketan, Vetoquinol Biowet Sp. z o.o., Poland & Vetoquinol S.A., France), medetomidine (0.85 mg/ml, Cepetor, CP-Pharma Handelsges mbH, Germany) and propofol (10 mg/ml NORBROOK, Northern Ireland, IRL.PN). All drugs were stored at room temperature up to 25°C. All intramuscular and intravenous injections were performed by the same person (DVM, PhD). The heart rate, body temperature and the number of breaths were monitoring during the all procedures. All efforts were made to minimize the number of animals used and their suffering.

Experiment 1: neuroleptanalgesia in domestic pigs

Five clinically healthy juvenile female crossbred gilts were used. Food, but not water was withheld for 12 h before the start

of the experiment. Atropine (0.035 mg/kg b.w.), ketamine (7.0 mg/kg b.w.), medetomidine (0.063 mg/kg b.w.) were mixed in the same syringe and injected intramuscularly into the cervical muscles caudal to the ear base at the border between the dorsal and middle third of the animal's neck. After injection, the pigs were left undisturbed but under surveillance, so that the times at which they became recumbent and when they remained so could be recorded.

When animals were in lateral recumbency, an 22GA (0.8 × 25 mm) angiocatheter was placed in the marginal auricular vein through which 10 ml of 0.9% NaCl (sodium chloride 0.9% WET Baxter, 9 g/1000 ml, Baxter Sp. z o.o., Poland) were injected. After intramuscular (i.m.) and intravenous (i.v.) injections, the pigs were left undisturbed but under surveillance to measure the time from i.m. injection to the point at which pigs managed to stand in recovery.

Follow up after the recovery the pigs were carried out with daily evaluations of behavior and water and food consumption for 8 days. The animals were observed for signs of pain, and some complications after i.m. and i.v. injections.

Experiment 2: medetomidine, ketamine and propofol general anaesthesia in domestic pigs

Ten clinically healthy juvenile female crossbred gilts were used. The pigs were not fed for 24 h before surgery, but had free access to the water. The pigs were premedicated with intramuscular atropine, ketamine and medetomidine injection. Atropine (0.035 mg/kg b.w.),

ketamine (7.0 mg/kg b.w.), medetomidine (0.063 mg/kg b.w.) were mixed in the same syringe and injected intramuscularly into the cervical muscles caudal to the ear base at the border between the dorsal and middle third of the animal's neck. After injection, the pigs were left undisturbed but under surveillance, so that the times at which they became recumbent and when they remained so could be recorded.

After the recumbency period, the marginal ear vein was canalized with a 22 standard wire gauge cannula and an intravenous anaesthetic induction was performed with 4.5 mg/kg b.w. propofol keeping spontaneous ventilation. The level of general anaesthesia was assessed by the lid reflex and by the response to nociceptive stimuli (clamping of the interdigital fold with forceps). After the induction of general anaesthesia the endotracheal intubation by 6.0 mm diameter tube was carried out and then animals were supine for laparotomy surgery.

The surgical procedures have been performed by a veterinary doctor (DVM, PhD). The depth of anaesthesia was monitored by testing the corneal reflex and the increase of heart and respiratory rate (Swindle 2007, Calzetta et al. 2014). The general anaesthesia was maintained with propofol (2.0 mg/kg b.w.) for up to an average of 10 to 15 min and after that time 2.0 mg/kg b.w. of propofol was used again. The main anaesthetic drug, propofol, was given intravenously in a fractionated infusion. During the transection surgery procedure, a conventional midline incision of the abdominal wall was made. The cecum and ileum were identified and the ileocecal valve (ICV) were isolated from the abdominal

cavity. The ileocecal valve was gently exposed to administer non-toxic aqueous solution of the fluorescence retrograde neuronal tracer Fast Blue (FB; EMS-Chemie GmbH, Groß-Umstadt, Germany). A total volume of 50 μ l 5% aqueous dye FB solution was injected into the wall of the ileocecal valve in multiple injections using a Hamilton syringe with a 26-gauge needle. A great attention was paid to avoiding any contamination of the surrounding tissues with FB due to the hydrostatic leakage from the injection canal. To avoid leakage, the needle was left in each place of FB injection for about tens of seconds. The peritoneum with the transverse abdominal muscles, the internal and external abdominal oblique muscles and the cutaneous muscle with subcutaneous fascia were closed in a simple continuous pattern. The skin was closed in a subcuticular pattern.

After the surgery (lasting approximately 51.8 \pm 4.52 min) animals received an intravenous drip infusion of 0.9% NaCl solution at 15 ml/kg b.w. and were transferred to the recovery room. The pigs were covered with emergency blanket. During recovery all pigs were monitored for signs of possible cardio-respiratory failure. The time from the muscular injection of atropine, ketamine and medetomidine to the point at which pigs managed to stand in recovery were recorded. Follow up after the recovery was carried out with daily evaluations of behavior and water and food consumption for 3 weeks. During this period the animals were observed for signs of pain, and surgical complications including infection or dehiscence of the surgical site.

The times (minutes) from intramuscular injection to the times at which pigs became recumbent and remained recumbent and managed to stand in recovery were calculated for both experiments. Duration of the surgery was recorded from cutting the skin to the last stitch skin for experiment 2. These data were expressed as means standard deviation (*SD*).

RESULTS AND DISCUSSION

All pigs used in both experiments survived the neuroleptanalgesic, general anaesthetic and surgical procedures without complications. The heart rate, body temperature and the number of breaths all remained in tolerable ranges during the all procedures. Neither vomiting nor nausea was detected. Any events of apnoea was not detected during both experiments. All animals maintained sufficient urinary output.

To achieve the adequate neuroleptanalgesia the animals required atropine (0.035 mg/kg b.w.), ketamine (7.0 mg/kg b.w.), medetomidine (0.063 mg/kg b.w.) in intramuscular injection. The neuroleptanalgesia was achieved rapidly after intramuscular injection of the drugs, and all pigs became recumbent without any signs of excitement. The average time from muscular injection to the point at which pigs became recumbent was 1.27 \pm 0.21 min. The average time from muscular injection to the point at which pigs remained laterally recumbent was 1.95 \pm 0.72 min. The neuroleptanalgesia permitted an adequate placement of the catheter in the ear veins of all gilts and intravenous injection of 10 ml of 0.9%

NaCl. The average time from muscular injection to the point at which pigs managed to stand in recovery was 75.80 ± 13.14 min. They were not observed any irregularities during 8 days evaluations. The neuroleptanalgesic protocol is good for reduce fear and induce restraint necessary for some small diagnostic procedures and physical examination.

The practical guidelines for general anaesthetic protocol in a 10 kg swine is summarized in Table to simplify the comprehension and the feasibility. To achieve adequate premedication animals required atropine (0.035 mg/kg b.w.), ketamine (7.0 mg/kg b.w.), medetomidine (0.063 mg/ml b.w.) in intramuscular injection. Premedication was achieved rapidly after intramuscular injection of the drugs. All pigs became recumbent within 1.20 ± 0.19 min without any signs of excitement. The average time from muscular injection to the point at which pigs remained laterally recumbent was 2.06 ± 0.67 min. The preanaesthetic sedation permitted an adequate placement of the catheter in the ear veins of all piglets. After an induction dose of propofol

(4.5 mg/kg b.w.), the endotracheal intubation was feasible. The intubation difficulty wasn't observed (spraying of lidocaine on the larynx wasn't necessary). All piglets of trial protocol had a soft and rapid induction of anaesthesia. The maintenance dose of propofol (2.0 mg/kg b.w.) resulted in adequate analgesia and anaesthesia that allowed surgical manipulation in all animals. The average time from muscular injection of atropine, ketamine and medetomidine to the point at which pigs managed to stand in recovery was 126.20 ± 24.75 min. No complications occurred intraoperatively concerning the general anaesthetic protocol. All animals survived the operation. There were no complications related to anaesthesia. Medetomidine, ketamine and propofol anaesthetic protocol is good for surgical procedures performed in the abdominal cavity.

The present study demonstrated that the proposed protocols for neuroleptanalgesia and general anaesthesia were safe and effective in domestic pigs thanks to combination of the appropriate dose of drugs. Propofol is a medication for intra-

TABLE. Practical guidelines for general anaesthetic protocol in a 10 kg swine

Steps of general anaesthetic protocol	Drug (active substance)	Dose of the drug per 10 kg b.w. (ml)
General anaesthetic premedication – mix in the same syringe and inject i.m.	Atropinum Sulfuricum (1 mg atropine/ml)	0.35
	Bioketan (100 mg ketamine/ml)	0.7
	Cepetor (0.85 mg medetomidine/ml)	0.75
Induction of general anaesthesia – inject i.v.	Scanofol (10 mg propofol/ml)	4.5
Maintenance of general anaesthesia – inject i.v.	Scanofol (10 mg propofol/ml)	2.0

venous use in swine at 4.0–13.0 mg/kg b.w., with short action beginning and lasting, absence of accumulative effects, quick and calm recovery, so that makes it ideal to induce and conduct general anaesthesia (Muir et al. 2012). Propofol is as a safe anaesthetic even for long anaesthesia for use in porcine experimental models (Kaiser et al. 2003, Gaviria et al. 2007). Ketamine is the most commonly injectable anaesthetic used in a variety of species. However, ketamine used as the sole anaesthetic is not recommended. In most cases, ketamine is used in combination with other injectable agents such as alpha-2 agonists or benzodiazepines to reduce or eliminate many of the less desirable side effects if used alone. Alpha-2 agonists are used for their sedative and analgesic properties in a variety of species. Used as the sole agent, they do not produce an adequate level of anaesthesia for even minor surgical procedures and they have very little therapeutic effect in swine. The degree of muscle relaxation produced by medetomidine seemed to be dose dependent and was stronger than that produced by xylazine. No analgesic effect was produced by xylazine, however moderate analgesia was obtained by medetomidine in swine (Sakaguchi et al. 1992). Xylazine is a potent sedative and central nervous system depressant. Medetomidine is more specific central alpha-2 agonists, resulting in longer, more profound sedation and analgesia than xylazine and fewer adverse cardiovascular side effects. In pigs, the effects of medetomidine are much more potent than those of xylazine (Sakaguchi et al. 1992). Medetomidine is a more selective and full agonist for the central alpha-2-adrenergic receptor than xylazine and

has significant dose dependent sedative effects. In combination with ketamine, alpha-2-agonists become much more useful and effective as anaesthetics for surgical procedures. Alpha-2 agonists can be combined with ketamine to produce adequate surgical anaesthesia in many species. Sakaguchi et al. (1996) showed that intramuscular administration of medetomidine, combined with butorphanol and ketamine, provides better anaesthesia than xylazine with butorphanol and ketamine combinations in pigs.

The results of this study suggest that dose combination of atropine (0.035 mg/kg b.w.), ketamine (7.0 mg/kg b.w.), medetomidine (0.063 mg/kg b.w.) administered as an intramuscular injection, has been shown to be one of most effective means of immobilizing pigs. Compared to other researches (Gaviria et al. 2007, Lee et al. 2010) there were the most rapid induction times and lateral recumbency times in both experiments. A short-lasting time for lateral recumbency after i.m. ketamine and medetomidine mixture injection (1.95 ±0.72 min in experiment 1 and 2.06 ±0.67 min in experiment 2) can allow optimizing the workflow of clinical practice in a laboratory animal farm. Gaviria et al. (2007) recommended to combine propofol with fentanyl after premedication with combination of ketamine with xylazine to achieve analgesic effect. Ketamine mixed with medetomidine provides a sedative and analgesic effect much better than combination of ketamine mixed with xylazine. Therefore, it was not necessary to use opioids during propofol anaesthetic-surgical procedures after premedication with medetomidine and ketamine.

It is very important to recognize the response of animals to pain after the surgical procedures. The somatic reflexes, cornealpalpebral reflexes are not a good indicator for evaluating the depth of anaesthesia in swine. Therefore the depth of anaesthesia of this study was monitored by not only testing the corneal reflex but first of all by the increase of heart and respiratory rate. The best way to identify signs of pain after the surgical procedures is to closely observe the appearance and behavior of the animal prior to surgery, and note any changes after surgery. No changed posture or a changed profile of the body of pigs were observed during both experiments. Animals in pain may show altered a behavior (e.g. animals may remain immobile or may exhibit restlessness), may stop eating and drinking, or markedly reduce their intake, resulting in rapid weight loss. None of the above-described behavior was observed during both experiments. Behavior of the animal during postoperative period, and before surgery was not changed. Any clinical or behavioral signs of pain were not observed.

The time that it takes until an animal is fully recovered from anaesthesia will vary depending on the anaesthetic agent, the type and duration of the surgery, and the physiological imbalances induced by the surgery or anaesthesia. Replacement fluid therapy is not usually required for many surgeries, because they do not involve longer operative times or result in significant blood loss. However, fluid therapy can be beneficial and aids in the postoperative recovery of the animal, therefore during experiment 2, after the surgery animals received an intravenous drip infusion 250 ml of 0.9% NaCl.

Reed et al. (2015) reported that the age and mass of commercial pigs do not influence the response to using azaperone, ketamine, medetomidine, midazolam in male pigs aged 105–166 days. So protocols of this study can be useful not only for animals weighting 16–18 kg.

CONCLUSIONS

Concluding the findings demonstrate that the proposed protocols permits to obtain a safe and an effective neuroleptanalgesia and general anaesthesia in swine and can be useful in biomedical investigations. This study demonstrated that the use of atropine, ketamine, medetomidine in intramuscular injection and propofol in intravenous infusion produces the rapid induction of anaesthetic events, good muscular relaxation and adequate analgesia. A short-lasting time for recumbency after intramuscularly injection of atropine, ketamine and medetomidine mixture injection can allow optimizing the workflow of clinical practice in a laboratory animal farm.

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- Streszczenie:** *Bezpieczne i skuteczne protokoły anestezjologiczne znieczulania świni domowej.* Celem tego badania jest ustalenie protokołu neuroleptoanalgetycznego oraz protokołu znieczulenia ogólnego świni domowej. Badania zostały zatwierdzone przez Lokalną Komisję Etyczną ds. Doświadczeń na Zwierzętach w Olsztynie (zezwolenie 73/2015). Doświadczenie przeprowadzono na 15 loszkach. W iniekcji domięśniowej zastosowano: atropinę (0,035 mg/kg m.c.), ketaminę (7,0 mg/kg m.c.) i medetomidynę (0,063 mg/kg m.c.). Podstawowy środek znieczulający, propofol, podawano dożylnie w celu indukcji i podtrzymania znieczulenia ogólnego. Aby zapewnić odpowiednią neuroleptanalgesję, zwierzętom podano domięśniowo w jednej strzykawce mieszaninę atropiny, ketaminy i medetomidyny. Średni czas od iniekcji domięśniowej do momentu, w którym świni pozostały w pozycji bocznej leżącej, wyniósł $1,95 \pm 0,72$ min. Świni odzyskały świadomość średnio po $75,80 \pm 13,14$ min od podania iniekcji domięśniowej. W celu osiągnięcia znieczulenia ogólnego użyto atropiny, ketaminy, medetomidyny i propofolu. Premedykację przy użyciu mieszaniny atropiny, ketaminy i medetomidyny osiągnięto bardzo szybko po iniekcji domięśniowej. Loszki znalazły się w pozycji

leżącej w ciągu $1,20 \pm 0,19$ min, bez jakichkolwiek oznak niepokoju. Średni czas od iniekcji domięśniowej do momentu, w którym świni pozostały w pozycji bocznej leżącej wyniósł $2,06 \pm 0,67$ min. Dawka indukcyjna propofolu wyniosła $4,5$ mg/kg m.c., a podtrzymująca $2,0$ mg/kg m.c. Podczas zabiegu nie zaobserwowano żadnych powikłań śródoperacyjnych. Powyższe badania wskazują, że proponowane protokoły są bezpieczne i skuteczne oraz mogą być użyteczne w badaniach biomedycznych. Krótki czas, w jakim świni znalazły się w pozycji leżącej po podaniu domięśniowym mieszaniny atropiny, ketaminy i medetomidyny, może pozwolić na zoptymalizowanie przebiegu prac w zwierzętarni.

Słowa kluczowe: znieczulenie, ketamina, medetomidyna, propofol, świnia

MS received 31.08.2016

MS accepted 13.10.2016

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Pathomorphological changes in the small intestine and liver of the European beaver (*Castor fiber* L. 1758): a case study

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Abstract: *Pathomorphological changes in the small intestine and liver of the European beaver (Castor fiber L. 1758): a case study.* The aim of the study is to examine and describe the morphology and patomorphology of small intestine and liver of European beaver (*Castor fiber*). In natural environment beavers are in constant contact with various both internal and external parasites. Histological analysis revealed the pathological changes within the digestive track and liver indicating long-term inflammation. It was hypothesized that the observed inflammation was caused by the parasites not related to beavers so far.

Key words: beaver, small intestine, liver, pathology, parasites

INTRODUCTION

European beaver is the largest rodent occurring in the area of Eurasia (Wilson 1971, Żurowski and Kasperczyk 1986, Halley et al. 2012). It is adapted to a semi aquatic lifestyle. This type of lifestyle is currently possible due to specific body adaptations that developed naturally in successive generations living in

such environment. In the course of evolution, interdigital webbing developed between the chest limb fingers while the animal tail was specifically widened. These adaptations allowed beaver good motility in water. Moreover, other organs are also well accommodated. Thanks to one of those adaptations beaver is able to dive in water for 15 min without a break. This allows beavers to avoid natural enemies as well as feed underwater (Czech 2010). Beaver is relatively unique animal that can adapt the environment to its particular needs. Such action requires specific type of logic and forecasting thinking and in the case of beaver it is possible due to relatively large brain. Rodents are characterized by the greatest ratio of brain to body mass. By cutting down the trees, which diameter can reach up to 1 m, beaver creates dams in the small rivers and streams (Hägglund and Sjöberg 1999). Backwaters that are formed this way become the territory where beavers create lodges, the areas

of breeding and reproduction (Żurowski 1992). They feed on almost all species of coastal and aquatic plants that grow in its space of living (Lahti and Helminen 1974, Vaughan et al. 2000, Czech 2010). Together with food, beavers absorb parasites, mainly flukes (Máca et al. 2015) and nematodes (Drózdź et al. 2000). Beaver intestines can colonize protozoa like *Cryptosporidium* and *Giardia*, which spread via contaminated aquatic environment (Paziewska et al. 2007). Based on the samples taken from three individuals, pathological lesions in the small intestine and liver typical for the European beaver was describe in the paper.

MATERIAL AND METHODS

Three beaver individuals were retrieved in the Population Reducing Program of the National Fishnig Farm in Kobryn, Belarus with the official permission of the Belarusian Minister of Environment. For histological examination, tissue was harvested from the middle of the small intestine and liver. Obtained tissues were fixed with 4% buffered formalin and then washed in water for 12 h. Afterwards the tissue was dehydrated in portions of ethanol with increasing concentrations of 70, 96 and 99.8%, respectively. After dehydration tissue fragments were triplicate rinsed in xylene and paraffin for 2 h. Prepared tissues were embedded in paraffin using Microm EC 350-1 and 350-2 EC cooling plate. Paraffin blocks were sliced using a microtome Microm HM 355S into the sections with the thickness of 3.5 μm , which were dried for 24 h at 37°C. Then the sections were deparaffinized in xylene and rehydrated

in ethanol in concentrations of 99.8, 96 and 70%. Then tissues were immersed in double-distilled water. The staining was performed with hematoxylin and eosin. Following staining, samples were again dehydrated with ethanol of increasing concentrations. Dehydrated and stained slides were treated with xylene and covered by coverslip with synthetic resin DPX. Slides were dried for 78 h at 37°C. Microscopic evaluation was conducted by light microscope Leica DM 750, equipped with a color camera Leica ICC 50 HD. Five separated areas from the intestine and liver samples taken from three animals were studied. Tissues examination were performed using Leica LAS EZ software.

RESULTS AND DISCUSSION

Intestinal villi and enterocytes were partially autolyzed post-mortally due to literature methodology (Madej et al. 2007). Leukocytes infiltrations, consisting of lymphocytes and eosinophils was observed within studied villi (Fig. 1).

The slides of the small intestine were of typical characteristic structure, however intestinal villi were partially distorted and significantly thickened. Paneth cells were clearly visible and normally located in the bottom of the mucous crypts. The cells contained the characteristic eosinophilic granules (Fig. 2). The lymph nodules were widespread in the intestinal villi in normal fashion. They represent large groups of lymphoblasts, clearly distinguishable in the wall of intestine. Significant number of macrophages capable of phagocytosis was noticed as well.

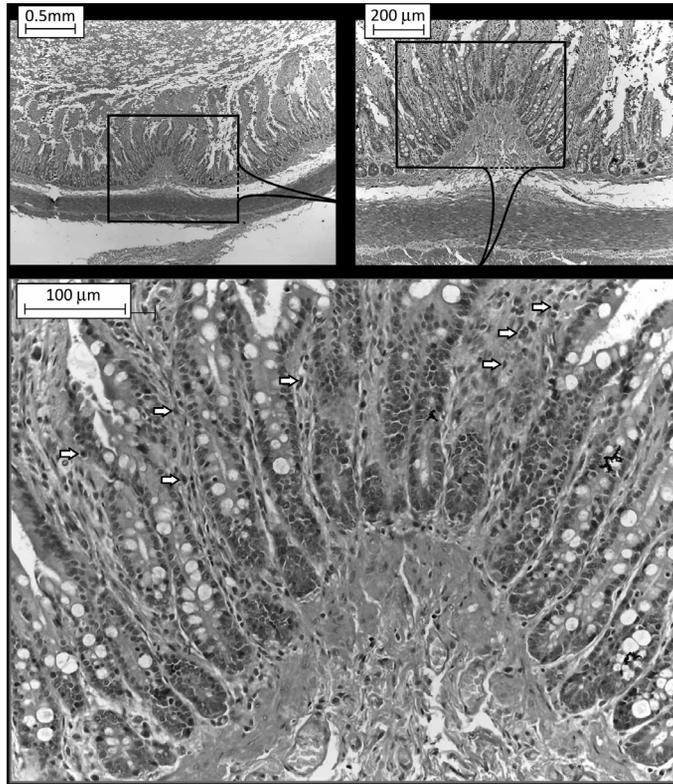


FIGURE 1. Intestine villi with eosinophils indicated by arrows

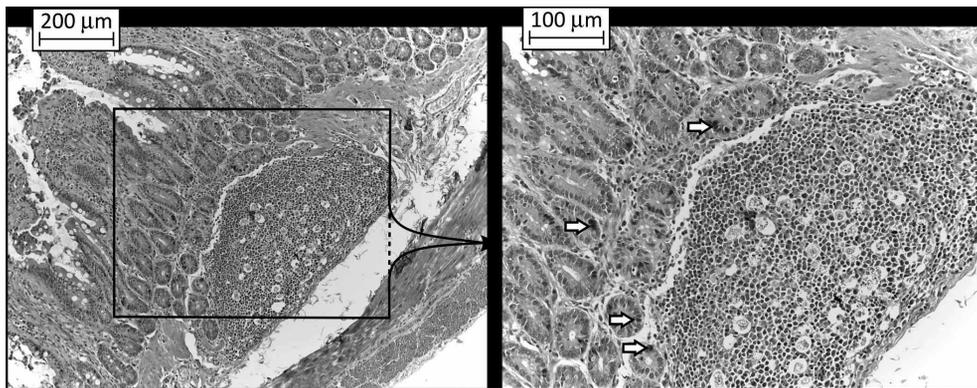


FIGURE 2. Intestine crypts with visible Paneth cells (arrows), lymph nodules of the small intestine

Slides of the liver tissue, allow for an accurate observations of its structure. Beaver liver has a macroscopic structure

characteristic rodents livers. Liver lobes are not clearly separated due to small amount of the connective tissue between

them therefore borders are not clearly visible (Kuryszko and Zarzycki 2000) – Figure 3. Olive color tissues occurred between the hepatocytes. It represented the bile, which was stagnated in the liver bile tubules and ducts. It may be referred to the necrosis of the hepatocytes, noticed in the analyzed slides. The necrosis was presented by the shrinking and destructive changes within cell nuclei. Some of cell nuclei undergo contraction that results in cell destruction and death.

connective tissue, resulted from chronic inflammation (Madej and Rotkiewicz 2007, 2011). It is also confirmed by the presence of the inflammatory infiltrates of the lymphocytes and eosinophils. The presence of the eosinophilic suggests the presence of the parasites in the analyzed organism. It should be noted that Maca et al. (2015) found the flukes of the *Stichorchis subtriquetrus* in the gastrointestinal tract of the beavers body examined in their study. It was hypothesize that

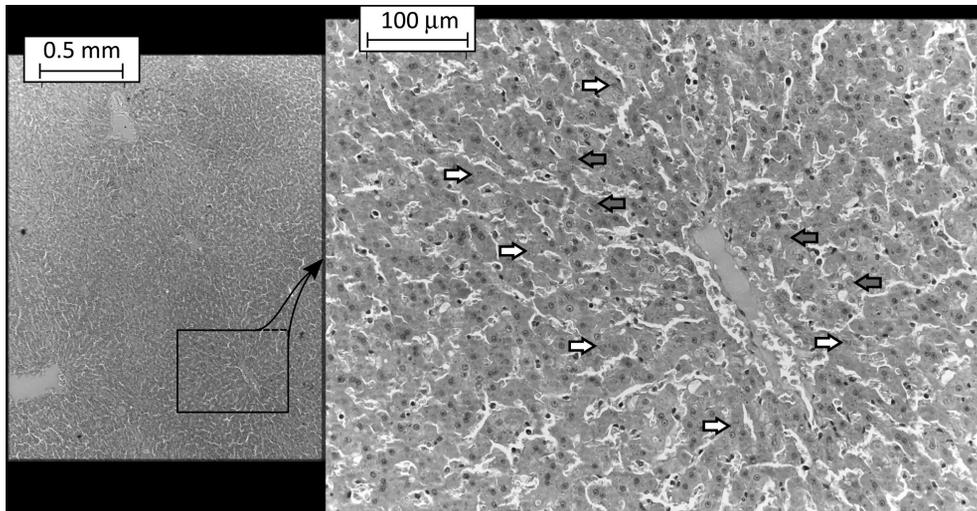


FIGURE 3. Liver with visible bile droplets (light arrows) and dark cell nuclei (dark arrows)

The degradation of intestinal tissue was most probably due to sampling long time after animal death. The tissues were improperly preserved and the enzymes partially digested the structures of tissues. Microscopic analysis of interstitial tissue indicated widespread and long-term inflammation. The presence of the chronic inflammation is also confirmed by the thickened villi. The increased thickness is associated with extensive growth of

mentioned parasite is the main factor of the inflammatory changes. Demiaszkiewicz et al. (2014) showed that *S. subtriquetrus* is a common parasite in beaver and the flukes usually locate in the further part of the digestive tract, inhabiting mainly the cecum that way. The small intestine is commonly inhabited by juvenile forms of the parasite. The inflammatory changes caused by the action of *S. subtriquetrus* were also observed in the

cecum and therefore the changes were potentially caused by the presence of juvenile forms of the flukes (Demiaszkiewicz et al. 2014). The study of Demiaszkiewicz et al. (2014) shows that the parasites such a *Psiloterma castoris* or *Trichostrongylus capricola* may also appear within beaver small intestine.

Slack of bile found in the liver can be associated with the blockage of bile outflow caused by parasites or gallstones (Madej and Rotkiewicz 2007). Cholestasis observed was most probably related to the hepatocytes necrosis, however, unequivocal identification of its robust reason was difficult. The liver changes occurred most likely during lifespan but after the animal death. It was hypothesized that the liver changes occurred due to the action of toxic products of parasites metabolism. The infection of the rodents may also be caused by the *Babesia* parasites. Demiaszkiewicz et al. (2014) did not report presence of Piroplasmid or any other parasites in the beaver blood samples. Kadulski (1998) reported the presence of ticks: *Ixodes apronophorus* and *Ixodes hexagonus*, in the beaver skin. *Ixodes hexagonus* is especially interesting as it may transfer other parasites that cause babesiosis, like *Babesia microti* (Bristol University, tick ID). Babesiosis is considered to be the type parasitosis which does not occur among the beavers.

Beaver, which is the subject of many studies, remains interesting research object as its physiological and pathological nature is unknown. Its biology certainly still hides many secrets and unraveling them could be a new discovery, also in the field of parasitology.

CONCLUSIONS

Beavers as the wild animals remain in the constant contact with different endo and ectoparasites. Microscopic observations of the small intestine revealed several pathological changes such an extensive connective tissue growth and the presence of lymphocytes and eosinophils, suggesting the state of long-term inflammation. It was assumed that the observed inflammation was caused by *Stichorchis subtriquetrus*, found in the gastrointestinal tract. Moreover cholestasis was observed in the liver samples. The genus *Ixodes* ticks found on the beaver skin, suggested the infection of parasites of the genus *Babesia*. Further studies did not find the parasites in the examined beaver's blood. Currently study results although of basic scientific knowledge can be soon applied for diagnostic of living animals health.

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Streszczenie: *Zmiany patomorfologiczne w jelicie cienkim i wątrobie bobra europejskiego (Castor fiber L.1758): studium przypadku.* Celem pracy jest ocena patomorfologiczna jelita cienkiego i wątroby bobra europejskiego (*Castor fiber*). W naturalnym środowisku bobry mają stały kontakt z pasożytami wewnętrznymi i zewnętrznymi. Ocena preparatów histologicznych wykazała zmiany patologiczne w obrębie układu pokarmowego i wątroby, wskazując na przewlekły stan zapalny. Założono hipotezę, że przyczyną obserwowanych patologicznych zmian w tkankach jest zapalenie wywołane pasożytami, jakich wcześniej nie stwierdzano u bobrów.

Słowa kluczowe: bóbr, jelito cienkie, wątroba, patomorfologia, pasożyty

MS received 23.06.2016

MS accepted 15.11.2016

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Effect of the brown coat-coding gene (*TYRP-1*) on wool and skin color of Żelaźnińska and Wrzosówka sheep

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Abstract: *Effect of the brown coat-coding gene (TYRP-1) on wool and skin color of Żelaźnińska and Wrzosówka sheep.* The study was conducted on randomly chosen ewes (Żelaźnińska sheep – 93; Wrzosówka sheep – 133) during the shearing. Color of wool and skin was examined using device Chroma Mater CR-400 (Konica Minolta Sensing Inc., 2011). Taking into account the results of genotyping in order to the brown coat-coding gene (*TYRP-1*), 66 Żelaźnińska ewes and 74 Wrzosówka ewes were chosen to next stage of study where effect of the brown coat-coding gene (*TYRP-1*) on wool and skin color was assessed within breed and between breeds. Based on the results significant and highly significant differences in all color measurements of wool and skin between tested breeds were found, which should be connected with different wool color in each breed. However, there is striking difference in color of wool and skin regarding to a* color parameter, which were exactly opposite. It probably means that proportion of red or green color in skin is different than in wool. Differences in color values of wool depending on *TYRP-1* gene genotypes were observed only for Wrzosówka sheep. The measurement of L* color parameter made on wool was highly significantly higher in the case of CC and CT genotypes in comparison to TT genotype. However, in the measurement of a* color parameter, the situation is opposite and homozygote TT had higher values compared to the others genotypes. No differences between wool and skin color of Żelaźnińska sheep and no differences in skin color of Wrzosówka sheep were found. The results of studies on wool color, depending on genotype of the *TYRP-1* gene in Wrzosówka sheep, make possibilities to conduct breeding work in order to develop standards for coat color for this breed.

Key words: sheep, wool, skin, color of wool and skin

INTRODUCTION

Management of sheep wool in the textile industry depend largely on its color. Colors from white to pale cream are preferred and such assumptions were maintained in most of Polish sheep breeds (www.stat.gov.pl, PZO 2015). In the breeding work a lot of attention is paid for wool color, but assessing it is based on subjective experience of selector. The first attempt to objectify the assessment of wool color was made by Kulesza et al. (2014) using a colorimeter. Studies provided information about possibilities for evaluation of color measurement and using objective methods for that. The color of wool is determined by various factors, among which the genetic factor plays a leading role. Especially by gene encoding the brown coat (*TYRP-1*), which has been known widely in analyzing sheep coat color, mainly in Asia (Deng et al. 2006) and in Europe among the breeds considered as ancestors of modern sheep breeds (Gratten et al. 2007). In Poland frequency of alleles and genotypes of *TYRP-1* gene was examined by Niżnikowski et al. (2013, 2015a, b) and

pointing to the significant differentiation between primitive and cultural sheep breeds (Niżnikowski et al. 2013), and relative low differences among Polish wool-meat sheep breeds (Niżnikowski et al. 2015a, b). Taking into account the results of Kulesza et al. (2014) and Niżnikowski et al. (2015a, b), it was hypothesized that there is a relationship between frequency of alleles and genotypes of brown coat-coding gene (*TYRP-1*) and color of wool and skin measured objectively. In order to better illustrate color differences two breeds were examined: white colored – Żelaźnieńska sheep, and colorful (mostly grey) Wrzosówka sheep.

MATERIAL AND METHODS

The study was conducted on mature ewes (Żelaźnieńska sheep – 93; Wrzosówka sheep – 133) maintained in research farm in Żelazna – WULS-SGGW in 2015. Animals were randomly selected during the shearing. Color of wool and skin was examined using device Chroma Mater CR-400 (Konica Minolta Ltd.). The color was measured using the system CIE $L^*a^*b^*$. Parameter L^* expresses clarity and varies from 0 (black) to 100 (white). Parameter a^* varies from –60 to +60: $-a^*$ goes from green, $+a^*$ goes towards red. Parameter b^* varies from –60 to +60: $-b^*$ goes towards blue, $+b^*$ towards yellow. Device was calibrated on white calibration plate before measurements. Color of wool and skin measurements were done on the right side of sheep at last rib.

The results of the colorimetric measurements was used to compare breeds

between wool and skin color. Taking into account the results of the brown coat-coding gene *TYRP-1* described by Niżnikowski et al. (2013, 2015a, b) 66 Żelaźnieńska sheep ewes and 74 Wrzosówka sheep ewes were selected for further analysis, in which the impact of genotype *TYRP-1* gene on wool and skin color within and between breeds was determined. Selected ewes have been already genotyped in order to *TYRP-1* gene. The results were statistically analyzed using the IBM SPSS Statistics 23 software. Regarding to wool and skin color measurements made on all sheep ANOVA system was used, while in the case of animals which had specified *TYRP-1* genotype two-factor analysis of variance was used, reflecting the *TYRP-1* gene genotype and sheep breed and the two-way interaction between these sources of variation. Differences tested features value were evaluated based on the comparison of subclasses interactive. The results of the statistical calculations are presented in tables.

RESULTS AND DISCUSSION

The results of wool and skin color between breed are presented in Table 1. For all color measurements breed had highly significant or significant impact on color parameters. Lightness value L^* for wool as well as skin were higher in Żelaźnieńska sheep than in Wrzosówka sheep. Values of a^* color parameter were highly significantly higher for wool of Wrzosówka sheep and significantly higher for skin of Żelaźnieńska sheep. Measurements of b^* color parameter showed highly significant higher values for wool

TABLE 1. Wool and skin color values according to breed

Specification		Żelaźnieńska sheep	Wrzosówka sheep	Statistical significance
color parameters	n	93	133	
wool				
L*	LSM	75.64	46.09	XX
	SE	3.20	8.83	
a*	LSM	0.67	2.33	XX
	SE	1.48	1.40	
b*	LSM	16.74	3.10	XX
	SE	5.84	2.75	
skin				
L*	LSM	70.03	54.26	XX
	SE	4.29	9.22	
a*	LSM	4.53	3.98	X
	SE	2.36	1.52	
b*	LSM	6.18	3.17	XX
	SE	3.23	1.82	

Statistical significance: XX – $P \leq 0.01$; X – $P \leq 0.05$.

and skin of Żelaźnieńska sheep than in Wrzosówka sheep. The values of these parameters in relation to color of wool in Żelaźnieńska sheep coincide with work published by Kulesza et al. (2014). Differences in color between Wrzosówka and Żelaźnieńska sheeps does not raise doubts due to the fact that both breeds differ significantly in terms of coat color. However, there is striking difference in color of wool and skin regarding to a* color parameter, which were exactly opposite. This means that proportion of red or green color in the skin is different than in the wool. Colors values of wool and skin depending on the interaction of *TYRP-1* genotype and breed are summarized in Table 2. The genotypes distribution of brown coat-coding gene *TYRP-1* within breed was characteristic for foreign sheep breeds (Deng et al. 2006, Gratten et al. 2007) and was also proven

in national research (Niżnikowski et al. 2013, 2015a, b). The effect of interaction was highly significant on all color parameters of the wool and on L* and b* color parameters of the skin. After analysis of color measurements on wool and skin of Żelaźnieńska sheep, there was no statistically significant differences between genotypes *TYRP-1*. The situation is different for Wrzosówka sheep. The measurement of L* color parameter made on wool was highly significantly higher in the case of CC and CT genotypes in comparison to TT genotype. However, in the measurement of a* color parameter, a situation is opposite and homozygote TT had higher values compared to the others genotypes. What is interesting, in the case of skin color of Wrzosówka sheep such differences were not found. In general summary, differences in color measurement values of wool were observed

TABLE 2. Wool and skin color values according to genotype

Specification		Żelaźnińska sheep			Wrzosówka sheep		
		CC (A)	CT (B)	TT (C)	CC (D)	CT (E)	TT (F)
Color parameters	<i>n</i>	41	22	3	40	26	9
		wool					
L*	<i>LSM</i>	75.56 ^{DEF}	74.87 ^{DEF}	72.80 ^{DEF}	47.25 ^{ABCF}	48.27 ^{ABCF}	38.10 ^{ABCDE}
	<i>SE</i>	0.98	1.33	3.61	0.99	1.23	2.09
a*	<i>LSM</i>	0.79 ^{DEF}	0.78 ^{DEF}	2.36	2.17 ^{ABf}	1.92 ^{AbF}	3.58 ^{ABdE}
	<i>SE</i>	0.21	0.28	0.77	0.21	0.26	0.45
b*	<i>LSM</i>	17.55 ^{DEF}	16.24 ^{DEF}	20.55 ^{DEF}	3.06 ^{ABC}	3.33 ^{ABC}	1.35 ^{ABC}
	<i>SE</i>	0.69	0.94	2.53	0.69	0.86	1.46
×		skin					
L*	<i>LSM</i>	69.58 ^{DEF}	69.22 ^{DEF}	71.01 ^{def}	55.57 ^{ABc}	51.92 ^{ABC}	54.10 ^{ABc}
	<i>SE</i>	1.26	1.71	4.64	1.27	1.58	2.68
a*	<i>LSM</i>	4.91	4.88	3.96	3.65	3.43	4.02
	<i>SE</i>	0.33	0.45	1.21	0.33	0.41	0.70
b*	<i>LSM</i>	6.12 ^{DEF}	6.45 ^{DEF}	10.57 ^{DEF}	3.37 ^{ABC}	2.83 ^{ABC}	2.35 ^{ABC}
	<i>SE</i>	0.42	0.57	1.55	0.42	0.52	0.89

Statistical significance: A... F – $P \leq 0.01$; a... f – $P \leq 0.05$.

only for Wrzosówka sheep. The lowest value of L* and a* color parameters of Wrzosówka sheep with the genotype TT compared to not dissimilar CC and CT was found. It could be state that for this breed that values of color measurements of heterozygote CT were similar to homozygote CC. The analysis indicates that the genotype of *TYRP-1* gene influenced only on measurements of wool color for Wrzosówka sheep – breed with colorful wool. It is difficult to relate the results of other research. However, in a practical sense, developing criteria of color distribution depending on the genotype could be used in breeding work to achieve patterns of coat color for this breed.

CONCLUSIONS

The obtained results led up to following statements and conclusions:

1. Significant or highly significant differences between assessed sheep breeds in all color measurements of wool and skin, which should be associated with different coat color in both breeds. Striking is the fact of the differences in the color of wool and skin in relation to the a* value, which are arranged exactly the opposite in both cases. This means that proportion of red or green color in skin is different as wool.

2. Differences in color measurement values of wool depending on *TYRP-1* gene genotypes were observed only for Wrzosówka sheep. The measurement of L* color parameter made on wool was highly significantly higher in the case of CC and CT genotypes in comparison to TT genotype. However, in the measurement of a* color parameter situation is opposite and homozygote TT was higher values compared to the other genotypes.
3. No differences between wool and skin color of Żelaźnińska sheep and no differences in skin color of Wrzosówka sheep.
4. The results of studies on the distribution of measurements of color wool, depending on the *TYRP-1* gene genotype of Wrzosówka sheep, make possibilities to conduct breeding work in this field, which could be used in breeding practice to develop standards of coat color for this breed.

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Streszczenie: Wpływ rasy oraz genu kodującego brązowe umaszczenie (TYRP-1) na barwę wełny i skóry u ras owcy żelaźnińskiej i wrzosówki polskiej. Badania przeprowadzono na maciorkach dorosłych, losowo wybranych w trakcie strzyży maciorek rasy żelaźnińskiej (93) i wrzosówki (133). Wykonano pomiary wełny i skóry przy użyciu urządzenia Chroma Meter CR-400 (Konica Minolta Sensing Inc., 2011). Uwzględniając wyniki określania genotypu genu kodującego brązowe umaszczenie *TYRP-1*, wybrano do dalszych analiz 66 maciorek żelaźnińskich i 74 rasy wrzosówka, na których oceniono wpływ genotypu *TYRP-1* na cech barwy wełny i skóry w obrębie rasy i pomiędzy nimi. Na podstawie przeprowadzonych badań stwierdzono bądź wysoko istotnie statystycznie różnice pomiędzy ocenianymi rasami owiec w zakresie wszystkich pomiarów barwy wełny i skóry, co należy wiązać z umaszczeniem u obu ras. Zasta-

nawiający jest jednak fakt innego układu różnic w barwie wełny i skóry w odniesieniu do wartości pomiarów udziału barwy czerwonej a^* , które układały się dokładnie na odwrót w obu przypadkach. Oznacza to, że udział barwy czerwonej bądź zielonej w skórze jest inny niż w wełnie. Pomiar jasności barwy L^* wykonany na wełnie wykazał wysoko istotne statystycznie większe wartości w przypadku genotypów CC i CT w porównaniu do TT. W przypadku pomiaru a^* sytuacja kształtowała się odwrotnie i to u osobników homozygotycznych TT osiągnęła większe wartości tej cechy w porównaniu do pozostałych. Nie wykazano zróżnicowania pomiarów barwy wełny i skóry u owcy żelaźniańskiej oraz skóry u wrzosówki. Wyniki badań dotyczących rozkładu pomiarów barwy wełny w zależności od genotypu *TYRP-1* u wrzosówki, stwarzają możliwość prowadzenia pracy hodowlanej w tym zakresie, co w konse-

kwencji może być wykorzystane w praktyce hodowlanej przy dążeniu do wypracowania skonsoleowanych standardów umaszczenia dla tej rasy.

Słowa kluczowe: owce, wełna, skóra, barwa wełny i skóry

MS received 13.07.2016

MS accepted 11.10.2016

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Meat quality of fattening pigs born from sows fed different diets during early pregnancy

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Abstract: *Meat quality of fattening pigs born from sows fed different diets during early pregnancy.* The aim of the study is to determine the pork quality of fattening pigs (Polish Landrace × Polish Large White × Duroc) originated from sows fed during early pregnancy (41 to 70 days) with diets differing in quantity and quality (LD1 vs LK sows – 130% of recommendations, LD2 sows – energy supplement). Thirty-six weaners from LK, LD1 and LD2 sows were selected for fattening and assigned to groups K, D1 and D2 (12 animals per group). Fatteners were fed in three phases and kept under standardized environmental conditions (individual pens, constant access to water). Better growth rate in the offspring was obtained as a result of temporarily more intense feeding of pregnant sows with increased daily rations. Modification of the sow diets had no appreciable effect on the slaughter traits of the fatteners postmortem, which shows that there are no contraindications for temporary changes in the feeding of pregnant sows. Good and uniform meatiness of the fatteners in the control and experimental groups was obtained. Chemical composition and physical characteristics of the meat were similar among the groups and the meat was of good quality. Statistically significant differences between the groups were found for several traits: crude ash content, a* colour value, and the proportion of C17:1 and C18:2 n-6 acids.

Key words: feeding of sows, fattening pigs, meat quality

INTRODUCTION

The nutrient supply of pregnant females and the satisfaction of their nutrient requirements are associated with their ef-

fects on fetuses, growth and development of the piglets after birth and weaning, and the quantity and quality of meat obtained at the end of fattening (Heyer et al. 2004, Du et al. 2010, Rekiel et al. 2015). It has been established that in addition to genotype, the internal environment and the associated nutritional factors affect the organism during embryonic development, thus determining its further pre- and post-natal development as well as production traits. The number of muscle cells is determined during the fetal period. During fetal life adipocytes are also formed, the number and size of which determine the amount of intramuscular fat as well as the sensory characteristics of pork.

Sows receiving increased amounts of diet during the second month of gestation gave birth to piglets that had a greater number of muscle fibres and produced carcasses with a higher quality of primal cuts at the end of fattening (Dwyer et al. 1994, Musser et al. 2006). It should be noted, however, that some studies report different results. Cerisuelo et al. (2009) and McNamara et al. (2011) observed no positive effect of the intensive feeding of pregnant sows on their offspring, its meatiness and pork quality.

Attempts have been made to limit intrauterine undernutrition (McNamara et al. 2011, Rehfeldt et al. 2012). Feeding

experiments are mainly concerned with changes in the supply of feed, energy, protein, and amino acids (Cerisuelo et al. 2009, McNamara et al. 2011, Rehfeldt et al. 2012, Oksbjerg et al. 2013).

The aim of the study is to determine the meat quality of fatteners whose mothers were fed during the second trimester (41–70 days) of pregnancy with diets differing in quantity and quality.

MATERIAL AND METHODS

Animals and experimental procedures

In the first stage of the experiment, 36 sows (Polish Landrace × Polish Large White; 12 primiparous and 24 multiparous) were assigned to three groups (12 animals per group), which received complete balanced diets according to Polish Swine Nutrition Requirements (1993). During early pregnancy, quantitative and qualitative changes were temporarily made to the diet between 41 and 70 days of pregnancy, as illustrated by the data in Table 1. The piglets were reared with mothers and additionally fed until 35 days of age. At weaning, they were moved to group pens, where

they were kept under standardized housing and feeding conditions for the next 5 weeks. Thirty-six weaners with an initial body weight of about 27 kg (12 animals each from LK, LD1 and LD2 mothers, 1 : 1 sex ratio) were selected for experimental fattening. Animals were kept in individual pens on shallow litter and fed in three phases with complete diets, similar in nutrient content and energy concentration for all groups (Table 2). Feeding was based on Polish Swine Nutrition Requirement (1993) and feed was given twice daily (morning and evening), with free access to water (automatic drinkers). Each diet was fed for 4 weeks and the fattening was 12 weeks long.

Animals were slaughtered by electrical stunning according to the technology used in the meat industry (Regulation of Minister of Agriculture and Rural Development – Journal of Laws of 2004 No 205, item 2102). Carcass meatiness (EUROP grading system) was determined using a CGM-Sydel needle-optical probe. The right half-carcasses were measured for acidity (pH₄₅ and pH₂₄) using a HI-98240 pH meter with an FC 231D penetration electrode (*musculus longissimus dorsi*). Samples for chemi-

TABLE 1. Feeding scheme for the sows (mothers of fatteners) during early and late pregnancy

Group	Gestation period			
	days 1–40	days 41–70	days 71–90	days 91–110
	complete ration (kg)			
Control – LK	2.3	2.3	2.3	3.2
Experimental 1 – LD1	2.3	3.0	2.3	3.2
Experimental 2 – LD2	2.3	2.3 + supplement*	2.3	3.2

*Energy supplement = 50 g glucose + 150 g maize meal.

TABLE 2. Ingredients and basic composition of the sows and fatteners (T1, T2, T3) diets (%)

Item	Diet for sows during pregnancy		Diet for fatteners		
	1–90 days	91–110 days	T1	T2	T3
Feed materials					
Maize, ground	35.0	40.0	5.0	5.0	5.0
Wheat, ground	30.0	20.0	63.1	67.1	66.0
Wheat bran	25.0	25.0	11.0	10.0	15.0
Sunflower meal	–	–	7.0	8.0	9.0
Soybean meal	–	–	10.9	6.9	2.0
Concentrate HGC SOW	10.0	15.0	–	–	–
Ground limestone	–	–	0.5	0.5	0.5
Lidermix-T premix*	–	–	2.5	2.5	2.5
Chemical composition					
Dry matter	88.84	90.03	87.24	86.16	82.62
Crude ash	4.16	5.44	5.02	4.18	3.96
Crude protein	12.41	16.46	16.43	15.71	14.57
Crude fat	1.87	1.78	2.33	1.75	1.28
Crude fibre	5.21	2.77	2.75	4.76	4.52

*Premix: lysine – 9%, methionine – 2%, threonine – 2%, Ca – 24.5%, P – 6.5%, Na – 6%, Mg – 1%, vitamins: A 375,000 IU, D₃ – 65,000 IU, E – 3,000 mg, K – 65 mg, B₁ – 60 mg, B₂ – 200 mg, B₆ – 100 mg, B₁₂ – 1 mg, biotin – 1 mg, niacin – 800 mg, choline – 4,000 mg, folic acid – 20 mg, pantothenic Ca – 800 mg, Mn – 2,000 mg, Zn – 4,000 mg, Fe – 4,000 mg, Cu – 750 mg, J – 40 mg, Co – 16 mg, betaine – 3,000 mg; natural stimulator (Vitacetrus), phytase.

cal analyses and physical determinations were collected from the cranial end of the *musculus longissimus lumborum*.

Analytical determinations

Basic analyses of the diets were performed according to commonly accepted procedures (AOAC 1990).

Samples of meat (part of the material) were ground to determine basic composition (dry matter, protein, fat and ash) (AOAC 1990) and the fatty acid profile. Fatty acid methylation was performed according to the trans esterification method EN-ISO 5509:2001: Identification of individual fatty acids in crude fat

was conducted using an Agilent 7890A GC (Agilent, Waldbronn, Germany) with flame-ionization detector (FID), HP Chem software and Varian Select FAME column (100 m length, 0.25 mm diameter, 0.25 µm film thickness; Varian/Agilent Technologies, Waldbronn, Germany). The separation was performed at pre-programmed temperature: 130°C for 1 min; 130–170°C at 6.5°C/min; 170–215°C at 2.75°/min; 215°C for 12 min, 215–230°C at 20°C/min and 230°C for 3 min. Each peak was identified 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). The atherogenic index (*AI*) and the thrombogenic index (*TI*) were determined according to the formulas reported by Ulbricht and Southgate (1991):

$$AI = (4 \times C14:0 + C16:0) / (MUFA + PUFA)$$

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

A chilled chop about 2 cm thick was used to determine the colour of meat (L^* – lightness, a^* – redness, b^* – yellowness). Three measurements of each sample were made with a Chroma Meter CR-400/410 (Konica-Minolta) and the results were averaged.

Drip loss was determined using a section of *longissimus lumborum* muscle. The samples were weighed (about 300 g), packed into polyethylene bags and stored in a refrigerator (+4°C) for 24 h. After this time, the liquid lost as drip was removed from each bag and expressed as a percentage of the original weight of the meat.

Muscle shear force was determined with a Zwick tensiometer. Samples of *longissimus lumborum* muscle (about 150 g) were placed in 1% NaCl at +4°C. Next, they were cooked for 30 s and placed into a +180°C oven, where they were roasted until the internal temperature reached +76°C in the geometric centre. Shear force was determined at room temperature on cube-shaped samples (20 × 20 × 20 mm), using Warner–Bratzler shear machine. A crosshead speed of 30 mm/min was applied until an initial tension of 2 N was reached, using 50 mm/min during the test proper.

Water holding capacity was determined in ground meat by the method of Grau and Hamm (1953) modified by Pohja and Ninivaara (1957).

Statistical analysis

The results were analysed using IBM SPSS Statistics 21. Normal distribution was tested by the Shapiro–Wilk test, significant differences by the Mann–Whitney U-test, and differences between the groups using the Kruskal–Wallis test.

RESULTS AND DISCUSSION

When the sows were mated to Duroc boars, backfat thickness at P2 averaged 20.0, 20.2 and 21.5 mm in groups K (control), D1 (experimental) and D2 (experimental), respectively. When pigs changed pens at 107 days of pregnancy, the respective values were 21.3, 21.0 and 22.4 mm. Fertility in the whole batch of sows averaged 11.08 animals and the mean piglet birth weight of 1.53 kg was similar among the groups.

The slaughter weight and lifetime gain were significantly higher in group D1 than in groups K and D2 (Table 3). Carcasses from the experimental animals were characterized by good meatiness ($P > 0.05$).

Basic composition of *musculus longissimus lumborum* did not differ among the groups except for ash content ($P \leq 0.01$) – Table 4. The lowest mean for this trait was noted for the meat samples of pigs from group K.

Meat pH₄₅ after slaughter, pH₂₄ as well as shear force and lightness were not different among the groups (Table 5).

TABLE 3. Results of fatteners growth and meatiness

Item	Group						P
	K		D1		D2		
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	
Number, <i>n</i>	12		12		12		
Birth weight (kg)	1.55	0.04	1.50	0.03	1.55	0.07	0.428
Slaughter weight (kg)	102.6 a	1.36	115.3 Aa	3.21	100.4 A	2.75	0.012
Lifetime daily gains (g)	656 a	7.64	739 Aa	17.18	642 A	15.10	0.015
Meatiness (%)	54.0	0.13	55.1	0.81	54.6	0.96	0.812

a, b – mean values in rows with the same letters differ significantly ($P \leq 0.05$); A, B – mean values in rows with the same letters differ significantly ($P \leq 0.01$).

TABLE 4. Chemical composition of *musculus longissimus lumborum* (%)

Item	Group						P
	K		D1		D2		
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	
Dry matter	26.73	0.07	27.04	0.23	27.16	0.24	0.056
Crude protein	22.88	0.11	22.52	0.22	22.51	0.18	0.068
Crude fat	1.91	0.09	1.75	0.17	1.70	0.13	0.407
Crude ash	1.12 AB	0.01	1.20 A	0.03	1.22 B	0.02	0.001

A, B – mean values in rows with the same letters significantly ($P \leq 0.01$).

TABLE 5. Quality parameters of the meat (*musculus longissimus lumborum*)

Item	Group						P
	K		D1		D2		
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	
pH ₄₅	6.24	0.05	6.28	0.06	6.25	0.03	0.782
pH ₂₄	5.87	0.05	5.90	0.01	5.88	0.02	0.959
Colour							
L*	52.0	1.91	50.1	0.92	50.6	1.27	0.544
a*	10.2 AB	0.84	7.0 A	0.42	7.6 B	0.28	0.009
b*	4.2	1.13	3.4	0.51	3.4	0.32	0.745
Drip loss (%)	4.0	1.19	3.1	0.52	3.9	0.60	0.766
Water holding capacity (cm ² /g)	27.5	4.13	28.0	2.71	28.4	2.16	0.872
Shear force (N)	60.0	3.08	62.8	1.07	62.1	2.43	0.131

A, B – mean values in rows with the same letters differ significantly ($P \leq 0.05$).

As regards meat colour, significant differences among the groups were found for redness. The highest a^* value was observed for the meat of control fatteners ($P \leq 0.01$).

Water holding capacity and drip loss did not differ among the studied groups. The highest water holding capacity and drip loss were characteristic of the meat samples from group K pigs.

The proportion of SFA and n-3 PUFA did not differ significantly among the groups (Table 6). The *AI* and *TI* values were similar. In group D2, the lowest proportion of C17:1 ($P \leq 0.05$) and C18:2 n-6 ($P \leq 0.01$) was found. Differences between the three analysed groups for the proportion of SFA, MUFA, n-6 PUFA and n-3 PUFA were small ($P > 0.05$) – Table 6.

Opinions are divided concerning the effect of giving increased feed or energy to pregnant sows on performance of offspring reared by their dams and after weaning. Fortin et al. (2003) and Cerisuelo et al. (2009) believe that it is beneficial; the opposite view is held by Dwyer et al. (1994), Heyer et al. (2004), and Lawlor et al. (2007). From the start of fattening to reaching slaughter weight, the growth rate improves, and, according to Dwyer et al. (1994), the improvement is significant ($P \leq 0.05$). A similar opinion is expressed by Fortin et al. (2003), who showed 4–8% better gains in the fattening of pigs whose pregnant mothers were temporarily fed more intensively. Our results support this view. The daily gains of pigs from group D1 were over 3% higher compared to group K ($P > 0.05$). The results obtained provide conclusive evidence that the increased supply of feed, well balanced for energy

and protein, together with the amount of protein and energy provided to the mother during gestation, may have a residual beneficial effect on rate growth of the fatteners.

Heyer et al. (2004), Musser et al. (2006) and Lawlor et al. (2007) show a positive relationship between the diets of sows and the slaughter value of their offspring. Rehfeldt and Kuhn (2006) and Oksbjerg et al. (2013) report that the diet of pregnant females is related to the development of muscle fibres in fetuses, birth weight, growth rate and feed conversion in growing pigs, as well as their slaughter value. The higher birth weight of the piglets means increased weight gains and improved carcass traits, including carcass lean content and muscle percentage in ham and loin (Heyer et al. 2004, Lawlor et al. 2007). In a study by Świątkiewicz (2010), 30-day feeding of early pregnant sows with a high energy and crude protein diet had a beneficial effect on carcass meatiness. Our findings also show some positive changes in meatiness in response to nutritional factors, although the differences between the groups were small (0.6–1.1 percentage points) and statistically non-significant ($P > 0.05$).

The modifications of pregnant sow diets in our study had little effect on the chemical composition and quality of pig meat. The findings of Lattore et al. (2004) and Zybert et al. (2015) indicate that sensory characteristics of pork vary according to the slaughter weight of the pigs or carcass weight. There are differing views on the relationship between pork quality and birth weight of the piglets. Rekiel et al. (2015) based on a review of the literature as well as Bérard

TABLE 6. Fatty acid profile (%) and ratio in the meat of fatteners

Item	Group						P
	K		D1		D2		
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	
SFA	37.22	0.58	37.18	0.62	37.29	0.19	0.754
C14:0	1.34	0.01	1.32	0.03	1.34	0.01	0.751
C16:0	24.15	0.29	24.11	0.37	24.22	0.11	0.424
C17:0	0.18	0.01	0.17	0.01	0.15	0.01	0.158
C18:0	12.71	0.29	12.74	0.30	12.75	0.12	0.997
C20:0	0.18	0.01	0.15	0.02	0.17	0.01	0.359
MUFA	51.81	1.28	53.27	0.68	53.70	0.32	0.360
C16:1	3.73	0.11	3.44	0.09	3.54	0.07	0.185
C17:1	0.18 a	0.01	0.18	0.02	0.14 a	0.01	0.038
C18:1	47.11	1.23	48.80	0.63	49.17	0.30	0.205
C20:1	0.79	0.02	0.84	0.03	0.84	0.02	0.124
PUFA n-6	6.49	0.24	6.81	0.28	6.14	0.14	0.116
C18:2 n-6	5.16	0.18	5.40 A	0.19	4.77 A	0.09	0.014
C20:2 n-6	0.24	0.01	0.26	0.01	0.23	0.01	0.195
C20:3 n-6	0.12	0.01	0.14	0.01	0.14	0.01	0.263
C20:4 n-6	0.81	0.04	0.83	0.10	0.83	0.04	0.799
C22:4 n-6	0.16	0.01	0.18	0.02	0.17	0.01	0.405
PUFA n-3	0.48	0.02	0.47	0.03	0.44	0.01	0.274
C18:3 n-3	0.19	0.01	0.18	0.01	0.17	0.01	0.052
C20:3 n-3	0.05	0.01	0.05	0.01	0.05	0.01	0.632
C20:5 n-3	0.07	0.01	0.08	0.01	0.07	0.01	0.749
C22:5 n-3	0.11	0.01	0.11	0.01	0.11	0.01	0.999
C22:6 n-3	0.05	0.01	0.05	0.01	0.05	0.01	0.324
n-6/n-3	13.56	0.23	14.48	0.44	13.90	0.22	0.265
MUFA/PUFA	7.50	0.41	7.37	0.27	8.22	0.22	0.102
MUFA/SFA	1.39	0.04	1.44	0.04	1.44	0.01	0.420
PUFA/SFA	0.19	0.01	0.20	0.01	0.18	0.01	0.246
AI	0.50	0.01	0.49	0.02	0.49	0.01	0.154
TI	1.25	0.03	1.21	0.04	1.22	0.01	0.304

a, b – mean values in rows with the same letters differ significantly ($P \leq 0.05$), A, B – mean values in rows with the same letters differ significantly ($P \leq 0.01$).

et al. (2008) and Beaulieu et al. (2010) report that drip loss and cooking loss do not change with birth weight. Beaulieu et al. (2010) suggest that piglet birth weight is unrelated to pork tenderness and colour. A different view is taken by Gondret et al. (2005) and Bérard et al. (2008) who claim that such an effect exists. In our study, the birth weight of the piglets and the meat quality parameters of the fatteners were similar ($P > 0.05$).

The content and percentage of fatty acids in pork have been the subject of many studies, but the literature directly related to our research is limited. The available publications analyse the effect of piglet birth weight on the quality traits of slaughter livestock and pig meat. In pigs, SFA and MUFA are synthesized *in vivo* while PUFA have to be supplied through diet (Enser et al. 2000). The use of vegetable oils in pig diets increases the PUFA content of meat but at the same time has a negative effect on its sensory characteristics and keeping quality, which has been confirmed experimentally (Koczanowski et al. 2002). In our study, animals from group D2 showed a slight increase in the proportion of oleic acid (18 : 1) concurrently with a reduction in linoleic acid (18 : 2), but this change had no effect on the analysed quality parameters and chemical composition of the meat. According to Wood et al. (1994), such a change improves the juiciness and tenderness of meat.

In our study, all the fatteners received the same diets. The modifications of the diets of sows who gave birth to the studied pigs had no effect on the fatty acid content of meat from the slaughter animals. The only significant or highly significant differences between the means

were noted for two fatty acids. In addition to the strongest factor of the composition of the diet fed directly to growing pigs (Raes et al. 2004), the fatty acid profile of the pig muscles is influenced by genetic factors including the breed (De Smet et al. 2004), housing conditions and the proportions of different muscle fibre types (Andrés et al. 2001). In our study, the genotype, housing and feeding were the same for all the pigs, which means that their effect on the fatty acid profile was also the same.

CONCLUSIONS

Better growth rate in the offspring was obtained during fattening as a result of temporarily more intense feeding of pregnant sows with increased daily rations.

Good and uniform meatiness of the fatteners was obtained in the control and experimental groups.

Chemical composition and physical characteristics of the meat were similar among the groups, and the meat was of good quality. Statistically significant differences between the control and experimental groups were confirmed for several traits: crude ash content, a* colour value, and the proportion of C17:1 and C18:2 n-6 acids.

Modification of the sow diets had no appreciable effect on the slaughter traits, which shows that there are no contraindications for temporary changes in the feeding of pregnant sows.

Acknowledgement

Source of research financing: author's project of the State Committee for Scientific Research, project N N311 082639.

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Streszczenie: *Jakość mięsa tuczników pochodzących od loch żywionych odmiennie w ciąży niskiej.* Celem pracy jest określenie jakości wieprzowiny pozyskanej od tuczników (pbz × wbp × duroc), których matki w okresie ciąży niskiej żywiono okresowo, od 41. do 70. dnia jej trwania, paszą, której ilość lub jakość zróżnicowano (lochy LD1 vs LK – dawka większa o 30% w stosunku do norm, lochy LD2 – dodatek energetyczny). Do tuczu wybrano 36 warchlaków od loch LK, LD1, LD2 i przydzielono do grup K, D1, D2 po 12 sztuk. Tuczniaki żywiono systemem trójfazowym

i utrzymywano w ujednoliconych warunkach środowiska (kojce pojedyncze, stały dostęp do wody). W efekcie zastosowanego okresowo intensywniejszego żywienia loch prośnych poprzez zwiększenie dziennej dawki paszy uzyskano u potomstwa lepsze tempo wzrostu. Modyfikacje żywienia matek nie miały znaczącego wpływu na cechy rzeźne tuczników określone poubojowo, co wskazuje na brak przeciwwskazań do okresowych zmian żywienia loch prośnych. Uzyskano dobrą, wyrównaną w grupach kontrolnej i doświadczalnych mięśność tuczników. Skład chemiczny mięsa i jego cechy fizyczne były na zbliżonym poziomie w grupach, mięso było dobrej jakości. Różnice istotne statystycznie między grupami potwierdzono dla nielicznych cech: zawartości po-

piołu surowego, wartości a* barwy oraz udziału kwasów C17:1 i C18:2 n6.

Słowa kluczowe: żywienie loch, tuczniki, jakość mięsa

MS received 03.10.2016

MS accepted 12.10.2016

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Association of *CAST* and *RYR1* genes polymorphism with carcass and meat quality in crossbreed pigs with a share of Pietrain breed

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Abstract: Association of *CAST* and *RYR1* genes polymorphism with carcass and meat quality in crossbreed pigs with a share of Pietrain breed. The aim of this study is to determine the effect of the calpastatin (*CAST/TaqI*) and ryanodine receptor (*RYR1*) genes polymorphism on carcass and meat quality traits in Pietrain crossbred pigs. The polymorphism in *CAST* and *RYR1* genes was detected using the PCR-RFLP (Restriction Fragment Length Polymorphism Analysis of PCR-Amplified Fragments) method. Two alleles of *CAST* gene were identified – *A* (0.34) and *B* (0.66) and three genotypes – *AA* (0.21), *AB* (0.25) and *BB* (0.54). In relation to carcass and pork quality, no statistically significant differences were found between the *CT* and *CC* genotypes of *RYR1* gene as well as between *AA*, *AB* and *BB* genotypes of *CAST* gene. In addition, no significant interaction was found between *CAST/TaqI* × *RYR1* genotypes and all the analyzed carcass and meat quality traits.

Key words: *CAST*, *RYR1*, meat quality, slaughter value, pigs

INTRODUCTION

Work on improving the quality of the pig carcass has been carried out for many years. The most important aspect is to increase the proportion of meat in the carcass in the way that does not decrease the quality of the meat. For example,

slaughter performance can be improved by the use of pigs with high meat content, mainly the Pietrain breed. However, intensive breeding work for improvement carcass quality in the crossbred offspring of Pietrain boars has revealed a number of problems, particularly related to the high frequency of the *RYR1*^T allele in this breed, which causes the occurrence of PSE (pale, soft, exudative) meat (Fiedler et al. 2001).

Calpastatin (*CAST*) is a specific inhibitor of calpain, a Ca²⁺ activated protease family and is considered to be responsible for the initiation of myofibrillar protein degradation in living muscle (Murachi 1989). The calpain system may also affect the number of skeletal muscle cells in domestic animals by altering the rate of myoblast proliferation and by modulating myoblast fusion. An increased rate of skeletal muscle growth can result from a decreased rate of muscle protein degradation, and this is associated with a decrease in activity of the calpain system, principally due to a large increase in calpastatin activity (Goll et al. 1998). The activity of calpastatin is strongly associated with muscle growth rate as well as with the rate of post mor-

tem proteolytic changes that make the meat tender. This is the reason why this protein is so important in relation of pork quality traits (Koćwin-Podsiadła and Kurył 2003, Melody et al. 2004).

The calpastatin gene has been mapped near the centromere of chromosome 2 (SSC2) in the region q2.1-q2.4. The calpastatin molecule consists of L domain, encoded by exons 2–8, and four repetitive domains, each of which is encoded by exons 9–14 (Stearns et al. 2005). Polymorphisms in the calpastatin gene (*CAST*), identified in the sixth intron with three restriction enzymes (*HinfI*, *MspI*, and *RsaI*) were first reported by Ernst et al. (1998). Further analysis showed that these polymorphisms are associated with meat colour, pH, water holding-capacity (WHC) and texture parameters measured in the *longissimus dorsi* and *semimembranosus* muscles in four purebreds used in Polish breeding programmes and one conservative breed (Ropka-Molik et al. 2014).

Ciobanu et al. (2004), however identified a *CAST* gene polymorphism in domains L, 1, and 4, recognized by *ApaLI*, *Hpy188I*, and *PvuII* enzymes, respectively. After sequencing the 1991bp DNA fragment of the *CAST* gene, a novel polymorphism – C/T transition was also detected in intron 24, which is recognized by *TaqI* enzyme (Wang et al. 1997). To date, it is the only paper containing data concerning *CAST/TaqI* genotypes frequency in six pig populations, without presenting their relation to production traits.

Previous studies also indicated that the ryanodine receptor gene (*RYR1*) variants significantly influence the carcass and meat quality traits (Urbański et

al. 2013) and could interact with other genes.

The aim of this study is to determine the relationship between calpastatin gene (*CAST/TaqI*) and the ryanodine receptor gene (*RYR1*) polymorphism and the carcass and meat quality traits in the crossbred offspring of Pietrain boars.

MATERIAL AND METHODS

Offspring were obtained by crossing German Landrace × German Large White and also Leicoma × German Large White sows with Pietrain boars. The study was carried out on 125 pigs (76 gilts and 49 barrows) from a pig farm located in Mecklenburg-Vorpommern (Germany). All the animals used in the study were kept under similar environmental conditions and fed with a balanced mix of feed *ad libitum*. All the test animals were assembled into one group and taken to the meat plant in Szczecin (Poland) in the evening (4 h transport over a distance of 250 km), and slaughtered the next day in the morning (lairage time – 12 h). After CO₂ stunning, blood was collected from pigs to extract DNA for the identification of the *CAST* and *RYR1* genotypes. Subsequently, following traits were measured: carcass percentage of lean meat, hot carcass weight, thickness of the *longissimus dorsi* muscle (LD) and the back fat between the third and fourth last ribs (7 cm laterally from the carcass split line, on the left-hand side of the carcass, by means of an CGM optic-needle apparatus (Sydel, France).

Two hours after slaughter, during carcass cooling, electric conductivity (EC₂) was measured in the *longissimus dorsi* muscle, between the fourth and fifth

lumbar vertebrae of the right-hand side of the carcass using an LF-Star MAT-THÄUS conductometer. After 24 h of carcass cooling, meat samples from the *longissimus dorsi* muscle were collected from the first to fourth, *lumbar vertebrae* section (*longissimus lumborum* – LL) of the right-hand side of the carcass. 24-hour *post mortem*, the meat pH₂₄ value (Elmetron CP-411 pH-meter) and the volume of drip loss from the muscle tissue were determined according to Honikel (1987).

Within 48 h *post mortem*, minced samples of LL muscle were measured for pH in a water solution (pH₄₈), and the pork colour parameters, i.e. L* (lightness), a* (redness) and b* (yellowness), were established by means of a Hunter-Lab Mini Scan XE Plus 45/0 with D65 light illuminant and 10° observer. The meat water-holding capacity (WHC) was determined according to Grau and Hamm (1952) as modified by Pohja and Niinivaara (1957). Thermal drip was calculated as the difference of the meat sample weight before and after heating in a water bath at 85°C for 10 min. The water-soluble protein content was determined by the Kotik method (1974). The basic meat chemical composition was estimated in the meat, i.e. total protein, fat, ash and dry matter (AOAC 2003).

Genomic DNA was extracted from the blood sample using a Master Pure Kit (Epicentre Technologies). Genotypes of *RYR1* and *CAST* were identified by PCR-RFLP method. The *CAST* genotypes were identified according to the method used by Wang et al. (1997) by use following primer sequences: *forward* 5'-GTGATGACAAAAACTTGACG-3' *reverse* 5'-TCATCCTTATCCAAGA-

GATGTC-3'. After digestion with 3U of the *TaqI* endonuclease (37°C/overnight) and electrophoresis in 2% agarose gels *CAST* genotypes were identified based on following restriction fragments length: *AA* – 963, 806 and 222bp; *AB* – 1028, 963, 806 and 222bp; *BB* – 1028 and 963bp. The *RYR1* genotypes were identified with following primers given by Brenig and Brem (1992): *forward* 5'-GTGCTGGATGTCCTGTGTTCCCT-3' *reverse* 5'-CTGGTGACATAGTTGATGAGGTTTG-3'. Digestion of amplicons with *Hin6I* restriction enzyme (37°C/overnight) and separation in 3% agarose gels allowed to identification two of three genotypes: *CC* – 84 and 50bp; *CT* – 134, 84 and 50bp.

Statistical analysis was performed to compare carcass and meat quality traits and also the meat chemical composition between pigs with the different *CAST* and *RYR1* genotypes using the least squares method of the GLM procedure (Statistica 9.1 PL) according to the following linear model:

$$Y_{ijkl} = \mu + a_i + b_j + c_k + bc_{jk} + e_{ijkl}$$

where:

Y_{ijkl} – trait measured;

μ – overall mean;

a_i – effect of sex ($i = 1, 2$);

b_j – effect of the *RYR1* genotype ($j = CT, CC$);

c_k – effect of the *CAST/TaqI* genotype ($k = AA, AB, BB$);

bc_{jk} – interaction (*RYR1* × *CAST/TaqI* genotype)

e_{ijkl} – random error.

A detailed comparison of the mean least squares (*LSQ*) for the analysed *CAST* and *RYR1* genotypes was conducted using a Tukey's test.

RESULTS AND DISCUSSION

The frequency of the alleles and genotypes of *CAST/TaqI* and *RYRI* genes in Pietrain-sired pigs are presented in Table 1. Two different alleles of *CAST* gene were identified – allele *A* (0.34) and *B* (0.66) and three genotypes – *AA* (0.21), *AB* (0.25) and *BB* (0.54). Two genotypes of *RYRI* gene, however were observed – *CT* (0.43) and *CC* (0.57).

The association between the genotypes of *CAST/TaqI* and *RYRI* and carcass and meat quality traits of the pigs are presented in Tables 2, 3 and 4. We did not find any significant differences between the genotypes *AA*, *AB*, and *BB* of the *CAST* in relation to carcass percentage of lean meat, backfat and LD muscle thickness, as well as in meat

quality and basic chemical composition determined in the *longissimus lumborum* muscle. Moreover, no significant effect of the *RYRI* polymorphism on carcass and meat quality or meat basic chemical composition was observed.

Based on the conducted research on the analyzed groups of pigs we found all three possible *CAST* genotypes. The presence of the three *CAST/TaqI* genotypes was also observed by Wang et al. (2007) in Suta pigs, PIC hybrids, and in crosses of Duroc, Landrace and Yorkshire. Similar to present study, the *BB* genotype characterized higher frequency followed by *AB* then *AA* genotypes. In the Yorkshire × Suta crosses the above mentioned authors noticed a higher frequency of heterozygotes (*AB*) than homozygotes, while in the Meishan breed

TABLE 1. The frequency of *CAST* and *RYRI* alleles and genotypes in analyzed pigs

Polymorphism	Allele frequency		Genotype frequency		
	<i>A</i>	<i>B</i>	<i>AA</i>	<i>AB</i>	<i>BB</i>
<i>CAST/TaqI</i>	0.34	0.66	0.21	0.25	0.54
<i>RYRI/Hin6I</i>	<i>C</i>	<i>T</i>	<i>CC</i>	<i>CT</i>	<i>TT</i>
	0.21	0.79	0.57	0.43	–

TABLE 2. Effect of the *CAST/TaqI* and *RYRI* genotypes on carcass quality traits in pigs

Trait	<i>CAST/TaqI</i> genotypes			<i>RYRI</i> genotypes		Significance of interaction influence
	<i>AA</i>	<i>AB</i>	<i>BB</i>	<i>CC</i>	<i>CT</i>	
Hot carcass weight (kg)	88.66 ±7.14	86.44 ±5.52	87.99 ±5.92	87.88 ±6.06	87.83 ±6.45	n.s.
Meatiness (%)	54.44 ±4.54	55.70 ±4.20	55.63 ±4.54	55.05 ±4.91	55.83 ±3.73	n.s.
Backfat thickness (mm)	15.85 ±4.36	14.65 ±4.28	14.64 ±4.25	15.39 ±4.60	14.27 ±3.71	n.s.
Thickness muscle (mm)	54.81 ±6.13	57.39 ±6.53	57.01 ±6.57	56.75 ±7.21	56.51 ±5.40	n.s.

n.s. – statistically not significant.

TABLE 3. Effect of the *CAST/TaqI* and *RYR1* genotypes on meat quality traits in pigs

Trait	<i>CAST/TaqI</i> genotypes			<i>RYR1</i> genotypes		Significance of interaction influence
	<i>AA</i>	<i>AB</i>	<i>BB</i>	<i>CC</i>	<i>CT</i>	
pH ₂₄	5.63 ±0.10	5.63 ±0.13	5.69 ±0.17	5.68 ±0.14	5.64 ±0.16	n.s.
pH ₄₈	5.53 ±0.09	5.54 ±0.12	5.60 ±0.19	5.58 ±0.14	5.56 ±0.18	n.s.
EC ₂ (mS/cm)	3.05 ±1.46	3.08 ±1.57	3.12 ±1.26	2.98 ±1.35	3.22 ±1.41	n.s.
L*	55.14 ±3.39	55.12 ±3.29	54.40 ±3.48	54.59 ±3.09	54.94 ±3.77	n.s.
a*	9.45 ±1.41	9.44 ±1.34	9.22 ±1.22	9.42 ±1.23	9.26 ±1.33	n.s.
b*	17.10 ±1.28	17.05 ±1.27	16.57 ±1.37	16.76 ±1.26	16.88 ±1.44	n.s.
Drip loss (%)	7.93 ±2.70	8.30 ±2.36	7.26 ±2.62	7.67 ±2.51	7.63 ±2.71	n.s.
WHC (% of free water)	18.35 ±5.55	18.19 ±4.63	16.71 ±4.87	17.00 ±4.62	17.96 ±5.39	n.s.
Thermal drip (%)	25.83 ±3.27	26.78 ±2.74	25.49 ±2.69	25.48 ±2.68	26.41 ±3.01	n.s.
Water-soluble protein (%)	8.38 ±0.90	8.03 ±1.01	8.24 ±0.93	8.27 ±0.89	8.15 ±1.00	n.s.

n.s. – statistically not significant.

TABLE 4. Effect of the *CAST/TaqI* and *RYR1* genotypes on basic chemical composition of meat in pigs

Trait	<i>CAST/TaqI</i> genotypes			<i>RYR1</i> genotypes		Significance of interaction influence
	<i>AA</i>	<i>AB</i>	<i>BB</i>	<i>CC</i>	<i>CT</i>	
Total protein (%)	22.51 ±0.57	22.35 ±0.80	22.39 ±0.69	22.34 ±0.74	22.47 ±0.63	n.s.
Fat (%)	2.51 ±0.55	2.46 ±0.52	2.54 ±0.66	2.50 ±0.55	2.55 ±0.66	n.s.
Ash (%)	1.19 ±0.07	1.18 ±0.07	1.18 ±0.08	1.18 ±0.07	1.18 ±0.08	n.s.
Dry matter (%)	26.21 ±0.66	26.00 ±0.71	26.11 ±0.79	26.02 ±0.73	26.21 ±0.74	n.s.

n.s. – statistically not significant.

they found no *AA* homozygotes while in Landrace × Sutai crosses no *BB* homozygotes. In the analyzed offspring of the Pietrain boars we found two *RYRI* genotypes – *CT* and *CC*, which is consistent with the approved German programme of animals qualification for crossing, where the sows should be free from the susceptibility to stress allele (*RYRI*^T), while boars do not (Rosner et al. 2003).

In the present study *CAST/TaqI* genotypes had no effect on the carcass quality traits, meat content, backfat thickness and LD muscle thickness at a similar warm carcasses weight. Kluzáková et al. (2014) found a significant effect of the *CAST/HinfI* variants on lean meat share (i.e. lower fat content) and *CAST/MspI* variants on lean meat share due to higher proportions of muscles mass in the main meat parts. Concerning the *CAST/RsaI* polymorphism, the study showed that this polymorphism does not influence any of the quantitative parameters under analysis.

In our study we found no relation between the *CAST/TaqI* gene polymorphism and meat quality traits and its basic chemical composition. Other study on the offspring of Hampshire × Pietrain boars showed associations between *CAST/RsaI* polymorphism and the concentration of glycogen and glycolytic potential of the LL muscle, between *CAST/HinfI* and pH₄₅ as well as between *CAST/MspI* and loin weight in the curing process (Koćwin-Podsiadła et al. 2003). Study of Ropka-Molik et al. (2014), performed on the common breeds maintained in Poland suggests that the most informative polymorphisms in *CAST* gene are *CAST/HpaII* and *CAST/RsaI*. They had the significant effect on WHC regardless

of the breed analyzed and on meat pH, firmness and toughness for most breeds. Interestingly for almost all breeds, the significant effect of both polymorphism on intramuscular fat content (IMF) was observed.

In the present study on the offspring of Pietrain boars, there were no statistically significant differences between the *CC* and *CT* genotypes of the gene *RYRI* regarding carcass and meat quality traits or the basic chemical composition of the meat, which was also confirmed in the research of Koćwin-Podsiadła et al. (2003). Other studies on the offspring of Pietrain boars, however showed that individuals with the *CT* genotype had a poor quality of meat compared to pigs with the *CC* genotype, which is reflected in a higher percentage of carcasses with PSE meat (Krzęcio et al. 2005).

We found no significant interactions between the genotypes of *RYRI* and *CAST/TaqI* in values of carcass and meat quality traits, nor in the basic chemical composition of the meat in the analyzed population of pigs. In studies on crossbred Duroc × Pietrain or Hampshire × Pietrain boars, the interactions between the *CAST* and *RYRI* genotypes were significant for muscle acidity (pH₂₄) and drip loss (Kurył et al. 2004, Krzęcio et al. 2005). In the study of Kluzáková et al. (2012) an important interaction was found between the identified polymorphisms *CAST/HinfI*, *CAST/MspI*, *CAST/RsaI* and the *RYRI* gene in relation to lean meat, ham share and main meat parts as well as meat quality traits, namely for pH₄₅ and drip loss. The results obtained by Kurył et al. (2004) in Pietrain crossbred pigs showed that the presence of meat with a significant drip loss and

a low water-holding capacity in pigs with *CC* genotype of *RYR1* gene, as well as the traits of meat quality in animals with *TT* genotype may results from modified impact of the *CAST* gene on *post mortem* changes in muscle.

To sum up, in the offspring of Pietrain boars we found no significant differences between the identified genotypes of *CAST/TaqI* (*AA*, *AB*, *BB*) and *RYR1* (*CC*, *CT*) in relation to the carcass and meat quality traits, nor the basic chemical composition of the meat. Moreover, we did not find any significant interaction between the *CAST/TaqI* and *RYR1* genes in relation to the quantitative and qualitative indicators of carcass value in the selected pig crossbreds.

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Streszczenie: *Zależność polimorfizmu genów CAST i RYR1 z cechami jakości tuszy i mięsa u świń mieszańców z udziałem rasy pietrain. Celem niniejszych badań jest określenie wpływu polimorfizmu genów kalpastatyny (CAST/TaqI) i receptora ryanodiny (RYR1) na cechy jakości tuszy i mięsa u świń mieszańców rasy pietrain. Polimorfizm genów CAST i RYR1 określono za pomocą metody PCR-RFLP (analiza polimorfizmu fragmentów restrykcyjnych amplifikowanych metodą PCR). Zidentyfikowano dwie allele – A (0,34) i B (0,66) oraz trzy genotypy genu CAST – AA (0,21), AB (0,25) i BB (0,54). W odniesieniu do jakości tuszy i mięsa nie zaobserwowano statystycznie istotnych różnic pomiędzy genotypami CT i CC genu RYR1 jak również genotypami AA, AB i BB genu CAST. Dodatkowo nie stwierdzono istotnych interakcji między genotypami CAST/TaqI × RYR1, a wszystkimi ocenianymi cechami jakości tuszy i mięsa.*

Słowa kluczowe: CAST, RYR1, jakość mięsa, wartość rzeźna, świnię

MS received 10.06.2016

MS accepted 05.09.2016

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Cow longevity in herds of different milk production levels and herd size

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Abstract: *Cow longevity in herds of different milk production levels and herd size.* The effect of herd production level and herd size on cow longevity was studied using the SYMLEK system data on 12,045 Polish Holstein-Friesian cows (Black-and-White variety) from 1,371 herds. The cows, which belonged to the active population in Pomerania and Kujawy, first calved in 2008 and were used or disposed from the herds by the end of 2015. FREQ and GLM procedures from the SAS package were used in the statistical calculations. With increases in herd size (from less than or equal 20 to beyond 200 cows) and herd production level (from less than or equal 6,000 to 9,000 kg milk), the culling level increased ($P \leq 0.01$) while the proportion of cows sold and alive decreased. Cow longevity was differentiated ($P \leq 0.01$) by herd size. As the number of cows in the herd increased, the lifespan and the length of productive life, as well as number of calvings decreased. The effect of herd production level on cow longevity was not statistically confirmed.

Key words: cow, milk, longevity, production level

INTRODUCTION

In view of the long-persisting tendency in Poland and the world to reduce the cows' lifespan and length of productive life, longevity is increasingly considered the most important functional trait that is crucial for breeding and production (Strapák et al. 2005, Brickell et al. 2010, Sawa 2011, Chabuz et al. 2016, Litwińczuk et al. 2016). Considering the economics of dairy cow production, the

possibility of increasing the length of productive life in cows is of particular interest for breeders. Róžańska-Zawieja et al. (2008) concluded that the lifespan of cows is highly significantly affected by breed, farm, cause of removal, maximum lactation number, maximum lactation length, and lifetime milk and milk constituents yield. Other determinants of cow longevity include milk production intensity (Jugowar et al. 2008) and herd size (Wroński et al. 2003, Jankowska et al. 2014).

Cattle and especially cow farming is characterized by differences in the scale of production. According to Ziętara (2007), an increase in the profitability of dairy farms depends on the possibility of reducing unit production costs, their magnitude being determined to a considerable extent by herd size and milk yield of the cows.

The aim of the study is to analyse the effect of herd production level and herd size on the cows' lifespan and length of productive life.

MATERIAL AND METHODS

Using data from the SYMLEK database on 12,045 Polish Holstein-Friesian cows (Black-and-White variety) from 1,371 herds, belonging to the active population

in Pomerania and Kujawy, which first calved in 2008 and were used or disposed from the herds by the end of 2015. Procedures of FREQ and GLM from the SAS (2014) package were used in the statistical calculations. The following longevity indicators were calculated:

- lifespan = culling date – birth date;
- length of productive life = culling date – date of first calving;
- number of calvings.

Chi square test of independence (SAS 2014) was used to analyse the effect of herd production level and herd size on percentage of cows removed (sold or culled) or surviving until the end of 2015.

The longevity (Y) of culled cows (lifespan, length of productive life, number of calvings) was analysed as the effect of herd production level and herd size, using the following linear model (SAS 2014):

$$Y = \mu + a_i + b_j + e_{ij}$$

μ – overall mean;

a_i – effect of i -th herd production level ($\leq 6,000$, 6,001–7,000, 7,001–8,000, 8,001–9,000, >9,000 kg milk);

b_j – effect of j -th herd size (≤ 20 , 20–50, 51–200, >200 cows);

e_{ij} – random error of observation.

Significant differences were analysed with the Scheffé test.

RESULTS AND DISCUSSION

The average lifespan of the cows was 5.36 years (3.12 years for length of productive life). These results fall within the range reported by other authors (Sawa 2011, Chabuz et al. 2016). Comparison of chi square values (Tables 1 and 2)

shows that differences in the proportion of the cows sold, culled and alive were influenced more by herd size than by herd production level. The relatively high (over 13%) proportion of cows sold from lowest producing herds and from herds that had the lowest stocking rate may be indicative of appropriate breeding work, but could also be due to insufficient profitability of milk production in these herds. According to Hadley et al. (2002) and Wolf (2003), milk production costs are lower in large herds. McDonalds et al. (2013) believe that with the abolition of EU milk quotas, the best strategy is to expand the farms and to increase the number of cows in the herd.

Analysis of the results given in Table 1 shows that the herd production level (which, as an outcome of many factors, mainly environmental ones, often serves as a measure of the quality of rearing conditions) has a statistically significant effect on the proportion of cows sold, culled and alive. As the herd production level increased to 9,000 kg milk, so did the proportion of culled cows, from 78.73 to 95.79%. Pytlewski et al. (2014), when summarizing the findings of other authors, concluded that the increase in milk yield may be accompanied by increased herd culling, and by higher herd replacement and veterinary costs due to greater morbidity rates and reduced fertility.

In our study, we found the proportion of the cows sold and alive to decrease (from 13.05 to 1.96% and from 8.22 to 2.25%, respectively) as the herd production level increased to 9,000 kg milk. In the highest yielding herds (beyond 9,000 kg milk), the proportion of cows sold and alive each exceeded 3%.

TABLE 1. Proportion of the cows sold, culled and alive in herds with different production levels

Herd production level (kg milk)	Number of herds	<i>n</i>	%	Proportion (%) cows ($\chi^2 = 411.93^*$)		
				sold	culled	alive
≤6 000	492	2 214	18.39	13.05	78.73	8.22
6 001–7 000	410	2 719	22.57	6.07	88.67	5.26
7 001–8 000	285	2 913	24.18	6.04	90.59	3.36
8 001–9 000	112	2 044	16.97	1.96	95.79	2.25
>9000	72	2 155	17.89	3.11	93.32	3.57

$P \leq 0.01$.

TABLE 2. Proportion of the cows sold, culled and alive depending on herd size

Number of cows in herd	Number of herds	<i>n</i>	%	Proportion (%) cows ($\chi^2 = 532.11^*$)		
				sold	culled	alive
≤20	608	2255	18.72	13.61	79.03	7.36
20.1–50	623	4225	35.08	7.53	87.14	5.33
50.1–200	107	2748	22.81	3.42	93.20	3.38
>200	33	2817	23.39	0.64	97.16	2.20

$P \leq 0.01$.

The results presented in Table 2 show that the proportion of the cows sold, culled and alive varied ($P \leq 0.01$) according to herd size. The lowest proportion of culled cows (79.03%) was observed in herds with less than 20 cows. These herds were also characterized by the highest proportion of the cows sold (13.61%) and alive (7.36%). The herds with more than 200 cows had the lowest proportion of the cows sold (0.64%) and alive (2.20%), and the highest proportion of the cows culled (97.16%). Production in large herds can be mechanized and automated, which enables increasing the number of cows being managed per person. However, limited contact with the cows may make the attendants unaware of their individual characteristics and first signs of disease, leading to prolonged treatment and even early culling.

Table 3 shows the results for the effect of herd productivity and number of cows in the herd on longevity. The herd production level had no appreciable effect on the lifespan, length of productive life and number of calvings. The length of productive life was almost the same for all the cows. However, the number of calvings was higher for cows that yielded more than 7,000 kg milk per lactation, but the difference was not significant. The effect of the number of cows per herd on their longevity was confirmed statistically. Cows from the herds with up to 50 animals had the longest lifespan, the greatest length of productive life and the greatest number of calvings. Differences between the herds with less than 20 and 20–50 cows were not significant. Significant differences were observed between the herds of less than 50 and more than

TABLE 3. Effect of herd production level and number of cows in herd on cow longevity

Factor	Value	Longevity indicator					
		lifespan (years)		length of productive life (years)		number of calvings	
		<i>LSM</i>	<i>SE</i>	<i>LSM</i>	<i>SE</i>	<i>LSM</i>	<i>SE</i>
Herd production level (kg milk)	≤6 000	5.52	0.05	3.21	0.05	2.87	0.04
	6 001–7 000	5.36	0.04	3.08	0.04	2.79	0.03
	7 001–8 000	5.33	0.04	3.13	0.04	2.86	0.03
	8 001–9 000	5.25	0.04	3.08	0.04	2.83	0.04
Number of cows in herd	>9 000	5.36	0.04	3.17	0.04	2.93	0.04
	≤20	5.58 ^{AB}	0.05	3.43 ^{AB}	0.05	3.10 ^{AB}	0.04
	20.1–50	5.54 ^{CD}	0.03	3.34 ^{CD}	0.03	3.04 ^{CD}	0.03
	50.1–200	5.25 ^{ACa}	0.04	2.95 ^{ACa}	0.04	2.70 ^{ACa}	0.03
	>200	5.08 ^{BDa}	0.04	2.81 ^{BDa}	0.04	2.58 ^{BDa}	0.03

A, B, C, D – means within columns followed by the same letters differ significantly at $P \leq 0.01$;

a – means within columns followed by the same letters differ significantly at $P \leq 0.05$.

50 cows. As the number of cows per herd increased, their longevity, as assessed by all the indicators used in the study, was found to deteriorate. The decreasing number of calvings with the increasing stocking rate is considered unfavourable because this causes the cows to remain for less time in the herd, thus having a direct impact on the profitability of milk production (Forabosco et al. 2004, Sewalem et al. 2008). In the loose housing system, Sawa et al. (2008) showed that increasing the number of cows per herd (from less than or equal 50 to beyond 200) had a negative effect on the length of productive life, which decreased from 3.68 to 2.64 years. In the tie-stall system, the productive life was longest for cows from herds with less than or equal 50 animals and shortest for herds with 50.1–200 cows. Jankowska et al. (2014) reported the longer lifespan (5.91 years) for cows from herds of less than or equal 50 animals, while in larger herds, the lifespan decreased to 4.99 years (herds of

51–100 cows) and 4.81 years (herds with beyond 100 cows). The same authors observed a similar trend for the length of productive life and the number of calvings. Also other researchers (Sawa et al. 2000, Wroński et al. 2003) found that cows in smaller herds are characterized by better longevity, which they attribute to the individual approach to every animal and better care in small compared to more mechanized, larger herds.

CONCLUSIONS

In summary, it is concluded that with the increasing herd size and herd production level to 9,000 kg milk, the culling rate increased ($P \leq 0.01$) while the number of cows sold and alive decreased. It was also found that cow longevity was differentiated ($P \leq 0.01$) by the herd size. As the number of cows per herd increased, the lifespan and the length of productive life as well as number of calvings

decreased. The effect of herd production level on cow longevity was not confirmed statistically.

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Streszczenie: *Długowieczność krów w stadach o zróżnicowanym poziomie wydajności i wielkości.* W pracy wykorzystano dane z bazy SY-MLEK o 12 045 krowach z 1317 stad. Badane krowy były rasy polskiej holsztyńsko-fryzyjskiej odmiany czarno-białej i należały do populacji aktywnej Pomorza i Kujaw. Krowy wycieliły się po raz pierwszy w 2008 roku i były użytkowane lub usuwane ze stad do końca 2015 roku. Analizowano wpływ poziomu wydajności stada i jego wielkości na długowieczność. W obliczeniach statystycznych zastosowano procedury *FREQ* i *GLM* z pakietu *SAS*. Stwierdzono, że wraz ze wzrostem liczebności stada z równo lub poniżej 20 do powyżej 200 krów oraz poziomu wydajności stada

z równo lub poniżej 6000 do 9000 kg mleka zwiększał się ($P \leq 0,01$) stopień brakowania, zmniejszał się natomiast udział krów sprzedanych oraz żyjących. Wykazano, że wielkość stada różnicowała ($P \leq 0,01$) długowieczność krów. Wraz ze wzrostem liczby krów w stadzie skracala się długość życia i użytkowania krów, zmniejszała się liczba ich wycieleń. Wpływ poziomu wydajności stada na długowieczność krów nie został potwierdzony statystycznie.

Słowa kluczowe: krowy, mleko, długowieczność, poziom produkcyjny

MS received 14.09.2016

MS accepted 10.11.2016

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Dairy cattle crossbreeding and milk production

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Abstract: *Dairy cattle crossbreeding and milk production.* The aim of this study is to compare the results of milk performance of purebred Polish Holstein-Friesian (PHF) cows and their cross-breeds (PHF × SRB). Data for the analysis originated from the Polish Federation of Dairy Cattle Breeder and Producers – cows reports. The results indicate a positive influence of the breed on milk composition: fat, protein and dry matter content and somatic cell count. Purebred Polish Holstein-Friesian (PHF) cows had significantly higher ($P \leq 0.05$) milk yield for both the 100 and 305 milking days. The milk production of cross-breeds cows is lower by 15.89%, at 100 days of lactation, and by 34.57% in the full lactation than PHF.

Key words: crossbreeding, milk production, milk composition

INTRODUCTION

High production of HF is due to the systematic and consistent genetic improvement towards milk production as well as wide use in AI of dairy bull semen only the most genetically outstanding males. Unfortunately, besides significant improvement of cows' milk yield, the use of small number of bulls was a "bottle neck" of the breeding program which to decrease heterozygosity and in consequence increase the inbreeding level and caused inbreeding depression in many countries (Kania-Gierdziewicz 2006). Inbreeding depression caused

health problems, deteriorating both the production and reproduction results and increased frequency of the lethal genes.

The genetic tool which can be used to limit inbreeding and to improve the low inheritable functional traits is crossbreeding (Sørensen 2007). That is why for last several years, an increase interest of dairy farmers to implement this method has been observed (Heins 2007). Besides the inbreeding limitation this method produces beneficial heterosis effect, which is due to favorable combination of genes. The heterosis effect is growing as the genetic distance between crossed breeds increases. According to Hansen et al. (2005), the effect of heterosis for production traits can be as high as 6.5%, while for fertility, health and survival may be as high as 10%. An additional advantage of crossbreeding is the acceleration of genetic improvement (Cassell 2007).

The most advanced research in this area were carried out in the United States, where as reported by Hansen et al. (2005), in 2004 the level of inbreeding was average at 5%, and increasing rate at 0.1% per annum. Many countries has reached a critical level of inbreeding amounting to 6.25%, and in Canada, according to Schaeffer and Burnside (2011) the level of inbreeding ranged from 6–7%. Ac-

ording to the same authors, an increase of 1% inbreeding can cause about 200 kg drop in milk production.

The availability AI had a very large impact on breeders who could use bull semen of many different breeds. In Poland, the most common breeds used for crossbreeding are: Simmental (SM), Montbéliarde (MO), Jersey (JE), Brown Swiss (BS), Swedish Red (SRB), Norwegian Red (NR), Danish Red (RDM) and Normande (NO). The use of these breeds is possible due to the wide range of companies operating on the Polish semen market. Among these breeds more and more popular are two Scandinavian breeds: Scandinavian Red (SRB) and Norwegian Red (NR). This is mainly due genetic ability of these breed for improvement of the health and reproductive traits.

The aim of this study is to compare the results of milk performance of purebred Polish Holstein-Friesian (PHF) cows and their crossbreeds (PHF × SRB).

MATERIAL AND METHODS

Experiment was carried out at the Experimental Farm of Warsaw University of Life Sciences – SGGW at Wilanów. The research material consisted of 50 cows. The cows were divided into two groups. The experimental group consisted of 25 PHF × SRB crossbreeds (MM), and 25 pure PHF in the control group. All selected primiparous were at the same stage of lactation.

Data including information on milk performance, chemical composition of milk: fat, protein and dry matter content and somatic cell count originated from test day records and cow-heifers record.

Statistical analyzes of data were performed using one way ANOVA. Statistical analysis was performed using the program Statgraphics 15.2.11.0. The obtained results were presented in the tables and charts. The F-test was used to assess whether the expected values of a quantitative variable within several pre-defined groups differ from each other.

RESULTS AND DISCUSSION

Figure 1 shows the lactation curve of PHF and crossbreed (MM). The pure breed PHF characterized by 20.74% ($p \leq 0.05$) higher average daily milk production in each month during the first lactation. Similar trend was observed by Heins et al. (2006a), but in their experiment, the differences in milk production between PHF and crossbreeds were much smaller. According to the results presented in Figure 1, MM cows reached the peak of the production at the second month of lactation compared to PHF which characterized by the highest daily yield at third month of lactation. At this stage of the lactation PHF still produced over 16.5% more milk than MM primiparous. Well balanced lactation curve of both breeds indicated that feeding ratio of this cows well balanced.

Figure 2 shows the milk fat concentration changes during the first 10 months lactation. The fat content was significantly ($p \leq 0.05$) higher (on average by 11.96%) in milk of MM cows than PHF ones over the first 8 month of the lactation. Nevertheless, PHF milk at ninth month of lactation characterized by

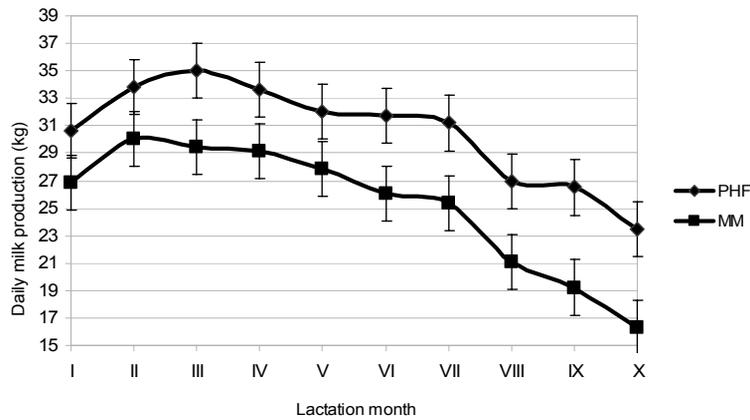


FIGURE 1. Lactation curve for pure PHF and MM

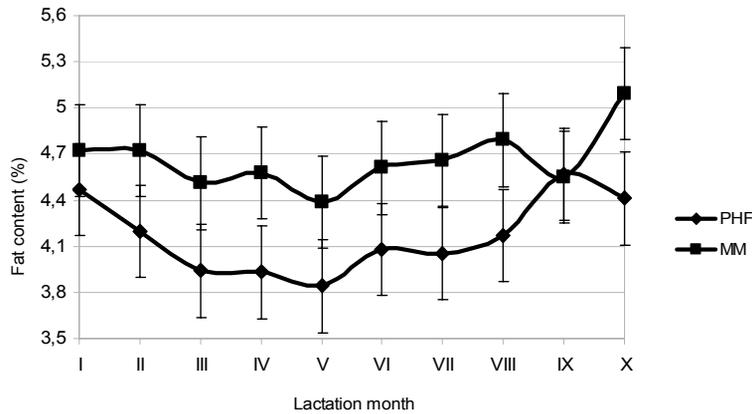


FIGURE 2. Milk fat content changes in milk of PHF and MM cows during the lactation

a higher fat content than MM ones. This could be due to the changes in cows feeding technology or/and feed quality. The average PHF cow at the end of the lactation (last 2 months of the lactation) produced over 8 kg of milk a day less than MM one what could explain significant increase in fat concentration as both milk and fat are negatively correlated. Moreover, lower milk production of MM cows resulted in quicker decision to move them to last feeding group where feeding rations mainly based on roughage. Elevated concentration of feeding

fibre had than direct effect on increased fat concentration in milk through higher production of octanes which are main precursors of milk fat.

Changes in milk protein content of PHF and MM cows during the lactation are presented in Figure 3. MM cows characterized by 9.13% higher protein content than PHF. The differences proved to be statistically significant ($P \leq 0.05$). A similar trend were observed by Petraškiēnēr et al. (2013) who indicated technological suitability of MM milk for cheese production.

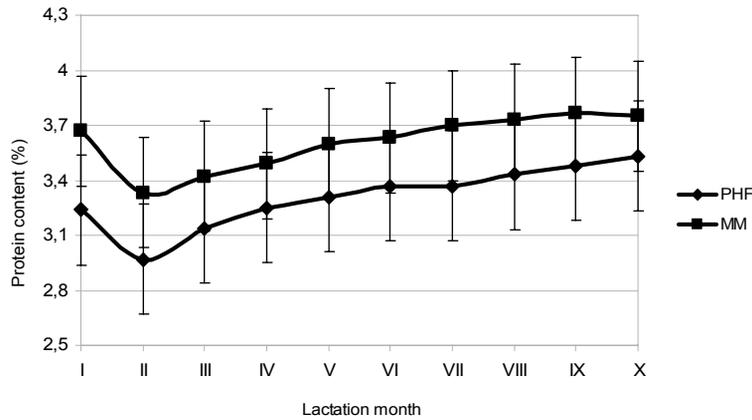


FIGURE 3. Milk protein content changes in milk of PHF and MM cows during the lactation

As the result of higher protein and fat concentration in crossbreed's milk, also the dry matter content in milk of MM cows was significantly ($P \leq 0.05$) higher (by average of 5.57%) – Figure 4. Osten-Sacken (2008), also reported the higher dry matter content in the milk of MM in his study. High dry matter content in milk positively correlated cheese yield, because of its better brevity, texture, cohesiveness, color and viscosity (Siemianowski et al. 2013). The increase of dry matter content at the ninth month of lac-

tation in PHF milk and its slight brake down in MM was probably caused by nutritional reasons.

Figure 5 shows the sinusoidal changes of SCC in milk of both breed in 10 months of lactation. It was observed that the SCC in milk of MM cows was lower by an average of 28.31% when compared to pure PHF. The same trend was observed in the study Osten-Sacken (2008), Begley et al. (2009), Heins and Hansen (2012). It can be concluded that MM primiparous were less prone to mastitis.

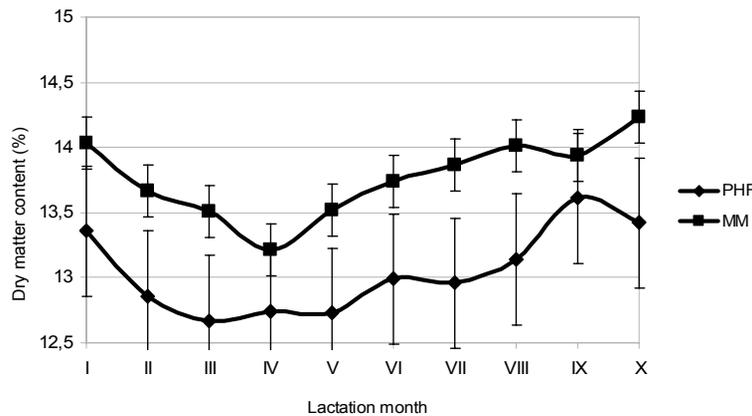


FIGURE 4. Changes in milk dry matter content of PHF and MM cows during the lactation

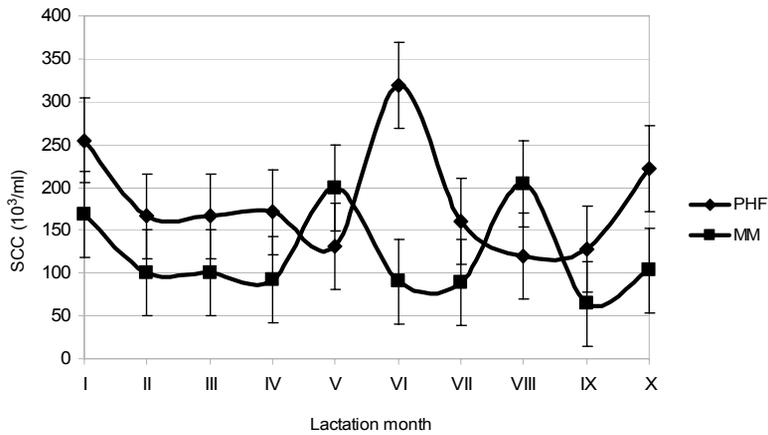


FIGURE 5. Changes in the somatic cell count (SCC) in milk of PHF and MM cows during lactation

Table shows the results of milk performance of studied cows at the first 100 days and full lactation. The milk production of MM cows is lower by 15.89%, at 100 days of lactation, and by 34.57% in the full lactation than PHF. The differences were statistically significant ($P \leq 0.05$). The large difference in milk production affected the fat yield both in 100 days and full lactation. In the first 100 day and full lactation PHF cows produced on average 4.44% and 11.98% respectively more milk fat than MM ones. Similar trend were observe in milk protein yield. Polish Holstein-Friesian cows produced 7.14 and 17.28% more proteins at 100 days and full lactation respective-

ly ($P \leq 0.05$). Production of milk components is much lower in MM than PHF despite the large difference in milk production. Opposite results were presented by Heins et al. (2006b), who stated that the production of fat and protein by the MM is at a similar to PHF. Milk production of crossbreeds was lower, however, there were no significant differences in milk components yield, such as fat and protein between pure and crossbreeds (Heins et al. 2006a). Study of Malchiodi et al. (2014) has proved that crossbreeds had a higher content protein casein in the milk than HF. Osten-Säcken (2008) reported that SRB crossbreeds were similar in the milk production with a higher

TABLE 1. Milk performance of PHF and MM primiparous

Breed	Milking days	Milk performance									
		milk (kg)		fat (kg)		fat (%)		protein (kg)		protein (%)	
		LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
PHF	100	3 341 ^a	38.26	141	1.58	4.2 ^a	0.03	105	0.79	3.14 ^a	0.02
	304	9 795 ^b	75.36	402	3.26	4.12 ^b	0.04	319 ^a	3.56	3.27 ^b	0.03
MM	100	2 883 ^a	35.12	135	1.79	4.65 ^a	0.05	98	0.88	3.4 ^a	0.03
	292	7 279 ^b	69.45	359	2.89	4.67 ^b	0.03	272 ^a	2.65	3.59 ^b	0.03

a, b – $P \leq 0.05$.

dry matter content and much lower (20 to 45%) somatic cells count, as well as improved reproduction rates compared to HF. According to reports of Petraškienė et al. (2013), hybrids (SRB) had a higher content protein than HF, but much lower than the pure SRB. According to results presented in Table MM lactation was shorter than PHF, what could influenced differences in milk production. Hansen's study (2005) reported the lactation persistence of crossbreeds was similar to pure HF.

Crossbreeding PHF with SRB bulls had a positive effect of cows during the first lactation, on the milk chemical composition (content of fat, protein and dry matter) and udder health (low SCC). However pure breed PHF characterized by significant higher milk production than MM.

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Streszczenie: *Krzyżowanie bydła ras mlecznych a użytkowość mleczna.* Celem pracy jest porównanie wyników użytkowości mlecznej czystorasowych krów (PHF) oraz mieszańców międzyrasowych F1 (PHF × SR). Dane do analizy pochodziły z raportów wynikowych i kart jałówki-krowy. Uzyskane wyniki wskazują na pozytywny wpływ rasy SR na skład mleka, tj. procentową zawartość tłuszczu, białka i suchej masy oraz liczbę komórek somatycznych. Czystorasowe krowy rasy

PHF charakteryzowały się istotnie wyższą statystycznie ($P \leq 0.05$) wydajnością mleka zarówno za 100 i 305 dni doju. Wydajność mleczna mieszańców za 100 dni laktacji była mniejsza o 15,89%, i 34,57% za laktację standardową niż wydajność krów rasy PHF.

Słowa kluczowe: krzyżowanie, wydajność mleczna, skład mleka

MS received 08.07.2016

MS accepted 27.10.2016

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Analysis of a fusion between rat glioma cells and biomimetic liposomes with encapsulated diamond nanoparticles or curcumin

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Abstract: *Analysis of a fusion between rat glioma cells and biomimetic liposomes with encapsulated diamond nanoparticles or curcumin.* Liposomes are used as carriers for different bioactive agents, both hydrophilic, which are encapsulated in water core of the liposome, and hydrophobic, which are entrapped within liposome walls. The walls are built from phospholipid bilayer, therefore their structure resembles cell membrane. It was hypothesized that if the wall is made of set of lipids typical for a cell, the liposome will be eagerly consumed by the cell. We performed the experiments using C6 rat glioma cells as an example, since central nervous system cells are extremely rich in lipids, including the unique ones. Since all cancer cells have high proliferation potential, they need to absorb precursors to build cell membrane around new cells, therefore such biomimetic liposomes may be one of the most effective way to deliver anticancer agents into the cell. Analysis of physicochemical properties of obtained liposomes, as well as *in vitro* tests, showed that obtaining such liposomes is possible and that the liposomes are biocompatible, stable carrier both for hydrophilic and hydrophobic agents. Encapsulation of diamond nanoparticles did not affect the liposomes, whereas entrapping of curcumin, which is a spice known in traditional Asian medicine for its anticancer properties, significantly increased its activity. Obtained results showed that biomimetic liposomes can be effective, individually-tailored carriers for bioactive agents.

Key words: glioma, liposomes, diamond nanoparticles, curcumin

INTRODUCTION

Intensive proliferation is one of the most prominent feature of all cancer cells, what allows them to rapid growth and to invade within an organism (Szala 2009). This feature is inseparable from the changed metabolism, since cell division requires cell membrane synthesis for newly arising cells, as well as energy storage in a form of lipid droplets. Thus, the changes include enhanced biosynthesis of lipids and highly enhanced intake of their precursors – cholesterol and fatty acids within lipoproteins. The mechanisms is especially noticeable within tumors in central nervous system (CNS), where cells are extremely rich in lipids, including the unique ones. It is known that in neural and glial cells membranes gangliosides are abundant, for example sphingomyelin which builds myelin sheath (Kłyszajko-Stefanowicz 2002). The lipid composition differs between normal and cancer cells, where there is less cholesterol and ratio of less complex to more complex gangliosides is higher than in healthy tissue (Baenke et al. 2013), what is important during

designing active agents delivery systems based on lipids, such as liposomes. Liposomes are artificially created vesicles composed from phospholipid bilayer, resembling cell membrane, where both hydrophilic and hydrophobic molecules can be transported (Mozafari 2004). For that reason they have been employed for successful delivering encapsulated agents such as drugs (Abreu et al. 2011), vitamins (Mozafari et al. 2008), dyes or nucleic acids (Sikorski et al. 2002). Since liposomes can be created from naturally occurring phospholipids, isolated from tissues, they are biocompatible and non-toxic. Usually, the composition comprises from one or a few most common phospholipids (e.g. lecithin) and cholesterol in a defined ratio. Considering the uniqueness of CNS cells, it was hypothesized that liposomes made of a lipid set typical for the cells might be one of the most effective way to deliver an agent into the cell, showing affinity to tumor cells, as for they need rapid cell membrane building, they eagerly consume necessary precursors.

In order to evaluate biocompatibility of the created liposomes the experiments were performed on rat glioma cells *in vitro* using liposomes that contained only water (“empty liposomes”). Furthermore, their applicability as a carrier for hydrophilic compounds was investigated employing diamond nanoparticles (DN). Their biocompatibility and active surface creates possibilities to use them as a platform for different ingredients (Grodzik et al. 2013), however they have a tendency to aggregation within an organism (Strojny et al. 2015). Liposomes can be solution for this problem, ensuring effective DN dispersion.

For the evaluation of delivering efficacy of hydrophobic agents, water-insoluble compound, which is curcumin (Cur), was chosen. It is a major active ingredient isolated from *Curcuma longa* rhizome, popular in traditional Asian medicine. Various biological activities of Cur has been demonstrated, including anticancer properties (Fan et al. 2014), however its usage is still restricted due to poor bioavailability (Anand et al. 2007), therefore functional carriers which increase Cur performance are still in search (Yallapu et al. 2012).

MATERIAL AND METHODS

Rat glioma cell culture

Rat glioma C6 cell line was obtained from the American Type Culture Collection. Cells were maintained in Dulbecco's Modified Eagle's Medium (Gibco™, Thermo Scientific, USA) supplemented with 10% foetal bovine serum (Gibco™), penicillin (100 U/mL) and streptomycin (100 mg/mL) and were maintained at 37°C in a 5% CO₂ and humidified atmosphere.

Liposomes preparation

Lipid film preparation and Cur encapsulation

Following steps were performed in three replicates. After obtaining cell monolayer (approximately $10 \cdot 10^6$ cells per 75 cm² bottle) medium was removed and cells were washed twice with cold PBS, then 2 ml of fresh PBS were added to collect cells by scratching and they were transferred to a 2 ml tube. After centrifugation (5 min, 400 × g), supernatant was

removed, 1 ml of dissolvent was added (chloroform : methanol, 1 : 2, v/v) and the pellet was vortex for 20 min. Then, 200 μ l of 0.9 % NaCl was added and the mixture was vortex for 5 min. before centrifugation (10 min, 500 \times g). When two phases with protein interphase appeared, the lower phase containing total lipid extract was collected into glass round-bottom tube. To one of the tube 36.8 mg of Cur (LKT Laboratories, USA) was added and mixed well in order to encapsulate Cur within liposomes hydrophobic walls. All tubes were evaporated under N₂ to total dry (approximately 1 h) in order to obtain lipid film. To remove the rest of the solvent, the film was lyophilized and stored tightly capped in -20°C.

Hydratation of films

To obtain control liposomes containing only water ("empty liposomes") or Cur, 1 ml of sterile ultrapure water (60°C) was added to tubes containing either clean lipid film or Cur film, in 100 μ l portions, mixing on vortex all the time (20 min). The same procedure was employed to encapsulate DN (Skyspring Nanomaterials Inc., USA); 1 ml of previously sonicated DN hydrocolloid (1,000 μ g/ml) was use instead of water. Suspensions were transferred into 1 ml tubes to ultrasound bath for 10 min to reduce size and lamella number in vesicles. Liposomes were stabilized for 1 h (RT) and stored in 4°C.

Determination of actual Cur concentration

Standard curve was prepared by series of 10x dilutions of 0.1 M solution of Cur in methanol. To determine Cur concentration in liposomes, 10 μ l of suspension was dissolved in 90 μ l of methanol. Ab-

sorbance was measured at 500 nm by Infinite® 200 PRO microplate reader with i-control™ Software (Tecan Group Ltd., Germany).

Transmission electron microscopy (TEM)

A droplet of a liposome suspension was placed onto formvar-coated copper grids (Agar Scientific, UK) and 10 μ l of 2% uranyl acetate was added for negative staining. After 2 min an excess was removed by filter paper. When totally dry, grids were inspected at 80 keV by TEM (JEOL, Japan).

Zeta potential and size distribution

The zeta potential and size distribution of liposome suspensions were determined after 120 s of stabilization at 25°C by the Dynamic Laser Scattering electrophoretic method with Smoluchowski approximation for zeta potential by Zetasizer Nano-ZS90 (Malvern, UK). The potential was also measured after 2 months of storage in 4°C to determine its stability in empty liposomes.

Fluorescent staining and fusion analysis

Stock of fluorescent dye [4-(didecyloamino)styryl] N-methylpyridinium iodide (DiA; Life Technologies, UK) was prepared by diluting in 99.99% ethanol (1 mg/ml). DiA shows affinity to phospholipid bilayer and fluorescence only in so bound form. Liposomes were stained by adding 1 μ l of stock solution to 1 ml of suspension. To measure dynamics of fusion between liposomes and glioma cells, cells were seeded on 96-well white-bottom plate at a density

of $1 \cdot 10^4$ cells/ml. The next day, the medium was removed and replaced with fresh medium containing dilutions of Cur at concentration 25 μM , stained liposomes with respective Cur concentration and stained empty liposomes with respective lipid concentration. Mean fluorescence intensity (MFI) of cells was measured at 0, 15, 30, 90 and 240 min time points, washing cells with PBS before readings to avoid background signal (separate wells for each of the time point, 6 replicates). Reading were performed at Ex/Em = 456/590 nm.

Cell proliferation assay

Cells were seeded as previously described on 96-well transparent microplates (Nest Scientific, USA). The next day, the medium was removed and replaced with fresh medium containing dilutions of liposomes, DN and Cur (at concentrations 50–100 ppm for DN, 25–50 μM for Cur and equivalent volumes of lipids in empty liposomes). Cell proliferation inhibition was assessed after 72 h by XTT assay (Sigma Aldrich, USA), where transparent soluble tetrazolium salt is converted to purple formazan crystals. Spectrophotometer readings were performed at 450 nm. Results were expressed as the percentage of the control group, which was 100%, and analyzed by ANOVA with Tukey's post-test. Differences with $P < 0.05$ were considered as significant.

RESULTS AND DISCUSSION

Presented results demonstrated that obtaining biomimetic liposomes produced of lipids isolated from glioma cells is possible, what was confirmed by meas-

urements of their physicochemical properties. TEM analysis showed typical images of liposomal vesicles, moreover, successful entrapping of DN in the water phase (the core of a liposome) was observed (Fig. 1). Size measurements also revealed that size of obtained liposomes was generally less than 1 μm and that all of the populations were not homogenic, what was expected due to lack of so-called calibration, the process which is needed for sizing liposomes. Most of the population for empty and Cur-entrapped liposomes has size around 100 nm, but for DN the size was rather around 1,000 nm (Fig. 2). However, this may result from free non-entrapped DN, which possibly may interference the measurements, since TEM analysis revealed that DN liposomes have similar size to the empty ones. Another parameter, zeta potential, was highly negative, about 40 mV, what clearly indicates on stable suspensions of liposomes without tendency to aggregation, even though DN have slightly negative impact, the potential still remained 14 mV. What is important, the potential of empty liposomes, measured after 2 months of storage in 4°C, remained ap-

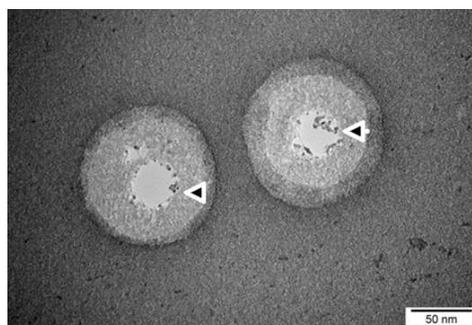


FIGURE 1. TEM photography of example liposomes. DN visible inside of the vesicles (arrows). Scale bar 50 nm

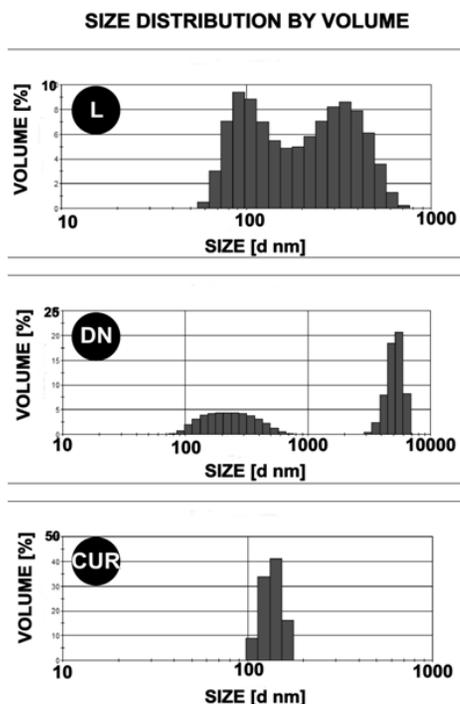


FIGURE 2. Size distribution of liposomes: L – empty, DN – with DN and CUR – with Cur

proximately the same, confirming liposomes stability.

In order to determine if liposomes are consumed by their source cells time-dependent analysis of fusion between the cells and fluorescently marked liposomes was performed. Since Cur is hydrophobic, it was entrapped within the liposome wall, which consist of phospholipid bilayer. Theoretically, it might have negative impact on fusion between the cells and liposomes, since it is the wall which has first contact with the cell membrane. Therefore, also fusion of Cur-entrapped liposomes was also compared. The analysis revealed very rapid increase of fluorescence in C6 glioma cells, what was clearly visible 30 min

since the treatment. Importantly, Cur encapsulation did not affect the dynamics of fusion (Fig. 3).

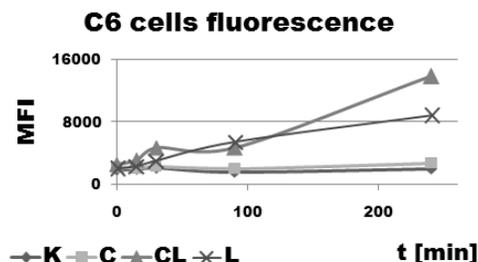


FIGURE 3. Mean fluorescence intensity (MFI) of C6 cells after treatment with dyed empty liposomes (L) and with Cur (CL). K – control cells, C – control cells treated with Cur

Finally, it was determined if the liposomes are biocompatible, meaning that the empty ones should not affect the cells, and if they are feasible as a carrier for hydrophilic and hydrophobic agents. Proliferation assay did not show any important impact of empty liposomes on C6 cells. There was also no visible difference between DN-treated cells and cells treated with DN-liposomes (Fig. 4), what showed that DN encapsulation has no negative impact hereby, since DN were proven previously to be

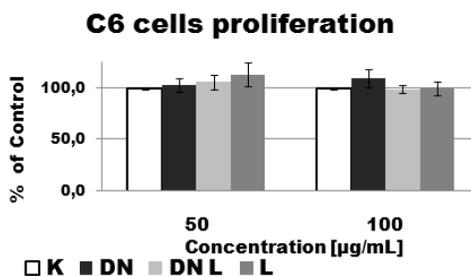


FIGURE 4. Mean proliferation of C6 cells after the treatment with: DN – diamond nanoparticles DN L – liposomes with DN, L – empty liposomes. No statistically significant differences between the groups ($P > 0.05$), ANOVA, Tukey post-test

non-toxic (Kurantowicz et al. 2015). It creates a possibility to employ the liposomes as a dispersing carrier for DN, which can serve as a platform for different chemicals. As for Cur, inhibition of cancer cells proliferation is one of Cur known activity, although observed mostly *in vitro* due to poor availability within living organism. When comparing Cur suspended in water and entrapped in liposomes in identical concentrations, we observed significant effect on C6 cells. Cur-encapsulated liposomes with 50 μM of Cur significantly decreased the cells proliferation, comparing to 50 μM of bare Cur and to control cells (Fig. 5). The observed effect is important, since it indicates on Cur bioavailability increase after entrapping in liposomes walls, making the liposomes promising carrier of Cur or any other hydrophobic agent within a living organism.

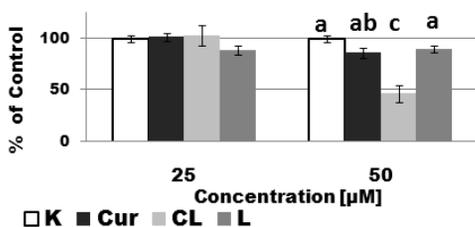


FIGURE 5. Mean proliferation of C6 cells after the treatment with: K – control (no treatment), Cur – curcumin; CL – liposomes with Cur, L – empty liposomes. Different letters indicate significant differences between the groups ($P < 0.05$). ANOVA, Tukey post – test. No significant differences for concentration 25 μM ($P > 0.05$)

CONCLUSIONS

In the presented studies possibility of creating biomimetic liposomes from total lipids isolated from rat glioma cells was

confirmed. The liposomes are biocompatible and can serve as a carrier both for hydrophilic and hydrophobic agents. Encapsulation of DN did not have negative impact on liposomes, what makes them good dispersive carrier for those non-toxic nanoparticles. Entrapping Cur within liposome walls significantly increased Cur activity and did not affect liposomes sorption by cells. Obtained results creates a possibility of production of personally tailored carriers for bioactive agents, which are biocompatible, effective and safe due to isolation of ingredients from host tissue biopsies.

Acknowledgement

This work was supported by Warsaw University of Life Sciences – SGGW grants 505-10-070400-L00297-99 and 505-10-070400-M00449-99.

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- Streszczenie.** *Analiza fuzji pomiędzy komórkami glejaka szczurzego i liposomami biomimicznymi z enkapsulowanymi nanocząstkami diamentu lub kurkuminy.* Liposomy są wykorzystywane jako nośniki dla biologicznie aktywnych związków, zarówno hydrofilowych, które są enkapsulowane w wodnym rdzeniu liposomy, jak i hydrofobowych, które mogą być zamykane w jego ścianie. Ściany liposomów zbudowane są z dwuwarstwy fosfolipidowej, przez co strukturalnie przypominają błonę komórkową. Założono, że jeżeli taka ściana zostanie stworzona z zestawu lipidów charakterystycznych dla danej komórki, liposomy będą chętnie pobierane przez taką komórkę. Wykonano doświadczenie, w którym jako przykład użyto komórek glejaka szczurzego linii C6, ponieważ wiadomo, że komórki centralnego systemu nerwowego są wyjątkowo bogate w lipidy, włączając w to także te nietypowe. Ze względu na to, że wszystkie komórki nowotworowe charakteryzuje wysoki potencjał proliferacyjny, muszą one pobierać prekursory niezbędne do budowania błony komórkowej wokół nowopowstających komórek. Liposomy biomimiczne mogą być więc jednym z najbardziej skutecznych sposobów na dostarczenie związków przeciwnowotworowych do takich komórek. Analiza właściwości fizykochemicznych, a także testy *in vitro* pokazały, że otrzymanie takich liposomów jest możliwe i że liposomy te są biozgodnym, stabilnym nośnikiem zarówno dla związków hydrofilowych, jak i hydrofobowych. Enkapsulacja nanocząstek diamentu nie wpłynęła na wytworzone liposomy, podczas gdy zamknięcie w ścianie kurkuminy, która jest znana w tradycyjnej medycynie azjatyckiej ze względu na swoje właściwości przeciwnowotworowe, istotnie podniosło jej aktywność. Otrzymane wyniki pokazały, że liposomy biomimiczne mogą być efektywnymi, indywidualnie dopasowanymi nośnikami dla związków biologicznie czynnych.
- Słowa kluczowe:* glejak, liposomy, nanocząstki diamentu, kurkumina
- MS received 05.10.2016*
MS accepted 14.11.2016
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Characteristics of hair coat in European bison

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Abstract: *Characteristics of hair coat in European bison.* The subject matter of the study was to analyse chosen characteristics of hair coat of 40 European bison (living in the Białowieża and Borecka forests), representing two age groups. Hair samples were collected in winter from the middle part of the animals' abdomen. They were used to determine the share of the hair fraction, the thickness within a fraction, the features of hair surface and its diameter. Hair fractions (down and medullated) were distinguished on the basis of differences in the hair length. The share of a fraction was determined according to the quantity of fibres within a fraction. The thickness of the fibre was measured by microprojection. Anatomical structure of hair was analysed on the basis of images from a scanning electron microscope. The studied hair coat showed predominance of the down fraction, i.e. thin, woolly, non-medullated hair. Its average share was higher in young European bison ($P \leq 0.05$) where it amounted to 73.41%, whereas in older animals it represented 65.50%. Higher share of down fraction in the fur of young animals was correlated with smaller hair diameter – both in down fraction and in the whole hair coat – namely 26.67 and 32.78 μm , respectively. Fibre diameter in the fur of mature animals was larger – 50.12 μm on average – i.e. 39.19 μm in the down fraction which proved perfectly even in terms of hair thickness and 91.71 μm in the medullated fraction. Animals representing the two age groups showed differences in the thickness of down fraction, medullated fraction as well as hair coat in general ($P \leq 0.01$). Discrepancies of hair thickness in young animals are worth noting. The presence of the core was observed in the long and thick guard hair (in 41.38% of it). The fibres featured predominantly continuous medulla (64.2%). Differences between down and guard hair were observed also in the structure of cuticle.

Key words: European bison, hair coat, hair thickness, medullary structure

INTRODUCTION

European bison's skin – just as is the case in most mammals – is covered with hair composing the so-called hair coat. The hair coat has different structure and appearance depending on its topographic distribution. Long hair on the lower neck forms a beard which starts with a triangular tuft of hair that can exceed 35 cm in length. Hair on the front parts of the body (flanks, withers and neck) is long and frizzy, thick on the head, slick by the muzzle (Olech et al. 2008). The rest of the body is covered with shorter hair.

Colour of the hair coat in European bison has a protective function. It is determined by fawn-brown hair with a reddish or greyish shade, lighter-coloured in summer than in winter. Cheeks, lips area and the tip of the tail are usually darker than other parts of the body (Raczyński 1978). In spring, in order to adapt to the changing weather conditions, European bison moult, i.e. shed the worn-out structures of the skin and replace them with new ones. Sleekness of the summer hair coat and a quick process of moulting are symptomatic of good condition and health of an animal.

Hair coat plays multiple roles: it controls water balance, contributes to thermoregulation and protects from negative impacts of the environment. It consists of hair varied in terms of length, thickness, resistance, colour and sheen (Kraśnińska and Kraśniński 2004). Not all of these features are equally important, nor can each one of them be subject to laboratory evaluation. Every assessment starts with determining the most important qualitative parameter – the hair thickness – as all of the other features are to a smaller or greater extent related to it. Thickness is also one of the most important physical characteristics of the hair.

The study aimed at conducting a comparative analysis of the chosen features of hair coat in European bison representing two different age groups. The assessment focused also on the differences in sizes and in three-dimensional image of shapes of the anatomic structure elements in European bison hair.

MATERIAL AND METHODS

The study involved European bison from the Białowieska Forest (37 specimens) and Borecka Forest (3 specimens) representing two age groups (up to 1.5 and over 2.5 years old). The study material consisted of winter hair coat samples collected from the middle part of the animals' abdomen. They were used to isolate staples within which – on the basis of differences in the hair length – two fibre fractions were distinguished: inner and outer. Quantity of hairs making up the isolated hair coats was determined and the share was expressed in percentage. Then, fibre thickness in each frac-

tion was specified. This most important qualitative feature of hair (defined as the average diameter of the hair section) was established with microprojection method (PN-72/P-04900 standard) using MP3H lanameter at 500-fold magnification. All the hairs within the field of vision of the preparation made according to the standard were measured.

Simultaneously to the thickness measurement also the medullary structure of the outer fraction was determined. Individual fibres were classified into one of four categories of hair: with continuous medulla, with intermittent medulla, with fragmented medulla and without medulla. Photographs of fibres were taken using NIKON ECLIPSE E 50i microscope with DS-Fi1 digital camera and NIS Elements D software.

The anatomic structure of hair was analysed on the basis of images from a QUANTA 200 scanning electron microscope made by FEI Company.

All the calculations were conducted using the SPSS 21.0 statistical package. The Kolmogorov–Smirnov test was applied to assess normality of the distribution of variables. All the variables – except for the share of medullated hair, with continuous and fragmented medulla – were characterised by normal distribution. The homogeneity of variance was assessed with the Levene's test. No homogeneity of variance was observed for the following variables: percentage share of down hair, number and thickness of the inner fraction hairs. Due to the small size of outer fraction hair sample, the differences in parameters of young versus adult animals' hair were estimated using the Mann–Whitney test. The t-test was used to assess the differences in pa-

rameters of down hair in young and adult animals, whereas the differences in parameters of medullated hair – because of the lack of normal distribution – were compared using the Mann–Whitney test.

RESULTS AND DISCUSSION

Hair coat in European bison is made of different anatomical types of hair, varied in terms of qualitative features, in particular thickness and length. The coexistence of various types of hair (Fig. 1) results in a clear-cut division of fibres into two basic fractions: short, thin, soft and woolly hair known as the down (inner) fraction versus long, stiff and thick guard hair of the medullated (outer) fraction. Each of them has different biologic functions (Pilarski 1962). The former plays a role in thermoregulatory processes, whereas the latter serves different protective purposes.

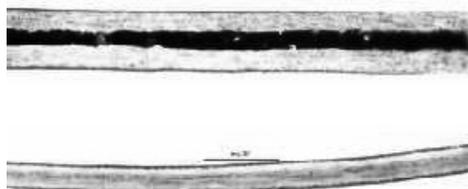


FIGURE 1. Comparison of down hair vs. guard hair structure in European bison

In all of the studied hair coats of European bison, a domination of down fraction was observed, i.e. of this thin, woolly, non-medullated hair. Its mean share in the hair coat was higher in young animals ($P \leq 0.05$) where it oscillated between 60.4 and 89.4%, whereas in mature animals it represented from 56.9 to 78.2% (Table 1). The share of down

fraction in hair coat changes with age: it is diminished and less diverse in older animals. Besides, the amount of down hair varies seasonally with an increase in winter (Sokolov 1962). Already in autumn, before the onset of cold season, down fraction starts to thicken forming an insulation layer.

The higher share of down fraction (73.41%) was correlated with smaller hair diameter – as well in down fraction as in the whole staple (Table 1). This is why – both in young and adult European bison – the most numerous, delicate down hairs have the smallest fibre diameter, namely 26.67 and 39.08 μm . Differences were recorded between the two age groups as regards the down fraction thickness ($P \leq 0.01$). The hair coat of adult animals proved perfectly even ($P \leq 0.01$) in terms of thickness.

Average diameter of the whole staple in animals younger than 1.5 years of age amounted to 32.78 μm and was lower ($P \leq 0.01$) than in animals older than 2.5 years where it reached 50.12 μm . Discrepancies of hair thickness in young animals are worth noting.

Hair coat of adult animals was characterised by a larger diameter of fibres (50.12 μm) and smaller discrepancies in the thickness of hair within the staple (Table 2).

With age, the hair coat of European bison undergoes numerous changes. The fibre is the thinnest during the first year of life and starts to thicken gradually as of the second year. In the following years the processes of changes within the fibre tend to stabilise.

The thickness of the stronger and longer guard hair of the outer fraction varied widely in the two age groups

TABLE 1. Share and thickness of down fraction and the whole staple in young European bison

Animal ID	Age (months)	Share of down hair (%)	Down fraction diameter			Staple diameter		
			number of hairs	mean (μm)	variation coefficient (%)	number of hairs	mean (μm)	variation coefficient (%)
892	4	89.4	711	26.71	22.92	800	29.76	37.24
873	5	76.1	809	24.90	26.19	676	40.04	47.18
874	5	63.2	379	26.67	23.27	707	29.56	39.80
920	5	61.6	645	26.54	28.45	712	29.01	37.20
923	5	63.2	640	22.67	19.86	686	24.34	33.39
891	6	87.9	1 038	27.62	25.02	758	32.06	43.82
925	6	61.1	646	26.46	21.66	741	30.03	39.87
894	7	83.3	953	28.28	23.42	717	32.75	44.32
911	7	63.2	436	28.77	27.47	501	33.44	42.76
912	10	73.4	496	24.12	19.30	565	27.94	44.06
899	11	60.4	425	27.22	21.89	781	43.35	44.89
898	13	70.1	567	26.94	22.12	802	35.71	44.10
902	14	70.2	434	29.90	20.63	618	41.77	50.89
881	15	89.5	860	25.77	23.24	627	29.23	40.30
895	17	88.5	1 144	27.43	23.10	711	32.65	35.35

TABLE 2. Share and thickness of down fraction and the whole staple in adult European bison

Animal ID	Age (years)	Share of down hair (%)	Down fraction diameter			Staple diameter		
			number of hairs	mean (μm)	variation coefficient (%)	number of hairs	mean (μm)	variation coefficient (%)
884	2.5	57.9	326	38.40	17.75	563	51.90	36.78
878	2.5	51.5	590	32.02	20.84	557	51.22	42.24
900	2.5	62.1	449	35.63	23.59	723	44.33	32.21
901	2.5	73.4	490	35.76	25.27	668	45.71	33.12
882	3.5	78.2	498	37.22	16.72	632	42.08	28.66
880	4.5	67.2	770	35.86	17.91	573	43.52	33.41
907	4.5	74.9	583	39.96	16.94	778	46.75	30.25
886	5.5	61.2	350	40.54	17.31	571	53.83	38.64
915	5.5	64.2	428	42.93	17.42	563	49.85	30.65
893	6	69.5	342	39.89	15.04	492	48.77	34.30
883	8.5	72.5	475	34.98	14.78	659	48.66	24.68
879	9	55.4	302	39.15	15.94	545	52.81	27.71
L522	9	77.8	637	35.21	18.50	725	46.88	33.22
L523	10	68.3	382	37.16	15.18	559	46.04	36.25
913	16	65.5	490	44.31	15.51	723	48.80	35.02
L555	18	56.9	456	38.95	17.53	527	50.54	27.42
906	19	58.3	244	39.29	19.24	652	61.92	37.17
903	20	60.2	204	44.40	19.48	457	60.79	43.63
896	21	72.5	324	41.41	17.07	447	50.06	29.84
897	23	70.2	354	44.96	14.09	559	55.02	25.71
890	26	57.7	426	42.62	15.84	739	53.02	27.99

(55.59–64.31 μm , 79.48–110.29 μm – Tables 3 and 4) reaching on average 61.08 and 91.71 μm , respectively. Differences between young and adult European bison were observed in the thickness of this hair fraction ($P \leq 0.01$). In young animals the thickness of the guard hair fibres was less homogenous ($P \leq 0.01$) – Table 5. It was specifically the guard hair that determined external features of the hair coat.

Within the outer fraction, composed – both in young and adult European bison – of the longest and thickest hair, the presence of medullated fibres was

observed. Their share in the coat varied widely (from 22.1 to 88.8%) and on average accounted for 41.5%.

The analysis of the core structure indicates the predominance of continuous medulla (63.8%) present at the whole length of a hair (Fig. 2). Being in both cases continuous, this type of core occupies more volume in adult and less in young animals' fibre. Sometimes the core takes an intermittent form (Fig. 3) or is present only in very short sections as the so-called fragmented medulla (Fig. 4). Within the studied hair coat the intermittent medulla was present in

TABLE 3. Thickness of guard fraction in young European bison

Animal ID	Age (years)	Outer fraction, guard hair diameter		
		number of hairs	mean (μm)	variation coefficient (%)
913	6	115	55.59	16.54
873	5	187	60.94	24.30
891	6	173	61.10	25.81
925	6	114	61.78	24.99
920	5	124	61.80	24.49
912	10	163	62.05	29.01
911	7	171	64.31	21.83

TABLE 4. Thickness of guard fraction in adult European bison

Animal ID	Age (years)	Outer fraction, guard hair diameter		
		number of hairs	mean (μm)	variation coefficient (%)
913	16	298	79.48	16.90
868	16	300	82.29	13.70
915	5.5	388	84.91	18.11
869	20	306	87.47	14.01
914	6	410	93.47	15.60
867	25	230	95.46	13.81
893	6	328	100.29	16.62
879	9	455	110.29	17.07

TABLE 5. Comparison of chosen traits of the hair coat in young versus adult European bison

Variable		Young			Adult			
		N	mean	SE	N	mean	SE	P
Share of down hair		15	73.41	2.97	21	65.50	1.70	0.030*
Down fraction thickness		15	26.67	0.47	21	39.08	0.77	0.000**
Staple thickness		15	32.78	1.39	21	50.12	1.11	0.000**
Outer fraction, guard hair thickness		7	61.08	1.01	8	91.71	3.63	0.001**
Medullated hair	percentage of hair	16	40.76	4.77	21	42.00	3.91	0.639
	continuous medulla	16	64.58	5.35	21	63.82	4.73	0.988
	intermittent medulla	16	20.64	2.75	21	19.12	2.31	0.705
	fragmented medulla	16	14.78	3.44	21	17.01	3.38	0.534

*Significant ($P \leq 0.05$); **highly significant ($P \leq 0.01$).

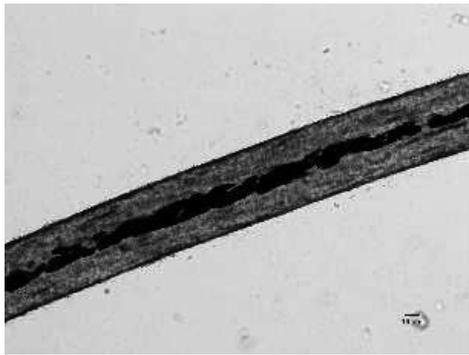


FIGURE 2. Continuous medulla in guard hair of European bison



FIGURE 4. Fragmented medulla in guard hair of European bison

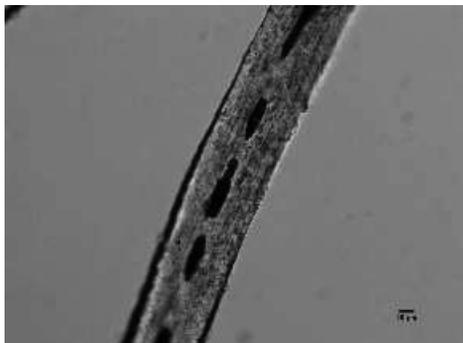


FIGURE 3. Intermittent medulla in guard hair of European bison

20.3% whereas the fragmented type in 15.9% of guard fibres in the outer fraction.

The main structural elements of the European bison hair are: the cuticle (a surface, epithelial layer), the deeper-lying cortex and the central medulla.

The cuticle of the analysed hair consisted of groups of cells taking a form of characteristic scales (*squamula cuticulae*) surrounding the hair and building its surface (Lutnicki 1977). Those polygonal, irregular scales arranged in several paral-

lel rows along the hair axis overlap one another like roof tiles. Their edges are uneven and slightly protruding, whereas the surface is modifiable: the layout, shape and size of scales can alter following a change in the hair thickness (Figs 5, 6).

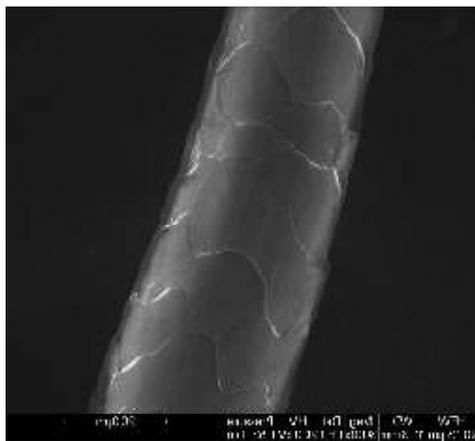


FIGURE 5. Arrangement of cuticulae scales on the surface of down hair

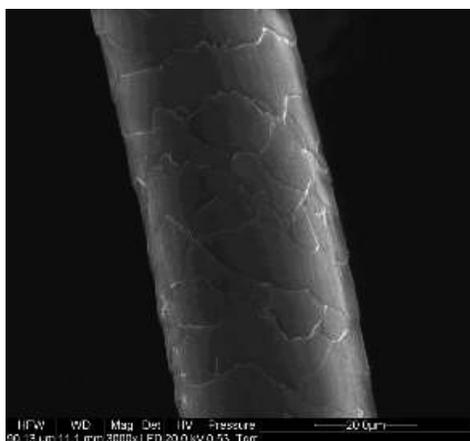


FIGURE 6. Uneven, serrated edge of guard hair cuticle

The surface layer of the European bison hair plays a crucial role: it serves as a barrier protecting from diffusion of various external substances into the cor-

tex, boosts the abrasion resistance of the hair and conditions its sheen (Szytych and Olech 2013).

The cortex constitutes the main body of the hair. It is composed of elongated, fusiform cells running parallel to the fibre growth direction (Ryder and Stephenson 1968). These are actually the cortex cells that determine the hair properties.

The medulla of the European bison hair, built of soft keratin, is arranged into a loose and porous weave. It is composed of polygonal, shrivelled dead cells with entirely cornfield protoplasm (Czernowa and Celikowa 2004). Cells of the medulla contain air bubbles which are usually found also in the narrow space between cells (Fig. 7).

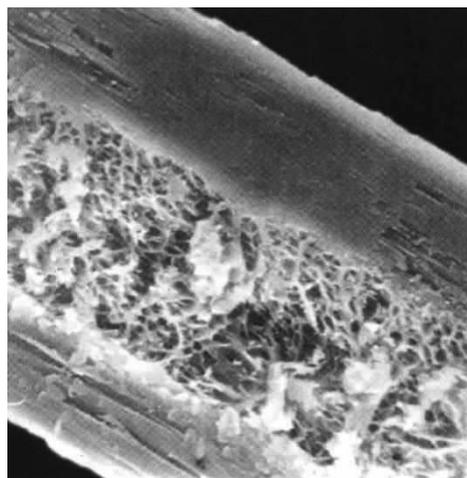


FIGURE 7. Cortical and medullary layer in vertical section of a bison hair

The presence of medulla in the hair coat of the European bison may be related to the animal's adaptation to the environmental conditions. Significant temperature fluctuations require a proper protective system whereas hair with an air-filled medulla offers a perfect insulation layer.

CONCLUSION

All the tests conducted point to a significant qualitative diversity of the hair coat of the study animals. It is demonstrated by the coexistence of different hair types within the hair coat, which is the outcome of the spatial arrangement in which they grow, the properties of the skin and finally the nature and the impact of environmental factors.

With age, the hair coat of European bison undergoes numerous changes. In adult animals the share of the inner, down fraction diminishes (increasing by the same the share of the outer fraction, i.e. guard hair), which results in hair thickening.

A characteristic trait of the studied European bison hair coat was its medullary structure dependant on the hair thickness. The diversity of medulla, the most changeable part of hair, provided the greatest number of distinctive features when determining the European bison hair type. It was absent in the woolly and thin down hair, while the probability of its occurrence grew with the increase in diameter. This correlation was registered in each of the studied hair coats.

All of the guard hairs were medullated to a smaller or greater extent; most of them featuring a continuous type medulla.

Differences between down and guard hair were also observed in the structure of the cuticle scales.

Acknowledgement

The study was undertaken with funding from the Polish Ministry of Science and Higher Education – grant 2516/B/P01/2009/37.

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Streszczenie: *Charakterystyka okrywy włosowej żubra.* Badania dotyczyły analizy wybranych cech okrywy włosowej 40 żubrów pochodzących z dwóch grup wiekowych. Próby włosów pobrane zimą posłużyły do określenia udziału frakcji włosów, grubości w obrębie frakcji oraz cech powierzchni włosów i ich przekrojów. Frakcje włókien (wewnętrzna i zewnętrzna) wydzielono na podstawie różnic w długości włosów. Grubość włókien określono metodą mikroprojekcyj-

na. Budowę anatomiczną włosa analizowano na podstawie obrazów ze skaningowego mikroskopu elektronowego. W badanej okrywie stwierdzono dominację warstwy wewnętrznej, czyli cienkich, bezrdzeniowych włosów puchowych. Jej średni udział we włosach młodych żubrów był większy ($P \leq 0,05$) i wyniósł 73,41%, zaś u dojrzałych zwierząt 65,50%. Większy udział frakcji wewnętrznej w okrywie młodych osobników, determinował mniejszą średnicę zarówno warstwy włosów wełnistych, jak i całego zespołu włosowego i wyniósł odpowiednio 26,67 i 32,78 μm . Okrywa włosowa dojrzałych osobników charakteryzowała się grubszą średnicą włókien (50,12 μm), przy czym średnia grubość, doskonale wyrównanej pod względem grubości warstwy wewnętrznej, wynosiła 39,19 μm , a zewnętrznej 91,71 μm . Zarejestrowano różnice w grubości frakcji wewnętrznej oraz zewnętrznej, a także całego zespołu włosowego ($P \leq 0,01$) między osobnikami należącymi do dwóch grup wiekowych.

Zwraca uwagę złe wyrównanie grubości włosów młodych osobników. W warstwie zewnętrznej, w długich, grubych włosach pokrywowych odnotowano występowanie rdzenistości (w 41,38% włosów). Dominowały włókna z rdzeniem ciągłym (64,2%). Stwierdzono różnice w budowie kutikuli włosów wełnistych i pokrywowych.

Słowa kluczowe: żubr, okrywa włosowa, grubość włosa, rdzenistość

MS received 18.05.2016

MS accepted 04.10.2016

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Mean body weight gains in standard mink depending on the number of kits in a litter

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Abstract: *Mean body weight gains in standard mink depending on the number of kits in a litter.*

The objective of the study is to determine the effect of litter size from which animals came on their weight at weaning and pre-slaughter, and as a consequence also on their mean daily gains. The study was conducted on a population of 330 minks, divided into groups depending on the size of litter from which they came: I (2–4 kits) – 74 animals (44 ♂, 30 ♀), II (5–7 kits) – 170 animals (92 ♂, 78 ♀), III (8–10 kits) – 86 animals (44 ♂, 42 ♀). We established a significant effect of litter size on body weight at weaning and mean daily gains. Animals from smaller litters were found to have a higher body weight at weaning; whereas higher gains were observed in animals coming from bigger litters. Pre-slaughter body weight was similar in all assessed groups.

Key words: mink, daily gains, litter size, body weight

INTRODUCTION

Female fertility, meaning the number of offspring in a single litter, is a decisive factor in successful and profitable mink breeding. It varies from 2 to 15 animals, with the mean value at 6–7 animals. Fertility is shaped by a number of genetic and environmental factors. It is largely influenced by polyspermy, which results from a female mating with more than one male (Sulik and Felska 2000). Multiple authors have reported that in two-

or three-year-old females, the number of animals born in a litter is much higher compared to one- or four-year-old females. Maintaining females for longer than four years is not cost-effective or efficient (Socha and Markiewicz 2001, Socha et al. 2003, Święcicka 2004, Felska-Błaszczuk et al. 2008). The higher the fertility in females, the higher the number of pelts obtained from them. Often, when a litter is too big, females struggle to feed the entire offspring, or kits reared in such litters are weaker and smaller. According to Lohi and Hansen (1990), body weight is positively correlated with pelt length; while Rozempolska-Rucińska et al. (2001) showed a negative correlation between body weight and pelt quality. Kubacki et al. (2010) observed that mink body weight has a positive effect on the final conformation score. High pelt prices at international auctions are largely influenced by both fur quality and pelt size.

The hypothesis adopted for this study is that the size of litter from which animals come affects their weight at weaning and prior to slaughter, and as a consequence also their daily gains. If this is confirmed, breeders will be able to take action earlier in order to obtain bigger pelts from minks.

MATERIAL AND METHODS

The study was conducted in the years 2014–15 on a mink farm in Poland, on the total of 330 standard mink, including 180 males (98 animals in 2014, and 82 animals in 2015) and 150 females (86 animals in 2014, 64 animals in 2015). The kits evaluated over two years came from the same dams (two-year-olds in 2014, and three-year-olds in 2015). The fathers are difficult to establish, as female minks mated two or three times with different males. The animals were all fed the same food, depending on maintenance requirements in respective breeding periods determined according to feeding standards (Gugolek et al. 2011). In each of the analysed years, animals were divided into three groups depending on the sizes of litters from which they came, and then they were divided further within these groups depending on their sex: I (2–4 kits) – 74 animals (44 ♂, 30 ♀), II (5–7 kits) – 170 animals (92 ♂, 78 ♀), III (8–10 kits) – 86 animals (44 ♂, 42 ♀). Animals were weighed twice: after weaning (at the age of seven weeks) and prior to slaughter (at the age of approx. seven months), using electronic scales. After seventh week of their lives, mink were kept at the same density, two animals of either sex in each cage (♂, ♀). Based on body weight data, we calculated daily body weight gains in mink using the following formula:

$$P = \frac{Mc_2 - Mc_1}{D}$$

where:

P – daily body weight gains;
 Mc_1 – body weight at weaning;

Mc_2 – pre-slaughter body weight;
 D – number of days from weaning to slaughter.

We characterised analysed traits statistically, calculating the arithmetic mean and standard deviations. Then we used the fixed effects model (GLM) and calculated the analysis of variance, applying the fixed model with an interaction. We incorporated the following effects into the model: year, sex, litter size:

$$y_{ijk} = \mu + R_i + S_j + P_k + (R \cdot S)_{ij} + (R \cdot P)_{ik} + (S \cdot P)_{jk} + e_{ijkl}$$

where:

y_{ijk} – body weight at weaning, pre-slaughter body weight, daily gains;

μ – general mean;

R_i – the i year effect;

S_j – the j sex effect;

P_k – the k effect of litter size;

$(R \cdot S)_{ij} + (R \cdot P)_{ik} + (S \cdot P)_{jk}$ – the effect of interactions between factors;

e_{ijkl} – random error.

Additionally, to enable estimation of the relations between the assessed traits, we calculated the Pearson correlation coefficient (Kot et al. 2011). The correlation was calculated on the basis of primary data. In order to verify the significance of differences between the group, we applied the Scheffé's test. All calculations were made using the Statistica PL. 9.0 data analysis software (StatSoft Inc. Statistica).

RESULTS AND DISCUSSION

Data from Table 1 show that the biggest population was constituted by group II animals (5–7 in a litter) – 92 ♂ and 78 ♀.

TABLE 1. Statistical characteristic of body weight at weaning in standard mink

Year	Statistical measures	Number of animals in a litter						Significant differences between groups	
		Group I (2–4)		Group II (5–7)		Group III (8–10)		♂	♀
		♂	♀	♂	♀	♂	♀		
2014	<i>n</i>	24	15	52	48	22	22	I, II, III*	III–I, II*
	\bar{x}	928.5 ^A	636.6 ^A	792.1 ^D	634.6 ^D	727.6 ^G	571.3 ^G		
	<i>SD</i>	231.3	33.9	47.3	41.8	142.2	114.4		
2015	<i>n</i>	20	15	40	30	22	20	I, II, III*	III–I, II*
	\bar{x}	956.4 ^B	640.1 ^B	796.6 ^E	630.5 ^E	777.6 ^H	586.2 ^H		
	<i>SD</i>	281.6	167.2	68.10	74.22	37.7	28.0		
Total	<i>n</i>	44	30	92	78	44	42	I, II, III*	III–I, II*
	\bar{x}	940.8 ^C	632.3 ^C	797.2 ^F	635.9 ^F	745.3 ^I	569.1 ^I		
	<i>SD</i>	265.4	109.4	57.7	61.4	107.7	92.1		

A, B, C – significant differences ($P \leq 0.01$) between sexes within a given group; * significant differences ($P \leq 0.01$) between a groups.

Mink coming from litters of 2–4 animals had higher body weight at weaning compared to other groups ($P \leq 0.01$). The lowest body weight, both in females as well as males, was found in group III (745.3 g ♂, 569.1 g ♀). No statistically significant differences were observed between the assessed years within the analysed groups. However, we established that in 2015 female and male body weights at weaning were slightly higher. Malmkvist and Palme (2008) proved that offspring of females with two births or older were on average heavier by 11–13%. The authors attribute it to bigger experience of dams which results in better care and rearing of kits. In our study, however, body weight varied depending on sex (Table 1). This is caused by the strongly developed sexual dimorphism in mink. Male body weight at weaning was higher during the two examined years compared to female body weight by approximately 200 g. Sławoń (1987) stated that animals of both sexes gain weight at the

same rate until day 10, and afterwards males begin developing quicker than females. The earliest differences may be observed in 30-day-old minks, when the body weight in males is higher by 9% compared to females. According to Lagerkvist et al. (1994), kit body weight at weaning largely depend on the size of litters from which they come as well as their mothers' lactation. The smaller the number of kits in a litter, the less intense the competition for food among siblings, resulting in a better physical development. Heavier and stronger animals are more capable of making sounds calling their mother and drawing attention. In mice and rats, sounds made by the young are important in taking them back to the nest because the mother gets a signal directing her to the stimulus (Ehret 2005). Similar dependencies were noted in mink by Clausen et al. (2008), who established that prior to being taken to the nest, kits first intensively call their mother. So, if an animal comes from a smaller litter,

this is the optimum situation for their development. This has been confirmed in studies by Lohi and Hansen (1990). They proved that mink from litters of 3–7 animals develop the best. Piórkowska et al. (2014), analysing the body weight in mink depending on the number of animals in a cage, concluded that body weight at weaning was at the same level in all of the examined groups; differences were noted in subsequent months when animals ate only solid food. In our study, we found that there was an effect of sex ($P \leq 0.01$) and litter size ($P = 0.02$) on the above trait; but the examined years had no effect on body weight at weaning. We did find interactions between the examined factors (year, litter size, sex) which influence body weight at weaning ($P = 0.004$).

Analysing the final pre-slaughter body weight, we established that in animals weighed at that time there were no significant differences between the examined groups. Similarly as with body weight prior to weaning, differences

between the sexes were also found at pre-slaughter weaning ($P \leq 0.01$). Body weight in females was at 1,600 g, and in males at 3,000 g (Tables 2 and 3). According to other authors, pre-slaughter body weight in mink, both in males as well as females, was approximately 2,000 g ♂ and 1,200 g ♀ (Piórkowska et al. 2004, Bielański et al. 2005, Piórkowska et al. 2014); whereas in a study by Pölönen et al. (1999) it equalled 1,800 g. Nurominen and Sepponen (1996) are of the opinion that mink stop to grow in mid-September, and any intensive feeding after that has a minimum effect on the final length of pelt. Lagerkvist (1997) established that pelts of mink born in big litters of approximately 10 animals were smaller. They also had a lower pre-slaughter body weight. Apart from feeding, the mean pre-slaughter body weight is significantly influenced by the placement of animals inside cages. Piórkowska et al. (2014) proved that adding another animal causes smaller body weights. However, it is difficult to deter-

TABLE 2. Statistical characteristic of pre-slaughter body weight in standard mink

Year	Statistical measures	Number of animals in a litter						Significant differences between groups	
		Group I (2–4)		Group II (5–7)		Group III (8–10)		♂	♀
		♂	♀	♂	♀	♂	♀		
2014	<i>n</i>	24	15	52	48	22	22	no significant differences between groups	
	\bar{x}	3 070.8 ^A	1 553.3 ^A	3 027.5 ^D	1 598.5 ^D	3 067 ^G	1 539.6 ^G		
	<i>SD</i>	214.6	147.6	187.5	134.9	157.7	138.25		
2015	<i>n</i>	20	15	40	30	22	20		
	\bar{x}	3 195.0 ^B	1 670.0 ^B	3 185.6 ^E	1 669.5 ^E	3 144.0 ^H	1 659.0 ^H		
	<i>SD</i>	408.78	161.0	199.0	343.6	186.0	129.9		
Total	<i>n</i>	44	30	92	78	44	42		
	\bar{x}	3 124.1 ^C	1 610.0 ^C	3 061.4 ^F	1 641.1 ^F	3 086 ^I	1 612.6 ^I		
	<i>SD</i>	337.8	150.9	208.7	268.8	162	135.2		

A, B, C – significant differences ($P \leq 0.01$) between sexes within a given group.

TABLE 3. The F_{emp} value and the significance of the effect of examination year, sex and litter size on body weight at weaning, prior to slaughter, and daily gains in brown mink

Factor	a F_{emp}/P	b F_{emp}/P	c F_{emp}/P
Examination year	3.22/0.07	1.24/0.267	2.90/0.08
Sex	149.89/0.001	1 806.46/0.001	1 275.54/0.001
Number of animals in a litter	3.89/0.02	3.01/0.05	5.043/0.007
Examination year × sex	14.25/0.002	1.00/0.95	2.041/0.153
Examination year × number of animals in a litter	13.16/0.003	1.85/0.15	6.224/0.002
Sex × number of animals in a litter	0.17/0.843	6.12/0.003	5.737/0.004
Year × sex × number of animals in a litter	10.40/0.004	3.64/0.03	6.272/0.02

a – body weight at weaning, b – pre-slaughter body weight, c – daily body weight gains.

mine the importance of litter size on the final pre-slaughter body weight. It can be assumed that kits from bigger litters with lower body weight at weaning, when moved to separate cages with the same number of animals and with constant access to food, recover body weight losses and grow faster than those which have a higher initial body weight at weaning; but the final body weight is similar in

all animals. In our study, we also established mean body weight gains, which in males were 16.8 to 18.0 g. Much smaller gains were registered for females (7.5 to 8.0 g). Furthermore, we found that sex ($P = 0.001$) and litter size ($P = 0.007$) had an effect on mean body weight gain in mink as well as interactions between the above factors ($P = 0.004$) which affect this trait (Tables 3 and 4). We ob-

TABLE 4. Statistical characteristic of daily body weight gains in standard mink

Year	Statistical measures	Number of animals in a litter						Significant differences between groups	
		Group I (2–4)		Group II (2–4)		Group III (2–4)		♂	♀
		♂	♀	♂	♀	♂	♀		
2014	n	24	15	52	48	22	22	I, II, III*	III–I, II*
	\bar{x}	16.5 ^A	7.1 ^A	17.2 ^D	7.4 ^D	18.0 ^G	8.2 ^G		
	SD	1.9	1.0	1.8	1.0	1.4	1.0		
2015	n	20	15	40	30	22	20	I–II, III*	I, II–III*
	\bar{x}	17.2 ^B	7.8 ^B	18.0 ^E	7.9 ^E	18.2 ^H	8.3 ^H		
	SD	2.9	2.0	3.2	2.7	1.4	0.9		
Total	n	44	30	92	78	44	42	I, II, III*	I, II–III*
	\bar{x}	16.8 ^C	7.5 ^C	17.4 ^F	7.7 ^F	18.0 ^I	8.0 ^I		
	SD	2.6	1.5	2.7	2.1	1.4	1.1		

A, B, C – significant differences ($P \leq 0.01$) between sexes within a given group; *significant differences ($P \leq 0.01$) between a groups

TABLE 5. Correlation coefficient (r_{xy}) for the number of animals in a litter and body weight at weaning, prior to slaughter, and daily gains, taking into account the sex of an animal

r_{xy}	Body weight at weaning		Pre-slaughter body weight		Daily body weight gains	
	♂	♀	♂	♀	♂	♀
Number of animals in a litter	-0.18**	-0.12	-0.01	-0.02	0.07	0.02

*Correlation high statistical significant ($P \leq 0.01$).

served statistically significant differences between the examined groups. Bigger gains were registered in mink from litters of 8–10 animals ($P \leq 0.01$) – Table 4. Based on correlation coefficients, we estimated relations within sexes between litter size and body weight at weaning, prior to slaughter, and mean daily gains. In males, there was a significant negative correlation between litter size and body weight at weaning: $r_{xy} = -0.18$ ♂ ($P \leq 0.001$), in females this value was $r_{xy} = -0.12$ ♀. Equally negative correlation in both males as well as females was found between litter size and pre-slaughter body weight of kits ($r_{xy} = -0.01$ ♂; -0.02 ♀). This proves that animals from smaller litters have a higher kit body weight after seven weeks of life, the same as when weighed prior to slaughter. Based on correlation results, it can be assumed that pelts obtained from these animals should be bigger. In our study, however, the values of correlation coefficients are very low in all cases; hence it is hard to presume that there is any strong dependency of these traits especially for pre-slaughter body weight. Similar results were obtained by Kubacki et al. (2010), who concluded that as the number of animals born in a litter grows, their body weight decreases ($r_{xy} = 0.034$). In our study, the correlation coefficient for litter size and mean

gains equalled respectively: $r_{xy} = 0.07$ ♂; -0.02 ♀). In this case, however, a positive correlation coefficient was found for both sexes (Table 5).

CONCLUSIONS

1. The adopted hypothesis has been partly confirmed. We established that litter size has a significant effect on body weight at weaning, and this in turn indirectly influences mink gains.
2. The highest body weight at weaning in both male and female animals was found in the group of mink coming from litters of 2–4 animals.
3. It was shown that the biggest body weight gains occur in animals from the largest litters of 8–10 animals.
4. Pre-slaughter body weight was similar in mink from all of the study groups.
5. Differences in terms of the examined traits were seen in both sexes. We established that males had higher daily gains as compared to females.

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Streszczenie: Średnie przyrosty masy ciała nerek odmiany brązowej w zależności od liczebności szczeniąt w miocie. Celem badań jest określenie wpływu wielkości miotu, z którego pochodziły zwierzęta, na ich masę przy odsadzeniu przed ubojem a w konsekwencji na średnie dobowe przyrosty. W badaniach wykorzystano populację 330 nerek, którą podzielono na grupy w zależ-

ności od wielkości miotu, z którego pochodziły zwierzęta: I (2–4 szczeniąt) – 74 szt. (44 ♂, 30 ♀), II (5–7 szczeniąt) – 170 szt. (92 ♂, 78 ♀), III (8–10 szczeniąt) – 86 szt. (44 ♂, 42 ♀). Stwierdzono istotny wpływ liczebności w miocie na masę ciała przy odsadzeniu i średnie przyrosty dobowe norek. Wykazano, iż zwierzęta pochodzące z mniejszych miotów charakteryzują się większą masą ciała przy odsadzeniu. Większe przyrosty natomiast zaobserwowano u osobników z bardziej licznych miotów. Masa ciała przed ubojem była zbliżona we wszystkich badanych grupach.

Słowa kluczowe: norka, przyrosty dobowe, liczebność w miocie, masa ciała

MS received 23.08.2016

MS accepted 27.10.2016

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Effect of management system on production results and slaughter value of fatteners

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Abstract: *Effect of management system on production results and slaughter value of fatteners.*

The studies were conducted in the farm, possessing three management systems and production of fatteners on litter-free (SB), shallow litter (SPS) and deep litter (SGS). There were managed 200 (SB), 446 (SGS) and 883 (SGS) four-breed fatteners (Landrace × Large White) × (Duroc × Pietrain), with the preservation of standards in respect of environmental parameters. After completion of 2-stage fattening, in which full-ration mixtures (from fattener body weight of from about 30 up to 120 kg) were employed, the animals were slaughtered. The effect of management system on growth rate and feed conversion (FCR) and slaughter value of pigs was evaluated. Daily gains for fatteners managed in SB, SPS and SGS systems were equal to 983, 971 and 845 g and FCR amounted to 2.71, 2.63 and 2.97 kg. The obtained results may be considered as very good ones. The deaths did not exceed 2% what is a good result. Meatiness of the fatteners kept in three discussed systems was higher than 58%, was very good and comparable in the groups. Qualification of the carcasses to the appropriate classes in EUROP system occurred to be most favourable for SGS (93.44% carcasses in classes S-E) although in the case of SB, all carcasses were classified into classes with a higher meatiness, that is, S-U. The results of fattening confirm the advantages of floor management system and its main superiority as compared to the systems of deep and shallow litter, whereas the results of slaughter evaluation indicate rather certain advantages of deep litter system. It seems, however, justifiable to utilize – in practice – different solutions in respect of management of the fatteners, with the indication to litter-free system as being more favourable in respect of the obtained production results.

Key words: fatteners, management systems, production results, slaughter value

INTRODUCTION

More than 20 years ago, the litter-free management system was considered as modern solution (Höges 1993), enabling application of new technologies (Richter 2011). It is employed in the regions with a high intensity of production of pigs. High density of animals results in the problems, connected with the need of supplying the litter materials and with the disposal of the produced manure. The mentioned system meets, however, the requirements of the best available techniques (BAT) of pig management (Hügler 2002, IBMER 2004, Romaniuk and Overby 2005); it makes also preservation of hygiene in piggery easier. In the pig houses with a littered concrete (solid) floor, hygienic quality of the straw is a serious problem as well as risk of fungal and parasitological diseases (Schnippe 2001). The choice of litter of litter-free system is most frequently determined by local management conditions. The litter-free housing or that one with a small quantity of the straw will be the future solution (Węglarzy et al. 2009, Baum 2012). The employed management sys-

tem specifies the solutions serving the storage of manure and its removal from piggeries and the level of ammonia emission (Pietrzak 2006). It creates also a smaller or greater threat to the animals, their health and the obtained production results (Kondracki et al. 2014).

In Polish piggeries, the animals are most frequently housed indoors, on a shallow litter. It was confirmed by the studies of Winnicki and Jugowar (2011), conducted in the Wielkopolska district, in the region with the highest population and intensity of pig production. In the discussed region, management of pigs on the shallow litter covers about 85–90% of the total pig population (sows, piglets, weaners and fatteners). The conducted analysis showed that floor (litter-free) system concerned 10.3% of the herds, keeping the weaners and 7.2% of the herds where the fatteners were kept; the population managed on the mentioned system was equal to 12.3 and 12.8%, respectively. On the deep litter, about 18% of weaners and fatteners were managed.

The effect of the management system of pigs on the result of fattening, slaughter value and quality of raw meat becomes the subject of interest and evaluation (Gentry et al. 2002, Carrapiso et al. 2003, Ventanas et al. 2007, Karpiesiuk et al. 2013). The obtained results do not allow, however, stating univocally which system of management of growing pigs affects especially more favourable the productivity and quality of meat obtained from the fatteners.

The aim of the paper is to determine the effect of the system of growing pig management on their production, fattening and slaughter results.

MATERIAL AND METHODS

The studies were conducted in the farm where three methods of management and obtaining the fatteners were carried out, i.e. litter-free (SB), shallow litter (SPS) and deep litter (SGS) systems. The conditions of pig keeping satisfied the requirements of the recommendations of the Ministry of Agriculture and Rural Development (Rozporządzenie MRiRW 2003, 2010). For fattening, hybrid weaners were purchased (Landrace × Large White) × (Duroc × Pietrain); they were characterized by a good health condition (free from *Mycoplasma hyopneumonia* and *Actinobacillus pleuropneumonia*). In litter-free system, 200 pigs were kept in total. On the day of introducing, the animals were classified into 5 groups, 40 pigs in each group; they were kept in the pens with an area of 42 m² each. In the system of shallow litter, 446 weaners were divided into 32 groups, 14 animals in each group; they were introduced to the pens with an area of 15 m² each. The pig fattening house, where the animals were kept on a deep litter, was divided into 13 chambers (compartments), with the area of 70 m² each; to each of them, 70 pigs were introduced. All animals, irrespectively on the management system, had the ensured constant access to dry feed (auto-feeder) and to water (automatic drinkers). The fatteners were fed the complete diet in two-stage system; their content and value have been given in Table 1. The feed was supplied automatically, using feed line to automatic feeders.

In the farm, the all-in/all-out procedure was employed; for disinfection of

TABLE 1. Raw materials of the feed mixtures, their energy and feeding value

Specification	Stage I of fattening – grower (from 30–70 kg b.w.)	Stage II of fattening – finisher (from 70 kg b.w./until the end of fattening)
Feed components (%)		
Wheat – meal	15	10
Barley – meal	36.5	25
Triticale – meal	30	50
Protein concentrate	17.5	15
Soya oil	1	–
Energy and nutritional value of the mixture		
Protein (%)	16.5	15.5
Lysine (g/kg)	11	10
Energy of the mixture (kcal/kg)	2 350	2 400

the premises or compartments, Famfluid and Rapticid (fumigation) were used. Additionally, preparations Agrisan/Virkon for dry disinfection of the floor were used once a month.

Microclimate in the fattening houses was controlled by mechanical ventilation; the mean temperature was equal to 16–17°C.

The health of the fatteners was examined as a prophylaxis; after transport, Doxymed and zinc oxide was employed. Periodically, individual animals were treated – depending on the needs – by the preparations administrated by injection or *per os* (Rapidexon, Floron, Amoxicillin, Fortamox, Tiamuline).

After obtaining slaughter body weight, the fatteners were slaughtered in meat manufacturing plants according to the binding procedures. Hot carcass weight and dressing percentage were determined; meatiness of carcasses was evaluated using ultrasound equipment Ultra-Fom 300; the carcasses were classified according to classes in EUROP system.

The results were statistically elaborated. The differences between the groups were determined by the Kruskal–Wallis test (IBM SPSS Statistics 23).

RESULTS AND DISCUSSION

To compare the suitability of different management systems, production criteria are employed such as the level of body weight gains, feed intake and conversion, health state of the animals and slaughter results. In Table 2, the results of fattening have been given.

The best daily gains were obtained by the fatteners kept in litter-free system, the comparable results were found in the case of shallow litter management. The animals kept on the deep litter were characterized by the weakest parameters of fattening. The differences in daily gains were as follows: SPS and SGS in relation to SB, respectively: 12 g (1.22%) and 138 g (14.04%). In the case of the deep litter management, the feed conversion per 1 kg of body weight gain was

TABLE 2. The effect of management system on the parameters of fattening

Traits	Management of fatteners			SEM	P
	SB	SPS	SGS		
Number of weaners for fattening (heads)	200	446	883	–	–
Mean body weight of weaners at commencement of fattening (kg)	29.85	29.15	31.84	0.746	0.925
Mean body weight of fatteners at slaughter (kg)	118.30	121.35	123.10	2.354	0.946
Death in fattening (heads / %)	1 / 0.50	3 / 0.67	14 / 1.58	–	–
Duration of fattening (days)	90	95	108	3.553	0.657
Body weight gain in fattening (kg)	88.45	92.21	91.25	1.762	0.758
Mean daily gain in fattening (g)	983	971	845	48.853	0.121
Consumption of mixtures in fattening per head (kg)	240.00	242.15	271.34	15.441	0.383
Feed conversion per 1 kg of body weight (kg)	2.71	2.63	2.97	0.298	0.374

SB – litter-free management; SPS – system of shallow litter; SGS – system of deep litter.

the weakest one; the fatteners used by 0.26 and 0.34 kg more feed as compared to SB and SPS, respectively. Fattening in the case of SGS was longer by 18 and 13 days in comparison to SB and SPS what indicates to the deterioration of productivity. Management of pigs on the deep litter is considered as one of the so-called pro-ecological methods of management (Dyrcz et al. 1995, Kreis et al. 1998). Dyrcz (1998) expresses the opinion that the litter improves the comfort of living and it allows increasing the body weight gains and abbreviation of fattening period; any such results were not recorded in our own studies. The technology of keeping the pigs on the deep litter and traditional management system (the so-called shallow litter) are employed quite often (Falkowski and Wernik 1998). They are characterized by better thermal conditions, they satisfy the natural needs of exploration, being

the important element of animal welfare but simultaneously, they constitute the better environment for development of pathogens and they are more labour-consuming (Kondracki et al. 2014). In spite of the prophylactic program, being employed in the own studies, the deaths of the animals were recorded and the percentage of them was recorded among the fatteners kept on the deep litter system. In the case of litter-free management, the cases of trauma of legs and cannibalism were found. Irrespectively of the employed system, the deaths in fattening did not exceed 2% and it is a good result.

In the own studies, a very good mean meatiness of carcasses was obtained (Table 3), being comparable with the results of other authors (Falkowski and Raubo 2007). It was similar in the groups what allows stating that value of the discussed factor was not affected by the management

TABLE 3. Weight of carcasses, indicator of dressing percentage and meatiness and participation of the carcasses, obtained from the fatteners kept in different management systems

Traits	Management systems			SEM	P
	SB	SPS	SGS		
Number of slaughtered fatteners (heads)	199	443	869	–	–
Hot dressing percentage (%)	81.00	78.31	79.56	1.548	0.837
Meatiness (%)	58.69	58.40	58.45	0.436	0.863
Participation of carcasses in classes (%)					
S	18.60	13.77	11.39	–	–
E	66.33	74.04	82.05	–	–
U	15.07	9.93	5.87	–	–
R	–	2.26	0.57	–	–
O	–	–	–	–	–
P	–	–	0.12	–	–

SB – litter-free management; SPS – system of shallow litter; SGS – system of deep litter.

system (Falkowski and Raubo 2007) but by a high genetic potential of the animals, used in fattening (Bojko and Rekiel 2014). In Table 3, the participation of carcasses in the particular classes of EUROP system has been presented. In total, the result of the participation in the classes with the highest meatiness – S and E, occurred to be the best in the case of the animals kept on the deep litter (SGS – 93.44%) whereas the results for two remaining systems were less favourable and comparable (SB – 84.93%, and SPS – 87.81%).

All carcasses, coming from fatteners kept in the litter-free system were classified into three best classes (S-U). The participation of the carcasses in class S was the highest one in SB management system as compared to SPS and SGS by 4.83 and 7.21 p.p., respectively. In the comparison, considering the participation of the carcasses, classified into classes S and E in total, SGS was the best: the domination in percentage points in comparison to SB and SPS was equal to 8.51 and 5.63 p.p., respectively.

CONCLUSION

The results, obtained in fattening indicate to the advantages of the litter-free management system and its principal domination over the shallow and deep litter systems; whereas the results of slaughter evaluation pay attention to certain advantages, resulting from a deep litter management. The practical application of different solutions in respect of fatteners' management, with the indication to the litter-free system as being more favourable in respect of the obtained results, seems to be justifiable.

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Streszczenie: Wpływ systemu utrzymania na wyniki produkcyjne i wartość rzeźną tuczników. Badania przeprowadzono w gospodarstwie dysponującym trzema systemami utrzymania i produkcji

tuczniaków, tj. bezściółkowym (SB), płytkiej ściółki (SPS) i głębokiej ściółki (SGS). Utrzymywano w nich odpowiednio 200 (SB), 446 (SPS) i 883 (SGS) tuczniaków czteroraszowych (Landrace × Large White) × (Duroc × Pietrain), z zachowaniem standardów w zakresie parametrów środowiskowych. Po zakończeniu dwufazowego tuczu, w którym stosowano mieszanki pełnoporcjowe (od masy tuczniaka ok. 30 do 120 kg), zwierzęta ubito. Oceniono wpływ systemu utrzymania na tempo wzrostu i zużycie paszy oraz wartość rzeźną świń. Przyrosty dobowe tuczniaków utrzymywanych SB, SPS, SGS wyniosły: 983, 971 i 845 g, a zużycie paszy na 1 kg m.c.: 2,71, 2,63, 2,97 kg. Uzyskane wyniki można uznać za bardzo dobre. Upadki nie przekroczyły 2%, co jest wynikiem dobrym. Mięsnosc tuczniaków utrzymywanych w trzech systemach wyniosła ponad 58%, była bardzo dobra i porównywalna w grupach. Kwalifikacja tusz do klas w systemie EUROP okazała się najkorzystniejsza dla SGS (93,44% tusz w klasie S-E), chociaż w przypadku SB wszystkie tusze zakwalifikowano do klas

o wyższej mięsności, czyli S-U. Wyniki tuczu potwierdzają korzyści systemu bezściółkowego oraz jego zasadniczą przewagę nad systemami głębokiej i płytkiej ściółki, a wyniki oceny rzeźnej na pewne zalety utrzymania na głębokiej ściółce. Zasadne wydaje się jednak wykorzystanie w praktyce różnych rozwiązań w zakresie utrzymania tuczniaków ze wskazaniem na system bezściółkowy, jako korzystniejszy pod względem uzyskiwanych wyników produkcyjnych.

Słowa kluczowe: tuczniaki, system utrzymania, wyniki produkcyjne, wartość rzeźna

MS received 06.07.2016

MS accepted 13.10.2016

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The effect of a housing system on production results and slaughter analysis of slow-growing chickens

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Abstract: *The effect of a housing system on production results and slaughter analysis of slow-growing chickens.* The study covered 720 Cobb × zielononóżka kuropatwiana (Cobb × Zk) chickens reared until the 63rd day of life. On the day of introduction to a hen house, the chickens were randomly divided into 2 groups: a control group (reared indoors – ID, 360 birds) and an experimental group (reared with outdoor access – OD, 360 birds), with 5 replications in each group (72 birds). The differentiating factor in the study was the possibility of using grassy free ranges up to the 28th day of life in the OD group. Individual body weight, feed intake and mortality rate were monitored throughout the production period. On day 63, 20 birds were selected at random from each group for slaughter (10 cocks and 10 hens, 2 from each replication). The selected birds had body weights similar to the average body weight for a given sex in a group. In total, 40 carcasses were dissected. The study demonstrated a significant ($P \leq 0.05$) effect of the access to a free range on the final body weight of hens. The housing system affected also the mortality rate of Cobb × Zk chickens. The birds having the access to the free range were characterized by a significantly ($P \leq 0.01$) lower mortality rate (0.55%) compared to the control birds (1.11%). In addition, the study showed a significantly ($P \leq 0.01$) lower carcass weight of cocks from the experimental group (OD, 1,491 g) compared to cocks from the control group (ID, 1,530 g) and a significantly lower weight of breast muscles (317 and 338 g, respectively). A similar tendency was observed in the case of hens, namely a lower carcass weight, breast muscle weight and fat weight in the group having access to grassy free ranges. The housing system had a significant effect of growth of the body weight of hens having the possibility of us-

ing grassy free ranges. The Cobb × Zk chickens characterized by high dressing percentage, similar contents of breast muscles and leg muscles as well as good health status, may be used as material for the rearing free range.

Key words: broiler, housing system, production results

INTRODUCTION

In Poland, the poultry production is based on the intensive system and utterly on fast-growing chickens. The contribution of meat types chickens reared with the possibility of using free ranges in the poultry production market is small. In the last couple of years, some withdrawal has been observed from the production of eggs and poultry meat under exclusively intensified conditions, whereas chicken production has been observed to increase under more extensive conditions and a lower stock density (Leinonen et al. 2014). Pietrzak et al. (2006) report that in Germany and France the meat of slow-growing chickens constitutes from 10 to 40% of the poultry meat available on the market.

Recently, the society has been expressing an increasing interest in the conditions of farm animals housing and

use. Growing demands of consumers regarding food products not only entail the concern about their nutritive value, health-promoting value and sensory traits, but also enforce the improvement of their quality (Krupiński et al. 2011). Contemporary consumers are aware of the relationship between wellbeing and the quality and safety of food. They are convinced of the better health status of chickens produced with the outdoor access and of the substantially better quality of their meat (Fanatico et al. 2008).

Sossidou et al. (2011) emphasize that – as a result of the selection process – the fast-growing chickens require a controlled rearing environment, which is not ensured outdoor. Considering the lack of local, slow-growing strains of poultry in Poland that could be used for chicken production in alternative systems, a need emerges for developing hybrids using both commercial production sets characterized by a high growth rate (Ross, Cobb, Hubbard) and conservation breeds (R11, S66, Z11, Z33, H22).

The conducted study was aimed at determining the effect of a housing system on production performance and slaughter analysis of Cobb × Zk chickens.

MATERIAL AND METHODS

The experiment was conducted at the RZD Wilanów Obory research station of the Warsaw University of Life Sciences – SGGW from the 2 August to the 4 October 2011. Experimental procedures were conducted accordingly to the guidelines of the Ethical Commission for Experiments with Animals 27/2009 of the 16 April 2009.

The study covered 720 Cobb × zielononózka kuropatwiana (Cobb × Zk) chickens reared until the 63rd day of life. On the day of introduction to a hen house, the chickens were randomly divided into 2 groups: a control group (reared indoors – ID, 360 birds) and an experimental group (reared with outdoor access – OD, 360 birds), with 5 replications in each group (72 birds). The differentiating factor in the study was the possibility of using grassy free ranges up to the 28th day of life in the OD group. The study was conducted in the period from 2 August to 4 October, during the experiment conditions were optimal. The area of the free range was dry with permeable soil and good insulation, and was covered with: ryegrass (*Lolium perenne* L.) (40%), red fescue (*Festuca rubra* L.) (50%), and smooth-stalked meadow-grass (*Poa pratensis* L.) (10%). The chickens were fed *ad libitum*, in a four-stage system (starter, grower I, grower II, finisher) – Table 1. The feed mixtures were free of coccidiostats.

Individual body weight, feed intake and mortality rate of chickens were controlled on days 1, 14, 35, 56, and 63 of rearing. On day 63, 20 birds were selected at random from each group for slaughter (10 cocks and 10 hens, 2 from each replication). The selected birds had body weights similar to the average body weight for a given sex in a group. They were fasted for 12 h, with *ad libitum* access to water, and then transported to a slaughterhouse. Carcasses were air-cooled at a temperature of 4°C for 24 h.

The 40 cooled carcasses, including 20 from the control group (ID) and 20 from the experimental group (OD), were weighed and dissected to determine:

TABLE 1. Nutritional value of feed mixtures

Nutritional value	Starter (1–11)	Grower I (12–24)	Grower II (25–56)	Finisher (57–63)
EM (kcal)	2 990.20	3 047.19	3 125.72	3 217.10
Total protein (%)	21.99	20.78	19.26	18.51
Fat	3.67	4.00	5.14	5.92
Dietary fiber	3.60	2.55	2.45	2.41
Ash	5.83	5.35	4.96	4.67
Lysine	1.38	1.28	1.19	0.97
Methionine + cystine	1.08	1.01	0.92	0.76
Available phosphorus	0.45	0.38	0.36	0.35

dressing percentage as well as the contribution of muscles and giblets (gizzard, liver, and heart) in carcass weight.

The results were analysed statistically by analysis of one-way variance. Statistics between group within sex. All calculations were carried out in a statistical package SPSS 21.0 (IBM).

RESULTS AND DISCUSSION

The study demonstrated a significant ($P \leq 0.05$) effect of the access to a free range on the final body weight of hens (Table 2). Regardless of the housing system, the cocks were characterized by similar body weights (2,168–2,171 g). The birds using grassy free ranges revealed a tendency for higher body weights. Both Gornowicz (2009) on day 63 of birds life and Fanatico et al. (2008) observed a significant ($P \leq 0.05$) effect of the rearing with outdoor access on the increased body weight of birds. In turn, opposite results were obtained by Skomorucha et al. (2007) in their study on the effect of broiler chickens (Cobb, Ross, Hubbard) reared until 42 days of life with outdoor access on their production results. They

observed a significantly ($P \leq 0.01$) higher body weight of birds produced in the conventional system. Branciaro et al. (2009) demonstrated the effect of both the housing system and the genotype on the final body weight of birds. They reported the highest body weights for the Ross chickens (4,202 g) reared under conventional conditions, that were significantly higher compared to the chickens reared with the access to grassy free ranges (3,434 g). Such a correlation was also observed by these authors for Kabir chickens characterized by a moderate growth rate (2,826 and 2,314 g, respectively) and for slow-growing Leghorn chickens (1,754 and 1,498 g, respectively).

The experiment conducted by Wang et al. (2009) indicated that the body weight of Gushi chickens reared with outdoor access (1,419 g) was significantly ($P \leq 0.05$) lower than of the birds kept indoors (1,610 g). The same correlation was observed by Castellini et al. (2002), Dou et al. (2009), and Połtowicz and Doktor (2011). Many authors, however, do not confirm the effect of the housing system on the final body weight of birds (Mikulski et al. 2011, Michalczyk et al. 2013, Sogunle et al. 2013).

TABLE 2. Body weight (g) of Cobb × Zk chickens in the rearing period ($n = 720$)

Sex	Group	Age (days)									
		1		14		35		56		63	
		\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
♂♂	ID	33	0.18	223 ^B	1.60	893 ^B	5.30	1 861	9.00	2 168	13.00
	OD	33	0.22	236 ^A	1.70	915 ^A	5.30	1 880	10.00	2 171	8.00
♀♀	ID	32	0.22	213 ^B	1.50	776 ^B	4.20	1 467 ^B	5.00	1 669 ^b	9.00
	OD	33	0.21	226 ^A	1.60	807 ^A	5.10	1 525 ^A	9.00	1 729 ^a	6.00

Explanations: control group (ID), experimental group (OD) – since day 28 the groups from experimental group were using grassy free ranges. Statistics between groups within sex: ^{a, b} – statistically significant differences at $P \leq 0.05$, ^{A, B} – statistically significant differences at $P \leq 0.01$.

In the production of boiler chickens, the food conversion ratio (FCR) is the key element of its cost-effectiveness for a producer. The presented study demonstrated the effect of the housing system on FCR values. The chickens reared with the access to free ranged had a significantly ($P \leq 0.01$) higher FCR value that reached 2.94 kg/kg of body weight gain (BWG), compared to the control birds (2.84 kg/kg BWG) (Table 3). Also Owens et al. (2006) and Leinonen et al. (2012) demonstrated that the access to a free range significantly increased the feed conversion ratio. Owens et al. (2006) observed such a correlation in both slow- and fast-growing chickens.

In the case of fast-growing chickens, the long-lasting selection directed at, e.g. reducing the feed conversion ratio, has caused that the FCR value does not exceed 2 kg/kg BWG in birds produced in the conventional system until 42 days of life (Połtowicz and Doktor 2011, Chen et al. 2013). Gruzewska and Biesiada-Drzazga (2008), who compared the commercial sets of broiler chickens, demonstrated the FCR values at: 1.89 (Hubbard F-15), 1.97 (Hubbard Flex), 2.03 (Ross PM3), and 2.06 (Ross 508) kg/kg BWG.

As reported by Fanatico et al. (2008) and Molee et al. (2011), higher FCR values are permitted in the longer rearing of slow-growing chickens. In turn, Michalczyk et al. (2013) showed no effect of the outdoor access on FCR values in slow-growing Hubbard JA 957 chickens reared until 63 days of life (2.32–2.33 kg/kg BWG), which confirmed findings of Sekeroglu et al. (2009) from a study on Ross chickens reared until 42nd day of life.

The housing system affected the mortality rate of Cobb × Zk chickens. The chickens reared with outdoor access were characterized by a significantly ($P \leq 0.01$) lower mortality rate (0.55%) compared to the control birds (1.11%). A similar tendency was observed by Michalczyk et al. (2013) – 3.9 and 4.7%. The unbeneficial effect of the access to a free range on the increased mortality of birds was reported by Fanatico et al. (2008), Mikulski et al. (2011), Połtowicz and Doktor (2011), and Leinonen et al. (2012). Fanatico et al. (2008) emphasized a significant increase in the number of dead birds in a flock in the fast-growing chickens reared in the elongated extensive system. These authors demonstrated a higher mortality

TABLE 3. Feed conversion ratio (FCR) and mortality rate of Cobb × Zk chickens in the entire rearing period (63 days), (n = 720)

Group	FCR (kg/kg BWG)	SE	Mortality rate (%)	SE
ID	2.84 ^B	0.70	1.11 ^A	1.10
OD	2.94 ^A	0.70	0.55 ^B	1.10

Explanations: control group (ID), experimental group (OD) – since day 28 the groups from experimental group were using grassy free ranges. Statistics between groups within sex: ^{a, b} – statistically significant differences at $P \leq 0.05$, ^{A, B} – statistically significant differences at $P \leq 0.01$.

rate (11%) in the fast-growing birds that were using free ranges compared to the control chickens (9%). In addition, they demonstrated a significantly ($P \leq 0.01$) lower mortality rate (3 and 0%, respectively) in the slow-growing birds kept under the same conditions. Łukasiewicz et al. (2013) also demonstrated a significantly ($P \leq 0.01$) lower mortality rate in slow-growing Hubbard JA 957 chickens (4.33%) compared to the fast-growing Hubbard Flex chickens (5.71%). In turn, Pietrzak et al. (2006) demonstrated that certified I 957 chickens reared outdoor were characterized by better health status and by a lower number of deaths compared to ISA 215 broilers, and especially to Hubbard chickens characterized by the highest mortality rate determined by these authors. Połtowicz and Doktor (2012) showed no effect of rearing

period elongation in the case of slow-growing chickens on the increase in their mortality rate, by achieving the mortality rate of 2.92% on days 56, 70, and 84 of rearing. Castellini et al. (2002), Branciarri et al. (2009) and Sekeroglu et al. (2009) emphasized that the fast-growing chickens are not adjusted to the production in alternative systems. In turn, Skomorucha et al. (2007) did not find any correlations between the housing system and mortality rate of birds.

The conducted experiment demonstrated a significantly ($P \leq 0.01$) lower carcass weight of cocks (1,491 g) from the experimental group (OD) compared to the control group (ID) – 1,530 g, and a significantly lower breast muscle weight (317 and 338 g, respectively) – Table 4. In the case of hens, a similar tendency was observed for a lower carcass weight,

TABLE 4. Slaughter analysis of Cobb × Zk chickens (g), (n = 40)

Sex	Group	Body weight		Carcass weight		Breast muscles		Leg muscles		Fat	
		\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
♂♂	ID	2 155	13.00	1 530 ^A	10.00	338 ^a	5.50	309	3.50	46	2.10
	OD	2 156	8.00	1 491 ^B	10.00	317 ^b	5.20	300	3.80	47	1.90
♀♀	ID	1 676 ^b	9.00	1 203	8.00	275	3.30	228	2.70	50	2.30
	OD	1 700 ^a	6.00	1 191	13.00	268	6.30	228	3.20	49	3.00

Explanations: control group (ID), experimental group (OD) – since day 28 the groups from experimental group were using grassy free ranges. Statistics between groups within sex: ^{a, b} – statistically significant differences at $P \leq 0.05$, ^{A, B} – statistically significant differences at $P \leq 0.01$.

breast muscle weight and fat weight in the groups having the access to grassy free ranges. However, no statistically significant differences were demonstrated. The cocks reared with outdoor access were characterized by a significantly ($P \leq 0.05$) lower breast muscle weight (317 g) compared to birds from the ID group (338 g).

Dressing percentage of the chickens reared with outdoor access ranged from 69.3 to 70.0% and was significantly ($P \leq 0.01$) lower compared to control birds (71.4–71.8%) – Table 5. Fanatico et al. (2008) and Wang et al. (2009) also demonstrated that the chickens using free ranges were characterized by a lower dressing percentage. In the case of certified I 957 chickens reared outdoors, Pietrzak et al. (2006) achieved dressing percentage at 69.4–69.8%. Gornowicz (2009) observed a lower dressing percentage in both Ross \times R-11 and Ross \times \check{Z} -33 hybrids using free ranges (71.25 and 71.12%, respectively) compared to the control group (71.57 and 71.29%, respectively), however the observed differences were not statistically significant. In turn, Połtowicz and Doktor (2011), Mikulski et al. (2011), Chen et

al. (2013), Michalczyk et al. (2013) and Sogunle et al. (2013) showed no effect of the housing system on dressing percentage of chickens.

Furthermore, the housing system was found to have no effect on the percentage content of breast muscles, leg muscles and adipose fat of Cobb \times Zk chickens (Table 5). Similar results were obtained by Gornowicz (2009) and Chen et al. (2013). The analyzed carcasses of Cobb \times Zk chickens were characterized by a similar contribution of breast and leg muscles (Table 5).

For many years, an increasing attention has been paid to the yield of breast muscles. In the case of the conventionally-produced fast-growing chickens, the percentage content of breast muscles may reach 30–31% (Pettracci et al. 2013), and is substantially higher than in the slow-growing chickens reared in alternative systems, in the case of which it may range from 18 to 22% (Skomorucha et al. 2008).

Our study demonstrated a tendency for a lower content of breast muscles in the carcass in the case of chickens using free ranges, which confirmed findings reported by Mikulski et al. (2011). In turn,

TABLE 5. Slaughter analysis of Cobb \times Zk chickens (%), ($n = 40$)

Sex	Group	Dressing percentage		Breast muscles		Leg muscles		Adipose fat	
		\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
♂♂	ID	71.4 ^A	0.28	21.9	0.37	20.1	0.23	3.0	0.13
	OD	69.3 ^B	0.35	21.2	0.25	20.1	0.20	3.2	0.13
♀♀	ID	71.8 ^A	0.22	22.8	0.24	19.0	0.19	4.1	0.18
	OD	70.0 ^B	0.75	22.4	0.42	19.2	0.21	4.2	0.24

Explanations: control group (ID), experimental group (OD) – since day 28 the groups from experimental group were using grassy free ranges. Statistics between groups within sex: ^{a, b} – statistically significant differences at $P \leq 0.05$, ^{A, B} – statistically significant differences at $P \leq 0.01$.

Połtowicz and Doktor (2011), Dou et al. (2009), Wang et al. (2009), and Castellini et al. (2002) demonstrated that carcasses of the chickens reared with outdoor access were characterized by a significantly higher percentage content of breast muscles. Owens et al. (2006), Wang et al. (2009) as well as Połtowicz and Doktor (2011) showed that rearing with outdoor access contributed to an increase in the percentage content of leg muscles, which was not confirmed in our study. Owens et al. (2006) suggest that it may be caused by increased physical activity of the chickens using grassy free ranges. In turn, Dou et al. (2009) demonstrated that the chickens reared outdoors were characterized by a significantly lower content of leg muscles in the carcass.

Our study, likewise experiments conducted by Dou et al. (2009), Gornowicz (2009), and Michalczuk et al. (2013), showed no effect of the housing system on the percentage content of fat in the carcass; its content ranged from 3 to 4%. Many authors emphasize that the production of chickens in alternative systems has a positive effect on a decrease in abdominal fat content (Castellini et

al. 2002, Wang et al. 2009), which was not confirmed in our study. According to Castellini et al. (2002) and Dou et al. (2009), the reduction in fatty tissue is affected by enhanced physical activity of the chickens using free ranges. In turn, Gornowicz (2009) as well as Połtowicz and Doktor (2011) demonstrated that rearing with outdoor access had a negative effect on fat content, by increasing its percentage content in the carcass.

The housing system was observed to influence the percentage content of giblets in the carcass of Cobb × Zk chickens (Table 6). The study demonstrated a significantly ($P \leq 0.05$) higher weight of liver and gizzard ($P \leq 0.01$) in hens and of heart in cocks with the access to free range.

Polak (2004) also demonstrated a significant ($P \leq 0.05$) increase in the weight of heart muscle in the birds produced in the extensive system compared to these reared in the intensive system. According to this author, the increase in heart weight noted in the birds reared with outdoor access was probably affected by enhanced cardiac muscle work induced by increased physical activity of the chickens using free ranges.

TABLE 6. Weight (g) and content (%) of edible giblets in carcasses of Cobb × Zk chickens ($n = 40$)

Sex	Group	Liver				Heart				Gizzard			
		g		%		g		%		g		%	
		\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
♂♂	ID	32.2	0.92	2.19	0.06	8.07 ^B	0.17	0.52 ^B	0.01	23.94	0.78	1.56 ^b	0.05
	OD	32.0	0.73	2.15	0.05	8.84 ^A	0.26	0.59 ^A	0.02	26.03	1.03	1.74 ^a	0.07
♀♀	ID	26.9 ^a	0.47	2.23 ^b	0.04	5.82	0.11	0.49	0.01	17.07 ^B	0.58	1.42 ^B	0.05
	OD	28.6 ^b	0.69	2.41 ^a	0.08	5.94	0.14	0.50	0.01	20.16 ^A	0.54	1.69 ^A	0.05

Explanations: control group (ID), experimental group (OD) – since day 28 the groups from experimental group were using grassy free ranges. Statistics between groups within sex: ^{a, b} – statistically significant differences at $P \leq 0.05$, ^{A, B} – statistically significant differences at $P \leq 0.01$.

Dou et al. (2009) and Wang et al. (2009) demonstrated a higher percentage content of gizzard in the slow-growing chickens reared in the free range system. These authors suggest that the higher weight of gizzard may be caused by the ingestion of insects, green forage, sand, and small stones. The increased content of crude dietary fiber through the intake of green forage may also contribute to its increased weight (Dou et al. 2009). As reported by Chen et al. (2013), the housing system has no significant effect on the content of edible giblets in chicken carcass.

CONCLUSION

The housing system had a significant effect of growth of the body weight of hens having the possibility of using grassy free ranges. The Cobb × Zk chickens characterized by high dressing percentage, similar contents of breast muscles and leg muscles as well as good health status, may be used as material for the rearing free range.

Acknowledgment

The study was conducted under the project “BIOFOOD – innovative, functional products of animal origin”, POIG.01.01.02-014-090/09-05 co-financed by the European Union from sources of the European Fund for Regional Development under the framework of the Operational Program Innovative Economy 2007–2013.

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Streszczenie: *Wpływ systemu utrzymania na wyniki produkcyjne i analizę rzeźną kurcząt wolno-rośnących.* Badaniem objęto 720 kurcząt Cobb × Zielononóżka kuropatwiana utrzymywanych do 63. dnia życia. W dniu wstawienia pisklęta losowo podzielono na 2 grupy: kontrolną (grupa bez wybiegu BW – 360 szt.) oraz doświadczalną (grupa z wybiegiem W – 360 szt.) po 5 powtórzeń w każdej (72 szt.). Czynnikiem różnicującym doświadczenie była możliwość korzystania z trawiastych wybiegów od 28. dnia życia w grupie W. Podczas trwania odchowu kontrolowano indywidualną masę ciała, spożycie paszy oraz śmiertelność kurcząt. W 63. dniu odchowu z każdej grupy wybrano do uboju po 20 szt. (10 kogutów i 10 kur, po 2 szt. z każdego powtórzenia)

o masie ciała zbliżonej do średniej dla danej płci w grupie. Przeprowadzono dysekcję łącznie na 40 tuszkach. Zaobserwowano istotny wpływ ($P \leq 0,05$) dostępu do wybiegu na wzrost masy ciała u kur. Kurczęta mające możliwość korzystania z wybiegu charakteryzowała istotnie mniejszą ($P \leq 0,01$) śmiertelność (0,55%) w porównaniu z kurczętami bez dostępu do wybiegu (1,11%). Zaobserwowano istotnie ($P \leq 0,01$) mniejszą masę tuszki kogutów (1491 g) z grupy doświadczalnej (W) w porównaniu z grupą kontrolną (BW) – 1530 g, oraz istotnie mniejszą masę mięśni piersiowych – odpowiednio: 317 oraz 338 g. U kur obserwowano podobną tendencję w grupie mającej możliwość korzystania z trawiastych wybiegów. System utrzymania wpłynął istotnie na wzrost masy ciała kur mających możliwość korzystania z trawiastych wybiegów. Kurczęta Cobb × Zk charakteryzują się dobrą wydajnością rzeźną, zbliżonym udziałem mięśni piersiowych i nóg oraz dużą zdrowotnością, mogą być wykorzystane jako materiał w chowie wolnowybiegowym.

Słowa kluczowe: kurczęta brojlery, system utrzymania, wyniki produkcyjne

MS received 10.10.2016

MS accepted 16.11.2016

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Analysis of the inbreeding level in the active population of pigs of different breeds in Poland

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Abstract: *Analysis of the inbreeding level in the active population of pigs of different breeds in Poland.* Pig breeders in Poland have made extensive use of the BLUP-AM method since 1999. The application of this method for evaluating the breeding value of pigs improves their breeding value in nucleus herds and in the general population. On the other hand, the use of many sources of information (including pedigree information) in the calculations considerably increases the risk of inbreeding. The objective of the study is to estimate the level of inbreeding in sows and boars from the domestic pig population, which have been selected for more than 10 years based on the BLUP-AM estimated breeding value. The study involved Polish Large White, Polish Landrace, Hampshire, Duroc, Pietrain and Puławska sows and boars born between 2007 and 2011. Data on a total of 16,842 sows and 977 boars representing the 6 breeds raised in Poland were collected for the pedigree analyses. During the analyzed period, the coefficient of inbreeding in sows (F) ranged from 0 to 0.25 (14 animals). Most of the animals were non-inbred (70% in the PLW and Puławska, over 80% in the PL, Duroc and Pietrain and 100% in the Hampshire). For the boars, the coefficient of inbreeding varied from 0 to 0.1875 (1 animal). The proportion of non-inbred boars was 77% in the PLW, 91% in the PL, 63% in the Puławska, and about 80% in the Duroc and Pietrain breeds. The results point to the appropriate structure of the pig population in terms of inbreeding, which shows that the selection of animals for mating has been correct and there have been no negative consequences of using the BLUP method.

Key words: pigs, inbreeding, BLUP

INTRODUCTION

In addition to the decreasingly popular selection index method, the breeding value of pigs in Poland is estimated by the BLUP-AM (Best Linear Unbiased Prediction-Animal Model). In Polish pig breeding, this method has been widely used since 1999. The application of the BLUP method for evaluating breeding value improves the breeding value of pigs in the nucleus population, as reflected in the results obtained in the general population. Long-term selection of pigs for lean meat production and daily weight gain has increased this parameter in the boars and gilts of all breeds (Eckert and Szyndler-Nędza 2015, Eckert et al. 2015). Using BLUP with information on relatives increases genetic progress but, on the other hand, though the use of many sources of information in the calculations when breeding material is intensively selected, it carries a significantly greater risk of inbreeding (Bijma and Woolliams 2000, Muir 2000, Żak and Różycki 2002, Żak and Różycki 2004, Colleau and Tribout 2008, Filistowicz 2015). Given that an excessive increase in inbreeding may lead to inbreeding depression, especially

with regard to low heritable traits associated with reproductive performance, it is essential that the level of inbreeding must be monitored for every breed raised in Poland (Mroczko and Różycki 2001, Szyndler-Nędza et al. 2014).

The inbreeding analysis performed in sows and boars born during 1989–1993 showed that average inbreeding in Poland was 0.0054 for sows and 0.0050 for boars, ranging from 0.0030 in Puławska pigs to 0.0176 in the Pietrain breed (Mroczko 1999). In the analyzed population, the inbreeding level of inbred sows and boars was similar – at 0.0344 and 0.0324, respectively. For sows and boars born in subsequent years, the inbreeding level increased as was found. Pedigree analysis performed by Szyndler-Nędza et al. (2013) for animals born between 2004 and 2010 showed an increase of inbreeding coefficient in the population of pigs of maternal breeds. Annual average changes in the coefficient of inbreeding in both populations (sows and boars) were 0.06% in the Polish Large White and 0.01% in the Polish Landrace pigs. Considering the negative effects of excessive inbreeding of animals in the active population, it is necessary and practically justified to perform periodic analyses of changes in the inbreeding coefficient separately in the sows and boars raised in Poland.

The studies involved analysis of inbreeding for the active population of the most frequent pig breeds in Poland. Currently, only information of single individuals has been utilized for mating. This kind of study was not considered earlier in Polish literature and in aspect of whole active boars and sows population.

The aim of the study is to estimate the degree of inbreeding in sows and boars from the domestic pig population, which have been selected for more than ten years based on BLUP-AM estimated breeding value.

MATERIAL AND METHODS

The study was performed at the National Research Institute of Animal Production and at the Institute's Experimental Station in Grodziec Śląski Ltd. The study involved Polish Large White (PLW), Polish Landrace (PL), Hampshire, Duroc, Pietrain and Puławska sows and boars born between 2007 and 2011. Pedigree data for a total of 33,569 sows and 2,926 boars were obtained for the study from available data sets.

Prior to determining the level of inbreeding, the completeness of data was analyzed in terms of the number of known ancestors of the sows and boars in different generations; this analysis was performed to calculate the pedigree completeness. Only animals with at least three complete generations of ancestors were included in the calculations. Following verification of the pedigree data, data for 16,842 sows and 977 boars representing 6 breeds in Poland were further used. The inbreeding coefficients were estimated based on the methods of Quass (1976) and Hendersson (1976) using the program Optimate 2000.

RESULTS AND DISCUSSION

In Polish pig breeding the use of BLUP together with information on relatives

significantly accelerates genetic progress in productive traits but, on the other hand, it may increase the degree of relationship in animals selected for parents of the next generation. As a result, inbreeding level in the population subjected to BLUP evaluation may increase and cause negative effects in breeding. We analyzed the level of inbreeding in the current pig population. Sows and boars born between 2007 and 2011 were investigated. Data were collected for a total of 16,842 sows and 977 boars of 6 breeds raised in Poland. The number of sows and boars in different breeds is presented in Table 1. Most of the animals originated from herds of 21–50 and 51–100 sows of the foundation stock. The number of sows and boars of all the studied breeds in herds with a different number of sows is shown in Table 2.

TABLE 1. The number of sows and boars of different breeds, born in the years 2007–2011, included in the study

Breed	The number of sows	The number of boars
PLW	6 244	319
PL	7 930	448
Puławska	1 462	144
Hampshire	16	–
Duroc	822	29
Pietrain	368	37
Total		
	16 842	977

The coefficient of inbreeding was estimated for the sows and boars. During the analyzed period, approximately 70% of the sows in maternal PLW and Puławska breeds were not inbred. Non-inbred sows accounted for over 80% in

TABLE 2. The number of sows and boars of all breeds, born in the years 2007–2011 in herds of different size of sows

Herd size (sows)	The number of sows	The number of boars
<5	2 209	167
6–10	99	10
11–20	1 442	66
21–50	8 097	492
51–100	3 003	193
>100	1 992	49
Total		
	16 842	977

the PL breed and the Duroc and Pietrain sire breeds, and 100% in the Hampshire breed (Table 3). The maximum value of the inbreeding coefficient in the sows was 0.25. Such a high degree of inbreeding was observed in 4 PLW sows, 2 PL sows, 5 Duroc sows and 3 Pietrain sows.

TABLE 3. Percentage of animals with inbreeding coefficient $F = 0$ in different breeds

Breed	Sows	Boars
PLW	74.98	77.14
PL	87.87	91.29
Puławska	71.89	63.89
Hampshire	100	–
Duroc	86.13	82.76
Pietrain	83.15	83.78

In maternal breeds (PLW, PL, Puławska) and in the Duroc breed, most of the sows had an inbreeding coefficient of 0.0156–0.0314 (13, 7.9, 18 and 7.9%, respectively), followed by 0.0625–0.125 (9, 3.6, 7.3 and 4.8%, respectively). The proportions for the Pietrain breed were the opposite, because in most sows the inbreeding ranged from 0.0625 to 0.125

(9.2%) – Figures 1–5. Compared to the inbreeding coefficients estimated by Mroczo (1999) for sows of different breeds raised in 1989–1993, it can be stated that over the last twenty years the number of non-inbred sows of the PLW, Puławska, Duroc and Pietrain breeds has diminished; whereas in the PL breed, the

number of animals with zero inbreeding is similar. The generally lower inbreeding coefficient in the breeds that were raised during the above period was influenced by the large number of sows whose inbreeding coefficient was up to 0.0313. In the active population, there were 77% and 73% of such sows in the PLW and

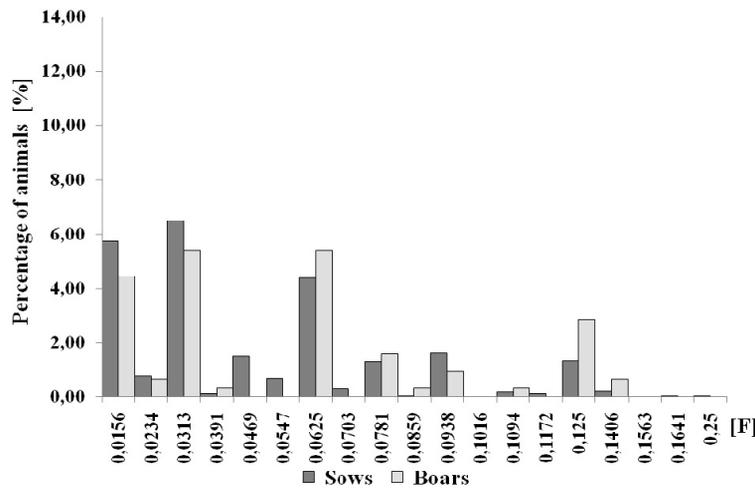


FIGURE 1. Distribution coefficients of inbreeding (F) in the population of animals – Polish Large White breed

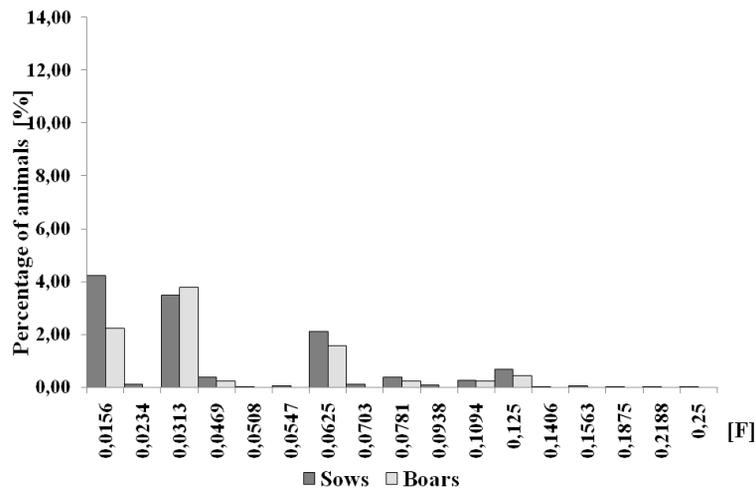


FIGURE 2. Distribution coefficients of inbreeding (F) in the population of animals – Polish Landrace breed

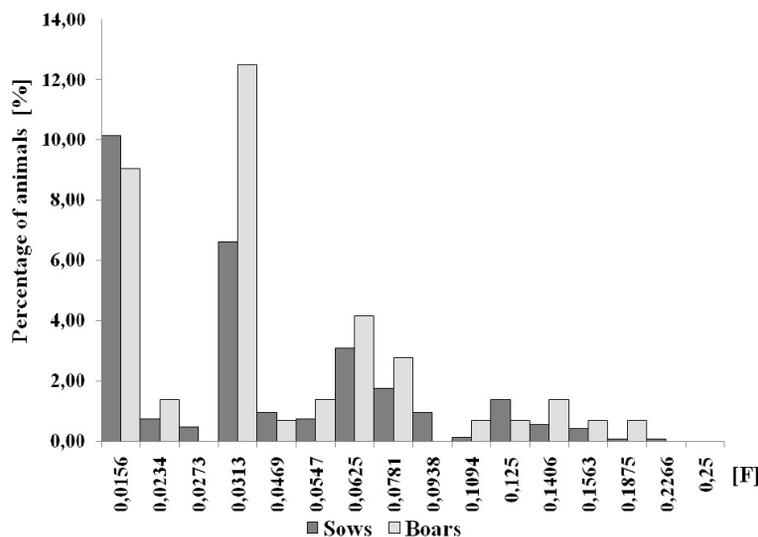


FIGURE 3. Distribution coefficients of inbreeding (F) in the population of animals – Puławska breed

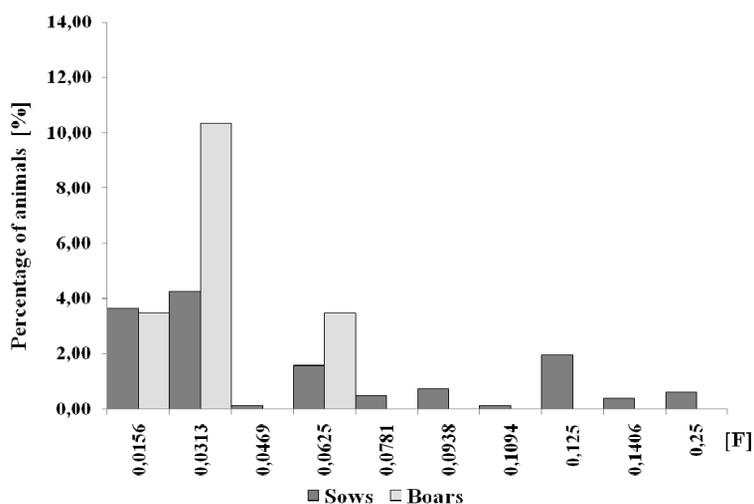


FIGURE 4. Distribution coefficients of inbreeding (F) in the population of animals – Duroc breed

PL breeds, 86% in the Puławska breed, and 69% and 73% in the Duroc and Pietrain breeds, respectively.

In the boars, the coefficient of inbreeding varied between 0 and 0.1875. Non-inbred boars accounted for 77% in the PLW breed, 91% in the PL breed, 63% in the Puławska and approximately

80% in the Duroc and Pietrain breeds (Table 3). The maximum coefficient of inbreeding was characteristic of one Puławska boar. When analyzing the distribution of males with specific inbreeding values in Figures 1–5, it was found that in the PLW breed most of the animals have inbreeding levels ranging from

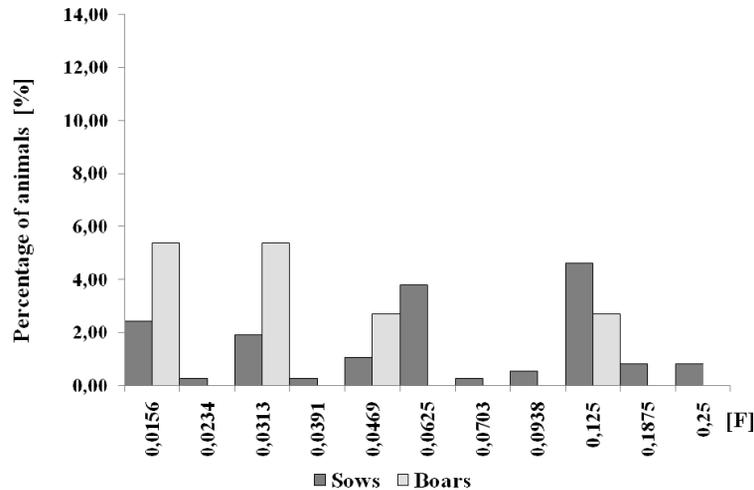


FIGURE 5. Distribution coefficients of inbreeding (F) in the population of animals – Pietrain breed

0.0625 to 0.1406. In the other breeds the situation was the opposite because most of the boars had an inbreeding value of 0.0156–0.0313. Such a distribution of the inbreeding coefficient may be due to the size of the population and the number of imported boars introduced into Polish farms. A low inbreeding is to be expected for large populations such as the PL, whereas in small populations, such as the Duroc and Pietrain, to which imported animals are often introduced, each imported boar contributes to a considerable decrease in the inbreeding coefficient within a given breed.

The relatively high number of sows with an inbreeding coefficient of up to 12.5%, boars with inbreeding of 6.25–14.06% (PLW), individuals with inbreeding of 12.5% (PL, Pietrain) and 12.5–18.75% (Puławska), found in the populations studied by other authors, increased the mean level of inbreeding in these breeds, which is particularly noticeable in the PLW (0.5%), Puławska

(2.5%) and Pietrain breeds (0.9%) (Szyndler-Nędza et al. 2013). Apart from the domestic populations, the inbreeding level of pigs of various breeds in different periods was also reported to increase in other countries. Welsh et al. (2010) found the inbreeding coefficient increased in pig populations raised in the United States in 2006–2009. These authors showed that 99% of the population was inbred, but most of the animals had inbreeding levels below 10%.

In large animal populations, the main reasons for losses in genetic variation and an accelerated increase in inbreeding are increased selection pressure, artificial insemination, which drastically reduces the number of sires, and the use of modern methods of breeding value evaluation, including the BLUP Animal Model (Rathje 2000, Colleau and Tributout 2008). Colleau and Tributout (2008), who considered the effect of different inbreeding reduction strategies on the preservation of genetic merit (breeding

value) in the French Landrace population, showed that only a proper choice of boars with a low coancestry coefficient for mating can reduce the value of the inbreeding coefficient in the population by an average of 21%, while introduction a proper choice of sows for mating will further contribute to decreasing the mean inbreeding coefficient in the population by another 11%. Therefore, efficient herd reproductive management is of the utmost importance in maintaining different herds, and thus whole populations of pigs within the permitted inbreeding levels.

CONCLUSIONS

The present findings show that the level of inbreeding in the domestic population of pigs is appropriate. This is evidenced by the estimated inbreeding coefficients, most of which are considerably lower than 10%, the value which is considered the limit of relationship that should not be exceeded to avoid the negative effects in breeding. The absence, or the low level, of inbreeding coefficients among pigs in the active population is indicative of the appropriate selection of both domestic and imported animals for mating, as well as the lack of negative consequences of using BLUP for estimating the breeding value of pigs.

Acknowledgement

Study conducted as part of statutory activity of National Research Institute of Animal Production in Kraków, project 01-1.11.1.

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- cji, w tym informacji rodowodowej, zwiększa się zagrożenie istotnego wzrostu stopnia inbredowania zwierząt. Celem pracy jest oszacowanie stopnia zimbredowania loch i knurów krajowej populacji świń, po kilkunastu latach stosowania selekcji bazującej na wartości hodowlanej szacowanej metodą BLUP-AM. Do badań zostały wybrane lochy i knury ras wielkiej białej polskiej, polskiej białej zwisłouchej, hampshire, duroc, pietrain oraz puławskiej, urodzone w latach 2007–2011. Do analiz rodowodowych pozyskano ogółem dane dla 16 842 loch oraz 977 knurów 6 ras hodowanych w Polsce. W analizowanym okresie czasu stwierdzono, że u loch wartość współczynnika inbrodu (F) mieściła się w zakresie od 0 do 0,25 (14 szt.), przy czym najczęściej osobników było niezimbredowanych (70% w rasach wbp i puławskiej, ponad 80% w rasach pbz, duroc i pietrain i 100% w rasie hampshire). W przypadku knurów rozpiętość wartości współczynnika inbrodu wynosiła od 0 do 0,1875 (1 szt.). Knurów niezimbredowanych było 77% w rasie wbp, 91% w rasie pbz, 63% w rasie puławskiej oraz około 80% w rasach duroc i pietrain. Uzyskane wyniki wskazują na właściwą strukturę pogłowia świń w zakresie zimbredowania, co wskazuje na poprawnie prowadzony dobór zwierząt do kojarzeń i brak negatywnych skutków stosowania metody BLUP.

Słowa kluczowe: świnie, inbred, metoda BLUP

MS received 29.04.2016

MS accepted 20.07.2016

Streszczenie: Analiza poziomu inbrodu populacji aktywnej różnych ras świń w Polsce. W hodowli trzody chlewnej w Polsce metoda BLUP-AM jest wykorzystywana na szeroką skalę od 1999 roku. Zastosowanie tej metody do oceny wartości hodowlanej świń wpływa na poprawę wartości hodowlanej świń w populacji zarodowej oraz w populacji masowej. Równocześnie poprzez wykorzystanie w obliczeniach wielu źródeł informa-

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