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Structure and the non-genetic and genetic effects on milk traits in Polish dairy goat population

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The aims of this study were to analyse the structure of Polish dairy goat population and to estimate the non-genetic and genetic sources of variation in five milk traits. The data set comprised 18,563 lactation records of 8,938 dairy goats, while the pedigree file covered information on 13,159 animals 6 generations deep. To estimate the environmental effects the GLM procedure, using a model with the random effect on the herd-sire interaction, the fixed effects of herd-year-season of kidding interaction, breed, litter size, parity, year of birth and regression on day-in-milk. To estimate the co(variance) of the components of milk, fat, and protein yields, as well as fat and protein contents the REML method based on the repeatability animal model was applied. The average inbreeding coefficient was 0.61% (sd=3.12%). Milk, fat and protein yields were affected by all the factors except for breed. The nanny goats with more than two kids had higher milk, fat and protein yields, but they had a lower percentage of milk components than those with one kid or twins. The goats in their first lactation had the lowest milk, fat and protein yields, but the highest fat content. The heritability estimates were moderate (0.21, 0.18, 0.19 for milk, fat and protein yields, respectively). Repeatability estimates ranged from 0.30 for milk, 0.28 for fat, and 0.27 for protein yields, and 0.25 and 0.28 for fat and protein contents. Genetic correlations between milk yield and fat and protein contents were negative and moderate (-0.27 and -0.30), between fat and protein contents (0.58) while those between yields were ranged from 0.71 to 0.86. In turn, correlations between fat yield and its content, and protein yield and its content were positive and moderate (0.35, 0.23).

KEYWORDS: dairy goats / genetic parameters / production traits

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In Poland the whole population consists of about 93,4300 does [GUS 2011]. The main Polish breed is the Polish White Improved goat (about 50% of the whole population), which was created by crossing local white goats with the German White Improved and the Czech White Shorthaired breeds in the 1980s, and with French and Dutch Saanen after the 1990s. The next breed is the Polish Fawn Improved goat (about 25% of the population), upgraded by the German Fawn Improved and French Alpine breeds. There are also French and Dutch purebred Saanen goats (*ca*. 20%) and the French Alpine breed (7%) [Kaba and Bagnicka 2009].

Before 2007 the active population of Polish dairy goats consisted of more than 5,000 does. To participate in the official milk control goat breeders should pay 30% of the costs of monthly evaluation visits by an employee of the breeding association. Since 2007 there has been no direct subsidization for farm animals by the Polish Ministry *of Agriculture* and Rural Development with the exception of animals kept as stocks under maintenance breeding. Therefore, most breeders withdrew from the official recording programme and the active population in Poland is very small at present. Although breeders do not participate in the official milking control, they are interested in genetic improvement of their herds. A reliable solution ensuring progress in Polish goat breeding would be a breeding centre based on the importation of frozen semen. Moreover, to conduct breeding work in a genetic centre, and select dams based on their own phenotypic production traits and bucks on the productivity of their dams in commercial herds, the heritability of milk traits and the genetic correlations between them should be known. However, due to the lack of actual milk recording data it was only possible to estimate the variance component ratios utilizing records up to 2008.

The aims of this study were to analyse the structure of Polish dairy goat population milk recording data and to estimate the non-genetic and genetic sources of variation of five milk traits.

Material and methods

The data set comprised 21,562 lactation records of 9,763 goats maintained in 211 herds in 12 breeding regions of Poland, collected from 1983 to 2000. Before the analysis outliers of were deleted being regarded as mistakes in the process of data recording. Lactations shorter than 50 days and longer than 400 days were rejected. Only lactations with an average fat content of between 1% and 7% and protein content of between 1% and 6% were included. The minimum and maximum values of the data used in the analysis are presented in Table 1. Records on daughters of bucks, which had fewer than 3 daughters, were also deleted. Finally, the analysed data covered information about 18,563 lactations of 8,938 goats kidded between 1983 and 2000.

To avoid many single herd-year-season classes all small herds were grouped into two herds within each breeding region [Strabel and Szwaczkowski 1999], according to their first lactation milk yield. The threshold was 500 kg – the average yield in the

Table 1. Minima and maxima of five dairy traits and days-in-milk

Trait	Minimum	Maximum
Days-in-milk	90	361
Milk (kg)	67	1465
Fat (%)	1.80	5.70
Protein (%)	2.16	4.20
Fat (kg)	2.04	68.59
Protein (kg)	1.90	53.72

first lactation from the entire Polish population during the recording period – 7,772 records. Finally, 78 herds were created.

Ten classes of year of birth and 10 classes of year of kidding were formed. The first level for the year of birth contained goats born between 1977 and 1990, while the first level for the year of kidding comprised goats, which gave birth between 1983 and 1991. Each consecutive year constituted a separate class. Two seasons of kidding were accepted with an October to March period including 14,920 records and April to September of 3,643 records. Based on the new herd set-up, 666 herd-year-season and 1,267 herd-sire classes were distinguished. Genetic groups of goats with unknown sires were created based on their year of birth and breed. There were three classes of litter size, with the third containing litters of more than two kids. Lactations were grouped into five classes, with the fifth containing all lactations after the fourth. The animals were divided into four breed groups: 1 – White Improved Goats of Polish, of German and Czech origin (12,683 records), 2 – Polish and German Fawn Improved (3,064 records), 3 – pure Alpine (978 records) and 4 – Saanen goats (1,838 records).

Milk, fat and protein yields, and fat and protein contents were the only collected production traits during the official milk recording, when it was in effect. To estimate the environmental effects, the GLM Procedure [SAS 1999-2001] was run using a model with random effect of the herd-sire interaction, fixed effects of the herd-year-season of kidding, breed, litter size, parity, year of birth, and regression on day-in-milk. The inbreeding levels were calculated using the INBREED procedure of SAS package [SAS 1999-2001]. Variance components were estimated with VCE4 [Groeneveld 1998] with the multiple-trait repeatability animal model with the remaining effects as above. The herd-sire interaction considered as a random effect should reflect similarity in yields between daughters of the same buck that are milked in the same herd [Wiggans and Hubbard 1991].

Results and discussion

The average yield of Polish goats was 500 kg of milk, with 3.3% fat and 3.0% protein in their first lactation, and about 690 kg milk, with 3.3-3.5% fat and 2.9-3.0% protein in later ones. The average lactation length was 250 and 264 days in the first *vs*. later parities. The average production level was lower than that for high yielding goats in France, Switzerland and the USA, where the mean lactation yield reaches more than 700 kg of milk, while fat and protein contents are the same [Bouloc 1996, Haenlein 2007]. Milk lactation yield was almost equal to that in Spain, Norway or Germany, but much higher than that of local breeds in Italy, or the Poitevine breed in France [Haenlein 2007, Krajinović *et al*. 2011].

The average number of lactations per goat was 2.08, with the greatest equal 8. The pedigree file included 13,159 animals 6 generation deep. There were 409 known sires and 4,013 known dams of recorded goats, and about 30% of the goats lacked data on their sires and dams. About 50% of the bucks had fewer than 10 daughters (Fig. 1), while 60% of the dams had only one daughter (Fig. 2). There were 1,270 full-sib groups.

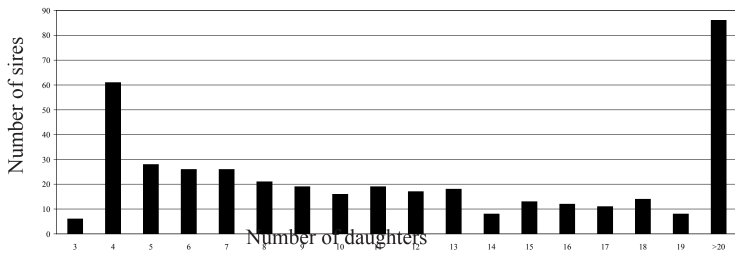

Figure 1. Distribution of paternal half-siblings.

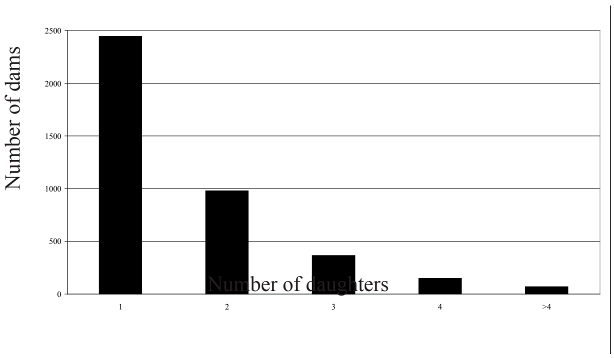

Figure 2. Distribution of maternal half-siblings.

Cross-classification of sires' offspring by herd is shown in Table 2. There were 6,233 daughters with known sires. Most of the daughters were sired by bucks used in 2 or 3 herds, in which altogether 6 to 10 sires were used. Only 13 goats were sired by bucks used in only one herd where no other sires were used.

On average there were 235 observations per herd (after grouping) during the whole observation period, with the smallest number being 19 and the largest 1000. Twenty one herds had between 100 and 150 records, and 14 herds had 150-200 records. Only 3 herds had fewer than 50 records. About 50% of herd-year-season classes had fewer than 10 observations.

Table 2. Number of daughters per sire across herds and herds across sires

Number of sires per herd	Number of herds per sire					Number of offspring
	1	2-3	4-5	6-10	>10	
1	13	4	26	0	0	43
2-3	59	8	1	0	0	68
4-5	498	355	150	70	0	1073
6-10	706	845	247	181	14	1993
11-15	306	432	67	59	7	871
16-20	489	388	98	28	8	1011
21-30	209	279	52	28	2	570
>30	200	228	105	50	21	604
Number of offspring	2480	2539	746	416	52	6233

The average inbreeding coefficient of all 8,938 recorded goats was 0.61% (sd=3.12%), with only 1,020 having an inbreeding coefficient larger than zero (Tab. 3). The average value for those animals was 5.34%, of minimum 0.02% and maximum 31.25%. The rate of inbreeding in five USA dairy goat breeds increased by 0.146/year for LaMancha and 0.247 for Saanen goats from 1976 to 2000, with the average coefficient lower than 7% in 2000 [Gipson 2002]. At that time over half of the goats in this population had a null inbreeding coefficient, and some 89% of the goats of non-null inbreeding had an inbreeding coefficient of 10% or less. According to the official data of the Agricultural Research Service of the United States Department of Agriculture the average inbreeding coefficient in 2012 reached 9.32%, while in 1981 it was only 2.91% (http://aipl.arsusda.gov/eval/summary/goats.cfm?R_Menu=Inbrd – accessed 15.01.2013). Thus, the inbreeding coefficient calculated for the Polish population is low, although the inbreeding coefficient could be seriously underestimated, because the proportion of missing parents is large. As it was shown by Lutaaya *et al*. [1999], when the proportion of identified dams decreases, the average inbreeding level also decreases.

Table 3. Numbers of recorded animals with inbreding coefficient (F) greater than zero

Number of animal	Inbreeding level
751	F≤5 %
110	5<F≤10 %
55	10<F≤15 %
4	15<F≤20 %
73	25<F≤30 %
27	F>30
1020	5.34% (sd=7.76%)

The coefficient of determination (R^2) for yield traits ranged from 0.75 to 0.79, while for milk constituent contents R^2s were much lower – 0.53 and 0.47. This means that some important effects were not fitted in the model, especially for the content traits (Tab. 4). The traits studied were affected by all the investigated factors, except for breed and parity in the case of protein content. The impact of herd, year and season or month of kidding on milk yield was also reported by other authors [Crepaldi *et al*. 1999, Kominakis *et al*. 2000]. Some authors confirmed the impact of litter size on milk and fat yields [Browning *et al*. 1995, Crepaldi *et al*. 1999], but contradictory results were also reported [Večeřová and Křižek 1993].

Table 4. Significance (p) of effects fitted in model of ANOVA for production traits

Effect*	Milk (kg)	Fat (%)	Protein (%)	Fat (kg)	Protein (kg)
hs	0.0001	0.0001	0.0001	0.0001	0.0001
HYS	0.0001	0.0001	0.0001	0.0001	0.0001
Breed	0.0918	0.9849	0.2872	0.2370	0.3884
Litter size	0.0001	0.0001	0.0001	0.0001	0.0001
Parity	0.0001	0.0033	0.4058	0.0001	0.0001
Year of birth	0.0001	0.0041	0.0001	0.0001	0.0001
Days-in-milk	0.0001	0.0492	0.0001	0.0001	0.0001
R^2	0.79	0.53	0.47	0.75	0.79

*hs – herd-sire interaction, HYS – herd-year-season interaction, R^2 – coefficient of determination.

The highest milk, fat and protein yields were attained in the 3rd and 4th lactations from goats with more than two kids, while the milk of goats with one kid had the highest concentrations of fat and total protein (Tab. 5). Most of these results are in agreement with other studies [Browning *et al*. 1995, Crepaldi *et al*. 1999, Kominakis *et al*. 2000, Zahraddeen *et al*. 2009], but Boichard *et al*. [1989] and Králíčková *et al.* [2013] showed the opposite impact of litter size on milk production. Milk yield in the present study increased up to the 3th lactation, as in the study by Krajinović *et al*. [2011], but Crepaldi *et al.* [1999] found that milk production increased up to the 5th lactation, while Browning *et al.* [1995] showed the highest milk yield in the 2nd lactation. Also Králíčková *et al*. [2013] showed differences between the first and later lactations than the second one, with no differences between the second and third ones. In terms of fat content (%) in milk, Krajinović *et al.* [2011] showed the highest values in the second, while Králíčková *et al*. [2013] found the highest values in the third lactation. The average protein content in the German population was the same in all studied lactations, while in the Czech population it decreased in the third lactation [Krajinović *et al*. 2011, Králíčková *et al*. 2013]. Generally, the results related to fixed effects obtained in this study did not differ from other studies. The significant impact of such effects as herd, year and season of kidding on milk yield means that proper management can improve milk production.

Table 5. Least squares means* (LSM) and their standard errors (se) of milk traits across fixed effect classes

Classes of effects	N	Milk yield		Fat content		Protein content		Fat yield		Protein yield	
		LSM	se	LSM	se	LSM	se	LSM	se	LSM	se
Breed**											
PWI	12,683	578.9	3.5	3.48	0.01	2.91	0.01	19.97	0.14	16.70	0.10
PFI	3,064	563.6	4.3	3.52	0.02	2.94	0.01	19.60	0.17	16.43	0.13
Alpine	978	623.2	11.7	3.59	0.05	3.04	0.02	22.20	0.46	18.71	0.34
Saanen	1,838	617.4	13.4	3.67	0.05	3.08	0.03	22.48	0.54	18.66	0.40
Litter size											
1	60,446	569.6^{A}	5.0	3.60^{A}	0.02	3.01^{AB}	0.01	20.39^{A}	0.20	16.95^{A}	0.15
2	10,532	594.4^{A}	4.9	3.57^{A}	0.02	2.99^{Aa}	0.01	21.06^{A}	0.20	17.59^{A}	0.15
>2	10,585	623.3^{A}	5.7	3.52^{A}	0.02	2.98^{Ba}	0.01	21.74^{A}	0.23	18.33^{A}	0.17
Parity											
1st	6,961	525.1^{ABC}	4.4	3.62^{ABC}	0.02	3.01	0.01	18.91^{ABC}	0.17	15.69^{ABC}	0.13
2nd	4,354	590.9^{ABC}	4.6	3.57^{A}	0.02	2.99	0.01	20.93^{ABa}	0.18	17.53^{ABC}	0.14
3rd	3,116	621.6^{A}	5.3	3.55^{B}	0.02	2.99	0.01	21.88^{A}	0.21	18.38^{Aa}	0.16
4th	2,038	625.4^{Ba}	6.5	3.57^{a}	0.03	2.99	0.01	22.08^{Bb}	0.26	18.44^{BD}	0.19
>4th	2,094	615.9^{Ca}	7.9	3.53^{Ca}	0.03	2.98	0.02	21.52^{Cab}	0.31	18.07^{CDa}	0.23

*Within columns means bearing the same superscripts differ significantly at: small letters– $p<0.05$; capitals – $p<0.01$.
**PWI – Polish White Improved, PFI – Polish Fawn Improved.

Table 6. Estimates* of heritability (h^2), repeatability (re), genetic (above diagonal) and phenotypic (below diagonal) correlation coefficients (standard errors in parentheses) of dairy traits

Traits	h^2	re	Correlation				
			milk (kg)	fat (%)	protein (%)	fat (kg)	protein (kg)
Milk (kg)	**0.21 (0.01)**	0.30	—	-0.27(0.03)	-0.30 (0.04)	0.71 (0.03)	0.86 (0.02)
Fat (%)	**0.23 (0.01)**	0.28	-0.13	—	0.58 (0.03)	0.35 (0.06)	0.02 (0.66)
Protein (%)	**0.27 (0.01)**	0.36	-0.13	0.35	—	0.15 (0.04)	0.23 (0.07)
Fat (kg)	**0.18 (0.01)**	0.25	0.90	0.29	NS	—	0.83 (0.02)
Protein (kg)	**0.19 (0.01)**	0.28	0.96	-0.04	0.09	0.90	—

*h^2 – heritability, re – repeatability.
NS – not significant.

Heritability coefficients for yield traits were almost identical at 0.21, 0.18 and 0.19 for milk, fat and protein yields, respectively (Tab. 6). The heritability co-efficient for fat content was lower than for protein content. The repeatability coefficients were 0.30, 0.28, 0.27, 0.25 and 0.28 for milk, fat, protein yields and fat and protein contents, respectively. The genetic correlations between milk yield and fat and protein contents were negative and moderate (-0.27 to -0.30), while those between fat and protein contents were positive and high (0.58). The genetic correlations between yield traits were also high and positive (0.71 to 0.86), while correlations between fat yield and fat content as well as between protein yield and content they were moderate (0.35, 0.23).

The h^2 estimates found in the present study for all traits are generally lower than those published for other populations [Boichard *et al*. 1989, Manfredi *et al.* 2000, Menéndez-Buxadera *et al.* 2010, Montaldo *et al.* 2010, Rupp *et al*. 2011, Garcia-Peniche *et al*. 2012]. This might have resulted from the scarce pedigree information. The estimates obtained by Analla *et al*. [1996] and Menéndez-Buxadera *et al*. [2010] for the Spanish population, by Moioli *et al*. [1995] for the Saanen population in Italy, and by Torrez-Vázquez *et al.* [2009] for the Saanen breed in Mexico were of the same magnitude as ours. The heritability coefficients estimated for production traits in Alpine and Saanen goat herds in Brazil were even lower [Brito *et al*. 2011] than those obtained in our study. The Spanish population data structure is probably similar to the Polish one. The h^2 values obtained for the Polish population for yield traits in earlier studies [Bagnicka and Łukaszewicz 1999, Bagnicka *et al.* 2004] were also low but majority data overlap. On the other hand, the heritability coefficients for milk yield obtained in the Swiss dairy goat population comprised the Alpine, Saanen and Toggenburg breeds and based on almost 100 000 lactation records from more than 3 000 herds they were also low and depended on breed (between 0.14 and 0.18) [Bapst *et al*. 2013]. Heritability for fat and protein contents was found to be higher than for yield traits, which is in agreement with results obtained in our earlier study and reported by other authors [Bagnicka and Łukaszewicz 1999, Bagnicka *et al.* 2004, Andonov *et al*. 2007, Torrez-Vázquez *et al.* 2009, Garcia-Peniche *et al*. 2012, Bapst *et al*. 2013], although Analla *et al*. [1996] reported a lower heritability for fat content than for milk yield (0.16 vs. 0.18 or 0.14 *vs*. 0.17, depending on whether a single- or a multiple-trait model was employed).

The repeatability coefficients estimated in the present study are also slightly lower than those in other studies [Analla *et al*. 1996, Valencia *et al.* 2007; Torrez-Vázquez *et al*. 2009, Garcia-Peniche *et al*. 2012]. The coefficients obtained in earlier studies on Polish goats were almost the same [Bagnicka and Łukaszewicz 1999, Bagnicka *et al*. 2004] which may mean that the data structure and variance ratios have not changed over time. Generally, both the genetic and phenotypic correlations recorded in this study had the same pattern as those presented in other papers, and also for world dairy goat populations [Analla *et al*. 1996, Manfredi *et al*. 2000, Torrez-Vázquez *et al*. 2009, Bapst *et al*. 2013].

The choice of correct selection criteria is the most important decision for animal breeders [Lopes *et al*. 2012]. Still, information about environmental and genetic effects on dairy traits is required for effective breeding work aiming at increasing the productivity of animals. Knowledge of the genetic nature of dairy traits and the relationships among them allows breeders to predict the response to selection and to speed up genetic progress. Due to the lack of a breeding programme for the Polish dairy goat population breeders have to select dams based on their own phenotype and bucks on the phenotypic productivity of their dams. A breeding nucleus centre producing superior males would be a good solution for the Polish dairy goat population.

Although the available data on milk performance are historical, it is possible to use them to design a breeding programme for a breeding centre based, for instance, on the importation of frozen semen, and to achieve genetic progress and spread it among commercial herds. However, the importation of animals or frozen semen from other populations also means the importation of foreign breeding goals. This happened in the Polish population in the 1990s, when animals from France were imported for the first time on a larger scale. A sudden decrease in genetic progress in milk yield was observed after 1995 (by 50 kg/year), while a positive permanent genetic trend for protein content was observed [Bagnicka *et al*. 2002], which was probably the result of using French bucks and semen in mating Polish goats, since in France the breeding objective is to increase protein content and yield. Nowadays, however, the breeding values of top French bucks for milk traits are much higher than in the Polish population, and thus improvement in both milk yield and content could be expected if the frozen semen of French bucks is used in the prospective breeding nucleus.

The structure of the Polish population performance data was unbalanced. Artificial insemination of goats is still underused in Poland, thus the genetic and environmental relationship between herds and bucks are still weak. Almost 40% of the sires are used only in individual herds. Nonetheless, almost 80% of does were maintained in herds using 4 to 20 bucks. Also 30% of recorded does had both parents missing.

The ratios of variance components for the dairy traits of goats in Poland do not diverge from such ratios in other goat populations. The negative genetic correlation estimates between milk yield and milk constituents mean that selection only for milk yield will result in a decrease of the latter. Therefore, breeders should also take into account fat and protein contents in their breeding work. Though the correlation between milk yield and percentage contents of fat and protein is about -0.30, it is possible to choose animals with high milk yield of high fat and protein contents. The phenotypic intra-herd selection of dams and the use of AI-born bucks from a breeding center could well suit the dairy goat breeders expectations.

REFERENCES

1. ANALLA M., JIMENEZ-GAMERO I., MUNOZ-SERRANO A., M. SERRADILLA L., FALAGAN A., 1996 – Estimation of genetic parameters for milk yield and fat protein contents of milk from Murciano-Granadina goats. ***Journal of Dairy Science*** 78, 1895-1898.
2. ANDONOV S., ODEGARD J., BOMAN I. A., SVENDSEN M., HOLME I.J., ADNOY T., VUKOVIC V., KLEMETSDAL, G., 2007 – Validation of Test-Day Models for Genetic Evaluation of Dairy Goats in Norway. ***Journal of Dairy Science*** 90, 4863–4871.
3. BAGNICKA E., DISTL O., HAMANN H., ŁUKASZEWICZ M., 2004. Heritabilities of and genetic correlation between the dairy traits in goats estimated in first *vs* later lactations. ***Animal Science Papers and Reports*** 22, 205-213.
4. BAGNICKA E., ŁUKASZEWICZ M., DISTL O., HAMANN H., 2002 – Genetic and environmental trends in the Polish dairy goat population. ***Animal Science Papers and Reports*** 20, 195-202.
5. BAGNICKA, E., ŁUKASZEWICZ, M., 1999 – Genetic and environmental variation of dairy traits in Polish population of goats. ***Animal Science Papers and Reports*** 17, 59-65.

6. BAPST B., MOLL J., BAES C., HERREN U., 2013 – Estimation of genetic parameters and breeding values for the major Swiss dairy goat breeds. Book of Abstracts of the 64th Annual Meeting of the European Federation of Animal Science No. 19, p. 323, 26-30 August, Nantes, France.
7. BOICHARD D., BOULOC N., RICORDEAU G., PIACERE A., BARILLET F., 1989 – Genetic parameters for first lactation dairy traits in the Alpine and Saanen goat breeds. ***Genetics Selection Evolution*** 21, 205-215.
8. BOULOC N., 1996 – Controle laitier. Results 1995***. La Chevre*** 214:32-33.
9. BRITO L.F., SILVA F.G., MELO A.L.P., CAETANO G.C., TORRES R.A., RODROGES M.T., MENEZES G.R.O., 2011 – Genetic and environmental factors that influence production and quality of milk of Alpine and Saanen Goats. ***GMR Genetic and Molecular Research*** 10, 3794-3802.
10. BROWNING R. JR., LEITE-BROWNING M. L., SAHLU T., 1995 – Factors affecting standardized milk and fat yields in Alpine goats. ***Small Ruminant Research*** 18, 173-178.
11. CREPALDI P., CORTI M., CICOGNA M., 1999 – Factors affecting milk production and prolificacy of Alpine goats in Lombardy (Italy). ***Small Ruminant Research*** 32, 83-88.
12. GARCÍA-PENICHE T.B., MONTALDO H.H., VALENCIA-POSADAS M., WIGGANS G.R., HUBBARD S.M., TORRES-VÁZQUEZ J.A., SHEPARD L., 2012 – Breed differences over time and heritability estimates for production and reproduction traits of dairy goats in the United States. ***Journal of Dairy Science*** 95, 2707–2717.
13. GIPSON T.A., 2002– Preliminary observations: Inbreeding in dairy goats and its effects on milk production. Proc. 17th Ann. Goat Field Day, Langston University, Langston, OK, 51-56.
14. GROENEVELD E., 1998 – Vce 4 User's Guide and Reference Manual Version 1.1. Institute of Animal Husbandry and Animal Behaviour, Federal Agricultural Research Centre (FAL), Neustadt.
15. GUS. Główny Urząd Statystyczny (Central Statistical Office), 2010 – Zwierzęta gospodarskie i wybrane elementy metod produkcji zwierzęcej. Powszechny Spis Rolny 2010. [Farm Animals and selected elements of animal production. National Agricultural Census 2010, in Polish]. Warszawa, 2011, p. 82.
16. HAENLEIN G.F.W., 2007 – About the evolution of goat and sheep milk production. ***Small Ruminant Research*** 68, 3-6.
17. KABA J., BAGNICKA E., 2009 – Breeding of Dairy Goats in Poland. ***Dairy Goat Journal*** 87, 46-49.
18. KOMINAKIS A., ROGDAKIS E., VASILOUDIS CH., LIASKOS O., 2000 – Genetic and environmental sources of variation of milk yield of Scopelos dairy goats. ***Small Ruminant Research*** 36, 1-5.
19. KRAJINOVIĆ M., I. PIHLER, V. SIMIN, A. JOCIĆ, S. NIĆIN, M. ŽUJOVIĆ., 2011– The influence of number of lactation on milk yield parameters in German Fawn goats. ***Biotechnology in Animal Husbandry*** 27, 1469- 1475.
20. KRÁLÍČKOVÁ Š., KUCHTÍK J., FILIPČÍK R., LUŽOVÁ T., ŠUSTOVÁ K., 2013 – Effect of chosen factors on milk yield, basic composition and somatic cell count of organic milk of Brown Short-Haired Goats. Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis, 1, 99-105.
21. LUTAAYA E., MISZTAL I., BERTRAND J.K., MABRY J.W., 1999 – Inbreeding in populations with incomplete pedigrees. ***Journal of Animal Breeding and Genetics*** 119, 475-480.
22. MANFREDI E., SERRADILLA J.M., LEROUX C., MARTIN P., SANCHEZ A., 2000 – Genetics for milk production. Proceedings of the 7th International Conference on Goats. May 15-21, Tours-Poitiers, France. I: 191-196.
23. MENÉNDEZ-BUXADERA A., MOLINA A., ARREBOLA F., GIL M.J., SERRADILLA J.M., 2010 – Random regression analysis of milk yield and milk composition in the first and second lactations of Murciano-Granadina goats. ***Journal of Dairy Science*** 93, 2718-2726.

24. MOIOLI B.M., PILLA A.M., ROSATI A., CATILLO G., FRESI P., 1995 – Heritability and repeatability of milk production and genetic evaluation of the Saanen breed of goats. ***Zootecnica e Nutrizione Animale*** 21, 231-236.
25. MONTALDO H.H., VALENCIA-POSADAS M., WIGGANS G.R., SHEPARD L., TORRES-VÁZQUEZ J.A., 2010 – Short communication: Genetic and environmental relationships between milk yield and kidding interval in dairy goats. ***Journal of Dairy Science*** 93, 370-372.
26. RUPP R., BERGONIER B., DION S., HYGONENQ M. C., AUREL M. R., ROBERT-GRANIÉ C., FOUERAS G., 2009 – Response to somatic cell count-based selection for mastitis resistance in a divergent selection experiment in sheep. ***Journal of Dairy Science*** 92, 1203–1219.
27. SAS/STAT (2002-2010). Release9.3. SAS Institute Inc., Cary, USA.
28. STRABEL T., SZWACZKOWSKI T., 1999 – The use of test day models with small size of contemporary groups. Journal of Animal Breeding and Genetics 116, 379–386..
29. TORRES-VÁZQUEZ, J.A., VALENCIA-POSADAS, M., CASTILLO-JUÁREZ, H., MONTALDO, H.H., 2009 – Genetic and phenotypic parameters of milk yield, milk composition and age at first kidding in Saanen goats from Mexico. ***Livestock Science*** 126, 147-153.
30. VALENCIA, M., DOBLER, J., MONTALDO, H.H., 2007 – Genetic and phenotypic parameters for lactation traits in a flock of Saanen goats in Mexico. Technical note. ***Small Ruminant Research*** 68, 318-322.
31. VEČEŘOVÁ D., KŘIŽEK J., 1993 – Výber modelu pro odhad plemenné hodnoty koz na podklade mlécné uzitkovosti. In Czech. ***Zivocišna Výroba*** 38, 9-20.
32. WIGGANS, G.R., HUBBARD, S.R., 1991 – Genetic evaluations for yield and type traits. ***Dairy Goat Journal*** July, 414.