THE PHENOMENON OF HETEROSIS AND EXPERIENCE IN CROSSING DIFFERENT BREEDS OF SHEEP IN SERBIA

Milan P. Petrovic, Violeta Caro Petrovic, Dragana Ruzic Muslic, Nevena Maksimovic, Ivan Pavlovic, Bogdan Cekic, Ivan Cosic

[1]Institute for Animal Husbandry, 11080 Belgrade-Zemun, Republic of Serbia
[2]Scientific Institute of Veterinary Medicine of Serbia, 11107 Belgrade, Republic of Serbia
Corresponding author: Milan P. Petrović, milanppet@yahoo.com
Review paper

Abstract: Crossbreeding serves as a predictable and cost-effective method to genetically increase lamb body weight by mating two or more breeds of sheep. The crossing over breed comes to a far greater number of combinations of genes and thus is more likely to express favorable allele carriers of economically important traits. The phenomenon of heterosis has used since the beginning of the last century. However, its genetic basis has remained unclear. From the very beginning of the knowledge of heterosis to the present day, there are several theories, but neither theory able to answer all questions that arise regarding the apparent strength of the F1 generation offspring. Not assert anything about the genetic or molecular phenomenon that causes heterosis. It has been increasingly experimentally confirmed that heterosis is the result of highly complex interactions within the genome as well as between the genome and the environment. In Serbia, some activity of domestic researchers regarding crossbreeding of sheep after the Second World War has been recorded up to date. It found out that crosses have a higher body weight than the maternal base in the F1 generation. In other words, they had better fattening capacity than purebreds. However, the results are not always in line with expectations due to the influence of various known and unknown factors.This review paper aims to draw attention to the phenomenon of heterosis through experience in its application in Serbia, in the hope that this biological phenomenon would clarify in the near future by applying modern scientific understandings and technologies.

Keywords: heterosis, crossbreeding, sheep, lamb, body weight

Introduction

Breed diversity is a treasured resource of the sheep industry, and the crossbreeding systems use breed diversity to increase productivity relative to purebred flocks *(Dawson and Carson, 2002; Leymaster, 2002).* The crossbreeding schemes aiming at the utilization of general and specific combining ability and breed substitution are some of the available methods that can be used to improve the productivity of the local breeds of sheep (*Mavrogenis, 1995*; *Gavojdian et al., 2013; Petrovic, 2013; Wolfová et al., 2014).* Purebreds are the raw material of crossbreeding, and good crossbreds only come from good purebreds particularly, the higher the genetic merit or breeding value of the purebreds, the higher the expected performance of the crossbreds *(Mitchell, 2000; Dvalishvili et al., 2015).* To improve the performance of low heritability, crossbreeding is often used, and when only one trait has considered, a heterosis effect seems minor. On the other hand, heterosis effects accumulate to provide rather a substantial improvement over straight bred sheep when the total productivity of such as lamb survivability and the growth rate has considered. Since no any breed best for all traits, the second benefit of crossbreeding is the advantageous use of breed complementary which refers to the combination of desirable traits from one or more breeds into one animal wherein the idea is that the strengths of one breed will compensate for the weaknesses of another breed *(Aaron, 2014).* Selecting the right population in the application of crossing and crossing system is necessary to fulfill its goal in sheep breeding (*Caro Petrovic et al., 2015*). Crossbreeding serves as a predictable and cost-effective method to genetically increase lambs rose per ewe (lamb crop) and by mating two or more breeds of sheep. Important genetic considerations to increase lamb crop were to use breeds and crossbreds that are suitable for the production system and well adapted to environmental conditions *(Leymaster, 2016).* Crossing over breed comes to a far greater number of combinations of genes and thus is more likely to express favorable allele carriers of economically important traits *(Petrovic et al., 2013).* The breeds of sheep had evolved over many thousands of years, their utility and function guided by their ability to adapt and survive in specific environments and production systems *(Leymaster, 2002).* An organized crossbreeding system can optimize the use of both hybrid vigor and breed complementarity and can have utilized by flocks of all sizes *(Thomas, 2006).* Making the most of crossbreeding is a combination of enhancing hybrid vigor and also selecting breeds that provide traits that maximized production within the farming system *(Mitchell, 2000).* This paper aims to draw attention to the phenomenon of heterosis through experience in its application in Serbia, in the hope that this biological phenomenon will be clarified in the near future by the application of modern scientific understandings and technologies.

The phenomenon of heterosis

In the broadest sense, heterosis indicates the appearance of a better expression of some quantitative traits (fertility, growth, food conversion, etc.) of F1 generation offspring relative to parents (*Petrovic et al., 1997).* The phenomenon of heterosis has used since the beginning of the last century in livestock and crop production, however, its genetic basis has remained unclear. From the very beginning of the knowledge of heterosis to the present day, there are several theories, which associate this phenomenon with gene dominance, superdominant and epistasis. None of the several theories is capable of answering all the questions that arise regarding the apparent strength of the F1 generation offspring. Writing about the fundamental aspects of sheep crossbreeding, *Leymaster (2002*) points out that complementarity, or the complementarity with each other, of the positive traits of crossbreeding breeds, is responsible for heterosis. However, this does not assert anything about the genetic or molecular phenomenon that causes heterosis. It has been increasingly experimentally confirmed that heterosis is the result of highly complex interactions within the genome as well as between the genome and the environment. However, no one has yet succeeded in explaining these intricate biological processes. In support of the scientific quest for an answer, we dare to state our position on it. We believe that the biological processes that take place inside the organism at the cell and gene level are quite superficially understood and simplified. Cells, as the basic but extremely complex and perfect unit of life, structure, function, and expression of genes, are still being treated mechanically-the principle of the key and lock, despite key technological advances. One allele pair of a gene or a particular group of genes is considered to carry fixed information, which must be expressed with minor deviations in plus or minus depending on the external environment, according to the formula $P = G + E$. The livestock environment generally includes climatic factors, nutrition, and animal care. The results of scientific studies show that there are high variations in the degree of expression of heterosis, despite the fulfillment of some conditions that are considered crucial for success in crossbreeding. In the study of *Colak et al. (2013*), the crossing of Akkaraman sheep with Hasak and Hasmer types did not improve the fattening performance and carcass quality compared with purebred Akkaraman lambs. The following table presents the usual schematic representation of gene interactions at crosses. Practice shows that the effects of crossbreeding are not completely consistent with this "alphabetic-mechanical" model.

Table 1.Example of the occurrence of heterosis depending on gene interaction (*Petrovic, 2000).*

Generation	Dominance	Over dominance	Epistasis
P	ААбб	А1А1Б1Б1	ААББ
	ааББ	А2А2Б2Б2	Аабб
F1	АаБб	А1А2Б1Б2	АаБб

As is well known the quantum physics is a thorough scientific discipline found in the description of matter, and energy, and is the basis of many disciplines, such as physics and chemistry, which means that it is the basis of everything. Therefore, it is logical to expect that its principles will be in biochemistry as well as molecular biology leading to the gene itself. That then we should not be surprised that life comes from quantum mechanics. Biology has pretty well explained many life processes at the molecule level. However, as stated in the paper of *Arndt et al. (2009)*, quantum physics and electrodynamics shape all molecules and thus, separate molecular recognition, protein work and DNA. Thus, van der Valsal's forces, discrete molecular orbitals, and maternal stability are all quantum physics and the natural basis of life and everything that is visible. Quantum aspects of life are increasingly being studied by a number of scholars around the world, presenting interesting results and ideas such as *Blankenship R E (2002)*, *Eisert and Viseman (2007),Gariaev et al. (2011)* and others. Because we thought that the phenomenon of heterosis could explained by a complete understanding of the principles of quantum physics, which gave birth to quantum biology, which will play a very important role in the future.

Prerequisite for the crossing program

Every sheep breeding program has to accept two basic factors if it is to succeed: genetic distance between crossed populations and crossing system.
It has argued that if the genetic distance or difference between populations selected for crossbreeding is greater, the effect of heterosis, and thus meat production will be greater. For example, if we cross two local breeds with low production, we will not certainly achieve a significant improvement in desirable traits in the offspring. There have been cases where no progress has made in the crossing of meaty breeds of similar production levels (*Petrovic, 2000*). Genetic differences between breeds are examined during the cross-breeding of sheep to realize breeding plans as efficiently as possible (*Konig et al., 2016*). A better knowledge of both the superiority and inferiority of exotic breed to the local breed will help design a more effective and reliable crossbreeding program *(Li et al., 2016)*. Another important factor that depends on the success of the crossing is the crossing system. It also has an impact on results (*Petrovic et al., 2011*). The results showed that in the system

of crossing two breeds of sheep only the heterosis of individual has used, while at the three-breed crossing beside the heterosis of individual, the heterosis of the mother has added, and in crossing of four breeds, in addition to the mentioned, the heterosis of the father has used.

Experience in crossing different breeds of sheep in Serbia

Sheep breeding as a method for increasing meat production in our country has not yet found wider practical application. However, in the domain of experimental scientific work, some activity of domestic researchers after the Second World War has been recorded to date *(Mitic et al., 1964; 1974; Kostic et al., 1977; Mitić, 1982; Petrovic, 2000; Petrovic et al., 2011; Caro Petrovic, 2014).* As the maternal have used female Pramenka breed of sheep, Tsigai, Merino and their two breed crosses, and rams of meaty sheep breeds. Thus, during the sixth and seventh decade of the twentieth century were found that crosses have a higher body weight than the maternal base in the F1 generation. In other words, they had better fattening capacity than purebreds (table 2). However, the results are not always in line with expectations due to the influence of various known and unknown factors.

Table 2. Effects of crossbreeding of different breeds of sheep in Serbia during the sixth and seventh decades of the last
century *(Mitic,1984)*

Genotype and crossing combination	Lambs body weight, kg		Age at weaning, days	Average daily gain, g
	At birth	Weaning		
Svirlig x Precose	3.57	24.75	100	206
Svirlig x Precose x Caucasian	3.75	25.15	100	208
Svirlig x Precose x Wirtemberg	4.23	25.45	100	212
Svirlig x Precose x Southdown	3.70	27.67	100	239
German Blackhead x Tsigai	4.85	28.00	100	232
German Blackhead x Tsigai x Southdown	4.80	28.50	100	237
Pirot x Merino d'Arl	3.88	21.71	90	198
Pirotska x Merino d'Arl x Wirtemberg	3.91	23.20	90	214
Svirlig x Corriedale	3.80	23.50	120	167
Svirlig x Corriedale x Caucasian	3.74	24.30	120	187
Caucasian x Stavropol	4.47	24.23	100	208
Caucasian x Stavropol x Southdown	4.42	28.44	100	240

According to *Mitic (1984*), to use heterosis in meat production, crosses of Tsigai with Ile de france and Hampshire rams were performed in F1 generation had higher body weight in both cases than purebred Tsigai sheep. In addition to the above activities on the use of heterosis, a group of researchers during that time, led by the mentioned author, crossed a Tsigai breed with a German black-headed sheep, a Tsigai with a Merino sheep, as well as some Russian sheep breeds. The offspring

from these crosses reached a body weight of up to 27.40 kg in the second case and 27.46 kg in the third case, while lambs of pure Tsigai breed had a weight of 26.56 kg. Positive results in the use of heterosis in our country have also obtained when crossing the Tsigai breed with Suffolk and Tsigai with Ile de France (*Petrovic, 2000*). We see that the terminal paternal breed Southdown has a positive effect, but not the same in all combinations of crossbreeding.

Table 3. Average body weight of lambs by genotype and age *(Petrović, 2000)*

Genotype	Body weight of lambs. kg	
	At birth	At 100 days
Stavroplol x Caucasian	4.47 ± 0.08	25.23 ± 0.58
Stavroplol x Caucasian x Southdown	4.42 ± 0.08	28.44 ± 0.71
Tsigai x German blackhead	4.85 ± 0.13	28.00 ± 0.66
Tsigai x German blackhead x Southdown	4.80 ± 0.15	28.50 ± 0.63
Svrlig x Prekoce	3.57 ± 0.15	24.75 ± 0.69
Svrlig x Prekoce x Southdown	3.70 ± 0.08	27.67 ± 0.74

A significant step in terms of increasing meat production in our country was made by introducing Weremberg sheep into breeding programs for domestic sheep populations. It was evident on the increase in lamb growth (*Petrovic and Nenadic, 1992*), as presented from the following table.

Table 4. Effect of Pramenka strain crossbreeding with the Wirtemberg (W) breed of sheep

Genotype	Body weight of lambs, kg		Daily gain, g
	At birth	With 90 days	
Svrlig (SV)	3.66	16.94	147
Sjenica (SJ)	3.81	19.68	176
R_1(SV xW)	3.92	21.07	190
R_1(SJ x W)	3.98	22.17	202

Under production conditions, crossing the Pramenka strain with the Wertemberg sheep resulted in an increase in body weight and daily gain. However, differences in weight and weight of lambs are evident.

Based on the positive results of crossbreeding, for further genetic improvement of Serbian sheep production, considerable research had conducted since the early 1990s with the aim of finding new possibilities for increasing lamb production (*Petrovic and Negovanovic, 1994; Petrovic et al., 1995*).

In this sense, as states *Petrovic (2000),* started the process of crossing the two-breed crosses with the third terminal breed, and remarkable results have been obtained (Table 5).

The table showed that in addition to a significant heterosis effect of two-bred crossing, three-bred crossing resulted in higher growth and body weight, which is, among the other thing, conditioned by the complete use (100%) of both the heterosis of the individual and heterosis of the mother.

Table 5. Effect of two- and three-fold crossbreeding on the expression of heterosis *(Petrovic et al., 1995; Petrovic, 2006)*

Genotype		Body weight of lambs, kg		Daily gain, g
		At birth	With 90 days	
A	Pure breed	3.85	20.52	185
A x B	Two breed	4.18	25.64	239
A x C	Two breed	3.80	26.76	255
D x C	Two breed	4.85	26.92	243
A x B x C	Three breed	4.45	31.86	303

Based on our past experience in breeding our domestic sheep population, with the aim of increasing meat production, we can conclude that, in addition to the Wirtemberg, the Il de France breed stands out in importance (*Petrovic, 2006*). These breeds have well adapted to our breeding conditions (*Mekić, 1994*). The results displayed in the next table.

Table 6. Body weight averages at birth (BWB), ages 30 days (BW30), 60 days (BW60) and 90 days (BW90) of different
        genotypes (*Caro Petrovic et al.,2015*).

Genotype/ crossing system	BWB		BW30		BW60		BW90	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
P	3.65	0.03	9.48	0.11	14.99	0.13	21.96	0.24
W	4.48	0.08	10.83	0.17	19.11	0.27	27.70	0.15
PxW	4.17	0.04	10.98	0.11	18.53	0.21	26.55	0.21
PxWxF	4.35	0.04	12.87	0.10	22.01	0.25	32.19	0.20

Conclusion

Heterosis is a biological phenomenon, which today attracts the same attention of the scientific public as at the beginning of the development of genetics. Many of the principles of its manifestation have clarified, but the substance is still

shrouded in secrecy. Not a lot has gone down in its shedding even using molecular genetics methods, but one thing is for sure. Heterosis has found practical application in many countries, where it makes a significant contribution to increasing the production of lamb meat, which is actually the real purpose of its implementation. Regardless of some research aimed at using the heterosis effect in our country from the Second World War to the present, the following can be stated. There are big differences depending on genotype and crossbreed combination. Most experiments were pioneering, sporadic, with no clearly defined objective, and on a small number of experimental individuals. In most cases, have not been analyzed the fixed effects of genetic and external factors. No unique method has used, and therefore, no possible comparison of results. Therefore, to date, in Serbia, we do not have a thorough, clear picture of which genotypes and crossing systems are most suitable for our practical and commercial conditions. Starting from the natural potentials, traditions, and interests of our producers, crossbreeding should be given priority in future programs for the production of quality lamb for domestic and foreign markets. In doing so, research on the various aspects of the occurrence of the heterosis effect should be continued, with particular reference to the elucidation of its phenomenon at the molecular and quantum levels.

Fenomen heterozisa i iskustvo u ukrštanju različitih rasa ovaca u Srbiji

Milan P. Petrovic, Violeta Caro Petrovic, Dragana Ruzic Muslic, Nevena Maksimovic, Ivan Pavlovic, Bogdan Cekic, Ivan Cosic

Rezime

Ukrštanje služi kao predvidljiva i isplativa metoda za genetsko povećavanje mase tela janjadi i drugih osobina, kombinovanim parenjem dve ili više rasa ovaca. Ovim postupkom se teoretski dolazi do daleko većeg broja kombinacija gena i na taj način je verovatnije da će se desitii povoljnije alelne veze nosioci ekonomski važnih osobina. Fenomen heterozisa se izučava i ukrštanjem praktično koristi od početka prošlog veka. Međutim, njegova genetska osnova je ostala nejasna. Od samog početka saznanja o heterozisu pa do danas, postoji nekoliko teorija, ali nijedna nije u stanju da odgovori na sva pitanja koja se javljaju u vezi sa očiglednom snagom potomstva generacije F1. Nema ozbiljnijih saznanja o molekularnom fenomenu koji uzrokuje heterozis. Sve više je eksperimentalno potvrđeno da je heterozis rezultat veoma složenih interakcija unutar genoma, kao i između genoma i okoline. U Srbiji je do danas zabeležena određena aktivnost domaćih istraživača u vezi sa ukrštanjem ovaca posle drugog svetskog rata. Došlo se do saznanja da melezi imaju veću telesnu masu od majčine rase u F1generaciji.

Drugim rečima, imali su bolje performanse tova od čistokrvnih populacija. Međutim, rezultati nisu uvek u skladu sa očekivanjima usled uticaja raznih poznatih i nepoznatih faktora. Takođe svetsko iskustvo u primeni heterozisa pokazuje da postoji i negativan efekat ili nezadovoljavajući u odnosu na očekivani bez obzira na ispunjenost uslova u smislu današnjeg shvatanja heterozisa. Ovaj pregledni rad ima za cilj da skrene pažnju na fenomen heterozisa iskustvom primene u Srbiji, u nadi da će se ovaj biološki fenomen razjasniti u bliskoj budućnosti primenom savremenijih naučnih tehnologija i shvatanja funkcije i uloge gena.

Acknowledgement

References

AARON D. K. (2014): Crossbreeding Considerations in Sheep. Agriculture and Natural Resources Publications. 156. https://uknowledge.uky.edu/anr_reports/156.
ARNDT M., JUFFMANN T., VEDRAL V. (2009): Quantum physics meets biology. HFSP Journal 3(6): 386–400.
BLANKENSHIP R. E. (2002): Molecular Mechanisms of Photosynthesis, Blackwell, Oxford, U.K.
CARO PETROVIC V. (2014): Effect of genotype and sheep crossing system on neonatal development quantity and quality of lambs meat. (Ph.D dissertation). University of Pristina, Faculty of Agriculture Kosovska Mitrovica, Lesak.
CARO-PETROVIĆ V., PETROVIĆ P.M., ILIĆ Z.Z., PETROVIĆ M.M., RUŽIĆ-MUSLIĆ D., MAKSIMOVIĆ N., SELIONOVA M.I., MANDIĆ V. (2015): Crossing system application and its effect on lambs growth traits. Biotechnology in Animal Husbandry 31 (4), 505-514.
ÇOLAK M., TEKİN M.E., AKTAŞ A.H., AKAY N., YILMA T.C. (2013): Fattening performance and carcass traits of lambs obtained by crossing the Hasmer and Hasak sheep types with the Akkaraman breed. Turkish Journal of Veterinary and Animal Science (2013) 37: 337-345.
DAWSON L.E.R., CARSON A.F. (2002): Effects of cross-bred ewe genotype and ram genotype on ewe prolificacy, lamb viability and lamb output in the lowland sector. Journal of Agriculture Science 139:169–181.
DVALISHVILI V.G., FATHALA M.M., VINOGRADOV I.S., DAWOD A. (2015): Influence of Crossbreeding Romanov Ewes with Crossbred Argali

Romanov Rams on Male Progeny Performance and Carcass Traits. Journal of Veterinary Science and Technology 6: 275. doi:10.4172/2157-7579.1000275.

EISERT J., WISEMAN H. (2007): "Quantum aspects of life," In Nontrivial Quantum Effects in Biology: A Skeptical Physicists' View, World Scientific, Singapore.

GARIAEV P. P., FRIEDMAN M. J., LEONOVA-GARIAEVA E. A. (2011): Principles of Linguistic-Wave Genetics. DNA Decipher Journal, Vol. 1, 011-024.

GAVOJDIAN D., CZISZTER L.T., PACALA N. , SAUER M. (2013): Productive and reproductive performance of Dorper and its crossbreds under a Romanian semi-intensive management system. South African Journal of Animal Science , 43 (2), 221-228.

KONIG E.Z., MIRKENA T., STRANDBERG E., AUDHO J., OJANGO J., MALMFORS B., MWAI OKEYO A., PHILIPSSON J. (2016): Participatory definition of breeding objectives for sheep breeds under pastoral systems—the case of Red Maasai and Dorper sheep in Kenya. Tropical Animal Health and Production 48: 9–20.

KOSTIĆ V., JOSIPOVIĆ S., KARAN DJURĐIĆ S. (1977): Uticaj industrijskog ukrštanja merino ovaca sa mesnatim Il de Frans ovnovima na prinos i kvalitet mesa. Kvalitet mesa i standardizacija, 263-267.

LEYMASTER K.A. (2002): Fundamental Aspects of Crossbreeding of Sheep: Use of Breed Diversity to Improve Efficiency of Meat Production. Sheep and Goat Research Journal, 17(3), 50-59.

LEYMASTER K. (2016): Productivity Best Practices: Increasing Your Lamb Crop Series Use Crossbreeding.United States Lamb Resource Center. lambresourcecenter.com/wp-content/uploads/2016/01/ALB-Crossbreeding-FACT-SHEET-CLREV-11-03-16.pdf

LI W., GUO J., LI F., NIU C. (2016): Evaluation of Crossbreeding of Australian Superfine Merinos with Gansu Alpine Finewool Sheep to Improve Wool Characteristics. PLoS ONE 11(11): e0166374. doi:10.1371/journal.pone.0166374.

MAVROGENIS A.P. (1995): Breeding systems and selection strategies for sheep improvement in Cyprus. In : Gabiña D. (ed.). Strategies for sheep and goat breeding. Zaragoza: CIHEAM, 1995. p. 17-26 (Cahiers Options Méditerranéennes; n. 11)

MEKIĆ C. (1994): Ispitivanje reproduktivnih i proizvodnih osobina il de frans rase ovaca. Doktorska disertacija. Poljoprivredni fakultet, Univerzitet u Beogradu.

MITCHELL J. (2000): Crossbreading in Sheep - Issues and Options with a Focus on Early Lamb Systems. Kellogg Project November 2000. https://core.ac.uk/download/pdf/35468455.pdf

MITIĆ N. (1984): Sheep breeding (Ovčarstvo-serbian). Zavod za udžbenike i nastavna sredstva, Beograd, 508 pp.

MITIĆ N., KOSTIĆ V., OGNJANOVIĆ A., JOSIPOVIĆ S., ZUBAC A. (1974): Rezultati ukrštanja merinizirane cigaje mesnatim anglian COBB i Il de frans ovnovima u proizvodnji meleza za meso. Arhiv za poljoprivredne nauke, 100.

MITIĆ N., SKALICKI Z., DJORDJEVIĆ V., MANIĆ M. (1982): Osobine meleza stvorenih komninacijskim ukrštanjem tri rasa ovaca (Pirotska oplemenjena ovca). Arhiv za poljoprivredne nauke, 43,151, 279-297.

MITIĆ N., ZEREMSKI D., BEŠLIN R. (1964): Tovna sposobnost jagnjadi meleza F1 generacije merino prekos x cigaja. Arhiv za poljoprivredne nauke, 55.

PETROVĆ P.M., NEGOVANOVĆ D. (1994): The effects of three breed crossing on demonstration of heterosis in major fattening traits in lambs. Biotechnology in Animal Husbandry, 5-6, 31-37.

PETROVIĆ P.M. (2000): Genetika i oplemenjivanje ovaca / Genetic and improvement of sheep. (Monografija). Naučna knjiga, Beograd, 365 pp.

PETROVIĆ P.M. (2006): Creation of meaty sheep breed. Mis sheep. Institute for Animal Husbandry, Belgrade, 43 pp.

PETROVIĆ P.M., SRETENOVIĆ, LJ., RUZIC MUSLIC D., PACINOVSKI N., MAKSIMOVIĆ N. (2011): The effect of crossbreeding systems on lamb meat production. Macedonian Journal of Animal Science, 1(1), 57–60.

PETROVIĆ P.M., ŽUJOVIĆ, M., NEGOVANOVIĆ, D., MEKIĆ, C., KRAJINOVIĆ, M., STOJKOVIĆ, M. (1997): Recent findings on heterosis and its application in sheep farming. International Symposium "Scientific achievements in animal husbandry 97", Proceedings, 305-312.

PETROVIC P.M., CARO PETROVIC V., ILIC Z.Z., RUZIC MUSLIC D., MILENKOVIC M., MILOSEVIC B., GRCAK D. (2013): Features of the New Breed of Sheep in Serbia Called Mis Sheep 1. Reproductive Characteristics and Body Development. Veterinarija Ir Zootechnika (Vet Med Zoot), (Vet Med Zoot). T. 64 (86),70-75.

PETROVIĆ P.M., NENADIĆ M. (1992): Directions for the further use of the Weremberg breed of sheep in the genetic improvement of sheep breeding in Serbia. Biotechnology in Animal Husbandry, 5-6, 143-151.

PETROVIĆ P.M., NEGOVANOVIĆ D., ŽUJOVIĆ M. (1995): New opportunities to increase the production of lamb by the method of cross - breeding. International Symposium. Biotechnology in Animal Husbandry, 11, 97-103.

THOMAS L.D. (2006): Useable Crossbreeding Systems for Small and Large Sheep Flocks. http://hulp.landbou.com/wp-content/uploads/2014/03/3cde64f8-1824-4e08-b602-798f7d388304.pdf

WOLFOVÁ M., WOLF J., MILERSKI M. (2014): Calculating economic weights for sheep sire breeds used in different breeding systems. Journal of Animal Science 89,1698–1711.