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Review article

Sheep of the synthetic lines BCP and SCP in practical breeding and experimental research

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The study presented the history of the synthetic sheep lines BCP and SCP and the method by which they were created by the employees of the Department of Small Ruminant Breeding and Agricultural Advisory, University of Life Sciences in Lublin. The article additionally describes the role of these animals in sheep production and experimental research. Comprehensive analysis of the effects of breeding work in these populations, together with the results of scientific research using them as subjects, indicates that sheep of the synthetic universal prolific meat lines BCP and SCP are fully suitable for production of meat lambs in both intensive and extensive rearing conditions. Animals of both lines underwent experiments related to the genetic, physiological and environmental determinants of the level of reproductive and meat performance, which showed that these populations are well-suited for scientific experiments. According to the authors, in further selection work on the synthetic BCP and SCP lines greater focus should be placed on the percentage of reared lambs and the conformation of the dorsal part of the torso. They also indicated the need for monitoring of genetic variation due to the risk of increased inbreeding.

KEY WORDS: sheep / breeding work / synthetic lines BCP and SCP

At the beginning of the 1990s a shift occurred in Polish sheep farming from wool and meat production to meat production, with a final product in the form of a slaughter lamb. Ewes of native breeds, characterized by high prolificacy, were to be used to produce slaughter lambs through commercial crossing with rams of meat breeds and lines. This technology, while effective, necessitated raising flocks of purebred sheep producing parent material for crossbreeding, which due to the fragmentation of native sheep farming

was highly problematic. A simpler means of producing livestock for slaughter is the use of synthetic lines produced by crossing several breeds and selecting for the desired characteristics in the population obtained. Examples of such synthetic populations include Canadian sheep of the lines Rideau Arcott, Outaouais or DLS [41]. Similar breeding measures have been carried out in New Zealand, Australia and in several countries of Western Europe [16].

A few synthetic populations have been created in Poland as well, and two (prolific-meat), called BCP and SCP, were created at the University of Life Sciences in Lublin on the initiative of professors Tomasz M. Gruszecki and Czesława Lipecka.

The aim of the study is to present the history of the BCP and SCP sheep lines and the role of these animals in sheep production and experimental research.

Breeding work on the creation of the BCP and SCP synthetic sheep lines

The idea of creating a synthetic line of sheep to produce slaughter lambs for the needs of the Lublin region arose at the beginning of the 1990s. It was not without significance that commercial crossing of native breeds—in this case Uhruska and Polish Merino sheep—with rams of meat breeds was relatively unpopular mainly because the population was highly fragmented. The results of previous research on commercial crossing conducted at the University of Agriculture in Lublin were very helpful in planning the breeding work. It should be noted that this research is currently being continued by the employees of the Department of Small Ruminant Breeding and Agricultural Advisory of the University of Life Sciences in Lublin.

Research on the use of various breeds of sheep for commercial crossing began in that department as early as the 1960s and 1970s [5]. In the 1980s, in consideration of the needs of farming practice, extensive work was undertaken to develop schemes for crossing Uhruska ewes with rams of meat breeds. Before the experiments were begun the choice of breeds of meat rams was an open question. The breeds selected were Berrichon du Cher, Suffolk and Ile de France. The choice of the first two was based on the results of studies by other authors, who extensively described these animals' suitability for commercial crossing, considering them to be among the best in the world [28, 29, 34, 40, 43]. Ile de France rams were selected on the basis of the results of a pilot study conducted at the university in Lublin [14].

The experiments showed that ewes of the Uhruska type of Polish Lowland sheep are fully suited for commercial crossing with rams of meat breeds, as the fattening efficiency and carcass value of their offspring is improved. Among meat breeds, Suffolk and Berrichon du Cher rams were recommended for crossing with Uhruska ewes—the former for production of both light (up to 30 kg) and heavy (up to 45 kg) lambs, and the latter for production of heavy lambs.

Understanding the importance of reproduction in production of slaughter lambs, the team at the university in Lublin, alongside the analyses described above, conducted research on the effects of crossing Uhruska sheep with rams of prolific breeds. The best results in terms of reproduction were noted in the crosses with rams of the Romanowska and Olkuska breeds [11, 38].

Based on the results of the studies cited above, measures were begun with the aim of producing synthetic populations adapted to the conditions of east-central Poland. This work was carried out at the Tadeusz Efner Small Ruminants Teaching and Research Station in Bezek, which is an integral part of the Department of Small Ruminant Breeding and Agricultural Advisory, University of Life Sciences in Lublin, and at the Experimental Farm in Uhrusk, also belonging to the University of Life Sciences in Lublin.

During the creative breeding work on lines of sheep the employees of the Department worked together with the management and employees of the Regional Association of Sheep and Goat Farmers (RZHOiK) in Lublin. Elements of the breeding work tested at the Research Station in Bezek were implemented in practice on selected sheep farms located in eastern Poland (the region where RZHOiK in Lublin operates).

From the start of the programme's implementation the creation of two separate lines was planned. The starting material for cross-breeding was ewes of domestic breeds, i.e. Polish Lowland sheep of the Uhruska variety (pon) or Polish Merino (mp), which came from the Lublin region and were thus adapted to local environmental conditions. Due to the need to maintain high reproduction parameters in the final population, it was decided that rams of prolific breeds should also be used in the cross-breeding programme. It was considered expedient to use the existing population of Uhruska and Polish Merino sheep in the region, which had been improved with a prolific breed under a prolificacy improvement programme. An effort was made, in accordance with knowledge obtained during earlier research [23], to use animals improved by rams of the Romanowska, Okulska, or in some cases Finnsheep breeds in the breeding work. Such ewes were crossed with rams whose genotype was 50% meat breed (Berrichon du Cher or Suffolk) and 50% Charollais. The use of the Charollais breed was dictated by the need to increase the prolific component in the final genotype without reducing meat content parameters. The choice of this particular breed was determined by the results of studies conducted in other research centres, confirmed by the results of our own research [2, 3, 4, 15, 31]. Implementation of the objectives of the crossbreeding programme required that the work should be conducted in two stages, as presented below:

Stage I:

Task:

to obtain a crossbred population for crossing in stage II

Means of implementation:

♀ Suffolk (S) x ♂ Charollais (C)
♀ Berrichon du Cher (B) x ♂ Charollais (C)

Outcome:
♀♂ (SC)
♀♂ (BC)

Stage II

Task:

to obtain the target population

Means of implementation:

♀ from PID[1] (25% prolific breed, 75% pon[2] or mp[3]) x ♂ SC
♀ from PID[1] (25% prolific breed, 75% pon[2] or mp[3]) x ♂ BC
♂ from PID[1] (25% prolific breed, 75% pon[2] or mp[3]) x ♀ SC
♂ from PID[1] (25% prolific breed, 75% pon[2] or mp[3]) x ♀ BC

[1]Prolificacy Improvement Programme [30];
[2]Polish Lowland sheep of the Uhruska variety (pon);
[3]Polish Merino (mp)

Outcome:

♀♂ BCP line with genotype: 37.5% domestic breed pon[2] or mp[3], 12.5% prolific breed (most often Romanowska or Finnsheep), 25% Berrichon du Cher and 25% Charollais

♀♂ SCP line with genotype: 37.5% domestic breed pon[2] or mp[3], 12.5% prolific breed (most often Romanowska or Finnsheep), 25% Suffolk, 25% Charollais

[2]Polish Lowland sheep of the Uhruska variety (pon);
[3]Polish Merino (mp)

In the year 2000, official registers of animals were opened, initiating use value assessment, and this date is regarded as the date when sheep with the names BCP synthetic line and SCP synthetic line were created. The names of the lines were formed from the first letters of the names of the contributing breeds.

The sheep of these populations are fairly large animals—the rams attain a body weight of about 100 kg, and the ewes about 70 kg, with well-defined musculature and a strong herd instinct. The head, legs, and lower torso are poorly covered in wool. They have prolificacy of above 150% and mature early, so that the ewes can be used for breeding in their first year of life.

From the start of the breeding work selection was carried out for prolificacy and meat performance traits. Up to 2005 performance control was carried out according to the principles and requirements for the paternal meat populations, using the selection index in use at that time in Poland. Since 2006 performance control in both lines has been carried out according to the principles and requirements for the maternal populations.

Performance traits of BCP and SCP sheep

From the beginning of their existence, i.e. since 2000, the sheep of both lines have enjoyed recognition among breeders and producers of slaughter lambs. An expression of this interest has been an increase in the number of these animals subject to use value assessment. In 2015 the population of breeding ewes of these lines entered in registers kept by the Polish Union of Sheep-Farmers (PZO) numbered about 400, which was 3.5% of the total population of breeding ewes in the Lublin region [39].

From the start of the breeding work great attention has been paid to the reproductive performance of the synthetic populations. Analysis of reproductive indicators over a period of 15 years showed that the mean fertility of these animals was 94.2-96.1%, which can be considered a very good level. The prolificacy level was also high, at over 153% (Tab. 1). The authors believe that there is further potential to improve individual reproductive parameters through consistent implementation of individual elements of breeding work and careful attention to environmental conditions.

Table 1
Results (%) of evaluation of reproductive performance of BCP and SCP ewes [39]

Year	BCP				SCP			
	n	fertility	prolificacy	% reared lambs	n	fertility	prolificacy	% reared lambs
2003	189	94.4	175.3	86.6	202	93.5	164.1	84.5
2010	165	97.2	177.5	82.1	156	93.6	158.0	88.3
2015	189	89.9	150.9	87.8	194	97.0	147.5	86.0

An extremely important characteristic of the performance of these sheep lines is the body weight of lambs at the age of 56 days. Table 2 presents data for this trait in lambs of each line, according to sex. Over the years certain fluctuations are observed, as a consequence of changing environmental conditions, associated mainly with changes in feed quality. The mean value for this trait calculated for 10 consecutive years was about 19 kg, which can be regarded as a good result.

Table 2
Body weight (kg) of BCP and SCP lambs at 56 days of age [39]

Year	Males				Females			
	BCP		SCP		BCP		SCP	
	n	body weight	n	body weight	n	body weight	n	body weight
2003	92	21.7	92	21.9	103	21.0	99	22.3
2009	168	19.9	183	19.4	111	19.1	141	19.6
2015	103	18.0	109	20.1	121	17.4	94	19.5

At the age of 8 months the body weight of the male and female BCP and SCP lambs over the years 2003-2015 ranged from 48.1 to 56.7 kg in females and 60.7 to 72.7 in males (Tab. 3). In most cases the values for this trait were similar in the two lines, which

Table 3
Body weight of male and female BCP and SCP lambs at 8 months of age in the breeding flock in Bezek [39]

Year	Females				Males			
	BCP		SCP		BCP		SCP	
	n	kg	n	kg	n	kg	n	kg
2003	39	55.8	37	54.3	8	60.7	9	62.8
2010	28	52.4	30	48.1	5	66.3	6	63.5
2015	32	56.7	31	50.2	7	72.7	7	68.4

indicates that the two lines are very similar, have good growth parameters, and—of particular importance—are fully adapted to the conditions prevailing in eastern Poland.

For a full characterization of the sheep of both lines, the yield and staple length of the greasy wool were monitored. Over the years a systematic decrease was observed in the values for both of these traits; they were 4.9 kg and 4.16 cm in 2003 and 3.11 kg and 3.35 cm in 2015. The reduction in these values is undoubtedly due to the fact that these traits were not considered during selection. In our opinion, in the case of animals to be used for production of slaughter lambs, this course of action is justified [19].

In selected animals of each line (from births in 2008) post-slaughter analysis was performed (Tab. 4). The carcasses evaluated according to the EUROP scale placed on average between conformation classes O and R, while fatness ranged from 2.21 to 2.31 points. These results indicate the need for further improvement of conformation, while fatness should be maintained at the current level. The mean dressing percentage ranged from 41.56% to 42.06%, which is also not an entirely satisfactory value and should be improved during further breeding work. Analysis of the share of primal cuts in the carcasses, which was 41-42%, leads to similar conclusions. However, analysis of the tissue composition of the leg showed that muscle tissue constituted about 68% and fat tissue about 16% [17]. These results are similar to those obtained in lambs obtained by crossing Uhruska ewes with rams of meat breeds [10].

Sheep of the BCP and SCP lines in experiments

Health and production consequences

One of the first experiments using sheep of the BCP and SCP lines analysed determinants of the spread of the Maedi-visna virus (MVV) and the consequences of its occurrence in flocks of small ruminants. Lower prevalence of MVV antibodies was observed in BCP and SCP sheep (about 20% infected animals) than in the Suffolk breed (about 53%). This research showed deterioration in reproductive parameters, a reduction in the level of meat and milk performance, and increased susceptibility to transport stress in infected herds as compared with herds free of MVV [17, 18, 32].

Table 4
Results of slaughter analysis of BCP and SCP male lambs in the breeding flock in Bezek [17]

Specification	BCP (n=29)	SCP (n=29)
Body weight at slaughter (kg)	31.76	33.28
Age of lambs at slaughter (days)	100	100
EUROP: conformation[1]	2.45	2.93
fatness	2.21	2.31
Dressing percentage	41.56	42.06
Share of primal cuts in the carcass (%)	41.28	42.01
Percentage of tissues in the leg		
muscle	68.23	68.60
fat	16.34	16.34
bone	15.43	14.79

[1]To calculate the means for the EUROP evaluation the following numerical values were used: class E – 5 pts., U – 4 pts., R – 3 pts., O – 2 pts., P – 1 pts.

A study was also conducted on the usefulness of a haptoglobin assay (Hp) to evaluate the welfare and health status of animals. The results indicated that haptoglobin should be assayed as an element of monitoring of the health of the flock and an opportunity to rapidly diagnose threats, particularly those posed by infectious diseases. Undetectable or low levels of Hp are good indicators of the absence of serious health disorders, whereas high concentrations of this protein indicate the need to perform additional diagnostic tests [27].

In another series of experiments, comparing different methods of antiparasitic prophylaxis, preparations based on natural plant substances as well as chemical preparations were found to effectively reduce Coccidia infection in lambs. At the same time the plant extract was found to have a beneficial effect on the health and development of the lambs [21].

An interesting direction of research was an analysis of the consequences of using five commercially available homeopathic preparations to improve udder health. Positive effects of the use of such preparations were improved udder health, a reduction in the somatic cell count in the milk, and improvement (by 30 percentage points) in reproductive performance results as compared to the control [42].

Meat and milk performance

A substantial portion of the research involved improving the nutritional value of lamb meat using feed supplements, including linseed. The results of the study indicated that

a 10% linseed supplement significantly improved the dietary value of the muscle tissue, increasing the content of unsaturated fatty acids by about 50%. In the meat of the lambs receiving feed supplemented with linseed the quantity of linoleic acid (C18:3) was four times higher than in the control [13].

Animals of both lines were the subject of research aimed at improving techniques for measuring conformation and fatness in living animals using ultrasonography. The studies showed that sheep of the BCP and SCP synthetic lines have similar values for both the depth of the longissimus dorsi muscle and back fat thickness measured above the eye of the loin [17, 20, 24].

Sheep farming systems

Sheep of the BCP line provided the material for research on how the farming system (indoor or pasture system) affects milk yield. This topic is particularly important in flocks in which lambs are born in the spring and reared using a pasture. BCP ewes raised on a pasture and those kept indoors had similar milk yield of about 177 kg of milk, which indicates that these animals can be raised in different types of systems [37].

This research also included determination of the level of haematological blood indicators in the ewes, and showed that these indicators were modified by the farming system, while remaining within reference values [36].

Analysis of reproductive indicators showed that the animals raised in the pasture had a higher ovulation rate and higher prolificacy, which indicates that ewes of the BCP line are suited to an outdoor system [35].

Reproduction

Research on determinants of the level of reproduction showed that the number of ovulation follicles in Uhruska and BCP sheep was directly dependent on the plasma level of IGF-1. Injection with hCG was found to increase the number of ovulations when administered at the start of oestrus, while administration of hCG at the end of oestrus may improve the embryo survival rate and prolificacy [1].

In another study in this area, triplets from the heaviest BCP ewes had significantly higher concentrations of GH, insulin and glucose and a lower level of IGF-1 than lambs of the same age from non-triplet births [25].

In another area of research, delayed sexual maturity in ewes with low birthweight and low daily weight gains was found to be linked to a reduced level of leptin and a lack of expression of KiSS-10 in the pituitary gland [26].

An interesting topic of research using sheep of the BCP and SCP lines was the use of semen of rams of both lines for laparoscopic insemination of ewes outside the reproductive season. The results obtained indicated that the semen of the rams of both lines had very good parameters and was well-suited for insemination in either fresh or frozen form [33].

Research using molecular techniques

Molecular biology techniques were used in studies on sheep of both lines, e.g. for phylogenetic comparison of the domestic sheep with the mouflon. Mitochondrial DNA (mtDNA) was used to analyse a fragment of the cytochrome b gene (cyt b) of the dome-

stic sheep (*Ovis aries*), represented by animals of the BCP synthetic line, and the mouflon (*Ovis musimon*). The occurrence of 18 haplotypes was observed, which form two separate clades in the domestic sheep and three in the mouflon. SNP mutations were noted—22 mutations in the mouflon and 14 in the domestic sheep. The authors concluded that the distribution of haplotypes in domestic sheep and mouflons suggests intercontinental dispersion of genes of the family *Ovidae*. It was further concluded that the results confirm the hypothesis that contemporary lines of sheep and the European mouflon have a common ancestor [22].

In another study on prolific meat sheep of the BCP and SCP synthetic lines, the occurrence of four alleles was noted in the 12th intron of the calpastatin gene (*CAST*): a, b, c and e. The e allele was identified for the first time in the world, and its nucleotide sequence was entered in the *GenBank* under number EU486168 [8].

Furthermore, the presence of eight genotypes of the *CAST* gene was demonstrated, and the results indicated that lambs with the aa genotype in the *CAST* locus should be given preference during selection, as they have the most favourable leg tissue composition, whereas animals of the ae genotype had the significantly highest content of intramuscular fat [6, 7].

As part of measures aimed at protecting sheep raised in European Union countries against scrapie, a study was conducted to analyse the reproduction results of sheep of the BCP and SCP lines and the growth of their offspring in relation to the polymorphic form of the gene PRNP within codons associated with susceptibility to scrapie (136, 154 and 171). Elimination of ewes with genotypes with high or very high susceptibility to scrapie from the flock was not found to reduce reproductive indicators in the flock or the growth of the offspring [12].

The genetic structure of sheep of the BCP and SCP synthetic lines in relation to the breeds used to create them was analysed on the basis of the genomic DNA of five selected microsatellite markers. The results showed relatively low genetic variation in the sheep populations and thus the need for further monitoring of genetic variation in this population. The phylogenetic tree distinguished two groups from the populations analysed. The first is formed by the starting lines, i.e. Romanowska, Charollais, Olkuska, Friesian, and Suffolk, while the SCP and BCP lines form a separate clade, which indicates differences in the genetic structure of these lines as compared to the starting breeds [9].

Conclusions

The following generalizations can be formulated on the basis of the results of the research conducted and the observations made in flocks of BCP and SCP sheep:

- The breeding work resulted in two similar synthetic lines of sheep, which are characterized by good growth parameters and meatiness and, importantly, are well-suited to the conditions prevailing in eastern Poland.
- Sheep of the BCP and SCP lines are a suitable material for experiments on the domestic sheep species.
- The high meat performance parameters of sheep of the synthetic lines BCP and SCP, in conjunction with measures carried out in the Lublin region to activate the domestic

market for lamb meat, contribute to rising interest in sheep farming and to an increase in the population of this species.

• During selection of sheep of the BCP and SCP lines close attention should be paid to the degree of conformation, with preference given to individuals with a long, wide torso and a meaty leg;

• There is potential for further improvement of reproductive parameters in these populations through systematic breeding work and careful attention to environmental conditions.

• Genetic variation should be monitored in both lines due to the risk of inbreeding, particularly in such a small population.

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