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RESEARCH ARTICLE

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Impact of variation in production traits, inputs costs and product prices on profitability in multi-purpose sheep

Zuzana Krupová[1]*, Emil Krupa[1], Marie Wolfová[1] and Monika Michaličková[2]

[1] *Institute of Animal Science. P.O. Box, 1. 104 01 Prague, Czech Republic.* [2] *NAFC-Research Institute for Animal Production Nitra. Hlohovecká, 2. 951 41 Lužianky, Slovak Republic*

Abstract

The impact of variation in production traits, and inputs costs and product prices on economic efficiency of a multi-purpose sheep breed farmed in a marginal area of Slovakia was examined using a bio-economic simulation model of the program package ECOWEIGHT. Variations in the proportion of milk processed to cheese on farms, sheep product prices and production costs were based on values observed in Slovakia from 2004 to 2010, and variation in ewe performance traits (milk yield, conception rate, litter size, ewe productive lifetime) was based upon breed standards for the Improved Valachian breed. Revenue from government subsidies was not included in farm returns. Profitability ratios of farms were negative for most combinations of production and economic factors (–6 to –37%). Only farms processing milk to cheese, farms with the highest simulated milk yield (180 kg per ewe) and farms receiving the highest simulated milk and cheese prices (0.99 and 8.36 € kg^{-1}) achieved positive profitability's of 11, 21 and 3%, respectively. Farms reaching the performance level of animals characterised by the breed standard had 9% higher revenue, 3% lower cost and 11 percentage points higher profitability ratio (–6%) than farms with average animal performance, when compared at the same average level of all product prices and costs. To promote economic sustainability of multi-purpose sheep breed enterprises in marginal areas, selection and management to achieve the biological potential of those breeds and increasing the proportion of milk processed to cheese on farms are recommended.

Additional key words: economic sustainability; marginal areas; revenues; costs; Improved Valachian.

Introduction

Business enterprises, sheep farms not excluded, should produce with maximum economic efficiency. The efficiency of an enterprise can be measured by the profitability ratio (profit gained per unit of costs). Rational utilisation of inputs and their target relationship to the value of outputs is one of the most important preconditions for effective production.

Jávor *et al*. (2005), Vláčil (2005) and Michaličková *et al.* (2014), conducted micro-economic analyses based on evaluation of data from commercial sheep enterprises; while Aguilar *et al*. (2006) and Cehla *et al*. (2012) examined by specific production chain such as lamb production or lamb finishing and of entire production systems. Bio-economic models for the economic evaluation of sheep breeding systems and for the estimation of the economic importance of performance traits have also been reported by Haghdoost *et al*. (2008) and Wolfová *et al*. (2009a,b). In those analyses, production strategy, performance levels for economically important traits, production costs and market prices were the most important factors influencing the economic efficiency of farm animal production. In Europe, many of these factors have changed in recent years (FAOSTAT, 2013; Suppl. Fig S1[pdf online]).

* Corresponding author: krupova.zuzana@vuzv.cz
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Abbreviations used: BL (base level of input parameters); BS (breed standard); CFE (average feed costs for roughage and concentrates); CFI (fixed costs); CLA (labour costs); CR (conception rate of ewes); LIF (productive lifetime of ewes in reproductive cycles or in years); LS (litter size in number of lambs born per ewe lambing); MCH (percentage of milk processed to cheese on farm); MY (milk yield); PL (price of lambs); PMCH (price of milk and cheese).

Changes in market prices and production practices for sheep commodities also varied importantly from country to country in the period from 2000 to 2010 (Suppl. Figs. S2a and S2b [pdf online]). Overall, market forces (demand *vs.* supply) and their impact on market prices of sheep commodities played a major role in the changes portrayed in the accompanying figures.

The long tradition of sheep farming, increased demand for dairy sheep products and increasing numbers of sheep in recent years are encouraging indicators for sheep farming in Slovakia. Additionally, economic sustainability of multi-purpose sheep breeds is an important factor for maintaining cultural landscape and settlements in marginal areas of Slovakia. According to Slovakian performance data (BS-SK, 2013), the production potential of some Slovakian sheep breeds has not been achieved. Improved animal performance could therefore be an important factor to improve economic efficiency of sheep farming.

For this purpose, a comprehensive approach considering the animal performance and economic evaluation was used to investigate the impact of various production and economic factors on economic efficiency of multi-purpose sheep farms. The most widespread Slovakian sheep breed farmed in marginal areas, Improved Valachian, was analysed using a bio-economic simulation model.

Material and methods

Basic characteristics of the production system

The Improved Valachian is a multi-purpose (milk-lamb-wool) sheep breed established in Slovakia in 1982. It is raised most frequently in mountains and foothill conditions higher than 800 m above sea level (marginal region) in the extensive or semi-extensive so-called Carpathian production system. Typical management practices include indoor lambing in winter, summer grazing on pasture, a single breeding season per year lasting from August to October and natural mating. Replacement ewes are mated for the first time at 17 to 19 months of age. To improve meat production and carcass quality, about 10% of the ewe population is crossed with rams of meat breeds. Average lambing date is February 15th. Lambs are reared together with ewes till Easter and sold at an average of 49 days of age. After weaning of lambs, ewes are milked twice a day through the end of the breeding season (October 15th on average). Of the total milk production, 40% is processed to cheese on farms, and the rest is delivered to dairies. The average values of the most important biological and production parameters recorded at Improved Valachian farms in Slovakia in the period from 2004 to 2010 are presented in Table 1. These values were based on own investigations on sheep farms and records in the database of the Breeding Service of the Slovak Republic (unpublished data). Further characteristics of the production system can be found in Krupová *et al.* (2009, 2012).

Economic efficiency of the farming system

The economic efficiency for the Improved Valachian breed in the production system described above was expressed as profit (P) ewe^{-1} year^{-1} and as profitability ratio (PR):

$$P = (R' - C') \times n \quad [1]$$

$$PR = \frac{100 \times P}{TC} \quad [2]$$

where R' and C' are the row vectors of revenues and costs per animal for the individual sheep categories (ewes, rams, weaned lambs, female and male flock replacements) and n is a column vector of the numbers of animals of each sheep category per ewe and reproductive cycle. The length of the reproduction cycle was 365 days (one lambing per year). Profitability ratio (PR) measures the effectiveness of expended total costs (TC), *i.e.* it is the value of profit per unit of costs.

Revenues came from sold milk and cheese, weaned lambs, culled ewes and rams, wool and manure. Milk price was based on milk fat and protein content and on somatic cell score. The price of lambs was per kg of live weight. Cross-bred lambs were sold for a 10% higher price than pure-bred lambs. Wool was sold as greasy wool without considering variation in quality. Manure for sale was produced only in winter. Costs for all sheep categories included expenses for feed, winter housing, labour, health care, milking, cheese production and shearing, purchase of rams for crossing and fixed costs. Fixed costs included depreciation expenses, energy, repairs, insurance and overhead costs and were expressed per each animal category per day. All costs connected with lambs prior to weaning (except for cost of supplementary feed over milk con-

Table 1. Biological and production characteristics for the Improved Valachian breed used in initial calculations and subsequent analyses

Parameter	Value[a]
Conception rate of ewe lambs (%)	92.8
Ewe to ram ratio	40:1
Average birth weight of lambs (kg)[b]	3.11
Relative frequency that a lamb is stillborn or died before 24 h of age (%)[b]	3.00
Survival rate of lambs till weaning (%)[b]	90.0
Average weaning weight of lambs (kg)[b]	13.68
Number of lambs weaned (lambs per 100 ewes)	114
Number of lambs sold at weaning for slaughter (lambs per 100 ewes)	78
Pure-bred female lambs reared for replacement (lambs per 100 ewes)	27
Pure-bred male lambs reared for replacement (lambs per 100 ewes)	1
Average daily gain of female lambs in rearing (g day^{-1})[c]	71
Average daily gain of male lambs in rearing (g day^{-1})[c]	90
Mature weight of ewes (kg)	50.0
Mature weight of rams (kg)	70.0
Fat content in milk (%)	7.57
Protein content in milk (%)	5.76
Somatic cell score	5.02
Fleece weight from rams (kg animal^{-1} year^{-1})	5.0
Manure from adult animals (kg animal^{-1} day^{-1} in winter)	5.0

[a] Based on own investigations on sheep farms and on the database of the Breeding Service of the Slovak Republic (unpublished data). [b] Pure-bred and cross-bred lambs together averaged over litter sizes and parities. [c] Pure-bred lambs averaged over litter sizes.

sumption) were part of the cost for categories of ewes. Total revenues and costs for the entire production system were expressed per ewe and per year. In order to evaluate the direct impact of the changes in production and economic circumstances on the profit and profitability ratio of the production system, no subsidies were included in the calculation of revenue. This was appropriate because all subsidies provided to Slovakian sheep farmers are not dependent on animal performance, revenues or production costs. All of the production and economic data needed for the calculation of revenues and costs during the analysed period were collected on 41 dairy sheep farms with the Improved Valachian breed. The average farm size was 400 to 450 ewes. Production and economic data of these farms were close to the average values over the whole population of the Improved Valachian breed in Slovakia. Averages of those factors over the time period 2004 to 2010 are presented in Table 2 for individual sheep categories. Detailed description of the econo-

Table 2. Production and economic characteristics used in base calculation

Parameter	Ewes	Rams	Replacements[a]
Amount of fresh feed matter per animal (kg day^{-1})	2.62	2.27	1.91
Number of man-hours per animal and year[b]	7[c]	3	6
Number of shearings per animal and year or per period	2	2	2
Costs per shearing (€ animal^{-1} year^{-1})	2.257	3.319	1.726
Costs for milking (€ kg^{-1} of milk)	0.048	—	—
Costs for cheese processing (€ kg of cheese)	0.199	—	—
Revenues from wool (€ animal^{-1} year^{-1})[d]	2.257	3.319	1.726
Revenues from manure (€ animal^{-1} year^{-1})	3.286	6.472	2.692
Revenues from culled adult animals (€ animal^{-1} year^{-1})	31.71	44.41	31.78
Revenues from sold lambs (€ ewe^{-1} year^{-1})[e]	28.23	—	—

[a] Ewe lambs from weaning to first lambing. [b] Without labour needed for milking and cheese processing. [c] Including lambs till weaning. [d] Based on a price of €0.664 kg^{-1} wool. [e] Based on the average price of €36.09 per sold lamb and on the proportion of 78.21 lambs sold per 100 ewes and year.

Table 3. Ranges for the production, biological and economical parameters used in the analyses and the breed standards

Parameter	Base level[a]	Lower bound (–)[b]	Upper bound (+)[c]	Breed standard[d]
Milk yield (kg per 150d milking period)	100	70	180	110
Conception rate of ewes (%)	84	74	94	95
Average litter size (lambs per lambed ewe)	1.21	1.01	1.41	1.30
Productive lifetime of ewes (reproductive cycles)	3.85	3.43	4.27	4.65
Proportion of milk processed to cheese on farms (%)	40	0	100	40
Market price of lambs (€ kg^{-1})	2.720	1.632	3.808	2.720
Market price of milk commodities				
Milk price (€ kg^{-1})	0.704	0.422	0.986	0.704
Cheese price (€ kg^{-1})	5.970	3.582	8.358	5.970
Price of feed rations (€ kg^{-1} fresh matter)				
Lactating ewes (with one lamb) in winter[e]	0.070	0.056	0.084	0.070
Labour costs (€ per man-hour)	3.319	2.656	3.983	3.319
Fixed costs (€ per stable place per day)				
Ewes including lambs till weaning[f]	0.159	0.127	0.191	0.159

[a] All parameter values are the averages obtained in Slovakia in the period from 2004 to 2010. [b] A decrease of product prices by 40% and of costs by 20% in comparison to the base level. [c] An increase of product prices by 40% and of costs by 20% in comparison to the base level. [d] Performance of ewes was set to the Improved Valachian breed standard keeping other production and economic parameters at the base level. The length of productive lifetime had also increased as a consequence of improved ewe conception rate. [e] This is only one example; price of feed have been increased and decreased for all sheep categories and all feed rations. [f] This is only one example; fixed costs have been increased and decreased for all sheep categories.

mic parameters used for the calculation can be found in Krupová *et al.* (2009, 2012). Additional biological, production and economic parameters whose levels were varied in comprehensive analyses are presented in Table 3.

Analysed production and economic parameters

To detect the relative impact of production and economic input parameters on the revenues, costs, profit and profitability ratios for multi-purpose sheep farms in Slovakia, 22 distinct calculations were done. The bio-economic model of the program EWSH1 which is included in the program package ECOWEIGHT (Wolf *et al.*, 2011) was used for all calculations. In the initial calculation, the program was run using the average level of production and economic parameters from the period 2004 to 2010 (base level, Table 3) as input parameters. In subsequent runs, the level of each of the investigated parameters was first increased and then decreased in a range representing the variability of that parameter in the 2004 to 2010 time period (see Table 3 for the upper and lower bound of the parameters). The prices for sheep products (lambs, milk and cheese) deviated from the base situation by ± 40%, whereas the costs for feed, labour, and fixed costs deviated from the base by ± 20%. The upper and lower bounds for milk yield, conception rate of ewes, litter size and ewe productive lifetime were set to the highest and to the lowest values of those traits recorded in the database of the Breeding Service of the Slovak Republic (unpublished data) during the investigated time period (Table 3).

In an additional run, levels of the main recorded traits were set equal to the Improved Valachian breed standard (ASGB, 2013), *i.e.* 110 kg milk yield in the 150-d milking period, 95% conception rate of ewes and a litter size of 1.30 lambs per lambed ewe. Productive lifetime of ewes is not included in the breed standard, but when increasing the conception rate from 84% (base calculation) to the breed standard (95%), the productive lifetime increased to 4.65 reproductive cycles (3.59 years).

In a final, the impact of alternative marketing strategies for dairy products on the investigated economic characteristics was examined by changing only the pro-

Table 4. Costs incurred by sheep categories in the modelled base production system

Category	Costs per animal (€)	Animals (No. ewe^{-1} year^{-1})	Total costs (€ ewe^{-1} year^{-1})
Ewes (averaged over all reproductive cycles)[a]	159.90	1.00	159.90
Lambs from birth to weaning[b]			
Female	3.65	0.48	1.73
Male	4.96	0.48	2.35
Ewe lambs from weaning to first lambing (at 23 months of age)	136.74	0.27	36.92
Male lambs from weaning to reproduction (at 18 months of age)	114.51	0.01	1.15
Purebred rams (per year)	97.00	1/40	2.43
All categories together	—	—	204.48

[a] Including all costs for lambs till weaning except supplemental feed over milk consumption. [b] Costs for supplementary feed.

portion of milk processed to cheese on farms from the base value of 40% to zero and to 100%, respectively.

Results

Impact of variation in input parameters on cost components

In all calculated variants of our modelled multi-purpose sheep production system, the highest proportion of total costs was allocated to ewes (see Table 4). Costs for other sheep categories (lambs, female and male replacements and rams) accounted for 22% of the total costs ewe^{-1} year^{-1}. Therefore, the sensitivity of specific cost components to variation in the marketing strategy for milk, in animal performance and in the prices of inputs will be presented here only for the adult ewe category, *i.e.* on costs per ewe in the second reproductive cycle (Table 5).

As expected, a change in the marketing strategy for milk influenced only the costs for cheese processing.

Table 5. Impact of production and economic parameters on the cost components for adult ewes during the second reproductive cycle

Input parameter and its variable[a]		Cost components (€ ewe^{-1} year^{-1})[b]						
		Veterinary	Labour	Fixed	Milking	Cheese processing	Feed	Total
Base level		8.70	22.36	55.92	5.84	9.67	53.75	159.90
Milk to cheese	+	8.70	22.36	55.92	5.84	24.17	53.75	174.41
	–	8.70	22.36	55.92	5.84	0.00	53.75	150.24
Milk yield	+	8.70	22.36	55.92	10.39	17.19	64.37	182.59
	–	8.70	22.36	55.92	4.05	6.70	47.23	148.62
Litter size	+	8.69	22.36	55.92	5.92	9.79	54.08	160.43
	–	8.70	22.37	55.92	5.77	9.56	53.45	159.43
Breed standard		8.70	22.36	55.92	6.20	10.26	54.61	161.71
Feed costs	+	8.70	22.36	55.92	5.84	9.67	64.10	170.25
	–	8.70	22.36	55.92	5.84	9.67	43.40	149.56
Labour costs	+	9.43	26.84	55.92	6.20	10.25	53.75	166.05
	–	7.96	17.89	55.92	5.48	9.09	53.75	153.75
Fixed costs	+	8.70	22.36	67.10	5.84	9.67	53.75	171.09
	–	8.70	22.36	44.73	5.84	9.67	53.75	148.72

[a] See Table 3 and the Section Material and Methods for the description of the parameters. [b] For all variants of input parameters, costs for shearing and bedding were €2.17 and €1.49 ewe^{-1} year^{-1}, respectively.

Variations in ewe performance (milk yield, litter size) had substantial influence on cost for feed. Costs for milking and cheese processing were highly sensitive to milk yield but varied to only a small extent with changes in litter size. Variation in ewe conception rate and productive lifetime did not affect any of the costs components per ewe in the second reproductive cycle; therefore those results are not presented in Table 5. The prices for feed and for inputs contributing to fixed costs influenced only the appropriate components of the total costs. Variation in labour costs, on the other hand, influenced all cost components except feed and fixed costs. The total cost per ewe during the second reproductive cycle and per year was €160 in the base calculation and varied from €149 to €183 in the other calculated analyses (see last column of Table 5).

The proportions of the main cost components (shown in Table 5) to total cost per adult ewe per year for each analysis are presented in Fig. 1.

For all of the scenarios evaluated, fixed costs and feed costs accounted for the highest proportions of total cost (30 to 39% and 29 to 38%, respectively). Labour costs accounted for 12 to 16% of the total cost. The proportions to total cost of veterinary cost and costs for shearing, bedding, milking and cheese processing remained nearly the same in all of the analyses, together accounting for approximately 18% of the total cost. Only when changing the proportion of milk processed to cheese or changing total milk yield did these other costs vary from 12 to 24% of total cost, which was caused by the change in costs for milking and cheese processing. The costs for other sheep categories given in Table 4 were most sensitive to changes in feed prices.

Sensitivity of the main economic characteristics of the production system

Economic characteristics of the evaluated production system for the base calculation, at altered levels of production and with different economic parameters are presented in Table 6. All of those characteristics are included in computation of the proportion of costs and revenues for all sheep categories (ewes at different lactations, lambs, replacements and rams as given in Table 4) and are expressed per ewe and year.

Total revenues were €170 ewe^{-1} year^{-1} in the base calculation and varied from €124 (for the marketing strategy in which all milk was sold to dairies) and €267 (for the highest milk yield of 180 kg ewe^{-1}, Table 6). Revenues from milk and cheese accounted for the highest proportion of total revenues, equalling at least 63% in all cases (see Fig. 2). The proportion at-

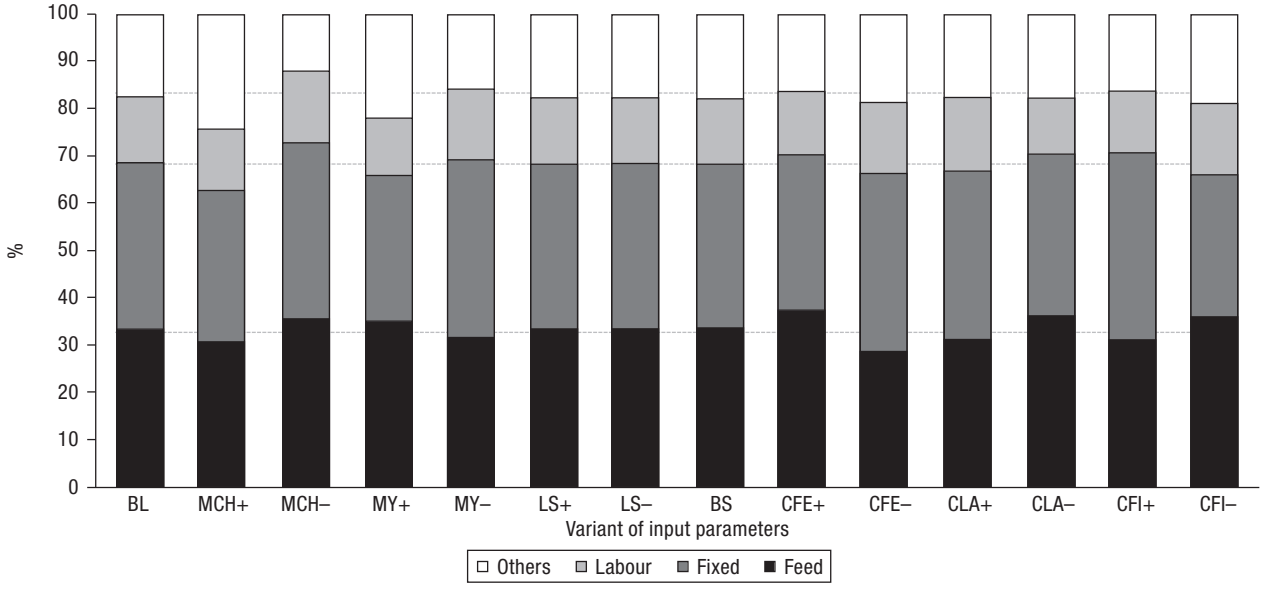

Figure 1. Proportion of the basic cost components on total costs per adult ewe during the second reproductive cycle and per year for different levels of the analysed production and economic parameters. BL: base level of input parameters. MCH: percentage of milk processed to cheese on farm. MY: milk yield. LS: litter size (number of lambs born per ewe lambing). BS: breed standard. CFE: average feed costs (for roughage and concentrates). CLA: labour costs. CFI: fixed costs. The sign behind the parameter abbreviation (+ and –) indicates the modified variant. For a detailed description of variants see Section Material and Methods and Table 3.

Table 6. Impact of production and economic parameters on the revenues, costs, profit and profitability ratio of the production system

Input parameter and its variable[a]		Economic result (€ ewe^{-1} year^{-1})						Profitability ratio (%)[c]
		Revenues				Costs	Profit	
		Milk	Cheese	Other[b]	Total			
Base level		47	78	45	170	204	–34	–17
Milk to cheese	+	0	196	45	241	217	25	11
	–	78	0	45	124	194	–71	–36
Milk yield	+	83	139	45	267	222	46	21
	–	33	54	45	132	194	–61	–32
Conception rate	+	48	80	47	175	195	–20	–10
	–	45	76	43	164	210	–45	–22
Litter size	+	48	79	50	177	205	–28	–13
	–	46	77	40	164	202	–38	–19
Lifetime	+	47	79	46	172	199	–27	–14
	–	47	78	44	169	208	–39	–19
Breed standard		51	85	49	185	197	–12	–6
Price of lambs	+	47	78	57	182	204	–22	–11
	–	47	78	33	158	204	–46	–23
Price of milk and cheese	+	66	100	45	211	204	6	3
	–	28	56	45	130	204	–75	–37
Feed costs	+	47	78	45	170	219	–49	–22
	–	47	78	45	170	190	–19	–10
Labour costs	+	47	78	45	170	212	–42	–20
	–	47	78	45	170	197	–27	–14
Fixed costs	+	47	78	45	170	219	–48	–22
	–	47	78	45	170	190	–20	–11

[a] See Table 3 and the Section Material and Methods for the description of the parameters and calculated variants. [b] Revenues from sold lambs, culled animals, wool and manure expressed per ewe and year are included. [c] Calculated as 100 × Profit/Costs.

tributed to other revenues (sold lambs, culled adult animals, wool and manure) never exceeded 36%. The dominant contribution from these other revenues was income from sold lambs (63%). The importance of wool as a revenue source was negligible (1.5% of total revenue) because of the very low price for wool (€0.664 kg^{-1}).

Total cost ewe^{-1} year^{-1} exceeded total revenue in nearly all calculations. Exceptions were the production system in which all milk was processed to cheese on the farm, the system in which production per ewe per milking period was 180 kg (even when only 40% of milk was processed on the farm) and in the system in which market prices for milk and cheese were high (€0.99 kg^{-1} milk and €8.36 kg^{-1} cheese). Only in those three situations positive profit (€25, 46 and 6 ewe^{-1} year^{-1}, respectively) and positive profitability (11, 21 and 3%, respectively) were achieved. In all other scenarios, production systems operated with losses of €12 to 75 ewe^{-1} year^{-1} and with negative effectiveness of expended costs of –37 to –6%.

Discussion

Costs components

A direct comparison of the absolute values of specific cost and revenue components in our study for Slovakian conditions and in investigations dealing with sheep economics in other countries is not possible because of differences in economic conditions and production system intensities. However, the relative contribution of individual components to total cost ewe^{-1}

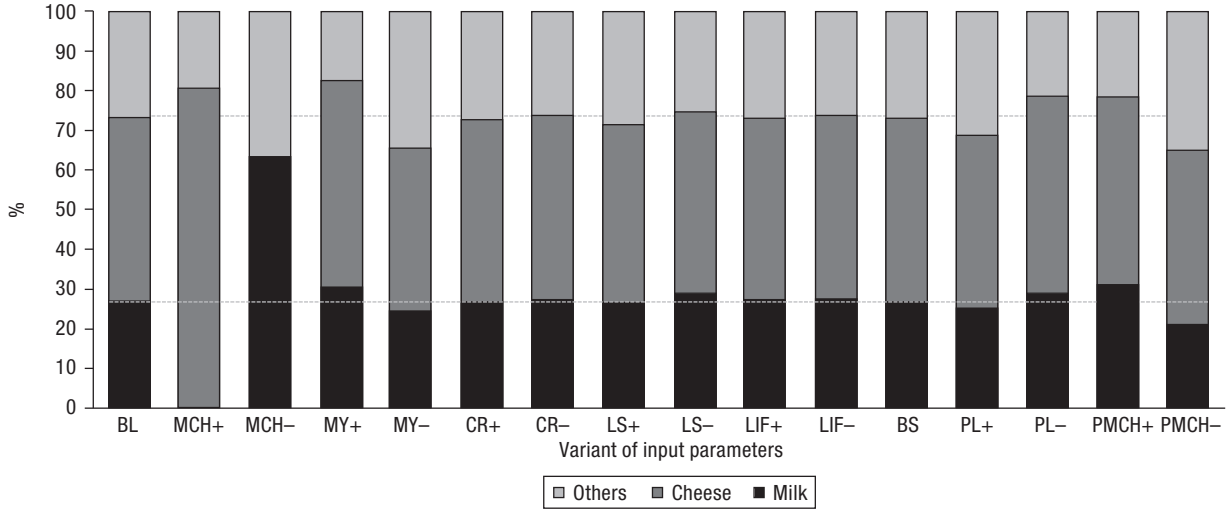

Figure 2. Revenues from the basic sheep commodities as proportion of the total revenues per ewe and per year for different levels of the analysed production and economic parameters. BL: base level of input parameters. MCH: proportion of milk processed to cheese on farm. MY: milk yield. CR: conception rate of ewes. LS: litter size (number of lambs born per ewe lambing). LIF: productive lifetime of ewes (in reproductive cycles). BS: breed standard. PL: price of lambs. PMCH: price of milk and cheese. The sign behind the parameter abbreviation (+ and –) indicates the modified variant. Others revenues included those from sold lambs, culled animals, wool and manure, expressed per ewe and year. For a detailed description of variants see Section Material and Methods and Table 3.

year^{-1} can be compared between our study and published reports.

Fixed costs accounted for 1 to 5% of total costs in traditional small ruminant husbandry systems in investigations of Kosgey *et al.* (2003), Haghdoost *et al.* (2008) and Tolone *et al.* (2011). However, in more intensive systems such as dairy sheep with machine milking, fixed costs made up 25 to 39% of total costs (Ligda *et al.*, 2000; Vláčil, 2005; Wolfová *et al.*, 2009b), which is in accordance with our results, even though depreciation costs of the ewe flock were not included in the fixed costs in our bio-economic model. These costs were calculated separately as the costs for rearing of replacements and were variable with respect to the productive lifetime of ewes. They accounted for 18% of the total costs ewe^{-1} year^{-1} in the base calculation (Table 4) but for only 14% when productive lifetime of ewes was increased from 3.85 to 4.65 reproductive cycles (not presented in the Results). In general, a high proportion of fixed costs to total cost is more common in the East European (post-communistic) countries than in the West European countries. This is caused mainly by differential average farm size and typical farm structure (high number of animals and larger area of crops for a typical West European farm). Thus, a reduction in the total fixed costs is limited, and more efficient utilization of these costs through higher animal performance should be achieved (to decrease the proportion of fixed costs per production unit).

Based on the literature cited above, feed and labour costs accounted for the largest portion of variable costs, contributing 28 to 47% and 15 to 21%, respectively, to total costs in both dairy and meat sheep. Similar proportions were found in our study at all levels of production and economic parameters (29 to 38% for feed costs and 12 to 16% for labour costs). A higher proportion for these cost components (39% for both) was reported by Fuerst-Waltl & Baumung (2009) for dairy farms in Austria, mainly as a result of higher production intensity and both utilization and hourly cost of human labour than in our analysis. For example, 21 working hours were needed per ewe per year with a wage of €10 hour^{-1} in Austria, whereas only 7 hours with a wage of €3.30 hour^{-1} were assumed in our analysis. Similarly, prices of feed components were nearly three times higher in Austrian flocks compared to those in Slovakia. (*e.g.* €0.13 *vs.* 0.05 kg^{-1} of hay).

Revenues

Regarding revenue components, the contribution from milk and/or cheese to the total revenues calcula-

ted in our study (63 to 83% in all scenarios) was similar to the range from 53 to 81% reported for dairy sheep by other investigators (Ligda *et al.*, 2000; El-Saied *et al.*, 2006; Tolone *et al*., 2011). In dairy sheep breeding flocks, the proportional contribution of milk revenue to total revenues can drop substantially on 40% due to income from sale of young breeding animals (Ligda *et al*., 2000) or on 38 to 50% in an open flock, while the contribution from sale of breeding animals was nearly 20% (Vláčil, 2005).

Compared to the previously mentioned studies, the contribution of revenues from milk to the total revenues was 67% in intensive dairy sheep farms in Austria, even though breeding rams were sold for a relatively high price (€500 ram^{-1}; Fuerst-Waltl & Baumung, 2009). However, when evaluating the economic efficiency of a sheep production system for a specific breed, a closed management system should be assumed. This is appropriate, because revenues from the sale of breeding animals from breeding flocks become costs for commercial flocks. In our bio-economic model, the costs for rearing of breeding animals for ewe and ram flock replacements were part of the total cost per ewe and per year, and generated no additional revenues from selling breeding stock.

Revenues from weaned lambs generated from 20 to 50% on the total revenue in the investigations cited, which was in agreement with our findings (21% for the lowest bound to 31% for the upper bound of market prices for lambs). In non-dairy sheep farms, the incomes from meat (lambs, culled replacements) can form up to 96% of total revenues (Haghdoost *et al*., 2008).

Profitability parameters

Profitability ratios calculated for the common Slovakian production system with the Improved Valachian breed at the average level of animal performance were negative (from –37 to –10%) for nearly all levels of input and product prices. Haghdoost *et al.* (2008) also reported negative profitability ratios for meat sheep farms. Those authors stated that higher costs for purchased feed, which was necessary to compensate for decreased pasture quality over the grazing season, was the main reason for that result. Vláčil (2005) calculated even larger negative profitability ratios of –40% and –38% for a dataset from extensive Slovakian dairy sheep farms with Improved Valachian and Tsigai breeds in 2002 and 2003, respectively. The main reason for the extremely low profitability was the very low milk yield of 60 kg ewe^{-1} year^{-1}. Most of the other production and economic parameters in his study were very similar to those in our base calculation. Positive profitability of 10% and 16% reported also in his study were reached only when including subsidies granted per farm (for produced cheese, gene pool of farmed animals) and per agricultural land area. These subsidies accounted on average for 52% of the total revenues. In our analysis, application of high market prices for milk and cheese generated a positive profitability ratio of 3% due to higher revenues at constant level of the total costs.

Next to higher market prices for sheep commodities, improved animal performance was the most important factor influencing economic efficiency of dairy sheep farms. For economic conditions in Hungary, Jávor *et al*. (2005) identified 70 to 80 kg milk per lactation and a litter size of one weaned lamb per ewe as minimal thresholds for profitability in extensive farms with the Merino breed. However, detailed assumptions leading to those conclusions are not given in their paper. In our investigation, even a milk yield of 110 kg and a litter size of 1.30 lambs (breed standard for Improved Valachian) did not result in a positive profitability ratio (–6% was observed) at the economic conditions existing in Slovakia during the period from 2004 to 2010.

The favourable economic efficiency (profitability of 9 to 48%) obtained in specialised dairy sheep breeds such as Lacaune, Chios and Valle del Belice (Ligda *et al*., 2000; Fuerst-Waltl & Baumung, 2009; Tolone *et al*., 2011) was attributable mainly to high milk yield of ewes (230 to 476 kg per milking period). This yield cannot be reached in pure-bred Improved Valachian ewes due to their biological and production limitations. The Improved Valachian is a multi-purpose breed and specifically adapted to extensive mountain conditions. Animals with a proportion of up to 12.5% of a foreign breed (*e.g.* Lacoune) are still considered as pure-bred animals in Slovakian sheep performance testing and were therefore included in our analysis. At their highest level of milk yield (180 kg ewe^{-1} year^{-1}), a high positive profitability ratio was obtained (+21%) for the average level of all other parameters investigated in our calculations. However, it must be stated that the use of these high performance animals in highland conditions is limited.

Srour *et al*. (2006) and Legarra *et al*. (2007) reported that cheese production on farms can be an impor-

tant strategy to improve economic efficiency of dairy sheep farms. This was confirmed in our study, where the processing of all milk to cheese on farms raised the profitability ratio to +11% at the average level of all other production and economic parameters. Mainly the high ratio of price per kg of cheese to milk (8.5:1) contributed to the positive profitability. However, when the ratio between cheese and milk price was unfavourable (4.6:1), positive profitability was not achieved at extensive dairy sheep farms even when all milk was processed to cheese (Vláčil, 2005).

Multi-purpose sheep production systems utilizing extensive local breeds in marginal conditions of Slovakia are presently not profitable. Losses currently are balanced by governmental subsidies and by EU payments. Because increased market prices for sheep commodities and decreased feed or other costs cannot be expected with certainty in the near future, the economic sustainability of multi-purpose sheep farms in marginal areas can be reached mainly by the exhaustion of the reserves in the biological potential of the current breeds (*e.g.* by feeding, management and selection for yield) and by an increase of the proportion of milk processed to cheese on farms. However, the latter option is limited by the purchasing power on the home market and by the export potential. Although our study was done on a local breed, the results and recommendations might be valid also for other extensive sheep breeds farmed in marginal areas. Moreover, the bio-economic model and computer program applied in this study should be a valuable and widely applicable tool for a comprehensive analysis of the impact of production and economic parameters on the efficiency of sheep farming.

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