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Changes in milk composition of sows during 28 days of lactation

Změny ve složení mléka prasnice v průběhu 28 dnů laktace

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ABSTRACT: Our trial was aimed at finding daily nutrient and milk production during 28 days of lactation. Daily production of protein, fat, ash and nitrogen free extract (NFE) was determined. The results can be described by regression equations for daily (x) production of fat (g/day) = $-0.5735x^2 + 25.009x + 273.14$ ($R^2 = 0.9209$), protein (g/day) = $0.0497x^3 - 2.3482x^2 + 30.882x + 247.72$ ($R^2 = 0.6896$), NFE (g/day) = $-0.6166x^2 + 29.463x + 129.58$ ($R^2 = 0.9857$) and ash (g/day) = $-0.121x^2 + 5.4817x + 32.781$ ($R^2 = 0.9749$). The mathematical expression of daily milk production in kg = $0.0004x^3 - 0.026x^2 + 0.6401x + 2.799$ ($R^2 = 0.9949$), where x = day of lactation. Other interesting results are the average dry matter of milk 184.31g/kg, that of protein 50.76 g/kg, fat 68.45 g/kg, NFE 5 797 g/kg and ash 14.12 g/kg. 1 kg milk contained 4.82 MJ energy on average.

Keywords: sows; milk; nutrient content; lactation curve; daily production of nutrients

ABSTRAKT: Cílem našeho pokusu bylo zjistit denní produkci živin a mléka během 28denní laktace. Zjišťovali jsme denní produkci proteinu, tuku, popela a BNLV. Zjištěné výsledky se dají popsat regresními rovnicemi pro denní (x) produkci tuku (g/den) = $-0{,}5735x^2 + 25{,}009x + 273{,}14$ ($R^2 = 0{,}9209$), proteinu (g/den) = $0{,}0497x^3 - 2{,}3482x^2 + 30{,}882x + 247{,}72$ ($R^2 = 0{,}6896$), BNLV (g/den) = $-0{,}6166x^2 + 29{,}463x + 129{,}58$ ($R^2 = 0{,}9857$) a popela (g/den) = $-0{,}121x^2 + 5{,}4817x + 32{,}781$ ($R^2 = 0{,}9749$). Matematické vyjádření denní produkce mléka v kg = $0{,}0004x^3 - 0{,}0263x^2 + 0{,}6401x + 2{,}799$ ($R^2 = 0{,}9949$, kde x = den laktace). Z dalších zjištěných výsledků je zajímavé, že průměrná sušina mléka byla 184,31 g/kg, NL 50,76 g/kg, tuku 68,45g/kg, BNLV 57,97 g/kg, popela 14,12 g/kg. 1 kg mléka v průměru obsahoval 4,82 MJ energie.

Klíčová slova: prasnice; mléko; obsah živin; laktace; denní produkce živin

INTRODUCTION

Milk production by a sow is currently the object of primary attention paid by breeders. It is of interest that milk production by cows was paid a considerable attention in the past, and milk production by sows remained beyond the interest. Modern pig types with weight gains higher than 650 g per day require full-value nutrition from their birth, which prolongs the feeding period and causes economic losses to breeders. In the Czech Republic, a number of scientific papers in the past dealt with milk production (Navrátil, 1955) or piglet weight related to milk production, or with lactation frequency and the position of the mammary gland, mainly in piglets of the Large White breed (Navrátil, 1958, 1959a, b). Abroad a similar study of milk production by sows was published by Noblet and Etienne (1989).

According to several authors, the daily milk production by a sow does not depend on lactation number (Klobasa and Werhahn, 1996) nor on the number of sucking piglets (Daza *et al.*, 1999). Attention was also paid to the sow milk composition (recently Bojčuková and Krátký, 2001), however, most studies were performed during several days of lactation, and the method of data collection for the whole lactation curve has not been described yet. The reason is that it is relatively difficult to obtain milk from a higher number of sows, and such an amount of milk that the samples might be analysed with sufficient accuracy.

MATERIAL AND METHOD

The aim of our investigations was to acquire data on daily milk production during 28 days of lactation and on its composition dynamics during the lactation. The trial was performed in an experimental farrowing house of the Research Institute of Animal Nutrition at Pohořelice;

Table 1. Composition of feed mixture (%)

Components	Content (%)
Barley	39.00
Wheat	25.00
Oats	10.00
Wheat bran	11.00
Peas	2.00
Meat and bone meal	1.00
Soybean meal	6.00
Yeast (*Saccharomyces cerevisae*)	2.00
MVK PK	4.00
Total	100.00

MVK PK contained per 1 kg: 220 g wheat flour, 125 g feeding salt, 325 g limestone, 120 g dicalcium phosphate, 50 g sodium pyrophosphate, 125 g vitamin premix P3 (200%), 35 g trace element premix MD I

Table 2. Nutrient content in feed mixtures

Nutrient	Content
Dry matter (g/kg)	885.89
MEp (MJ/kg)	12.22
Protein (N × 6.25) (g/kg)	150.11
Lysine (Lys) (g/kg)	6.37
Sulphur Amino Acids (SAA) (g/kg)	5.19
Threonine (Thr) (g/kg)	5.19
Tryptophan (Try) (g/kg)	1.76
Ad_Lys (g/kg)	4.94
Ad_SAA (g/kg)	4.11
Ad_Thr (g/kg)	3.65
Ad_Try (g/kg)	1.18
Td_Lys (g/kg)	5.18
Td_SAA (g/kg)	4.37
Td_Thr (g/kg)	3.98
Td_Try (g/kg)	1.29
Fat (g/kg)	23.73
Crude fibre (g/kg)	11.10
Linoleic acid (g/kg)	52.23
Calcium (g/kg)	8.24
Digestible Phosphorus for pigs (g/kg)	2.98

Ad_ = apparent digestibility
Td_ = true digestibility
MEp = metabolisable energy for pigs

it lasted for 420 days. Experimental investigations included 64 crossbred sows of the Large White × Landrace breed. During this period a sufficient amount of milk (60 ml at least) was obtained from 5 sows at least on each lactation day. During the trial, sows were fed the KO complete mixture of 2.20 kg + 0.4 kg per each nursed piglet. The mixture composition and nutrient content are presented in Tables 1 and 2. Milk from sows was obtained by hand milking (3 persons) in such a way that the appropriate day was tentatively selected when milk was taken 3 times from all sows present in the farrowing house at that time. Litter weight was determined before and after sucking. Milk samples were taken from 5 sows on each day of lactation. The samples were stored in a refrigerator and then they were lyophilised. Milk samples corresponding to certain days of lactation (from 5 sows) were mixed in relative proportions and the resulting dried sample was analysed for dry matter, fat, protein and ash contents according to the methods presented by Kacerovský *et al.* (1990). A total of 140 assays was obtained during the trial (28 days, 5 assays per day).

RESULTS AND DISCUSSION

No health disorders were observed during our trial. The feed mixture had relatively low contents of energy and protein, and for these reasons the sows were included in the trial for the first time only with their higher weight, which was documented by their high average weight after farrowing amounting to 183.93 ± 18.928 kg, on day 21 of lactation 182.76 ± 18.904 kg and after 28 days of lactation 172.72 ± 20.454 kg. The daily milk production is affected partly by energy consumption as confirmed e.g. by Van den Brand *et al.* (2000).

The production of milk components during 28 days of lactation is represented in Figures 1 to 3. The highest average milk production was achieved by sows on approx. 25th day of lactation, namely 8.33 kg milk. Daily energy output with milk was highest during the last days of lactation, and it amounted to 38 MJ/day (Figure 2). Milk dry matter production by a sow is represented in Figure 1. Figure 3 shows the production of milk components. The daily average milk production during lactation was 7.06 kg, daily average output of protein was 341.25 g, that of fat 477.77 g, NFE 386.94 g and ash 78.93 g. The average dry matter of milk was 184.31 g/kg, that of protein 50.76 g/kg, fat 68.45 g/kg, NFE 57.97 g/kg and ash 14.12 g/kg. 1 kg milk contained 4.82 MJ energy on average. The production of individual milk components can be described statistically by regression equations.

$$\text{Fat} = -0.5735x^2 + 25.009x + 273.14 \text{ (g/day)} \quad (R^2 = 0.9209)$$

$$\text{NFE} = -0.6166x^2 + 29.463x + 129.58 \text{ (g/day)} \quad (R^2 = 0.9857)$$

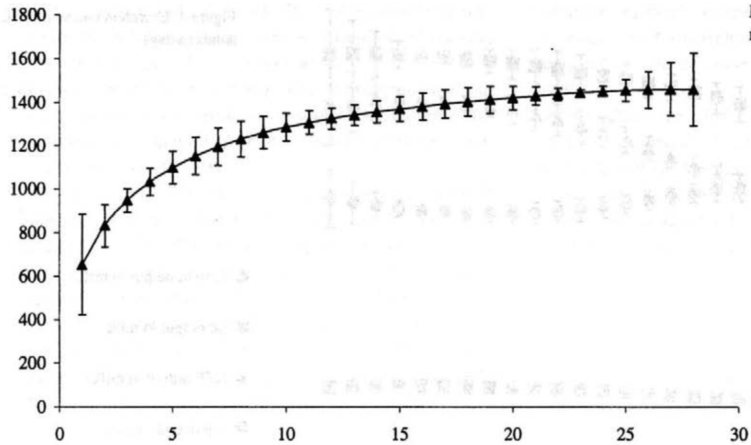

Figure 1. Dry matter production in sow milk during lactation

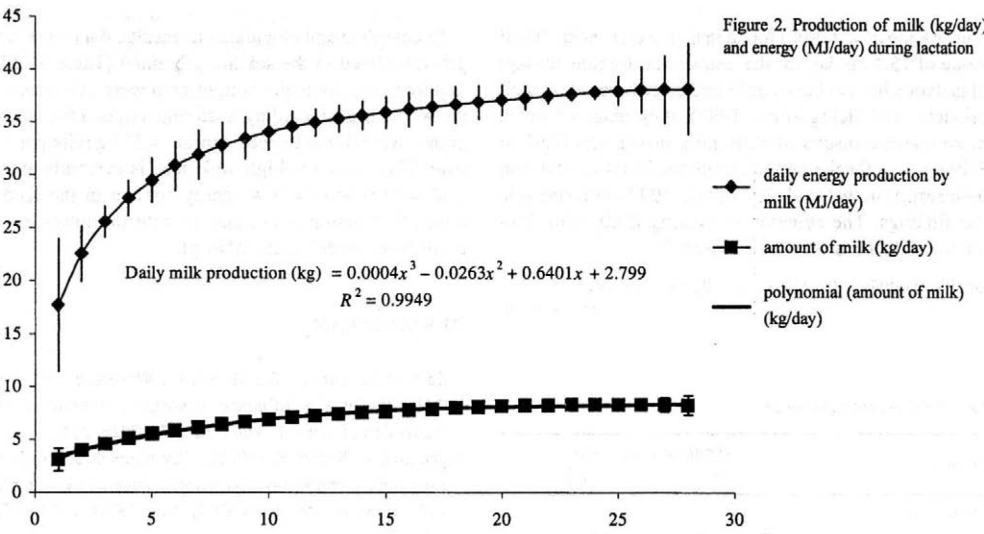

Figure 2. Production of milk (kg/day) and energy (MJ/day) during lactation

$$\text{Protein} = 0.0497x^3 - 2.3482x^2 + 30.882x + 247.72 \text{ (g/day)} \quad (R^2 = 0.6896)$$

$$\text{Ash} = -0.121x^2 + 5.4817x + 32.781 \text{ (g/day)]} \quad (R^2 = 0.9749)$$

Variations of protein production (and content) in milk (see $R^2 = 0.6896$) were associated with the milk daily production and it was highest at the end of lactation. Garst *et al.* (1999) also drew similar conclusions. Of the above milk components, the production of milk dry matter (Milk DM) can be described by the polynomial equation (Figure 1). It is evident from the error abscissae for the determination reliability interval on particular lactation days that the highest variations in dry matter content were recorded at the beginning and at the end of the lactation period under observation.

$$\text{Milk DM} = -1.4968x^2 + 65.309x + 750.27 \quad (R^2 = 0.9463)$$

The data on total milk production obtained in our trial correspond approximately to the data obtained by Auldist *et al.* (2000), who found the milk production of approx. 7.819–8.920 kg/day. However, it has to be stated that there exist sows with almost twofold milk produc-

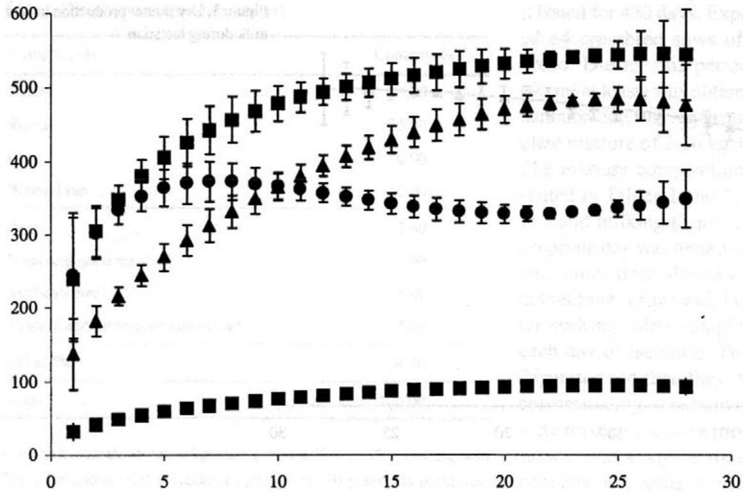

Figure 3. Excretion course of milk solids (g/day)

tion as King *et al.* (1998) found in their experiments. Their value of 15.4 kg/day for the second and fourteenth days of lactation has not been confirmed elsewhere yet. In their previous trial (King *et al.*, 1997), they obtained much more realistic results of daily milk production (6.65 or 8.49 kg/day) for the period before the lactation end, and their results in that trial (King *et al.*, 1997) correspond to our findings. The equation estimating Daily Milk Production (DMP) is derived in Figure 2.

$$DMP = 0.0004x^3 - 0.0263x^2 + 0.6401x + 2.799 \text{ (kg)} \quad (R^2 = 0.9949)$$

Table 3. Sex-related piglet weight

Results	Group (average ± SD) barrows	gilts
After Birth		
Total weight (kg)	7.49 ± 2.34	6.25 ± 2.59
Average weight (kg)	1.33 ± 0.19	1.30 ± 0.21
No. of piglets	5.63	4.82
At 21 days		
Total weight (kg)	20.39 ± 6.98	18.29 ± 7.86
Average weight (kg)	4.10 ± 0.73	4.04 ± 0.73
No. of piglets	4.97	4.53
At 28 days		
Total weight (kg)	24.58 ± 8.49	21.32 ±9.35
Average weight (kg)	5.02 ± 0.87	5.04 ± 0.88
No. of piglets	4.90	4.23

SD = standard deviation

To complete and elucidate our results, data on piglets' growth related to the sex are presented (Table 3). Milk requirements per piglet weight gain were calculated for the whole trial (including dead piglets), and the weaned piglets were found to need approx. 4.31 kg milk per 1 kg gain. This relatively high milk need is evidently associated with relatively low energy content in the feeding ration for nursing sows, and so with the lower energy production in milk (4.82 MJ/kg).

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Variability of milk production within the contemporary groups in prediction of breeding value

Proměnlivost mléčné užitkovosti uvnitř skupin vrstevnic při odhadu plemenné hodnoty

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ABSTRACT: Calving frequency within the year and variability of milk production within the herd-year-season (HYS) for cows in the 1st to 3rd lactation of the Czech Pied (C) and Holstein (H) cattle calved in 1996 to 1997 was determined. The herds were divided into seasons on the basis of the number of observations from 2 to 15. Systematic effects of the environment (HYS) and third degree polynomial regression for the age at 1st calving, for the service period, and previous calving interval were taken into account. With the increasing number of individuals within HYS, the season was prolonged and resulted in the increase of residual variability. In dependence on the number of individuals within HYS and lactation number, in C cattle the systematic effects explained 47 to 52% variability, the random environment accounted for 38 to 43% and genetic disposition for 10% of total variability of measured data. In H cattle, these data were 54 to 60%, 28 to 33% and 13%, respectively. In the 1st lactation, systematic effects explained a lower portion of variability than in the following lactations. Based on the number of observations in herds, it was possible to determine the lengths of seasons that guarantee the given number of individuals within HYS. The mean error of production deviation from the contemporaries decreased dependent on their number. Starting from the number of contemporaries equal to 7, further increase in their number has no effect on the mean error that reached approximately 3/4 of maximum value at one contemporary. Taking into account the parents reduced the mean error by 3 to 5%.

Keywords: cattle; milk production; residual variability; breeding value; size of contemporary group; deviation error

ABSTRAKT: Na základě mléčné užitkovosti krav českého strakatého (C) a černostrakatého (H) skotu na první až třetí laktaci, otelených v letech 1996 až 1997, je stanovena četnost otelení v průběhu roku a proměnlivost uvnitř stáda-roku-období (HYS). Stáda jsou dělena na období na základě počtu případů od 2 do 15. V úvahu jsou vzaty systematické efekty chovatelského prostředí HYS a polynomická regrese třetího stupně pro věk při prvním otelení, pro délku service periody a předchozího mezidobí. Se zvyšováním počtu jedinců uvnitř HYS se toto prodlužuje a téměř lineárně stoupá reziduální proměnlivost. V závislosti na počtu jedinců uvnitř HYS a pořadí laktace vysvětlily u C skotu systematické efekty 47 až 52 % proměnlivosti, náhodné prostředí činilo 38 až 43 % a genetické založení 10 % z celkové proměnlivosti naměřených údajů. U H skotu jsou tyto údaje 54 až 60 %, 28 až 33 % a 13 %. Na první laktaci je vysvětleno systematickými efekty méně proměnlivosti než na laktacích následujících. Na základě rozdělení četností ve stádech jsou stanoveny délky období, které zaručují pro jednotlivé laktace stanovené počty jedinců uvnitř HYS. Střední chyba odchylky užitkovosti od vrstevnic v závislosti na jejich počtu klesá. Od počtu vrstevnic 7, zvyšování jejich počtu již prakticky nemá vliv a střední chyba dosahuje přibližně 3/4 maximální hodnoty při jedné vrstevnici. Zohlednění rodičů snižuje střední chybu o 3 až 5 %.

Klíčová slova: skot; mléčná užitkovost; reziduální proměnlivost; plemenná hodnota; velikost skupiny vrstevnic; chyba odchylky

Prediction of breeding value is done with an error that is to be minimised both by the test organisation and by the proper implementation of milk records and the method of data evaluation. A significant role is played by a group of contemporaries within the herd to which the particular evaluated animal is compared. This group

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should have the standard error as lowest as possible and represent the breed average. Variability of breeding value and the performance deviation from the contemporaries is described by Přibyl (1986). The error depends on the number of observations, number of contemporaries, genetic and residual variability. The formula for determination of the error of breeding value in dependence on the number of the sires tested (number of contemporaries) and the number of herds in which the testing was done was derived by Herrendörfer *et al.* (1974).

Planning of the test is connected with construction of contemporary groups for direct mutual comparison of animals. In milk production, it is determined by the optimum length of HYS (herd × year × season). It is desirable that HYS is as short as possible with equal conditions of the environment for all animals within it and at the same time with the possible highest number of contemporaries. To determine appropriate HYS magnitude, Dempfle (1982) used the ratio of residual variability to the effective number of observations. The effect of HYS magnitude, number of non-related contemporaries, and the occurrence of direct conctedness of tested animals within HYS at a various level of heritability were discussed by Tosh and Wilton (1994). They determined the reliability of breeding values of sires and dams.

With the season (HYS) prolongation, effects that increase the uncontrollable variability are also included in the systematic environment. The effect of the season of the year on milk production was described by Kučera *et al.* (1999). They showed that milk production fluctuated during the year within the amplitude of several hundred kg. Besides, there can be deviations from the general trend in each herd and the interaction of concrete HYS explains a substantial portion of variance.

Schmitz *et al.* (1991) were concerned with methods of HYS clustering. They calculated a bias that occurs in different methods of clustering and in connection with HYS prolongation. The increase in variability within HYS is due to uncontrolled variability. A long HYS may lead to the bias of evaluation due to systematic trends. Some ways of formation of contemporary groups were described by Chauhan a Hill (1986). The clustering viewpoint was lowest residual variability, highest the possible effective number of observations and smallest the possible herd-year-month interaction. They considered especially the last factor to be most important. Based on the analysis of the first three lactations, Kučera *et al.* (1999) recommended that HYS should be formed for each parity separately. Mainly in the first lactation, the systematic effects of the environments have a different course from that in the following lactations. To form contemporary groups Chauhan and Thompson (1986) used a principle when the evaluated individual is in the middle of the evaluated season – rolling season. In this way the same individual is found simultaneously as a contemporary in several seasons. In the evaluation model it is manifested by correlations within HYS. Meyer (1987) pointed out that systematic genetic and environment trends are simultaneously manifested within the contemporary groups. If the animals are divided into contemporary groups, the individuals are also included in genetic groups. The contemporary and genetic groups may depend on each other, especially in longer seasons, which can consequently influence the breeding value estimation. A small number of observations in some herds plays an important role also in Test Day Models. Three ways of formation of contemporary groups for this case were evaluated by Pösö *et al.* (1996). The algorithm for clustering of individuals into groups was formed by Strabel (1997).

The aim of this study is to determine variability of milk production within HYS in dependence on the size of contemporary group and to determine the error of production deviation of an individual from the contemporary group in Czech Pied and Holstein Cattle in the Czech Republic.

MATERIAL AND METHODS

The effect of the number of contemporaries within HYS was evaluated in the first three lactations of cows that calved in 1996 and 1997. In Czech Pied Cattle (C) it was 182 633 first, 141 532 second and 101 862 third lactations. In Holstein Cattle (H) 106 761, 74 726 and 48 627 lactations were assessed. In the period of 2 years each herd was separately divided into successive HYS according to the number of observations, starting from January 1, 1996. Alternately HYS were conformed with the number from 2 to 15 individuals. Those seasons were excluded from the evaluation (herds with a low number of cows) when the difference in the dates between the two nearest calvings exceeded 40 days. Residual variabilities were calculated for HYS sets determined in this way.

In the 1st lactation, based on the model equation:

$$y_{ij} = \mathrm{HYS}_i + bv(\mathrm{age}_{ij}) + bsp(\mathrm{SP}_{ij}) + e_{ij} \qquad (1)$$

In the 2nd and 3rd lactation based on the following equation:

$$y_{ij} = \mathrm{HYS}_i + bm(\mathrm{cai}_{ij}) + bsp(\mathrm{SP}_{ij}) + e_{ij} \qquad (2)$$

where: y_{ij} = measured milk production of cow j in HYS i
HYS_i = effect of HYS
$bv(\mathrm{age}_{ij})$ = 3rd degree polynomial regression for the first calving age
$bsp(\mathrm{SP}_{ij})$ = 3rd degree polynomial regression for current service period (SP)
$bm(\mathrm{cai}_{ij})$ = 3rd degree polynomial regression for the length of previous calving interval
e_{ij} = random residual uncontrollable factors

The cows were compared with a different number of non-related contemporaries in the herd. Their parents had known breeding values and progeny also in other herds. The random error of milk production deviation depends on the residual and genetic variability. The heritability coefficients were used according to Dědková and Wolf (2001). The heritability corresponds with the HYS magnitude on average with 8.6 individuals (approx. 9). The same heritability $h^2 = 0.32$ for H, or 0.21 for C cattle is considered for all lactations. We presume that with the increasing number of individuals within HYS it is prolonged, which results in an increase in unexplained residual variability while the genetic variability remains constant.

The variances were corrected in dependence on the length of season (HYS) by the coefficient t according to (3).

$$t = \sigma_n^2/\sigma_9^2 \quad (3)$$

where: σ_n^2 = variability (e) from equations (1) and (2) at the number of individuals in HYS equal to n

σ_9^2 = variability (e) from equations (1) and (2) at the number of individuals in HYS equal to 9

Further correction is made according to the effective number of observations (w) within HYS (Přibyl, 1986), which takes into consideration variability of deviation in accordance with the number of contemporaries.

$$w = v/(1 + v) \quad (4)$$

where: v = number of contemporaries within HYS

Further, according to the reliability of parental breeding values (about the individual observed as well as their contemporaries):

$$r_P^2 = (r_S^2 + r_D^2)/4 \quad (5)$$

where: r^2_P, r^2_S, r^2_D = reliabilities of breeding value estimations of individuals, their sires and dams. In sires we calculate with average reliability of 0.85 and in dams 0.35, of which the average reliability of breeding value estimation of their offspring 0.30 follows.

The total error variability of production deviation from the contemporary group within HYS is:

$$\sigma_D^2 = (t\,\sigma_9^2 - r_P^2\,\sigma_g^2)/w \quad (6)$$

where: σ_g^2 = genetic variance

RESULTS AND DISCUSSION

Variability of milk production

Calving is not quite proportional during the year. Based on the database of cows calved in 1996 and 1997, the numbers of calvings in basic dairy breeds in the Czech Republic are given in Table 1 and Figures 1 and 2. The population decreases mainly in the Czech Pied cattle during the period of observation. In Holstein the cattle population is better balanced. The highest number of calvings takes place during the winter season, the lowest number in September. According to lactations and breeds the months with the lowest number of calvings account for 72 to 81% of the most months represented. Larger differences are in C and in lower parities.

Table 1. Number of calvings according to parities in 1996 and 1997

Month	Czech Pied			Holstein		
	1st	2nd	3rd	1st	2nd	3rd
1	17 865	13 835	9 790	10 097	6 898	4 567
2	15 863	12 147	8 659	8 756	5 892	3 917
3	16 672	13 111	9 302	9 452	6 097	4 015
4	16 492	12 249	8 407	8 904	5 858	3 652
5	16 223	12 307	8 550	8 967	6 198	4 005
6	14 001	11 552	8 329	7 999	6 209	3 988
7	14 666	11 356	8 356	8 543	6 463	4 186
8	14 275	10 894	7 808	8 841	6 199	4 047
9	13 367	9 773	7 046	7 809	5 611	3 653
10	12 113	10 090	7 515	7 966	5 904	3 903
11	15 387	11 819	8 706	9 406	6 603	4 293
12	15 709	12 399	9 394	10 021	6 794	4 401
Total	182 633	141 532	101 862	106 761	74 726	48 627

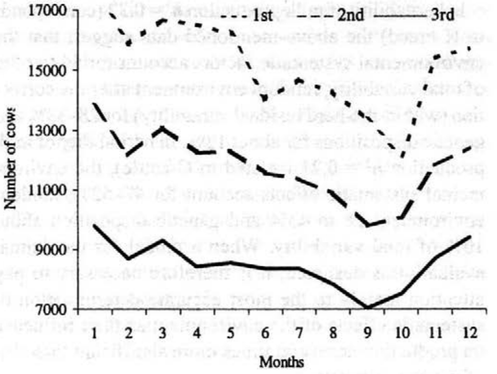

Figure 1. Frequency of calving in the year according to parities – Czech Pied

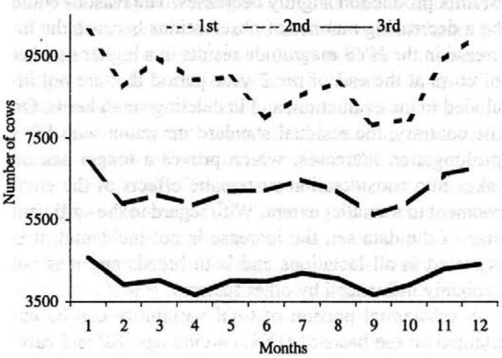

Figure 2. Frequency of calving in the year according to parities – Holstein

Kučera *et al.* (1999) pointed out that production per lactation fluctuated in dependence on the month of calving. The lowest milk yield was produced by cows that calved in summer, differentiated according to the lactation number (August – 1st lactation, May – 2nd lactation, May/June – 3rd lactation). Maximum production was achieved by cows that calved in autumn (second and third lactations) and in winter (1st lactation). Clustering of cows into HYS should take into consideration both factors – similar level of production and at the same time frequency of observations in the successive months so that these seasons could be as short as possible.

The estimation of breeding value is based on the deviation from the contemporaries within the year and season, within the herd (HYS). It depends on the number of individuals within HYS. The longer the season, the higher the number of individuals, and the unexplained variability.

Table 2 shows the residual standard error of the measured milk production after the correction from the environmental systematic factors according to equations (1) and (2) in dependence on the number of individuals within HYS. With an increase in the number of animals within HYS the season becomes longer and total variability

Table 2. Residual standard error (σ_e) of milk kg within HYS in dependence on the number of individuals within HYS, breed and parity

Individuals within HYS	Czech Pied			Holstein		
	1st	2nd	3rd	1st	2nd	3rd
2	714	809	846	873	1 041	1 046
5	724	813	852	892	1 053	1 062
8	729	818	858	898	1 062	1 067
11	733	824	865	905	1 068	1 078
15	738	829	869	911	1 076	1 087

Table 3. Variability of milk yield within HYS in % of total variability according to breeds, parities and number of individuals within the season

Individuals within HYS	Czech Pied			Holstein		
	1st	2nd	3rd	1st	2nd	3rd
2	48.5	47.6	48.2	41.8	**40.2**	41.0
5	50.2	48.5	49.3	43.9	41.1	41.8
8	51.3	49.4	50.3	44.6	41.8	42.2
11	52.1	49.9	51.2	45.3	42.4	43.3
15	**53.0**	50.8	52.1	46.2	43.0	44.4

of milk production slightly decreases. The reasons could be a decreasing number of observations because the increase in the HYS magnitude results in a higher number of cows at the end of the 2-year period that are not included in the evaluation, and in deleting small herds. On the contrary, the residual standard deviation with HYS prolongation increases, which proves a longer season takes into consideration systematic effects of the environment to a smaller extent. With regard to the sufficient size of the data set, the increase is not incidental, it is repeated in all lactations and both breeds and it is not probably influenced by other factors.

A substantial portion of total variability can be explained on the basis of HYS, calving age, SP and calving interval (equations 1 and 2). The variability of milk production within HYS in % of total variability is given in Table 3 and Figures 3 and 4. The internal HYS variability is 40 to 53% of total variability. Systematic effects explain a higher portion of variability in H cattle than in C, which may be connected with larger herds and shorter season in H cattle herds to provide for the given number of observations within HYS. A lower portion of variability was explained in the 1st lactations than in the following lactations. In both breeds, a higher portion of variability was explained in the 2nd lactations than in the 3rd lactations. This could be connected with the age because there were fewer individuals in the 3rd lactation and the season with the equal number of cows within HYS had to be longer. The obtained results are in accordance with the data published by Dědková and Wolf (2001), who estimating genetic parameters in a more extensive set of the H cattle found a residual variability of 44% of the total variability for the 1st lactation, 42% for the 2nd lactation and 45% for the 3rd lactation.

In heritability of milk production $h^2 = 0.32$ (corresponds to H breed) the above-mentioned data suggest that the environmental systematic factors account for 54 to 60% of total variability, random environment after the correction (within-the-herd residual variability) for 28–33% and genetic dispositions for about 13%. In heritability of milk production $h^2 = 0.21$ (related to C cattle), the environmental systematic effects account for 47–52%, random environment 28 to 43% and genetic disposition about 10% of total variability. When a model for the animal evaluation is designed, it is therefore necessary to pay attention mainly to the most accurate determination of systematic effects of the environment as their influence on production is several times more significant than that of genetic disposition.

Table 3 shows variability of milk production within HYS in dependence on the length of the season according to each breed and lactation number. The increase in variability has almost a linear course in dependence on the number of observations (and therefore also on HYS prolongation). For simplification of the following calculations, we use the average. The average variability within HYS in dependence on the number of individuals (and therefore in dependence on season length) is expressed by the following function:

$$\sigma^2 = 0.43323832 + 0.00759844\ n - 0.00070867\ n^2 + 0.00004240\ n^3 - 0.00000096\ n^4 \quad (7)$$

Length of season

The identical number of individuals within HYS is reached in dependence on the size of herds at different season length. Table 4 shows the averages and standard

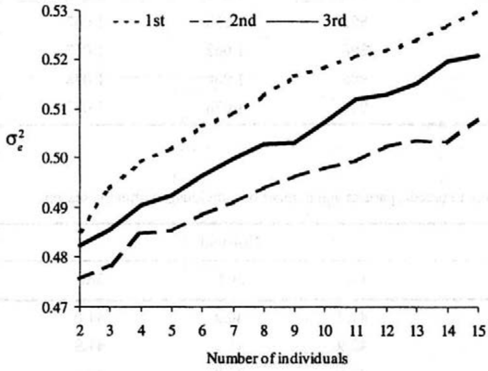

Figure 3. Variability within HYS (proportion) according to parities – Czech Pied

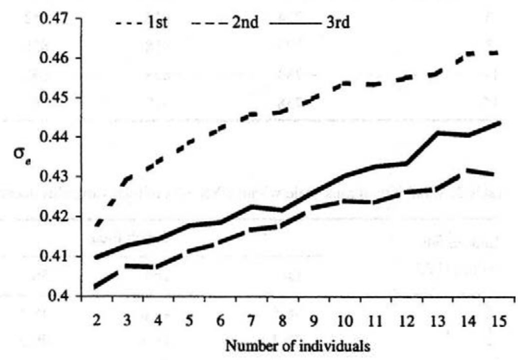

Figure 4. Variability within HYS (proportion) according to parities – Holstein

deviations of the season length (σ length). With the increasing number of individuals within HYS, it becomes prolonged. The minimum length of HYS was practically only a few days, even at a number of individuals within the season equal 15 (large herds). Fluctuation of the season length with the equal number of observations is shown by the standard error of season length. The season length means that at the given length of the season, 50% cows are included in these seasons. If the season length is prolonged by one standard deviation, 84% cows are included, and at prolongation of the season by two standard deviations, 97% cows are included.

Based on the given data (distribution of observations at various HYS magnitude), it is possible to determine the probability how many individuals will be included in HYS of different magnitudes at its constant length. The data on the representation of cows in HYS at the season length = 60 days and at the season length = 90 days for both breeds and the parities are summarised in Table 5.

An increase in the length of the season in dependence on the number of individuals within HYS is practically linear (Table 6). The same number of individuals is reached in the herds of H cattle at a shorter season than in herds of C cattle. As the number of animals decreases with age, approximately the same number of individuals within HYS of H cattle in the 2nd lactation can be reached as in the 1st lactation in C cattle. It follows from the long-term age structure on average for both breeds it is 65%

Table 4. Season length and length standard deviation in HYS (in days) in dependence on the number of individuals within HYS, breed and parity

Individuals within HYS	1st		2nd		3 rd	
	season length	σ length	season length	σ length	season length	σ length
Czech Pied						
2	10.21	13.80	13.91	15.71	17.38	17.79
5	43.22	39.06	56.31	42.20	70.73	46.49
8	76.70	62.10	99.29	67.11	124.34	73.86
11	109.01	83.12	142.52	92.15	180.01	101.38
15	151.72	110.06	198.40	123.37	252.38	137.49
Holstein						
2	8.58	12.95	11.61	14.89	15.64	17.37
5	35.09	37.96	45.72	42.38	60.48	46.47
8	61.16	61.15	78.67	68.30	105.35	75.81
11	87.95	85.29	110.89	94.07	147.15	102.39
15	122.50	115.69	153.67	127.53	207.60	143.19

Table 5. Cumulative frequency of cows in % in differently numerous HYS, at the season length 60 and 90 days according to breed and parities

Individuals in HYS	Czech Pied			Holstein		
	1st	2nd	3rd	1st	2nd	3rd
60 days						
2	100.0	99.8	99.2	100.0	99.9	99.5
5	66.6	53.5	40.9	74.4	63.2	49.6
8	39.4	27.9	19.2	49.2	39.2	27.5
11	27.8	18.5	11.8	37.2	29.4	19.7
15	20.6	13.1	8.1	29.5	23.1	15.1
90 days						
2	100.0	100.0	100.0	100.0	100.0	100.0
5	88.4	78.8	66.1	92.6	85.2	73.7
8	58.5	44.5	32.1	68.1	56.6	42.0
11	41.0	28.4	18.7	51.0	41.2	28.8
15	28.7	19.0	11.9	38.9	30.9	20.6

Table 6. Regression of HYS length (days) in dependence on the number of contemporaries within HYS, according to breeds and parities

	1st	2nd	3rd
Czech Pied	10.9	14.3	18.1
Holstein	8.7	10.9	14.6

cows in the 2nd lactation compared with the 1st lactation and in the 3rd lactation 73% of the 2nd lactation (Přibyl and Přibylová, 2001). According to the analysis of a limited set of lactations from the last period of 1996 and 97, in C cattle 77% are in the 2nd lactation compared with the 1st lactation and 72% in the 3rd lactation compared with the 2nd lactation. In H cattle, these data are 70 and 65%. It may however be connected with the total change in the population size. A similar relation (equality of regression coefficients) is also valid for comparison of the 2nd and 3rd lactations of the mentioned breeds.

Mean error of deviation

The number of contemporaries with which we compare the particular observed individual is a base of comparison that should represent the breed average after pedigree information has been taken into consideration. In dependence on the number of individuals in a contemporary group, the mean error of the group average is different (Přibyl and Přibylová, 1996). The mean error of the average of breeding values (σ_{BV}) of non-related individuals is:

$$\sigma_{BV} = \sigma_g ((1 - r^2_p)/n)^{1/2} \quad (8)$$

With the increasing number of observations the standard error of the average of breeding values falls from the maximum value – genetic standard deviation as it is shown in Table 7 and Figure 5. This figure expresses the error of correction of the comparison base within HYS on breed average. The upper line of the graph represents the standard error if the parents are not known, the lower line with the parents taken into consideration, which results in a decrease in the error. For r_p^2 the expected value 0.30 is substituted (equation. 5). Correction for pedigree plays a greater role in the case of the lower number of observations.

Table 7. Mean error of the average of breeding value of *n* animals (proportion σ_g)

Individuals	σ_{BV} with known parents	σ_{BV} without known parents
1	0.84	1.00
3	0.48	0.58
7	0.32	0.38
15	0.22	0.26
29	0.16	0.19

The error of production deviation from the contemporaries depends on genetic and residual variability and quantity of information. If the known breeding values of parents are considered, the random error of deviation decreases. The mean error of production deviation can be expressed as the root of equation (6). The results are in Table 8 and Figure 6.

The upper line in the graph expresses the mean error of production deviation without taking into account the parents, the lower one after their being taken into account, both with the same reliability in an observed individual and in all contemporaries. The graph is a combination of two factors. The mean error of production deviation decreases with the number of pieces of information. An increasing number of contemporaries within HYS influenced its prolongation and growth of uncontrollable variability within it. The course of both graphs is similar, the

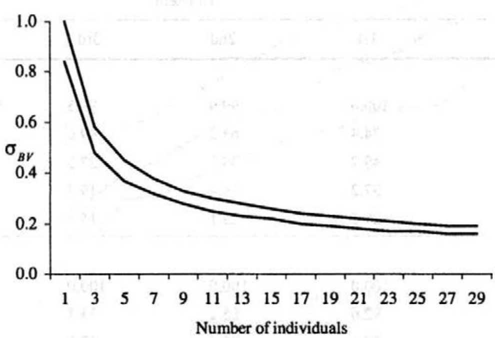

Figure 5. Standard error of the average of breeding values of *n* animals (proportion of σ_g)

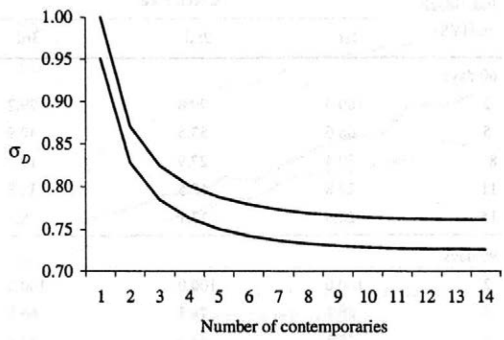

Figure 6. Standard error of production deviation (proportion), h^2 = 0.32

Table 8. Mean error of deviations of production from the contemporaries in dependence on their number and consideration of breeding values of parents (relatively to maximum error at one contemporary)

Number of contemporaries	Mean error without parents	Mean error with parents, $h^2 = 0.21$	Mean error with parents, $h^2 = 0.32$
1	1.00	0.97	0.95
2	0.87	0.84	0.83
4	0.80	0.78	0.76
7	0.77	0.75	0.74
14	0.76	0.74	0.73

decrease in the error is slowed down and at reaching of 7 contemporaries, it does not change basically. If the parents are taken into account, the error is reduced. The magnitude of the error that occurs without taking into account the parents, at 10 contemporaries and more, is reached already at 4 contemporaries after their being taken into account. In $h^2 = 0.21$, the error is a little higher, but the difference is negligible.

In estimation of the breeding value, the pedigree of a majority of individuals is known. Therefore it is more practical to follow the lower graph with the parents. Even at the highest number of contemporaries the error falls approximately to 3/4 of its maximum value (at one contemporary). The more exact determination of the production deviation cannot be attained.

CONCLUSION

1. Milk production is influenced mainly by systematic factors of the environment that explain up to 60% of total variability (Table 3) while the genetic disposition of an individual explains 10 to 14% of variability.

2. For this reason it is necessary to choose such a scheme of testing and methods of breeding value estimation that mainly systematic factors of the environment could be determined with the highest possible exactness. In the case of their incorrect determination it is not possible to estimate the breeding value of an animal (the less important effect) correctly.

3. In clustering of individuals into seasons, the increased number of individuals within season results in season prolongation (Table 6), which consequently leads to the increase in uncontrollable variability (within HYS). Therefore it is necessary to create the shortest possible season within the herds. The herds can be joined together for the purposes of animal evaluation only in exceptional cases of extremely small herds.

4. The mean error of production deviation of a cow from contemporaries decreases with the number of contemporaries. After reaching 7 contemporaries it does not however improve with the increasing number of contemporaries and becomes constant at the approximate value 3/4 of maximum error at one contemporary.

5. Taking into account the pedigree information of animals allows to reduce the error of production deviation and decrease the number of contemporaries.

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Expected reliability of cow's breeding value for average life-time milk production

Očekávaná spolehlivost odhadu plemenné hodnoty průměrné celoživotní mléčné užitkovosti krav

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ABSTRACT: Reliability of breeding value estimation of cows for average life-time milk production is modelled on the basis of animal model method. Only the first or the first three lactations are considered for prediction. The number of contemporaries within (HYS) herd-year-season (1 to 15), degree of relationship between contemporaries, number of half-sisters (10 to 100) and relationship with the father only or full relationship over 3 generations of ancestors are taken into account. Two levels of heritability are used (0.32 and 0.21). Within-the-herd variability changed with the increasing magnitude of HYS. With data on 3 lactations and all other information available, it is possible to achieve the reliability of prediction of breeding value for the average of life-time production $r^2 = 0.535$. It is by 12% higher than with the first lactation only. Reliability increases if the contemporaries are not related. Reliability also increases with the increasing number of contemporaries within HYS. When reaching 5 contemporaries, further increase in reliability is low. Reliability is influenced by the number of half-sisters. With 50 half-sisters and more, at least a 90% level of maximum possible reliability is attained, practically regardless of the number of contemporaries within the herd.

Keywords: breeding value; reliability; milk production; contemporary; half-sisters; animal model; length of season

ABSTRAKT: Spolehlivost odhadu plemenné hodnoty krávy pro průměrnou celoživotní mléčnou užitkovost je modelována na podkladě metody animal model. Jsou uvažovány pouze první, nebo první tři laktace. Zohledněny jsou počty vrstevnic uvnitř (HYS) stáda-roku-období (1 až 15), stupeň vzájemné příbuznosti vrstevnic, počty polosester (10 až 100), příbuznost pouze k otci, případně úplná příbuznost přes tři generace předků. Jsou použity dvě úrovně dědivosti (0,32 a 0,21). S velikostí HYS je měněna vnitrostádová proměnlivost. Při třech laktacích a maximálním využití všech informací lze dosáhnout spolehlivosti předpovědi plemenné hodnoty průměru celoživotní užitkovosti $r^2 = 0{,}535$. To je o 12 % více než při použití pouze první laktace. Spolehlivost zvyšuje nejsou-li vrstevnice příbuzné. S nárůstem počtu vrstevnic uvnitř HYS stoupá spolehlivost. Při dosažení pěti vrstevnic je však již další zvyšování spolehlivosti malé. Spolehlivost ovlivňuje počet polosester. Při překročení přibližně 50 polosester je dosaženo přinejmenším 90 % maximálně dosažitelné spolehlivosti bez ohledu na počet vrstevnic ve stádě.

Klíčová slova: plemenná hodnota; spolehlivost; mléčná užitkovost; vrstevnice; polosestry; animal model; délka období

INTRODUCTION

The estimation of breeding value (u) is done with an error that is to be minimised by the test organisation, proper implementation of milk records and method of data evaluation. The total error consists of two parts – bias and the prediction error itself (Van Vleck, 1986). The total error variance (TEV) is the variance caused by the bias and the error of determination of breeding value.

$$\text{TEV} = (BIAS)^2 + \text{var}_{PE} \quad (1)$$

which can be specified for an individual (i)

$$\text{TEV}_i = [E(\hat{u}_i - u_i)]^2 + V(\hat{u}_i - u_i) \quad (2)$$

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Breeding value estimation is done on the basis of BLUP method, therefore the estimations should be unbiased and only the second part of the given equation is considered for the estimation of breeding value reliability. Breeding value reliability is expressed by the coefficient of determination r^2, which directly depends on var_{PE} and variability of the estimated random effect σ^2_u

$$r^2 = \frac{\text{cov}_{\hat{u}u}}{\text{var}_{\hat{u}}\ \text{var}_u} = 1 - \text{var}_{PE} / \sigma^2_u \qquad (3)$$

Methods of breeding value estimation are based on a solution of the equation system, and the exact reliability of estimated constants should be determined on the basis of elements of the inversion left hand side (LHS) matrix of the system (Searle, 1971; Henderson, 1984). To find a solution of the equation system, the variance ratio $k = \sigma^2_e/\sigma^2_u$ is often used. Then the reliability coefficient is:

$$r^2_i = 1 - k \times C_{ii} \qquad (4)$$

where: C_{ii} = diagonal element of the inversion of LHS matrix, related to the evaluated individual (i)

In case that breeding value is estimated for the complex of traits by multidimensional models, then an index is used. In the previous equations, the variance components are substituted by the blocks of covariance matrices, multiplied from the left and right sides by vectors of weights of traits in the index (Schneeberger *et al.*, 1992). Grasser and Tier (1997) used for var_{PE} in a special case the value

$$(\mathbf{R}^{-1} + \mathbf{G}^{-1})^{-1} \qquad (5)$$

where: **R** and **G** are the residual and genetic covariance matrices of traits

The iteration procedures are regularly used and therefore the inversion of the matrix is not known. For this reason, various approximate procedures are applied for the calculation of reliability. The simplest way (for example Čermák *et al.*, 1986) for estimation of the diagonal element of the inverted matrix is the inversion value of the diagonal element of the LHS matrix.

$$r^2_i = 1 - k/d_{ii} \qquad (6)$$

where: d_{ii} = diagonal element of LHS matrix after absorption of HYS (herd-year-season) equations that express the effective number of observations w plus the coefficient k

$$d_{ii} = k + \sigma w_i$$

After substitution and simplification, the well known formula is obtained:

$$r^2 = \Sigma w/(\Sigma w + k) \qquad (7)$$

which is used in simulation studies for prediction of the expected value of reliability. The course of reliability in dependence on the number of observations is typically curved, the increment is slowing down and its curve is approaching a limited value.

Some authors worked out the improved estimation of reliability by including other information. Meyer (1989) used the block from the LHS connected with individual, his parents and HYS in which the individual is presented. Then she approximately determined the elements of the inversion matrix on the basis of the given block inversion. In connection with the AM method, several generations of ancestors are used for breeding value estimation. Grasser and Tier (1997) transformed all information into the equivalent of effective number of progeny, originating from different sources. Harris and Johnson (1998) worked with partial reliabilities according to the source of information "corrected" by information already included in another source. Gengler and Misztal (1996) used the canonical transformation and suggested the methodology which allows to work also with incomplete data.

Reliability is already included in breeding value. Therefore it is less important for the actual selection of animals for the breeding purposes. The main use of this coefficient is to plan the organisation of milk recording and the procedure for the data evaluation to minimise the expected error.

Variability of breeding value and production deviation from contemporaries was described by Přibyl (1986). It depends on the number of observations, number of contemporaries for each observation, genetic and residual variability. The formula to determine the error of breeding value estimation in dependence on the number of tested bulls and the number of herds in which the test is done was derived by Herrendörfer *et al.* (1974). The effect of the relationship of animals on breeding value reliability was studied by Mostager (1970, 1971).

The planning of evaluation is connected with the assessment of groups of contemporaries for direct comparison of animals. In milk production it is given by the optimum HYS length. It is desirable that HYS should be as short as possible with equal environmental conditions for all the animals within it and simultaneously with the highest possible number of contemporaries. The effect of HYS magnitude, number of non-related contemporaries and the incidence of direct comparison of tested animals within HYS at a different level of heritability were studied by Tosh and Wilton (1994). A higher number of contemporaries in the group results in the higher accuracy of breeding value estimation but after the number of contemporaries in the group exceeds 5, it does not improve the estimation any longer.

The long HYS can lead to an estimation bias due to systematic trends. The effect of the season of the year on milk production was described by Kučera *et al.* (1999). Schmitz *et al.* (1991) showed that the prolongation of HYS led to introduction of systematic effects of the environment, which increased uncontrolled variability. With regard to the evaluation of bulls they arrived at a conclusion that the way of combining the animals into groups was not essential, but a more important role was played by the number of progeny. A higher number of contemporaries in the group from 2 to 3 improved the accuracy of evaluation but the increase over 10 contemporaries was not particularly beneficial. The variability within HYS in dependence on its magnitude was studied by Přibyl and Přibylová (2001b). Systematic effects of the environment explained up to 60% of total variability while genetic disposition from 11 to 14%. At the same time they determined the mean standard error of deviation of milk production of the observed cow from the group of contemporaries. In dependence on the number of contemporaries within HYS the mean standard error of deviation falls to the level of approximately 3/4 of the maximum value at one contemporary. From the number of 7 contemporaries it practically does not change with increase in their number. Consideration of the pedigree allowed further decrease in the error.

The animal breeding is aimed at average life-time milk production. The estimation of breeding value is under this condition. Prediction of breeding value for average life-time production according to the known first lactations is done with some reliability only (Přibyl and Přibylová, 2001a).

Breeding value of sires is usually determined with sufficient reliability thanks to a high number of the offspring. The aim of this study is to determine, on the basis of simulated calculations, the expected reliability of breeding value for average life-time milk production of the cow, in dependence on the number of contemporaries within HYS and a different number of paternal half-sisters.

MATERIAL AND METHODS

Breeding value for the first lactation

In dependence on the HYS magnitude from 1 to 15 contemporaries and the number of paternal half-sisters, the reliability of breeding values is simulated by means of the animal model. Only the first lactations and two effects are considered:

$$y = HYS + J + e \quad (8)$$

where: J = random effect of an individual with the relationship matrix (relationship includes only the sire of the cows)

The cow is compared to a different number of contemporaries within the herd that are not related to it. Its father and fathers of contemporaries have also daughters in other herds, one daughter in each of them. All herds are of the same size. The father's offspring range from 10 to 100. The cases when all contemporaries are the progeny of one sire or all contemporaries over all herds are not related are considered.

Reliability is determined on the basis of the inversion matrix element according to equation (4). The heritability coefficient $h^2 = 0.32$ (corresponds approx. with Holstein Cattle), or $h^2 = 0.21$ (corresponds approx. with Czech Pied Cattle) for the animal model is according to Dědková and Wolf (2001). The value of the given heritability corresponds with HYS of the average number of about 9 individuals. With the increasing number of individuals within HYS it is prolonged which results in higher unexplained residual variability while genetic variability remains constant. In dependence on the HYS magnitude, the coefficient k, substituted into the equation system of the animal model (8), is calculated according to:

$$k = (t - h^2_{ZA})/h^2_{ZA} \quad (9)$$

where: $t = \sigma^2_n/\sigma^2_{ZA}$

σ^2_n = variability within HYS at the number of individuals in HYS – n

σ^2_{ZA} = variability within HYS at the number of individuals in HYS according to the basic variant, where the heritability coefficient h^2_{ZA} was set

Milk production variability within HYS (Přibyl and Přibylová,2001b) is given by the function

$$\sigma^2_n = 0.43323832 + 0.00759844\,n - 0.00070867\,n^2 + 0.00004240\,n^3 - 0.00000096\,n^4 \quad (10)$$

Reliability according to several lactations

Breeding is aimed at the average of life-time production. Breeding value is calculated according to several known first lactations included in an index (Přibyl and Přibylová, 2001a). We used the first three lactations. Reliability is established iteratively on the basis of the selection index theory, by which we adequately simulate MT – AM with relationship over 3 generations (both parents are known). Each cow has (v) contemporaries within the herd (from 1 to 15) that are not related to each other. Each dam has only one daughter with production. Each sire has (z) daughters (from 10 to 100), each in a different herd. The size of all herds is the same.

The index of the cow with three lactations is as follows:

$$\mathbf{P} \times \mathbf{b} = \mathbf{GC} \times \mathbf{EH} \quad (11)$$

where: **P** = 3 × 3 covariance matrix of production deviation from contemporary within HYS for the first three lactations

b = vector of the weights of lactations in the index

GC = 3 × 10 genetic covariance matrix of lactations in the index to the lactations of total genotype

EH = vector of economic values of lactations

Reliability of the breeding value estimation according to the index is as follows:

$$r^2 = (\mathbf{b'} \times \mathbf{GC} \times \mathbf{EH})/(\mathbf{EH'} \times \mathbf{G} \times \mathbf{EH}) \quad (12)$$

where: G = 10 × 10 genetic covariance matrix of ten lactations of total genotype

The phenotype variances and covariances in the **P** matrix are corrected for variability in dependence on the HYS length by the coefficient t (equation 9). Furthermore, according to the effective number of observations w within HYS (Přibyl, 1986), which takes into consideration variability of deviation in accordance with the number of contemporaries

$$w = v/(1 + v) \quad (13)$$

where: v = number of contemporaries within HYS

Corrections are also made according to reliability of parental breeding values (Přibyl and Přibylová, 1996) because the pedigree information (about the animal observed as well as their contemporaries) reduces the random error of deviation

$$r_J^2 = (r_S^2 + r_D^2)/4 \quad (14)$$

where: r_J^2, r_S^2, r_D^2 = are reliabilities of estimation of the probands, their sire and dam

The total correction of variability is:

$$\sigma_P^2 = (t \times \sigma_{ZA}^2 - r_J^2 \times \sigma_g^2)/w \quad (15)$$

where: σ_g^2 = genetic variability

Genetic and economic parameters (Table 1) are taken from Dědková and Wolf (2001) and Přibyl and Přibylová (2001a).

The index for the sire is established by combination of (z) daughters according to equations (11) and (12).

In this case the matrix **P** is a combination of ($z \times z$) blocks. Diagonal blocks correspond to the matrix **P** from the cow's index. The blocks outside diagonal are $0.25\mathbf{G}_{33}$, where $\mathbf{G}_{33}$ is the block for the first three lactations from the genetic covariance matrix **G**.

In this case, the right side of the equation system (covariance of daughters' performance to the father) is a combination of repeated blocks **0.5GC** of the cow's index.

The parents are considered in the index where the information on the proband, sire and dam is combined. The structure of information is complicated in this case. Therefore the equation system for the combination of sources was modified according to the reliabilities of partial indices (Přibyl and Přibylová, 1998). After corrections, the matrix **P** has dimension 3 × 3 and includes the reliabilities of partial breeding values (indices) of the proband r_J^2 (cow, or bull), sire r_S^2 and dam r_D^2.

$$\mathbf{P} = \begin{bmatrix} r_J^2 & 0.5r_J^2r_S^2 & 0.5r_J^2r_D^2 \\ 0.5r_J^2r_S^2 & r_S^2 & - \\ 0.5r_J^2r_D^2 & - & r_D^2 \end{bmatrix} \quad (16)$$

Similarly the right side:

$$\mathbf{GC} = \begin{bmatrix} r_J^2 \\ 0.5r_S^2 \\ 0.5r_D^2 \end{bmatrix} \quad (17)$$

Variability of the whole genotype after corrections is 1. Total reliability of the breeding value estimation of the proband, including parental information is

$$r^2 = \mathbf{b'} \times \mathbf{GC}$$

Table 1. Correlations between lactations (%) – above diagonal genetic, below diagonal phenotype, standard deviations for lactations in Czech Pied (C) and Holstein (H) cattle and discounted economic values (EH) with interest rate 5%

Lactation	1	2	3	4	5	6	7	8	9	10
1	–	91	90	85	80	75	70	65	60	55
2	70	–	98	95	90	85	80	75	70	65
3	60	70	–	98	95	90	85	80	75	70
4				–	98	95	90	85	80	75
5					–	98	95	90	85	80
6						–	98	95	90	85
7							–	98	95	90
8								–	98	95
9									–	98
σ_{gC}	324	372	387	388	386	385	377	373	361	361
s_{gH}	485	589	586	544	526	495	487	468	450	446
EH	0.369	0.221	0.153	0.103	0.067	0.041	0.024	0.012	0.007	0.003

In the previous step calculated values of cows and bulls were substituted for the value of the sire's and dam's reliabilities. For the given size of the herd and the given number of daughters of the sire, the whole technique is iteratively 3 times repeated (3 generations of ancestors) according to equations (14), (15), (11), (12), (16), (17) and (18).

RESULTS AND DISCUSSION

Reliability of breeding value in the first lactation

The reliability of the breeding value of a cow in the first lactations is simulated by means of AM. All contemporaries are the progeny of the same sire. The sire of the particular cow, similarly like the sire of contemporaries, has the same number (10 to 100) of daughters in the other herds that meet with daughters of other sires. Neither relationship to the dams nor to other generations of ancestors is considered. The reliability is shown in Table 2 and Figure 1.

In the case of heritability $h^2 = 0.32$ and if the contemporaries do not have any half-sisters, reliability of the breeding value estimation increases in dependence on the number of contemporaries from the value 0.16 to 0.260. With the increasing number of half-sisters it increases up to 0.253 (one contemporary, 100 half-sisters), and 0.326 (15 contemporaries, 100 half-sisters). According to both viewpoints, the increment is a curve, the increment of reliability is slowed down with higher amount of information. It reaches the upper limit within the range from 13 to 15 contemporaries.

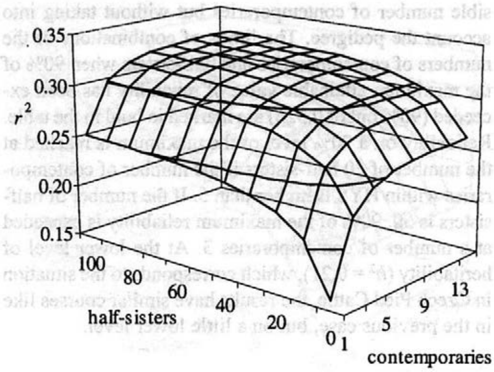


Figure 1. Cow's reliability, first lactation, contemporaries related ($h^2 = 0.32$)

The points with the same reliability that can be attained by various combinations of information are linked in the graph. In the consideration of the number of contemporaries only, the critical limit is 3 to 5, exceeding this limit results in negligible changes. As it follows from the above mentioned facts, after the fulfilment of minimal limits, the course of the graph is flat and the increment of reliability with the increased amount of information is not important.

In the breeding value estimation, the sire is practically always known. If the sire has several tens of daughters (30 and more), it becomes more important for the cow evaluation than the numbers of contemporaries within HYS. If the sire has only 10 daughters and the cow has only 3 contemporaries, the reliability of the breeding value estimation is higher than in the case of the highest pos-

Table 2. Reliability of breeding value estimation of the cow in the first lactation in dependence on the number of contemporaries and half-sisters in other herds. All contemporaries are progeny of the same sire

Contemporaries	Paternal half-sisters						
	0	10	20	40	60	80	100
$h^2 = 0.32$; 90% = 0.293							
1	0.160	0.207	0.225	0.240	0.247	0.251	0.253
3	0.226	0.264	0.278	0.290	**0.296**	**0.299**	**0.301**
5	0.245	0.280	**0.293**	**0.305**	0.310	0.313	0.315
9	0.257	0.290	**0.303**	0.314	0.319	0.322	0.324
15	0.260	0.292	**0.304**	0.316	0.321	0.324	**0.326**
$h^2 = 0.21$; 90% = 0.239							
1	0.113	0.157	0.177	0.197	0.206	0.212	0.216
3	0.161	0.198	0.216	0.233	**0.241**	**0.246**	**0.249**
5	0.175	0.21	0.227	**0.243**	0.251	0.256	0.259
9	0.184	0.218	0.234	**0.250**	0.258	0.262	0.265
15	0.186	0.219	0.235	**0.251**	0.259	0.263	**0.266**

sible number of contemporaries but without taking into account the pedigree. The limits of combinations of the numbers of contemporaries and half-sisters when 90% of the maximum attainable value of reliability has been exceeded (90% out of 0.326) are marked in bold in the table. Reliability on a 90% level of the maximum is reached at the number of 20 half-sisters if the number of contemporaries within HYS is higher than 5. If the number of half-sisters is 50, 90% of the maximum reliability is exceeded at a number of contemporaries 3. At the lower level of heritability ($h^2 = 0.21$), which corresponds to the situation in Czech Pied Cattle, the results have similar courses like in the previous case, but on a little lower level.

The given case is at the lower limit of the attained reliability when we presumed that all the contemporaries are related to the same sire. The lower the relationship between contemporaries, the higher the reliability of evaluation.

Table 3 shows an opposite case when the contemporaries of evaluated cow and all the contemporaries of its paternal half-sisters in other herds are fully unrelated (the sire has one daughter only in each herd).

The results of reliabilities have a similar course like in the previous case, but with a little steeper increment. The higher reliability is attained, it reached ($h^2 = 0.32$) the value $r^2 = 0.399$, which is by 22% more in comparison

Table 3. Reliability of breeding value estimation of the cow in the first lactation in dependence on the number of contemporaries and half-sisters in other herds. Contemporaries not related to each other

Contemporaries	Paternal half-sisters						
	0	10	20	40	60	80	100
$h^2 = 0.32$; 90% = 0.359							
1	0.160	0.209	0.239	0.272	0.289	0.300	0.307
3	0.235	0.289	0.317	0.344	0.356	**0.363**	**0.368**
5	0.258	0.312	0.339	**0.363**	**0.374**	0.381	0.385
9	0.273	0.327	0.353	**0.376**	0.386	0.392	0.396
15	0.276	0.331	0.356	**0.379**	0.389	0.395	**0.399**
$h^2 = 0.21$; 90% = 0.302							
1	0.113	0.153	0.183	0.219	0.239	0.252	0.262
3	0.166	0.215	0.245	0.278	0.294	**0.305**	**0.312**
5	0.181	0.232	0.263	0.293	**0.309**	0.319	0.325
9	0.191	0.243	0.274	**0.303**	0.318	0.327	0.333
15	0.194	0.246	0.276	**0.306**	0.321	0.33	**0.336**

Table 4. Reliability of breeding value estimation of the sire for average life-time production according to the first three lactations of daughters in dependence on the number of contemporaries within the herd and number of daughters

Contemporaries	Daughters					
	10	20	40	60	80	100
$h^2 = 0.32$; 90% = 0.812						
1	0.436	0.581	0.717	0.783	**0.822**	**0.849**
3	0.534	0.670	0.786	**0.839**	0.869	0.889
5	0.556	0.689	0.801	**0.850**	0.878	0.897
9	0.570	0.701	0.809	**0.857**	0.884	0.901
15	0.572	0.703	0.810	**0.858**	0.885	**0.902**
$h^2 = 0.21$; 90% = 0.779						
1	0.352	0.493	0.639	0.716	0.765	**0.798**
3	0.443	0.584	0.718	**0.784**	**0.823**	0.849
5	0.465	0.605	0.735	**0.798**	0.835	0.859
9	0.478	0.618	0.745	**0.806**	0.842	0.865
15	0.481	0.620	0.747	**0.808**	0.843	**0.866**

with Table 2. 90% of this highest reliability (90% out of 0.399) is exceeded if the amount of information exceeds 70 daughters of the sire and 3 contemporaries, or 40 daughters and 5 contemporaries, or 30 daughters and 7 contemporaries.

The given results are in accordance with Tosh and Wilton (1994), who showed the effect of the relationship of contemporaries and direct relatedness of animals on the reliability of the cow's breeding value estimation. The conclusions of their study are similar to ours. The same applies to the number of observations that are necessary for the evaluation.

In practical cases, the reliability is within the range of given extremes (Tables 2 and 3) because the contemporaries are always related to a certain degree.

If we want to predict the reliability of breeding value for the average of life-time production on the basis of the first lactation, it is necessary to multiply the given values by 0.90 (Přibyl and Přibylová, 2001a).

Reliability of prediction of life-time production according to first three lactations

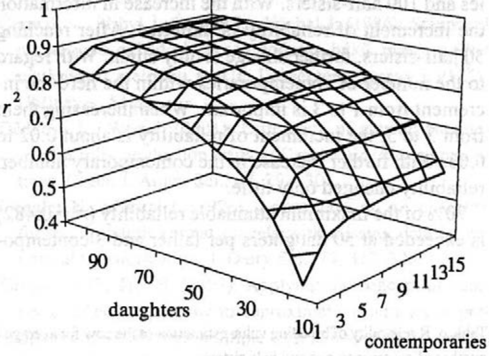
A breeding goal is the highest possible production on the average of the cow's life time (Přibyl and Přibylová, 2001a). Prediction is done according to the first three lactations. For simplification we use the same number of contemporaries in all three lactations for every cow. All contemporaries are not related to each other. Three generations of ancestors are used for the evaluation and previous generations have the same structure and amount of information as in the youngest generation.

Sires – 3 lactations

Reliability of the sire's breeding value calculated under the same conditions is presented for comparison. Reliability of the breeding value of the sire for the average of life-time production is given in Table 4 and Figure 2.

At a higher level of heritability the reliability is increasing from $r^2 = 0.436$ in the case of 1 contemporary within HYS and 10 daughters to $r^2 = 0.902$ with 15 contemporaries within HYS and 100 daughters, each with 3 lactations. As the generations of ancestors are considered, relatively high reliability is reached at a low amount of information (progeny and contemporary).

After the number of contemporaries in the herds reached 5, the reliability did not practically change with further increase in their number. An important role is played above all by the number of progeny. 90% of maximum reliability ($r^2 = 0.812$) is overrun at 80 daughters and only 1 contemporary within HYS, or 50 daughters and 3 contemporaries. With the increase in the number



2. Sire's reliability, 3 lactations ($h^2 = 0.32$)

of daughters, the effect of contemporaries becomes less important and differences in reliability according to the number of contemporaries decrease.

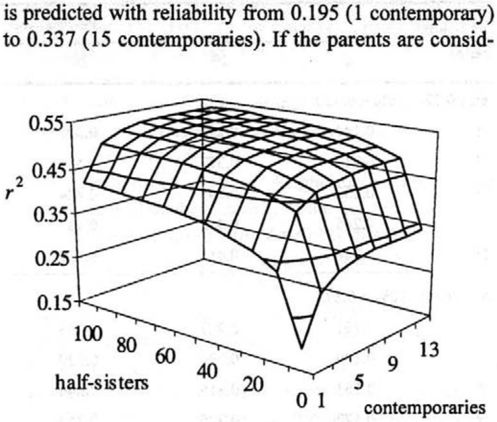
In heritability $h^2 = 0.21$ the reliability is lower in general and 90% of the maximum is achieved with a slightly higher amount of information.

With regards to the fact that in testing of sire, the sufficient number of progeny is provided in advance, it is possible to have a small number of contemporaries in herds (about 3) without any practical effect on the resulting reliability of the breeding value estimation.

Cows – 3 lactations

Reliabilities of estimation of the cow's breeding value according to 3 lactations are shown in Table 5 and Figure 3.

In the case of heritability $h^2 = 0.32$ and isolated evaluation of the herd, the breeding value for life-time production is predicted with reliability from 0.195 (1 contemporary) to 0.337 (15 contemporaries). If the parents are consid-



3. Cow's reliability, 3 lactations ($h^2 = 0.32$)

ered, reliability increases to 0.535 with 15 contemporaries and 100 half-sisters. With the increase in information the increment of reliability is inhibited. After reaching 50 half-sisters, further change is only slight. With regard to the number of contemporaries within the herd the increment from 1 to 3 is important. When increasing them from 3 to 5, the increment of reliability is about 0.02 to 0.03. With further increase in the contemporary number, reliability changed only little.

90% of the maximum attainable reliability ($r^2 = 0.482$) is exceeded at 50 daughters per father and 3 contemporaries, or 20 daughters per father and 5 contemporaries, or 10 daughters per father and 11 contemporaries within each HYS. After exceeding the number of contemporaries in the herd 5 and 20 half-sisters, further increment of reliability of the cow's breeding value is suppressed in dependence on the amount of information and is small. It is documented by the wide and flat crown in Figure 3.

Similarly like in previous cases for heritability $h^2 = 0.21$, 90% of the maximum value is exceeded at a higher number of half-sisters. The effect of the number of contemporaries is the same as in previous cases.

Table 5. R reliability of breeding value estimation of the cow for average life-time production according to the first three lactations in dependence on the number of contemporaries and half-sisters

Contemporaries	Paternal half-sisters						
	0	10	20	40	60	80	100
$h^2 = 0.32$; 90% = 0.482							
1	0.195	0.331	0.363	0.395	0.41	0.419	0.425
3	0.287	0.436	0.457	0.480	**0.490**	**0.495**	**0.499**
5	0.315	0.463	**0.482**	**0.503**	0.512	0.517	0.520
9	0.333	0.479	**0.498**	0.517	0.525	0.530	0.533
15	0.337	**0.483**	0.501	0.520	0.528	0.533	**0.535**
$h^2 = 0.21$; 90% = 0.408							
1	0.137	0.256	0.288	0.327	0.346	0.359	0.367
3	0.202	0.342	0.366	0.396	**0.411**	**0.420**	**0.426**
5	0.221	0.364	0.386	**0.414**	0.428	0.436	0.441
9	0.234	0.377	0.398	**0.426**	0.438	0.446	0.451
15	0.237	0.380	0.401	**0.428**	0.441	0.448	**0.453**

Table 6. Reliability of breeding value estimation of the cow for average life-time production according to the first lactation and considering the ancestors with three lactations in dependence on the number of contemporaries and half-sisters

Contemporaries	Paternal half-sisters						
	0	10	20	40	60	80	100
$h^2 = 0.32$; 90% = 0.430							
1	0.144	0.292	0.327	0.360	0.376	0.386	0.392
3	0.212	0.377	0.404	0.429	**0.440**	**0.447**	**0.451**
5	0.232	0.399	0.424	**0.447**	0.457	0.463	0.466
9	0.245	0.412	**0.437**	0.458	0.468	0.473	0.476
15	0.249	0.415	**0.439**	0.460	0.470	0.475	**0.478**
$h^2 = 0.21$; 90% = 0.373							
1	0.101	0.227	0.263	0.302	0.323	0.336	0.345
3	0.149	0.297	0.329	0.361	**0.377**	**0.386**	**0.393**
5	0.163	0.315	0.346	**0.376**	0.390	0.399	0.405
9	0.172	0.326	0.356	**0.385**	0.399	0.407	0.413
15	0.175	0.329	0.358	**0.387**	0.401	0.409	**0.414**

Reliability of prediction of life-time production according to the first lactation

The number of lactations of the cow gradually increases. Therefore the breeding value is estimated according to the first lactation, and finally according to the first three lactations in total. For the evaluated cow we consider only the first lactation while for 3 generations of ancestors all 3 lactations. Reliability of the breeding value estimation for life-time production according to the first lactation of the cow and their ancestors at $h^2 = 0.32$ is shown in Table 6.

In dependence on the amount of information the course of reliability is similar to the previous case, but at a lower level, achieving from 86 to 92% of the value at 3 lactations. The life-time production is predicted with reliability ceiling $r^2 = 0.478$. The first column of Table 6 presents the evaluation in comparison with unrelated contemporaries only within one herd with respect to life-time production. Table 2 shows evaluations by animal model according to the first lactation only. The first column of Table 2, after multiplication by the coefficient 0.90 (Přibyl and Přibylová, 2001a) (transformation into life-time production), is in accordance with the first column in Table 6. The other columns illustrate differences caused by consideration of dams and other generations of ancestors (Table 6).

CONCLUSIONS

An analysis of the expected reliability of cow's breeding value for milk production was performed. Several variants were compared in dependence on the amount of information.

1. On the basis of consideration of production in the first 3 lactations and maximum exploitation of all information, including 3 generations of ancestors, it is possible to achieve the reliability of the breeding value prediction for the life-time production of cow $r^2 = 0.535$. It is by 12% more than if only the first lactation is used. Every subsequent lactation adds less to the previous reliability and is less important.

2. The reliability of breeding value estimation increases if the contemporaries are not related to each other, which can be provided by planned mating.

3. The number of half-sisters influenced the reliability. Exceeding approx. 50 half-sisters represents at least 90% of the maximum attainable value of reliability, practically regardless of the contemporary number within the herd.

4. Reliability increases with the number of contemporaries within HYS. After reaching 5 contemporaries, further increment is low.

5. With regard to reliability of the cow's breeding value, it is possible to substitute the number of contemporaries by a higher number of half-sisters.

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Retention of protein and fat in the meat of fast and slow-growing chickens fattened to higher age

Retence bílkovin a tuku v mase rychle a pomalu rostoucích kuřat vykrmovaných do vyššího věku

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ABSTRACT: In a trial with fast-growing cockerels of hybrid combination Ross 208 (FG) and slow-growing (SG) hybrids Isa Brown, basic production parameters and content of dry matter, protein and fat in breast and thigh meat were investigated in the course of fattening in the age interval from the 5th to the 18th week. Chickens were fed a mixture containing a high level of crude protein. In FG group, the changes in the content of dry matter, protein and fat in breast meat, and dry matter and fat in thigh meat were not significant ($P > 0.05$), the content of protein in thigh meat increased significantly ($P < 0.01$) with the age. In SG group the content of dry matter and fat in breast meat increased significantly ($P < 0.01$), other values did not change. In FG chickens the weight of breast meat, thigh meat and protein content in breast and thigh meat increased by 25, 20, 28 and 24% and in SG group by 18, 13, 26 and 14% faster than their body weight; the increase in fat deposition in breast meat of FG and SG groups was slower by 16 and 30%, respectively. In FG group a relative increase in fat content in thigh meat was lower by 8% while in SG group it was higher by 9% than the growth rate of chickens.

Keywords: chickens; prolonged fattening; meat composition

ABSTRAKT: V pokusu s rychle rostoucími kohoutky hybridní kombinace Ross 208 (FG) a pomalu rostoucími hybridy Isa Brown (SG) byly zjišťovány základní produkční parametry a obsah sušiny, bílkovin a tuku v prsní a stehenní svalovině při výkrmu do věku 5 až 18 týdnů. Po celý výkrm byla zkrmována směs s vysokým obsahem dusíkatých látek. U FG se obsah sušiny, bílkovin a tuku v prsní svalovině i sušiny a tuku ve svalovině stehenní s přibývajícím věkem průkazně neměnil ($P > 0,05$), obsah bílkovin ve stehenní svalovině se průkazně zvyšoval ($P < 0,01$). U SG se průkazně ($P < 0,01$) zvyšoval obsah sušiny a tuku v prsní svalovině, ostatní hodnoty se neměnily. U FG se hmotnost prsní svaloviny, stehenní svaloviny a množství bílkovin uložených v prsní a stehenní svalovině zvyšovala o 25, 20, 28 a 24 % a u SG o 18, 13, 26 a 14 % rychleji než živá hmotnost kuřat, zatímco růst množství uloženého tuku v prsní svalovině FG a SG byl pomalejší o 16 a 30 %. Relativní rychlost růstu obsahu tuku ve stehenní svalovině FG byla o 8 % menší a u SG o 9 % vyšší než relativní rychlost růstu celého kuřete.

Klíčová slova: kuřata; prodloužený výkrm; složení masa

INTRODUCTION

A continued increase in consumer demand for cut-up, processed and value added poultry products brings an increasing demand of the processing industry for chickens fattened to higher body weight. Besides that, the market with slow-growing hybrids fed to a higher age to achieve better taste characteristics is expanding in some European countries. Chickens with the growth potential that resembles rather that of laying hybrids than that of broilers are used for this purpose. Larbier and Leclercq (1994) give some data on the growth and feed conversion of such chickens, but the tissue composition has not been described in available literature.

If the time of fattening is prolonged, feed conversion and yield of the body parts change. The percentage of

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carcass and breast and thigh meat in live weight increases with the age of chickens (Sailer and Seemann, 1988; Skřivan and Tůmová, 1990). However, only the percentage of carcass and breast meat significantly increased while that of thigh meat remained unchanged during the fattening period of cockerels prolonged till the age of 16 weeks in experiments of Jeroch *et al.* (1983) and Zelenka *et al.* (1989). Differences between meat- and egg-type breeds can be attributed to the inherited potential of each breed. The results of Plavnik and Hurwitz (1983) indicate that meat breeds are about three times heavier than egg-type hybrids at 10 weeks of age. Similar differences were reported by Shires *et al.* (1987). In an experiment conducted by Plavnik and Hurwitz (1983) the content of carcass fat, expressed as percentage of body weight, was nearly twice as high in broiler chickens as in laying breeds, whereas that of carcass protein was higher in the latter.

Jeroch *et al.* (1983) reported a constant fat content in the tissues of cockerels in the age interval of 10 to 16 weeks that received a sufficiently high content of dietary crude protein.

The objectives of the present study were to determine the chemical composition of meat and to quantify basic production parameters of broiler type and laying type cockerels fattened to higher age because their knowledge is essential for production systems and for poultry processing.

MATERIAL AND METHODS

Ninety-five cockerels with the genetic potential of fast growth (FG, Ross 208) and ninety-five cockerels without the potential (slow-growing hybrid, SG, Isa Brown) were kept in cages with the surface area 8 500 cm². Stocking density at the end of the experiment was eight birds of SG hybrid and four birds of FG hybrid per cage, respectively.

The initial environmental temperature 35°C was decreased daily by 0.7°C to 21°C and, thereafter, maintained at the same level to the end of experiment. Continuous artificial lighting was used.

In order to support the maximum utilisation of genetic potential for protein retention and to put down excessive fat deposition, the birds deliberately received a diet with narrow energy/protein ratio (536), i. e. with high content of crude protein and lower level of energy, during the whole experimental period. All chicks were fed a diet containing 225 g crude protein (i.e. 36 g N), 37 g crude fat and 12.06 MJ nitrogen-corrected metabolisable energy per 1 kg of fresh matter (88% of dry matter). The formulation of the diet is presented in Table 1. The feed was supplied *ad libitum*. There was no deprivation of feed and water before slaughter.

Table 1. Composition of the diet

Ingredient	g/kg
Maize meal	510
Wheat meal	120.5
Soybean meal	260
Meat-and-bone meal	60
Fish meal	30
Dicalcium phosphate	7
Ground limestone	5
Sodium chloride	1.5
Dl-methionine	2
Premix of feed additives[1)]	4

[1)] The premix supplied the following (mg/kg diet): Cu 9.6; Zn 19.2; Fe 35.2; Mn 64; Co 0.096; Se 0.128; I 0.72; retinyl acetate 4.13; cholecalciferol 0.06; DL-α-tocopherol acetate 32; menadione 0.8; thiamine 2.4; riboflavin 4.8; pyridoxine 4; cyanocobalamine 0.0272; biotin 0.112; niacinamid 24; folic acid 1.12; pantothenic acid 8.8; L-lysine HCl 1 152; sodium monensinate 80

The body weight of chickens, feed consumption and dry matter of the feed were recorded daily till the age of 22 days and thereafter in three-day intervals.

FG and SG chickens, respectively, were slaughtered in parallel at weekly intervals at the age from 35 to 126 days. Fourteen birds were taken from each group.

Breast muscle and thigh muscle without skin were separated after cooling. Visible external fat was removed, intermuscular fat was left in the muscle. Skin was separated including subcutaneous fat. The tissues were weighed and dry matter, nitrogen according to Kjeldahl and total lipids after extraction with diethyl ether were determined immediately using the methods required by Decree No. 222/1996 of the Czech Ministry of Agriculture. Crude protein content was calculated using the factor 6.00 ($N \times 6$).

The regressions of determined values were calculated according to Snedecor and Cochran (1967).

To express the relationship between carcass weight, breast meat weight, thigh meat weight, dry matter, $N \times 6$ and fat retained in the meat and the body weight of the chicken a power function (Brody, 1945) was used:

$$Y = aX^b$$

where: Y = content of the component in body weight in g

X = body weight of chicken in g

a = extrapolation of Y for $X = 1$

b = allometric coefficient, ratio of percentual change in Y to the corresponding percentual change in X

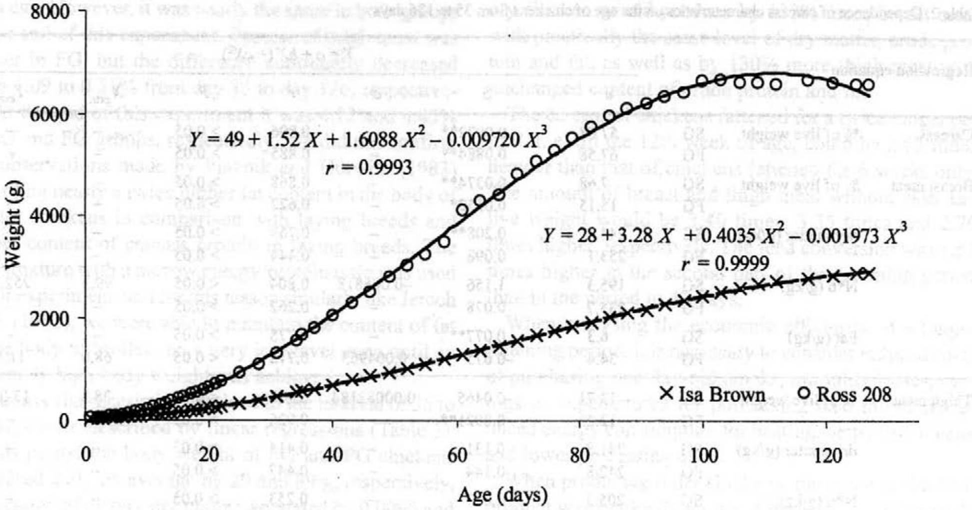

Figure 1. Body weight of chickens

RESULTS AND DISCUSSION

The dependence of body weight in grams (Y_{SG} – slow-growing Isa Brown and Y_{FG} – fast-growing Ross 208) on the age of chickens in days (X) from hatching to day 126 was expressed by the 3rd degree parabolas (Figure 1) with inflection points on day 69 (1503 g) and day 56 (3397 g), respectively. The dependence of dietary dry matter consumption from hatching per unit of weight gain on the age of chickens was described by the equations

$$Y_{SG} = 1.19 + 0.0257\,X - 0.00006862\,X^2$$
$$r = 0.680;\ P < 0.01$$

$$Y_{FG} = 0.83 + 0.0211\,X - 0.00007921\,X^2$$
$$r = 0.959;\ P < 0.01$$

SG and FG chickens were raised under identical environmental and dietary conditions. Similarly like in experiments by Plavnik and Hurwitz (1983) and Shires *et al.* (1987), the broiler chickens were about three times heavier than the laying-type chickens at 10 weeks of age (4 712 and 1 549 g, respectively).

When evaluating the period from 5 to 18 weeks of age (Table 2), carcass percentage in live weight increased significantly ($P < 0.01$) with age by 0.09% per day in both hybrids. Carcass percentage of FG chickens was higher by 10.0–10.4% than that of SG. The proportion of the most valuable breast meat in live weight of SG and FG groups increased linearly by 0.037% ($P < 0.01$) and 0.055% ($P < 0.05$), respectively; higher values were found in FG group. The difference between SG and FG increased from 8.1 to 9.7% in the period from day 35 to day 126, respectively. In FG group, the thigh meat proportion increased linearly by 0.092% ($P < 0.01$) per day while in SG a highly significant increase in thigh meat yield was expressed much better ($P < 0.05$) by the ascending branch of the convex 2nd degree parabola. In FG group, the thigh meat proportion was higher by 2.4 to 4.4% than that of SG. Changes in the percentage of carcass and breast meat in the live weight of chickens were similar to those recorded by Jeroch *et al.* (1983), Sailer and Seemann (1988), Zelenka *et al.* (1989) and Skřivan and Tůmová (1990). However, the nonexistence of the dependence of thigh meat proportion observed by Jeroch *et al.* (1983) and Zelenka *et al.* (1989) was not confirmed. It follows from these data that chickens fattened to higher age are much better for processors.

In breast meat of SG group, the content of dry matter and fat increased linearly and highly significantly during the whole experimental period. The content of crude protein increased only till the age of 100 days. Dry matter and crude protein (N × 6) contents in FG chickens did not change significantly ($P > 0.05$) with age. The content of N × 6 was practically the same in both hybrid combinations. In FG chickens, the dependence of fat content on age was parabolic with the minimum in the 10th week of age. Fat content in FG group was higher by 76% than in SG group (measured values were 2.81 and 1.60% in FG and SG groups, respectively) at the end of this experiment.

The contents of dry matter and fat in thigh meat in SG and FG did not change ($P > 0.05$) with increasing age. The content of nitrogen in thigh meat in SG group was constant while in FG it increased significantly ($P < 0.01$)

Table 2. Dependence of carcass characteristics on the age of chickens from 35 to 126 days

Regression equation			$Y = a + bX (+ cX^2)$						
			a	b	c	r	P	$X_{extr.}$	$Y_{extr.}$
Carcass	% of live weight	SG	57.08	0.0922**	–	0.896	> 0.05	–	–
		FG	67.58	0.0884**	–	0.885	> 0.05	–	–
Breast meat	% of live weight	SG	7.68	0.0374**	–	0.868	> 0.05	–	–
		FG	15.15	0.0552*	–	0.622	> 0.05	–	–
	dry matter (g/kg)	SG	244.4	0.208**	–	0.769	> 0.05	–	–
		FG	253.1	0.098	–	0.444	> 0.05	–	–
	N*6 (g/kg)	SG	195.3	1.156	–0.005818	0.804	< 0.05	99.3	252.7
		FG	235.7	0.078	–	0.262	> 0.05	–	–
	Fat (g/kg)	SG	6.3	0.077**	–	0.775	> 0.05	–	–
		FG	34.4	–0.675	0.004963	0.712	< 0.05	68.0	11.5
Thigh meat	% of live weight	SG	13.71	–0.0465	0.00082184	0.969	< 0.05	28.3	13.05
		FG	12.23	0.0921**	–	0.926	> 0.05	–	–
	dry matter (g/kg)	SG	241.8	0.131	–	0.414	> 0.05	–	–
		FG	242.8	0.144	–	0.447	> 0.05	–	–
	N*6 (g/kg)	SG	205.3	0.067	–	0.253	> 0.05	–	–
		FG	188.8	0.201**	–	0.760	> 0.05	–	–
	Fat (g/kg)	SG	30.6	0.084	–	0.380	> 0.05	–	–
		FG	44.5	–0.002	–	0.006	> 0.05	–	–

X – age in days; r – correlation coefficients; a, b, c – parameters of equation; P – significance of the deviation from linearity
Significance of linear regression $^*P < 0.05$; $^{**}P < 0.01$

Table 3. Dependence of carcass characteristics on the age of chickens from 35 to 84 days

Regression equation			$Y = a + bX$		
			a	b	r
Live weight (g)		SG	–480	29.0**	1.000
		FG	–1 551	89.5**	0.998
Feed conversion ratio		SG	1.88	0.0095**	0.979
		FG	1.16	0.0098**	0.962
Carcass	% of live weight	SG	59.20	0.0536	0.522
		FG	66.29	0.1085**	0.835
Breast meat	% of live weight	SG	7.21	0.0449*	0.756
		FG	12.39	0.1038*	0.757
	dry matter (g/kg)	SG	243.3	0.223	0.665
		FG	261.6	–0.055	0.173
	N*6 (g/kg)	SG	217.3	0.414	0.665
		FG	230.5	0.170	0.279
	Fat (g/kg)	SG	7.0	0.067	0.578
		FG	18.6	–0.098	0.315
Thigh meat	% of live weight	SG	11.51	0.0418*	0.751
		FG	12.13	0.0917**	0.840
	dry matter (g/kg)	SG	252.3	–0.070	0.124
		FG	259.0	–0.156	0.401
	N*6 (g/kg)	SG	208.1	0.0070	0.014
		FG	188.6	0.213	0.663
	Fat (g/kg)	SG	37.3	–0.0441	0.141
		FG	57.4	–0.248	0.482

X – age in days; a, b – parameters of equation; r – correlation coefficients
Significance of linear regression $^*P < 0.05$; $^{**}P < 0.01$

with age. However, it was nearly the same in both groups at the end of this experiment. Fatness of thigh meat was higher in FG, but the difference continually decreased from 1.09 to 0.31% from day 35 to day 126, respectively. At the end of this experiment it was 4.12 and 4.43% in SG and FG groups, respectively. We did not confirm the observations made by Plavnik and Hurwitz (1983) regarding nearly a twice higher fat content in the body of broiler chickens in comparison with laying breeds and higher content of carcass protein in laying breeds. The feed mixture with a narrow energy/protein ratio was used in our experiment, and for this reason similarly like Jeroch *et al.* (1983), we were able to maintain the content of fat in the body of broilers on a very low level even until an extremely high body weight was achieved.

Carcass characteristics obtained in the interval of 35 to 84 days were described by linear regressions (Table 3). In this period the body weight of SG and FG chickens increased daily on average by 29 and 89 g, respectively, conversion of dietary dry matter worsened by 0.0095 and 0.0098, carcass yield increased by 0.0536 and 0.1085%, percentage of breast meat without skin in live weight increased by 0.0449 and 0.1038% and percentage of thigh meat without skin increased by 0.0418 and 0.0917%, respectively. The deviation from linearity was not significant ($P > 0.05$).

A survey of weekly changes in basic production parameters of broiler chickens is presented in Table 4. For the time being, chickens are usually fed till the age of 42 days. In our experiment, the average body weight of cockerels at this age was 2 207 g. If we want to double the body weight of chickens, it is necessary to prolong the fattening period till the age of 67 days. In the last 25 days of fattening, the feed conversion would be 1.980, i.e. by 26% worse than in the first 42 days of fattening, and every chicken would produce by 133% more breast meat with practically the same level of dry matter, crude protein and fat, as well as by 130% more thigh meat with unchanged content of crude protein and fat.

The carcass of chickens fattened for a twice longer period, i. e. till the 12th week of age, could be 2.88 times heavier than that of chickens fattened for 6 weeks only. The amount of breast and thigh meat without skin and live weight would be 3.40 times, 3.35 times and 2.70 times higher, respectively. The feed conversion was 1.52 times higher in the second part of the fattening period than in the period to 42 days.

When analysing the economic efficiency of a longer fattening period, it is necessary to consider reduced costs of purchasing one-day-old chicks, mortality losses, savings of expenditures for purchasing feed mixtures, reduced energy consumption for heating, better use of halls and lower processing costs.

When producing older chickens, the value of the final product was markedly higher. Allometric coefficients *b*, which expressed the relationship between carcass weight, breast meat weight, thigh meat weight, dry matter, N × 6 and fat retained in meat on the one hand and live weight of chicken on the other hand are presented in Table 5. The weight of breast meat, thigh meat and the amount of protein in breast and thigh meat in SG chickens increased by 18, 13, 26 and 14% and in FG group by 25, 20, 28 and 24% faster than their body weight. The increase in the fat content in breast meat of SG and FG groups was lower by 30 and 16%, respectively, than the growth rate of chickens. The relative increase in fat content in thigh meat was higher by 9% in SG group while in FG chickens it was lower by 8% that the relative growth rates of chickens.

Table 4. Basic production parameters of chickens fattened to different age

Age of chickens in days	Live weight of chickens (g)	Feed conversion from hatching in dry matter	Feed conversion from 43rd day in dry matter	Carcass (g)	Breast meat (g)	Thigh meat (g)	Carcass % of live weight	Breast meat % of live weight	Thigh meat % of live weight
35	1 581	1.499	–	1 108	253	243	70.09	16.02	15.34
42	2 207	1.568	–	1 564	370	353	70.84	16.75	15.98
49	2 833	1.637	1.838	2 029	495	471	71.60	17.47	16.62
56	3 460	1.705	1.877	2 504	630	597	72.36	18.2	17.27
63	4 086	1.774	1.956	2 988	773	732	73.12	18.93	17.91
67	**4 444**	**1.813**	**1.980**	**3 269**	**860**	**812**	**73.56**	**19.34**	**18.27**
70	4 712	1.842	2.068	3 482	926	874	73.88	19.66	18.55
77	5 339	1.911	2.222	3 985	1 088	1 025	74.64	20.38	19.19
84	5 965	1.980	2.389	4 498	1 259	1 183	75.40	21.11	19.83

Table 5. Coefficients *b* and indexes of correlation of allometric power functions from 35 to 84 days of age

Allometric function			$Y = aX^b$		
			b	I_{YX}	*F*-value
Carcass	weight (g)	SG	1.029	0.999	2482**
		FG	1.058	0.999	3836**
Breast meat	weight (g)	SG	1.178	0.991	312**
		FG	1.246	0.982	161**
	dry matter weight (g)	SG	1.215	0.993	439**
		FG	1.241	0.986	208**
	N × 6 weight (g)	SG	1.261	0.994	481**
		FG	1.279	0.976	119**
	fat weight (g)	SG	0.696	0.634	4
		FG	0.843	0.703	6
Thigh meat	weight (g)	SG	1.128	0.993	444**
		FG	1.199	0.991	322**
	dry matter weight (g)	SG	1.125	0.984	182**
		FG	1.162	0.988	249**
	N × 6 weight (g)	SG	1.137	0.988	236**
		FG	1.243	0.992	349**
	fat weight (g)	SG	1.087	0.862	17**
		FG	0.924	0.843	15**

X – age in days; *b* – parameter of equation; I_{YX} – index of correlation
Significance of I_{YX} ** $P < 0.01$

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The effect of dry matter content on the energy value of silages and organic matter digestibility

Vplyv rôzneho obsahu sušiny na energetickú hodnotu siláži a stráviteľnosť organickej hmoty

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ABSTRACT: Silages (n = 193) were examined for nutrient contents with special attention paid to crude fibre, NDF and ADF and the respective derived parameters of nutritive value; the results were summarized in overviews. The values of the whole fibrous component were shown to be variable. The following parameters were determined in samples of clover silages: crude fibre (min. 197, max. 416 g/kg DM), NDF (292 vs. 632 g/kg DM) and ADF (297 vs. 593 g/kg DM). The following minimum and maximum values of the investigated parameters were determined for grass silages: crude fibre 251 vs. 387 g/kg DM, NDF 422 vs. 648 g/kg DM and ADF 270 vs. 422 g/kg DM. In maize silages the contents of crude fibre, NDF and ADF amounted to 192 vs. 340, 373 vs. 642 and 216 vs. 371 g/kg, respectively. The mean value of the effective degradability of organic matter (EDg OM) in clover silages (n = 23) was 52% (35–55%) whereas in maize silages (n = 11) and sugar-beet top silages (n = 4) it was 64% (45.9–78.1%) and 80% (78–84%), respectively. The *in vitro* digestibility of OM in maize silages ranged from 52.4% (43.5 to 62.60) to 71.3% (62.6–76.2%). The increase in the content of crude fibre was followed by a decrease in OM degradability and digestibility. The proportions of NDF and ADF can be used as indicators of NEL as well as of OM digestibility under specific conditions. Fodder should be of standard quality, DM and other nutrient contents, i. e. the variability of the initial material, should also be taken into account. The following relations were valid for lucerne silages containing 40.1–50% DM: NEL (MJ/kg DM) = 5.982 – 0.003 ADF (g/kg DM), r^2 = 0.774; NEL (MJ/kg DM) = 5.776 – 0.002 NDF (g/kg DM), r^2 = 0.744. Whereas for grass silages containing 30.1–35% DM the relations were as follows: NEL (MJ/kg DM) = 7.674 – 0.006 ADF (g/kg DM), r^2 = 0.870; NEL (MJ/kg DM) = 6.985 – 0.003 NDF (g/kg DM), r^2 = 0.926.

Keywords: clover silage; lucerne silage; maize silage; oat silage; sugar-beet top silage; clover-grass silage; dry matter; crude fibre; NDF; ADF; NEL; NEV

ABSTRAKT: Urobili sme analýzy siláží (n = 193) a spracovali prehľad výsledkov obsahu živín s dôrazom na hrubú vlákninu, NDV a ADV a z nich odvodených ukazovateľov výživnej hodnoty. Výsledky vykazujú variabilné hodnoty celej vlákninovej zložky. Vo vzorkách siláží ďatelinovín sa obsah hrubej vlákniny pohyboval od 197 do 416 g/kg sušiny, NDV od 292 do 632 g/kg sušiny, ADV od 297 od 593 g/kg sušiny. V silážach tráv bol obsah hrubej vlákniny 251–387 g/kg sušiny, NDV 422–648 g/kg sušiny, ADV 270–422 g/kg sušiny. Vo vzorkách siláží kukurice sa obsah hrubej vlákniny pohyboval od 192 do 340 g/kg sušiny, NDV od 373 do 642 g/kg sušiny a ADV od 216 do 371 g/kg sušiny. Priemerná hodnota efektívnej degradovateľnosti organickej hmoty (EDg OH) v silážach ďatelinovín (n = 23) bola 52 % (35–55 %), v kukuričných silážach (n = 11) 64,0 % (45,9–78,1 %), a v silážach cukrovarských skrojkov (n = 4) 80 % (78–84 %). Stráviteľnosť OH in vitro v kukuričných silážach (n = 23) bola 52,4 % (43,5–62,6 %), v silážach cukrovarských skrojkov (n = 12) 71,3 % (62,6–76,2 %). Zvyšovanie obsahu hrubej vlákniny sa prejavilo znižovaním degradovateľnosti a stráviteľnosti OH. Podiel NDV a ADV môže byť použitý ako ukazovateľ na výpočet obsahu energie (NEL), resp. stráviteľnosti OH iba za určitých podmienok. Dôležité je zohľadnenie sušiny. Pre siláže lucernové s obsahom 40,1–50 % sušiny platil vzťah: NEL (MJ/kg sušiny) = 5,982 – 0,003 ADV (g/kg sušiny) r^2 = 0,774; NEL (MJ/kg sušiny) = 5,776 – 0,002 NDV (g/kg sušiny) r^2 = 0,744. Pre siláž trávnu s obsahom 30,1–35 % sušiny: NEL (MJ/kg sušiny) = 7,674 – 0,006 ADV (g/kg sušiny), r^2 = 0,870; NEL (MJ/kg sušiny) = 6,985 – 0,003 NDV (g/kg sušiny), r^2 = 0,926.

Kľúčové slová: ďatelinová siláž; lucernová siláž; kukuričná siláž; ovsená siláž; siláž repných skrojkov; ďatelinovo-trávna siláž; sušina; vláknina; NDV; ADV; NEL; NEV

INTRODUCTION

In dependence on climatic conditions and crop-production traditions of the countries more than 56% of feeds are preserved in the form of silages. In countries with intensive animal production and high milk yields in cattle herds silages account for more than 65–95% of the total production of preserved feeds. In Slovakia more than 60% of feeds are fermented. The level of cattle production is closely connected with the quality of produced feeds. Dietary fibre content, composition of the fibrous component, proportion, surplus or shortage of fibre in feed rations influence the consumption and utilization of feeds and nutrients. Analytical values and their relations to other indicators of nutritive value have been scarce in original scientific papers until now (Kirchgessner *et al.*, 1977; Reeves, 1987; Kirchgessner, 1987; Kirchgessner and Kellner, 1981; Givens *et al.*, 1990; Moss and Givens, 1990; Morand-Fehr *et al.*, 1993; Pesti and Miller, 1993, Wagener *et al.*, 1993). In extreme cases the correlations derived from the above data range between zero and 1 and are influenced by the number of feeds examined as well as other specific factors, often also by the analytical methods employed (Schneider and Flachowsky, 1991). In Slovakia, Regulation No. 1497/4/1997 of the Ministry of Agriculture and its Table Appendix "Nutrient and nutritive value requirements for feeds for cattle, sheep and goats" contain only basic data on the crude fibre content in feeds (Sommer *et al.*, 1994). The NRC (1990) and INRA(1987, 1999) standards comprise also other indicators of feed quality (fibre components) that are not available for feeds under the climatic and soil conditions of this country. In order to be compatible with the systems used in the EU supplementation of these components is needed. At the same time our standards need to be updated in order to comply with the practical requirements of users as well as scientific and control institutions.

The aim of this work was to determine nutrient contents in silages prepared from clover, lucerne, grasses, maize, oats, sugar beet tops and mixtures with special attention to fibre content (ADF, NDF) and the effects on nutritive value, degradability and digestibility.

MATERIAL AND METHODS

Data were obtained from the analyses of clover, lucerne, grass, maize, oats, sugar beet top and mixed silages carried out at a chemical laboratory of the Institute of Animal Nutrition, Research Institute of Animal Production in Nitra in 1990–1998 (total: 193 samples). Weender analysis was used to determine the content of dry matter, crude protein, fat, ash and crude fibre whereas neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to van Soest (Lutonská and Pichl, 1983) using the Fibertec equipment by Tecator. Organic matter degradability (EDg OM) was determined in the rumen of 3 young bulls of the Black-Pied breed with a rumen fistula (internal diameter 80 mm). The animals (live weight 350–400 kg) were fed a ration composed of maize silage, lucerne hay and crushed grain. The tested feeds were weighed into 9 × 15cm bags (Uhelon 120T) and incubated for 6, 9, 12, 24, 48 and 72 hours. The parameters of effective degradability were calculated according to Ørskov and McDonald (1979). The *in vitro* digestibility of OM (DOM *in vitro*) was determined by the enzyme method (cellulase-pepsin). The silages were classified into groups on the basis of DM content with a difference of 5%. The nutritive value was calculated from the data on nutrient contents in the feeds under examination (Sommer *et al.*, 1994). The nutrient contents of silages were evaluated in relation to DM contents. In addition to the basic variation indices regression analysis was used to determine the relationship between NEL and ADF, NEL and NDF, ADF and NDF and between the *in vitro* digestibility of OM and NDF. The statistical data were PC-processed using the MS Excel for Windows 95 programme.

RESULTS AND DISCUSSION

The results of chemical analyses of silage samples are given in Tables 1–4 showing the whole fibre component to assume different values. Crude fibre contents in lucerne silages reached a minimum and maximum of 197 and 416 g/kg DM, respectively, whereas the respective values of NDF and ADF were 292 vs. 632 and 292 vs. 593 g/kg DM. DM contents ranged from a minimum of 151 g/kg to a maximum of 734 g/kg. The DM contents were proved to be unfavourable in 22% of the 42 samples under examination (< 200 and > 501 g/kg). Increasing DM contents were not accompanied by a proportional increase in crude fibre, NDF and ADF contents. Maximum NDF and ADF contents were observed in lucerne silages containing 25.1–30% DM (410–551 and 358 to 510 g/kg, respectively) and in withered lucerne silage containing more than 50% DM (410–632 and 370–593 g/kg, respectively). According to Škultéty *et al.* (2000) it is mainly the delayed harvest of lucerne with a high average content of crude fibre (337–412 g/kg DM) that decreases the quality of lucerne silages. In Austria, Gruber and Wiedner (1994) studied a larger set of feeds. In lucerne silages containing 37% DM fibre contents approached 283 g/kg DM, which was almost identical with our results. In comparison with the formerly valid Czechoslovak Standard ČSN 46 7093, lucerne silages containing 20.1–25% DM displayed a crude fibre content that was lower by 5% (327 g/kg DM). In comparison with the data for 22% DM content given in the Table Appendix by Sommer *et al.* (1994) the crude fibre content also

Table 1. Nutrient contents (per kg DM) of silages – clover crops

Denomination		Original DM (g)	NL (g)	Fibre (g)	ADF (g)	NDF (G)	Fat (g)	Ash (g)	NEL (MJ)	NEV (MJ)	PDIE (g)	PDIN (g)
Red clover	x	231	165	285	357	403	40	97	4.71	4.33	73	104
less than 30% DM	s	27.5	3.9	11.0	10.5	13.2	2.4	7.7	0.14	0.14	0.5	2.5
$n = 3$	min.	192	160	270	346	388	37	87	4.58	4.18	72	101
	max.	253	170	296	371	420	42	105	4.87	4.51	73	107
Withered red clover	x	518	169	283	374	414	31	106	5.21	4.96	77	106
more than 50% DM	s	3.2	3.5	3.3	5.3	1.2	0.9	2.5	0.00	0.01	0.6	2.2
$n = 2$	min.	514	165	280	369	413	31	103	5.21	4.95	77	104
	max.	521	172	286	379	415	32	108	5.21	4.96	78	108
Lucerne	x	179	197	279	367	404	39	141	5.19	4.98	74	122
less than 20% DM	s	16.2	21.2	51.2	39.9	77.6	5.1	27.1	0.28	0.39	10.3	13.4
$n = 6$	min.	151	166	197	297	292	31	106	4.75	4.37	58	105
	max.	197	223	359	411	513	45	184	5.65	5.64	85	140
Lucerne	x	222	172	327	388	420	39	131	4.88	4.58	73	107
20.1–25% DM	s	10.7	20.0	22.4	24.4	19.6	5.4	24.3	0.15	0.18	3.2	11.4
$n = 9$	min.	211	154	291	360	390	26	112	4.69	4.33	65	97
	max.	246	216	366	441	464	45	181	5.17	4.91	76	132
Lucerne	x	271	184	351	427	466	31	106	4.74	4.37	72	112
25.1–30% DM	s	16.0	27.2	44.6	51.7	53.0	4.4	25.3	0.19	0.23	7.2	16.6
$n = 8$	min.	252	131	273	358	410	24	54	4.48	4.04	63	80
	max.	297	224	416	510	551	36	135	5.07	4.77	87	137
Lucerne	x	318	213	324	407	433	31	112	4.91	4.56	75	130
30.1–35% DM	s	9.7	14.0	19.1	17.6	15.8	4.7	14.2	0.17	0.22	4.0	84.3
$n = 4$	min.	305	193	304	391	407	26	92	4.73	4.33	70	118
	max.	331	232	355	437	450	38	132	5.09	4.81	80	141
Withered lucerne	x	383	221	289	346	369	32	127	4.86	4.52	79	138
35.1–40% DM	s	10.2	25.6	41.6	42.3	49.7	1.5	27.4	0.17	0.20	4.5	16.9
$n = 5$	min.	366	183	233	292	309	31	90	4.72	4.33	74	115
	max.	393	250	343	401	441	34	159	5.13	4.88	84	158
Withered lucerne	x	449	182	345	400	444	27	113	4.78	4.44	74	111
40.1–50% DM	s	29.0	25.9	38.2	48.6	57.1	2.6	17.5	0.15	0.20	4.9	15.3
$n = 10$	min.	411	145	295	347	376	22	92	4.52	4.09	66	89
	max.	494	231	392	505	546	30	144	4.98	4.69	82	135
Withered lucerne	x	574	173	337	438	491	23	98	4.78	4.41	74	105
more than 50% DM	s	93.9	21.0	45.7	90.5	87.1	4.0	14.3	0.16	0.20	4.0	12.7
$n = 4$	min.	506	150	297	370	410	18	79	4.60	4.15	67	91
	max.	734	197	413	593	632	29	113	5.03	4.71	77	120

decreased by 2%. When compared with the DLG-standard (DLG, Germany, 1997), the crude fibre contents matched the standards for lucerne silages from the first harvest in the middle or at the end of bud stage (342 g/kg DM), which was less by 4%. Biro and Juráček (1999) observed the effects of chemical and biological additives on the fermentation process and composition of crude fibre in lucerne silages. In untreated silages containing 34% DM crude fibre, NDF and ADF contents approached 363, 473 and 435 g/kg DM, respectively, whereas in silages containing 52% crude fibre the respective values were 346, 454 and 409 g/kg DM.

The DM contents in grass silages ranged from a minimum of 124 g/kg to a maximum of 508 g/kg. Of the 41

Table 2. Nutrient contents (per kg DM) in silages – grass

Denomination		Original DM (g)	NL (g)	Fibre (g)	ADF (g)	NDF (G)	Fat (g)	Ash (g)	NEL (MJ)	NEV (MJ)	PDIE (g)	PDIN (g)
Grass silage	*x*	162	152	308	360	483	47	133	5.67	5.58	80	91
less than 20% DM	s	23.2	23.2	31.4	35.4	48.7	6.3	24.9	0.21	0.27	5.2	13.9
n = 20	min.	124	127	251	270	422	40	82	5.19	5.02	72	76
	max.	200	231	384	400	604	59	163	6.14	6.16	97	139
Grass silage	*x*	220	176	363	395	599	46	83	5.48	5.24	84	106
20.1–25% DM	s	7.2	5.2	16.4	11.6	10.5	7.4	2.3	0.11	0.14	1.4	3.1
n = 7	min.	209	168	326	387	582	40	78	5.43	5.18	82	101
	max.	231	186	377	415	609	63	86	5.76	5.59	87	112
Grass silage	*x*	283	176	378	399	561	46	86	5.40	5.15	77	105
25.1–30% DM	s	2.0	7.6	4.3	1.5	55.7	8.0	10.0	0.04	0.04	9.4	3.4
n = 3	min.	280	166	372	397	505	36	78	5.34	5.09	63	100
	max.	284	185	382	400	616	56	100	5.43	5.18	84	108
Grass silage	*x*	314	174	349	378	574	39	93	5.51	5.30	83	105
30.1–35% DM	s	12.3	4.0	45.0	29.1	67.0	2.4	26	0.16	0.25	2.0	2.6
n = 5	min.	301	169	259	329	459	36	78	5.43	5.17	79	101
	max.	329	180	373	405	621	42	145	5.83	5.79	85	108
Grass												
35.1–40% DM	*n* = 1	364	110	348	374	544	37	93	5.91	5.83	72	66
Withered grass silage	*x*	443	115	355	376	552	29	86	4.89	4.56	68	70
40.1–50% DM	s	40.8	21.2	40.5	45.5	68.2	2.7	7.6	0.27	0.33	3.6	13.0
n = 5	min.	404	82	275	306	457	24	76	4.50	4.08	64	50
	max.	508	147	387	422	648	32	96	5.32	5.10	75	89

samples under observation as much as 49% contained unfavourable DM contents (< 20%). In these silages a high variability of the whole fibrous component was also recorded. Depending on the DM content crude fibre, NDF and ADF contents were determined in intervals of 251 to 387, 422–648 and 270–422 g/kg DM. In a set of 1638 herbage silages with grass predominating, Gruber and Wiedner (1994) reported an average DM content of 35.5% and crude fibre content of 292 g/kg DM; these values are lower by 16% when compared to our values determined in silages with comparable DM content. Gallo (1999) stated as much as 87% of grass silage samples in Slovakia to contain more than 26% fibre, this value being very high from the viewpoint of cattle nutrition; he also documented a very late start of harvest. When confronted with formerly valid Czechoslovak Standard ČSN 46 7093, Table Appendix by Sommer *et al.* (1994) and DLG-standard (1986), crude fibre contents in grass silages containing 35% DM (373 g/kg DM) were increased by 5, 20 and even 27%, respectively. According to the newly proposed system of silage quality evaluation (Škultéty, 1998), silages made of fodder crops in which fermentation is medium or very difficult can be classified as 1st, 2nd and 3rd quality silages if they contain < 270, < 290 and < 350 g/kg crude fibre, respectively; the remaining silages (those containing more than 351 g of crude fibre per kg) are classified as 4th (bad) quality. On the basis of this evaluation and according to the crude fibre contents the silages analyzed in our work were of lower quality. According to Weddell (1999) NDF values in grass silages ranged from 300–700 g/kg DM. Hanada *et al.* (1999) reported untreated grass silage with 23% DM to contain 384 g ADF/kg DM; this value was by 3% lower than that recorded in our trial.

With regard to its chemical composition, mainly the high content of fermentable sugar, maize is ideal for silage production irrespective of the dry matter content. This is also confirmed by the range between minimum and maximum DM content (140 and 422 g/kg, respectively). Maximum and minimum crude fibre contents (236–327 and 192–281 g/kg DM, respectively) were determined in silages containing 20% and 35.1–40% DM, respectively, however, only two samples of the latter were examined. In Austria, Gruber and Wiedner (1994) reported silages with a DM content of 30% to have a lower average fibre content (228 g/kg DM). The crude fibre

Table 3. Nutrient contents (per kg DM) in silages – maize (grains)

Denomination		Original DM (g)	NL (g)	Fibre (g)	ADF (g)	NDF (G)	Fat (g)	Ash (g)	NEL (MJ)	NEV (MJ)	PDIE (g)	PDIN (g)
Maize silage	*x*	177	93	294	316	565	29	75	5,83	5,73	58	57
less than 20% DM	s	21.7	27.6	35.5	55.5	51.5	3.2	16.0	0.19	0.22	7.1	17.2
n = 7	min.	140	71	236	260	513	24	44	5.67	5.54	50	44
	max.	199	159	328	371	616	33	95	6.27	6.23	67	98
Maize silage	*x*	227	97	271	302	543	33	64	5.89	5.78	61	60
20.1–25% DM	s	11.8	21.9	23.7	17.7	47.2	3.5	25.4	0.12	0.17	4.5	13.5
n = 17	min.	202	56	228	252	430	25	23	5.68	5.50	54	34
	max.	243	151	340	335	621	41	127	6.08	6.11	72	93
Maize silage	*x*	275	87	262	301	552	32	54	5.97	5.88	65	56
25.1–30% DM	s	12.8	18.6	19.2	27.4	60.0	4.2	8.6	0.37	0.46	4.8	12.7
n = 18	min.	254	64	233	248	439	27	39	4.67	4.25	51	40
	max.	292	135	304	344	642	42	72	6.53	6.56	71	84
Maize silage	*x*	329	80	235	265	508	33	50	6.27	6.25	69	49
30.1–35% DM	s	11.7	6.3	19.3	32.9	43.3	4.1	6.4	0.11	0.14	1.8	4.1
n = 6	min.	311	70	203	216	456	29	40	6.07	6.00	68	42
	max.	346	89	264	308	573	41	59	6.37	6.38	73	55
Withered maize silage	*x*	370	72	246	274	493	33	46	6.13	6.06	65	44
35.1–40% DM	s	16.1	12.7	29.9	18.6	62.9	3.9	5.3	0.26	0.32	3.4	7.7
n = 7	min.	351	55	192	250	373	28	36	5.74	5.57	59	34
	max.	393	84	281	297	553	40	54	6.42	6.43	70	52
Withered maize silage	*x*	416	87	207	242	397	33	43	6.23	6.18	70	53
40.1–50% DM	s	6.0	6.5	9.3	0.0	14.5	2.1	3.6	0.19	0.23	0.2	4.2
n = 2	min.	410	80	197	242	382	31	39	6.04	5.94	69	49
	max.	422	93	216	242	411	35	46	6.41	6.41	70	57
Oats	*x*	323	104	352	394	582	39	76	4.83	4.47	65	64
30.1–35% DM	s	8.8	10.9	25.7	20.1	42.0	8.0	9.1	0.30	0.36	3.8	6.9
n = 3	min.	315	95	319	376	540	28	64	4.58	4.18	61	58
	max.	335	119	382	422	624	47	86	5.25	4.98	70	74
Withered oats	*x*	389	88	326	367	587	35	83	4.97	4.67	61	54
35.1–40% DM	s	7.1	11.8	10.3	7.5	4.6	3.7	8.7	0.41	0.50	6.1	7.3
n = 3	min.	379	71	312	359	582	30	74	4.67	4.30	54	44
	max.	396	97	337	377	593	39	95	5.56	5.37	69	60

contents in maize silages containing 25.1–30% DM approached 262 g/kg; when confronted with Czechoslovak Standard ČSN 46 7093 (274 g/kg DM), Table Appendix by Sommer *et al.* (1994) (203 g/kg DM) and DLG-standard (248–212 g/kg DM), the crude fibre content was lower by 4%, higher by 23% and higher by 5–19%, respectively. According to Škultéty (1998) 1st and 2nd class maize silages must not contain more than 260 g/kg DM; 14% of our samples complied with this requirement. Depending on the DM contents NDF and ADF contents ranged within 373–642 and 197–371 g/kg DM, respectively. Wagener *et al.* (1993) reported maize silage with 25% DM to contain 223–256 g/kg crude fibre (which is less by 9%) as well as 502–551 and 311–334 g of NDF and ADF per kg DM, respectively, which are values comparable with those obtained in our study.

In our study the high variability of the fibrous component of silages was influenced by the type of fodder, morphological and anatomical differences in plant species as well as climatic, soil, topographic and other factors. Similar conclusions were drawn by McNeil *et al.* (1984), Givens *et al.* (1990), Kirchgessner and Kellner (1981),

Table 4. Nutrient contents (per kg DM) in silages – root crops and mixtures

Denomination		Original DM (g)	NL (g)	Fibre (g)	ADF (g)	NDF (G)	Fat (g)	Ash (g)	NEL (MJ)	NEV (MJ)	PDIE (g)	PDIN (g)
Root crops												
Beet chips	$n = 1$	173	85	207	255	471	6	80	6.41	6.66	75	51
Beet tops	x	187	141	139	204	3	29	321	5.35	5.63	63	88
$n = 12$	s	19.1	12.6	17.7	11.1	0.2	1.7	88.6	0.18	0.31	4.00	8.3
	min.	162	114	108	195	2	26	123	4.82	4.99	56	70
	max.	231	166	169	226	3	32	448	5.57	6.13	69	102
Mixtures												
Clover + grass	x	285	136	323	366	532	41	113	5.62	5.49	70	83
20.1–35% DM	s	53.2	23.7	47.0	46.8	65.4	4.7	31.3	0.35	0.48	6.3	14.3
$n = 5$	min.	207	105	262	313	434	33	78	5.37	5.16	60	64
	max.	345	168	387	420	618	47	167	6.30	6.44	80	102
Clover + grass	x	519	170	356	416	478	24	94	5.31	5.06	81	104
more than 50% DM	s	12.3	33.0	37.2	41.1	61.6	2.2	7.1	0.40	0.48	7.0	19.1
$n = 5$	min.	505	129	302	379	419	20	85	4.86	4.53	70	78
	max.	538	216	413	491	589	26	105	6.02	5.92	92	131
Oats with clover	$n = 1$	327	104	323	363	564	38	77	4.88	4.53	66	64
Clover + wheat	$n = 1$	266	178	306	343	467	38	91	4.87	4.42	71	109
Oats + lucerne	$n = 1$	435	109	339	351	585	40	88	5.53	5.35	70	67
Lupine + lucerne	x	248	155	362	430	524	29	119	4.74	4.40	62	90
+ oats	s	13.0	13.5	20.5	0.5	0.0	4.0	14.5	0.08	0.09	2.7	10.5
$n = 2$	min.	235	141	341	429	524	25	104	4.66	4.31	59	80
	max.	261	168	382	430	524	33	133	4.82	4.48	64	101
Lucerne + lupine	$n = 1$	408	173	398	507	550	19	118	4.55	4.16	75	105
Barley + wheat	$n = 1$	374	110	277	288	565	28	50	5.33	5.04	69	67
Wheat + barley + rye	$n = 1$	421	115	283	278	506	28	50	5.33	5.04	70	70

Svetlanská *et al.* (1999), etc. Crude fibre, NDF and ADF contents were highly affected by the vegetation, growth and developmental stage of the harvested crops.

Depending on the DM contents of clover silages the effective degradability of organic matter (EDg OM) in the rumen of bulls ($n = 23$) showed an average value of 52% (35–55%). For maize and sugar-beet top silages ($n = 11$; $n = 4$) the respective EDg OM values amounted to 64% (46–78%) and 80% (78–84%), respectively. The high contents of crude fibre, NDF and ADF did not always become manifest in OM degradability in an identical way. The *in vitro* EDg OM of maize and sugar-beet top silages ($n = 23$; $n = 12$) was determined to be 52% (44–63%) and 71% (63–76%), respectively. An increase in crude fibre, NDF and ADF contents became manifest in the decreasing degradability and digestibility of OM. In future, this problem will have to be analyzed in greater detail and broader context using a larger set of feeds.

Regression analyses revealed negative correlations between NEL, EDg OM and DOM on the one hand and crude fibre, NDF and ADF contents on the other. Numerous irrational relations and relations with a low level of reliability (r^2) were also found. This could be influenced by the variability of the initial material, by the climatic, soil and topographic conditions as well as by numerous other factors mainly affecting bulk feeds (Kirchgessner *et al.*, 1977; Kirchgessner and Kellner, 1981; Kirchgessner, 1987; Graham, 1988; Graham *et al.*, 1988).

In lucerne silage containing 20% DM the following relations were determined (Figure 1, 2):

NEL (MJ/kg DM) = 6.964 – 0.005 ADF (g/kg DM)
$r^2 = 0.491$ ($n = 6$)

NEL (MJ/kg DM) = 6.296 – 0.003 NDV (g/kg DM)
$r^2 = 0.596$ ($n = 6$)

In lucerne silage with 25.1–30% DM:

NEL (MJ/kg DM) = 5.924 – 0.003 ADF (g/kg DM)
$r^2 = 0.593$ ($n = 8$)

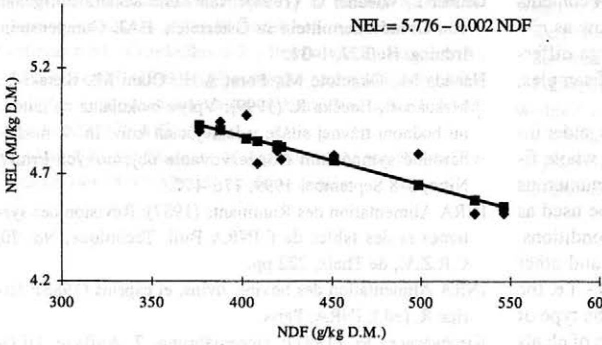

Figure 1. Regression relation between NEL and NDF in lucerne silage (40.1–50.0% DM)

NEL (MJ/kg DM) = 5.987 – 0.003 NDF (g/kg DM)
$r^2 = 0.576$ ($n = 8$)

ADF (g/kg DM) = 10.474 + 0.893 NDF (g/kg DM)
$r^2 = 0.840$ ($n = 8$)

In lucerne silage with 40.1–50% DM:

NEL (MJ/kg DM) = 5.982 – 0.003 ADF (g/kg DM)
$r^2 = 0.774$ ($n = 10$)

NEL (MJ/kg DM) = 5.776 – 0.002 NDF (g/kg DM)
$r^2 = 0.744$ ($n = 10$)

ADF (g/kg DM) = 95.329 + 0.687 NDF (g/kg DM)
$r^2 = 0.812$ ($n = 10$)

In grass silage with 25.1–30% DM:

NEL (MJ/kg DM) = 6.555 – 0.030 ADF (g/kg DM)
$r^2 = 0.750$ ($n = 3$)

NEL (MJ/kg DM) = 4.947 – 0.001 NDF (g/kg DM)
$r^2 = 0.750$ ($n = 3$)

In grass silage 30.1–35% DM:

NEL (MJ/kg DM) = 7.674 – 0.006 ADF (g/kg DM)
$r^2 = 0.870$ ($n = 5$)

NEL (MJ/kg DM) = 6.985 – 0.003 NDF (g/kg DM)
$r^2 = 0.926$ ($n = 5$)

ADF (g/kg DM) = 131.735 + 0.428 NDF (g/kg DM)
$r^2 = 0.971$ ($n = 5$)

In maize silage with less than 20% DM:

NEL (MJ/kg DM) = 7.281 – 0.005 ADF (g/kg DM)
$r^2 = 0.538$ ($n = 7$)

NEL (MJ/kg DM) = 8.627 – 0.005 NDF (g/kg DM)
$r^2 = 0.538$ ($n = 7$)

In maize silage with 30.1–35% DM:

NEL (MJ/kg DM) = 5.768 – 0.002 ADF (g/kg DM)
$r^2 = 0.308$ ($n = 6$)

NEL (MJ/kg DM) = 5.469 – 0.002 NDF (g/kg DM)
$r^2 = 0.369$ ($n = 6$)

Prediction of NEL in lucerne silage containing 20.1 to 25, 35.1–40 and more than 50% DM, in grass silage with less than 20% and with 40.1–50% DM, in oat silage, in maize silage containing 20.1–25, 25.1–30 and 35.0–40% DM but mainly NEL prediction in the whole set of silag-

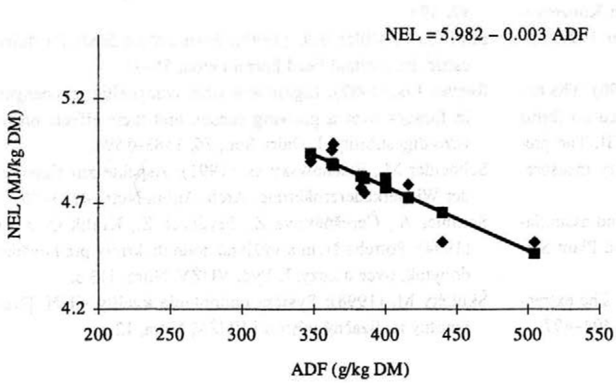

Figure 2. Regression relation between NEL and ADF in lucerne silage (40.1–50.0% DM)

es irrespective of classification according to DM contents revealed relations at a level of reliability as low as r^2 = 0.200–0.300. This could be influenced by large differences in the initial material, in the number of samples, etc.

In conclusion it can be stated that the silages under investigation displayed a high variability of the whole fibrous component; this could be influenced by numerous factors. The NDF and ADF proportions can be used as indicators to predict NEL only under specific conditions. The feeds should be of standard quality, DM and other nutrient contents have to be taken into account – i.e. the heterogenity of the initial material caused by the type of feed, morphological and anatomical specificities of plants as well as climatic, soil, topographic and other factors which mainly affect bulk feeds. NEL prediction cannot be used generally for all silages; even within one type of silage the feed needs to be of standard quality and classified according to the DM content. Based on the above data suitable combinations of feeds in cattle diet will help to optimize the fibre content. Complementation of the database on silages produced under the climatic and soil conditions of Slovakia will help to innovate the tables on nutritive values of feeds and nutrient requirements of cattle. Since it has a multifactorial effect, the given problem will have to be analyzed in future in greater detail and broader context.

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Effects of stage and number of lactation on the chemical composition of goat milk

Vliv stadia a pořadí laktace na chemické složení kozího mléka

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ABSTRACT: The aim of this research was to establish the effects of stage and number of lactation on changes in the chemical composition of goat milk (Alpine and Saanen) during five consecutive lactation periods. All animals were milked manually and kept under the same accommodation and feeding conditions. Milk analyses included determinations of the content of dry matter, solids non fat, fat, protein, lactose, ash, calcium and phosphorus. Established average minimum and maximum contents (%) were as follows: dry matter (11.15–11.90); solids non fat (7.89–8.48); fat (3.26– 3.58); protein (2.73–3.04); lactose (4.18–4.50); ash (0.792–0.802); calcium (0.110– 0.124); phosphorus (0.083–0.092). During the five lactations, significantly higher ($P < 0.01$) contents of dry matter, solids non fat, lactose, calcium and (partially) phosphorus were determined at the beginning of lactations in comparison with the middle of lactation. Significant correlations ($P < 0.001$) were established between the content of dry matter and the content of solids non fat (0.76), fat (0.77), protein (0.64) and lactose (0.46).

Keywords: goat milk; Alpine; Saanen; chemical composition; stage and number of lactation

ABSTRAKT: Cílem výzkumu bylo zjištění vlivu stadia a pořadí laktace na změny chemického složení kozího mléka (u plemene alpského a sánského) v průběhu pěti po sobě následujících laktací. Všechna zvířata jsme dojili ručně a jejich odchov probíhal za stejných podmínek ustájení a výživy. Rozbory mléka zahrnovaly stanovení obsahu sušiny, tukuprosté sušiny, tuku, N-látek, laktózy, popelovin, vápníku a fosforu. Stanovili jsme tyto minimální a maximální obsahy (%): sušina (11,15–1,90); tukuprostá sušina (7,89–8,48); tuk (3,26–3,58); N-látky (2,73–3,04); laktóza (4,18–4,50); popeloviny (0,792–0,802); kalcium (0,110–0,124); fosfor (0,083–0,092). V průběhu pěti laktací jsme na začátku laktací zaznamenali významně vyšší ($P < 0,01$) obsah sušiny, tukuprosté sušiny, laktózy, vápníku a fosforu než v polovině laktace. Mezi obsahem sušiny a obsahem tukuprosté sušiny (0,76), tuku (0,77) a laktózy (0,46) existovaly významné korelace ($P < 0,001$).

Klíčová slova: kozí mléko; alpské plemeno; sánské plemeno; chemické složení; etapa a pořadí laktace

INTRODUCTION

In recent years the traditional, extensive form of goat farming has been gradually replaced by the intensive breeding of dairy goats (Alpine and Saanen breed) imported from France and Germany. Introduction of breeding programmes and intensification of goat farming has made research into milk yield, and the composition and properties of goat milk, increasingly important. This fresh approach to goat farming also requires comprehensive research into the chemical composition of goat milk which, depending on stage of lactation, varies considerably due to a number of factors. The stages and the number of lactation are but two of those factors which are dealt with in this paper. Changes in the level of the main components of goat milk occurring during lactation were reported by (Boroš, 1986; Jančić and Antunac, 1986; Csapo *et al.*, 1986; Voutsinas *et al.*, 1990; Chornobai *et al.*, 1999; Khaled *et al.*, 1999; Soryal et *al.*, 1999).

MATERIAL AND METHODS

A research project focused on the effect of stage and number of lactation on the chemical composition of milk covered a part of the population of Alpine and Saanen goats, kept on a farm. The number of goats varied throughout the research period: 10 in I, 12 in II, 12 in III, 16 in IV and 16 in V lactation, depending upon their health condition. Average age of a goat at the beginning of the first lactation was 15 months for Alpine and 13.5 months for Saanen goats. Due to the fact that the age of animals at the start of individual lactations varied, correction was made by a non-linear function. Goats were housed in separate boxes, each 20 × 5 m in size. Each animal had 2 m^2 of floor area and about 2.5 m^2 of outlet.

All animals were kept under constant similar conditions and were provided with the same care and feed. Daily feed ration comprised roughage (meadow hay and a clover-grass mixture) with the addition of maize grain silage as well as a portion of fodder mixture with 14% protein content. Since the goats produced kids in winter months (February and March), their daily ration at the start of lactation period consisted of hay (*ad libitum*) and 700 g of fodder concentrate per animal. At the start of the vegetation cycle (April and May) the animals received a daily ration of 5–6 kg of cow-pea or common vetch. During July, August and September they were also given a clover-grass mixture. Such a composition of the diet was usual in farm's conditions and it was chosen to reduce a source of variability for the chemical composition of milk. A total of 8–10 controls of milking were carried out, depending on the duration of lactation period. On the day of the controls the animals were milked manually, and a proportional sample of milk was taken from each animal from both morning (6 a.m.) and evening (6 p.m.) milking. Milk samples were not preserved but they were kept in a refrigerator at a temperature of +4°C until the time of analyses. Total number of analyses of milk samples in the course of individual lactations depended on the number of monthly controls of milking capacity, on the number of goats and on the number of analyses designed to determine the composition: dry matter, solids non fat, fat, protein, lactose, ash, calcium and phosphorus.

Methods

The following methods were used to determine the chemical composition of milk: dry matter (%w/w) – gravimetric method, drying at 102°C, (FIL-IDF, 1987); solids non fat – calculation of the difference between total solids and fat content; fat (%w/w) – butyrometric method (Gerber) (FIL-IDF, 1981); crude protein (%w/w) – dye-binding (Amido Black), (FIL-IDF, 1985a, b). Pro-Milk apparatus was calibrated against the known sample standards. Protein percentage was obtained from a calibration curve based on the crude protein content established by the Kjeldahl method in 10 samples of goat milk. Lactose monohydrate (%w/w) – titrimetric with chloramine T, (FIL-IDF, 1974); ash (%w/w) – gravimetric method, furnace < 550°C; (AOAC, 1995), calcium (%w/w) – titrimetric, after oxalate precipitation, (FIL-IDF, 1992); phosphorus (%w/w) – spectrometric molybdenum blue, (FIL-IDF, 1990).

Statistical data processing

Processing of data on individual components of milk was based on the 2nd degree polynomial: $Y_n = \Sigma\, a_n x^n$

where: a = parameter
x = time

The estimated values of the 50th, 100th, 150th and 200th days of lactation were used to determine the effect of the number of lactation and breed on the chemical composition of milk, in accordance with the linear model (Harvey, 1975):

$$Y_{ijk} = \mu + A_i + B_j + e_{ijk}$$

where: Y_{ijk} = value of the observed characteristics
μ = mean value corrected to factors A_i and B_j
A_i = constant effect of number of lactation ($i = 1...5$)
B_j = constant effect of breed (j = 1 and 2)
e_{ijk} = unexplained effect

Significance test was conducted by F-test. Statistical values for each individual lactation were calculated on the basis of data obtained by Harvey's model. Thus, we obtained the least mean value (LSM), standard deviation (SD), standard error (SE) and coefficient of variance (CV). The analysis of variance enabled us to use F-test for checking the effect that individual factors bear on specific characteristics. In the course of five lactations coefficients of correlation between all milk components were also calculated.

RESULTS AND DISCUSSION

Average content of dry matter in goat milk for five lactation periods is presented in Table 1.

The highest content of dry matter was found in milk obtained at the end (day 200) of lactations I and II, and at the beginning (day 50) of lactations III, IV and V. In all lactation periods the lowest content of dry matter was found between days 100 and 150, which is in accordance with the results reported by (Boroš, 1986; Voutsinas *et al.*, 1990). Csapo *et al.* (1986), Chornobai *et al.* (1999), Soryal *et al.* (1999) also drew attention to the significant effect of individual stages of lactation on the content of dry matter in milk while Mba *et al.* (1975) found no significant differences.

From the middle (day 100–day 150) to the end (day 200) of lactation periods I, II and V, goat milk was found to have a significantly higher content ($P < 0.01$) of dry matter compared with lactation period IV. In lactation periods producing the highest milk yield (III and IV) the content of dry matter was lowest.

Average content of solids non fat in goat milk for five lactation periods is presented in Table 2.

An analysis of all lactation periods shows that the highest content of solids non fat was established at the beginning (day 50) of all lactation periods, with the exception of lactation I, where it occurred at the end (day 200), which corresponds to the content of dry matter. The lowest content of solids non fat during the individual lactation periods was found in the middle of each period (between days 100 and 150).

In lactation periods I, II and V, a significantly higher ($P < 0.01$) content of solids non fat in goat milk was found at the beginning (day 50), in the middle (day 100–day 150) and at the end (day 200) of the period, in comparison with lactation period IV. A significantly higher ($P < 0.01$) content of solids non fat compared with lactations III, IV and V was also established in lactation period I. Significant ($P < 0.001$) correlations were found to exist between the content of dry matter and solids non fat (0.76 to 0.77).

Average content of milk fat in goat milk for five lactation periods is presented in Table 3.

The highest average content of milk fat in lactation periods I, II and III (3.7%, 3.94% and 3.68%, respectively) was established at the end (day 200), and in periods IV and V (3.59% and 3.8% respectively) at the beginning (day 50). The lowest content of milk fat in all lactations was found in the middle of the periods (between day 100 and day 150) – (Table 3). Barbosa and Miranda (1986), Voutsinas *et al.* (1990), Mioč (1991), Chornobai *et al.* (1999), Soryal *et al.* (1999) also reported a significant effect of individual stages of lactation on the content of milk fat. The number of lactation had no significant effect ($P > 0.05$) on milk fat content in goat milk either at the beginning or in the middle of lactations although significant differences ($P < 0.05$ and $P < 0.01$) were established on day 150 and day 200. Antunac *et al.* (1999) reported that parity had a significant ($P < 0.05$) effect on fat content in milk of Alpine and Saanen goats. Milk produced in lactation periods I, II, III and V had a

Table 1. Average content of dry matter (%) in goat milk during five lactations

Lactation	I			II			III			IV			V		
(day)	*n*	LSM	SE	*n*	LSM	SE	*n*	LSM	SE	*n*	LSM	SE	*n*	LSM	SE
50	10	12.05	0.20	12	12.10	0.18	12	11.99	0.18	16	11.67	0.16	16	12.31	0.16
100	10	11.59	0.18	12	11.53	0.16	12	11.09	0.16	16	10.90	0.14	16	11.60	0.14
150	10	11.58	0.17	12	11.64	0.16	12	11.13	0.16	16	10.78	0.14	16	11.45	0.14
200	10	12.41	0.21	12	12.35	0.19	12	11.85	0.19	16	11.26	0.16	16	11.93	0.16
$\bar{x}$		11.90			11.90			11.51			11.15			11.82	

Table 2. Average content of solids non fat (%) in goat milk during five lactations

Lactation	I			II			III			IV			V		
(day)	*n*	LSM	SE	*n*	LSM	SE	*n*	LSM	SE	*n*	LSM	SE	*n*	LSM	SE
50	10	8.53	0.12	12	8.55	0.11	12	8.25	0.11	16	8.08	0.10	16	8.51	0.10
100	10	8.34	0.10	12	8.23	0.09	12	7.93	0.09	16	7.78	0.08	16	8.12	0.08
150	10	8.35	0.11	12	8.12	0.10	12	7.91	0.10	16	7.73	0.08	16	8.08	0.08
200	10	8.70	0.13	12	8.33	0.12	12	8.13	0.12	16	7.98	0.10	16	8.34	0.10
$\bar{x}$		8.48			8.31			8.05			7.89			8.26	

Table 3. Average content of milk fat (%) in goat milk during five lactations

Lactation	I			II			III			IV			V		
(day)	*n*	LSM	SE	*n*	LSM	SE	*n*	LSM	SE	*n*	LSM	SE	*n*	LSM	SE
50	10	3.57	0.14	12	3.58	0.12	12	3.60	0.12	16	3.59	0.11	16	3.80	0.11
100	10	3.26	0.13	12	3.31	0.12	12	3.23	0.12	16	3.12	0.10	16	3.49	0.10
150	10	3.12	0.12	12	3.47	0.11	12	3.26	0.11	16	3.04	0.10	16	3.36	0.10
200	10	3.70	0.14	12	3.94	0.12	12	3.68	0.12	16	3.28	0.11	16	3.58	0.11
$\bar{x}$		3.41			3.58			3.44			3.26			3.56	

significantly higher ($P < 0.01$ and $P < 0.05$) content of milk fat in comparison with lactation IV. Kala and Parkash (1990) reported a decrease in milk fat content as the number of lactation periods increases, explaining it by a negative correlation between the amount of milk and content of milk fat. Throughout all five lactation periods, milk fat content showed a significant correlation ($P < 0.001$) with dry matter content (0.77), which accords with the results arrived at by (Anifantakis and Kandarakis, 1980; Voutsinas *et al*., 1990; Chornobai *et al*., 1999).

Average protein content in goat milk for five lactation periods is presented in Table 4.

The lowest content of protein (from 2.59% in period IV to 2.86% in period I) in all lactation periods was established in the middle of every period (day 100) whereas the highest protein content was recorded at the end (day 200) of each lactation (from 2.9% in period III to 3.42% in period I). Individual stages of lactation were found to have a significant effect ($P < 0.01$) on protein content in milk (Rakes *et al*., 1981). The highest protein content in milk at the end of lactations was reported by (Voutsinas *et al*., 1990; Khaled *et al*., 1999).

According to (Voutsinas *et al*., 1990; Chornobai *et al*., 1999), significant correlations ($P < 0.001$) were established between protein content and dry matter content (0.64). We found no significant correlations between fat and protein content although they were reported by Mba *et al*. (1975) for Saanen breed, by Boichard *et al*. (1989) for Saanen and Alpine breeds, by Voutsinas *et al*. (1990) for Alpine breed, and by Zeng and Escobar (1996). The reason was the fact that the highest fat and protein content was found in different lactations. In the middle (day 150) and at the end (day 200) of lactation periods II, III, IV and V, milk had a significantly lower ($P < 0.01$) content of protein in comparison with lactation I (Table 4).

Average lactose content in goat milk for five lactation periods is presented in Table 5.

Throughout all five lactation periods the highest lactose content (from 4.38% in period IV to 4.71% in period I) was established at the beginning (day 50), with the

Table 4. Average protein content (%) in goat milk during five lactations

Lactation (day)	I			II			III			IV			V		
	n	LSM	SE	n	LSM	SE	n	LSM	SE	n	LSM	SE	n	LSM	SE
50	10	2.88	0.07	12	3.03	0.06	12	2.86	0.06	16	2.76	0.05	16	2.90	0.05
100	10	2.86	0.06	12	2.82	0.06	12	2.72	0.06	16	2.59	0.05	16	2.75	0.05
150	10	3.01	0.07	12	2.82	0.06	12	2.71	0.06	16	2.63	0.05	16	2.77	0.05
200	10	3.42	0.09	12	3.07	0.08	12	2.90	0.08	16	2.94	0.07	16	3.06	0.07
$\bar{x}$		3.04			2.94			2.80			2.73			2.87	

Table 5. Average lactose content (%) in goat milk during five lactations

Lactation (day)	I			II			III			IV			V		
	n	LSM	SE	n	LSM	SE	n	LSM	SE	n	LSM	SE	n	LSM	SE
50	10	4.71	0.05	12	4.55	0.05	12	4.55	0.05	16	4.38	0.04	16	4.62	0.04
100	10	4.58	0.06	12	4.47	0.05	12	4.39	0.05	16	4.17	0.04	16	4.39	0.04
150	10	4.40	0.05	12	4.39	0.04	12	4.31	0.04	16	4.11	0.04	16	4.32	0.04
200	10	4.30	0.05	12	4.26	0.04	12	4.24	0.04	16	4.07	0.04	16	4.28	0.04
$\bar{x}$		4.50			4.42			4.37			4.18			4.40	

Table 6. Average ash content (%) in goat milk during five lactations

Lactation (day)	I			II			III			IV			V		
	n	LSM	SE	n	LSM	SE	n	LSM	SE	n	LSM	SE	n	LSM	SE
50	10	0.764	0.012	12	0.802	0.011	12	0.792	0.011	16	0.804	0.009	16	0.810	0.04
100	10	0.754	0.009	12	0.789	0.009	12	0.786	0.009	16	0.789	0.008	16	0.790	0.04
150	10	0.784	0.010	12	0.789	0.009	12	0.797	0.009	16	0.794	0.008	16	0.790	0.04
200	10	0.866	0.013	12	0.819	0.012	12	0.830	0.012	16	0.822	0.011	16	0.819	0.04
$\bar{x}$		0.792			0.800			0.801			0.802			0.802	

Table 7. Average calcium (Ca) and phosphorus (P) content (%) in goat milk during five lactations

Lactation		I			II			III			IV			V	
(day)		n	LSM	SE	n	LSM	SE	n	LSM	SE	n	LSM	SE	n	LSM	SE
50	Ca	10	0.124	0.003	12	0.124	0.003	12	0.122	0.003	16	0.130	0.002	16	0.137	0.002
50	P	10	0.085	0.002	12	0.099	0.002	12	0.101	0.002	16	0.085	0.002	16	0.089	0.002
100	Ca	10	0.119	0.002	12	0.110	0.002	12	0.104	0.002	16	0.118	0.002	16	0.123	0.002
100	P	10	0.083	0.002	12	0.085	0.002	12	0.085	0.002	16	0.077	0.002	16	0.082	0.002
150	Ca	10	0.116	0.002	12	0.105	0.002	12	0.103	0.002	16	0.111	0.002	16	0.116	0.002
150	P	10	0.082	0.002	12	0.084	0.002	12	0.085	0.002	16	0.079	0.002	16	0.083	0.002
200	Ca	10	0.118	0.003	12	0.112	0.003	12	0.111	0.003	16	0.113	0.002	16	0.119	0.002
200	P	10	0.083	0.003	12	0.096	0.002	12	0.097	0.002	16	0.090	0.002	16	0.092	0.002
$\bar{x}$	Ca		0.119			0.113			0.110			0.118			0.124	
$\bar{x}$	P		0.083			0.091			0.092			0.083			0.087	

level decreasing (from 4.07% in period IV to 4.3% in period I) towards the end (day 200) of the lactation period. We found a significantly higher lactose content in goat milk at the beginning (day 50), in the middle (days 100 and 150) and at the end (day 200) of lactation periods I, II, III and V in comparison with period IV (Table 5).

Average ash content in goat milk for five lactation periods is presented in Table 6.

The lowest ash content (from 0.745% in period I to 0.79 in periods II, III, IV and V) during lactations was found in the middle (day 100) of the periods while the highest values (from 0.819% in periods II and V to 0.866% in period I) were established at the end (day 200). Significant differences were found to exist only between period I and the other four lactation periods (on days 50, 100 and 200) whereas differences in other lactations were not significant.

Average calcium content in goat milk for five lactation periods is presented in Table 7.

Throughout all five lactation periods the lowest content of calcium (from 0.103% in period III to 0.116% in periods I and V) was found on day 150 while the highest (from 0.13% in period IV to 0.137% in period V) was established on day 50. Significant differences ($P < 0.01$) were found to exist between lactations I and II, I and III and II and IV in the middle of lactation periods (days 100 and 150) while the difference ($P < 0.01$) between lactations II and V, III and IV and III and V manifested itself at the very beginning of lactations (day 50).

Average phosphorus content in goat milk for five lactation periods is presented in Table 7.

During the first three lactations the lowest phosphorus content (from 0.082% in period I to 0.085% in period III) was found on day 150, and the highest (from 0.085% in period I to 0.101% in period III) on day 50. In lactations IV and V the lowest phosphorus content (from 0.077% to 0.082%) was manifested on day 100, and the highest (from 0.09% in period IV to 0.092% in period V) at the end of the periods. We found significant differences between the phosphorus content in milk, but we did not observe any regular pattern during the course of lactations (Table 7). Average phosphorus content throughout the five lactation periods was 0.087% and it was identical at the start and at the end of lactations.

CONCLUSION

The stage and number of lactations were found to have a significant effect on the chemical composition of milk of Alpine and Saanen breeds of goat throughout five consecutive lactation periods. Significantly higher ($P < 0.01$) contents of dry matter, solids non fat, lactose, calcium and (partially) phosphorus were established at the beginning of lactations in comparison with the middle. The lowest contents of dry matter, solids non fat, fat, protein, ash, calcium and phosphorus in goat milk were found in the middle of lactation periods. The highest contents of protein, ash and (partially) milk fat were established at the end of lactations. In lactation periods I, II, III and V, milk had a significantly ($P < 0.01$ and $P < 0.05$) higher content of dry matter, solids non fat, milk fat and protein in comparison with lactation IV. There were also significant correlations ($P < 0.001$) between the content of dry matter and the contents of solids non fat (0.76), fat (0.77), protein (0.64) and lactose (0.46).

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