IMPACTS OF LACTATION PHYSIOLOGY AT HIGHER AND AVERAGE YIELD ON COMPOSITION, PROPERTIES AND HEALTH INDICATORS OF MILK IN HOLSTEIN BREED*

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Milk yield (MY) is the amount of milk and its quality during lactation. MY is an important economic and health factor closely connected with the health status of dairy cows, their reproduction, performance, longevity and milk composition and properties. The differences within milk indicators between high yielding herds with an average MY (H1 a H2) were tested in four herds. The files with 224 and 234 individual milk samples were collected in the summer and winter for three years. The files were balanced in factors of lactation. Group 1 had higher genetical value and had even better nutrition according to the MY. The MY was higher by 43% ($P \leq 0.001$). The studied high MY factor had statistically significant influence ($P \leq 0.05$ and $P \leq 0.001$; Table 1; Fig. 1) on the following milk parameters: fat (FAT), lactose (LAC), solids non fat (SNF), alcohol stability (AL), rennet curds firmnes (RCF), crude protein (CP), casein (CAS), true protein (TP), fat/true protein ratio (F/CP). Selected differences were: FAT (H1 3.68 ± 0.77; H2 3.99 ± 0.93%); CAS (H1 2.50 ± 0.27; H2 2.59 ± 0.29%); TP (H1 2.99 ± 0.30; H2 3.09 ± 0.33%). Other 16 milk parameters (e.g. SCC (H1 289 > 210 103.ml^{-1} H2), urine, ratio of urea nitrogen in the non protein nitrogen, acetone, pH and rennet curds firmness) were influenced insignificantly ($P > 0.05$). The differences in milk indicators between group H1 and H2 did not indicate problems of the health status. The high MY reached by the genetic improvement of animals does not result in impaired quality of raw milk. Surprisingly, MY and urine content in milk did not correlate positively in Holstein dairy cows.

milk yield; milk indicators; Holstein cattle; milk composition; milk properties; physiology of lactation

INTRODUCTION

Genetic improvement and well balanced nutrition are the main factors in improving the milk yield (MY) in dairy cattle. Decisions on many aspects of cattle keeping (breeding, feeding and milking technologies) are necessary for a good farmer strategy. Additional information about processing capacities or situation on the milk market are essential for competent decisions. These facts have paramount importance for the MY and consequently its economic efficiency. It is valid for extensive and intensive production systems. Nutrition and feeding technology may help to fully exploit the genetic potential, especially in the Holstein (H) population.

High MY is preferred because of higher milk income. MY is also under criticism for suspicion of the possible negative impact on animal health, poor reproduction performance and the propensity of cows to production disorders and reduced longevity. In general, better control of these factors in dairy herds may enhance the lactation physiology and also the composition and milk properties of high yielding cows. The resistance against secretion disorders (mastitis) or stress and other production disorders of dairy cows depends also on the above – mentioned influences of course. Decision for the effective level of MY is a part of the breeder's strategy. At the same time, it is very important to make a good estimation of a commercial advantages which is reached due to higher cows MY does not bring simultaneously negative compensations in terms of lower price of milk because of the main component decreasing. There could be also higher costs on monitoring, prevention and treatment necessary for production disorder control (Piatkowski et al., 1981; Butler et al., 1996; Ropstad, Refsdal, 1987; Říha, Hanuš, 1999a, b; Hlásný, 2001; Hanuš et al., 2001b, c).

Development in the Czech Holstein population has been described by more authors in the last time (Kvapilík, 2002; Kvapilík, Střeleček, 2003; Kvapilík et al., 2002, 2003, 2004; Kvapilík, Hanuš, 2004; Motyčka, 2004; Bucek et al., 2004). Beside population increase, MY has also been elevated markedly. However, pregnancy and longevity of dairy cows have also been worsened lucidly at the same time. That is why a study on the influences of MY increasing on dairy cows, their lactation physiology, health state and milk quality is becoming more and more important. A strategy on genetical improvement of cow longevity has been included with higher efficiency into H breeding programme (Motyčka, 2004).

The goal of this study was to assess possible effects of a high MY on milk composition, properties and health indicators in Holstein cows and also estimate possible changes in milk processability. The mentioned problems

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have been proposed to the solution in more papers (Kvapilík et al., 2002, 2003, 2004; Kvapilík, Hanuš, 2004; Motyčka, 2004). We compared the effects of lactation physiology between higher and average MY on H milk quality.

MATERIAL AND METHODS

Animals, herd and keeping conditions

During three years of experimental investigation the individual milk samples (MSs) were taken in four herds of Holstein dairy cows. Animals were selected from herds for sampling as follows: with higher MY in herd; according to typical herd profile in terms of stage and number of lactation; only clinical and strong subclinical mastitis free. In this way the animal groups represented the real herds with respect to the mentioned breeder's factors. MSs were collected regularly in summer (August, September) and winter (February, March) feeding seasons. Animals were fed with addition of the concentrates according to MY and standard demands. The feeding rations consisted of roughage according to herds: grass silage + corn silage + GPS (silage) from cereals (herd 1); lucerne silage + corn silage (herd 2); clover silage + corn silage (herd 3 and 4). Nutrition was not equal among herds. One herd was milked three times a day, the others twice a day (Remond et al. 2004; Ayadi et al. 2003). Herds were kept in altitude from 215 to 570 m above sea level.

Milk sample analyses

The analyses were performed in the accredited laboratory of the Research Institute for Cattle Breeding in Rapotín. MSs were analysed as preservation free and/or preserved (with bronopol 0.04%) after cooling transport (< 10 °C). The following milk indicators were noted and analysed: DMY = daily milk yield (kg of milk/day); FAT = fat (g/100 ml; %); LAC = lactose (monohydrate; g/100 g; %); SNF = solids non fat (g/100 g; %); SCC = somatic cell count ($103.ml^{-1}$); U = urea ($mg.100g^{-1}$); AC = acetone ($mg.l^{-1}$); pH = H ions; EC = electrical conductivity ($mS.cm^{-1}$); AL = alcohol stability (in ml); SH = titration acidity (in ml of 0.25 $mol.l^{-1}$ NaOH solution for 100 ml of milk); TEC = time for enzymatic coagulation (in seconds); RCQ = subjective estimation of the rennet curds quality (in classes); RCF = rennet curds firmness (in mm); WV = whey volume (in ml); CP = crude protein (Kjeldahl total N × 6.38; g/100 g; %); CAS = casein (Kjeldahl casein N × 6.38; g/100 g; %); TP = true protein (Kjeldahl protein N × 6.38; g/100 g; %); WP = whey protein (difference TP – CAS; g/100 g; %); NPN = non protein nitrogen matter (CP – TP nitrogen × 6.38; g/100 g; %); URN = ratio of urea nitrogen in the non protein nitrogen (%); F/CP = fat/crude protein ratio. The casein numbers on the basis of crude and true protein in % (CN-CP, CN-TP). DMY was measured using Tru-Test flow milkmeters or by the electronic milk flow meters. The main milk indicators as FAT, LAC and SNF were investigated using MilkoScan 133B (Foss Electric, Denmark). Instruments were regularly calibrated according to reference methods (ČSN 57 0536, ČSN 57 0530). The SCC was determined using the Fossomatic 90 instrument (Foss Electric, Denmark) according to the standard ČSN EN ISO 13366-3. The nitrogen protein fractions as CP, TP and CAS were determined by reference Kjeldahl's method using 2200 Kjeltec Auto Distillation apparatus (Foss-Tecator AB, Sweden; ČSN 57 0530). The urea concentration was determined using an Ureakvant instrument (specific enzymatic and conductometric method). The milk acetone was investigated by spectrophotometry at 485 nm wavelength by microdiffusion in alkaline solution with salicylaldehyde (Spekol 11, Carl Zeiss Jena, Germany). EC was measured using OK 102/1 (Radelkis, Hungary). Active acidity was measured using pH-meter CyberScan 510 (Eutech Instruments) at 20 °C. The titration acidity was determined by milk titration (ČSN 57 0530). The alcohol stability was determined by milk titration (10 ml) by the 96% ethanol to creation of the first visible flakes of precipited milk protein. At cheesemaking evaluation, TEC, RCF, RCQ and WV were measured according to internal standards: time for enzymatic coagulation from Renilase addition (microbial enzyme) to the first visible milk protein coagulation; rennet curds firmness (in mm in contrary sense to real firmness value, the more mm the poorer curds firmness); subjective estimation of rennet curds quality (from 1st = excellent to 4th = poor); volume of the whey obtained at rennet precipitation (after 1 hour coagulation).

Statistical evaluation

All animals were grouped approximately to halves in their herds according to their own lactation MY: H1 (over real group average lactation MY within herd, higher MY); H2 (below real group average lactation MY, average MY in terms of country breed MY results). H1 and H2 groups from herds were put together: H1 (animals with higher MY, from all herds; $n = 234$ MSs /animals/); H2 (animals with average MY, from all herds; $n = 224$). The effects of sampling season, herd conditions, lactation stage and lactation number were balanced in this way. Higher MY was reached by a higher level of individual genetic basis and more effective nutrition, it means higher consumption of roughage and concentrates by animals.

Milk indicator values with no normal data frequency distribution were log transformed (Ali, Shook, 1980; Hanuš et al., 1995a, b, 1999, 2001a, b, c). The basic statistical characteristics were calculated (Microsoft Excel 2003): arithmetic mean (x); geometric mean (xg); standard deviation (sd); median. Average group differences in milk indicators were investigated by t-test. Group frequency distributions of milk indicators with significant differences were demonstrated by box graphs.

RESULTS AND DISCUSSION

The average DMY in H1 was higher by 43% than in H2 and this high difference was significant ($P \leq 0.001$; Table 1 and Fig. 1, DMY). The studied high MY factor had statistically significant influence ($P \leq 0.05$ and $P \leq 0.001$; Table 1; Fig. 1) on the following milk indicators: fat, lactose, solids non fat, alcohol stability, rennet curds firmnes, crude protein, casein, true protein and fat/true protein ratio. Other 14 milk indicators as SCC (H1 289 > 210 103 ml^{-1} H2), log SCC, U, AC, log AC, pH, EC, SH, TEC, RCQ, WV, WP, UNP, URN, CN-CP and CN-TP were influenced insignificantly ($P > 0.05$; Table 1). Differences for $P \leq 0.001$ significance level were (Table 1; Fig. 1): fat content 0.31% (H1 3.68 ± 0.771; H2 3.99 ± 0.93%; 7.77% relatively, H2 is equal to 100%); CAS 0.09% (H1 2.50 ± 0.27; H2 2.59 ± 0.29%; relatively 3.47%); TP 0.10% (H1 2.99 ± 0.30; H2 3.09 ± 0.33%; 3.24%). Differences for $P \leq 0.01$ significance level were: AL 0.25 ml (H1 1.36 ± 0.84; H2 1.61 ± 1.08 ml; 15.53%); RCF 0.8 mm (H1 17.18 ± 2.90; H2 16.38 ± 3.42 mm; 4.88%); CP 0.10% (H1 3.16 ± 0.32; H2 3.26 ± 0.35%; 3.07%). Differences for $P \leq 0.05$ significance level were: LAC 0.04% (H1 5.00 ± 0.21; H2 4.96 ± 0.22%; 0.81%); SNF 0.08% (H1 8.69 ± 0.37; H2 8.77 ± 0.39%; 0.91%) and for F/CP 0.06 (H1 1.17 ± 0.25; H2 1.23 ± 0.30; 4.88%). In general, the results show lower contents of main milk components (which are important for milk processing into milk products, especially cheeses) at higher MY. It is mostly different as compared to previous

Table 1. Differences in milk chemical components, health indicators and physical and technological properties between H cows with higher (H1) and average (H2) MY

		H1		H2			
		x ± *sd*	*xg*	*x* ± *sd*	*xg*	*t*	sign.
n		234		224			
NL	–	2.38 ± 1.33		2.30 ± 1.28		0.65	ns
SL	–	149.3 ± 81.3		149.9 ± 90.4		0.08	ns
DMY	(kg/day)	32.2 ± 6.8		22.5 ± 5.5		16.73	***
FAT	(%)	3.68 ± 0.77		3.99 ± 0.93		3.88	***
LAC	(%)	5.00 ± 0.21		4.96 ± 0.22		1.96	*
SNF	(%)	8.69 ± 0.37		8.77 ± 0.39		2.25	*
SCC	(10^3.ml^{-1})	289 ± 663		210 ± 341		1.58	ns
log SCC	–	1.9517 ± 0.5931	89	1.9845 ± 0.5094	96	0.63	ns
U	(mg.$100g^{-1}$)	21.98 ± 10.33		21.94 ± 10.36		0.04	ns
AC	(mg.l^{-1})	2.95 ± 5.50		3.30 ± 4,34		0.75	ns
log AC	–	0.2344 ± 0.4664	1.72	0.3034 ± 0.4721	2.01	1.57	ns
pH	–	6.74 ± 0.11		6.74 ± 0.14		0	ns
EC	(mS.cm^{-1})	4.39 ± 0.49		4.39 ± 0.57		0	ns
AL	(ml)	1.36 ± 0.84		1.61 ± 1.08		2.77	**
SH	(ml 0.25 mol .l^{-1} NaOH)	7.27 ± 0.90		7.28 ± 1.03		0.11	ns
TEC	(second)	116.8 ± 56.5		117.6 ± 62.7		0.13	ns
RCQ	(class)	2.83 ± 0.91		2.74 ± 0.97		1.02	ns
RCF	(mm)	17.18 ± 2.90		16.38 ± 3.42		2.70	**
WV	(ml)	35.79 ± 2.90		35.16 ± 4.07		1.91	ns
CP	(%)	3.16 ± 0.32		3.26 ± 0.35		3.22	**
CAS	(%)	2.50 ± 0.27		2.59 ± 0.29		3.41	***
TP	(%)	2.99 ± 0.30		3.09 ± 0.33		3.44	***
WP	(%)	0.49 ± 0.092		0.50 ± 0.090		1.17	ns
NPN	(%)	0.17 ± 0.070		0.17 ± 0.066		0	ns
URN	(%)	40.10 ± 16.53		40.53 ± 16.12		0.28	ns
F/CP	–	1.17 ± 0.245		1.23 ± 0.300		2.34	*
CN-CP	(%)	79.15 ± 3.24		79.45 ± 2.82		1.05	ns
CN-TP	(%)	83.65 ± 2.80		83.68 ± 2.62		0.12	ns

Statistical significance of differences: ns = $P > 0.05$, * = $P \leq 0.05$, ** = $P \leq 0.01$, *** = $P \leq 0.001$; *n* = number of samples, *x* ± *sd* = arithmetic mean ± standard deviation, *xg* = geometric mean, *t* = test criterion of *t*-test, sign. = significance of the difference; NL – number of lactation, SL – stage of lactation, DMY – daily milk yield, FAT – fat, LAC – lactose, SNF – solids non fat, SCC – somatic cell count, U – urea, AC – acetone, pH – acidity, EC – electrical conductivity, AL – alcohol stability, SH – titration acidity, TEC – time for enzymatic coagulation, RCQ – rennet curds quality, RCF – rennet curds firmness, WV – whey volume, CP – crude protein, CAS – casein, TP – true protein, WP – whey protein, NPN – non protein nitrogen, URN – urea nitrogen/non protein nitrogen ratio, F/CP – fat/crude protein ratio, CN-CP and CN-TP – casein numbers

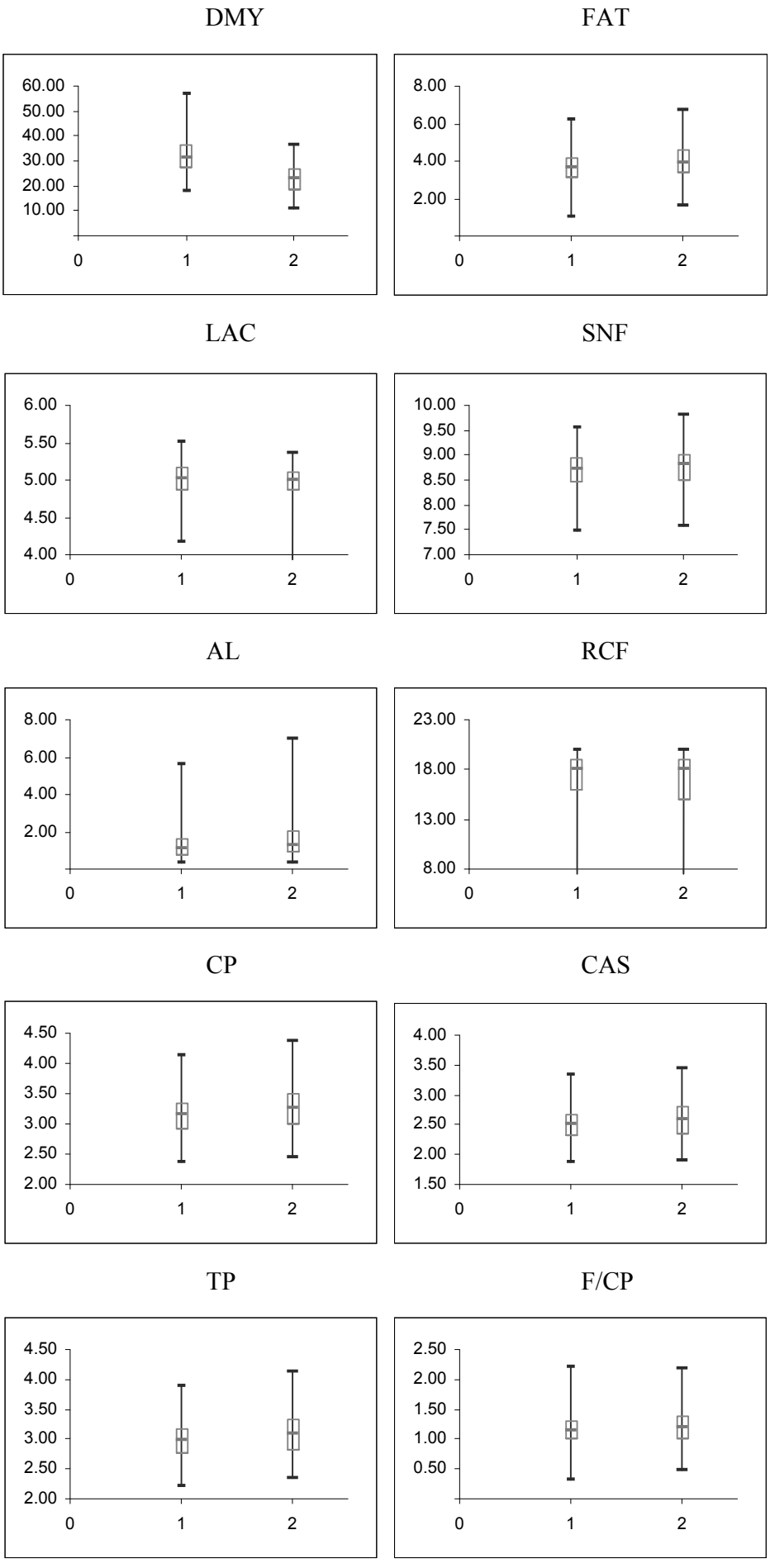

Fig. 1. Presentation of the main central statistical moments and characteristic of data frequency distribution for cases of significant differences in milk indicators betweens H cows with higher (1) and average (2) MY

results (Janů et al., 2007; Hanuš et al., 2007). Technological properties (AL and RCF) were slightly better at lower MY.

Regarding the general principles of the energy metabolism (Andersson, Lundström, 1984a, b; Andersson, 1984, 1985; Andersson, Emanuelson, 1985; Gravert et al., 1986; Diekmann, 1987; Gustafsson, Emanuelson, 1993; Geishauser et al., 1997, 1998; Pechová et al., 2000; Kirchnerová et al., 2001) the milk fat content was statisticly significantly influenced ($P \leq 0.001$). F decreased with higher MY. It is in accordance with our previous results in Czech Fleckvieh (Hanuš et al., 2007) but not in Holstein (Janů et al., 2007). The same situation is valid for the fact that the milk crude and true protein contents and casein content were significantly affected by the level of dairy cow MY in this case.

The F/CP ratio as a possible indicator of cow energy metabolism (Heuer et al., 1999, 2001) was also influenced significantly (Table 1) but in the opposite direction as expected. There were no serious problems with the ketosis in the set, as it is also confirmed by lower acetone values in both sets H1 and H2 and no significant effect by MY on these.

The SCC trend showed higher values connected with higher milk yield (Table 1; $P > 0.05$). However, the geometric mean difference is very small. So this SCC increase probably has no practical importance. In addition, with increasing of the MY level the approach towards breeding is changing. For instance Motyčka (2004) referred about the increasing of importance of secondary production function signs including cow health state markers and longevity markers in breeding models of the most effective dairy cow populations.

Milk urea is an energy and nitrogen metabolism indicator (Piatkowski et al., 1981; Oltner, Wiktorsson, 1983; Kirchgessner et al., 1985; Zhai et al., 2006). That is why urea was studied also from genetic (Johnson, Young, 2003; Miglior et al., 2006; Stoop et al., 2007) and farmer (Godden et al., 2001b; Mottram et al., 2002; Jílek et al., 2006) points of view. Its unsatisfactory (high, sometimes also low) values are often linked with aggravated reproductive performance (Piatkowski et al., 1981; Ropstad, Refsdal, 1987; Butler et al., 1996; Larson et al., 1997; Říha, Hanuš, 1999a; Hlásný, 2001; Legáth et al., 2001; Rajala-Schultz et al., 2001; Guo et al., 2004; Hojman et al., 2004; Kubešová et al., 2008; Bezdíček et al., 2009) and longevity (Fig. 2; Miglior et al., 2006). However, Godden et al. (2001a), Řehák et al. (2009) and Kubešová et al. (2009) suggested slightly opposite results in terms of cow reproduction. Urea was influenced insignificantly ($P > 0.05$; Table 1) by high MY in this work. It is not in accordance with previous results, where higher MY was connected with higher U in Holstein and also Czech Fleckvieh cattle (Janů et al., 2007; Hanuš et al., 2007). This disproportion could be explained by the fact that in previous papers the result distribution into groups with high and low MY was done according to herds (where herd is also significant effect on U level as reported Jílek et al., 2006) in contrast to this procedure which was done according to individual lactation MY within herds. This could mean that U depends on nutrition level in terms of protein/energy maintenance among herds. However, the cows with higher genetic potential for MY have a better ability to utilize nitrogen matter from feeding ration under the same environmental conditions (identical herd). Nevertheless, Legáth et al. (2001) found significantly lower MU levels in dairy cows with higher MY. However, this higher MY was comparable just to our average MY (H2). There could be an explanation of this discrepancy from these and our previous (Hanuš et al., 2007; Janů et al., 2007) results. URN as a relative indicator was influenced non-significantly (Table 1; Fig. 1; URN, $P > 0.05$). The cows with high MY had higher URN than the cows with average MY. It is in accordance with higher U in milk of high yielding cows. Johnson and Young (2003) reported that U nitrogen in milk decreased with increasing CP and increased with higher MY in H and Jersey cows. This fact about MY is in accordance with our previous result (Janů et al., 2007; Hanuš et al., 2007). Our actual results are not in accordance with theirs. However, this is probably without significant practical impact.

Also milk acetone is an energy metabolism indicator (Andersson, 1984, 1985; Andersson, Lundström, 1984a, b; Andersson, Emanuelson, 1985; Gravert et al., 1986; Diekmann, 1987; Gustafsson, Emanuelson, 1993; Geishauser et al., 1997, 1998; Hanuš et al., 2001c; Enjalbert et al., 2001; Baticz et al., 2002). That is why acetone was studied also from genetic (Gravert et al., 1986; Wood et al., 2004) and farmer (Hanuš et al., 1999; Mottram et al., 2002) points of view. Its higher values are also linked with aggravated reproductive performance (Hanuš et al., 1999; Říha, Hanuš, 1999b; Bezdíček et al., 2009). Acetone was influenced insignificantly ($P > 0.05$; Table 1) by high MY in this work

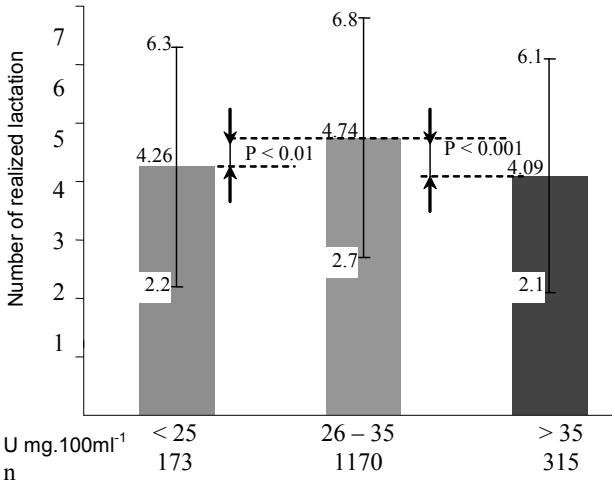

Fig. 2. The impacts of nitrogen loading of metabolism in consideration of long-period milk urea (U) level on longevity of dairy cows (Hanuš et al., 2001b)

too. It is not in accordance with previous results, where higher MY was linked with higher AC in Czech Fleckvieh cows (H a n u š et al., 2007). Nevertheless, this result is in accordance with results in Holstein (J a n ů et al., 2007).

CONCLUSIONS

In terms of obtained results, we determined that diferences in milk indicators between group H1 and H2 have no fundamental effect on milk quality. There are no serious health problems with higher MY. Realized significant differences among parameters FAT, LAC, SNF, AL, RCF, CP, CAS, TP and F/CP in cows H1 and H2 have not caused the impaired technological milk quality. However, technological quality was slightly better at lower MY. The high MY reached by the genetic improvement of animals and their more efficient nutrition does not result in markedly impaired quality of raw milk. Nevertheless, there is reduced efficiency of milk processing into concentrated milk products (yoghourts and cheeses) a little.

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Vlivy fyziologie laktace při vyšší a průměrné užitkovosti na složení, vlastnosti a zdravotní ukazatele mléka dojnic holštýnského plemene skotu.

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Mléčná užitkovost (MY) znamená množství mléka a jeho kvalitu během laktace. MY je důležitý ekonomický faktor spojený se zdravotním stavem dojnic, reprodukcí a délkou života. Byly testovány rozdíly v mléčných ukazatelích mezi vysoce a průměrně užitkovými dojnicemi (H1 a H2) ve čtyřech stádech. 234 a 224 individuálních vzorků mléka bylo odebráno v letním a zimním krmném období během tří roků. Soubory byly vyváženy ve faktorech laktace. Skupina 1 byla podle fenotypu (MY) na vyšší genetické úrovni a měla tak podle MY i lepší výživu. MY u H1 byla vyšší o 43 % ($P \leq 0{,}001$). MY měla významný vliv ($P \leq 0{,}05$ a $P \leq 0{,}001$) na: tuk (FAT), laktózu (LAC), tukuprostou sušinu (SNF), alkoholovou stabilitu (AL), pevnost syrovátky (RCF), hrubé bílkoviny (CP), kasein (CAS), čisté bílkoviny (TP), podíl tuk/hrubé bílkoviny (F/CP). Vybrané rozdíly byly: FAT (H1 3,68 ± 0,77; H2 3,99 ± 0,93 %); CAS (H1 2,50 ± 0,27; H2 2,59 ± 0,29 %); TP (H1 2,99 ± 0,30; H2 3,09 ± 0,33 %). Dalších 16 ukazatelů, jako počet somatických buněk (H1 289 > 210 103.ml^{-1} H2), močovina, poměr močovinového dusíku v nebílkovinném dusíku, aceton, pH, syřitelnost, bylo ovlivněno nevýznamně ($P > 0{,}05$). Rozdíly v mléčných ukazatelích mezi H1 a H2 nepředstavují zdravotní problémy. Vysoká MY dosažená šlechtěním a efektivnější výživou nevedla ke zhoršené kvalitě mléka, ale k jeho mírně nižší technologické výtěžnosti. U plemene holštýn nebyla vyšší MY překvapivě spojena s vyšším obsahem močoviny v mléce.

mléčná užitkovost; mléčné ukazatele; holštýnské plemeno; složení mléka; mléčné složky; fyziologie laktace

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