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The chemical composition, cytological quality and technological suitability of the milk of three breeds of red and white cows fed in a TMR system

Joanna Barłowska[1], Zygmunt Litwińczuk[2], Anna Wolanciuk[1], Robert Pastuszka[1]

[1]University of Life Sciences in Lublin,
Department of Commodity Science and Processing of Raw Animal Materials,
[2]University of Life Sciences in Lublin,
Department of Breeding and Conservation of Cattle Genetic Resources,
ul. Akademicka 13, 20-950 Lublin

The aim of the study was to evaluate the chemical composition, cytological quality and technological suitability of the milk of three breeds of red and white cows fed in a TMR system, taking into account the effect, if any, of daily milk yield (≤25 and >25 kg). The analysis included 540 milk samples collected from cows of the breeds Polish Red-and-White Holstein Friesian (PHF RW), Simmental (SM) and Montbéliarde (MO). Content of fat, protein, casein, dry matter and non-fat dry matter, active and potential acidity, heat stability, rennet clotting time and somatic cell count were determined. The milk of the MO cows was found to have the highest concentration of dry matter (13.65%), while the highest cytological quality (p≤0.01) was noted in the milk of the PHF RW and SM cows. The best raw material for cheese production was obtained from the MO cows, as it had the highest (p≤0.05) content of non-fat dry matter (9.30%) and the shortest rennet clotting time (4:18 min). In the case of milk yield >25 kg, content of dry matter in the milk of the PHF RW cows decreased (by 0.54 p.p.), including content of protein (by 0.30 p.p.) and fat (by 0.31 p.p.). In cows of the Simmental breed the differences were 0.85, 0.24 and 0.70 p.p., respectively, while in the MO breed the milk components remained at similar levels. Moreover, for daily milk yield >25 kg a significant (p≤0.01) decrease in content of non-fat dry matter, including casein, was noted in the PHF and SIM cows, while in the SM cows there was a significant (p≤0.05) increase in rennet clotting time.

KEY WORDS: milk / breeds of cow / daily milk yield / basic chemical composition / technological suitability / cytological quality

In Poland there are currently 12 breeds of cow used for dairy purposes: Polish Holstein-Friesian, with two colour varieties – Black-and-White and Red-and-White, Jersey,

Simmental, Montbéliarde, Brown Swiss, Swedish and Norwegian Red, and native breeds, i.e. White-Backed, Polish Red, Polish Black-and-White and Polish Red-and-White. The most numerous are the Polish Black-and-White Holstein-Friesians (87.56% of the active population of cows) [18].

Among colour breeds, two are of great importance in milk production: Polish Red-and-White Holstein-Friesian and Simmental. The former is raised mainly in Silesia and the Bieszczady Mountains, and a large percentage of cows of this breed are used in intensive farming technologies. Simmental cows can be found mainly in the Bieszczady region, although they are becoming increasingly popular in other areas as well, due to their relatively high milk yield, adaptability to difficult climate conditions, and very good meat characteristics [17]. The milk of these cows is considered an excellent raw material for cheese production [13, 17, 20]. In intensive systems, cows of this breed achieve higher yields with better milk composition, but the rennet clotting time is longer [3].

A third colour breed, which is increasingly valued in Poland and is well suited to intensive farming technologies, is Montbéliarde [10]. Animals of this breed were first imported from France in 1995, and in 2001 the Ministry of Agriculture and Rural Development authorized the establishment and maintenance of herd books [8]. In 2013 the active population numbered 2,428 cows, which accounted for 0.36% of the total population of dairy cows subject to use value assessment [18].

Montbéliarde cattle are a dual-purpose (meat and dairy) breed. The largest population is in France, where, as in Ireland, it is the breed with the second largest population [9, 21]. The milk of this breed has a more favourable chemical composition than that of Polish Holstein-Frisians [11, 21]. In France, Montbéliarde cow milk is considered to be an excellent raw material for production of high quality cheeses (Comté in the Montbéliarde region, Cantal – Central France, Reblochon – south-eastern France, Mont d'Or – Montbéliard region, Abondance – south-eastern France), due to the high frequency of the B allele of κ-casein and high protein content [16]. According to Trela [21], the Montbéliarde breed should not be treated in Poland as competition for other breeds, but as one of many, producing milk that is particularly valued in processing.

The aim of the study was to evaluate the chemical composition, cytological quality (somatic cell count), and processing suitability of the milk of cows of three red-and-white breeds (Polish Red-and-White Holstein-Friesian, Simmental and Montbéliarde) fed in a TMR system, taking into account the effect of daily milk yield.

Material and methods

The research was carried out on three farms in eastern Poland. Two of them, raising Polish Red-and-White Holstein-Frisian (PHF RW) and Montbéliarde (MO) cows, had

free-stall barns without litter, with resting boxes separated by barriers and mats for bedding. The Simmental cows (SM) had no boxes and lay on straw. All of the barns had milking parlours – 'herringbone' on the farms raising PHF RW and SM, and 'side-by-side' in the case of MO. All cows were fed a TMR diet, with feed supplied from a feeding wagon twice a day.

The herds were subject to use value assessment for dairy cattle and met the requirements for milk production set out in Commission Regulation (EC) No 1662/2006 of 6 November 2006, amending Regulation (EC) No 853/2004 of the European Parliament and of the Council laying down specific rules on the hygiene of food of animal origin.

The research material consisted of 540 milk samples collected from cows of the breeds Polish Red-and-White Holstein-Friesian (214 samples), Simmental (126 samples) and Montbéliarde (200 samples), in their second or third lactation (between 30 and 210 days in milk). Milk samples were collected individually from each cow, from a complete milking session, into 250 ml plastic bottles. Samples from cows with diseased udders were eliminated (positive result for the California mastitis test). The milk was transported in thermal bags with freezer packs to the laboratory of the Department of Commodity Science and Processing of Raw Animal Materials, University of Life Sciences in Lublin, according to AOAC [2].

The content of fat, protein, lactose and dry matter was determined in each milk sample with a Bentley Infrared Milk Analyzer. The results were used to calculate the content of non-fat dry matter. Casein content was determined according to AOAC [1], active acidity (pH) with a Radiometer Analytical Pioneer 65 pH meter; and potential acidity (°SH) by the titration method according to PN-86/A-86122. The heat stability of the milk at 140°C was determined in a TEWES-BIS oil bath by White and Davies' method, and rennet clotting time by Schern's method (moment when the first casein floccules appear). The somatic cell count was determined with a Bentley Somacount 150. The somatic cell count (SCC), expressed in 1,000/ml milk, was transformed to a natural logarithm (LnSCC) in Excel®, to meet the conditions for normal distribution of this characteristic.

Data on the daily milk yield of the cows (on the day of sample collection) was obtained from breeding documentation conducted by the Polish Federation of Cattle Breeders and Dairy Farmers.

The statistical analysis took into account the breed of cow (Polish Red-and-White Holstein Friesian, Simmental and Montbéliarde) and daily milk yield ($\leq$25 and >25 kg of milk).

The results were analysed statistically in StatSoft Inc. STATISTICA, using one-way and two-way analysis of variance (with interaction), distinguishing breed and daily yield as sources of variation. The effect of factors was determined at significance levels of $p \leq 0.05$ and $p \leq 0.01$.

Results and discussion

The data presented in Table 1 show the highest average daily yield for the Montbéliarde (MO) cows, at 28.2 kg, slightly lower yield for Polish Red-and-White Holstein Friesians (PHF RW) with 27.05 kg, and the lowest for the Simmentals (SM) at 24.32 kg. The milk of the MO cows also had the highest concentration of dry matter (13.65%). It should be noted that the protein content of the MO milk was slightly lower (by 0.04 pp) than the SM milk, the fat level in the two breeds was the same (4.35%), and lactose content was significantly ($p \leq 0.01$) higher (by 0.29 pp). In a previous study by Litwińczuk et al. [14], PHR RW and SM cows fed TMR diets had similar daily yield (23.32 and 23.20 kg) and fat content in their milk (4.18% and 4.16%). The milk of the SM cows, however, had significantly ($p \leq 0.01$) more protein (by 0.18 pp) and a more beneficial ($p \leq 0.05$) protein--to-fat ratio. Gołębiewski and Brzozowski, who [7] conducted similar analyses in 2002--2004 for Black-and-White cows and Montbéliarde cows, showed that the latter produced less milk (1.51 kg) with a lower fat content (by 0.19 pp) but higher protein content (by 0.08 pp). Januś and Borkowska [10], comparing daily yield of Polish Red-and-White Holstein Friesian and Montbéliarde cows and the chemical composition of their milk, showed similar correlations as in the present study. The average daily milk yield of PHF HO cows was 2.1 kg lower, with a lower concentration of fat, protein and dry matter (by 0.32, 0.20, 0.09 and 0.53 pp) as compared to MO.

The milk of the PHF RW and SM cows had a more favourable somatic cell count (LnSCC = 11.56) than that of the MO cows (LnSCC = 12.12; $p \leq 0.01$). Borkowska and Januś [4] showed that the average somatic cell count in the milk of Montbéliarde cows for all samples together was 465,000/ml, and converted to LnSCC was 12.01. An analysis by Walsh et al. [22] of the somatic cell count of the milk of four cow breeds showed the lowest LnSCC for the Norwegian Red (10.31) and Montbéliarde (10.47) breeds, as compared to 10.96 for Holstein-Friesians and 10.88 for the Normande breed.

The data in Table 1 indicate that the daily yield influenced ($p \leq 0.01$) the composition of the milk of the PHF RW and SM cows. In the PHF RW cows, for daily milk production > 25 kg, the dry matter content in the milk was lower by 0.54 pp, and of this, protein was lower by 0.30 pp and fat by 0.31 pp. For the milk of SM cows, the differences were 0.85, 0.24 and 0.70 pp, respectively. On the other hand, the content of lactose increased significantly ($p \leq 0.01$) in the milk of the SM breed (by 0.14 pp). In the MO breed, milk composition remained at an even level, with only lactose content increasing significantly ($p \leq 0.05$), by 0.08 pp, when daily yield was higher. The reduction in fat and protein concentration in the milk of Holstein-Friesian cows as daily yield increases is also confirmed by other authors [5, 19]. Januś and Borkowska [10] report that daily yield (<20.0; 20.1-30.0; > 30.0 kg of milk) in PHF HO and MO cows had a significant ($p \leq 0.01$) effect on the energy content of the milk; in the case of the former breed the differences between <20 kg and ≥30 kg milk/day were significantly higher (55.1 vs 19.5 kcal/kg).

Table 1
Basic chemical composition and cytological quality of milk, taking into account daily milk yield

Breed	Range of daily milk yield (kg)	n	Daily milk yield (kg)		Protein (%)		Fat (%)		Lactose (%)		Dry matter (%)		LNSCC	
			$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
PHF RW	≤25	56	**21.28^{A}**	2.25	**3.83^{B}**	0.39	**4.40^{B}**	0.67	**4.82**	0.25	**13.76^{B}**	0.97	**11.76**	1.31
	>25	158	**29.10^{B}**	3.80	**3.53^{A}**	0.39	**4.09^{A}**	0.55	**4.81**	0.33	**13.22^{A}**	0.83	**11.47**	1.28
	average	214	**27.05^{Y}**	4.88	**3.61^{X}**	0.41	**4.17^{x}**	0.60	**4.81^{Y}**	0.35	**13.36^{x}**	0.90	**11.56^{X}**	1.29
SM	≤25	63	**20.13^{A}**	3.10	**3.91^{B}**	0.35	**4.70^{B}**	0.36	**4.63^{A}**	0.32	**13.99^{B}**	0.69	**11.59**	1.13
	>25	63	**28.51^{B}**	2.93	**3.67^{A}**	0.33	**4.00^{A}**	0.27	**4.77^{B}**	0.26	**13.14^{A}**	0.53	**11.51**	1.10
	average	126	**24.32^{X}**	5.17	**3.79^{Y}**	0.36	**4.35^{y}**	0.47	**4.73^{X}**	0.29	**13.56^{xy}**	0.75	**11.56^{X}**	1.11
MO	≤25	55	**21.15^{A}**	3.07	**3.81**	0.29	**4.38**	0.52	**4.79^{a}**	0.22	**13.68**	0.76	**12.12**	0.80
	>25	145	**30.87^{B}**	4.50	**3.73**	0.34	**4.34**	0.58	**4.87^{b}**	0.21	**13.64**	0.75	**12.12**	0.87
	average	200	**28.20^{Z}**	6.01	**3.75^{Y}**	0.33	**4.35^{y}**	0.57	**4.85^{Y}**	0.22	**13.65^{y}**	0.75	**12.12^{Y}**	0.85
Influence of the factor *(p-value)*	breed		0.00057		0.01818		0.04769		0.00506		0.04500		0.00001	
	daily milk yield		0.00000		0.00000		0.00000		0.06029		0.00000		0.20194	
	interaction breed x daily milk yield		0.05736		0.02222		0.00000		0.21194		0.00005		0.057360	

PHF RW – Polish Red-and-White Holstein Friesian
SM – Simmental
MO – Montbéliarde
x, y – differences between breeds significant at p≤0.05; X, Y, Z – significant at p≤0.01
a, b – differences between ranges of daily milk yield within a breed significant at p≤0.05; A, B – significant at p≤0.01

Analysis of the simultaneous effect of breed and daily yield showed significant interactions ($p \leq 0.01$) for fat and dry matter content and slightly smaller interactions ($p \leq 0.05$) for protein content (Table 1).

The suitability of milk for processing is largely determined by the content and proportions of its components, mainly the content of non-fat dry matter, total protein, including casein, and minerals. The rate of curd formation and the compactness of the curd are primarily determined by milk composition [12], especially the content of casein [6, 23].

The data in Table 2 show that the best raw material for cheese production was obtained from the Montbéliarde cows. The milk of these cows had the lowest ($p \leq 0.01$) acidity, both active (pH 6.72) and potential (6.68 °SH), significantly ($p \leq 0.05$) the highest dry matter content (9.30%), and the shortest rennet clotting time (4:18 min). However, this milk was the least ($p \leq 0.01$) resistant to heat treatment (2:46 min).

The milk obtained from Polish Red-and-White Holstein Friesian cows had the least favourable parameters determining the suitability of raw material for cheese production; it contained the least non-fat dry matter (9.22%), including casein (2.75%), and had a longer rennet clotting time (4:49 min). On the other hand, it had the highest heat stability (3:46 min).

Malchiodi et al. [15] compared parameters determining the cheese production suitability of the milk of F1 crossbred cows: Holstein x Swedish Red (HO x SR), Holstein x Montbéliarde (HO x MO) and Holstein x Brown Swiss (HO x BS). They showed that HO x SR cows produced 29.89 kg of milk per day, with the highest content of fat (4.34%) and protein (3.86%), including casein (3.00%). HO x MO cows produced the most milk (32.29 kg/day), but it had slightly less fat (4.24%) and protein (3.82%), with the same level of casein (3.00%). The HO x BS crossbreds had the least favourable indicators: 28.49 kg, 4.17, 3.79 and 2.96%, respectively. However, the milk of the HO x MO cows had the best coagulation time (RCT) and curd firmness (a_{30}) – 19.7 min and 38.6 mm, with slightly worse indicators noted for the HO x BS milk – 20.1 min and 35.9 mm, and the worst for the milk of HO x SR – 22.3 min and 33.4 mm.

Analysis of the effect of daily yield on the technological parameters of the milk (Table 2) revealed that the higher milk yield of the Montbéliarde cows did not negatively affect indicators of the suitability of the raw material for cheese production, increasing only its heat stability. In the case of the other two breeds (PHF RW and SM), a significant ($p \leq 0.01$) decrease in dry matter content, including casein, was observed for daily milk yield > 25 kg, and in the case of SM, a significantly ($p \leq 0.05$) longer rennet coagulation time as well.

Significant ($p \leq 0.01$) interactions for breed x daily yield were noted for active acidity and heat stability, and slightly lower interactions ($p \leq 0.05$) for non-fat dry matter and casein content (Table 2).

Table 2
Selected indicators of technological suitability, taking into account daily milk yield

Breed	Range of daily milk yield (kg)	n	Acidity				Non-fat dry matter (%)		Casein (%)		Clotting time (min)		Heat stability (min)	
			pH		°SH									
			$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
PHF RW	≤25	56	**6.75^{B}**	0.15	**7.33**	0.96	**9.40^{B}**	0.48	**2.87^{B}**	0.39	**4:50**	2:05	**3:39**	1:17
	>25	158	**6.68^{A}**	0.12	**7.25**	0.89	**9.14^{A}**	0.55	**2.71^{A}**	0.33	**4:49**	2:10	**4:06**	1:21
	average	214	**6.70^{y}**	0.13	**7.27^{y}**	0.91	**9.22^{x}**	0.55	**2.75**	0.35	**4:49^{y}**	2:08	**3:46^{Yy}**	1:19
SM	≤25	63	**6.71**	0.11	**7.39**	0.83	**9.27^{B}**	0.48	**2.94^{B}**	0.30	**4:21^{a}**	1:53	**3:02**	1:18
	>25	63	**6.64**	0.11	**7.61**	0.90	**9.11^{A}**	0.42	**2.73^{A}**	0.34	**5:00^{b}**	1:54	**3:15**	1:18
	average	126	**6.67^{X}**	0.11	**7.50^{Z}**	0.87	**9.19^{x}**	0.46	**2.84**	0.34	**4:40^{xy}**	1:55	**3:08^{Yx}**	1:18
MO	≤25	55	**6.72**	0.06	**6.77**	0.69	**9.30**	0.33	**2.83**	0.34	**4:23**	1:29	**2:30**	1:13
	>25	145	**6.72**	0.07	**6.65**	0.75	**9.30**	0.33	**2.83**	0.38	**4:15**	1:33	**2:53**	1:11
	average	200	**6.72^{y}**	0.07	**6.68^{X}**	0.74	**9.30^{y}**	0.33	**2.83**	0.37	**4:18^{x}**	1:32	**2:46^{X}**	1:12
Influence of the factor (*p-value*)	breed		0.00041		0.00000		0.07211		0.45953		0.04962		0.00000	
	daily milk yield		0.00000		0.94372		0.00025		0.00020		0.14162		0.03402	
	interaction breed x daily milk yield		0.00483		0.18909		0.02051		0.03056		0.34466		0.00302	

PHF RW – Polish Red-and-White Holstein Friesian
SM – Simmental
MO – Montbéliarde
x, y – differences between breeds significant at p≤0.05; X, Y, Z – significant at p≤0.01
a, b – differences between ranges of daily milk yield within a breed significant at p≤0.05; A, B – significant at p≤0.01

In conclusion, among the three breeds of red-and-white cows fed TMR diets, the Montbéliardes had the highest productivity, while their milk had the highest parameters determining suitability for cheese production, irrespective of daily yield. Significant deterioration in milk composition and its suitability for cheese production at higher yields was observed for the Polish Red-and-White Holstein Friesian cows. The valuable properties of the milk of the Simmental cows (considered to be an excellent raw material for cheese production) also deteriorated when productivity was higher (> 25 kg/day).

REFERENCES

1. AOAC, 2000 – Official Methods of Analysis. Casein Nitrogen Content of Milk. 998.06. ***AOAC International*** 32, 52.
2. AOAC, 2000 – Official Methods of Analysis. Collection of Milk Laboratory Sample. 925.20. ***AOAC International*** 33, 4.
3. BARŁOWSKA J**.,** LITWIŃCZUK Z., KOWAL M., 2014 – Influence of production season and lactation stage on the technological suitability of milk from cows of various breeds fed in the TMR system. ***Annals of Animal Science*** 14 (3), 649-661.
4. BORKOWSKA D., JANUŚ E., 2010 – Ocena wpływu wybranych czynników na liczbę komórek somatycznych w mleku krów rasy montbeliarde. ***Acta Scientiarum Polonorum, ser. Zootechnica***, 9 (4), 39-46.
5. DE FREITAS JÚNIOR J.E., RENNÓ F.P., DOS SANTOS M.V., GANDRA J.R., FILHO M.M., VENTURELLI B.C., 2010 – Productive performance and composition of milk protein fraction in dairy cows supplemented with fat sources. ***Revista Brasileira de Zootecnia*** 39 (4), 845-852.
6. FREDERIKSEN P.D., HAMMERSHOJ M., BAKMAN M., ANDERSEN P.N., ANDERSEN J.B., QVIST K.B., LARSEN L.B., 2011 – Variations in coagulation properties of cheese milk from three Danish dairy breeds as determined by a new free oscillation rheometry-based method. ***Dairy Science*** **and** ***Technology*** 91, 309-321.
7. GOŁĘBIEWSKI M., BRZOZOWSKI P., 2008 – Comparison of dairy performance of Montbeliarde and Black-and-White cows housed in the same environmental conditions. ***Annals of Animal Science*** 8 (1), 3-11.
8. GOŁĘBIEWSKI M., BRZOZOWSKI P., 2009 – Porównanie wybranych wskaźników rozrodu krów rasy montbeliarde oraz polskiej holsztyńsko-fryzyjskiej odmiany czarno-białej. ***Medycyna Weterynaryjna*** 65 (8), 566-570.
9. JANUŚ E., BORKOWSKA D., 2010 – Ocena wpływu wybranych czynników na dobową wydajność i skład mleka krów rasy montbeliarde. ***Zeszyty Problemowe Postępów Nauk Rolniczych*** 556, 663-668.

10. JANUŚ E., BORKOWSKA D., 2011 – Wpływ wybranych czynników na wartość energetyczną mleka krów rasy polskiej holsztyńsko-fryzyjskiej odmiany czarno-białej oraz montbeliarde. ***Żywność. Nauka. Technologia. Jakość*** 5 (78), 141-149.
11. JANUŚ E., BORKOWSKA D., PIĄTEK D., 2013 – Ocena wpływu wybranych czynników na skład chemiczny mleka wysokowydajnych krów rasy polskiej holsztyńsko-fryzyjskiej i montbeliarde. ***Medycyna Weterynaryjna*** 69 (6), 378-384.
12. JENSEN H.B., POULSEN N.A., ANDERSEN K.K., HAMMERSHØJ M., POULSEN H.D., LARSEN L.B., 2012 – Distinct composition of bovine milk from Jersey and Holstein-Friesian cows with good, poor, or noncoagulation properties as reflected in protein genetic variants and isoforms. ***Journal of Dairy Science*** 95, 6905-6917.
13. LITWIŃCZUK Z., BARŁOWSKA J., CHABUZ W., BRODZIAK A., 2012 – The nutritional value and technological suitability of milk from cows of 3 Polish breeds included in the programme of genetic resources conservation. ***Annals of Animal Science*** 12 (3), 423-432.
14. LITWIŃCZUK Z., KOWAL M., BARŁOWSKA J., 2014 – Podstawowy skład chemiczny oraz udział kwasów tłuszczowych i zawartość cholesterolu w mleku krów czterech ras użytkowanych w intensywnych technologiach chowu. ***Żywność. Nauka. Technologia. Jakość*** 4 (95), 108-121.
15. MALCHIODI F., CECCHINATO A., PENASA M., CIPOLAT-GOTET C., BITTANTE G., 2014 – Milk quality, coagulation properties, and curd firmness modeling of purebred Holsteins and first- and second-generation crossbred cows from Swedish Red, Montbéliarde, and Brown Swiss bulls. ***Journal of Dairy Science*** 97, 4530-4541.
16. Montbeliarde: Bred for the French cheese Industry –/http://www.auzredxb.com.au/media/docs/MB_CheesemakersChoice.pdf/
17. PERIŠIĆ P., SKALICKI Z., PETROVIĆ M. M., BOGDANOVIĆ V., RUŽIĆ-MUSLIĆ D., 2009 – Simmental cattle breed in different production systems. ***Biotechnology in Animal Husbandry*** 25 (5-6), 315-326.
18. POLSKA FEDERACJA HODOWCÓW BYDŁA I PRODUCENTÓW MLEKA, 2014 – Wyniki oceny wartości użytkowej krów mlecznych za 2013 rok. Wyd. PFHBiPM, Warszawa.
19. RADKOWSKA I., 2012 – Skład chemiczny oraz zawartość komórek somatycznych i mocznika w mleku krów w zależności od systemu utrzymania. ***Roczniki Naukowe Zootechniki*** 39 (2), 295-305.
20. STURARO A., TIEZZI F., PENASA M., DE MARCHI M., CASSANDRO M., 2012 – Study of milk coagulation properties in multibreed Italian dairy herds. ***Acta Agriculturae Slovenica,*** 3, 89-92.
21. TRELA J., 2003 – Aklimatyzacja i niektóre wskaźniki produkcyjne bydła rasy montbeliarde w Polsce. ***Zeszyty Naukowe Przeglądu Hodowlanego*** 67, 67-77.

22. WALSH S., BUCKLEY F., BERRY D.P., RATH M., PIERCE K., BYRNE N., DILLON P., 2007 – Effects of breed, feeding system, and parity on udder health and milking characteristics. ***Journal of Dairy Science*** 90, 5767–5779.
23. WEDHOLM, A., LARSEN L. B., LINDMARK-MANSSON H., KARLSSON A. H., ANDREN A., 2006 – Effect of protein composition on the cheesemaking properties of milk from individual dairy cows. ***Journal of Dairy Science*** 89, 3296-3305.