DOI: 10.2478/v10083-012-0040-y

ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA

VOL. XXX (4) SECTIO EE 2012

Department of Breeding and Genetic Resources Conservation of Cattle
University of Life Sciences in Lublin, Akademicka 13,
20-950 Lublin, e-mail: jerzygnyp@interia.pl

JERZY GNYP

Milk-yield and the relationship between the fat and protein content of milk from cows fathered by bulls from different countries

Wydajność mleka i relacje między zawartością tłuszczu i białka w mleku krów po buhajach z różnych krajów

Summary. The milk yield, the composition and the relationships between the protein and fat content in milk during three lactation periods over 305 days in 1790 Holstein-Friesian black and white cows fathered by bulls from Poland, Holland, Germany, USA and Canada were compared. It was shown that those cows which had been fathered by bulls from the USA showed the highest milk yield during three lactation periods and also significantly the lowest fat content in the milk. They were also characterised by the lowest significant difference between the fat and protein content in the milk (DFP) and the highest relationship of protein to fat in milk (PFR) during three lactation periods. Over three consecutive lactations, the highest protein content was found in the milk of cows which had been fathered by Dutch bulls, while the lowest protein content was to be found in the milk from cows which had been fathered by bulls from the USA. The highest frequency of cows giving milk with a fat content equal to, or lower than, the protein content was found in cows which had themselves been fathered by bulls from the USA; the lowest was in the animals fathered by Canadian bulls. The unfavourable (i.e. the highest) difference between the fat and protein content (DFP) and the least favourable relationship between the protein and fat content (PFR) in the milk, during the three lactation periods, was found in the milk from those cows which had been fathered by Canadian bulls, whereas the best DFP and the most favourable PFR was found in the milk from cows which had been fathered by bulls from the USA.

Key words: origin of bulls, milk yield of cows, fat to protein relationship

INTRODUCTION

The productivity of a cow depends, to a large extent, on her paternal origin. Hence, the use of semen from the best bulls for mating, in large cow herds, is the best method to significantly enhance breeding in livestock [Sitkowska and Mroczkowski 2004, Nicolazzi *et al*. 2011].

Van Tassel and Van Vleck [1991] state that the principal genetic enhancement in milk traits is achieved as a result of selection through father-son and father-daughter lineages, about 40% and 30%, respectively, whereas genetic enhancement through mother-son and mother-daughter lineages is 20% and 10% of genetic enhancement, respectively.

Genetic enhancement in the Holstein-Friesian cow population of the black-and-white variety used in our country takes place by crossing dairy breeds of bulls [Niedziałek *et al.* 2002, Tomaszewski *et al.* 2007]. Around 100 thousand semen portions from Holstein-Friesian (HF) bulls were imported to Poland mainly from the USA, Canada, Holland, France and Germany [Reklewski 2001, Pakuła and Pakuła 2003]. The import of genetic resources from other countries has significantly influenced the cattle type current in Poland, simultaneously improving milk productivity, composition and udder structure [Reklewski 2001, Gnyp *et al*. 2001, Sitkowska and Mroczkowski 2004, Antkowiak *et al*. 2009].

The aim of the present study is to compare milk productivity and composition as well as the relationships between fat and protein over three lactation periods of 305-days, in HF cows of the black-and-white variety, themselves having been fathered by bulls from Poland, Holland, Germany, USA, France and Canada.

MATERIAL AND METHODS

The present study was carried out in the period 2004-2011 at 95 milk dairy farms in the Lublin District. Data from the breeding documentation carried out for the herds analysed (heifer-cow charts, reports on the periodic evaluation of a cow's utility – RW-1, RW-2 and RW-5) as well as our own observations and calculations. The analyses covered 1790 HF cows of the black-and-white variety with a $\geq$ 75% contribution of this breed and had three first lactation periods. Cows fathered by 249 Polish bulls, 177 German bulls, 117 Dutch bulls, 107 French bulls, 68 American bulls and 27 Canadian bulls were selected. The number of cows fathered by Polish, German, Dutch, French, American and Canadian bulls was, respectively, 759, 333, 252, 210, 159 and 77 animals.

In the cows fathered by bulls from various countries, the milk productivity, the fat, the protein and the VCM (milk corrected for the fat and protein content according to the formula by Arbel *et al.* 2001), fat and protein, as well as the difference between the above component contents in the milk (DFP) together with the relationship between protein and fat content (PFR) were compared during three, consecutive lactation periods conducted over 305 days. Moreover, the frequency with which the cows - which had been fathered by bulls from various countries - gave milk, in which the difference between fat and protein content during three consecutive lactation periods (jointly) was $\leq$ 0% (protein content equal to or higher than fat content), 0.01–0.60%, 0.61–1.20% and

above 1.20%. Similarly, the frequency of animals fathered by bulls from various milk producing countries in which the relationship between protein and fat (PFR) was ≤ 0.700, 0.701–0.800, 0.801–0.900 and above 0.900.

The material collected was statistically analysed using STATISTICA software. The significance in the differences between the groups was determined by means of the Tukey test and the significance of the frequency of the difference between the fat and protein content (DFP), and the relationship between the protein and fat content (PFR) in the milk of those cows fathered by bulls from various countries was evaluated using the Ch^2 test.

RESULTS AND DISCUSSION

It was found that the highest productivity of milk, fat, protein and VCM milk during the first 305-day lactation period was achieved by those cows who had been fathered by bulls from the USA (Tab. 1). The predominance of these animals over the milk production of cows sired by bulls from Holland, France, Canada, Germany and Poland was, respectively, in milk productivity – 17, 19, 21, 28 and 36%, in fat – 5, 11, 8, 16 and 26%, in protein – 12, 16, 21, 23 and 33%, and in VCM milk – 10, 14, 17, 21, 31% and was statistically highly significant (compared to the fat productivity in the cows from Holland and Canada – the differences were not significant).

Similar results were obtained by Antkowiak *et al*. [2009] who discovered that in cows fathered by bulls from the USA, France and Canada, the highest milk productivity during the first 305-day long lactation period was achieved by the animals having been sired by bulls from the USA. In studies by Niedziałek *et al*. [2002], the highest milk, fat and protein productivity during the first lactation period was achieved by the animals whose fathers had come from the USA and Canada as compared to the heifers fathered by European (French, German and Dutch) bulls. Similarly, Szarek and Pogorzelska [2006] quote that the highest milk productivity during the first 305 day lactation was achieved by the cows fathered by bulls the from the USA.

Our own studies showed (Tab. 2) that during the second lactation period, those cows which had been fathered by bulls from the USA also achieved a significantly higher productivity of milk and its components as well as VCM than that from animals sired from other countries, however the differences were lower than during the first lactation period (except for the fat productivity in those cows fathered by bulls from Canada and Holland, and the differences were not significant).

During the third lactation period, no significant differences were noted in the milk, fat and protein productivity of those cows, fathered by bulls from the USA and those animals sired by bulls from Holland and Canada (Tab. 3). Cows sired by bulls from the USA were still characterised by a significantly higher productivity of milk and its components during the third lactation period than were those animals which had been sired by Polish or German bulls (except for the fat and protein productivity in cows sired by bulls from Germany and the USA – where the differences were not significant).

The results presented in Tables 1–3 showed that the cows sired by bulls from the USA were characterised by the significantly lowest fat content in the milk during the first three lactation periods when compared to cows sired by bulls from various other countries,

Table 1. The milk yield, fat and protein contents in 1st 305-day lactation periods and relations between these milk components in cows fathered by bulls from different country

Tabela 1. Wydajność mleka, zawartość tłuszczu i białka w I 305-dniowej laktacji oraz relacje między tymi składnikami w mleku krów po buhajach z różnych krajów

Bulls from Buhaje z		Cows (pcs) Krowy (szt.)	Yield, (kg) Wydajność (kg)			Content, (%) Zawartość (%)		DFP RTB (%)	PFR SBT	VCM (kg)
			milk mleka	fat tłuszczu	protein białka	fat tłuszczu	protein białka			
Poland	$\bar{x}$	759	5848^{aA}	233.42^{A}	191.12^{A}	3.99^{aA}	3.27^{ac}	0.72^{aAC}	0.819^{aAC}	6695^{A}
Polski	sd		1567.41	65.14	52.68	0.50	0.21	0.50	0.109	1807.99
Holland	$\bar{x}$	252	6825^{B}	281.73^{BD}	226.69^{B}	4.13^{bA}	3.32^{bdA}	0.81^{AC}	0.803^{AC}	7988^{B}
Holandii	sd		1758.82	70.94	57.94	0.46	0.18	0.44	0.088	1993.54
Germany	$\bar{x}$	333	6248^{bAC}	253.51^{C}	206.50^{C}	4.06^{A}	3.31^{A}	0.75^{AC}	0.815^{AC}	7248^{CE}
Niemiec	sd		1797.95	75.52	62.06	0.50	0.21	0.47	0.103	2136.45
Francji	$\bar{x}$	210	6704^{BC}	264.64^{BC}	220.02^{BC}	3.95^{aA}	3.28^{adAC}	0.67^{AD}	0.830^{AB}	7677^{BC}
France	sd		2273.35	84.29	73.69	0.53	0.19	0.51	0.106	2488.39
USA	$\bar{x}$	159	7968^{D}	294.89^{DE}	254.80^{D}	3.70^{B}	3.20^{bcBC}	0.50^{BD}	0.864^{B}	8779^{D}
USA	sd		1979.71	63.73	60.14	0.54	0.20	0.51	0.121	1944.82
Canada	$\bar{x}$	77	6562^{AB}	273.88^{BCE}	211.16^{ABC}	4.17^{A}	3.22^{ac}	0.95^{bC}	0.772^{bC}	7530^{ABE}
Kanady	sd		1479.84	58.62	46.70	0.53	0.20	0.51	0.105	1573.29

Means values denoted with different letters are significantly different: a, b – at $P \leq 0.05$; A, B – at $P \leq 0.01$.
DFP – difference between fat and protein.
PFR – protein to fat content ratio.
VCM – value corrected milk with respect to fat and protein.
The same symbols are used in tables 1–3.
Średnie oznaczone różnymi literami różnią się istotnie: a,b – przy $P \leq 0,05$; A,B – przy $P \leq 0,01$.
RTB – różnica pomiędzy zawartością tłuszczu i białka.
SBT – stosunek zawartości białka do tłuszczu.
VCM – mleko skorygowane na zawartość tłuszczu i białka.
Te objaśnienia dotyczą tabel 1–3.

Table 2. The milk yield, fat and protein contents in 2nd 305-day lactation periods and relations between these milk components in cows fathered by bulls from different country

Tabela 2. Wydajność mleka, zawartość tłuszczu i białka w II 305-dniowej laktacji oraz relacje między tymi składnikami w mleku krów po buhajach z różnych krajów

Bulls from Buhaje z		Cows (pcs) Krowy (szt.)	Yield, kg Wydajność kg			Content, (%) Zawartość (%)		DFP RTB (%)	PFR SBT	VCM (kg)
			milk mleka	fat tłuszczu	protein białka	fat tłuszczu	protein białka			
Poland	$\bar{x}$	759	6911^{aA}	277.78^{aA}	229.10^{aA}	4.02^{A}	3.32	0.70^{A}	0.825^{A}	8012^{aA}
Polski	sd		1857.96	77.04	60.74	0.63	0.25	0.57	0.124	2088.06
Holland	$\bar{x}$	252	7998^{acBC}	325.07^{B}	268.20^{C}	4.06^{A}	3.35^{A}	0.71^{A}	0.825^{A}	9383^{cBE}
Holandii	sd		2268.67	86.08	71.60	0.53	0.24	0.47	0.104	2431.57
Germany	$\bar{x}$	333	7418^{bAB}	298.60^{bcAC}	245.41^{bAE}	4.03^{A}	3.31	0.72^{A}	0.821^{A}	8591^{bACF}
Niemiec	sd		2301.14	88.31	73.28	0.58	0.21	0.54	0.122	2485.76
Francji	$\bar{x}$	210	7865^{BC}	304.68^{acBC}	260.97^{BCE}	3.87^{A}	3.32^{a}	0.55^{a}	0.857^{a}	9025^{BF}
France	sd		2650.19	89.56	84.88	0.63	0.23	0.56	0.127	2776.04
USA	$\bar{x}$	159	9216^{D}	332.78^{bB}	296.98^{aD}	3.61^{B}	3.22^{bB}	0.39^{bB}	0.891^{bB}	10137^{dDE}
USA	sd		2203.19	65.19	62.81	0.59	0.24	0.50	0.116	2005.23
Canada	$\bar{x}$	77	7905^{bcAB}	328.77^{BC}	262.26^{b}	4.16^{A}	3.32	0.84^{bA}	0.798^{A}	9265^{BCD}
Kanady	sd		1908.29	70.18	59.82	0.60	0.24	0.53	0.115	1985.38

Table 3. The milk yield, fat and protein contents in 3rd 305-day lactation periods and relations between these milk components in cows fathered by bulls from different country

Tabela 3. Wydajność mleka, zawartość tłuszczu i białka w III 305-dniowej laktacji oraz relacje między tymi składnikami w mleku krów po buhajach z różnych krajów

Bulls from Buhaje z		Cows (pcs) Krowy (szt.)	Yield, (kg) Wydajność (kg)			Content, (%) Zawartość (%)		DFP RTB, (%)	PFR SBT	VCM (kg)
			milk mleka	fat tłuszczu	protein białka	fat tłuszczu	protein białka			
Poland	$\bar{x}$	759	7258^{aA}	291.13^{A}	239.67^{aA}	4.01^{A}	3.30	0.71^{A}	0.822^{aA}	8385^{aA}
Polski	sd		1895.23	78.64	61.18	0.62	0.23	0.60	0.127	2097.68
Holland	$\bar{x}$	252	8350^{BD}	341.88^{B}	279.19^{B}	4.09	3.34	0.75^{A}	0.816^{A}	9797^{B}
Holandii	sd		2028.52	84.61	64.94	0.63	0.20	0.59	0.117	2221.18
Germany	$\bar{x}$	333	7727^{bAC}	308.72^{AC}	254.72^{bAC}	4.00^{A}	3.30	0.70^{A}	0.825^{A}	8905^{bAC}
Niemiec	sd		2133.42	80.60	67.22	0.62	0.22	0.59	0.126	2248.41
Francji	$\bar{x}$	210	8096^{BC}	319.32^{aBC}	267.73^{aBC}	3.94^{A}	3.31	0.63^{a}	0.840^{A}	9316^{BC}
France	sd		2591.81	93.63	83.54	0.65	0.23	0.60	0.129	2773.68
USA	$\bar{x}$	159	8888^{D}	329.28^{BC}	290.23^{bB}	3.70^{B}	3.27	0.43^{bB}	0.883^{B}	9947^{B}
USA	sd		1945.10	67.55	60.76	0.61	0.22	0.56	0.132	1963.57
Canada	$\bar{x}$	77	8483^{BCD}	358.83^{bB}	278.50^{BC}	4.23^{A}	3.28	0.95^{A}	0.775^{A}	9919^{BC}
Kanady	sd		1855.93	87.51	60.79	0.61	0.22	0.57	0.105	2164.51

Table 4. The frequency of cows giving milk, characterized by the specified difference between the fat and protein content (DFP) in relation to the country of origin of their fathers

Tabela 4. Częstotliwość występowania krów dających mleko o określonej różnicy między zawartością tłuszczu i białka (RTB) w zależności od kraju pochodzenia ich ojca

Class intervals between fat and protein content, (%) Przedziały klasowe różnic między zawartością tłuszczu i białka, (%)	Bulls from – Buhaje z											
	Poland Polski		Holland Holandii		Germany Niemiec		France Francji		USA USA		Canada Kanady	
	n	%	n	%	n	%	n	%	n	%	n	%
	$Chi^2 = 171.03^{**}$											
Percentage of fat equal to, or lower than, the percentage of protein – Procent tłuszczu równy i mniejszy niż procent białka	194	8.52	45	5.95	81	8.11	67	10.64	83	17.40	9	3.90
0.01– 0.60	736	32.32	226	29.90	281	28.13	225	35.71	213	44.66	43	18.61
0.61–1.20	947	41.59	343	45.37	448	44.84	229	36.35	133	27.88	109	47.19
> 1.20	400	17.57	142	18.78	189	18.92	109	17.30	48	10.06	70	30.30
Total – Razem	2277	100.00	756	100.00	999	100.00	630	100.00	477	100.00	231	100.00

**Significant at $P \leq 0.01$ – Istotne przy $P \leq 0{,}01$.

Tabela 5. The frequency of cows giving milk with a specified protein to fat ratio (PFR) in relation to the country of origin of their fathers
Table 5. Częstotliwość występowania krów dających mleko o określonym stosunku zawartości białka do tłuszczu (SBT) w zależności od kraju pochodzenia ich ojca

Category of protein to fat ratio Przedziały klasowe stosunku zawartości białka do tłuszczu	Bulls from – Buhaje z											
	Poland Polski		Holland Holandii		Germany Niemiec		France Francji		USA USA		Canada Kanady	
	n	%	n	%	n	%	n	%	n	%	n	%
$Chi^2 = 169.77^{**}$												
≤ 0.700	242	10.63	73	9.66	96	9.61	68	10.79	21	4.40	37	16.03
0.701–0.800	726	31.88	252	33.33	360	36.04	163	25.87	98	20.55	105	45.45
0.801–0.900	763	33.51	287	37.96	346	34.63	220	34.92	162	33.96	60	25.97
> 0.900	546	23.98	144	19.05	197	19.72	179	28.41	196	41.09	29	12.55
Total – Razem	2277	100.00	756	100.00	999	100.00	630	100.00	477	100.00	231	100.00

**Significant at P ≤ 0.01 – Istotne przy P ≤ 0,01.

especially those cows having been sired by Canadian bulls (except for those cows having been sired by bulls from Holland in the third lactation period where the differences were not significant). A significantly lower content of fat in the milk of heifers fathered by bulls from the USA as opposed to that from animals having been sired by bulls from France and Canada was also proved in the studies by Antkowiak *et al*. [2009].

The highest protein content in three consecutive lactation periods (Tab. 1–3) was found in the milk from cows having been sired by Dutch bulls (from 3.32 to 3.35%), and the lowest was found in the milk of the animals having been sired by bulls from the USA (from 3.20 to 3.27%). A higher percentage of protein in the milk from cows sired by bulls from Holland than in that from animals sired by bulls from Germany and France was also shown in the study by Sawicka [1999] and Sawicka *et al.* [2000]. Moreover, in our own studies (Tab. 1), a higher protein content in milk was found during the first lactation period in the daughters of French sires than in the milk of the descendants of the American and Canadian bulls which was also noted by Antkowiak *et al.* [2009].

In studies by Sawa [2003] carried out on a numerically significant population of active cows, it was shown that in the milk of those animals of which the protein content was equal to or higher than the fat content, constituted as little as 1.07% of the total population. Hence, while evaluating the milk productivity of cows, the differences between fat and protein content (DFP) and the relationships between protein and fat content (PFR) in the milk are significant issues [Groen *et al*. 1997, Hibner *et al*. 1997, Gnyp *et al*. 2001, Pogorzelska *et al.* 2004, Tomaszewski *et al*. 2007].

It was also ascertained that those cows fathered by bulls from Canada showed an unfavourable (the highest) difference between fat and protein content (DFP) in the milk and the least favourable relationship between protein and fat content (PFR), whereas the best (the lowest) DFP and the most favourable (the highest) PFR was achieved in the milk of those cows fathered by bulls from the USA during all three lactation periods (Tab. 1–3). Similarly, in the milk of those cows fathered by bulls from the USA, the highest relationship was between protein and fat of 0.864, whereas the lowest of 0.772, was found in the milk of the cows fathered by bulls from Canada (at $P \leq 0.01$).

Table 4 presents the frequency of differences between fat and protein content in the milk (jointly from the first three 305-day long lactation periods) in the cows fathered by bulls from various countries in the specified class intervals. The results of the Ch^2 test showed a highly significant difference in the frequency of the cows giving milk with a determined difference between fat and protein content depending on the country of origin of their father. The highest percentage of cows producing milk with percentage fat content equal to, or lower than, the content of protein was noted among the animals sired by bulls from the USA (17.4%), and the lowest was among the cows sired by bulls from Canada (3.90%). In the least favourable interval (> 1.20) there were almost twice as many cows sired by bulls from Poland, Holland, Germany and France and 3 times more cows which had been sired by Canadian bulls than had been sired by USA bulls.

A detailed analysis of the relationship of protein to fat (PFR) in the milk from the cows sired by (jointly during three first 305-day long lactation periods) bulls from various countries in the class intervals established, was presented in Table 5. Results of the Ch^2 test showed highly significant differences in the frequency of those cows giving milk with a specific PFR depending on the origin of sires from various countries. It was ascertained that as many as 16% of the cows sired by Canadian bulls appeared in the first (the

least favourable) PFR interval (≤ 0.700) as compared to only 4% of those cows sired by bulls from the USA. Forty-one percent (41%) of those cows fathered by bulls from the USA and only 13% of those animals sired by bulls from Canada were found in the highest (the best) interval of the relationship of protein to fat (> 0.900).

In conclusion the study has shown that those cows which had been fathered by bulls from the USA showed the highest milk yield during three lactation periods and also showed the significantly lowest fat content in the milk. They were also characterised by the lowest significant difference between the fat and protein content in the milk (DFP) and the highest relationship of protein to fat in milk (PFR) during three lactation periods. Over three consecutive lactations, the highest protein content was found in the milk of cows which had been fathered by Dutch bulls, while the lowest protein content was to be found in that milk taken from cows which had been fathered by bulls from the USA. The results of this study may be used to the advantage of Polish farmers specialising in the production of milk, have a selection of semen of bulls from different countries for breeding cows depending on the expected milk (quantity, composition of milk and its final destination).

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Streszczenie. Porównano wydajność i skład mleka oraz relacje między zawartością tłuszczu i białka w mleku w trzech 305-dniowych laktacjach 1790 krów holsztyńsko-fryzyjskich odmiany czarno-białej po buhajach z Polski, Holandii, Niemiec, USA, Francji i Kanady. Wykazano, że krowy po rozpłodnikach z USA uzyskały najwyższą wydajność mleka w trzech laktacjach, przy istotnie najniższej zawartości tłuszczu w mleku oraz cechowały się istotnie najmniejszą różnicą między zawartością tłuszczu i białka w mleku (RTB) i najwyższym stosunkiem białka do tłuszczu (SBT) w trzech laktacjach. Stwierdzono największą zawartość białka w mleku krów po rozpłodnikach holenderskich, najmniejszą zaś w mleku po buhajach z USA w trzech kolejnych laktacjach. Największą częstość występowania krów dających mleko o zawartości tłuszczu równej i mniejszej od zawartości białka wykazano u krów po buhajach z USA, najmniejszą zaś u zwierząt po buhajach z Kanady. Niekorzystną (największą) różnicą między zawartością tłuszczu a zawartością białka (RTB) oraz najmniej korzystnym stosunkiem zawartości białka do tłuszczu (SBT) w mleku w trzech laktacjach cechowało się mleko krów po buhajach z Kanady, natomiast najlepszą RTB i najkorzystniejszym SBT mleko krów po buhajach z USA.

Słowa kluczowe: pochodzenie buhajów, mleczność krów, relacje tłuszcz–białko