Journal of Microbiology,
Biotechnology and
Food Sciences

Barłowska et al. 2012 : 1 (5) 1205-1220

REGULAR ARTICLE

EFFECT OF THE PRODUCTION SEASON ON NUTRITIONAL VALUE AND TECHNOLOGICAL SUITABILITY OF MILK OBTAINED FROM INTENSIVE (TMR) AND TRADITIONAL FEEDING SYSTEM OF COWS

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ABSTRACT

The seasonal variations in milk yield and its chemical composition arise mainly from changes in feeding of the cattle in different seasons of the year. A constant quantity of production and a similar quality of the raw material supply farms, where the feeding of cows is uniform throughout the year (TMR and PMR). The study included 1211 samples of milk obtained in the summer season (663) and in the winter season (548) from cows maintained in traditional and intensive (TMR) system of production. Following parameters were determined: content of fat, protein, casein, lactose and dry matter; acidity (pH value); heat stability; rennet coagulation time; content of α-lactalbumin, β-lactoglobulin, bovine serum albumin, lactoferrin, lysozyme and fatty acid profiles. Cows fed in the TMR system produced significantly ($P \leq 0.01$) more milk and of a better chemical composition regardless of the season of production. Milk obtained from cows fed traditionally had the most profitable protein to fat ratio (0,90) and the shortest time of rennet coagulation (3:26 min). It contained significantly ($P \leq 0.01$) more whey proteins and had better fatty acid profiles for health. In addition the differences were usually larger in the summer season than in the winter season. It is possible to state that in summer season, when the animals are maintained on the pasture, milk obtained from cows fed traditionally is more suitable for processing and contains more biologically active substances. The daily milk yield and other important quality features of milk, significant interactions between season of production and system of feeding were revealed.

Keywords: milk, nutritional value, technological suitability, production season, production system

INTRODUCTION

The dairy industry requires acquired raw material to be of both balanced chemical composition and technological parameters throughout the year. Seasonal variations in milk yield and its chemical composition arise mainly from changes in feeding of the cattle in different seasons of the year **(Barłowska and Litwińczuk, 2006; Ozrenk and Selcuk Inci, 2008; Slots *et al.*, 2009)**. It concerns mostly small farms that use traditional system of feeding. Larger farms where the feeding of cattle is uniform throughout the year (TMR – *Total Mixed Ration* and PMR - *Partial Mixed Rations*) **(Tucker *et al.*, 2001)** however, assure the constant size of production and balanced quality of the raw material.

Despite the fact that in the last 20-30 years in the intensification of milk production has appeared in developing countries from the global point of view, small farms still determine the level of milk production. The data from 2010 **(IFCN Dairy Report, 2011)** clearly show that 145 mln of farms participate in the production of milk worldwide. From 90 evaluated countries (98% of world milk production) only in 11 herds that run above 100 cows occur whereas in most farms only between 1 to 3 cows can be found. In recent years vital changes have occurred in Polish milk farms structure among others going towards the increase of the number of cows in herds. In 2010 (in comparison to 2009) the number of farms keeping milk cows decreased by 6% (to approximately 465 thousands). Mostly the smallest farms holding up to 9 cows withdrew from milk production. The number of such farms diminished by about 1/3, whereas in larger farms keeping from 100 to 199 cows the amounts increased approximately by half **(Olkowska, 2011)**.

In larger farms, set for intensive production of milk, cows of highly productive breeds are kept. Their genetic potential (taking balanced feeding into consideration) is responsible for substantial gains in production. Local breeds of cows are held in small farms (cows of lower milk yield). Because of years of living in a particular area they adapted to the environmental conditions: they are more resistant to diseases and can utilize available fodder better **(Litwińczuk, 2011)**.

In small farms, frequently localized where the landscape prevents the intensification of agricultural production and where there is still a high participation of grassland, traditional system of feeding is adapted. Cows from spring to autumn exploit use the pastures or green forage is delivered to the barn, whereas in winter as a base of their feeding hay and hay silage is distributed. High variations of milk production and chemical composition are registered there **(Barłowska and Litwińczuk, 2006; Gardzina-Mytar *et al.*, 2007)**. In the intensive production systems, where similar feeding of animals is practiced for the whole year (TMR and PMR), the seasonal differences in this range are slighter **(Strzałkowska *et al.*, 2010)**.

Most of the recent publications associated with the evaluation of season influence on milk production concentrate on their interaction with milk yields and variations in basic chemical composition **(Litwińczuk *et al.*, 2006; Gardzina-Mytar *et al.*, 2007; Ozrenk and Selcuk Inci, 2008)**.

The aim of the study was to evaluate the influence of the production season on nutritional value and technological suitability of milk obtained from cows being held in farms with intensive (TMR) and traditional system of feeding.

MATERIALS AND METHODS

The study included 1211 milk samples obtained in the summer season (663) and in the winter season (548) from cows maintained in traditional (823) and intensive (388) system of production. In 50 farms practicing traditional husbandry system 3 local breeds of cows were kept, i.e. White-Backed (BG), Polish Red (RP), Polish Black and White (ZB) and Simmental (SM). Animal feeding in summer was generally based on lenient grazing and winter included hay, hay silage and optionally fodder beets, potatoes, and concentrated feed that was self-manufactured. In 6 farms producing milk with the use of intensive system, cows of Polish Holstein-Friesian breed (PHF) and Simmental (SM) were kept. They were maintained in free-stall barns and fed in TMR system (*Total Mixed Ration*) that consisted of maize silage, hay silage and industrial concentrated feed. In 3 farms from this group during summer cows were given extra green forage from meadow grass. All of the farms were included in the Milk Recording.

Milk samples were collected on each farm, individually from cows between 30th and 240th day of lactation, twice a year, that is in summer and winter production season, in total 976 milk samples.

Following parameters were determined:

- basic chemical composition, i.e. content of fat, protein, lactose and dry matter - Infrared Milk Analyzer (Bentley Instruments);
- casein concentration – Wolker's method (according to PN 68/A-86122);
- active acidity (pH value) –Pionneer 65 pH-meter (Radiometer Analytical);
- heat stability in 140 °C in oil bath (TEWES-BIS) with White and Davies' method (**Barłowska, 2011**);
- rennet coagulation time according to Shern's method, expressed as the time of formation of casein flakes **(Barłowska, 2011)**;
- concentration of whey proteins, i.e. α-lactoalbumin (α-LA), β-lactoglobulin (β-LG), bovine serum albumin (BSA), lactoferrin and lysozyme – using reverse-phase high-performance liquid chromatography (RP-HPLC). The procedure of protein separation was based on the method elaborated by **Romero *et al.* (1996)** with own modifications.

Additionally, 246 milk (summer season – 121, winter season – 125) samples were examined for fatty acid profile with the use of gas chromatograph Varian CG 3900 with flame-ionization detector (FID) and Star GS Workstation ver. 5.5 program. These examinations included following groups of fatty acids:

- SFA – saturated fatty acids, SFAsmc – short and medium chain saturated fatty acids, including acids from C4:0 to C14:0 and SFAlc – long chain saturated fatty acids, including acids from C15:0 to C18:0;
- UFA – unsaturated fatty acids, including monounsaturated fatty acids (MUFA – C10:1, C14:1, C15:1, C16:1, C17:1 and C18:1) and polyunsaturated fatty acids (PUFA –C18:2, C18:3 and CLA – conjugated linoleic acid).

Moreover, proportions between aforementioned fatty acids were calculated, i.e. SFA/UFA, MUFA/SFA, PUFA/SFA and CLA/PUFA.

The examinations included samples collected exclusively from animals with a healthy udder, namely with somatic cell count in milk not exceeding 400,000 SC in 1 ml of milk – Somacount 150 apparatus manufactured by Benteley Instruments.

The results obtained were analyzed statistically using StatSoft Inc. software. STATISTICA ver. 6, on the basis of one- and two-way ANOVA with an interaction, means and standard deviations were given for individual analyzed traits, the significance of differences between means was estimated by Fisher's LSD test at $P \leq 0.05$ level.

RESULTS

Cows fed in the TMR system obtained significantly ($P \leq 0.01$) higher daily milk yield with regardless of the season of production, i.e. approximately 8.3 kg in the summer season and 13.1 kg in the winter season (Tab 1). Milk from these cows had significantly ($P \leq 0.01$) better basic chemical composition and in regard to fat, casein and dry matter content, differences were larger in the summer season, appropriately: (0.66 vs 0.15%), (0.22 vs 0.10%) and (0.91 vs 0.33%), and for total protein in the winter season (0.19 vs 0.20%). Milk obtained from cows fed in that system was characterized by a higher resistance to thermal processing (approximately 0:22 min in the summer season and 0:26 min in the winter season). However milk acquired from cows fed traditionally in the summer season had significantly ($P \leq 0.01$) superior ratio of protein to fat (0.90) and shorter time of rennet coagulation (3:26 min) in comparison to animals fed in full dose system (appropriately: 0.81 and 5:07 min). In the winter season similar differences were not observed.

Milk acquired from cows fed in the traditional system contained significantly ($P \leq 0.01$) more functional whey proteins (Tab 2). Those differences were generally greater in the summer season than in the winter season, i.e. for β-lactoglobulin (0.55 vs 0.28 g/L) and lactoferrin (90.56 vs 19.54 mg/L). For lysozyme higher content was observed in the winter season (1.05 vs 3.65 μg/L).

Milk obtained from cows fed in the traditional system had better healthier profile of fatty acids, especially in the summer season, what was confirmed statistically ($P \leq 0.01$) – Tab 3. It contained 3.30% more unsaturated fatty acids (UFA) in which 2.76% were polyunsaturated fatty acids (PUFA). Moreover, especially it contained 1.42% more CLA and 3.06% less saturated acids (SFA), in which 3.51% were long chain saturated acids (SFAlc). In the winter season the differences were not significant.

Table 1 Milk yield and physical-chemical parameters of milk obtained from cows of analyzed breeds with the season of production and feeding taken into consideration

Item		**Summer season**			**Winter season**			**Interaction of the season x feeding system**
		System of feeding		Approximately in the season	System of feeding		Approximately in the season	
		traditonal	TMR		traditional	TMR		
No.		433	230	663	390	158	548	
Daily milk yield (kg)	$\bar{x}$	18.7^{A}	27.0^{B}	21.6**	15.0^{A}	28.1^{B}	18.8**	xx
	SD	6.9	6.4	7.83	6.3	8.8	9.2	
Fat (%)	$\bar{x}$	3.93^{A}	4.59^{B}	4.16	4.17^{A}	4.32^{B}	4.21	xx
	SD	0.57	0.48	0.62	0.56	0.57	0.56	
Protein (%)	$\bar{x}$	3.48^{A}	3.67^{B}	3.55**	3.41^{A}	3.61^{B}	3.47**	ns
	SD	0.44	0.38	0.43	0.37	0.55	0.44	
Casein (%)	$\bar{x}$	2.58^{A}	2.80^{B}	2.66**	2.54^{A}	2.64^{B}	2.57**	xx
	SD	0.40	0.41	0.42	0.38	0.39	0.38	
Protein to fat ratio	$\bar{x}$	0.90^{B}	0.81^{A}	0.87**	0.83	0.84	0.83**	xx
	SD	0.12	0.09	0.12	0.09	0.10	0.09	
Lactose (%)	$\bar{x}$	4.63^{A}	4.72^{B}	4.67**	4.79	4.78	4.78**	xx
	SD	0.35	0.24	0.32	0.30	0.33	0.31	
Dry matter (%)	$\bar{x}$	12.75^{A}	13.66^{B}	13.07	13.02^{A}	13.35^{B}	13.12	xx
	SD	0.88	0.72	0.94	0.82	1.09	0.92	
Urea (mg/L)	$\bar{x}$	225.5^{B}	191.5^{A}	213.7**	165.7	163.0	164.9**	xx
	SD	90.2	91.4	92.0	68.3	48.2	63.3	
Acidity (pH value)	$\bar{x}$	6.70	6.71	6.71**	6.76	6.77	6.77**	ns
	SD	0.11	0.06	0.10	0.11	0.09	0.10	

Coagualation time (min)	$\bar{x}$	3:26[A]	5:07[B]	4:05**	6:06	6:15	6:08**	xx
	SD	1:31	2:19	2:02	3:23	3:01	3:16	
Heat stability (min)	$\bar{x}$	2:50[A]	3:12[B]	2:58**	3:59[A]	4:25[B]	4:06**	ns
	SD	1:07	1:52	1:23	1:44	1:14	1:37	

Legend: a, b – differences between feeding systems within the season significant at P≤0.05, A, B – significant at P≤0.01; ** – differences between seasons significant at P≤0.01; interaction of factors: ^{x} – significant at P≤0.05; ^{xx} – at P≤0.01; ns – non significant

Table 2 The concentration of selected whey proteins in milk obtained from cows of analyzed breeds with regard to the season of production and feeding system

Item		Summer season			Winter season			Interaction of the season x system of feeding
		System of feeding		Approximately in the season	System of feeding		Approximately in the season	
		traditional	TMR		traditional	TMR		
No.		433	230	663	390	158	548	
α-LA (g/L)	$\bar{x}$	1.05^{B}	0.98^{A}	1.03**	1.08^{B}	1.01^{A}	1.06**	ns
	SD	0.17	0.10	0.15	0.15	0.14	0.15	
β-LG (g/L)	$\bar{x}$	3.39^{B}	2.84^{A}	3.20	3.32^{B}	3.08^{A}	3.25	xx
	SD	0.54	0.29	0.54	0.34	0.32	0.36	
BSA (g/L)	$\bar{x}$	0.36^{A}	0.47^{B}	0.40**	0.46^{B}	0.43^{A}	0.45**	xx
	SD	0.15	0.18	0.17	0.13	0.10	0.12	
Lactoferrin (mg/L)	$\bar{x}$	181.18^{B}	90.62^{A}	149.77**	117.35^{B}	97.81^{A}	111.72**	xx
	SD	63.60	22.79	68.41	14.06	15.80	17.05	
Lysozyme (μg/L)	$\bar{x}$	8.63^{b}	7.58^{a}	8.27**	11.16^{B}	7.51^{A}	10.11**	xx
	SD	7.10	4.24	6.27	5.12	2.46	4.81	

Legend: α-LA – α-lactalbumin; β-LG – β-lactoglobulin; BSA – bovine serum albumin; a, b – differences between systems of feeding within the season significant at P≤0.05, A, B – significant at P≤0.01; ** - differences between seasons significant at P≤0.01; interaction of factors: ^{x} – significant at P≤0.05; ^{xx} – at P≤0.01; ns – non significant

Table 3 Fatty acid profile (%) of milk from cows of analyzed breeds with regard to the season of production and feeding system

Item		**Summer season**			**Winter season**			**Interaction of the season x system of feeding**
		System of production		Approximately in the season	System of production		Approximately in the season	
		traditional	TMR		traditional	TMR		
No.		89	32	121	82	43	125	
CLA	$\bar{x}$	1,70[A]	0,28[B]	1,08*	1,10[A]	0,49[B]	0,90*	ns
	SD	0,95	0,30	0,84	0,64	0,67	0,55	
SFA	$\bar{x}$	61,38[a]	64,44[b]	62,19**	67,26	67,10	66,20**	ns
	SD	7,62	6,20	7,37	8,05	6,46	7,55	
SFAsmc	$\bar{x}$	15,48	15,03	15,36	16,95	16,16	16,68	ns
	SD	4,80	4,13	4,62	9,95	4,85	8,53	
SFAlc	$\bar{x}$	45,91[a]	49,42[b]	46,83**	51,57	50,93	51,34**	x
	SD	7,97	4,33	7,34	7,68	6,17	7,17	
UFA	$\bar{x}$	38,63[b]	35,33[a]	37,75**	32,32	32,82	32,50**	ns
	SD	7,11	6,39	7,41	8,49	6,53	7,85	
MUFA	$\bar{x}$	32,67	32,13	32,53**	28,66	29,74	29,03**	ns
	SD	5,60	5,81	5,64	7,28	5,36	6,68	
PUFA	$\bar{x}$	5,96[B]	3,20[A]	5,23**	3,76	3,08	3,52**	x
	SD	4,90	1,38	4,42	2,67	1,77	2,41	
SFA/UFA	$\bar{x}$	1,69	1,91	1,75**	2,34	2,15	2,27**	ns
	SD	0,60	0,54	0,57	1,17	0,55	1,00	
MUFA/SFA	$\bar{x}$	0,55	0,51	0,54**	0,44	0,46	0,45**	ns
	SD	0,16	0,14	0,16	0,17	0,14	0,16	

PUFA/SFA	$\bar{x}$	0,11[B]	0.05[A]	0,09**	0,06	0.05	0,06**	ns
	SD	0,11	0,03	0,09	0.05	0,04	0.05	
CLA/PUFA	$\bar{x}$	0,22[B]	0,08[A]	0,19	0,27[B]	0,13[A]	0,22	x
	SD	0,17	0,08	0,16	0,17	0,10	0,16	

Legend: CLA – conjugated linoleic acid; SFA – saturated fatty acids, smc – short and medium chain, lc – long chain; UFA – unsaturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids; a, b – differences between systems of feeding within the season significant at P≤0.05, A, B – significant at P≤0.01; ** - differences between seasons significant at P≤0.01; interaction of factors: [x] – significant at P≤0.05; [xx] – significant at P≤0.01, ns – non significant

For daily milk yield and the other important features of milk, such as: the contents of fat, casein, lactose, dry matter, whey protein, protein to fat ratio, long chain saturated acids (SFAlc), polyunsaturated fatty acids (PUFA) and the ratio of CLA to PUFA, significant interactions between season of production and system of feeding were noticed.

DISCUSSION

Higher milk yield, with a better basic chemical composition from cows being fed with TMR system in comparison to traditional systems (cows fed on a pasture), presented in this research are confirmed by other researchers' studies **(White *et al.*, 2001; Bargo *et al.*, 2002; Schroeder *et al.*, 2003; Barłowska, 2007; Januś, 2009)**. **White *et al.* (2001)** report that cows of Holstein-Friesian breed fed in TMR system indicated 9.2 kg more milk yield, 0.10% and 0.20% higher amounts of fat and lactose in comparison to cows fed on pastures. As far as Jersey breed cows are concerned, the differences present as follows: 0.42% for fat, 0.19% for proteins and 0.07% for lactose. In addition, **Schroeder *et al.* (2003)** in their research presented that cows of Holstein-Friesian breed fed with TMR system produced 1.0 kg more milk daily with a higher content of fat (0.46% more), protein (0.21% more) and lactose (0.18% more) than the animals held on pastures and fed with a concentrate on the basis of milled maize.

Higher milk yield differences and the chemical composition between evaluated feeding systems (traditional and TMR) in the summer season arise mainly from the diverse types of cow feeding. The main forage in the traditional system of feeding in the summer is rangeland and alternatively added concentrate does not fully balance the nutritional dosage. It is confirmed by significantly worse base milk composition with a higher content of urea ($P \leq 0.01$). **Gardzina-Mytar *et al.* (2007)** claim that nutrition is an essential factor influencing differences of milk yield and its chemical composition (in particular fat and to a lesser degree, proteins). Cows of Polish Red breed in the summer season of feeding achieved higher productivity with a lower content of dry matter in the milk. In the winter season, as shown by this study, lesser variations in the basic composition of milk and no significant differences in the content of urea demonstrate better balance of the nutritional dosage in farms using traditional nutrition.

The most profitable parameters in the evaluation of technological suitability of raw material, i.e. the best ratio of protein to fat (0.90) and the shortest time of rennet coagulation (3:26 min) offered milk from the summer season from farms that used traditional system of nutrition. **Tyriesevä *et al.* (2003)** claim that feeding cows with green forage from pastures shortens the time of enzymatic coagulation of milk. **Devold *et al.* (2000)** state that the nutrition system has an influence on protein content (casein, whey proteins) and mineral composition (calcium, magnesium and citrates) quantity and ratio of which have a significant effect on the time of milk coagulation.

In the farms practicing traditional systems of nutrition cows of local breeds (Polish Red, White-Backed and Polish Black and White) and as well Simmental were kept. Many studies (**Chiofalo *et al.*, 2000; Barłowska, 2007; De Marchi *et al.*, 2007; Gandini *et al.*, 2007**) indicate that milk from such animals is characterized by better parameters for processing, especially in cheese production. **Chiofalo *et al.* (2000)**, while compering two factors that determine the effectiveness of milk for cheese production in two breeds of cows, i.e. Modicana (local) and Holstein (high productive), indicated that milk from the first breed offered better results (5,0 min shorter time of coagulation (r), 4,2 min shorter curd formation time (K_{10}) and 17,8 better curd firmness (A_{30}). **De Marchi *et al.* (2007)** conducted similar research on five breeds of cows and indicated that the best results offered a local breed called Redena (r = 13.5 min, K_{10} = 5.9 min and A_{30} = 27 mm)), whereas the worst – cows of Holstein-Friesian breed (r = 18.0 min, K_{10} = 8.2 min and A_{30} = 17.5 mm).

It should be noted that milk obtained from cows in the summer season fed within the traditional system contained as much as 191.2 mg/L of lactoferrin. That is nearly two times more than in the other three underlined groups (90.6 – 117.4 mg/L). Lactoferrin and its peptides (lactoferricin, lactoferramin) are one of the most important biologically active compounds in milk that have a large impact on health promotion (**Król *et al.*, 2011; Szwajkowska *et al.*, 2011**). **Król *et al.* (2008)** emphasize the favorable impact of pasture feeding on the whey protein composition in milk.

Many authors indicate that in the case of cows being fed traditionally, especially on pastures (**Chilliard *et al.*, 2001; Schroeder *et al.*, 2003; Bargo *et al.*, 2006**), the profile of fatty acids content is beneficial. In particular higher content of polyunsaturated fatty acids (in which is CLA) and lesser amounts of saturated fatty acids. This contributes to the fact that fresh fat from the grass has high concentration (55-65%) of α-linoleic acid and CLA is an indirect product of biohydrogenation of linoleic acid (C18:2 *cis*9, *cis*12) and α-linoleic (C18:3 *cis*9, *cis*12, *cis*15), that undergo this process through the microflora of the ruminant's rumen. CLA can also be obtained as a result of desaturation of vaccenic acid (18:1, *trans*11) inside the mammary gland **(Chilliard *et al.*, 2001; Bauman *et al.*, 2006; Frelich *et al.*, 2008**).

CONCLUSION

The system of nutrition of cows has the highest impact on milk yield and nearly all other analyzed physical-chemical parameters of milk, i.e. basic chemical composition, heat stability, content of whey proteins and a profile of fatty acids.

Cows fed within the TMR system produced (regardless of the season) definitely more milk with a better content of base composition (fat, proteins in which casein, dry matter), though with a lower amount of biologically active compounds (whey proteins and polyunsaturated fatty acids in which CLA).

Highly significant influence of the season of production on daily milk yield as well as nearly all analyzed indicators of technological suitability (content of proteins in which casein, protein to fat ratio and rennet coagulation time) and the content of biologically active compounds was proved in this study.

Milk with more favorable parameters in this range was obtained in the summer season. This is probably associated with green forage feeding indicated by the fact that in this season the variances in evaluated parameters of milk quality between TMR and traditional system were greater than in the winter season. It should be noted that nearly two times greater amount of lactoferrin was present.

Significant interactions between the season of production and the system of nutrition were demonstrated. It concerned daily milk yield and important features of milk quality such as: content of fat, casein, lactose, dry matter, protein to fat ratio, content of whey proteins, long chain saturated fatty acids (SFAlc), polyunsaturated fatty acids (PUFA) and ratio of CLA to PUFA as well.

Acknowledgments: This work was conducted as part of Ministry of Science and Higher Education project no. NN 311 02 83 34.

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