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Influence of production season x breed and feeding system interactions on daily yield and milk physical-chemical composition

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The aim of this study was to determine the effect of production season x breed and feeding system interactions on daily yield and milk physico-chemical properties. Analyses covered 2278 milk samples collected from Polish Holstein-Friesian Black-and-White and Red-and--White, Jersey and Simmental cows. The pH value, casein content, basic chemical composition including crude protein, fat, lactose and dry matter, as well as somatic cell count were recorded. When evaluating the simultaneous effect of breed and production season on milk chemical composition significant interactions were shown for all analysed parameters except for fat. For most studied parameters, apart from lactose content and protein to fat ratio, the simultaneous effect of the feeding system and production season was recorded. Simmental cows managed in the TMR feeding system in both seasons produced milk with higher contents of basic components.

KEY WORDS: milk / breed / production season / feeding system / interactions

The chemical composition and physico-chemical properties of milk are determined by genetic and environmental factors. It is generally acknowledged that over 50% variation in contents of milk components is related with genetic factors and approx. 40% − with environmental factors [9, 13]. Cow productivity and milk quality are determined mainly by feeding, which in turn to a considerable extent is connected with the production season [7, 8, 14, 18]. Genetic and environmental interactions indicate a significant effect of genotype and environment on production traits of animals, including milk production. However, it needs to be stressed that certain parameters are more sensitive to changes in the environment, including those introduced in the production system [5, 9, 15].

The aim of this study was to determine the effect of production season x breed and feeding system interactions on yield and physico-chemical properties of milk.

Material and Methods

The analyses were conducted in the years 2007-2009 on 17 farms keeping cows of the Polish Holstein-Friesian Black-and-White (PHF BW) and Red-and-White breed (PHF RW), as well as Jersey and Simmental cows. The farms are located in eastern and south--eastern parts of Poland and the cows kept on those farms are covered by the milk recording scheme.

Cows of the Polish Holstein-Friesian and Jersey breeds were kept in the loose barn housing in the intensive management system. Throughout the year an identical feeding regime was adopted for the cows on all the farms based on the Total Mixed Ration (TMR) – 20 kg maize silage, 15 kg haylage, 4 kg balanced feed and 1 kg protein concentrate. Moreover, on all the farms the animals received a similar addition of a standard mineral and vitamin mix for dairy cows (MMB) at 120-170 g / 24 h depending on their productivity and mix type.

Simmental cows kept in the Lubelszczyzna region and the Bieszczady Mts. were housed in loose barns. They were also fed TMR with approx. 25 kg haylage, 4 kg balanced feed and 1 kg protein concentrate, supplemented with 120-170 g standard mineral-vitamin mix. In turn, cows of that breed housed in stanchion barns (in the Bieszczady Mts.) in the spring--summer season grazed on the pasture (*ad libitum*), taking up approx. 50 kg green forage daily and they additionally received 3 kg hay and 2 kg ground grain. In the autumn-winter period their diet was based on haylage (approx. 30 kg), 2 kg hay and 2 kg ground grain. Thus two feeding systems were used in the case of the Simmental breed, i.e. TMR (complete feed all year round) and conventional (pasture in the spring-summer season and silage in the autumn-winter season). This was done in order to provide a more accurate determination for the effect of the feeding system on contents of analysed milk components.

Milk samples were collected individually from each cow during test milking in two seasons, i.e. spring-summer (May – July) and autumn-winter (December – February). Care was taken to collect milk samples from the same cows. A total of 2278 milk samples were collected for analyses, of which 789 came from Polish Holstein-Friesian Black-and-White cows, 486 – Polish Holstein-Friesian Red-and-White cows, 768 – Simmental cows and 235 – from Jersey cows. From Simmental cows fed TMR a total of 395 milk samples were collected, while from those managed in the conventional system it was 373 samples.

Milk samples were transported under cold storage conditions to the laboratory of the Department of Commodity Science and Processing of Raw Animal Materials, the University of Life Sciences in Lublin [1]. In each non-preserved sample the following parameters were recorded: pH using a pH-meter (Elmetron CP-401, Poland), casein content according to AOAC [2], basic chemical composition, i.e. contents of crude protein, fat, lactose and dry matter with an Infrared Milk Analyzer (Bentley Instruments, USA) and somatic cell count by flow cytometry using a Somacount 150 (Bentley Instruments, USA).

Milk samples with somatic cell counts below 400 thousand/cm^3 were selected for further analyses.

To present productivity of evaluated cows data on their milking performance were collected from breeding records run by the Polish Federation of Cattle Breeders and Dairy Farmers.

When assessing the simultaneous effect of production season and cattle breed as well as production season and feeding system the two-way analysis of variance with interaction was applied according to the following linear model:

$$Y_{ijk} = \mu + a_i + b_j + (a_i \text{ x } b_j) + e_{ijk}$$

where:

Y_{ijk} – dependent variable,
μ – effect of total mean,
a_i – effect of *i*-th factor,
b_j – effect of *j*-th factor,
(a_i x b_j) – interaction of two factors,
e_{ijk} – random error.

Statistical calculations were performed using the StatSoft Inc. STATISTICA ver. 6 software. Analyses were conducted based on the General Linear Model (GLM) with the ANOVA procedure for factorial systems with interactions. Significant differences between means in groups were determined using Tukey's test for varying populations at the significance levels $p \leq 0.05$ and $p \leq 0.01$.

Results and Discussion

Results given in Table 1 indicate significant differences ($p \leq 0.01$) in daily milk production of the evaluated cattle breeds. The greatest milk yields were recorded for Polish Holstein-Friesian Black-and-White cows. In turn, milk of Jersey cows was significantly better in terms of its contents of basic components. On average it contained by 1.47% more solids, including by 0.42% more casein, by 0.52% more crude protein and by 0.97% more fat, respectively. Recorded pH values indicate freshness of the analysed raw material and at the same time also its processibility. Król et al. [10] found a lower active acidity (pH=6.63) in milk collected from Jersey cows, while it was higher (pH=6.68) in milk from Polish Holstein-Friesian cows. These differences proved to be statistically significant at $p \leq 0.01$.

Irrespective of the analysed cattle breed (except for Jersey cows) a greater daily productivity was recorded in the spring-summer season (Table 1). In the case of PHF Black-and-White cows and Simmental cows the differences turned out to be statistically significant (at $p \leq 0.01$) and amounted to 3.0 kg and 1.9 kg. In turn, in the autumn-winter season milk contained higher levels of analysed components. Highly significant differences ($p \leq 0.01$) in contents of casein and crude protein were recorded in milk collected from Jersey cows – in both cases they amounted to 0.27%. For casein significant seasonal differences ($p \leq 0.05$) were also observed in milk of PHF Black-and-White cows (0.08%). A significant effect (at $p \leq 0.05$) of the production season on fat content was shown only for milk of PHF Red-and-White cows. In the autumn-winter season in Jersey cows a significantly higher ($p \leq 0.01$) protein to fat ratio was recorded – by 0.05. When assessing the simultaneous effect of breed and production season highly significant interaction were shown (at $p \leq 0.01$) for all the investigated parameters except for fat content (Table 1).

Table 1

Daily yield, pH value and basic chemical composition of milk from evaluated cows' breeds, with regard to production season (mean ±mean standard error; n – number of milk samples)

Breed	Production season	n	Daily yield (kg)	pH	Casein (%)	Crude protein (%)	Fat (%)	Protein to fat ratio	Lactose (%)	Dry matter (%)
Polish Holstein-Friesian Black-White variety	spring-summer	414	28.7^{B} ±0.4	6.71 ±0.01	2.58^{a} ±0.02	3.47 ±0.02	4.24 ±0.03	0.83 ±0.01	4.77 ±0.01	13.14 ±0.05
	autumn-winter	375	25.7^{A} ±0.4	6.70 ±0.01	2.66^{b} ±0.02	3.49 ±0.02	4.26 ±0.03	0.82 ±0.01	4.76 ±0.01	13.16 ±0.05
Polish Holstein-Friesian Red-White variety	spring-summer	219	23.5 ±0.5	6.67^{A} ±0.01	2.66 ±0.03	3.52 ±0.03	4.20^{a} ±0.04	0.85 ±0.01	4.74 ±0.02	13.10 ±0.06
	autumn-winter	267	22.2 ±0.5	6.71^{B} ±0.01	2.73 ±0.03	3.53 ±0.03	4.29^{b} ±0.04	0.83 ±0.01	4.82 ±0.02	13.29 ±0.06
Simmental	spring-summer	391	22.5^{B} ±0.4	$6{,}72^{a}$ ±0.01	2.73 ±0.02	3.62 ±0.02	4.17 ±0.03	0.87 ±0.01	4.72 ±0.01	13.15 ±0.04
	autumn-winter	377	20.6^{A} ±0.4	6.73^{b} ±0.01	2.80 ±0.02	3.69 ±0.02	4.21 ±0.02	0.88 ±0.01	4.72 ±0.01	13.26 ±0.04
Jersey	spring-summer	135	20.1 ±0.4	6.71^{B} ±0.01	2.97^{A} ±0.04	3.94^{A} ±0.05	5.16 ±0.08	0.77^{A} ±0.01	4.76 ±0.02	14.51 ±0.12
	autumn-winter	100	20.6 ±0.3	6.69^{A} ±0.01	3.24^{B} ±0.04	4.21^{B} ±0.04	5.18 ±0.06	0.82^{B} ±0.01	4.73 ±0.03	14.76 ±0.09
Factor influence	breed		xx	xx	xx	xx	xx	xx	xx	xx
	production season		xx	xx	xx	xx	x	xx	ns	ns
	breed x production season interaction		xx	xx	xx	xx	ns	xx	xx	xx

Differences between production season within breed: a, b – differences significant at $p \leq 0.05$; A, B – differences significant at $p \leq 0.01$
Factor influence: x – significant at $p \leq 0.05$; xx – significant at $p \leq 0.01$; ns – not stated

Auldist et al. [3], Litwińczuk et al. [14] and Barłowska [4] also found a more advantageous chemical composition of milk produced in the autumn-winter season. Similarly as in this study, Barłowska et al. [6] showed that milk produced in the spring-summer period by Black-and-White cows, in comparison to that from Red-and-White cows, had greater contents of dry matter (milk solids) (by 0.81% at $p \leq 0.01$), as well as higher levels of lactose (by 0.09%) and fat (by 0.57% at $p \leq 0.01$), while the protein to fat ratio was less advantageous, amounting to 0.79 ($p \leq 0.01$). In turn, Reklewska et al. [16] also reported differences in the contents of analysed components in milk of Simmental cows depending on the production season. In the summer, when cows grazed in the pasture, milk contained by 0.76% less crude protein and by 0.61% less fat.

Data presented in Table 2 show that Simmental cows fed TMR in both seasons produced daily on average 3.6 kg milk more ($p \leq 0.01$) than cows maintained in the conventional management system. At the same time crude protein content was by 0.33% higher, casein content by 0.21% higher, while the contents of fat were by 0.22% and milk solids by 0.51% higher. Additionally, the protein to fat ratio was by 0.03 higher in milk of cows fed using the TMR system. In all the analysed cases these differences proved to be statistically significant at $p \leq 0.01$. Milk obtained from cows fed using the conventional system was characterised by a greater lactose content – by 0.04% ($p \leq 0.05$). Studies conducted by many authors confirmed the effect of feeding on productivity of cows and milk chemical composition [7, 12, 18]. Reklewska et al. [16] reported that cows fed TMR produced milk with higher contents of basic components, i.e. 4.09% crude protein and 4.66% fat. In comparison to the results recorded in this study the difference amounted to +0.28% and +0.37%, respectively. Milk from cows in that group was also found to have a more advantageous protein to fat ratio (0.85). According to Barłowska [4], Simmental cows kept using the conventional feeding system in comparison to those fed balanced ration produced by 7.0 kg less milk daily and their milk contained less dry matter (by 0.09%), protein (by 0.15%) and lactose (by 0.08%). In turn, Król et al. [12] showed that Simmental cows housed in a loose barn and fed TMR produced daily on average by 6.82 kg more milk ($p \leq 0.01$) in comparison to cows maintained in deep litter barns with tying stalls and grazing on the pasture. At the same time in milk of cows receiving TMR all year round the content of crude protein was by 0.07% greater ($p \leq 0.01$), casein – by 0.06% higher ($p \leq 0.05$) and the protein to fat ratio was by 0.03 higher ($p \leq 0.05$). White et al. [18] recorded an increase in daily milk yield (by 9.2 kg) as well as greater contents of fat (by 0.10%) and lactose (by 0.20%) in Holstein cows fed TMR in comparison to the animals maintained in the pasture-based feeding system. In turn, milk of Jersey cows fed in the conventional system was characterised by a less advantageous composition at a higher daily milk production. This finding was also confirmed by Croissant et al. [8], who reported significant differences (at $p \leq 0.05$) also in contents of dry matter and fat in milk of Holstein cows fed TMR and cows in the pasture-based feeding system. Dry matter content in milk produced by cows grazing on the pasture was 11.85%,

Table 2

Daily yield, pH value and basic chemical composition of milk from Simmental cows' breed, with regard to feeding system and production season (mean ±mean standard error; n – number of milk samples)

Feeding system	Production season	n	Daily yield (kg)	pH	Casein (%)	Crude protein (%)	Fat (%)	Protein to fat ratio	Lactose (%)	Dry matter (%)
TMR Intensive	spring-summer	203	23.5 ±0.5	6.70^{**} ±0.01	2.91^{*} ±0.03	3.81 ±0.03	4.25^{*} ±0.03	0.88 ±0.01	4.70 ±0.02	13.50 ±0.06
	autumn-winter	192	23.2 ±0.4	6.73^{**} ±0.01	2.82^{*} ±0.02	3.81 ±0.02	4.34^{*} ±0.04	0.90 ±0.01	4.69 ±0.02	13.40 ±0.05
	average	395	23.4^{A} ±0.3	6.72 ±0.01	2.86^{B} ±0.02	3.81^{B} ±0.02	4.29^{B} ±0.02	0.89^{B} ±0.01	4.70^{a} ±0.01	13.45^{B} ±0.04
Conventional	spring-summer	188	21.7^{**} ±0.6	6.73 ±0.01	2.53^{*} ±0.03	3.41^{*} ±0.03	3.98^{*} ±0.04	0.86 ±0.01	4.73 ±0.02	12.77^{**} ±0.06
	autumn-winter	185	17.5^{**} ±0.5	6.75 ±0.01	2.77^{*} ±0.03	3.56^{*} ±0.03	4.16^{*} ±0.03	0.86 ±0.01	4.74 ±0.02	13.12^{**} ±0.06
	average	373	19.6^{B} ±0.4	6.74 ±0.01	2.65^{A} ±0.02	3.48^{A} ±0.02	4.07^{A} ±0.02	0.86^{A} ±0.01	4.74^{b} ±0.01	12.94^{A} ±0.04
Factor influence	feeding system		xx	ns	xx	xx	xx	xx	x	xx
	production season		xx	xx	x	x	x	ns	ns	xx
	feeding system x production season interaction		xx	x	xx	xx	xx	ns	ns	xx

Differences between feeding system within breed: a, b – differences significant at $p \leq 0.05$; A, B – differences significant at $p \leq 0.01$
Differences between production season within breed: a, b – differences significant at $p \leq 0.05$; A, B – differences significant at $p \leq 0.01$
Factor influence: x – significant at $p \leq 0.05$; xx – significant at $p \leq 0.01$; ns – not stated

while its level in milk fed TMR was 12.43%. Fat content amounted to 3.20% and 3.75%, respectively.

Results of two-way analysis of variance indicate a highly significant ($p \leq 0.01$) effect of the breed x production season interaction on contents of all analysed parameters except for fat content (Table 1). In turn, Barłowska [4] in her study on milk of cows from 7 breeds used in Poland recorded a significant effect of breed and production season on daily yields and protein content. Similarly, Król et al. [11] also stated a highly significant effect of the interaction between both these factors on daily yields as well as casein content. In turn, Topyła [17] showed that the breed x production season interaction significantly ($p \leq 0.01$) determines contents of basic milk components except for casein level. Investigations conducted by Barłowska et al. [5] confirmed a highly significant effect of the discussed interaction on contents of crude protein, fat and dry matter in milk. In turn, the interaction between the feeding system and production season (Table 2) had a significant effect on daily yields and contents of crude protein, including casein, as well as fat and dry matter (at $p \leq 0.01$). In contrast, the protein to fat ratio and lactose content were not correlated with the feeding system or production season. Mavrogenis [15], when evaluating three breeds of purebred sheep and five groups of crossbred sheep maintained in three different production systems stated that not only the production system, but also its interaction with the breed group has a significant effect ($p \leq 0.01$) on production traits of animals, including milk production.

When assessing the simultaneous effect of breed and production season on the chemical composition of milk, interactions were shown (at $p \leq 0.05$ and $p \leq 0.01$) for all the analysed components except for fat. Moreover, for most of the investigated parameters except for lactose content and the protein to fat ratio a simultaneous effect of the feeding system and production season was observed.

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