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OPTIMIZATION OF REARING DAIRY BREED CALVES ACCORDING TO ORGANIC PRINCIPLES*

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Abstract

The aim of the study was to determine the degree to which different whole milk feeding systems according to ecological standards affect the results of rearing, some blood biochemical and haematological parameters, and health status of Polish Holstein-Friesian calves. The experiment was conducted from birth to 150 days of age with 32 calves (16 heifer and 16 bull calves), assigned to four analogous groups (8 animals: 4 ♀ and 4 ♂ per group). In group I, calves suckled colostrum (*ad libitum*) and mother's milk from 5 to 90 days of age (twice daily for 30 minutes); in group II, they suckled colostrum (*ad libitum*), mother's milk from 5 to 42 days of age (twice daily for 30 minutes), and received milk from nipple buckets (6 l twice daily) from 43 to 90 days of age; in groups III and IV calves received from nipple buckets a limited amount of colostrum (4.5–6 l/day) and milk (on average 5.82 and 4.82 l/day, respectively). Feeding limited whole milk from nipple buckets to the calves did not cause significant differences in haematological blood indices, serum concentrations of glucose and IgG, and health status of calves compared to those suckling their mothers. Calves which remained with their mothers during colostrum feeding were characterized by a significantly lower concentration of serum cortisol at 2 days of age compared to calves that received colostrum from nipple buckets. Compared to the calves suckling their mothers (group I), the use of economical milk feeding system (III and IV groups) reduced rearing costs and increased the amount of milk intended for sale by 700–760 l/cow.

Key words: calves, ecology, feeding, rearing results and costs, blood parameters

Dairy farming in accordance with ecological methods contained in Polish and EU regulations is developing rapidly (Budzyńska and Weary, 2008). The increased interest in ecological principles and methods of animal production is motivated by efforts to maintain a balance between economic needs and environmental protection, and

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by the growing consumer interest in the health value of food and in the housing and welfare conditions of farm animals (Kristensen and Struck Pedersen, 2001). According to ecological principles, natural milk should be the basic liquid feed of calves to at least 90 days of age (Journal of Laws, 2009; Council Regulation, 2007). In Poland, like in other European Union countries, calves of dairy breeds are most often fed according to traditional systems with limited amounts of liquid feeds from nipple buckets (Bilik and Łopuszańska, 2008). Recent research shows that current feeding systems prevent animals from performing their natural behaviour, which negatively affects their welfare and health compared to calves that can ingest mother's milk *ad libitum* (Podgham, 2008). It was also found that the amount and type of liquid feed given during this period of rearing has an effect on the anatomical and functional development of forestomachs (Barlett et al., 2006; Khan et al., 2007) and mammogenesis, which determines the subsequent productive value of heifer calves (Wagenaar and Langhout, 2007; Podgham, 2008; Sweeney et al., 2010). However, exhaustive studies to determine the optimum method of feeding dairy breed calves, the optimum amount of milk fed and the economic efficiency of rearing in accordance with ecological principles are few in number.

The aim of this study was to determine the degree to which different colostrum and whole milk feeding systems according to ecological standards will affect the results and economic efficiency of rearing, some blood biochemical and haematological parameters, and health status of Polish Black-and-White Holstein-Friesian calves.

Material and methods

Experimental design, animal feeding and housing

The experiment was conducted at the Experimental Station Chorzelów Ltd. of the National Research Institute of Animal Production in 2009–2011 using 32 calves (16 heifer and 16 bull calves) of the Polish Black-and-White Holstein-Friesian breed from birth to 150 days of age. Four experimental groups (n = 8; 4 ♀ and 4 ♂) were established, differing in colostrum feeding regime from birth to 4 days of age and in whole milk feeding regime from 5 to 90 days of age, and using the same solid feeds in all the groups (Table 1). Calves were assigned to experimental groups based on the analogue principle, taking into account birth date, birth weight and sex. All the groups were assembled within about 3 months. During the study one female calf from group IV was eliminated due to upper respiratory tract infection (in the first month of rearing).

During the colostrum feeding period, calves from groups I and II were kept with their mothers in calving pens, and in the remaining period of milk feeding, they were kept in individual straw-bedded pens (1.5 m × 1.0 m) like calves from the other groups. Pens had perforated side walls, holders for buckets of milk or drinking water, and containers for hay and concentrate. Buckets were suspended at a height of 70 cm above the floor of the pen, forcing the calves to adopt natural position during

colostrum and milk feeding. Proper body position allows the passage of food through the esophageal groove directly into the abomasum (excluding rumen). At the end of the milk feeding period, calves were moved to group pens bedded with straw and equipped with automatic drinkers. Animals were housed in a barn equipped with a milking parlour, roof-ridge skylights, and supply and exhaust gravity ventilation. Calves and cows were subjected to routine (commissioned by the district veterinarian) medical examination for tuberculosis, brucellosis and leucosis; additionally, the health of the mammary gland (mastitis) was tested in cows using the California Mastitis Test.

Table 1. Experimental design

<table>
<tr><th rowspan="2">Age (days)</th><th colspan="4">Feeding groups</th></tr>
<tr><th>I</th><th>II</th><th>III</th><th>IV</th></tr>
<tr><td>0–4</td><td colspan="2">Ad libitum colostrum from udder of dam kept with calf in calving pen</td><td colspan="2">Colostrum 3 times daily from nipple bucket, 4 to 6 l/day</td></tr>
<tr><td>5–42</td><td colspan="2">Calves allowed to suckle their dams (twice daily for 30 min), with constant access to concentrate[1] and meadow hay</td><td colspan="2">Feeding milk from nipple buckets (twice daily), with constant access to concentrate[1] and meadow hay</td></tr>
<tr><td></td><td colspan="2"></td><td>8 l/day
(304 l in total)</td><td>6 l/day
(228 l in total)</td></tr>
<tr><td>43–90</td><td>As above</td><td>Feeding milk from nipple buckets (3 l twice daily, 228 l milk in total) + concentrate[1] and meadow hay – ad libitum</td><td colspan="2">Feeding milk from nipple buckets (twice daily), with constant access to concentrate[1] and meadow hay</td></tr>
<tr><td></td><td></td><td></td><td>3–6 l/day
(201 l in total)</td><td>3–5 l/day
(187 l in total)</td></tr>
<tr><td>91–150</td><td colspan="4">In all groups, identical level of feeding organic farm-produced feeds (concentrates 2.0 kg/day, meadow hay 1.8 kg/day), wilted grass silage – ad libitum</td></tr>
</table>

[1]For composition and nutritive value of concentrate, see Table 2.

Measurements and chemical analyses

Solid feed samples for chemical analyses were collected twice: at the beginning of the experiment and after weaning from milk.

The colostrum and milk intake from nipple buckets was recorded individually by daily weighing of feed offered and refused. The daily amount of milk intake by suckling calves was determined based on their weighing before and after suckling, on one day of each week of rearing "with mother" (Bar-Pelled et al., 1995). Concentrate and meadow hay intake from 5 to 90 days was also monitored individually based on weighing (on two successive days of each milk feeding week) feed offered and refused. The intake of solid feeds from 91 to 150 days of age was evaluated based on weighing (on 2 successive days of weeks 16, 18 and 20) total feed offered and refused.

Body weight (at birth and at 5, 42, 90 and 150 days of age) was determined by weighing the calves each day before morning feeding.

Calf vigour was assessed according to the method using a scale from V3 to V0: V3 – full muscle tone, raised head, all reflexes retained, calf able to suckle on its own; V2 – weaker calf, with a reduced number of reflexes, partial muscle tone, requiring assistance when raising and support of head during suckling; V1 – neonates with only cardiac activity at calving, showing no reflexes or muscle tone; V0 – stillborn calves (no reflexes, no cardiac activity, no muscle tone), and diarrhoea and its intensity was judged based on faecal appearance and consistency on a 4-point scale (Kowalski, 2005): 1 – normally formed (but not hard); 2 – soft (formless, resembles melting icecream); 3 – liquid, dripping (melts easily like pancake batter); 4 – watery.

At 2, 43 and 70 days of calves age, blood samples were collected from the jugular vein prior to morning feeding. Whole blood was analysed for haematological parameters, and blood serum for the concentration of immunoglobulins (IgG), glucose and cortisol.

Milk samples were collected once a week and preserved with Gropol. The amount of milk drawn from each cow after suckling by calves was monitored daily, and basic chemical composition of milk was determined at weekly intervals.

Samples of biological material intended for analyses were stored in a freezer at –20ºC.

Basic chemical analysis of the feeds was performed using standard procedures (AOAC, 2005), and neutral (NDF) and acid detergent fibre (ADF) using the method described by Van Soest et al. (1966).

The acetic and butyric acid content of silage was determined with a Varian 3400 gas chromatograph with 8200 CX autosampler. Lactic acid in silage was determined by high-performance liquid chromatography (HPLC) after centrifugation of water filtrates with 24% metaphosphoric acid using a Shimadzu chromatograph (column Nucleosil 250/4 – C18, detector UV-Vis SPP-6 AV and autosampler SIL-10 AX). The pH of silage was determined using an Elwro N 517 pH meter.

Haemoglobin was determined according to the method of Drabkin using a Spekol spectrophotometer at a wavelength of 540 μm, and haematocrit value with a micromethod by centrifugation in a haematoctrit tube at 3500 rpm for 5 min. Red and white blood cell counts were determined electrometrically with a digital cell counter (TUR ZG-2, Zeiss). Serum glucose and cortisol concentrations were determined with competitive enzyme immunoassay using Immulite 2000 analyser (Siemens), and the concentration of immunoglobulins (IgG) in accordance with the method described by Ślebodziński et al. (1982).

The amount of milk drawn from each cow was determined with TRU-TEST milk meters. Fat, total protein, lactose and solids content of milk was determined with MilkoScan FT 120 (Foss Electric).

Calculations and statistical analysis

Nutritive value of the feeds and composition of the concentrate mixture were calculated according to the nutrient requirements of ruminants (IZ PIB-INRA, 2009),

using INRAtion ver. 4.05 (2009). Silage quality was evaluated according to the Flieg-Zimmer scale (Podkówka, 1974).

The energy and protein requirement of a calf was calculated by comparing mean daily intake of energy (UFL) and protein digestible in the intestine (PDI) with the requirement reported in IZ PIB INRA for calves of large dairy breeds.

The economic efficiency of rearing the calves in different feeding groups was determined from direct surplus, calculated as the difference between the market value of milk drawn from a cow after calf feeding and the value of the milk ingested by the calf. Feed costs were calculated according to the financial and accounting records of the experimental station, based on prices from the fourth quarter of 2011.

The feeding and health parameters obtained during the milk feeding period and the rearing results of the calves from birth to 150 days of age were analysed statistically with the ANOVA procedure of variance analysis using SAS statistical package (1999/2001). Significant differences between the groups were determined with Duncan's test. The other results for economic efficiency parameters and feeding indicators during the rearing period (days 91 to 150) were presented as the means for feeding groups.

Results

The chemical composition and nutritive value of feeds, expressed in INRA units, are given in Table 2. The data show that the nutrient content and nutritive value of milk, concentrates and roughages correspond to the values characteristic of good or medium quality feeds (Śliwiński et al., 2010).

The results for daily feed intake (Table 3) showed that the milk feeding systems caused significant ($P \leq 0.05$ or $P \leq 0.01$) differences between the groups in the amount of milk and feed intake (groups III and IV) or differences (groups I and II) in meadow hay intake. Calves from group I had the highest milk and the lowest concentrate intake, those from group IV had the lowest milk and highest concentrate intake, with intermediate amounts ingested by calves from groups II and III.

The data indicate that calves from group I (Table 4) had a significantly ($P \leq 0.01$) higher intake of energy (UFL), crude protein (CP) and protein digestible in the intestine (PDI) from 5 to 90 and from 43 to 90 days of age compared to the other groups, and a significantly lower intake of dry matter compared to group IV. Feed and nutrient intake from 91 to 150 days of age was similar in all the groups. The milk feeding systems provided 100% or 111–119% of the energy requirement (UFL) of the calves compared to IZ PIB-INRA feeding standards. Calves from groups II and IV were provided with 92.3% and 98% of the requirement for protein (PDI) from 43 to 90 days of age, calves from groups II and III were also fed slightly below the requirement from 5 to 90 days of age, while calves from group I were fed in excess of the requirement in all milk feeding periods and calves from groups III and IV from 5 to 42 days of age.

Table 2. Chemical composition (%) and nutritive value of the feeds

Components	Feeds			
	cow's milk	concentrate mixture[1]	meadow hay	grass silage
Dry matter	13.04	87.3	86.2	38.9
Crude protein	3.19	15.0	8.95	5.69
Crude fat	4.25	1.52	2.57	1.45
Crude fibre	-	5.40	27.3	14.0
N-free extractives	4.84	59.78	42.18	13.43
Crude ash	0.76	5.60	5.20	4.33
NDF			47.5	20.3
ADF			25.3	11.9
Lactic acid				1.30
Acetic acid				0.59
Butyric acid				0.06
pH				4.70
Content in 1 kg feed:				
PDI (g)[2]	30.6	85.0	63.0	25.6
PDIN (g)[3]	-	94.7	70.0	30.6
PDIE (g)[4]	-	85.0	63.0	25.6
UFL[5]	0.22	0.93	0.67	0.31

[1]Composition (%) and nutritive value of the concentrate mixture: ground barley 30, ground wheat 25, ground oats 17, rapeseed expeller 15, ground faba beans 5, pea meal 5, dried brewer's yeast 1, mineral mixture MM Land 2: in 1 kg DM: 1.05 UFL, 170 g CP, 109 g PDIN, 102 g PDIE; in 1 kg mixture: 102 g P, 165 g Ca, 46 g Mg, 92 g Na.

[2–5]According to ruminant feeding standards (IZ PIB-INRA).

Table 3. Feed intake by calves in different growth periods

Item	Groups[1]				SEM
	I	II	III	IV	
Daily in growth periods (days of age):					
5–42					
whole milk (l)	8.96 A	9.51 A	7.88 B	6.00 C	0.759
concentrate mixture (kg)	0.18 C	0.18 C	0.41 B	0.63 A	0.062
meadow hay (kg)	0.035	0.039	0.044	0.046	0.016
43–90					
whole milk (l)	12.96 a	6.00 b	4.19 c	3.89 c	0.454
concentrate mixture (kg)	0.59 d	1.43 c	1.78 b	2.00 a	0.129
meadow hay (kg)	0.17 c	0.32 b	0.42 a	0.48 a	0.086
5–90					
whole milk (l)	11.1 a	7.54 b	5.82 c	4.82 d	0.503
concentrate mixture (kg)	0.41 d	0.89 c	1.15 b	1.39 a	0.087
meadow hay (kg)	0.11 c	0.20 b	0.25 a	0.29 a	0.050
91–150					
concentrate mixture (kg)	1.98	1.98	2.00	1.88	-
meadow hay (kg)	1.63	1.61	1.67	1.69	-
grass silage (kg)	3.21	3.14	3.31	3.42	-
Total feeds during growth:					
whole milk (l)[2]	954.6 A	648.4 B	504.8 C	414.5 D	43.25
concentrate mixture (kg)	154.1	195.3	199.1	220.9	-
meadow hay (kg)	107.2	113.1	121.9	126.2	-
grass silage (kg)	192.6	188.4	198.6	205.2	-

a, b, c, d – $P \leq 0.05$; A, B, C, D – $P \leq 0.01$.

[1]See experimental design.

[2]Milk intake by suckling calves was determined by additional weighing of the calves before and after suckling on one day of each week of maternal nursing, and in calves fed from nipple buckets based on daily milk intake.

Table 4. Daily nutrient intake by the calves in different growth periods and the energy and protein requirement of the calves in different milk feeding periods

Item	Groups				SEM
	I	II	III	IV	
Growth period (days of age):					
5–42					
dry matter (kg)	1.35	1.43	1.41	1.38	0.089
crude protein (g)	316.2 aAB	333.8 aA	315.9 aAB	2.90 bB	21.68
PDIN (g)	294.2 abA	310.6 aA	282.4 bA	246.9 cB	21.24
PDIE (g)	291.8 abA	309.1 aA	278.1 bA	240.4 cB	21.50
UFL	2.16 aA	2.28 aA	2.14 aAB	1.94 bB	0.149
43–90					
dry matter (kg)	2.34 bcB	2.30 cB	2.45 bB	2.67 aA	0.108
crude protein (g)	500.1 aA	434.0 cC	437.4 cCB	460.7 bB	18.40
PDIN (g)	464.2 aA	341.1 bB	325.6 cB	341.5 bB	14.10
PDIE (g)	457.3 aA	325.1 bB	305.5 cC	318.8 bcCB	13.57
UFL	3.51 aA	2.86 cCB	2.83 cC	3.03b B	0.124
5–90					
dry matter (kg)	1.88 B	1.92 B	1.97 B	2.09 A	0.088
crude protein (g)	421.9 A	386.0 B	378.0 B	388.5 B	19.35
PDIN (g)	384.2 A	330.2 B	304.1 C	298.5 C	15.62
PDIE (g)	379.6 A	318.6 B	291.3 C	284.1 C	15.02
UFL	2.88 A	2.61 B	2.51 B	2.55 B	0.116
91–150					
dry matter (kg)	4.38	4.34	4.47	4.53	-
crude protein (g)	627.2	618.8	637.8	646.2	-
PDIN (g)	404.4	395.6	407.6	412.5	-
PDIE (g)	353.9	351.6	359.9	364.1	-
UFL	3.92	3.89	4.00	4.06	-
Requirement[1] (%) in periods (days of age):					
5–42					
energy (UFL)	113.7	116.3	115.8	117.3	-
protein (PDI)	105.8	103.0	114.9	107.8	-
43–90					
energy (UFL)	117.0	100.1	100.4	119.7	-
protein (PDI)	118.7	92.3	100.0	98.0	-
5–90					
energy (UFL)	104.2	102.3	111.5	115.5	-
protein (PDI)	106.6	97.4	97.1	101.5	-

a, b, c – P≤0.05; A, B, C– P≤0.01.

[1] For calves with mean body weights and daily gains in different milk feeding periods compared to IZ PIB-INRA ruminant feeding standards determined for calves of large dairy breeds.

The groups fed from nipple buckets (III and IV) or using the "combined" system (II) throughout were characterized by a significantly (P≤0.01) higher amount of milk drawn and 2.4–3.8-fold higher economic efficiency of rearing compared to group I, in which calves were allowed to suckle their dams throughout the milk feeding period (Table 5). No statistically significant differences (P>0.05) were found between the groups in milk yield or in content of the major milk components.

Table 5. Amount of milk drawn from a cow after "nursing" the calf, milk yield and chemical composition, and economic efficiency of calf rearing

Item	Groups				SEM
	I	II	III	IV	
Amount of milk drawn from a cow after "nursing" the calf:					
during milk feeding period (5–90 days of age)					
(l/day)	16.1 B	20.2 AB	24.2 A	24.9 A	5.58
(l/total)	1385 B	1736 AB	2085 A	2141 A	479.9
throughout growth period (5–150 days)					
(l/day)	19.1 B	21.9 AB	25.3 A	24.8 A	3.46
(l/total)	2789 B	3197 AB	3694 A	3621 A	505.5
Milk yield of cows during milk feeding period:					
(l/day)	28.3	27.2	29.4	29.7	6.11
(l/total)	2340	2384	2590	2556	525.7
Milk yield of cows throughout growth period:					
(l/day)	25.9	26.4	28.7	27.7	5.23
(l/total)	3783	3811	4190	4044	763.2
Nutrient content of cow's milk during milk feeding period (%):					
fat	4.14	4.19	4.25	4.25	0.473
protein	3.17	3.25	3.16	3.18	0.161
lactose	4.78	4.77	4.88	4.78	0.117
solids	13.1	12.4	13.4	13.2	0.677
Economic efficiency of calf rearing:					
during milk feeding period:					
value of milk drawn after "nursing" the calf, zloty					-
total feed cost[1]/calf, zloty	1676	2101	2523	2591	-
direct surplus[2]	1185	853	700	609	
(zloty)	521	1248	1823	1982	-
(%)	31.1	59.4	72.2	76.5	-
throughout rearing:					
value of milk drawn after "nursing" the calf, zloty		3562	4017	4057	-
total feed cost[1]/calf, zloty	3119	992	841	750	-
direct surplus[2]:	1326				
(zloty)	1793	2570	3176	3307	-
(%)	57.5	72.1	79.1	81.5	-

A, B – P≤0.01.

[1]Feed costs according to ZD IZ PIB Chorzelów sp. z o.o. (zloty/kg): cow's milk 1.21, concentrate 0.76 (including: ground barley 0.73), ground wheat 0.85, ground oats 0.53, ground faba beans 0.78, pea meal 0.78, mixture MM Land 4.6, dried brewer's yeast 3.50, meadow hay 0.23, wilted grass silage 0.08.

[2]Mean value of milk drawn from a cow minus the cost of feed/calf.

Body weight (Table 6) at 90 and 150 days and daily gain during the milk feeding period were the highest in calves from group I, intermediate in groups II and III, and the lowest in group IV. The differences found were statistically significant (P≤0.05 or P≤0.01). No significant differences were observed between the groups in daily gain

at 91–150 days of age. The cost of feed per kg gain during the feed milk period was higher in group I than in the other groups, with a similar feed cost in the remaining period of rearing. A tendency towards higher conversion of dry matter, crude protein and energy (UFL) per kg gain in different rearing periods was found in calves from group I, with a similar conversion of protein digestible in the intestine (PDI) in all the groups.

Table 6. Body weight, daily gain, feed cost and nutrient conversion (kg/kg gain) of the calves

Item	Groups				SEM
	I	II	III	IV	
Body weight (kg) at days of age:					
at birth	43.1	44.1	41.3	42.5	5.09
5	45.7	47.3	43.6	44.9	5.05
42	78.2 a	80.8 a	72.8 ab	69.2 b	7.82
90	135.4 a	127.1 ab	116.4 bc	111.4 c	11.18
150	182.6 aA	175.3 abAB	165.5 bcAB	158.9 cB	14.75
Body weight gain during growth period (g/day):					
5–42	855 abA	894 aA	770 bAB	642 cB	100.47
43–90	1192 A	965 B	908 B	875 B	118.48
5–90	1042 aA	928 bAB	847 bcB	773 cC	88.42
91–150	787	804	819	791	162.13
Cost of feed[1] (zloty)/kg gain in periods (days of age):					
5–90	13.2	10.7	9.61	9.15	-
91–150	2.94	2.86	2.87	2.98	-
Nutrient conversion per kg gain (days of age):					
5–42					
dry matter (kg)	1.60 B	1.63 B	1.89 AB	2.18 A	0287
crude protein (g)	374.4 b	381.4 b	421.7 ab	460.7 a	12.48
PDI (g)	345.5	353.3	371.0	381.2	57.12
UFL	2.56 b	2.61 ab	2.85 ab	3.07 a	0.435
43–90					
dry matter (kg)	2.00 cC	2.40 bBC	2.76 abAB	3.10 aA	0.385
crude protein (g)	426.7 nB	453.8 bAB	491.8 abAB	533.8 aA	66.96
PDI (g)	390.2	339.8	343.5	369.8	49.99
UFL	2.99 b	2.99b	3.18 ab	3.52 a	0.450
5–90					
dry matter (kg)	1.82 cC	2.09 bcBC	2.36 bAB	2.73 aA	0.270
crude protein (g)	406.7 bB	418.9 bB	453.8 bBA	507.0 aA	51.66
PDI (g)	365.7	345.7	349.8	370.8	40.07
UFL	2.78 bB	2.84 bAB	3.02 abAB	3.31 aA	0.344
91–150					
dry matter (kg)	5.39	5.75	5.96	5.94	-
crude protein (g)	772.2	821.0	851.0	847.8	-
PDI (g)	436.0	466.8	480.0	477.7	-
UFL	4.82	5.16	5.33	5.32	-

a, b, c – $P \leq 0.05$; A, B, C– $P \leq 0.01$.

[1]See Table 4 .

Table 7. Calf vigour and health during milk feeding period, haematological blood parameters and serum concentrations of immunoglobulins (IgG), glucose and cortisol

Item	Groups				SEM
	I	II	III	IV	
Calf vigour (vitality)[1]	2.50	2.66	2.83	3.00	0.495
Nutritional diarrhoea[2]	1.17	1.27	1.33	1.43	0.491
Haemoglobin (g/dl)	10.5	10.7	9.8	10.1	1.454
Haematocit value (%)	28.8	32.2	27.2	28.3	5.297
Erythrocytes (10^6/mm^3)	7.7	7.8	7.2	7.3	1.148
Leukocytes (10^3/mm^3)	11.9	10.2	10.7	11.0	2.720
IgG (g/l) at days after birth:					
2	13.1	14.2	13.3	13.6	2.406
70	8.3	9.1	8.3	9.5	1.335
Glucose (mml/l) at days after birth:					
2	3.82	4.58	4.43	3.59	1.385
43	4.00	3.54	3.74	3.99	1.044
70	3.65	4.19	3.79	3.96	1.080
Cortisol (mml/l) at days after birth:					
2	27.9 B	30.33 B	52.5 A	54.7 A	14.274
43	13.2 b	17.2 a	14.5 ab	13.9 b	2.870
70	17.5	14.29	14.1	13.8	4.280

a, b – $P \leq 0.05$; A, B – $P \leq 0.01$.
[1, 2] According to corresponding point scales (see Material and methods).

No significant differences ($P > 0.05$) were found between the groups in calf vigour at birth and in health of calves during the milk feeding period (Table 7). Calves that were allowed to suckle their dams were relatively quick to suckle on their own, and short-term cases of diarrhoea only occurred during the first days of life but resolved spontaneously within a few days. There were also sporadic cases of diarrhoea in calves fed from nipple buckets, although they were more acute and in several cases required antibiotic treatment. No significant differences ($P > 0.05$) were found between the groups in haematological blood parameters and serum glucose levels of the calves at 2, 43 and 70 days of age, or in serum immunoglobulin (IgG) concentrations at 2 and 70 days of age. Calves that were weaned after birth into pens and fed colostrum from nipple buckets had significantly higher ($P \leq 0.01$) serum cortisol concentrations on the second day of life compared to calves that stayed with their dams in calving pens during the colostrum feeding period. Higher cortisol concentrations compared to calves from groups I, III and IV were also observed at 43 days of age in calves from group II. No significant differences between the groups in serum cortisol concentrations were observed at 70 days of age.

Discussion

Feed intake values for the period between 5 and 90 days of age indicate that compared to the calves that were allowed to suckle their dams, the use of limited milk feeding from nipple buckets caused a significant decrease in the amount of milk

intake at the cost of increased concentrate and meadow hay intake. However, this did not compensate for the amount of energy intake (UFL) by the calves compared to those allowed to suckle their dams and decreased their body weight at the end of milk feeding. Also other studies (Foldager et al., 1997; Gratte, 2004; Fröberg et al., 2008) showed that calves fed intensively on whole milk were characterized by higher body weight at weaning from milk compared to limited feeding. Similar to our study, other authors (Wagenaar and Langhout, 2007) observed that calves suckling dams that were milked twice daily for 30 min had a daily milk intake of 8–10 l in the first weeks of rearing and more than 12 l later on, depending on the breed of cows and body weight of the calves. Based on our data and those of other authors (Wagenaar and Langhout, 2007), it is believed that when feeding limited amounts of milk to calves, the amount of milk recommended for rearing one calf should be about 8 l in the first six weeks of life and 4–6 l per day in the remaining period of feeding. This feeding strategy enables doubling "birth" weight at eight weeks of age and rearing animals characterized by good health and optimum growth parameters for dairy breed cattle (Hoffman, 1997). This was also confirmed by the values that we obtained for the energy and protein supply of the animals during the milk feeding period. They showed that the whole milk feeding systems for the calves provided 100% of the requirement for energy (UFL) and almost 100% of the requirement for protein digestible in the intestine (PDI), in accordance with the IZ PIB INRA feeding standards. In a study conducted on organic dairy farms with cattle producing an average of 5200–7100 kg milk, Wagenaar and Langhout (2007) also showed that keeping calves with mothers or foster mothers during rearing ensures better living conditions and a more natural environment, which also contributes to their better health. The same authors stress that cows selected as foster mothers were willing to accept the calves assigned to rearing, which also contributed to more complete udder evacuation and improved udder health. On the other hand, calves nursed only by foster mothers experience stress at weaning and show considerable differences in growth rate during the milk feeding period, as a result of competition for food. Moallen et al. (2006) and Khan et al. (2007) demonstrated, however, that calves fed whole milk containing many bioactive components are characterized by a more rapid anatomo-functional development of forestomachs and better milk performance parameters in the first lactation compared to the calves receiving analogous amounts of milk replacer liquid. More beneficial production results for the first lactation were also obtained in first-calf heifers which were allowed to suckle their dams for a shorter (up to 42 days of age) than longer period (up to 87 days of age) during calfhood (Foldager et al., 1997).

Similar to our experiment, a study conducted on organic dairy farms (Gratte, 2004) reported no differences in the health parameters of the calves according to the milk feeding system (allowing calves to suckle their dams twice daily for 30 min during eight weeks or feeding milk from nipple buckets). In calves kept in group pens and fed from nipple buckets, the same author observed much more cases (67%) of cross-sucking and pen licking compared to suckling calves (20%). A questionnaire survey carried out on organic dairy farms in Sweden (Lidfors et al., 2002) showed that 26% of the farms allow calves to suckle their dams for 12 weeks, 17% for

1–2 weeks, and 3% for 6 weeks, while on other farms calves are fed from nipple buckets. Compared to rearing in pens or outdoor hutches only, rearing calves with milked mothers or unmilked foster mothers allows animals to show natural behaviours and habits such as the cow-calf bond, the natural sucking reflex, and a maternal reflex in the cow, which brings dairy farming closer to consumer expectations (Gratte, 2004; Langhout and Wagenaar, 2007).

An important role in livestock breeding is attributed to the efficiency of feed utilization per unit of product and feeding costs. Our findings support the results of other authors (Foldager et al., 1997) that with different levels of whole milk feeding during the milk feeding period, the use of a uniform system of feeding solids feeds to calves after weaning from milk makes nutrient consumption similar. Also our results obtained for the amount of milk drawn per cow after "rearing" a calf and for the economic efficiency of rearing calves allowed to suckle mothers milked throughout the milk feeding period confirmed the results reported by other authors (Wagenaar and Langhout, 2007). They showed that allowing the calves to suckle mothers milked throughout the 90-day milk feeding period reduces the amount of milk intended for sale and increases calf feeding costs. The same authors also observed that organic farms now use two principal systems of rearing calves after feeding their own mothers' colostrum: rearing "single" calves that suckle milked mothers two to three times daily or group rearing (2–4 calves) by one unmilked foster cow, as well as the combination of these two methods of rearing suckling calves, which is often used in agricultural practice.

The erythrocyte and leukocyte counts, the concentration of haemoglobin and haematocrit values determined in the calves at 2, 43 and 70 days of age were within the physiologically normal range (Kuleta, 1993; Winnicka, 1997). These values were similar to the parameters reported by other authors for calves reared under optimum hygienic and feeding conditions (Bilik, 1999; Szewczyk and Walczak, 2006). Also serum glucose levels in the blood collected from calves of the same age were close to the physiologically normal values (Winnicka, 1997) and to the results of some authors (Szewczyk and Walczak, 2008). The values obtained for serum glucose levels are also indicative that the energy requirement of the calves during the milk feeding period has been met. The significantly lower serum cortisol level, found at two days of age in calves that were kept with their mothers during the colostrum feeding period shows that this approach creates more natural and less stressful living conditions compared to keeping calves in individual pens after birth and feeding them with colostrum from nipple buckets (Wilson et al., 1999; Szewczyk and Walczak, 2008). Regardless of the colostrum feeding method, the similar serum concentration of immunoglobulins (IgG), found at two days of age in all the groups (13.1–14.2 g/l) is evidence that the calves were adequately supplied with antibodies from the colostrum of their mothers (Ramin et al., 1996; Skrzypek, 2002; Szewczyk and Walczak, 2008). The immunity level obtained from colostrum is adequate when blood serum contains at least 10 g/l IgG at two days of age (Skrzypek, 2002), which was also confirmed by the satisfactory calf vigour and health results in all the groups.

It is concluded that the use of the whole milk feeding systems together with *ad libitum* feeding of concentrate and meadow hay ensure normal growth parameters of

the calves that conform to current breeding standards for the Polish Black-and-White Holstein-Friesian breed. Feeding calves with limited amounts of whole milk (5.8 or 4.8 l/day on average) from nipple buckets does not decrease haematological blood parameters, serum glucose and IgG concentrations or the health status of the calves compared to the calves allowed to suckle milked dams. Based on serum cortisol concentrations at two days of age it is believed that keeping dairy breed calves during the colostrum period in calving pens together with their mothers creates better, more natural and less stressful living conditions compared to keeping newborn calves in individual pens and feeding them with colostrum from nipple buckets. Compared to the calves suckling milked mothers throughout the milk feeding period, the use of economical milk feeding systems increases the economic efficiency of rearing and the amount of milk intended for sale by 350–760 l/cow.

Therefore, under Polish conditions, rearing in individual pens using limited amounts of milk fed from nipple buckets or "combined" feeding (especially for breeding heifer calves) should be the preferred system of rearing calves in organic farms producing market milk. The liquid feeding systems used in the experiment covered the energy requirements of calves and ensured their optimal growth rate, in accordance with the IZ PIB INRA standards.

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Optymalizacja odchowu cieląt ras mlecznych według wymogów ekologicznych

STRESZCZENIE

Celem badań było określenie w jakim stopniu zróżnicowany system odpajania mlekiem pełnym cieląt rasy phf według wymogów ekologicznych wpłynie na wyniki odchowu, wybrane wskaźniki hematologiczne i biochemiczne krwi oraz status zdrowotny. Doświadczenie przeprowadzono w okresie od urodzenia do 150. dnia życia na 32 cielętach (16 cieliczkach i 16 buhajkach), przydzielonych do czterech analogicznych grup (po 8 sztuk). W grupie I cielęta ssały siarę (*ad libitum*), a mleko matki od 5. do 90. dnia życia (dwa razy dziennie po 30 minut), w grupie II ssały siarę (*ad libitum*), mleko matki od 5. do 42. dnia życia (dwa razy dziennie po 30 minut), a od 43. do 90. dnia życia otrzymywały mleko z wiaderek ze smoczkiem (2 × dziennie po 3 l), w grupach III i IV cielęta pojono ograniczonymi dawkami siary (4,5–6 l dziennie) i mleka pełnego (śr 5,82 l/dz. i 4,82 l/dz.; odpowiednio) z wiader ze smoczkiem. Żywienie cieląt ograniczonymi dawkami mleka pełnego z wiader ze smoczkiem nie spowodowało istotnego zróżnicowania wartości wskaźników hematologicznych krwi, stężenia glukozy i IgG w surowicy krwi, ani stanu zdrowotnego cieląt w porównaniu z dopuszczanymi do ssania matek. Cielęta utrzymywane w okresie pojenia siarą razem z matkami odznaczały się natomiast istotnie niższym stężeniem kortyzolu w surowicy krwi w 2. dniu życia niż pojone siarą z wiader ze smoczkiem. W porównaniu z cielętami dopuszczanymi do ssania matek (grupa I) zastosowanie mleko-oszczędnych systemów odpajania (grupy: III i IV) wpłynęło na obniżenie kosztów odchowu i zwiększenie ilości mleka przeznaczonego do sprzedaży o 700–760 l/krowy.