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The Optimal Feeding Level and Housing System for Female Calves under Production Conditions

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In1996, the average annual milk yield in Poland amounted to 3249 kg per cow (Statistical Yearbook of Agriculture, 1998) while in 2016 - 5563 kg (GUS, 2017). In the researched population of the leading Polish breed of Holstein-Friesian cows, the average yield is currently 8055 kg of milk (Milk Cattle Rating, 2017). This impressive growth is a result of both the progress of breeding, programmed by biological information contained in the DNA sequence, and the accompanying increase in the knowledge in the field of nutrition of highly efficient dairy cattle (Ziętara, 2007). The latest research results indicate that the milk yield of cows is also programmed by the environmental factor, which is the nutrient content allowing for high body weight gains in the first months of life of calves (Niwińska, 2017). This follow-up and time-related dependency was documented for the first time in 2005. It was revealed that cows that in the first two months of life received the unrestricted amounts of whole milk and obtained higher daily weight gains (> 880 g) as compared to those that were fed with restricted doses of milk replacer liquids, and the increase in their weight did not exceed 600 g - produced about 130 kg more milk in the 1st lactation (Shamay et al., 2005). There are also studies indicating that obtaining daily weight gains of up to 800 g following the administration of restricted doses of milk replacer liquid formulas enriched with protein and energy is beneficial in the financial terms as compared to feeding with milk (Soberon et al., 2012). In the practical farming of milk producing cattle in balancing the profitability of production, the cost of feed administered to calves in the first two months of rearing plays a significant role - especially the cost of liquid feed, which is why one of the important goals remains the reduction of this position in the total costs (Mandecki, 2011). However, on the other hand, when raising the calves intended for the replacement of your own cattle, the correct development of production capacity is of fundamental importance. Therefore, a question arises how to feed the calves to ensure their optimal weight gains and future milk yield. In comparison to the administration of standardised liquid feed doses, is it more reasonable and favourable to allow animals to take any amount of these expensive feeds?

In order to obtain the answer to such a question, a nutritional test was carried out in the conditions of a milk producing farm. The purpose of the test was to compare weight gains, to assess the health and economic efficiency of rearing calves fed with cow's whole milk up to 28 days of age and then the milk replacer liquid formula in restricted, standardised doses to day 49, providing 800 g daily increase vs liquid feed administered ad libitum. The research was carried out as part of co-operation of the National Research Institute of Animal Production in Balice with the "Nowe Jankowice" Sp. z o.o. Stud in Nowe Jankowice.

Materials and methods

The nutritional test was carried out on the Polish breed of Holstein-Friesian female calves in the period from the day 3 to 75 of their life under the production conditions. The research was carried out with an open-type "calf village" on a milk-producing farm in Nowe Jankowice, and the implementation time line covered the period from September 2015 to March 2016. The female calves participating in the test were born as a result of the 1st (23%), 2nd (23%) or 3-4th gestations (54%) by cows with the yield of 12 598 (± 1356) kg of milk in the previous lactation.

Experimental design

The experiment was carried out in a 1-factor statistical system; the research factor was the feeding system with liquid feed formulas during the rearing period from the 3rd to the 49th day of life. The observations covered 30 female calves assigned randomly to 2 equal groups. In the nutritional group marked with the symbol RESTRICTED, the female calves received daily doses of liquid feeds calculated according to the recommendations of Soberon et al. (2012) based on the American nutrition standards for dairy cattle NRC (2001); in the group of AD LIBITUM the animals were allowed to take up any amount of liquid feeds. The impact of the liquid feeding with unrestricted access to solid feeds was assessed on the basis of a comparison of the obtained body weight gains, health assessment and estimated economic effectiveness characterising calf rearing in the period from the 3rd to 75th day of life in both experimental groups.

Nutrition and breeding

In the feeding calves cow's whole milk obtained on the farm was used as liquid feed and milk replacer feed with 143 g of TMR in 1 kg - Polmass Milk Red Full milk replacer powder (produced by Polmass S.A., Bydgoszcz, Poland).

Solid starter concentrate (TMs) - Promilk CJ Corn (manufactured by Agrifirm Polska Sp. z o.o., Szamotuły, Poland) and feed mixture given to cows in the 2nd lactation period (TMR_{II}) were administered as solid feeds. The chemical composition and nutritional value of the administered feeds are presented in Table 1.

In the period preceding the tests the female calves were kept in individual pens in the delivery room, and after birth they were fed with 7.5 kg of good quality colostrum with a specific gravity of 1065.5 ± 5 gl^{-1} on the 1st day, and on the 2nd day - about 7.5 kg of milk from the mother. The animals were randomly assigned to the test groups on the 3rd day in the morning, before the feeding. The daily amounts and types of liquid feeds administered to calves in the group designated as RESTRICTED (n = 15) and in the AD LIBITUM group (n = 15) are shown in Table 2. In the tables presenting the comparison of values of indicators characterising the calves, the background was colour-marked depending on the level of nutrition with liquid feed.

In both groups solid feed was administered ad libitum: from day 3 to day 28 – only TM_S, from day 29 to day 49 a mixture composed of 80% TM_S and 20% TMR_{II}, from day 50 to 64 - a mixture composed of 50% TM_S and 50% TMR_{II}, and from day 65 until the end of the test only TMR_{II}. The feeding schedule was adapted to the calf breeding system in the "calf village" (Kaczor and Mandecki, 2014). Under the open roof structure, a technological system was used, including straw-filled Igloo-type hutches along with pens. Depending on the weather the gable and side walls were covered with polyester windscreen nets.

The technological system included 22 individual and 6 group hutches. The arrangement of the test groups is presented at Diagram 1.

Table 1. Chemical composition and nutritive value of the feeds

Item	Liquid feeds		Solid feeds	
	cow milk	Milk replacer[1]	starter concentrate[2] (TMs)	mixed feeds (TMR II)[3]
No. of samples	4	2	2	6
Chemical composition[4]				
Dry matter (g kg^{-1} fresh matter)	122	936	895	489
in dry matter (g kg^{-1} fresh matter):				
crude protein	312	204	239	152
crude fat	298	159	31	36
lactose[5]	329	566		
crude fibre			43	153
starch				194
neutral detergent fibre			487	294
acid detergent fibre			62	174
crude ash	61	71	87	81
nutritive value (kg^{-1} dry matter):				
gross energy[6] (MJ)	25	20	18	18
metabolizable energy[6] (MJ	23	19	12	12
digestible crude protein[6] (g)	291	189		
feed unit for lactation[7]			1	1
ileal digested protein[7] (g)			58	29
nitrogen-dependent rumen microbial protein[7] (g)			138	94
energy-dependent rumen microbial protein[7] (g)			122	95

[1] *Milk replacer:* Polmass Milk Red Full (Polmass S.A., Bydgoszcz, Polska).

[2] *Complete feed:* Promilk CJ Corn (Agrifirm Polska Sp. z o.o., Szamotuły, Polska).

[3] *Complete mixed feeds produced on the farm contained cereal whole-crop silage, maize ear silage, lucerne silage, barley grain, wheat straw, and complementary feed 5000 MTR Balance* (De Heus Sp. z o.o., Łęczyca, Polska).

[4] *Acc. to certificates of analysis of Feed Laboratory in Stare Pole.*

[5] *Lactose content (g × kg^{1}) = 1000 – CP – fat – ash.*

[6] *Calculated acc. to the system described in Nutrient Requirements of Dairy Cattle (NRC, 2001).*

[7] *Calculated acc. to the system described in Feeding Recommendations for Ruminants (Strzetelski et al., 2014).*

Table 2. Types and amounts of liquid feeds administered daily to female calves in test groups

Item		Liquid feeding			
		RATIONED		AD LIBITUM	
Rearing period (from – to; days of age)	No. of days	whole milk (kg)	milk replacer liquid (kg)	whole milk (kg)	milk replacer liquid (kg)
3 –7	5	7,5		ad libitum + 0.5 previous day intake x coefficient:	
8 – 21	14	8,0	–		
22 – 23	2	6,3	2,7	0,7	0,3
24 – 25	2	4,5	4,5	0,5	0,5
26 – 28	3	2,7	6,3	0,3	0,7
29 – 42	14		9,0		
43 – 49	7		4,5	ad libitum + 0.5	

Diagram 1. Calf housing and feeding system during the test

Item		Liquid feeding		Age of female calves (from – to; days of age)	Type of liquid feed	Solid feeds (ad libitum)
		RATIONED	AD LIBITUM			
Calf village	individual hutches[1]			3–10	MILK	TM_S [3]
	group hutches[2]	I	II	11–23		
				24–28	MILK + REPLACER	
		III	IV	29–49	REPLACER	80% TM_S + [4] 20% TMR
		V		50–64		50% TM_S + 50% TMR_{II}
		VI		65–75		TMR_{II}

[1] *Shown on photo 1.*
[2] *Shown on photo 2.*
[3] *Starter concentrate.*
[4] *Mixed roughages, concentrates and vitamin-mineral ingredients for lactating cows (total mixed ration).*

Calves up to day 10 were kept in individual pens, which were equipped with containers for the concentrate and buckets for drinking water (photo 1). The milk was administered three times a day in a teat pail. From day 11 until the end of the test, the calved remained in group hutches with pens, equipped with a liquid feed feeding station, bowl troughs and feed grazing dugouts (Fig. 2).

Photo 1. Individual hutches with outside pens in a calf village (Nowe Jankowice Stud Ltd.)

Photo 2. Group hutches with outside pens in a calf village (Nowe Jankowice Stud Ltd.)

Collecting data

Measurements of the calves' weight were taken on days 3, 11, 29, 50, 65 and 76, always in the morning between 6:00 and 7:00. The data for the individual intake of liquid feeds were collected. The data on the intake of solid feeds related to the individual feed intake during the period of the calves' stay in individual hutches and the average daily intake for the group of animals staying in given group hutches. Individual data on health status were collected by recording the number of days with disease signs (diarrhoea or pneumonia) based on the assessment made by the veterinary surgeon.

Chemical analyses

Chemical analyses of fodder and remains were carried out in the Feed Laboratory in Stare Pole. The dry matter content was determined using the weight method (drying for 3h at 105°C), ash by the weight method (combustion in a mill furnace at 500°C), protein by the Kjeldahl method (N x 6.25), crude fat by the Soxhlet method and crude fibre, acid-detergent fibre (ADF) and neutral detergent fibre (NDF) using the ANKOM 200 Fiber Analyser (ANKOM Technology, Macedon NY, USA). The chemical analyses of fodder were carried out according to the Commission Regulation (EC) No. 152/2009 of 27 January 2009 establishing methods for sampling and analysis for the purpose of official feed control.

Calculations an statistical analysis

Body mass gains, feed consumption per kg body weight gain, the share of days with symptoms of disease throughout the test period and the costs of feeds per kg body weight gain of calves were calculated. The economic efficiency was estimated based on data characterising the consumption and costs of feed used to obtain 1 kg of body weight gain. The results are shown as means (± standard deviation).

The nutritive value of liquid feed was calculated using the formulas presented in the "Dairy cattle demand for nutrients" (NRC, 2001). Based on the results of chemical analysis of feed and the estimated lactose content according to the equation lactose ($g \times kg^{1}$) = 1000 - BO – fat - ash, the gross energy concentration (EB) was calculated according to the equation: EB ($MJ \times kg^{1}$) = 0.057 BO + 0.092 fat + 0.0395 lactose, metabolic energy (EM) according to the EM equation ($MJ \times kg^{1}$) = 0.93 EB, digestible protein assuming a digestibility coefficient of 0.93 determined in non-ruminating calves for milk-derived protein. The nutritive value of solid feed was calculated according to cattle nutrition standards included in the Nutritional Recommendations for Ruminants (Strzetelski et al., 2014) based on the results of the chemical analysis of feed using the INRAtion computer software (ver. 4.05, Copyright INRA, 1988–2004).

The Statistica 8 PL software (StatSoft Polska Sp. z o.o., Krakow) was used to assess the probability of statistically significant differences between the mean values characterising the test groups using the univariate analysis and the Duncan test. It was assumed that the impact was significant at the probability of statistical significance of differences $P \leq 0.05$.

The results and their discussion

The fodder administered to calves was characterised by assumed chemical composition and expected nutritional value (Tab. 1). The results of analyses of the milk replacer and starter mixture were in line with the manufacturers' declarations, and milk as well as a complete feed mixture was consistent with literature (NRC, 2001) (Strzetelski et al., 2014).

Feeding the calves in the period from day 3 to day 28 with milk, and then to day 49 with milk replacer feed ad libitum allowed to get a higher body weight both at day 29, just after the end

of the milk feeding period (P≤0.05), on day 50 after the end of liquid feed (P≤0.05) and after the test (P≤0.05), as compared to the values characterising diets fed with restricted doses (Tab. 3).

Animals fed with the liquid diets ad libitum after the milk feeding period were heavier by about 3.0 kg, and after finishing the feed with liquid feed the body weight was higher by 4.4 kg on average; an analogous difference was found on day 76. The calves in the milk feeding period from day 11 to 28 gained most weight (879 ± 163 g), and the daily gain obtained during this period depended on the level of nutrition (P≤0.02).

In the group of animals fed with restricted doses, the obtained gains were in line with the expectations of nearly 800 g, and in the group fed ad libitum were close to 1000 g. Daily body weight gains in periods following milk feeding in both groups were similar (P> 0 05).

Table 3. Effect of liquid feeding level on body weight and weight gain of female calves

Item	*Liquid feeding*		*Mean*	SD[1]	P[2]≤
	RATIONED	*AD LIBITUM*			
	mean	*mean*			
Number (n)	*15*	*15*	*30*		
Body weight (kg) *at days of age:*					
3	41,9	43,1	42,9	*6,4*	0,40
11	46,1	46,2	46,5	*6,6*	0,35
29	60,4	63,3	62,3	*8,4*	0,05
50	73,6	78,0	76,1	*9,3*	0,05
76	98,1	102,5	100,4	*12,2*	0,05
Overall gain (kg): *during the period (from – to; days of age):*					
3 – 10	4,2	3,7	4,0	*1,8*	0,41
11 – 28	14,3	17,2	15,8	*3,5*	0,02
29 – 49	13,1	14,5	13,8	*4,6*	0,44
3 – 49	31,7	35,0	33,4	*6,7*	0,03
50 – 75	24,5	24,2	24,4	*6,1*	0,12
3 – 75	56,2	59,2	57,7	*9,6*	0,05
During the period (from – to; days of age):					
3 – 10	529	460	495	*226*	0,41
11 – 28	796	961	879	*163*	0,02
29 – 49	625	689	658	*220*	0,44
3 – 49	674	745	710	*142*	0,05
50 – 75	909	896	902	*226*	0,84
3 – 75	760	800	780	*129*	0,05

[1] *Standard deviation.*
[2] *Level of statistically significant differences between the parameters of the experimental groups.*

Higher increases in body weight of calves fed ad libitum were accompanied by higher milk intake (P≤0.01) and the milk replacer feeder (P≤0.01) as compared to calves fed with restricted doses (Tab. 4). In the period

from day 29 to 49 in the group fed ad libitum with liquid feed, the calves took less starter mixture (P≤0.02), and in the final result, both groups revealed similar weight gains (P> 0.05).

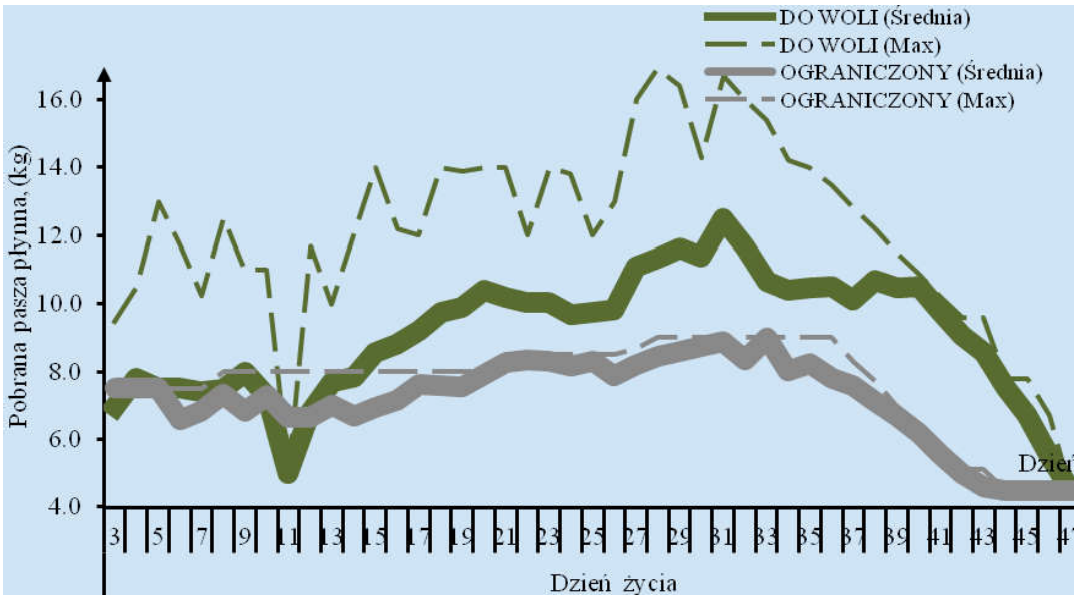
Table 4. Effect of liquid feeding level on feed intake by female calves

[1] *Standard deviation.*

Item		*Liquid feeding*		*Mean*	SD[1]	P[2]≤
Period (from – to; days of age)	*type of feed*	*RATIONED*	*AD LIBITUM*			
		mean	*mean*			
3 – 10	milk (kg)	55,9	61,3	58,6	7,2	0,06
	TMs (kg)	0,09	0,07	0,08	*0,1*	0,27
11–28	milk (kg)	109,9	131,4	120,6	18	0,00
	milk replacer liquid (kg)	28,5	35,3	31,9	4,9	0,01
	MTs (kg)	0,79	0,67	0,73	0,4	0,44
29–49	*milk replacer liquid (kg)*	139,5	191,7	165,6	29	0,01
	TMs (kg)	9,0	6,7	7,8	0,4	0,02
	TMR II (kg)	1,1	0,9	1,0	0,4	0,09
50 –75	MTs (kg)	30,7	30,0	30,3	*2,7*	0,12
	TMR II (kg)	78,7	90,2	84,5	*8,7*	0,02
3 – 75	Milk (kg)	165,8	192,6	179,2	*23*	0,01
	Milk replacer liquid (kg)	168,0	227,0	197,5	*33*	0,01
	TMs(kg)	40,6	37,4	38,9	3,1	0,06
	TMR II (kg)	79,8	91,1	85,5	8,8	0,17

[2]*Level of statistically significant differences between the parameters of the experimental groups.*

The calves fed with unrestricted doses consumed 1.8 kg of liquid feeds more per day, on average, and the maximum daily amounts in week 4 reached 17 kg (Figure 1).



Liquid feed intake; *AD LIBITUM (mean/max)*; *RATIONED (mean/max)*.

Figure 1. Liquid feed intake of female calves from 3 to 49 days of age

The level of nutrition did not affect the number of cases of diarrhoea and pneumonia (P> 0.05), however, in the group fed ad libitum these diseases lasted longer (Tab. 5).

Table 5. Effect of liquid feeding level on female calf health

Item	*Liquid feeding*								P[1] ≤
	RATIONED				*AD LIBITUM*				
	no. of calves			*Total days with signs (per group)*	*no. of calves*			*Total days with signs (per group)*	
	with signs of		*healthy*		*with signs of*		*healthy*		
	diarrhea	*pneumonia*			*diarrhea*	*pneumonia*			
During the period (from – to; days of age):									
3 – 10	2	1	14	12	3	1	11	25	0,14
11 – 28	3		12	12	3	1	11	32	0,09
29 – 49	1	2	12	15	1	3	11	24	0,35
50 – 75			15				15		

[1] *Level of statistically significant differences between the parameters of the test groups.*

In order to compare - whether in the rearing of calves under the production conditions, a better solution is to limit expensive liquid feeds as compared to feeding ad libitum - the economic efficiency of nutrition was estimated. The assessment was based on the calculation of the cost of used fodder per weight gain (Tab. 6). The costs of used feed were calculated based on current market prices. It was found that the applied feeding levels with liquid feed did not affect the costs of feed used to obtain 1 kg body weight gain (P> 0.05).

Table 6. Effect of level of liquid feeding on the cost of feeds per weight gain in female calves

Item		Liquid feeding		Mean	SD[1]	P[2] ≤
		RATIONED	AD LIBITUM			
Period (from – to; days	feed conversion (kg feed/kg gain)	mean	mean			
3 – 49	*milk* (kg)	5,47	5,62	5,55	*1,09*	0,72
	milk replacer liquid (kg)	5,54	6,65	6,10	*1,32*	0,02
	TMs (kg)	0,32	0,22	0,27	*0,13*	0,05
	TMR II (kg)	0,04	0,03	0,03	*0,02*	0,05
	cost (zł/*zloty*)	15,42	16,75	16,09	*3,13*	0,25
50 – 75	TMs (kg)	1,50	1,31	1,40	*0,79*	0,52
	TMR II, (kg)	3,84	3,94	3,89	*1,99*	0,90
	cost (zł/*zloty*)	3,45	3,16	3,30	*1,79*	0,66
3 – 75	*milk* (kg)	3,05	3,29	3,17	*0,58*	0,26
	milk replacer liquid (kg)	3,09	3,90	3,49	*0,71*	0,01
	TMs (kg)	0,75	0,65	0,70	*0,19*	0,15
	TMR II (kg)	1,47	1,58	1,53	*0,33*	0,39
	cost (zł/*zloty*)	9,92	11,09	10,50	*1,91*	0,10

[1] *Standard deviation.*
[2] *Level of statistically significant differences between the parameters of the experimental groups.*
[3] 1,58 zł; MTR II – 0,28 zł – *The costs were estimated based on the following prices (gross) of 1 kg: raw milk with tandard parameters – 1.58 zloty (Rynek mleka, 2018); milk replacer Polmass Milk Red Full – 7.91 zloty (retail price); concentrate Promilk CJ Corn – 1.58 zloty (producer price); MTR II – 0.28 zloty (producer price).*

Although the cost of all fodder used for rearing of one calf in the period from day 3 to day 75 in the group fed ad libitum amounted to about PLN 645.40 and was 19% higher as compared to the cost of PLN 538.30 in the group fed ad libitum, the calves in this group obtained both after liquid feeding and after finishing the test body weight higher by 4.4 kg. The average daily weight gain in these animals was about 800 g, which suggests that such a feeding system allows for the optimal milk production capacity in the future use of cows. The conclusions drawn in 2013 by Soberon and Van Amburg should be taken into account in the assessment of the economic effects of the level of nutrition. Based on the meta-analysis of test results from the last 20 years, the quoted authors found that the effect of increasing body weight gain during the feeding of liquid feeds (the first 2 months of age) on future milk production is described by the following equation: milk yield = -106 kg + 1515.4 kg × increase in daily weight gain (kg/day; P = 0.01). This equation means that per every kilogram of increase in body weight, the milk yield increases by 1550 kg in the 1st lactation. In the light of these suggestions, we estimate that calves fed ad libitum and growing by 0.071 kg per day will produce during the 1st lactation about 107 kg of milk more than calves with lower daily gains and fed with restricted doses. This increase in milk production according to current prices will increase revenue by PLN 170. It should be emphasised that the test was carried out on a milk producing farm where the average yield in 2016 was 12,932 kg. According to the ranking presented by the Polish Federation of

Cattle Breeders and Milk Producers (Evaluation of Milk Cattle, 2017), the farm holds the third place in terms of the average yield of the evaluated dairy cows in the Kujawsko-Pomorskie Voivodeship.

Conclusions

The obtained results of the nutritional test carried out on the Polish breed of Holstein-Friesian calves in the period from day 3 to 75 under the production conditions provide the basis for the following conclusions:

- the levels of feeding with liquid feeds allow obtaining daily body weight gain of about 900 g in calves kept in group pens in an open-type "calf village" during feeding with whole milk (from day 11 to 28), and about 700 g during the entire feeding period with liquid feed (from day 3 to 49) and about 800 g in the rearing period from day 3 to 75;
- calves fed during the feeding period with liquid feeds administered ad libitum, in comparison to those fed with standardised doses, according to the dietary needs of calves growing around 800 g per day, take more liquid feed (+85.8 kg), gain a higher body weight (+4.4 kg) and higher daily weight gain (+71 g);
- the feeding levels used for liquid feed did not affect the health of the calves nor did they affect the cost of feed used to achieve 1 kg of body weight gain.

Summary

Increased intake of liquid feeds and accompanying higher gains and higher body weight as well as the lack of increased susceptibility to diseases indicate that the applied level of nutrition ad libitum with milk up to day 28 and then up to day 49 with milk replacer liquid feed may be recommended for wide use in practice.

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THE OPTIMAL FEEDING LEVEL AND HOUSING SYSTEM FOR FEMALE CALVES UNDER PRODUCTION CONDITIONS

Summary

The purpose of the test was to analyse the impact of liquid feeding levels (restricted vs. unrestricted) from 3 to 49 days of age on weight gains, health status and economic efficiency of rearing female calves under conditions of a milk producing farm.

The female calves *(n=30)* were fed whole milk (days 3 to 28), milk replacer liquid (up to day 49), as well as *ad libitum* starter concentrate and mixed feeds for second lactation cows during the entire test period (days 3 to 75). The animals were kept in a roofed, curtain-sided outside yard for calves, in individual pens from days 3 until 10 and in group pens until day 75. Data were collected on the daily individual intake of liquid feeds and the average total daily intake of solid feeds in group pens.

The results indicate that unrestricted liquid feeding allowed for higher daily weight gains and higher body weight after the milk feeding period ($P\leq0.05$), after the liquid feeding period ($P\leq0.05$), and at the end of the test ($P\leq0.05$), compared to the values of the calves fed restricted diets. The higher weight gains were accompanied by higher intake of milk ($P\leq0.01$) and milk replacer liquid ($P\leq0.01$).

The results showed that the cost of feeds per kg body weight gain in female calves did not depend on the liquid feeding level ($P>0.05$). Using a mathematically described relationship between the obtained weight gains in the first two months of life and the first lactation milk yield, it was estimated that female calves, which were characterized by a higher daily weight gain, would produce more milk during future lactations.

In summary, the feeding system (unrestricted amounts of milk up to day 28 and milk replacer liquid up to day 49) applied in female calves can be recommended for wide use in practice.

Key words: calves, feeding level, economic efficiency of earing

Photo at work: B. Niwińska