

OPERATING COSTS IN NON-LITTER CATTLE BARNES OF HIGH LEVEL OF AUTOMATISATION IN POLAND

KOSZTY EKSPLOATACJI W OBORACH BEZŚCIÓŁKOWYCH W POLSCE O WYSOKIM POZIOMIE AUTOMATYZACJI

Summary: Recently non-litter dairy cattle barns have become more and more popular in Poland. It is reasonable because of higher costs of littered system. As a result of it, multi criterial approach was applied to assess technical, technological and economic indicators. The following factors were tested: technical, technological and economic. Technical assessment included the areas: constructional, production and utility as well as cubage. Within the frame of technological assessment, all technological treatments were considered (milking and milk cooling, feeding and natural manure removing). Energy, labour and investments cost were used to calculate operating costs of machinery and equipment according to own elaborated methodology. In cattle barn with „fish bone” milking parlor there were the lowest operating costs and in building with 1 milking robot the mentioned costs were the highest.

Keywords: energy inputs, milking robots, non-littered housing, operating costs

Streszczenie: W ostatnich czasach w Polsce staje się coraz bardziej popularny bezściółkowy system utrzymania bydła mlecznego. Jest to uzasadnione coraz wyższymi kosztami ściółkowego systemu utrzymania. W związku z tym, przeprowadzono wielokryterialną ocenę obór w systemie bezściółkowym. Zbadano czynniki: techniczne, technologiczne i ekonomiczne. Charakterystyka techniczna obejmowała kubaturę oraz powierzchnię: zabudowy, produkcyjną i użytkową. W ramach oceny technologicznej uwzględniono wszystkie zabiegi technologiczne (doju i wstępnej obróbki mleka, przygotowanie i zadawanie pasz, usuwania i magazynowania nawozów naturalnych). Nakłady energetyczne, robocizny oraz inwestycyjne posłużyły do obliczenia kosztów eksploatacji wyposażenia oraz maszyn i urządzeń wg opracowanej metodyki własnej. Najniższe koszty eksploatacji były w oborze wyposażonej w halę udojową „rybia ość” a najwyższe w oborze z jednym robotem udojowym i najniższą obsadą zwierząt.

Słowa kluczowe: nakłady energii, roboty udojowe, obory bezściółkowe, koszty eksploatacji

Introduction

Adapting of buildings barns and their equipment to the requirements of animal welfare, environmental protection, with ensuring of the profitability of production is a necessary condition for sustainable development in view of the intensification of production. The overview of literature leads to the conclusion that there are no studies, which are completely describing the problem of influence of the solutions applied on costs of milk production in non-littered cattle barns, concerning buildings and their equipment with machinery. The analysis contained the human labour inputs, electrical and mechanical energy inputs, what was the basis for calculation of operating costs.

Till now, operating costs in agricultural production were the objectives of the studies of many researchers (Szulc, 2008; Kowalik, Grześ, 2006; Sonnenberg, Graef, 1999).

Objective and scope of research

The main aim of research performed was to analyze the influence of technological solutions in non-littered cattle barns on labour, energy inputs and costs of milk production.

The fragmentary aims included, *inter alia*:

- determination of investment costs of buildings;

- equipment and machinery for technological treatment in milk production such as: milking and milk cooling, preparation of feed and feeding, manure removing, its storage and other work;
- determination of labour inputs and mechanization level in treatments in milk production, in particular cattle barns;
- determination of electric and mechanical energy inputs;
- determination of operating costs of buildings and equipment for mechanization of all technological treatments.

Among many solutions of tied-up and free-stall cattle barns three free-stall cattle barns were chosen in view of the possibility of mechanization and automation of all technological treatments. The scope of research covered three cattle barns.

In particular, the scope of research consisted of the following elements:

- **technical:** description of buildings, construction, mechanization of technological treatments in milk production – machinery and equipment, including three robots for milking, feed scraping and cleaning of slatted floor;
- **technological:** labour inputs, electric and mechanical energy inputs;
- **economical:** investment costs, electric energy costs, mechanical energy costs, labour costs, operating costs.

Methodology

The field tests were conducted by a direct moderated interview method and photography of working day was made, as well as timing scheme. Unitary operating costs of buildings and equipment with machinery taking part in mechanization of four treatments constituted the sum of unitary maintenance and use costs (Kapela et al., 2017; Kowalik, Grześ, 2006). The equations (1) to (9) shows the way of these costs' calculation.

$$C_c = \frac{C_m + C_a}{N} \quad [\text{PLN} \cdot \text{LU}^{-1} \cdot \text{year}^{-1}] \quad (1)$$

C_e – unitary operating costs [PLN · year⁻¹]
 C_m – costs of maintenance [PLN · year⁻¹]
 C_{us} – costs of use [PLN · year⁻¹]
 N – number of Large Units

Costs of maintenance:

Costs of maintenance (C_m) were the sum of amortization costs of buildings, machinery and their insurance (eq.2)

$$C_m = \frac{C_b}{T_b} + \sum \frac{C_{im}}{T_m} + C_{ins}^b + C_u \quad [\text{PLN} \cdot \text{year}^{-1}] \quad (2)$$

C_b – investments costs of buildings [PLN]
 T_b – the assumed stability of the building [number of years]
 C_{ins}^b – insurance costs of building [PLN · year⁻¹]
 C_m – price (value) replacement of machinery or equipment [PLN]
 T_m – the assumed stability of the machinery [number of years]
 C_u – costs of insurance of machinery and equipment [PLN · year⁻¹]

Costs of usage:

$$C_u = C_e^b + C_r^b + C_e^m + C_m + C_r^m + C_L \quad [\text{PLN} \cdot \text{year}^{-1}] \quad (3)$$

C_u – costs of usage [PLN · year⁻¹]
 C_e^b – costs of electrical energy of buildings [PLN · year⁻¹]
 C_r^b – costs of repairs in buildings [PLN · year⁻¹]
 C_e^m – costs of electrical energy of machinery and equipment for mechanization [PLN · year⁻¹]
 C_m – costs of mechanical energy [PLN · year⁻¹]
 C_r^m – costs of repair of machinery and equipment [PLN · year⁻¹]
 C_L – costs of labour inputs [PLN · year⁻¹]

Results

The tested farms were located in the podlaskie (1 cattle barn) and mazovian voivodships (2 cattle barns). The area of farms was from 65 ha to 802 ha of agricultural land and the size of herds was between 83 and 170 LU [Livestock Units]. The milk yield was from 8500 to 9600 l of milk in extra class. These cattle barns were characterized by at least fourth level of mechanization, i.e. diurnal human labour inputs below 10 working minutes per LU. In two cattle barns milking is performed by milking robots (Automatic Milking System or Voluntary Milking System), in one there was a traditional dairy room. The milk cooling was conducted in milk tanks, which were situated in milk rooms.

The cattle barns had a separated feeding corridor, on which feed was discharged by mixer wagons with tractors, the forage was supplied in PMR system (Partly Mixed Ratio). Supplementary dose of concentrates was fed in milking robots (2 barns) or in feeding station (1 barn). The slurry was stored in deep channels under slatted floor, which was situated in manure-walking alleys, whence was periodically pumped out. In all objects tested the cows were in non-littered area. The characteristic of farms and barns tested concerning the ways of mechanization of particular production treatments was shown in table 1.

Table 1. Characteristic of cattle barns tested

No. of barn	LU milk yield [dm3]	Mechanization of treatments: I- milking and milk cooling, II- feeding, III – r moving and storing of natural manure			
		I type of dairy unit capacity of milk cooler [dm3]	II feeding wagon, company, capacity/power of engine/the technological line for concentrates feeding	III type of manure, power of tractors's engine + capacity of slurry spreader	IV hoof knife power/swinging brushes power
1	109 9600	„fishbone” 2x5(10) 7000	Siloking 12 m ³ /150 KM/ 2 feeding stations, spiral transporter, silos 12,5 m ³	slurry, deep channels, tractor 77,2 KM + slurry spreader 10m ³	electrical 0,25kW
2	170 8500	2 robots Astronaut A4 10000	RMH 14m ³ /95 KM/ feeding in two milking robots, spiral transporter, silos 14 m3 and 15 m3	slurry, deep channels, tractor 160 KM + slurry spreader 14,2 m ³	electrical 0,25kW/ 3 electrical swinging cow brushes 0,12 kW
3	83 9500	robot VMS 5000	SEKO 11 m ³ /110 KM/ feeding in milking robot and 1 feeding station, spiral transporter, silos 8 m ³ and 10 m ³	slurry, deep channels, tractor 123 KM + slurry spreader 12,7 m ³	electrical 0,25kW/ 2 electrical swinging cow brushes 0,12 kW

Table 2 shows the characteristic of buildings, regarding the area of building, using, resting areas, cubage, kind of roof construction and ventilation system, size of slatted floor and capacities of slurry channels.

Two barns had the construction of roof founded on columns, the remaining building had non-columned construction i.e. steel frames. The steel frames although more expensive, are recommended for objects

with width up to 30 meters. Thanks to it there are possibilities for future adaptation of building in case of development. The lack of internal partitions in one-room spaced cattle barns makes the ventilation more effective, because there are not partitions which disturb in gravitational movement of air, making worse the quality of air exchange

Table 2. Building characteristic of cattle barns, using, production and resting areas, slatted floor and capacities of channels for liquid manure.

No of barn	Construction of buildings	Cubage [m ³ •DJP ⁻¹]	Ventilation/ air inflow/ air outflow	Areas					Unitary capacities of slurry channels
				building [m ² •LU ⁻¹]	using [m ² •LU ⁻¹]	production [m ² •LU ⁻¹]	resting [m ²]/ [m ² •LU ⁻¹]	slatted floor [m ²]	[m ³ •LU ⁻¹]
1	one - room spaced non-columned, steel frames	39,74	gravitational /windows roof ridge gap	9,38	9,01	7,85	120/1,10	361,4	3,95
2	three-room spaced, columned	70,64	gravitational/ adjustable curtains/ roof ridge gap	12,44	11,64	10,98	363,5/3,3	1094,8	33,9
3	three-room spaced, columned	74,43	gravitational /windows roof ridge gap	14,86	14,35	11,73	82,8/0,99	461,72	10,43

Tables 3–6 contain the set of machinery and equipment in barns tested, prices and costs of cattle barns buildings

Table 3. Machinery, equipment and prices set for mechanization of technological treatments, costs of cattle barn no 1.

Treatment	Machinery or equipment	Price Cm [PLN•pcs. ⁻¹]	Number of pieces	Price total [PLN]
I	„fish bone” 2x5(10) DeLaval	110 000	1	110 000
	milk cooler 7000 dm ³	49 000	1	49 000
	heater	500	1	500
II	mixing wagon Siloking 12m ³	76 000	1	76 000
	tractor for mixing wagon Ursus 1614 150 KM	199 348	1	199 348
	telescopic, self-going loader MLT 627 20 Zoll 101KM	158 600	1	158 600
	the technological line for concentrates feeding: spiral transporter, 2 feeding stations, silo	45 000	compl.	45 000
	self-locking feed ladder Meprozet Koscian	17 300	compl.	17 300
	drinking bowls with two chambers, with constant water's level Arntjen	700	2	1400
	drinking pots with one chamber with constant water's level Arntjen	520	2	1040
III	slurry mixer (own production)	4500		4500
	tractor for slurry mixer MF 255 48 KM	87 200	1	87 200
	slurry spreader with pump Meprozet Koscian 10 000 dm ³	59 778	1	59 778
	tractor for slurry spreader	215 000	1	215 000
IV	hoof knife	350	1	350
	electrical aggregate	6 500	1	6 500
Total outfit [PLN]				1 031 546
Investments costs of building (barn no. 2) [PLN]				824 236
Costs of machinery, equipment and cattle barn building [PLN•LU⁻¹]				17 025,52

Table 4. Machinery, equipment and prices set for mechanization of technological treatments, costs of cattle barn no 2.

Treatment	Machinery or equipment	Price Cm [PLN·pcs. ⁻¹]	Number of pieces	Price total [PLN]
I	milking robot LELY Astronaut A4	350 000	2	700 000
	milk cooler LELY 10000 dm ³	140 000	1	140 000
	heater	14 000	1	14 000
II	mixing wagon RMH 14 m ³	98 400	1	98 400
	tractor for mixing wagon SAME 95KM	105 000	1	105 000
	telescopic, self-going loader	221 400	1	221 400
	silage cutter	8 100	1	8 100
	the technological line for concentrates feeding (spiral transporter, silos 14 m ³ and 15 m ³)	40 000	compl.	40 000
	feed pusher (robot) LELY JUNO 150 NN765	65 700	1	65 700
	chambered drinking bowls	2 500	4	10 000
	drinking bowls	80	7	560
III	slurry mixer	16 000	1	16 000
	tractor for slurry mixer 130 KM	172 200	1	172 200
	slurry spreader with pump for slurry 14 200 dm ³	120 000	1	120 000
	tractor for slurry spreader 160 KM	466 000	1	466 000
	robot for cleaning of slatted floor	52 200	1	52 200
IV	hoof knife	350	1	350
	swinging cow brush LELY	6 000	3	18 000
Total outfit [PLN]				2 247 910
Investments costs of building (barn no. 3) [PLN]				1 500 000
Costs of machinery, equipment and cattle barn building no 3 [PLN·LU⁻¹]				22 046,52

Table 5. Machinery, equipment and prices set for mechanization of technological treatments, costs of cattle barn no 3.

Treatment	Machinery or equipment	Price Cm [PLN·pcs. ⁻¹]	Number of pieces	Price total [PLN]
I	milking robot VMS	400 000	1	400 000
	milk cooler DeLaval 5000 dm ³	55 000	1	55 000
	heater (with heat recovery)	850	1	850
II	mixing wagon SEKO 11 m ³	70 000	1	70 000
	tractor for mixing wagon SAME Roller 450 110 KM	120 000	1	120 000
	tractor SAME 123 KM	200 000	1	200 000
	the technological line for concentrates feeding (spiral transporter, 2 feeding stations, silos PRO AGRO)	40 000	1	40 000
	head- loader TUR -6	25 000	1	25 000
	feed pusher (robot) LELY JUNO	50 000	1	50 000
	chambered drinking bowls	1 000	2	2 000
	drinking bowls	80	4	320
III	slurry mixer (own production)	4 000	1	4 000
	tractor for slurry mixing SAME 90 KM	-	-	-
	slurry spreader 12 600 dm ³	67 000	1	67 000
	tractor for slurry spreader SAME 123 KM	the same for mixing wagon	-	-
	robot for slatted floor cleaning	64 500	1	64 500
IV	hoof knife	350	1	350
	swinging cow brush DeLaval	6 250	2	12 500
Total outfit [PLN]				111 520
Investments costs of building (barn no. 4) [PLN]				100 525
Costs of machinery, equipment and cattle barn building no 4 [PLN·LU⁻¹]				26 651,14

Tables 6-8 shows labour and energetic inputs in cattle barns tested.

Table 6. Labour, electrical and mechanical energy inputs set in cattle barn no 1.

Treatment	Activity/process	Process time	Process time	Labour inputs	Power of energy source	Energy inputs on process
		[h·LU ⁻¹ ·year ⁻¹]	[h·year ⁻¹]	[working minutes· year ⁻¹]	[kW]	[kWh·year ⁻¹]
I	milking + dairy unit washing	12,24	1334,667	85775	2,2 ;0,55; 1,5 heater	4953,05
	milk cooling+ milk tank washing	174,128	18980	1825	4,0+0,75+0,12	9909,75
II	feed loading	1,834	200	12000	74,2	14840
	feed mixing and discharge	2,752	300	18000	110,3	33090
III	slurry mixing	0,183	20	1200	35,3	706
	slurry pumping out	0,825	90	5400	77,2	6948
IV	decornization	2,0	218	13 080	0,25	54,5
	ordering activities, cleaning the walls /ceiling	0,11	12	720	1,75	21,828
	lighting	-	-	not appl.	-	2640,094
Total labour per year				138000	-	73163,22
Daily labour inputs per LU				3,468	-	1,838

Table 7. Labour, electrical and mechanical energy inputs set in cattle barn no 2.

Treatment	Activity/process	Process time	Process time	Labour inputs	Power of energy source	Energy inputs on process
		[h·LU ⁻¹ ·year ⁻¹]	[h·year ⁻¹]	[working minutes· year ⁻¹]	[kW]	[kWh·year ⁻¹]
I	milking -2 milking robots+ washing	89,75	8200	21717,5	2,2 ;0,55	22 550
	milk cooling +washing of milk tank	27,058	4200	1930,44	5,0;2x0,22+2x0,07	22 932,65
II	feed loading	1,17	200	12000	58,8	11760
	feed mixing and discharge	2,35	400	18000	69,8	27920
	feed pushing	2,47	420	not appl.	55 Ah (3,67kW)	4964
III	slurry mixing	0,729	124	7440	95,6	11854,4
	slurry pumping out	0,729	124	7440	110,3	13677,2
	slatted floor cleaning	10,735	1825	not appl.	0,165	310,25
IV	decornization	1,66	283	16980	0,25	70,75
	ordering, cleaning the walls/ceiling	0,08	14,57	874,2	1,75	25,5
	lighting	not appl.	not appl.	not appl.	-	6105,89
	swinging cow brushes	18,81	not appl.	not appl.	3x0,12=0,36	799,45
Total labour per year				84451,7	-	122 970
Daily labour inputs per LU				1,361	-	1,981

Table 8. Labour, electrical and mechanical energy inputs set in cattle barn no 3.

Treatment	Activity/process	Process time	Process time	Labour inputs	Power of energy source	Energy inputs on process
		[h·LU ⁻¹ ·year ⁻¹]	[h·year ⁻¹]	[working minutes· year ⁻¹]	[kW]	[kWh·year ⁻¹]
I	milking + 1 milking robot, washing (water heating)	89,759	7450	29200	2,2; 0,55; 2,0	12309,295
	milk cooling (aggregate, mixer; ventilator), water heater)	53,012	4400	3650	6,0; 0,78; 0,13; 2,0	11351,1
II	feed loading	1,20	100	6000	74	7400
	feed mixing and discharge	3,01	250	15000	66	16500
	feed pushing	5,18	430	not appl.	55Ah	1578,1
III	slurry mixing	0,05	4	240	66	264
	slurry pumping out	0,96	80	4800	74	5920
	slatted floor cleaning	13,19	1095	not appl.	0,165	180,675
IV	decornization	1,66	138	8280	0,25	34,58
	ordering, cleaning the walls/ceiling	0,175	14,57	874,2	1,75	25,5
	lighting	-	-	not appl.	-	3004,829
	swinging cow brushes	24,09	2000	not appl.	0,12	240
Total labour per year				68044,2	-	58808,079
Daily labour inputs per LU				2,246	-	1,941

On table 9 operating costs were presented, when in table 10 total labour and mechanical and electrical energy, as well as operating costs of buildings and machinery and equipment were given.

Table 9. Costs of operating of buildings, machinery and equipment for mechanization of production treatments.

No. of cattle barn	Costs of maintenance (machinery)	Costs of maintenance (building)	Costs of using (machinery)	Costs of using (building)	Operating costs (machinery)	Operating costs (building)	Total operating costs C_e		Investment costs C_i
	C_m^m	C_m^b	C_u^m	C_u^b	C_{e^m}	C_{e^b}	PLN-year ⁻¹	PLN-year ⁻¹ ·LU ⁻¹	PLN·LU ⁻¹
1	84894,92	16 744,72	124462,84	6 286,94	209357,7	23 031,66	232389,42	2132,01	17025,52
2	178166,85	30 400,00	207200,43	11 831,7	385367,3	42 231,77	427599,05	2515,28	22 046,52
3	89188,46	22 410,50	101826,73	8 238,28	191015,19	30 648,79	221663,98	2670,65	26651,14

Table 10. Energetic and electric indicators set of cattle barns tested.

No. of cattle barn	Unitary investment costs	Unitary daily labour inputs	Mechanization level	Unitary daily energy inputs	Unitary operating costs
	PLN·LU ⁻¹	working minutes·day ⁻¹ ·LU ⁻¹		kWh·day ⁻¹ ·LU ⁻¹	PLN· year ⁻¹ · LU ⁻¹
1	17 025,52	3,47	V	1,838	2 132,01
2	22 046,52	1,36	V	1,981	2 515,28
3	26 651,14	2,24	V	1,941	2 670,65

Conclusions

- Significantly higher investments costs for buildings and their equipment and machinery for mechanization as well as exploitation costs were noted in cattle barns with robots, wherein the lowest was in cattle barn with more livestock (170 LU).
- The energetical energy inputs calculating for 1 LU per day were the highest in cattle barn with one milking robot.
- The lowest daily labour inputs were in two barns with robots for milking, feed pushing and cleaning of slotted floor. The highest labour inputs were in cattle barn with milking unit "fishbone" 2x5 (10) and amounted 3,47 working minutes per day and per LU - fifth level of mechanization was ensured.
- The highest exploitation costs of the buildings were in farm with the highest herd size and with two milking robots. The highest total exploitation costs (regarding buildings and their equipment with machineries) were in cattle barns with milking robots. Higher exploitation costs in robotized cattle barns resulted, inter alia, from high investment costs, but also higher, comparing with other buildings- electric energy inputs.

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