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ECONOMIC ANALYSIS OF NON-LITTER CATTLE BARNS

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ABSTRACT

The objective of the article was to show exploitation costs from three cattle barns in a non-litter loose housing system. The method was based on the multi criteria approach which referred to following factors: technical, technological (mainly energetic and labour), economic (costs of energy, labour, investment). Within technical assessment, the building characteristics was carried out which pertained to the areas of productivity, building, laying and cubage. In order to carry out technological assessment, all methods of mechanization were analysed and as a result, energetic, energy and investment inputs were obtained. Exploitation costs of machinery, equipment and cattle barn buildings were calculated according to the methodology developed in IBMER *[Institute for Construction, Mechanization and Electrification in Agriculture]*. The lowest exploitation cost was in a cattle barn with a traditional "herring bone" milking unit and amounted to 2 132.01 PLN·year^{-1}·LU^{-1}. The highest exploitation costs amounting to 2 670.65 PLN·year^{-1}·LU^{-1}, were in a cattle barn with one milking robot and the lowest herd size.

Introduction

Adapting buildings, barns and their equipment to the requirements of animal welfare, environmental protection, with ensuring production profitability is a necessary condition for sustainable development in view of the intensification of production (Romaniuk and Mazur, 2014; Mazur, 2012). The overview of literature leads to the conclusion that there are no studies, which fully describe the problem of impact of the applied solutions on the milk production costs in non-littered cattle barns, concerning buildings and their equipment with machinery. The analysis contained the human labour inputs, electrical and mechanical energy inputs, which constituted the basis for calculation of exploitation costs.

Till now, exploitation costs in agricultural production have been the objectives for studies carried out by many researchers (Freiberger et al., 2005, Jucherski and Król, 2011, Majchrzak, 2013, Naes et al., 2010, Muzalewski 2010, Naess and Stokstad 2010, Szulc, 2009; Szulc and Markiewicz, 2010). All these publications only describe chosen technological treatments and their costs, but none of them takes into account total exploitation costs of machinery, equipment and buildings.

The objective of research

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

The fragmentary objectives were as follows:

– 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 feed discharge, manure removal, its storage and other works;
– determination of labour input and the mechanization level in milk production, in particular cattle barns;
– determination of electric and mechanical energy inputs,
– determination of exploitation costs of buildings and equipment for mechanization of all technological treatments.

The scope of research

Among many solutions 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, which jointly met the following input conditions:

– herd size above 80 LU,
– at least 4^{th} level of mechanization,
– milk yield in herd above 8000 dm^3 milk in extra class.

In particular, the scope of research consisted of such elements as:

– *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,
– *economic*: investment costs, electric energy costs, mechanical energy costs, labor costs, exploitation costs.

Methodology

The field tests were conducted by a direct moderated interview method, a picture of a working day was taken, and a timing scheme was made. In all buildings the same activities within a year were performed. Unitary exploitation costs of buildings and equipment with machinery taking part in mechanization of four treatments were the sum of the unitary maintenance and use costs. Equations (1) to (3) show the method of calculation of these costs (Muzalewski, 2010; Gazzarin and Lips, 2013; Gazzarin and Hilty, 2002).

$$C_e = \frac{C_m + C_{us}}{N} \quad (PLN \cdot LU^{-1} \cdot year^{-1}) \tag{1}$$

c_e – exploitation costs, ($PLN \cdot year^{-1}$)
C_m – costs of maintenance, ($PLN \cdot year^{-1}$)
C_{us} – operating costs, ($PLN \cdot year^{-1}$)
N – number of Livestock Units (Muzalewski 2010, Gazzarin and Hilty, 2013; Gazzarin and Lips, 2002)

Costs of maintenance:

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

$$C_m = \frac{C_{ib}}{T_b} + \sum \frac{C_{im}}{T_m} + C^b_{ins} + C_{ui} \quad (PLN \cdot year^{-1}) \tag{2}$$

C_{ib} – replacement value of buildings, (PLN)
T_b – the assumed stability of the building, (number of years)
C^b_{ins} – insurance costs of building, ($PLN \cdot year^{-1}$)
C_{im} – price (value) replacement of machinery or equipment, (PLN)
T_m – the assumed stability of the machinery, (number of years)
C_{ui} – costs of insurance of machinery and equipment, ($PLN \cdot year^{-1}$) (Muzalewski 2010)

Operating costs:

$$C_u = C^b_{ee} + C^b_r + C^m_{ee} + C_{me} + C^m_r + C_L \quad (PLN \cdot year^{-1}) \tag{3}$$

C_u – operating costs, ($PLN \cdot year^{-1}$)
C^b_{ee} – costs of electrical energy of buildings, ($PLN \cdot year^{-1}$)
C^b_r – costs of repairs in buildings, ($PLN \cdot year^{-1}$)
C^m_{ee} – costs of electrical energy of machinery and equipment for mechanization, ($PLN \cdot year^{-1}$)
C_{me} – costs of mechanical energy, ($PLN \cdot year^{-1}$)
C^m_r – costs of repair of machinery and equipment, ($PLN \cdot year^{-1}$)
C_L – costs of labour inputs, ($PLN \cdot year^{-1}$) (Muzalewski 2010)

Research results

The farms tested were located in Podlaskie (1 cattle barn) and Mazowieckie Voivodships (2 cattle barns). The size of herds was between 83 and 170 LU (Livestock Units). The milk yield was from 8500 to 9600 liters of milk in extra class. These cattle barns were characterized with at least fourth level of mechanization, i.e. diurnal human labour inputs below 10 working minutes per LU. In two cattle barns milking was conducted by milking robots (Automatic Milking System or Voluntary Milking System), one of them was equipped with a traditional dairy room. The milk cooling was provided 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 the use of tractors, forage was in the PMR system (Partly Mixed Ratio). A supplementary dose of concentrates was provided in milking robots (2 barns) or in a feeding station (1 barn). The slurry was in deep channels under slatted floor, which was situated in manure-walking alleys, from which it was periodically pumped out. In all tested objects cows were in a non-littered area. The characteristic of the investigated farms and barns concerning the methods of mechanization of particular treatments was presented in Table 1.

Table 1
Characteristic of investigated cattle barns

No. of barn	LU milk yield (dm^3)	Mechanization of treatments: I – milking and milk cooling, II – feeding, III – removing and storing of natural manure; IV – other works			
		I type of dairy unit capacity of milk cooler (dm^3)	II feeding waggon, – company, capacity/ power of engine / the technological line for concentrates feeding	III type of manure, power of tractors engine + capacity of slurry spreader	IV hoof knife power/ swinging brushes power
1	109 9600	„herring bone” 2x5(10) 7000	Siloking 12 m^3/ 110 kW/ 2 feeding stations, spiral transporter, silos 12,5 m^3	slurry, deep channels, tractor 56 kW + slurry spreader 10m^3	electrical 0.25 kW
2	170 8500	2 robots Astronaut A4 10000	RMH 14m^3/ 65 kW/ feeding in two milking robots, spiral transporter, silos 14 m^3 and 15 m^3	slurry, deep channels, tractor 117 kW+ 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/ 80 kW/ feeding in milking robot and 1 feeding station, spiral transporter, silos 8 m^3 and 10 m^3	slurry, deep channels, tractor 90 kW + slurry spreader 12.7 m^3	electrical 0,25kW/ 2 electrical swinging brushes 0.12 kW

Table 2 shows the characteristic of buildings, regarding the area of a building, using, resting areas, cubage, the type of roof construction and a 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. Steel frames although more expensive, are recommended for objects with width up to 30 meters. Due to this solution there are possibilities for future adaptation of a building in case of further development (Romaniuk et.al., 2012). Lack of internal partitions in one-room spaced cattle barns causes, that ventilation is more effective, because there are no partitions which disturb gravitational movement of air, causing bad exchange of air and worse quality of air. This means, that when we have the same number of windows and doors, directions of wind and its velocity and geographical location of buildings, in a building without columns (steel frame construction) there is much bigger freedom for movement.

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

No of barn	Construction of buildings	Cubage	Ventilation/ air inflow/ air outflow	Areas					Unitary capacities of slurry channels
				building	using	production	resting (m^2)/	slatted floor	
		($m^3 \cdot LU^{-1}$)		($m^2 \cdot LU^{-1}$)	($m^2 \cdot LU^{-1}$)	($m^2 \cdot LU^{-1}$)	($m^2 \cdot LU^{-1}$)	(m^2)	($m^3 \cdot LU^{-1}$)
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 investigated barns, including prices and costs of cattle 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	Replacement value (PLN)
I	„herring 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 12 m^3	76 000	1	76 000
	tractor for mixing wagon Ursus 1614 110 kW	199 348	1	199 348
	telescopic, self-going loader MLT 627 20 Zoll 74 kW	158 600	1	158 600
	the technological line for concentrates feeding: spiral transporter, 2 feeding stations, silo	45 000	set[1]	45 000
	self-locking feed ladder Meprozet Koscian	17 300	set[1]	17 300
	drinking bowls with two chambers, with constant water level Arntjen	700	2	1400
	drinking pots with one chamber with constant water level Arntjen	520	2	1040
III	slurry mixer (own production)	4500		4500
	tractor for slurry mixer MF 255 (35 kW)	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
	electric aggregate	6 500	1	6 500
Total outfit (PLN)				1 031 516
Replacement value of building (barn no. 1) (PLN)				824 236
Replacement value of equipment and cattle barn building (PLN·LU^{-1})				17025

Table 4

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

Treatment	Machinery or equipment	Replacement value Cm (PLN·pcs.$^{-1}$)	Number of pieces	Replacement value 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 69 kW	105 000	1	105 000
III	telescopic, self-propelled 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	set	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
	slurry mixer	16 000	1	16 000
	tractor for slurry mixer 69 kW	172 200	1	172 200
	slurry spreader with pump for slurry 14 200 dm^3	120 000	1	120 000
	tractor for slurry spreader 117 kW	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	6000	3	18 000
Total outfit (PLN)				2 247 910
Replacement value of building (barn no.2) (PLN)				1 500 000
Replacement value of equipment and cattle barn building no. 2 (PLN·LU^{-1})				22 047

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

Treatment	Machinery or equipment	Replacement value Cm ($PLN \cdot pcs.^{-1}$)	Number of pieces	Replacement value 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 vagon SAME Roller 450 60 kW	120 000	1	120 000
	tractor SAME 74 kW	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 74 kW	-	-	-
	slurry spreader 12 600 dm^3	67 000	1	67 000
	tractor for slurry spreader SAME 74 kW	the same for mixing vagon	-	-
	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)				1 111 525
Replacement value of building (barn no.3) (PLN)				1 100 525
Replacement value of machinery, equipment and cattle barn building no. 3 ($PLN \cdot LU^{-1}$)				21 169

Tables 6-8 shows labour and energetic inputs in cattle barns tested. Remarks to tables 6-8: [1)]vacuum pump, [2)]milk pump,[3)]heater, [4)]aggregate, [5)]ventilator, [6)]mixer.

The electric energy for lighting was calculated based on normative 2W per m^2 of the building area for animals assuming the “artificial day” duration in months from September to March from 3 pm to 8 am, and in the remaining days from 6 pm to 6 am.

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

Treatment	Activity /process	Process time ($h \cdot LU^{-1} \cdot year^{-1}$)	Process time ($h \cdot year^{-1}$)	Labour input (man- minute· $year^{-1}$)	Energy source (kW)	Energy input on process ($kWh \cdot year^{-1}$)
I	milking + dairy unit washing	12.24	1 334.67	85 775.00	2.20[1)]; 0.55[2)] 1.50[3)]	4 953.05
	milk cooling+ milk tank washing	174.13	18 980.00	1 825.00	4.0[4)]; 0.75[5)]; 0.12[6)]	9 909.75
II	feed loading	1.83	200.00	12 000.00	74.,20	14 840.00
	feed mixing and discharge	2.75	300.00	18 000.00	110.30	33 090.00
III	slurry mixing	0.18	20.00	1 200.00	35.30	706.00
	slurry pumping out	0.83	90.00	5 400.00	77.20	6 948.00
IV	decornization	2.00	218.00	13 080.00	0.25	54.50
	ordering activities, cleaning the walls /ceiling	0.11	12.00	720.00	1.75	21.83
	lighting	-	-	not appl.	-	2 640,09
Total labour per year				138000	-	73 163.22
Daily labour inputs per LU				3.468	-	1.84

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

Treatment	Activity /process	Process time ($h \cdot LU^{-1} \cdot year^{-1}$)	Process time ($h \cdot year^{-1}$)	Labour inputs (man-minute·$year^{-1}$)	Power of energy source (kW)	Energy input on process ($kWh \cdot year^{-1}$)
I	milking -2 milking robots+ washing	89.75	8 200.00	21 717.50	2.20[1)]; 0.55[2)]	22 550.00
	milk cooling +washing of milk tank	27.06	4 200.00	1 930.44	5.00[4)]; 2x0.22[5)] 2x0.07[6)]; 1,20[3)]	22 932.65
II	feed loading	1.17	200.00	12 000.00	58.80	11 760.00
	feed mixing and discharge	2.35	400.00	18 000.00	69.80	27 920.00
	feed pushing	2.47	420.00	not appl.	3.67	4964.00
III	slurry mixing	0.73	124.00	7 440.00	95.60	11 854.40
	slurry pumping out	0.73	124.00	7 440.00	110.30	13 677.20
	slatted floor cleaning	10.74	1 825.00	not appl.	0.17	310.25
IV	decornization	1.66	283.00	16 980.00	0.25	70.75
	ordering, cleaning the walls/ceiling	0.08	14.57	874.20	1.75	25.50
	lighting	not appl.	not appl.	not appl.		6 105.89
	swinging cow brush-es	18.81	not appl.	not appl.	3x0.12=0.36	799.45
Total labour per year				84451.70	-	122 970.00
Daily labour inputs per LU				1.36	-	1.98

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

Treatment	Activity/process	Process time ($h \cdot LU^{-1} \cdot year^{-1}$)	Process time ($h \cdot year^{-1}$)	Labour inputs (man-minute $\cdot year^{-1}$)	Power of energy source (kW)	Energy inputs on process ($kWh \cdot year^{-1}$)
I	milking + 1 milking robot, washing (water heating)	89.76	7 450.00	29 200.00	$2.2^{1)}$; $0.55^{2)}$; $2.0^{3)}$	12 309.30
	milk cooling (aggregate, ventilator, mixer;), water heater)	53.01	4400.00	3 650.00	$6.0^{4)}$; $0.75^{5)}$ $0.13^{6)}$ $2.0^{3)}$	11 351.10
II	feed loading	1.20	100.00	6 000.00	74	7 400.00
	feed mixing and dis-charge	3.01	250.00	15 000.00	66	16 500.00
	feed pushing	5.18	430.00	not appl.	55Ah	1578.10
III	slurry mixing	0.05	4.00	240	66	264.00
	slurry pumping out	0.96	80.00	4800.00	74	5 920.00
	slatted floor cleaning	13.19	1 095	not appl.	0.165	180.68
	decornization	1.66	138	8280	0.25	34.58
IV	ordering, cleaning the walls/ceiling	0.18	14.57	874.20	1.75	25.50
	lighting	-	-	not appl.	-	3 004.83
	swinging cow brushes	24.09	2000.00	not appl.	0.12	240.00
Total labour per year				68044.20	-	58 808.08
Daily labour inputs per LU				2.24	-	1.94

Table 9 presents exploitation costs, table 10 total labour, mechanical and electrical energy, as well as exploitation costs of buildings, machinery and equipment.

Table 9
Costs of exploitation of buildings, machinery and equipment involved in mechanization of production processes

No of barn	Costs of mainte-nance (machinery) C_m^m	Costs of maintenance (building) C_m^b	Operating costs (machinery) C_u^m	Operating costs (building) C_u^b	Exploitation costs (machinery) Ce^m	Exploitation costs (building) Ce^b	Total exploitation costs C_e		Investment costs C_i
	($PLN \cdot year^{-1}$)						($PLN \cdot year^{-1}$)	($PLN \cdot year^{-1} \cdot LU^{-1}$)	($PLN \cdot LU^{-1}$)
1	84894.9	16 744.7	124462.8	6 286.9	209357.7	23 031.6	232389.4	2132.0	17025.5
2	178166.9	30 400.0	207200.4	11 831.7	385367.3	42 231.7	427599.0	2515.3	22 046.5
3	89188.5	22 410.5	101826.7	8 238.3	191015.2	30 648.8	221663.9	2670.7	26651.1

Table 10
Energetical and electrical indicators of investigated cattle barns

No. of cattle barn	Unitary investment costs	Unitary daily labour inputs	Mechanization level	Unitary daily energy inputs	Unitary exploitation costs
	$(PLN \cdot LU^{-1})$	$(Man\text{-}minute \cdot day^{-1} \cdot LU^{-1})$		$(kWh \cdot day^{-1} \cdot LU^{-1})$	$(PLN \cdot year^{-1} \cdot LU^{-1})$
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

1. The lowest daily labour input was in a barn equipped with two robots for milking, one robot for feed pushing and cleaning of slatted floor. The highest labour inputs were in a cattle barn with a "herringbone" 2x5 milking unit (10) and amounted to 3.47 working minutes per day and per LU – fifth level of mechanization was ensured. The automatic milking systems could be with all certainty used everywhere, where there are no human resources for service.
2. A significantly higher investment cost for buildings and their equipment and machinery for mechanization as well as exploitation costs were observed in cattle barns with robots, whereas the lowest was in a cattle barn with more livestock (170 LU).
3. The energy inputs calculated for 1 LU per day were the highest in a cattle barn with one milking robot.
4. The highest exploitation costs of buildings were in a farm with the highest herd size and with two milking robots. The highest total exploitation costs (regarding buildings and their equipment with machinery) were in cattle barns with milking robots. Higher exploitation costs in robotized cattle barns resulted in higher investment costs, but also higher, compared to other buildings – electric energy inputs.

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ANALIZA EKONOMICZNA OBÓR BEZŚCIÓŁKOWYCH

Streszczenie. Celem artykułu było przedstawienie kosztów eksploatacji trzech obór w bezściółkowym systemie utrzymania bydła. Metoda bazowała na podejściu wielokryterialnym, które odnosi się do następujących czynników: technicznych, technologicznych (głównie energetycznych i nakładów pracy), ekonomicznych (koszt energii, robocizny, inwestycji). W ramach oceny technicznej przeprowadzono charakterystykę budowlaną, która dotyczyła powierzchni produkcyjnych, zabudowy, legowiskowych i kubatury. W celu przeprowadzenia oceny technologicznej zostały przeanalizowane wszystkie sposoby mechanizacji i jako wynik uzyskano nakłady energetyczne i inwestycyjne. Koszty eksploatacji maszyn, wyposażenia i obór dla bydła obliczono zgodnie z metodologią opracowaną w IBMER *[Instytut Budownictwa, Mechanizacji i Elektryfikacji Rolnictwa]*. Najniższe koszty eksploatacji były w oborze z tradycyjną dojarnią „rybia ość" i wynosiły 2 132.01 PLN·rok^{-1}·DJP^{-1}. Najwyższe koszty eksploatacji wynoszące 2 670.65 PLN·rok^{-1}·DJP^{-1} były w oborze z jednym robotem do dojenia i najwyższą obsadą.

Słowa kluczowe: nakłady energii, nakłady robocizny, koszty eksploatacji, wolnostanowiskowe utrzymanie