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DEVELOPMENT OF ENVIRONMENTAL CONDITIONS IN FREE-STALL CATTLE BARNS

Summary

The aim of this study was to define influence of different housing systems and barns on costs and energetic inputs in milk production and assessment of microclimate conditions. There were twelve free-stall cattle barns for dairy cows tested and the analysis contains: investment costs of buildings, equipment for mechanization of technological treatments (milking and milk cooling, forage preparing and feeding, manure removing and storing and other works), electric and mechanical energy inputs, labour inputs, exploitation costs of equipment and buildings, concentration of harmful gases, temperature of air and relative humidity inside and outside of barns. The limitations to the choice of the best technical- technological solution were assumed: average investment cost ≤ 19000 PLN, average labour inputs ≤ 4,6 working minutes, electric energy inputs ≤ 0,40 kWh, mechanic energy inputs ≤ 2,006 HP, NH_3 concentration ≤ 10,9 ppm and CO_2 concentration ≤ 1500,8 ppm. These values are per day and per LU. The best functional - technological solutions were in two barns, which fulfilled all limitations. It were: one boxed cattle barn with litter and one boxed non-littered barn, both with high number of animals, 144 LU and 109 LU respectively. Simultaneously in these two barns the lowest unitary exploitation costs were calculated and amounted to 1710,98 PLN·LU^{-1} and 2088,57 PLN·LU^{-1}.

***Key words**: housing system, investments, exploitation costs, dairy cows, energy input*

KSZTAŁTOWANIE WARUNKÓW ŚRODOWISKOWYCH W OBORACH WOLNOSTANOWISKOWYCH DLA BYDŁA

Streszczenie

Celem badań było określenie wpływu różnych systemów utrzymania na koszty i nakłady energetyczne w produkcji mleka oraz ocena warunków mikroklimatu. Zbadano 12 obór wolnostanowiskowych dla krów mlecznych i analiza obejmowała: koszty inwestycyjne budynków oraz wyposażenia dla mechanizacji zabiegów technologicznych (dój i wstępna obróbka mleka, przygotowanie i zadawanie pasz, usuwanie i magazynowanie nawozu i prace różne), nakłady energii elektrycznej i mechanicznej, nakłady pracy, koszty eksploatacji budynków stężenia szkodliwych gazów, temperaturę i wilgotność powietrza, koszty eksploatacji wyposażenia i budynków. Zostały ustalone graniczne wartości: średnie koszty inwestycyjne ≤ 19000 PLN, średnie nakłady robocizny≤ 4,6 roboczominut, nakłady energii elektrycznej ≤ 0,40 kWh, nakłady energii mechanicznej ≤ 2,006 KMh, stężenie NH_3 ≤ 10,9 ppm, stężenie CO_2 ≤1500,8 ppm. Wszystkie te wartości były w odniesieniu do 1 doby i 1 DJP. Najlepszymi rozwiązaniami technologiczno – funkcjonalnymi były dwie obory, które spełniły wszystkie ograniczenia. Były to: obora boksowa ściółkowa oraz boksowa bezściółkowa, obie z dużą obsadą, odpowiednio 144 DJP oraz 109 DJP. Jednocześnie, w tych dwóch oborach odnotowano najniższe jednostkowe koszty eksploatacji, które wynosiły 1710,98 PLN·DJP^{-1} oraz 2088,57 PLN·DJP^{-1}.

***Słowa kluczowe**: system utrzymania, inwestycje, koszty eksploatacji, krowy dojne, nakład energetyczny*

1. Introduction

Modern systems of animal housing could be realized only in functional buildings, with machines and equipment which ensure acquisition of milk of high quality and good conditions for animals. Sustainable technologies in agriculture should lead to minimalizing of energetic inputs.

Technology is analysed and evaluated in the scope of production treatments in animal housing. In Poland nowadays designed and also existing buildings for farm animals should comply technological standards which ensure animal welfare and should be compatible with Polish and EU law regulations.

Directions of scientific-research activities for the next time:
- analysis of state of the art and needs in the scope of technology and buildings in animal housing and production safety,
- research of minimalizing of economics inputs, including energetic inputs in milk production and other animal materials,
- research of environmental conditions in housing buildings and definition of directions of improving of state,
- research of obtainment of non- conventional energy with the significantly use of substrate from natural manure,
- research of effectiveness of using of robots for milking, feeding and natural manure removing,
- complex elaboration and implementation of model solutions of livestock objects with different mechanization, automatization and robotization level fulfilling particular criteria: economical, energetic, ecological, animal welfare and other.

Taking into account problems mentioned above, it was attempted to evaluate existing buildings for dairy cows in the scope of exploitation costs of buildings machines and equipment, human labour inputs, energetic inputs and microclimate conditions.

The review of compulsory Polish and EU law regulations and polish and foreign literature was made in the scope:
- housing systems of dairy cows [4, 10, 19] and other

publications;
- mechanization, automatization and robotization of technological treatments: milking and milk cooling [7, 15], preparing of forage and feeding, removing and storing of natural manure [2] and other works [6] and also other publications;
- microclimate parameters and factors in formation of microclimate in free-stall cattle barns for dairy cows [17] and other publications;
- costs of milk production and energetic inputs [7, 8, 14], and other publications;
- methods of designing of functional - spatial solutions [5, 20] and other publications,

Scientific problem was formulated in the result of analysis of literature and preliminary research, as three questions:
- how do technological solutions influence on mechanization level and energetic inputs in cattle barns?
- how do technological solutions influence on formation of microclimatic conditions in cattle barns?
- how do mutual relationships between elements of functional - technological solutions of cattle barns influence on costs in milk production?

Main aim of the thesis was multicriterial evaluation of free-stall cattle barns for dairy cows.

Detailed aims:
- evaluation of technological – functional elements of free-stall cattle barns for dairy cows,
- definition of mechanization level of objects tested,
- definition of influence of housing systems on energetic inputs in milk production,
- definition of evaluation model of technological – functional solutions in order to describe most advantageous solutions,
- choice of most advantageous solutions according to assumed limitations.

2. Material and methods

There were twelve among about forty cattle barns chosen and tested, fulfilling following preliminary criteria: - at least 4th level of mechanization; - average annual milk yield of herd above 6200 litres; - number of animals above 39. These barns were in loose housing system, with and without litter (4 with deep litter, 4 boxed with shallow litter and 4 boxed with slurry system and channels). The objects tested were described in the scope of technological-architectural solutions including ways of mechanisation of four technological treatments (milking and milk cooling, forage preparing and feeding, manure removing and storing and other works).

Detailed scope of research included:
- technical elements characterizing buildings tested such as: dimensions of resting and feeding area, manure corridors, and as result of these measurements, cubage of barn,
- technological elements such as: labour inputs on four technological treatments, electric and mechanical energy inputs in milk production and mechanization's level of cattle barns,
- calculation of investments and exploitation costs of buildings, equipment and machines,
- microclimate parameters,
- evaluation of objects tested and choice of most advantageous solution taking account of limitations.

M e a s u r i n g m i c r o c l i m a t e p a r a m e t e r s. There were temperature and relative humidity of air, NH_3 and CO_2 concentration in 3-4 days period in each barns in the animal area measured. Besides, temperature and relative humidity of air outside the barn were measured. Values (averages) from every 5 minutes were obtained. Following apparatus: 4 thermo-, hygro-, barometers, 4 gas multimeters measuring NH_3 and CO_2 (infra-red sensors) concentration - all with internal memories, and 4 thermo-hygrometers with transferring to the data-concentrator were used- all data was finally transported to PC and elaborated in STATISTICA 10 PL.

M o d e l o f f i n a l m u l t i c r i t e r i a l e v a l u a t i o n. The final evaluation was made on the basis of the following target function – minimalization of exploitation costs (1):

$$ke = \frac{Km + Ku}{N} \rightarrow \text{minimum} \qquad (1)$$

where: ke – unitary exploitation costs [PLN · year $^{-1}$ · LU^{-1}],
Km – cost of maintenance [PLN · year $^{-1}$],
Ku– costs of use [PLN · year $^{-1}$],
N – number of LU.

E x p l o i t a t i o n c o s t were calculated according to equations described by Gazzarin as well as Muzalewski [8, 14] Limitations to the choice of the best solution were the criteria to the final function as follows:

Terminal investment's inputs

$$\mathbf{k}_{invest.} \leq \mathbf{k}_{limit.\ invest}.\ [PLN \cdot LU^{-1}] \qquad (2)$$

II Permissible labour inputs on 4 technological treatments

$$\mathbf{n}_{labour.} \leq \mathbf{n}_{limit.\ labour}\ [\text{working minutes} \cdot day^{-1} \cdot LU^{-1}] \qquad (3)$$

III Permissible concentrations of harmful gases (CO_2 and NH_3)

$$\mathbf{S}_{CO2} \leq \mathbf{S}_{limit.\ CO2}\ [ppm] \qquad (4)$$

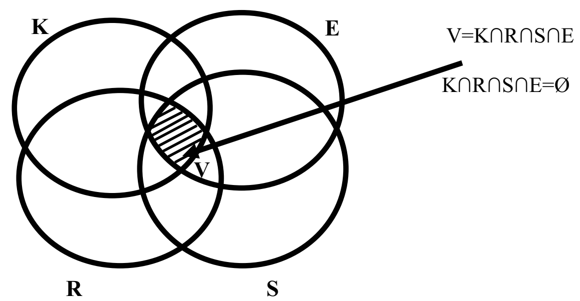
$$\mathbf{S}_{NH3} \leq \mathbf{S}_{limit.NH3}\ [ppm] \qquad (5)$$

IV Terminal energy inputs (electrical and mechanical)

$$\mathbf{e} \leq \mathbf{e}_{limit}.\ [kWh \cdot day^{-1} \cdot LU^{-1},\ HP \cdot day^{-1} \cdot LU^{-1}] \qquad (6)$$

All solutions were set in order of exploitations costs straining to minimum.

The way of choice of best solutions with maintenance of all limitations shows diagram below (Fig. 1).



Source: own study / Źródło: opracowanie własne

Fig. 1. Choice of best solutions according to target function - exploitation costs

Rys. 1. Wybór najlepszych rozwiązań zgodnie z funkcją celu – kosztów eksploatacji

Set V is a common part of sets K, R, S and E, fulfilling all limitations, were:
K - set cattle barns fulfilling limitation I,
R - set of cattle barns fulfilling limitation II,

R - set of cattle barns fulfilling limitation III,
E - set of cattle barns fulfilling limitation IV.

3. Results

The farms studied are individual farms. Table 1 shows overall characteristic of barns tested. The cattle barns were built in the last ten years. There were four cubical littered, four cubical non - littered, four deep litter cattle barns tested. The number of cows was in the range from 39 LU to 170 LU.

Ways of mechanization in barns shows Table 2. Annual average milk yield of cows was from 6200 litres to 9600 l of milk with extra class.

Milking was in milking parlours: herring-bone 2x4 (three barns), 2x3 (one barn), 2x5 (four barns), one 2x6 herring-bone, one tandem 2x4 and in two barns was automatic system. The power of milking pumps was 0,55 kW. Milk tanks had capacities from 1600 litres to 10 000 litres and their power was from 1,25 kW to 6 kW. Roughage mixed with concentrates were fed by feed mixer with the capacities from 7 to 20 m^3. They worked with tractors from 52 HP to 160 HP. In two cattle barns forage was fed directly by tractor and loader.

Table 1. Overall characteristic of tested farms
Tab. 1. Ogólna charakterystyka zbadanych obór

No of barn	1	2	3	4	5	6	7	8	9	10	11	12
LU Breed	93 phf – cb simental 7300	87 phf – cb jersey	100 simental mont' beliarde phf – cb	100 phf – cb 9000	44 phf- cb 7000	81 phf- cb 7000	39 phf- cb 6500	144 phf- cb 7500	170 phf- cb	83 phf- cb	87 phf- cb	109 phf- cb
housing system	deep litter	deep litter	deep litter	deep litter	boxed, litter	boxed, litter	boxed, litter	boxed, litter	boxed, without litter	boxed, without litter	boxed, without litter	boxed, without litter
average milk yield	7300	8000	6200	9000	7000	7000	6500	7500	8500	9500	9600	9600

Source: own study / Źródło: opracowanie własne

Table 2. Mechanization in tested barns
Tab. 2. Mechanizacja w badanych oborach

No of barn	Mechanization of main treatments			
	1st treatment: milking and milk cooling Milking unit (type) Capacity of milk tank [dm^3]// Power vacuum aggregate /aggregate of milk tank [kWh]	2nd treatment: preparing of feed and feeding	3rd treatment: manure removal and storage	4th treatment: other works
1	FB 2x6(12) 6000// 3/ 4,2	feed mixer 17 m^3+ tractor 140 HP + loader; TMR	tractor 120 HP + loader, manure spreader	swinging cow brush, electric hoof knife
2	FB 2x4(8) 6700//2,2/ 4,2	feed mixer 10 m^3+ tractor 82 HP + loader, TMR	tractor 82 HP + loader, manure spreader	electric hoof knife;
3	FB 2x5(10) 2500// 2,6/1,25	feed mixer 18 m^3+ tractor 80 HP + loader; TMR	tractor 120 HP+ loader, manure spreader	2 swinging cow brush, electric hoof knife
4	FB 2x5(10) 8100/ 2,2/1,25	feed mixer 13 m^3+ tractor 120 HP+ loader; TMR	tractor loader 120 HP, manure spreader	ventilator, electric hoof knife
5	FB 2x4(8) 1600//2,2/2	feed mixer 7 m^3+ tractor 55 HP+ loader; TMR	solid floor, manure scrapers, tractor 90 HP + loader	electric hoof knife
6	FB 2x5(10) 800// 2,2/1,25	tractor 100 HP + loader	solid floor, manure scrapers, tractor 100 HP + loader	electric hoof knife
7	FB 2x3(6) 2500//3,0/3,0	tractor 80 HP + loader	solid floor in alleys, tractor 52 HP + shovel	electric hoof knife
8	Tandem 2x4(8) 2700/1500// 3,0/6,0 and 4,0	feed mixer 20 m^3+ tractor-loader 120 HP ;TMR	solid floor, manure scrapers, tractor 100 HP + loader	electric hoof knife
9	2 milking robots 10000// 3,0/2,2	feed mixer 14 m^3+ tractor 95 HP+ loader; TMR	deep slurry, robot-scraper, tractor 160 HP, slurry spreader	3 swinging cow brushes, electric hoof knife
10	VMS 5000// 3,0/2,2	feed mixer 11 m^3+ tractor 110 HP + loader, TMR	deep slurry, robot-scraper, tractor 74 HP, slurry spreader	swinging cow brushes, electric hoof knife
11	FB 2x4(8) 2600//3,0/1,5	feed mixer 12,5 m^3+ tractor 126 HP + loader; TMR	slurry in channels, tractor 126 HP + slurry spreader	electric hoof knife
12	FB 2x5(10) 4000// 2,6/4,0	feed mixer 12 m^3+ tractor 75 HP, loader TMR	slurry in channels tractor 77,2 HP +slurry spreader	electric hoof knife

Source: own study / Źródło: opracowanie własne

Tractors cooperating the loaders in ten cattle barns and in two self-going loaders with the power from 60 HP to 100 HP were used for loading of forage on feed mixer. In two robotized cattle barns, forage on the feeding table was pushed by feed pusher - a kind of robot which can drive and push the forage in the direction of feeding corridor.

Natural manure from deep litter system was removed by loaders and tractors. In three cubicle cattle barns with litter, manure was removed by manure scraper with total power (longitudinal and cross scraper) from 4 kW (2 barns) to 4,5 kW directly on the manure plate. In one cubical, littered cattle barn, manure was removed by shovel installed on tractor with 52 HP. Slurry from four non-littered cattle barns was stored in deep channels under slatted floor and periodically applied on fields. In addition, in two of them, there were robots for cleaning of slatted floors. The buildings tested were as one-room spaced construction or with pillars. Table 3 shows constructional characteristic of barns tested, ventilation and microclimatic parameters. The ventilation was gravitational with the outlet of air by roof ridge gap.

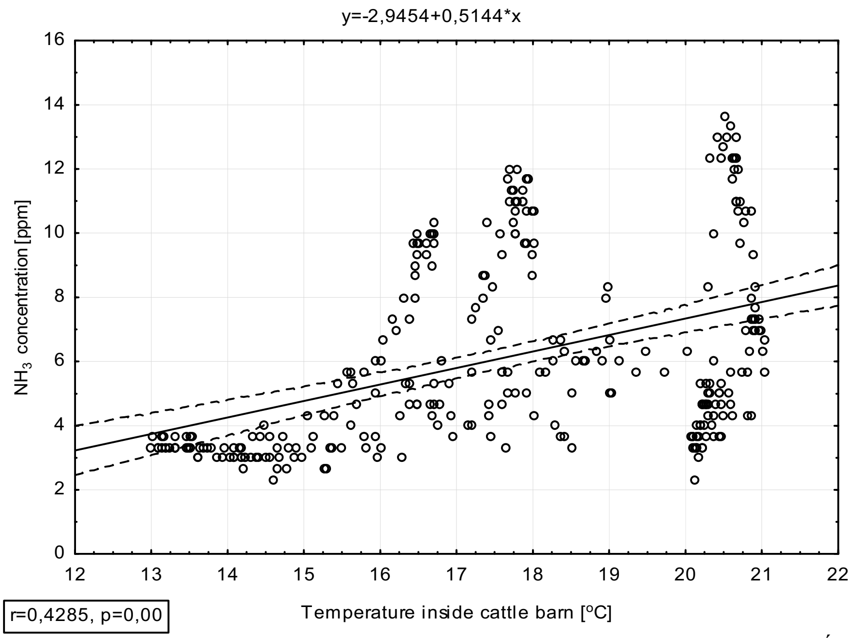
Average ammonia concentration amounted from 1,82 ppm in cowshed with deep litter (number 4) to 13,84 in boxed cattle barn with litter (number 7). Average carbon dioxide concentration amounted from 626,47 ppm in cattle barn with deep litter (number 4) to 1500,8 ppm in cattle barn without litter (number 12). There was positive correlation between ammonia concentration and internal temperature only in barn number 10 observed (correlation r = 0,4285) (Fig. 2).

Table 3. Characteristics of building construction, ventilation and microclimate parameters

Tab. 3. Charakterystyka konstrukcyjna budynku, wentylacji i parametrów mikroklimatu

No of barn	Building construction	Cubage $m^3 \cdot DJP^{-1}$	Ventilation inflow/outflow	Concentration / average min.-max.		Temperature / average		Relative humidity	Relative humidity inside
						min.-max.	min.-max.		
				NH_3 min.-max. [ppm]	CO_2 min.-max. [ppm]	outside	inside	outside	inside
1	three bay construction with pillars	40,67	gravitational/windows//roof ridge gap	4,07 1-8,3	737,13 300-1400	22,87 16,7- 31,6	25,82 20,6- 32,08	73,34 40,8-94,6	73,29 46,4-94,43
2	three bay construction with pillars	53,2	gravitational/windows//roof ridge gap	10	1360	18,52 16-23	18,29 14,33-23,7	83,38 71,5-93,6	79,54 59,3-95,57
3	three bay construction with pillars	68,41	gravitational/windows//roof ridge gap	3,23 1,67-6,6	715,2 400-1200	18,26 11,4-25,2	21,05 16,19-25,84	18,26 11,41-25,24	64,01 47,9-78,87
4	one room spaced without supporting pillars	126,1	gravitational/windows//roof ridge gap	1,82 0,75-3,4	626,47 475- 900	0,84 0,01-2	1,88 0,69-3,06	65,15 26,7-78,2	77,01 61,8 -81,17
5	two bay construction with pillars	107,8	gravitational/wall gaps//roof ridge gap	8,79 1-17	792,5 300-1733,3	22,36 15,08-34,24	23,92 19,95-26,80	73,86 38,6-96,7	73,30 54,35-86,40
6	three bay construction with pillars	51,02	gravitational/wall gaps// roof ridge gap	10,26 5-15	1313,4 770-2190	16,61 11,9-22,6	14,82 9,10-22,37	76,21 53,7-95,2	75,87 46,56-95,73
7	three bay construction with pillars	66,59	gravitational/windows//roof ridge gap	13,84 2-17	922,17 480-1810	20,28 11,5-29	21,41 17,47-25,43	62,38 26,80-97,5	70,92 35,90-94,47
8	three bay construction with pillars	42,25	gravitational/windows//roof ridge gap	4,5 1,3-7	941,70 500-1750	5,33 1,73-10,93	12,10 9,63-14,63	71,91 39- 90,3	58,48 36,90-69,37
9	three bay construction with pillars	70,64	gravitational/mobile curtains// roof ridge gap	11,97 0,6-20	845,50 472- 1380	23,07 16,80-38,80	23,69 18,59-30,6	48,14 18,4-67,6	58,31 21,28-77,32
10	three bay construction with pillars	74,43	gravitational/windows// roof ridge gap	6,1 2,3-13,6	665,51 300-1500	18,32 12-23	17,60 13-21,03	59,25 38,10-91	66,47 46,97-83,5
11	one room spaced without supporting pillars	36,7	gravitational/windows//roof ridge gap	9,48 4-15	835,99 540-1400	15,50 11,6-19	14,4 9,83-18,83	81,21 51,7-93,8	73,70 45,82-89,98
12	one room spaced without supporting pillars	39,74	gravitational/windows//roof ridge gap	10,6 3,7-17,5	1500,8 920-1850	8,16 4,63-10,7	10,92 7,8-13,5	92,97 82,6-97,55	80,00 81-96,6

Source: own study / Źródło: opracowanie własne



Source: own study / Źródło: opracowanie własne

Fig. 2. Correlation between ammonia and internal temperature (T_w) in barn number 10. Number of n-1 = 288. Confidence interval 95%. Correlation coefficient r = 0,4285

Rys. 2. Zależność między stężeniem amoniaku i temperaturą wewnątrz (T_w) w oborze nr 10. Liczba n-1 = 288. Przedział ufności 95%. Współczynnik korelacji r = 0,4285

Table 4. Unitary labour inputs, investment costs, electric and mechanic energy inputs
Tab. 4. Jednostkowe nakłady robocizny, inwestycyjne, energii elektrycznej i mechanicznej

No of barn	Unitary labour inputs working-minutes $\cdot day^{-1} \cdot LU^{-1}$	Unitary investment costs of technical equipment and building $PLN \cdot LU^{-1}$	Unitary electric energy inputs $kWh \cdot day^{-1} \cdot LU^{-1}$	Unitary mechanic energy inputs $HPh \cdot day^{-1} \cdot LU^{-1}$
1	6,97	27 747,58	0,569	3,427
2	4,14	16 131,69	0,215	1,351
3	6,62	15 864,59	0,364	1,400
4	5,92	18 510,65	0,397	2,131
5	6,00	20 494,61	0,301	2,006
6	3,54	13585,15	0,257	1,235
7	7,25	22203,93	0,274	3,423
8	4,52	11556,69	0,400	1,170
9	0,78	22193,09	0,826	1,435
10	1,93	26648,38	0,816	1,282
11	3,54	16410,34	0,208	2,437
12	2,96	14992,86	0,269	1,88

Source: own study / Źródło: opracowanie własne

The average temperature inside almost all cattle barns (with exception of one – with deep litter) did not exceeded the recommended temperature 25°C.

Table 4 contains economic and energetic values measured in cattle tested. The highest unitary investment costs of buildings and technical equipment for mechanization of technological treatments were in barn with deep litter (number 1) and amounted 27747,58 $PLN \cdot LU^{-1}$. On the second place regarding of unitary investments costs of equipment and building were cattle barn number 10 with three robots (one for milking, one feed-pusher, one floor scraper) and amounted 26648,38 $PLN \cdot LU^{-1}$. The lowest unitary investment's costs was in boxed cattle barn with litter (number 8) and amounted 11556,69 $PLN \cdot LU^{-1}$. Cattle barns which are complying with requirements for 1st criterion (unitary investment costs, both building and equipment ≤19 000 $PLN \cdot LU^{-1}$): 2, 3, 4 , 6, 8, 11 and 12.

Average unitary daily labour inputs amounted from 0,78 for robotised barn with robots for milking, feed pushing and removing manure from slatted floors to 7,25 working-minutes$\cdot day^{-1} \cdot LU^{-1}$ in barn with the lowest number of cattle. In 7 barns they were below 5 working-minutes·day-1·LU-1 (5th level of mechanization) and in 5 they did not exceed 10 working-minutes·day-1·LU-1(4th level of mechanization). Technological treatment milking and milk cooling was this, with the highest human labour inputs. However, the lowest unitary daily labour inputs were in cattle barn with two milking robots and one feed pusher and slatted floor cleaner robot (number 9) and amounted 0,88 working minutes$\cdot day^{-1} \cdot LU^{-1}$. Cattle barns which are complying with requirements for 2nd criterion (average unitary *daily* labour inputs ≤ 4,6 working minutes $\cdot day^{-1} \cdot LU^{-1}$): 2, 6, 8, 9, 10, 11 and 12.

Cattle barn which are complying with requirements for 3rd criterion (average ammonia concentration ≤ 10,9 ppm, average carbon dioxide concentration ≤ 1500,8 ppm): 1, 3, 4, 5, 6, 8, 10, 11 and 12.

Average electric energy inputs for four technological treatments were from 0,208 $kWh \cdot day^{-1} \cdot LU^{-1}$ (cowshed number 11) to 0,827 $kWh \cdot day^{-1} \cdot LU^{-1}$ (robotized cowshed number 9). Cattle barns which are complying with requirements for 4th criterion (average daily unitary electric energy inputs ≤ 0,40 kWh): 2, 3, 4, 5, 6, 7, 8, 11, 12. Average mechanical energy inputs amounted from 1,172 $HPh \cdot day^{-1} \cdot LU^{-1}$ (boxed cattle barn with litter -number 8) to 3,427 $HPh \cdot day^{-1} \cdot LU^{-1}$ (cowshed with deep litter – number 1) - Cattle barns which are complying with requirements for 4th criterion (average unitary daily mechanic energy inputs ≤ 2 $HPh \cdot day^{-1} \cdot LU^{-1}$): 2, 3, 6, 8, 9, 10 and 12.

Table 5 shows final set of exploitation costs in barns tested in growing order. Summarising, the best solutions were boxed cattle barn with litter (number 8) and boxed cattle barn without litter (number 12). They are barns, which fulfilled all limitations. The robotized cattle barns (number 9 and 10) had the highest electric energy inputs and investments costs with the lowest human labour inputs.

Table 5. Unitary exploitation costs of building and equipment in growing order
Tab. 5. Jednostkowe koszty eksploatacji budynku i wyposażenia w porządku rosnącym

Number of barn	Large Unit	Unitary exploitation costs $PLN \cdot year^{-1} \cdot LU^{-1}$
6	81	1589,17
8	144	1710,98
2	87	1859,67
3	100	2036,24
12	109	2088,57
11	87	2190,69
7	39	2379,85
5	44	2504,66
9	170	2671,49
10	83	2887,15
4	100	3065,01
1	93	3519,88

Source: own study / Źródło: opracowanie własne

4. Discussion

Many books and articles describe animal housing systems [1, 4, 18, 26, 27]. They show many technological and technical aspects of planning, designing of barns for cattle. Although, there is lack of expertise with economic and energetic analysis containing comparisons between these systems aiming at energetic, economic and welfare evaluations. There are many examples of publications with evaluations of each individual factors (costs of investments, exploitation costs, energy inputs, labour inputs, animal welfare). Methods of planning of functional- technological solutions of cattle barns are multifarious. Nowadays electronic media are used for planning layout of cattle barns and also for cattle housing, including electronic control of microclimate conditions [23]. Economic aspect of designing was described by Næss and Stockstad [16].

The lowest labour inputs among 12 cattle barns were in two buildings with robotic milking. According to Schick , use of robots in comparison with traditional milking system leads for significant, even double decrease in labour inputs of its treatment [24]. Næss and Bøe, Freiberger, as wel as Hogeveen and Meijering observed meaningful reduction of human labour inputs in cattle barns with robotic milking [7, 9, 15]. Sonck writes, that labour inputs are reduced in robotic milking buildings (RMB) about 37% to 66,1% [25]. According to de Koning, compared with the conventional twice daily milking, there is an average of 20% - 30% reduction in total labour with robotic milking [11,12].

Burton and Turner indicated, that there are over hundred different gases and substances emitted from housing buildings for farm animals [2]. According to Polish regulations, concentrations of harmfully gases should be on the level which shouldn't be harmful on animals. For calves it should not exceed 3000 ppm for carbon dioxide and 20 ppm for ammonia [21, 22]. Average concentration of both gases in 12 cattle barns – ammonia and carbon dioxide was below half of values allowed by this regulations. Ngwabie investigated correlation between methane and ammonia emissions and internal temperature of cowshed. There were high correlation (r=0,66) between this factors (Ngwabie et al. 2011). Dairy cattle are sensitive to heat stress because of the high metabolic heat production and feed intake associated with rumen fermentation and milk yield [3].

Heat stress in cattle is characterized by increased rectal temperature, elevated respiration rates and decreased feed intake which contributes to the decreased milk yield. The environmental temperature range from -5 to 23.9ºC has little impact on milk yield and composition and is referred to as the thermoneutral zone for the lactating dairy cow [3] However, temperatures above 23.9ºC are known to decrease solids-not-fat (SNF), protein, lactose and fat percentage of milk [3]. At the temperature above 30^{o}C milk yield is decreasing about 20% and frequently is combined with increased number of somatic cells in milk [13]. Besides, airflow patterns in animal buildings influence the distribution of air temperature, gas concentrations, and the release of gases from manure. In cattle barn tested the average temperature of internal air was from 1,88^{o}C to 25,82^{o}C, what is considered as conditions of good animal welfare. Simultaneously the relative humidity of air did not exceed the allowed by farm standards value 80%.

Summarising: by planning of farm's buildings there are many factors having regard and final evaluation is impeded. There were only attempts of evaluation of environment conditions in cattle barns, regarding many factors (economic, energetic, quality – animal welfare) made.

5. Conclusions

1. The best solutions, which fulfilled all limitations were two boxed barns with (number 8) and without litter (number 12. In first barn the most important indicators, which led to final evaluation as the best solutions were as follows: investments costs 11556,69 PLN $\cdot LU^{-1}$, labour inputs 4,52 working-minutes $\cdot day^{-1} \cdot LU^{-1}$, electric energy inputs 0,4 kWh $\cdot$ day^{-1} $\cdot LU^{-1}$, mechanic energy inputs 1,17 HPh$\cdot$ $day^{-1} \cdot LU^{-1}$ and exploitation costs 1710,98 PLN$\cdot$ $year^{-1} \cdot$ LU^{-1}.
In second barn (non-littered, boxed) investments costs amounted 14992,86 PLN$\cdot LU^{-1}$, labour inputs 2,96 working-minutes $\cdot day^{-1} \cdot LU^{-1}$, electric energy inputs 0,4 kWh $\cdot$ day^{-1} $\cdot LU^{-1}$, mechanic energy inputs 1,88 HPh$\cdot$ day^{-1} $\cdot LU^{-1}$ and exploitation costs 2088,57 PLN$\cdot$ $year^{-1} \cdot$ LU^{-1}.

2. Although the best cattle barns (number 8 and 12) had large number of animals (144 LU and 170 LU respectively), the microclimate conditions especially concentration of harmful gases, temperature of air and relative humidity didn't exceed the recommended values. It was because they had good ventilation solutions.

3. Robotising of main technological treatments in milk production led to low human labour inputs. In two robotised cattle barns with robots for milking, feed pushing and slatted floor cleaning there were low labour inputs observed, amounting 0,78 and 1,93 working minutes $\cdot day^{-1} \cdot LU^{-1}$.

4. Also cleaning of slatted floors by robots led to relatively low concentrations of harmful gases NH_3 and CO_2, which amounted in these robotised barns (number 9 and 10) respectively 11,97 ppm and 6,1 ppm for NH_3 and 845,5ppm and 665,5 ppm for CO_2, which concentrations was about and below half of recommended levels.

6. References

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