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MODERN SOLUTIONS OF BARNS FOR DAIRY CATTLE ON THE BASIS OF WOLF SYSTEM SUGGESTIONS

ROZWIĄZANIA NOWOCZESNYCH OBÓR DLA KRÓW MLECZNYCH NA PRZYKŁADZIE PROPOZYCJI WOLF SYSTEM

Summary: *Modern livestock buildings should ensure the appropriate environmental conditions. The following factors, affecting the environmental conditions were discussed: functionality of the buildings, microclimate of the premises, management technology, housing system and livestock building. The solutions of Wolf System, and in particular, the suggestions of free-stall, boxed littered and non-littered cattle barns and littered barns with the self-flowing bed system were presented. In the buildings with the mentioned solutions, there is a correct microclimate owing to the manually or automatically operated ventilation systems.*

Keywords: *cattle barn, functionality, microclimate, ventilation, construction*

Streszczenie: *Nowoczesne budynki inwentarskie powinny zapewniać odpowiednie warunki środowiskowe. Omówiono czynniki kształtujące warunki środowiskowe do których zaliczono: funkcjonalność budynków, mikroklimat pomieszczeń, technologię chowu, system utrzymania, budynek inwentarski. Przedstawiono rozwiązania Wolf System, w szczególności propozycje obór wolnostanowiskowych boksowych ściółkowych, bezściółkowych oraz z podłożem samospławialnym. W budynkach z takimi rozwiązaniami panuje właściwy mikroklimat dzięki systemom wentylacyjnym sterowanym ręcznie lub automatycznie.*

Słowa kluczowe: *obora, funkcjonalność, mikroklimat, wentylacja, konstrukcja*

Introduction

Cattle husbandry is one of the most important branches of agricultural production in Poland. Dairying has been always considered as one of the strategic sectors of food economy. The participation of cattle management in global agricultural production constitutes 19%, including ca. 16% for milk production and 3.4 % for beef production. The participation in commercial agricultural production is equal to 24% in total, including 19% for milk and 5.0% for beef.

Our country is a leading milk producer in Europe; in respect of the production level, it occupies the 4th place from among the EU countries (after Germany, France and Great Britain). There are, however, certain differences in the production concentration and milk performance of the total cow population in Poland as compared to the remaining EU countries. As a result of the so-far effective work on genetic improvement of our cows in the country, their production performances are almost equal to the results, obtained from the cows in the countries of the former EU (25 countries). The mean milk yield in Poland in 2019 from the herds of active population (cows under milk recording system) was equal to 8 530 kg [PFHBiPM, 2019]. The barns covered with the milk recording tested by ITP (Institute of Technology and Life Sciences) have the mean annual milk performance at the level of 7350 kg. Therefore, when having the cows, valuable in respect of genetics in our country, we should take care of the improvement of their welfare *via* betterment of environmental conditions and, in particular, in respect of cattle management techniques.

Production effects obtained from the cattle are a result of the impact of genetic and environmental factors, from among of which the following ones should be distinguished: functionality of buildings and functional courses, microclimate of premises, management technology, housing system and livestock building.

One of the most important scientific tasks of the contemporary agricultural engineering in respect of cattle production includes development and improvement of technique, employed in dairy cattle management in modern agricultural family farms and farming enterprises.

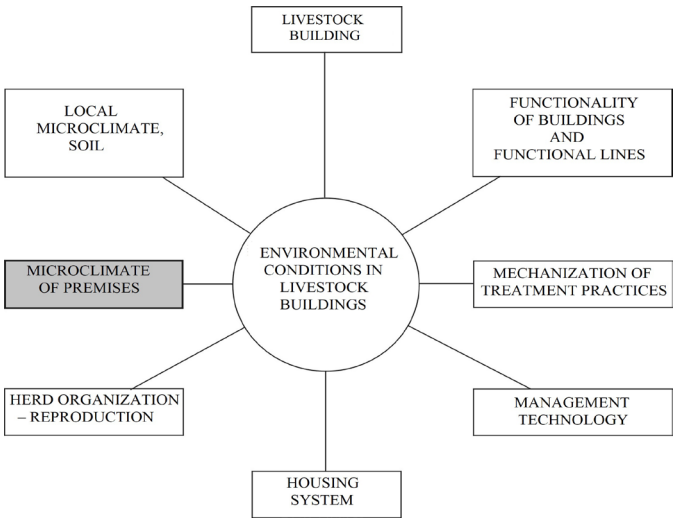
Apart from the important biological factors, the technique used in cattle management, including the activity in respect of building, mechanization and technology, determines effectiveness of milk production in a great degree. Functional livestock building such as cattle barn, should ensure the welfare to the animals, their high production performance

and good health state *via* the optimum environmental (mainly microclimate) conditions.

Under the differentiated climatic conditions of Poland, the cattle barn is an indispensable and, simultaneously, expensive object of the farm's infrastructure, which should ensure the mentioned above effectiveness owing to appropriate organization of the particular functional courses and technological lines: preparation of feeds and their supply, milking and cooling of milk and removal and storage of manure, and creation of optimum microclimatic environment in the zone of animals' staying.

Since 1999, the Institute of Building, Mechanization and Electrification of Agriculture (IBMER) and since 2010 (after reorganization), the Institute of Technology and Life Sciences has conducted a continuous field work on improvement of mechanization and technology and the environmental conditions in respect of cattle management which are mainly focused on free-stall cattle barns.

Fig. 1. Factors, shaping the environmental conditions in the livestock building for cattle [2]



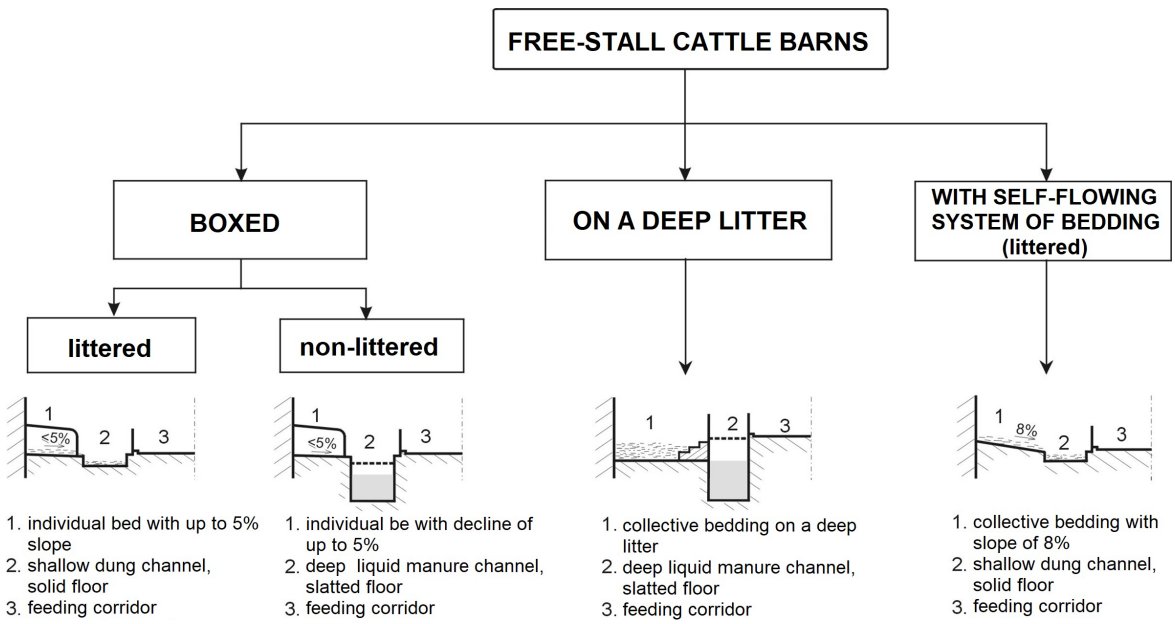
The most important factors, shaping the environmental conditions in the barns for the dairy cows are illustrated in Fig. 1.

Brief characteristics of the mentioned above factors:

1) Livestock building, in this case cattle barns: architecture, construction, roof, floor, walls, bedding, area and space (cubature) per one animal, auxiliary premises;
2) Functionality of the interior of the building and collision-free combination with mobile standing equipment, auxiliary rooms and functional courses of feeding and drinking supply, milking and milk cooling and receipt, straw spreading on beds, and removal and storage of manure, release of animals to the enclosures and cattle yards and in summertime – to the pastures;
3) Mechanization and automation of technological lines (including robotization): feeding and drinking supply, milking and milk cooling, removal and storage of manure;
4) Management technology connected with the production operations in technological lines;
5) Systems of cow housing: illustrated in Fig. 2.
6) Organization of herd: in a closed or open cycle, ensuring the parturition place for the cows and newborn calves;
7) Microclimate of the premises for the housed cows: requirements concerning temperature, relative humidity, admitted concentration of harmful animal gases (CO_2, NH_3, H_2S), value of air cooling down, velocity of air movement, contamination with the dust particles and microorganism, warm retention of baffles, lighting, heating in the auxiliary rooms and milking parlour, noise level, ventilation system and the appropriate air exchange;
8) Protection from negative effect of local climate, especially in autumn-winter season.

In view of the animal welfare and management effectiveness, the free-stall cattle barns have been recently preferred. Technological solutions of free-stall cattle barns in Poland are given in Fig. 2.

Fig. 2. Scheme of classification of free-stall cattle barns according to the housing systems. Source: own elaboration



Free-stall housing system, with the regulated access to the outside run, consists in keeping the cows without ties, mainly in boxes. Box housing consists in separation of the rest function for the cows from the function of their feeding. In the free-stall system, littered or non-littered boxes are employed. Boxes are covered with cut straw, sawdust, peat, river sand and separated solid fraction of liquid manure (slurry). The non-littered boxes have a soft rubber covering, called mattress.

Nowadays, the following free-stall littered barns with the grouped housing in the collective pens, with individual beds, are introduced:

- Individual boxes with littered beds or rubber mattresses in the littered and non-littered system;
- On a deep litter in the rest course;
- On a deep litter with the separated feeding-dung channel on a slatted floor;
- Littered beds with self-flowing (self-cleaning) system and dung-walking corridor on a solid floor;
- According to the WOLF SYSTEM projects, in deep free-stall boxes, covered with the separated solid fraction of liquid manure. Natural manure is removed from walking runs, using mechanical scrapers to a special channel, situated transversally in relation to the barns. Near the transverse channel, a closed construction separator separates a solid fraction up to min. 35% dry matter content of the slurry. Such fraction serves for a direct covering of the boxes twice a week.

In the free-stall housing system, the cows are always milked in the milking parlour by milking machine or by milking robots; the cows are directed to the milking parlour by the specially fenced off corridors.

The most important advantages of free-stall barns include:

- The higher number of cows, served by one operator;
- Easier human labour, especially in the case of milking (when milking is carried out by robot, the operators have only to supervise the robot who performs the whole work automatically);
- Better hygiene of milking;
- Conditions of cow housing correspond to their natural needs and welfare;
- Better possibilities of production mechanization and automation;
- The possibility of greater concentration of herds in the barn and introducing the computer-based management system in respect of herd organization, breeding selection, reproduction regulation, reasonable feeding with multi-componential feeds, milking hygiene and health state (udders and reproduction organs).

In the free-stall system of cattle housing, the highest level of mechanization and automation of production process may be obtained via introduction of the mentioned above computerized system of herd management which has been already introduced in a part of the barns, tested by Institute of Life Sciences and Technology (ITP).

In cattle management, we may observe a progress in effectiveness, especially in the newly constructed objects and in the old modernized ones, in farms with a higher area, having more than 50 ha. The constructed new objects in greater farms are usually free-stall barns. The older objects, as being erected in the 70ties and the 80ties are actually modernized, developed and adapted also to the free-stall cow housing system.

The mentioned above activities are accompanied by the increase in the concentration of herd, specialization of production, complex mechanization of particular production operations, rationalization of feeding with the concentrates via new preservation technologies and automatic feed mixing. The modern milking system in the milking parlours and cooling down of milk in a closed system improves perfectly the hygiene of milking and the quality of raw milk.

The aim of the paper

The aim of the work was to analyze and evaluate the existing solutions of the objects in cattle management and, in particular, functionality of barns, housing systems, milking and milk cooling procedures, preparation of feeds, feeding and drinking of animals, removal and storage of faeces as well as microclimate in the premises for animals and in the milking parlour, including the suggestion of modern solutions, on the example of barns, constructed in WOLF system.

The suggested solutions of WOLF SYSTEM (Fig.3 – 10)

The submitted solutions are modern and effective, ensuring the welfare and appropriate climate for the animals, safe and hygienic condition of the service work and a high level of mechanization in milk production.

Fig. 3. Cross-section of free-stall cow barn with steel-steel construction with intermediate pillars. Source: Wolf System

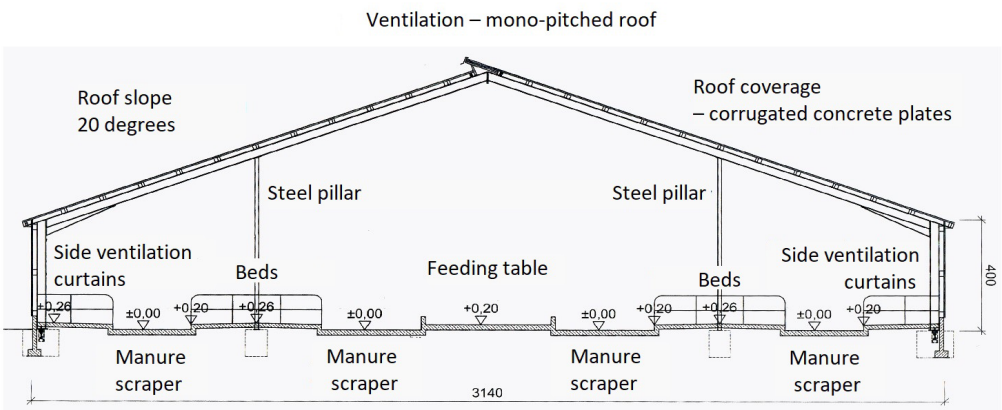


Fig. 4. Free-stall boxed barn with a slatted floor and channels for manure, side and roof ventilation with additional light. Source: Wolf System

Fig. 5. Side view of the barn with mechanically operated ventilation curtains. Source: Wolf System

Fig. 6. System of roll-up curtains, opened from the top, with electric or manual drive

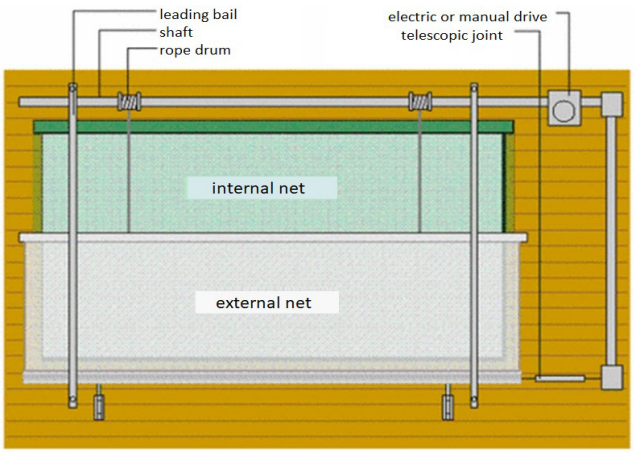
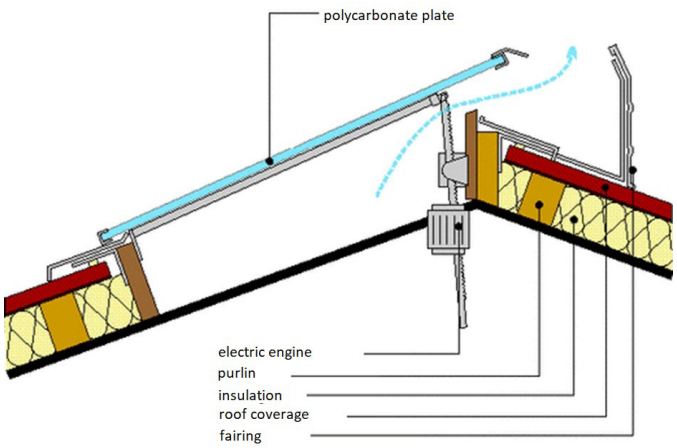


Fig. 7. Automatic control of exhaust channel of roof, using weather sensors a) with the thermal insulation of the roof, b) without insulation, without weather control device Source: Wolf System



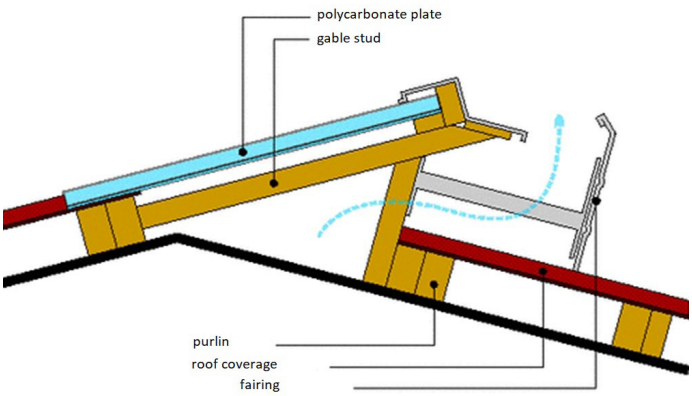


Fig. 8. View of boxed cattle barn, with polycarbonate skylights, with manure scrapers, roof ridge ventilation; side walls made in a form of net curtains, with a full PCV membrane. Source: Wolf System

Fig. 9. Littered barn with self-flowing system and mechanical manure scraper and ridge ventilation and polycarbonate curtains; construction of the barn – steel-steel with intermediate pillars. Source: Wolf System

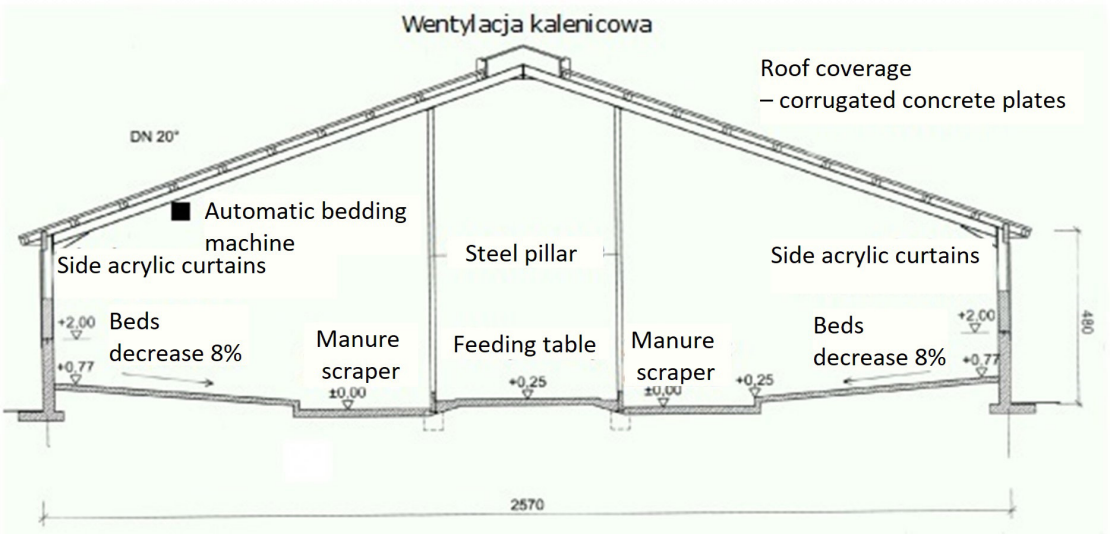


Fig. 10. View of free-stall boxed non-littered barn by Wolf System. Source: Wolf System

Field tests of the microclimate conditions

The methodology of testing the parameters of microclimate was based upon branch standard BN-86/880-03 (Industrial Standard 1986).

The following equipment was employed:

- Thermal hygrometers (cable sensors) for measurement of air temperature and humidity; with concentrator, equipped with memory for data collection having a volume of 3600 records;
- T
- Mobile thermal hygro-barometers with internal memory for constant testing of temperature, relative humidity and atmospheric pressure;
- Double-gas measuring devices of recorders for determination of CO_2 and NH_3 concentration;
- Multi-gas measuring device iTX, measuring the concentration of harmful gases: methane (CH_4), ammonia (NH3), hydrogen sulphide (H_2S) and nitrogen oxide (NO).

The results of the tests of the barns for the dairy cows in respect of environmental conditions, including microclimate, as referred to in the solutions, given in Fig. 3, 4 and 9, are presented in Tab. 1.

Tab. 1. Parameters of microclimate in the tested barns

Type of barn /housing system	Tz Mean min. - max	Tw Mean min. - max	Wz Mean min. - max	Ww Mean min. - max	CO_2 Mean min. - max	NH_3 Mean min. - max
Boxed littered	5.1 1.7 -10.8	11.5 7.6-15.8	72 41-90.3	60.3 36-73.5	932.6 500 -1900	4.5 1-9
Boxed non-littered	18.32 12 -32	17.60 13-21.03	59.25 38.10-91	66.47 46.97-80.0	665.51 300-1500	6.1 2.3-13.6
Littered with self-flowing (cleaning) system	23.1 15.3 -30.5	24.5 17.7-29.0	60.5 30.5-90.7	65.96 41.1-79.9	818 400-1600	4.23 1-9

Source: Own elaboration based upon: Mazur 2012, Romaniuk et al., 2012 [7]

Tz – air temperature outside the building [°C];
Tw – temperature inside the building [°C];
Wz – relative air humidity outside the building [%];
Ww – relative air humidity inside the building [%];
CO_2 – concentration of carbon dioxide CO_2 [ppm];
NH_3 – concentration of ammonia NH3 [ppm]

Summing up and conclusions

1. The suggested solutions meet the requirements for modern livestock barns for the cattle, i.e. ensuring as follows:
   - A sufficient space for the animals and equipment for mechanization and automation of production operations;
   - Functionality i.e. appropriate mutual situation of technological elements;
   - Efficient ventilation of barns with additional light in the roof ridge.
2. Such solutions ensure the following microclimatic conditions:
   - Mean carbon dioxide concentration, not exceeding 100 ppm, in relation to the limit, recommended value of 3000 ppm,
   - Mean ammonia concentration, not exceeding 10 ppm,
   - Mean air temperature during the period of summer heat, not higher than 25°C at relative air humidity not higher than 80%.
3. When choosing the most advantageous solution by the investor, e.g. of the dairy barn, we should be directed by the minimization of the operating costs for obtaining 1 litre of milk of the appropriate quality, with the consideration of the following limitations:
   - In respect of microclimate: concentration of $CO_2 \leq 3000$ ppm, concentration of $NH_3 \leq 20$ ppm, temperature not higher than 25°C and not lower than -4°C.
   - Level of mechanization V, characterized by labour outlays ≤ 5 working minutes $\cdot$ $DJP^{-1} \cdot 24h^{-1}$.

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