OPTIMIZATION OF CHOOSING AND EVALUATION OF MILKING PARLOURS FOR DAIRY FARMS IN LATVIA

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Abstract. The aim of this paper is to show how to use the calculation model of milking parlours for different basic operating parameters which could be used for solution of the principal questions important for choosing, optimization and evaluation of a milking parlour in the conditions of Latvian agriculture. The choosing and evaluation of the milking parlour parameters is based on the available information and results of previous research in dairy farms in Latvia, using the mathematical model created in the Czech Republic. Time for milking and the final specific direct costs are the main parameters, which enable evaluation and choosing of a suitable milking parlour for the dairy farms with capacity 1 000 cows, 2 000 cows and 3 000 cows. Comparison of rotary milking parlours with 80 and 40 milking stalls and 4 or 6 milkers showed that the number of milking stalls in the milking parlour does not increase the milking capacity, if there is not increased number of milkers, but the maximum number of operators must be controlled to achieve the best exploitation.

Keywords: costs, equipment, milking process, rotary milking parlours.

Introduction

Livestock production in countries with intensive agriculture is undergoing big and rapid changes. Capacities of farms are expanding and increasing the average annual milk production per cow. These factors lead to modernization of milking equipment. European housing systems are steadily changing from stanchion barns towards loose cowsheds and larger herd sizes [1-4]. Due to these changes, many dairy farmers will have to design and build new milking parlour systems.

Modern large-scale farms require appropriate modern technical equipment. Equipment producers want to sell you the most expensive product, which is not always appropriate. Operation is affected, e.g., by the selected number of milking stalls, high or low number of milkers, sometimes incorrectly selected or by choosing insufficient automation equipment. Therefore, it is important to compare different possibilities of milking parlours and try to find the strengths and weaknesses of some proposals. Model calculations allow comparing options and making decisions according to the accurate and uniform criteria correctly according to the results of calculations.

The leading companies producing milking equipment usually offer a variety of constructions of milking parlours recommended for different capacity of farms. Many publications present results of research and recommendations focused on automatic milking systems (AMS), usually also including comparison of AMS and milking parlours, e.g. [5-8]. They also recommend the possible level of automation and the number of milkers to work in the milking process [9-11]. But there are rather big differences in the local conditions of the farms according to the production, economic, market and labor situation of the country or province. Some publications [12; 13] present models focused on choosing of milking parlours, but not in a complete universal approach, which could be adapted everywhere. The results of the research and basic equations used for calculation of several parameters of milking parlours are presented in [2].

Also the publication in [14] is focused on these problems. In this paper the authors present their experiences and results of the research from five Latvian dairy farms with a capacity from 240 to 500 cows, equipped with rotary milking parlours with 20 to 36 milking stalls. For comparison of the milking equipment the following criteria were used in this publication: productivity of milking equipment, specific capital investment, specific consumption of labor, specific exploitation costs and the loading coefficient of the milking equipment. Many partial results of measurements and calculations were used as a basis for subsequent calculations, newly processed in this work by the below described calculation model and methodology.

For objective assessment and selection of milking parlours a lot of different aspects can be used and considered, e.g.: animal welfare, capacity, price, number of milkers, complexity and sophistication of the operation, reliability, dimensions and complicated installation in the building, demand of maintenance and service, some other aspects. The same milking parlours have different operating

conditions in different countries around the world. Dairy farms in Latvia are interesting, because at present in addition to the traditional small farms also new large-scale farms with thousands of cows arise. For these farms it is necessary to calculate (model in advance) different variants of equipment and operating conditions by precisely selected and uniform criteria.

Materials and methods

It is not possible to present here all formulas used in the model because of the extent of this paper. There are mentioned only some principal equations. The first criterion, which is important for the practical function of the farm, is duration of one real milking of all cows, which can be calculated according to equation (1).

$$T_{vd} = \frac{N}{Q_{LS}} + T_{pr}, \quad (1)$$

where T_{vd} – duration of one real milking, min;
N – number of lactating cows on the farm, cow;
Q_{LS} – real capacity of the milking parlour, cow·min^{-1};
T_{pr} – time of working breaks, min.

The total time of duration of one milking including preparatory operations and finishing work after milking is calculated according to equation (2).

$$T_{cd} = T_{vd} + T_p + T_c, \quad (2)$$

where T_{cd} – total time of duration of one milking including preparatory operations and finishing work after milking, min;
T_p – time of preparatory work before milking, min;
T_c – time of finishing and cleaning work after milking, min.

The second decisive criterion for choosing the appropriate milking parlour should be the economic criteria. It is necessary to compare the specific data, which are in this case the final specific direct costs of a milking parlour per cow and year ${}^{u}C_{MP}$, which are calculated according to the equation (3) as a sum of specific labor costs of milking per cow and year ${}^{u}C_{W}$, specific costs of the milking equipment per cow and year ${}^{u}C_{P}$ including the parlour construction, and specific costs ${}^{u}C_{S}$ of the consumed supplies including water, electricity, disinfections etc. per one cow and year.

$${}^{u}C_{MP} = {}^{u}C_{W} + {}^{u}C_{P} + {}^{u}C_{S}, \quad (3)$$

where ${}^{u}C_{MP}$ – final specific direct costs of the milking parlour, EUR·cow^{-1}·year^{-1};
${}^{u}C_{W}$ – specific labor costs per cow and year, EUR·cow^{-1}·year^{-1};
${}^{u}C_{P}$ – specific costs of the milking equipment, EUR·cow^{-1}·year^{-1};
${}^{u}C_{S}$ – specific costs of the consumed supplies, EUR·cow^{-1}·year^{-1}.

Specific labor costs ${}^{u}C_{W}$ are calculated on the basis of the labor requirements per cow per year T_r (h·cow^{-1}·year^{-1}) by using equation (4) and average hourly wage of the milker. The labor requirement T_d can be calculated by equation (5).

$$T_r = \frac{365 \cdot T_d}{60}, \quad (4)$$

where T_r – labor requirement for milking per cow per year, h·cow^{-1}·year^{-1};
T_d – labor requirement during milking per cow per day, min·cow^{-1}·day^{-1}.

$$T_d = i \cdot \left[\frac{N \cdot (t_{rc} + t_p + t_c) + T_{pr} \cdot n_{ds}}{N} \right], \quad (5)$$

where i – number of milking per day, day^{-1};
t_{rc} – average net labor requirement for milking per cow, min·cow^{-1};

t_p – time of preparatory work before milking calculated per one cow, min·cow^{-1};
t_c – time of finishing and cleaning work after milking calculated per one cow, min·cow^{-1};
n_{ds} – real number of milkers, pers.

Specific costs of the milking equipment $^{u}C_P$ are calculated as specific data of the total operating costs of the milking machine converted per one cow. Therefore, it includes amortization of the machinery, which is the purchase price of the machine expressed by percentage of machine amortization, further amortization of the construction that includes the construction costs and percentage of building amortization and the costs of servicing, maintenance and repairs, which are usually expressed as a percentage of the planned acquisition costs.

Specific costs of the consumed supplies $^{u}C_S$ are calculated as a sum of the costs of all necessary operating materials and energy. The consumption of electricity is proportional to the power inputs of motors and all electrical appliances of the milking parlour during their operation, water, disinfection etc. All is re-calculated per cow and year (EUR·cow^{-1}·year^{-1}).

The real number of milkers for the whole farm n_{ds} is the rounded integer n_d. It is an important criterion to ensure a successful function of the milking parlour in real farm conditions. The theoretical required number of milkers n_d is based on calculation of equation (6).

$$n_d = \frac{Q_{PL}}{W_d}, \tag{6}$$

where n_d – theoretical required number of milkers per one parlour, pers.;
Q_{PL} – required capacity of the milking parlour, cow·min^{-1};
W_d – working capacity of one milker, cow·min^{-1}.

The maximum reasonable number of milkers per a parlour n_{dm} is a very important criterion to avoid the idle time or complicated work of milkers. It is calculated by the number of milking stalls m_Z divided by the number of clusters n_s that one milker can operate.

$$n_{dm} = \frac{m_Z}{n_s}, \tag{7}$$

where n_{dm} – maximum number of milkers per one parlour, pers.;
m_Z – number of milking stalls in the milking parlour, pcs;
n_s – maximal number of clusters per milker, pcs.

An important technical parameter is the theoretical number of milking stalls in a parlour m_T, calculated by using equation (8).

$$m_T = Q_{PL} \cdot (t_d + t_v), \tag{8}$$

where m_T – theoretical number of milking stalls in the parlour, pcs;
t_d – average duration of milking by milking machine per one cow, min;
t_v – average idle time of a cluster, min.

$$t_v = t_n + t_s + t_m, \tag{9}$$

where t_n – average time for cluster attachment, min;
t_s – average time to remove the cluster, min;
t_m – average time for manipulation with the cluster, min.

The aim of this paper is to show how to use the calculation model of milking parlours for different basic operating parameters. For the calculation a dairy farm A was selected with capacity of 1 000 cows and equipped by the rotary milking parlour. By changing the number of milking stalls and the numbers milkers different options for improvement of operations can be compared. Finally, in this paper the comparison of the operating conditions for a possible increased capacity to 2 000 cows in the farm B, or even up to 3 000 cows in the farm C is shown.

Table 1

Basic parameters and variants of studied dairy farms

Farm	A1, B1, C1	A2, B2, C2	A3, B3, C3
Number of milking stalls	80	80	40
Number of milkers	4	6	4

Results and discussion

The results of calculations of the farm A are presented in Figures 1 and 2. Time of milking 3.2 hours is the same in the milking parlours with 80 and 40 milking stalls, if there are 4 milkers working. Increasing the number of milkers to 6 will shorten the duration of one milking by about one hour. Specific costs are the lowest in case of the milking parlour with 40 milking stalls due to low investments.

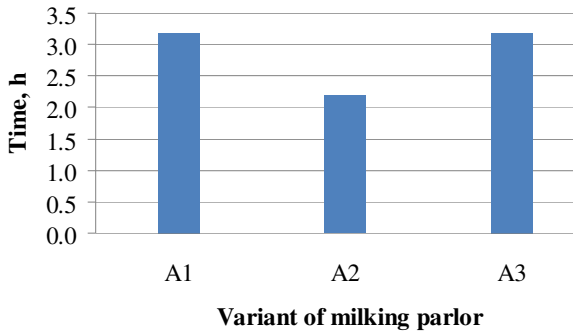

Fig. 1. **Time for milking, farm A, 1 000 cows**

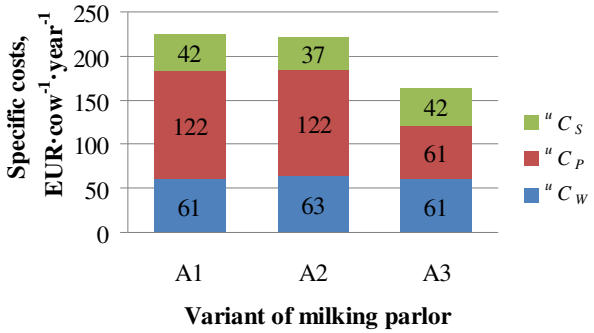

Fig. 2. **Specific costs, farm A, 1 000 cows**

The results of calculations of the farm B are presented in Figures 3 and 4. The specific costs are lower thanks to better exploitation of the milking parlour. The time of milking is increased, but it is still acceptable. The results of calculations of the farm C presented in Figures 5 and 6 are different. The specific costs are lower, but the time of milking is in the case of the milking parlours with 4 milkers increased over 8 hours, which is not acceptable as there is milking three times per day.

Fig. 3. **Time for milking, farm B, 2 000 cows**

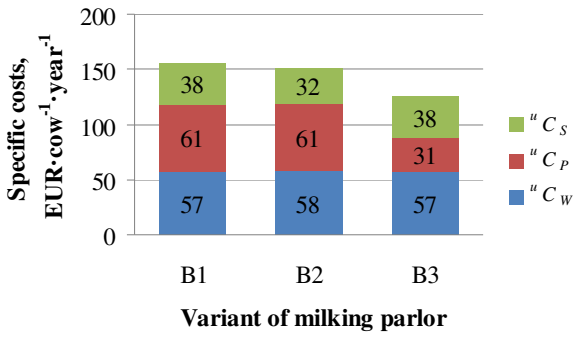

Fig. 4. **Specific costs, farm B, 2 000 cows**

With regard to the maximum extent of this paper it is not possible to present here all possible cases and proposals that could be solved in the model and calculated. For this paper therefore were only some interesting examples selected. We can suppose that from the below text of this article it is obvious that are the other possibilities and importance of these model calculations for further research and application in practice.

Fig. 5. **Time for milking, farm C, 3 000 cows**

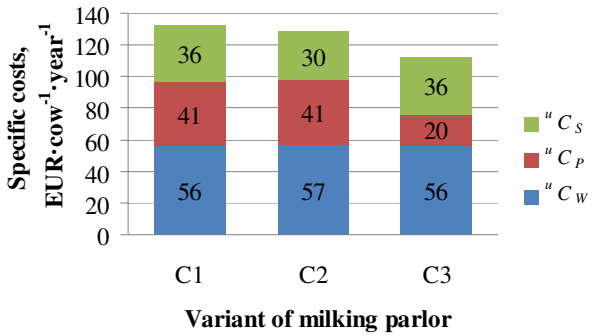

Fig. 6. **Specific costs, farm C, 3 000 cows**

The suitable number of milking stalls m_T and the required number of milkers n_d for each farm calculated by the model according to equations (6) and (8) with the aim to achieve duration of one real milking T_{vd} = 3 hours are in Table 2.

Table 2

Optimal parameters for dairy farms

Farm	A = 1 000 cows	B = 2 000 cows	C = 3 000 cows
m_T	38	75	113
n_d	4	8	13

The parameters listed in Table 2 might fit well in operation only while ensuring all technical requirements in terms of reliability features of the milking parlours and organizational conditions in terms of the quality of work of people. Therefore, it remains to solve and decide whether it would be more appropriate to achieve the required capacity for the farms 2 000 and 3 000 cows by dividing the required number of milking stalls into two milking parlours with half-capacity. It is probable that this could be a simpler solution for construction of access roads to the stables including waiting rooms before milking and scheduling the timetable of farming operations. In case of failure of one of the parlours the remaining parlour could in this situation serve as a functional reserve.

Conclusions

The main ideas, principles of calculation and the decision process presented in this paper can be generalized in the following conclusions.

1. The time for milking and the final specific direct costs are the main parameters, which enable evaluation and choosing of a suitable milking parlour for the dairy farm. Neglecting one of the mentioned criteria may lead to uneconomic investment or impaired operation of a farm.
2. The number of milking stalls of the milking parlour does not increase the milking capacity, if there is not increased number of milkers.
3. Increased capacity of dairy farm enables to reduce the final specific direct costs for milking.
4. The preliminary calculations in the preparatory phase before developing the project enable to evaluate (positive and negative) various solutions of milking parlours.
5. The evaluation of the existing milking parlours in the farms can help improve the milking process and operations from the point of view of either technical improvement or improved activity of milkers.

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