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Evaluation and optimization of milking in some Polish dairy farms differed in milking parlours

M. Gaworski[1,*], N. Kamińska[1] and P. Kic[2]

[1]Warsaw University of Life Sciences, Department of Production Management and Engineering, Nowoursynowska str. 164, PL02-787 Warsaw, Poland
[2]Czech University of Life Sciences Prague, Faculty of Engineering, Department of Technological Equipment of Buildings, Kamycka 129, CZ165 21 Prague 6, Czech Republic
[*]Correspondence: marek_gaworski@sggw.pl

Abstract. Farms are continuously growing and modernized in Poland during the last years. The increased dairy herds require also modernization of milking equipment. The aim of this paper was to present the main criteria, which could be used for the solution of principal questions important for the choosing, optimization and evaluation of milking parlours in conditions of Polish agriculture. The research was conducted on three modern dairy farms in Poland to assess effectiveness of different milking parlours use. The first farm with 60 cows was equipped by side by side milking parlour, the second farm with 85 cows was equipped by herringbone milking parlour and the third farm had 80 cows and autotandem milking parlour. The choosing and evaluation of milking parlours parameters were based on the available information and results of previous research in dairy farms in the Poland, using the mathematical model created in the Czech Republic. Time for milking and final specific direct costs were main parameters which enable evaluation and choosing of suitable milking parlour for the dairy farm. The results of measurement and calculation in current farms were compared with possible future enlarged farms to capacity of 200 cows.

Key words: milking parlours, dairy farms, costs, cows, milking process.

INTRODUCTION

Livestock production in countries with intensive agriculture is undergoing big and rapid changes. Number 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 tied barns towards loose barns and larger herd sizes (Maton et al., 1985; Bottema, 1992; Hansen, 1999; Bieda & Herbut, 2007; Gaworski et al., 2013; Gaworski & Leola, 2014; Gaworski & Priekulis, 2014; Gaworski & Priekulis, 2015). Due to these changes, many dairy farmers will have to design and build new milking parlour systems.

The milking process is the key operation on dairy farms. The function of milking parlour is one of the factors which affect the efficiency of milk production on the farm. There are many problems which influence the choosing and proper use of milking parlour. Some of them should be solved in advance during the preparation and design of dairy farm.

Modern large-scale farms require appropriate modern technical equipment. Equipment producers want very often to sell farmers the most expensive product which is not always appropriate. Operation is affected e.g. by selected number of milking stalls, by high or low number of milkers, sometimes by 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 decision taking into account the accurate and uniform criteria correctly according to the results of calculations.

The same milking parlours have different operating conditions in different countries around the world. Dairy farms in Poland are interesting, because traditional small farms are rapidly growing and milking technology should be modernized. For these farms it seems to be useful to calculate (model in advance) different variants of equipment and operating conditions by precisely selected and uniform criteria. The objective of the paper was to present the main criteria, which could be used for the solution of principal questions important for the choosing, optimization and evaluation of milking parlours in conditions of Polish agriculture.

MATERIALS AND METHODS

Many books, reports and scientific publications present results of research and recommendations focused on the problems of AMS (automatic milking system), usually also including comparison of AMS and milking parlours, in some publications information related to problems of performance and economic analysis (Bottema, 1992; Kic & Nehasilova, 1997; Kic, 1998; Priekulis & Laurs, 2012).

Leading companies producing milking equipment usually offer a variety of constructions of milking parlours recommended for different number of cows on the farm. They also recommend the possible level of automation and number of milkers which should work in the milking process (Brunsch et al., 1996; Dolezal et al., 2000; Chiumenti, 2004). But there are rather big differences in local conditions of the farms according to the production, economic, market and labour situation of the country or province. Although the use of AMS for large farms with a big capacity is developing, the high cost of this solution discourages many farmers. The question for medium and large farms is to currently choose an appropriate type of milking parlour.

It is possible to say that there are two divergent interests and goals in choosing the appropriate type of milking parlour. On the one hand there is interest of manufacturer and dealer who strives for the highest price contract and on the other hand, a farmer who would like to receive the best parlour, but for the price as favourable as possible, i.e. the lowest investment costs.

There are various practical recommendations in the literature, however, there are usually not sub-economic data included which result in a specific numerical data, characterizing the overall result of milking parlour solutions. Some publications (Provolo, 1992; Provolo & Marcon, 1993) present models focused on the choosing of milking parlours, but not in a complete universal approach which could be adapted everywhere. Results of research and basic equations used for calculation of several parameters of milking parlours are presented by Gaworski & Priekulis (2014). Similar calculations, completed with several important economic results which are valid for rotary milking parlours are presented by Ozolins et al. (2012).

The question is which criteria would be suitable to determine the type of milking parlour for each farm. If we know them, according to them can be evaluated different milking parlours, as well as we follow them when consider specific aspects and individual issues which influence the selection of milking parlour for the farm.

For objective assessment and selection of milking parlours there can be used and considered a lot of different aspects, e.g.: animal welfare and ventilation system (Herbut et al., 2012; Herbut & Angrecka, 2015; Herbut et al., 2015), capacity, price, the number of milkers, the complexity and sophistication of the operation, reliability, the dimensions (Gómez et al., 2017) and complicated installation in the building, demand of maintenance and service, and some other aspects like producer satisfaction (Wagner et al., 2001).

Overestimating or underestimating some aspects may result in problems during the normal operation of the milking parlour in practice and thus negatively affect the operation of the farm. In some cases this may lead to unnecessary wastage of finance for investment, without any real benefit to the operation of the farm.

To develop problem concerning evaluation of milking process, three farms typical for current situation in the Polish conditions were included in the investigations. All data used for the calculation were based on the data from modern dairy farms in the Poland.

The Farm 1 with 60 cows was equipped by side by side milking parlour (2 × 5). The Farm 2 with 85 cows was equipped by herringbone milking parlour (2 × 7) and the Farm 3 had 80 cows and autotandem milking parlour (2 × 3). The investigated dairy farms were under milk recording system. The following annual milk yield per cow was identified in particular farms (in kg cow^{-1} $year^{-1}$): 8,400 (Farm 1), 8,700 (Farm 2) and 8,200 (Farm 3). In all farms cow herds weren't divided into technological groups. The Holstein Friesians breed of dairy cattle was kept in all investigated farms.

There were calculated criteria and compared results between current situation and future, when increased herd size of all three farms would be 200 cows.

The first criterion which is important for the function of the farm is the time for milking. The fast milking of all cows enables to have enough free time in which cows have the opportunity to take feed and relax, to go to pasture and so on. The duration of one real milking of all cows can be calculated according to the equation (1).

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

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

As regards of a human working process and working operations there is important the total time of duration of one milking including preparatory operations and finishing work after milking, calculated according to the equation (2).

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

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

When this period T_{cd} is short enough then there is enough time for workers (milkers) to carry out the other activities (feed preparation, cleaning, control of animals etc.). Therefore the time should be a criterion for optimization and the selection of a suitable milking parlour for the farm.

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 labour costs of milking per cow and year ${}^{u}C_{W}$, specific costs of the milking equipment per cow and year ${}^{u}C_{P}$ and specific costs ${}^{u}C_{S}$ of consumed supplies.

These specific costs are sum of many individual parameters, which presentation is not the aim of this paper, mainly because of the extent. Specific labour costs of milking per cow and year ${}^{u}C_{W}$ are based on the labour need per cow per year and the average salary of milker, specific costs of the milking equipment per cow and year ${}^{u}C_{P}$ are including the annual percentage of technique depreciation, annual percentage depreciation of parlour building and specific repair costs expressed and calculated by a coefficient of repairs. Specific costs ${}^{u}C_{S}$ of consumed supplies are including sum of the cost of electricity, water for washing, chemicals for cleaning, disinfectants and towels needed during the milking.

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

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

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

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

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

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

where: i – the number of milking per day, day^{-1}; t_{rc} – the average net labour requirement for milking per cow, min cow^{-1}; t_p – the time of preparatory work before milking calculated per one cow, min cow^{-1}; t_c – the time of finishing and cleaning work after milking calculated per one cow, min cow^{-1}; n_{ds} – the real number of milkers, pers.

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

Specific costs of consumed supplies ${}^{u}C_{S}$ are calculated as a sum of 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 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. The theoretical required number of milkers n_d is based on the calculation of equation (6).

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

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

The maximum reasonable number of milkers per a parlour n_{dm} is a 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 can operate one milker.

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

where: n_{dm} – the maximum number of milkers per one parlour, pers.; m_Z – the number of milking stalls in milking parlour, pcs; n_s – the 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 – the theoretical number of cows which are in milking parlour in one moment (this corresponds to theoretical number of milking stalls in parlour), pcs; t_d – the average duration of milking by milking machine per one cow, min; t_v – the average idle time of a cluster, min.

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

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

RESULTS AND DISCUSSION

The results of calculations of current situation at the Farm 1–3, including the abovementioned data on annual milk yield per cow and the others were presented on the Figs 1–3. Two milkers were supposed to work in all variants of milking parlours at all three Farms. There was a standard level of technical equipment in all variants of milking parlours.

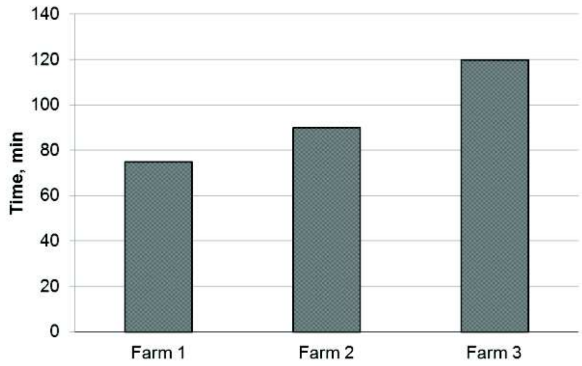

Figure 1. Current time of one milking in dairy Farm 1 (side by side milking parlour), Farm 2 (herringbone milking parlour) and Farm 3 (autotandem milking parlour).

The aim the Fig. 1 was to show the whole time of one milking, which is important for farmer from practical point of view. It is comparable with the results of bigger farm (200 cows) presented in the Fig. 4.

The data concerning time of one milking (Fig. 1) were usable to propose and calculate the index of milking stall load per cow. In order to find the index value, the time of milking was multiplied by number of milking stalls (in the milking parlour) and divided by number of cows in the farm (herd). Differences in the index values for investigated dairy farms were presented in the Fig. 2.

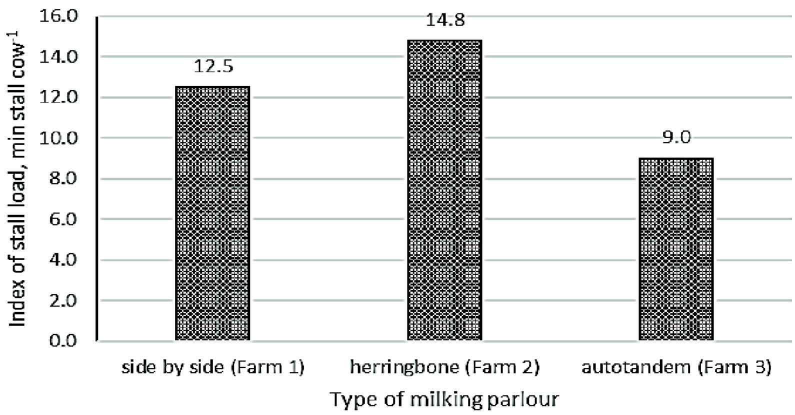

Figure 2. Index of milking stall load for three type of milking parlours in the investigated dairy farms.

The index of milking stall load shows the lowest value for autotandem type of milking parlour. Such result confirms that cow milking in individual stalls like autotanded can reduce time spent by each animal in milking parlour. The side by side and herringbone milking parlours include group milking so as a result it is possible to indicate longer time spent by each cow in milking stall. It can be suggested that higher number of stalls in herringbone milking parlour (14 stalls) decide about higher index of milking stall load in comparison with the index calculated for side by side milking parlour (10 stalls). The lower values of the index of milking stall load can identify shorter time spent by cows in milking parlour and such situation would be recognized as a more comfortable for animals.

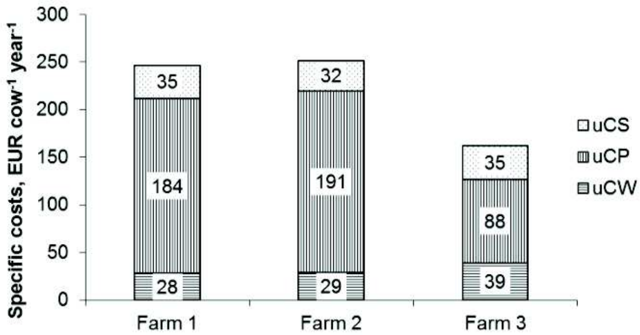

Figure 3. Specific costs of milking in the milking parlours in current situation in dairy Farm 1 (60 cows, side by side milking parlour), Farm 2 (85 cows, herringbone milking parlour), Farm 3 (80 cows, autotandem milking parlour).

The variant in Farm 1 (60 cows) with milking parlour side by side 2 × 5 milking stalls has rather good labour productivity as well as sufficient milking capacity therefore the labour requirements are not too high in this variant and the time of one milking (Fig. 1) is shorter than in the Farm 2 (85 cows) with herringbone milking parlour 2 × 7 and shorter than in the Farm 3 (80 cows) autotandem milking parlour 2 × 3. On the other side milking parlour in the Farms 3 is cheaper (${}^{u}C_{P}$), which results in the lower final specific direct costs of milking parlour ${}^{u}C_{MP}$ (Fig. 3).

The evaluation of current milking conditions is a background for calculations of future situation in all farms with increased number 200 cows. There are calculated and checked some basic principle parameters.

The real values of number of milking stalls in a parlour m_Z and real number of milkers n_{ds}, the theoretical number of milking stalls in a parlour m_T according to the equation (8), the theoretical required number of milkers n_d based on the calculation of equation (6) and the maximum reasonable number of milkers per a parlour n_{dm} according to the equation (7) are presented in the Table 1.

Table 1. Real and theoretical values of main parameters of milking parlours in the Farms 1–3

Parameter	Farm 1	Farm 2	Farm 3
m_Z	10	14	6
m_T	21	18	10
n_{ds}	2	2	2
n_{dm}	1.3	2	1.5
n_d	2.8	2.6	2.6

Explanation: m_Z – the number of milking stalls in milking parlour; m_T – the theoretical number of milking stalls in parlour; n_{ds} – the real number of milkers; n_{dm} – the maximum number of milkers per one parlour; n_d – the theoretical required number of milkers per one parlour.

The theoretical values are calculated with respect to the current duration of one real milking time T_{vd} and the total time of duration of one milking including preparatory operations and finishing work after milking T_{cd}.

Calculated numbers of milking stalls m_T which should be in the milking parlours in farms with future capacity 200 cows are in all Farms 1–3 bigger than real number of milking stalls m_Z in currently used milking parlours. It means that the time of milking will be longer. It is confirmed by results presented in the Fig. 3. Number of milkers n_{ds} should be theoretically higher (n_d), but on the other hand the maximum reasonable number of milkers per a parlour n_{dm} is lower. In the case of the Farms 1 and 2 it is even lower than currently working milkers n_{dm}.

The results of calculations of the farms with increased future herd size to 200 cows are presented on the Figs 4 and 5. The time per one milking is increased and differences between three milking parlours are more obvious (Fig. 4). The variant at Farm 1 with milking parlour Side by Side 2 × 5 milking stalls is thanks to good labour productivity as well as sufficient milking capacity still acceptable as the time of one milking which can be expected (2.5 h) is shorter than in the Farm 2 (3 h) with herringbone milking parlour 2 × 7 and shorten than in the Farm 3 (4.5 h) autotandem milking parlour 2 × 3.

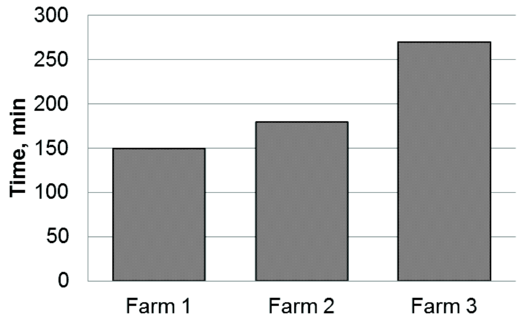

Figure 4. Time of one milking at dairy Farm 1, Farm 2, Farm 3 in future with 200 cows.

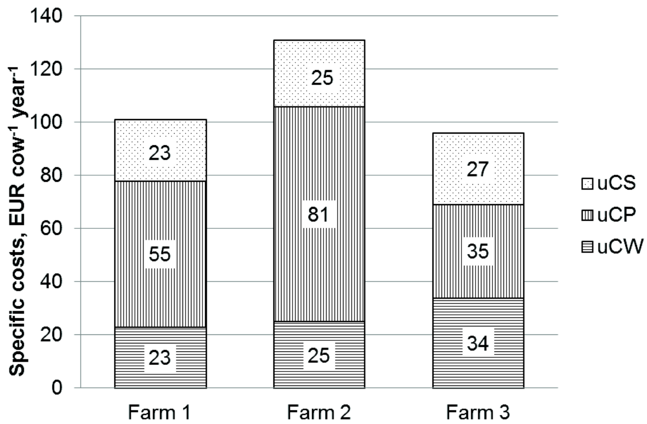

Figure 5. Specific costs of milking at dairy Farm 1, Farm 2, Farm 3 in future with 200 cows.

The final specific direct costs $^{u}C_{MP}$ of milking calculated per one cow and year (Fig. 5) are dramatically lower than the current situation in all three farms (Fig. 3). It looks that the best results are achieved in the Farm 1, equipped with the milking parlour Side by Side 2 × 5 milking stalls. Specific direct costs are rather low and the time of milking is the shortest from all three studied farms. The Farm 3 has slightly lower specific direct costs, but time of milking is very long; it could complicate the organization of all technological activities in the farm during the whole day. In the case of increased capacity of farms it is recommendable to modernise the milking parlour and install the new one with bigger capacity. The final decision of choosing the suitable milking parlour will depend on the priorities of the farmer, if he prefers cheaper solution or more expensive variant but with higher capacity and shorter time of milking.

Currently there are a variety of mathematical models, including stochastic models (Nitzan et al., 2006) which can help us to optimize the solution of various functional dependencies. It is always necessary to find appropriate criteria for the decision-making process. Some results of optimization and calculation based on mathematical model focused on the conditions of dairy farms and milking production in Czech Republic presented by Kic (2015a, 2015b) constitute one of the examples to develop some considerations concerning increase in milking effectiveness.

CONCLUSIONS

The time for milking and the final specific direct costs are the main parameters which enable evaluation and choosing of suitable milking parlour for the dairy farm. Both previous mentioned parameters in proposed methodology include the main technical parameters, indicators of labour productivity and economic criteria which can be used for determination of optimal parameters of milking parlour.

Calculation for all evaluated farms showed that the increased capacity from current situation (60, 85 and 80 cows) to the capacity 200 cows brings significantly lower final specific direct costs of milking parlour (reduction about 40% in the Farm 1, about 48% in the Farm and about 41% in the Farm 3). The time of one milking at all dairy farms is significantly increased; the biggest extension of milking time is in the farm equipped with the smallest milking parlour (Farm 3).

It is advantage that the calculation using this model allows, unlike the calculations solved earlier by other authors, to change all basic parameters of the construction and operation of the milking parlour on dairy farms. The preliminary calculations in the preparatory phase before developing a project enable to evaluate (positives and negatives) various solutions of milking parlours. The evaluation of existing milking parlours in the farms can help to improve the milking process and operations from the point of view of either technical improvement or improved activity of milkers, especially for the future development of farms.

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