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ANALYSES OF OPERATIONAL AND ECONOMIC CONDITIONS IN SELECTED DAIRY FARMS

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Abstract: Dairy farms are an essential component of livestock production in Türkiye. This article aims to show the current situation on these dairy farms and incredibly show the technical and operational conditions in milking technology. We researched 32 dairy farms with 6 to 681 lactating dairy cows. The milking technology on these farms corresponds to the usual structure of milking equipment on Turkish dairy farms. It includes bucket milking, pipe-line milking systems, tandem milking parlour, herringbone milking parlours and side-by-side milking parlours. To analyse the current situation, we used a calculation on the model, with evaluation criteria: the total time required for milking and the final direct specific costs. Evaluation of existing milking systems showed the possibilities of reducing human labour costs by optimizing the work activities. Larger farms characterize by more progressive milking technology, higher milk yields, and lower specific costs.

Keywords: Cost, Cow, Milking equipment, Milking process, Model, Milking parlour

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1. Introduction

Dairy farming is one of the oldest areas of animal production and is widespread throughout the world. The efficiency of milk production is greatly influenced by the capacity of the farm (Chiumenti et al., 2020; Dorottya Ivanyos et al., 2020) and specific differences in housing technologies (Dorottya Ivanyos et al., 2020; Leso et al., 2019), feeding (Silva et al., 2021) and especially milking (Chiumenti et al., 2020; Silva at al., 2021; Mangalis et al., 2019). All of this depends largely on the technological and technical development of agriculture in the country and region (Celozzi et al., 2020). The selection of an appropriate milking system depends on many factors, but gentle and quick milking and herd size are very important aspects in this farm management decision (Ózsvári and Ivanyos, 2021).

The analysis of the farmers' efficiency in the dairy production using cross-sectional data collected from 92 sample dairy farmers in the West Mediterranean Region of Türkiye is presented in (Yılmaz et al., 2020). The study used the Stochastic Frontier Analysis (SFA) to measure the efficiency farmer's technical in milk production. The technical efficiency of the sample of dairy farms ranged from 0.30 to 1.00. The most significant factors affecting the efficiency of dairy products were household size, the total number of cattle, and the ratio of the total number of dairy cows to the total number of livestock, technological level, barn type, and production of maize silage.

The comparison of dairy farms on different scales regarding milk production cost and profitability in Hatay Province, Türkiye, is the subject of research in publication (Tapki, 2019). The results show that dairy enterprises with fewer milking cows yield the lowest milk production costs, low milk yield, high feed prices and shortages of feed, insufficient regular veterinary control, and low technology adoption, especially in rural areas where the costs are even lower. Despite the low cost of milk production on small-scale farms, mainly because of their low input costs, both milk yields and the efficiency with which farm inputs are used are very limited. The production cost per litre of milk (0.305 USD) and the selling price (0.370 USD) was the highest in the fourth group.

In a study recorded by Unakıtan and Kumbar (2019), energy use efficiency and feed conversion ratios of feed costs of different size dairy cattle farms were calculated in the Thrace region. In addition, the results of the economic analysis of dairy farms were given. When the energy efficiency coefficients are examined, it is seen that the average of the region is 0.23. Although energy efficiency is desired to be higher than 1, this coefficient is generally low in analyses of perennial plants and animal production. On the other hand, the positive reflections of the specialization and the scale of the farms on the producer's income have been revealed as a result of the economic analysis. In Türkiye, the monthly minimum wage is 285 USD. Considering this situation, a dairy farm must breed at least 22 cattle units to obtain enough income.

In other study (Aydemir et al., 2020), cost analysis and technical efficiency were performed for dairy cattle farms in Artvin province of Türkiye, milk production costs were calculated, and the factors influencing milk production were identified. Research data were gathered through the questionnaires with 118 dairy cattle farms selected through the random sampling method. Total production costs per farm were calculated as 17557.64 USD, and 57.76% of such a sum was constituted by variable costs and 42.24% by fixed costs. The average cost of 1-litre milk was calculated as 0.32 USD.

Growing consumers' awareness, high production costs and low milk price, hi-tech offer, mortgages, production diseases, high replacement rates, and issues like antibiotic resistance and environmental impact makes the modern dairy farmer constantly under target (Brombin et al., 2019).

The results of milk production on dairy farms are influenced by the health status of dairy cows and by milking technology, as well. It has a great influence on the quality of milk. Systematic collection of all necessary data and good management are of great importance for controlling the situation on farms (Cabrera et al., 2020; Leso et al., 2021). It can be used to support herd management decisions. The optimization calculation makes it possible to determine the necessary parameters of milking equipment, which is important for large farms. This is important for those farms that use rotary milking parlours with movable milking stalls (Mangalis et al., 2019), but most milking parlours are simpler at a lower cost and have immovable milking stalls.

Several Italian farms were studied (Chiumenti et al., 2020). The time for milking and the final specific direct costs are the main parameters that enable the evaluation and choice of suitable milking parlour from the dairy; neglect or promotion of only one of the mentioned criteria may lead to an uneconomic investment or impaired operation of a farm.

The issue of milking time and its effect on efficiency is studied in the article (Poulopoulou et al., 2018). Shares of the activities of milking and feeding stands for more than half of the total working time. The highest potential to increase productivity can be the adoption of certain milking systems or feeders, despite their costs, of course. However, the possible investment in machinery should be made under careful examination of the proposed capacity used. Especially in small- and medium-sized herds, investments will increase labour productivity, but not necessarily farm income if machinery is not used at its capacity.

The impact of housing, including an outdoor stay of cattle even in the cold season, has a positive impact on health (Sjostrom et al., 2019). To obtain reliable and objective results, the management of accurate data collection on farms is important (Van Os et al., 2018), which needs to be emphasized in terms of animal welfare evaluation.

Appropriate farm solutions and milking techniques are also affected by the local situation, and the human factor also plays an important role. E.g. research results according to (Pugliese et al., 2021) demonstrated that in Sicily, the semi-intensive farm is better than the intensive one to satisfy the conditions of animal welfare.

The article (Dorottya Ivanyos et al., 2020) surveys the milking technology and the relationship between the milking technology, the herd size, and the milk production parameters on the Hungarian commercial dairy farm. The large capacity brings advantages for efficiency and milk yields.

According to Silva et al. (2021), the use of precision technology is increasingly seen as an option to improve productivity, animal welfare, resource use efficiency, and workplace features on dairy farms. Analyses results presented in (Yang et al., 2021; Edwards et al., 2020) are focused on labour-saving technologies and innovations on New Zealand dairy farms. The use of automation plays an important role in reducing the working time of partial work operations during milking processes.

Despite the growing number of farms equipped with AMS (Pezzuolo et al., 2017), the most common and available milking system is the use of milking systems without robotization, especially in countries with a lower cost of human labour. However, it must be emphasized that robotization is not for everyone. Differences between AMS and conventional systems are quite challenging and complex (Filho et al., 2020). The introduction of AMS implies important changes (Bugueiro et al., 2019) in farm routine and management. It also changes culling dynamics (both modifying causes for culling and increasing the percentage of animals culled), at least during the first years after installation. The modification of culling dynamics will have a great impact on dairies.

AMS have the potential to increase dairy farm productivity and profitability; however, adoption rates, particularly in pasture-based systems, have been lower than expected (Gargiulo et al., 2020). The AMS farms had higher overhead costs such as depreciation and repairs and maintenance; however, no differences in total labour costs were observed between systems.

Risk factors for mastitis were evaluated at the cow level and the herd level in the article (Silva et al., 2021). The risk factors evaluated at the herd level were related to milking management, environment and management practices. The authors identified some risk factors; increased parity, later stage of lactation, not milking clinical and subclinical cases last, lack of routine cleaning of the milking parlour, using the dry-off treatment and optimized feed before calving.

According to Sánchez-Duarte et al. (2020), increasing milking frequency from twice to three times per day positively affects milk production and yields of milk fat and milk protein without increasing dry matter intake. Application of three times per day milking frequency must consider dairy cow management, labour availability, and milking parlour infrastructure particular to each dairy farm.

Influence of milking technology on operating conditions from the point of view of health protection of farmworkers is also significant (Edwards and Kuhn-Sherlock, 2021) appropriate technology and automation help to reduce injuries.

The goal of the article (Lopes et al., 2021) was to assess the economic impact of some environmentally friendly technologies on the production costs and cost-effectiveness of a dairy cattle confinement system, estimating environmental costs and their representativeness in both effective and total operating costs, as well as in the total cost. The results of this research showed, among other things, that in terms of costs are also high costs of machines and tools, maintenance, improvements and energy consumption.

According to the results of cost analysis (Koç and Uzmay, 2019), it was determined that climate change will lead to a 10-50% cost increase on dairy farms by the year 2044. The heat stress is responsible for 48-71% of the increase in the cost of production, whereas 24-52% is due to an increase in feed prices. Based on the outcome of this research, it was suggested that agricultural extension activities should be carried out for farms to get adapted to climate change.

For the analysis of dairy farms in terms of milking technology, it is appropriate to use a mathematical model (Kic, 2015) developed so that it is possible to evaluate the existing situation on the dairy farm in terms of milking and use specific criteria to objectively assess the conditions in terms of labour costs, costs of technical equipment and operating costs for consumed material, energy, etc. The model can be used to model conditions under which it would be possible to improve the current situation and achieve savings, such as better use of milking equipment, modernization of technical equipment, changing operating conditions, or model changed conditions in an extended farm with a larger herd of dairy cows, with larger milk production.

This article aims to analyse the current conditions in milking equipment on farms in Türkiye. The analysis of operating and economic conditions in selected dairy farms allows us to show the strengths and weaknesses and recommend options for possible improvements.

2. Materials and Methods

The research was focused on farms in the Cukurova Region, which has very intensive agriculture, and conducted in March - July 2018. Cattle breeding is one of the developed areas of animal production. The examined farms are mainly focused on milk production (Figure 1). From the figure and the course of the intersected line, it is obvious that the percentage of dairy cows in the whole cattle herd is approximately the same for all farm sizes. It increases only slightly with the size of the herd.

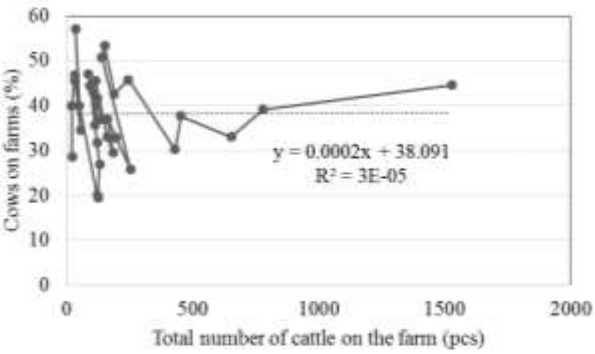

Figure 1. Percentage of dairy cows (%) depending on the number of cattle bred in the all farms.

In addition to dairy cows, other categories of cattle (calves, heifers and cattle fattening) are kept on farms, as shown in Figure 2. It can be seen from Figure 2 that larger farms can keep a larger number of other categories of cattle, but following results valid for cows presented in Figure 1, the percentage is approximately the same on all farms.

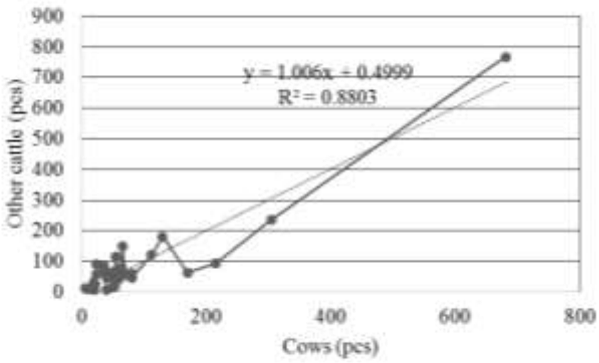

Figure 2. Number of cattle of other categories (calves, heifers, fattening cattle, breeding bulls, pcs) depending on the number of dairy cows.

Table 1 shows an overview of farms in terms of the number and size of farms (number of milked cows from 6 to 681cows) and basic data on milking equipment (type of milking equipment and number of milking units on the farm). The structure of the farms examined roughly corresponds to the usual structure of milking equipment on Turkish dairy farms.

The most common are milking parlours (MP), mainly Herringbone Milking Parlours (HBMP). There are also quite common milking parlours Side by Side (SBSMP) with parallel arrangements of milking stalls. Tandem Milking Parlours (TMP) are less common than others nowadays. Since many dairy farms still have a small herd capacity, many smaller farms still use a milking system in a cowshed, either Bucket Milking (BM) or Pipe-line

Milking Systems (PLMS). The results of measurements and calculations are divided into groups of farms according to the type of milking equipment. Farms in group A are equipped with BM, group B has PLMS, group C has TMP, farms in group D have HBMP, and farms E are equipped with SBSMP.

Table1. Analysed dairy farms and their milking equipment.

Farm Groups	Milking equipment			NF	Number of Lactating Cows		
	Type	Age (Years)	NC		Mean	Minimum	Maximum
A	BM	6 ± 2	4 ± 2	5	13	6	20
B	PLMS	7 ± 3	9 ± 1	2	30	19	40
C	TMP	13	10	1	60	60	60
D	HMP	6 ± 2	18 ± 6	17	81	20	305
E	SBSMP	8 ± 5	19 ± 9	7	161	24	681
Summary	-	-	-	32	84	6	681

NC= number of clusters, NF= number of farms

The first parameter taken into consideration is the milking time. Having a short duration of milking time enables cows to take feed and rest, to go grazing, and so on. As regards human working process and working operations, the total duration time of single milking T_{cd} includes the time of preparatory work before milking and subsequent work (cleaning after the milking, etc.) according to Equation (1).

$$T_{cd} = T_p + T_{vd} + T_c \quad (1)$$

Where;
T_{cd} – total duration time of single milking, T_p – the time of preparatory work before milking, h; T_{vd} – the duration of one milking, h; T_c – the time of subsequent work after milking, h;
When the period of 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 selection of suitable milking parlour for the farm. The total duration time of single milking T_{cd} can be recalculated according to Equation (2) as a specific time of single milking per cow t_{cds}.

$$t_{cds} = \frac{T_{cd}}{N} \quad (2)$$

Where;
N – number of lactating cows on the farm, cow.
In modelling and analysis of the current state (Kic 2015), the overall real capacity of milking equipment Q_h is calculated according to Equation (3) based on several lactating cows in the dairy herd and time data.

$$Q_h = \frac{N}{T_{cd}} \quad (3)$$

Where;
Q_h – the overall real capacity of milking equipment, cow h^{-1}; N – number of lactating cows on the farm, cow; T_{cd} – the total duration time of single milking, h.
In terms of the operational function of the milking equipment and the milker's work, the real capacity of the milking equipment was calculated according to Equation (4).

$$Q_{LS} = \frac{N}{T_{vd} - T_{pr}} \quad (4)$$

Where;
Q_{LS} –real capacity of milking equipment, cow h^{-1}; N – number of lactating cows on the farm, cow; T_{vd} – duration of one milking, h; T_{pr} – duration time of working breaks, h.
This real capacity of milking equipment is affected by the working capacity of one milker, which can be calculated according to Equation (5).

$$W_{dh} = \frac{Q_{LS}}{n_{ds}} \quad (5)$$

Where;
W_{dh} – the working capacity of one milker, cow h^{-1}; n_{ds} – the number of milkers, pers.
From the working capacity of one milker, it is possible to determine, according to Equation (6), the need for human labour for one milking of one dairy cow.

$$t_{rc} = \frac{1}{3600 \cdot W_{dh}} \quad (6)$$

Where;
t_{rc} – the time of human labour spent for milking operations of one dairy cow, s cow^{-1}.

The second decisive criteria for optimizing and selecting a suitable milking system for the farm 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 system per cow and year $^{u}C_{MP}$, calculated according to Equation (7) 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 $^{u}C_{P}$ including the construction of milking parlour (if it is used), and specific costs $^{u}C_{S}$ of supplies including the water, electricity, disinfectants, etc. per one cow and year.

$$^{u}C_{MP} = {}^{u}C_{W} + {}^{u}C_{P} + {}^{u}C_{S} \quad (7)$$

Where;
$^{u}C_{MP}$ – the final specific direct costs of the 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 determined based on labour requirements per cow per year T_r (h cow^{-1} year^{-1}) obtained by using Equation (8) and an average hourly wage of the milker. The labour requirement T_d can be used by equation (9).

$$T_r = \frac{365 \cdot T_d}{60} \quad (8)$$

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

$$T_d = i \cdot \left[\frac{N \cdot (t_{rc} + t_p + t_c) + T_{pr} \cdot n_{ds}}{N} \right] \quad (9)$$

Where;
i –number of milking per day, day^{-1}; t_{rc} –average net labour 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}.
Specific costs of the milking equipment $^{u}C_{P}$ are evaluated as specific data of total operating costs of the milking machine per single cow. Hence, it takes into consideration of amortization of machinery, amortization of construction which includes construction costs and percentage of building amortization and the cost of servicing, maintenance and repairs.
Specific costs of supplies $^{u}C_{S}$ are determined 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 during their operation, water, disinfection etc. All are re-computed 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 (10).

$$n_d = \frac{Q_{PL}}{W_d} \quad (10)$$

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}.
The maximum reasonable number of milkers per 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.

$$n_{dm} = \frac{m_Z}{n_s} \quad (11)$$

Where;
n_{dm} – the maximum number of milkers per one parlour, pers.; m_Z – the number of milking stalls in the milking parlour, pcs; n_s – the maximal number of clusters per milker, pcs.
An important technical parameter is a theoretical number of milking stalls in a parlour m_T, obtained by using Equation (12).

$$m_T = Q_{PL} \cdot (t_d + t_v) \quad (12)$$

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

$$t_v = t_n + t_s + t_m \quad (13)$$

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.
Some important measured data were evaluated using the program *STATISTICA - ANOVA F-test* method, i.e. a hypothesis H_0 presents a statistically insignificant difference among measured data ($p > 0.05$) and a hypothesis H_1 presents a rejection of the hypothesis H_0, i.e. there is the statistically significant difference among measured data ($P < 0.05$).

3. Results and Discussion

Evaluation of the current milking conditions enables us to compare all farms and milking parlours and propose some ideas for improvement. A summarized results of measurements at the farms with different milking systems and model calculations of the current situation and suggested improvements are in Tables 2 and 3, and Figures 3 to 8.
The results obtained from all farms allow assessing the effect of farm size (number of dairy cows) on milk production, which is shown in the graph in Figure 3. It can be seen from Figure 3 that with the growing size of the farm (with the number of dairy cows) the average milk production efficiency on the farm also increases.

The more detailed analysis allows evaluation of milk production on farms listed in Table 2. The highest productivity is on farms equipped with HBMP (7696 ± 553 kg cow^{-1}year^{-1}) and SBSMP (7316 ± 1048 kg cow^{-1}year^{-1}). Significantly the lowest productivity is on farms with BM (5521 ± 464 kg cow^{-1}year^{-1}), which are also farms with the lowest number of cows.

The number of non-dairy cows (e.g. dry cows, cows with health problems, etc.) as a function of the total number of dairy cows on the farm in Figure 4, expressed as a percentage depending on the total number of dairy cows on the farm, decreases, indicating a positive trend.

Table 2. Average milk yield per cow, per year, according to the type of milking equipment.

Farm Groups	Type of Milking equipment	Annual Milk Yield per Cow (kg cow^{-1}year^{-1})		
		Mean	Minimum	Maximum
A	BM	5521 ± 464 ^{a}	4575	6100
B	PLMS	6176 ± 686^{a,b}	5490	6863
C	TMP	7168 ± 0.0^{a,b}	7168	7168
D	HBMP	7696 ± 553 ^{b}	6100	9150
E	SBSMP	7316 ± 1,048 ^{b}	6100	10675
Summary	-	7146 ± 956	4575	10675

$^{a, b}$ Different superscript letters is a sign of high significant difference (ANOVA; Tukey HSD Test; P ≤ 0.05) between the mean values of milk yields of different milking equipment.

Table 3. Data determined by analysis from farms): overall resulting real hourly capacity of the milking equipment Q_h, the real capacity of a milking equipment Q_{LS}, the working capacity of one milker W_{dh}, and the need for human labour for one milking of one dairy cow t_{rc}.

Farm Groups	Type of Milking equipment	Q_h	Q_{LS}	W_{dh}	t_{rc}
		(cow h^{-1})	(cow h^{-1})	(cow h^{-1})	(s cow^{-1})
A	BM	8.83 ± 1.78 ^{a}	15.0 ± 3.0 ^{a}	9.5 ± 4.2^{a}	462 ± 118^{a}
B	PLMS	19.67 ± 7.00^{a,b}	29.5 ± 10.5^{a,b}	14.8 ± 5.3^{a,b}	279 ± 99^{a,b}
C	TMP	12.00 ± 0.00^{a,b}	40 ± 0.0^{a,b}	20 ± 0^{a,b}	180 ± 0^{a,b}
D	HBMP	35.63 ± 13.04^{b}	53.3 ± 17.6^{b}	27.8 ± 9.5^{b}	154 ± 46^{b}
E	SBSMP	49.46 ± 37.57^{a,b}	71.7 ± 44.9^{a,b}	26.2 ± 8.5^{a,b}	163 ± 61^{b}

$^{a, b}$ Different superscript letters are signs of high significant difference (ANOVA; Tukey HSD Test; P ≤ 0.05) between the mean values of milk yields of different milking equipment.

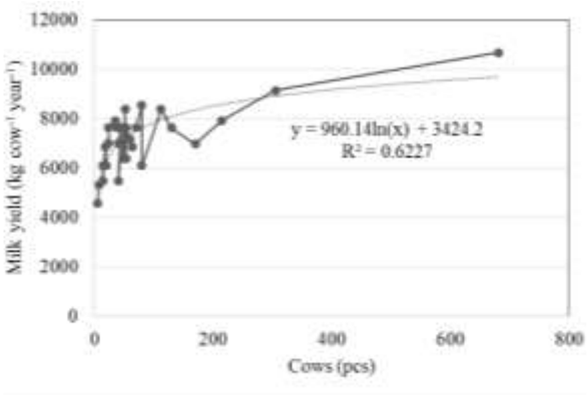

Figure 3. Average milk yield per cow, per year according to the number of milked cows on the farm.

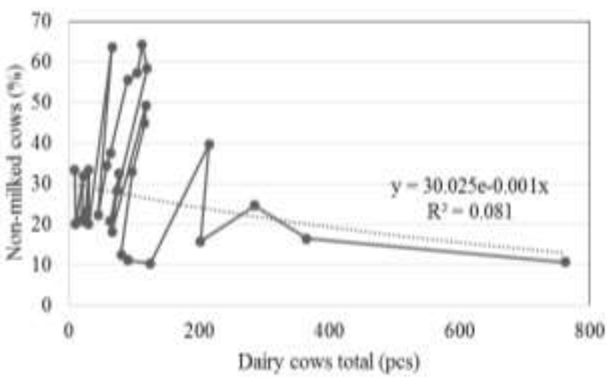

Figure 4. Percentage of non-milked cows (e.g. dry cows, cows with health problems, etc.) as a function of the total number of dairy cows on the farm.

The overall time of the whole single milking covers all milking- related activities, it also includes time for pre-milking and post-milking activities, incidental activities and loss times that degrade the performance and capacity of milking equipment. The specific time of single milking per cow t_{cds}, shown in Figure 5 shows a significant decrease in the use of MP compared to BM or PLMS milking.

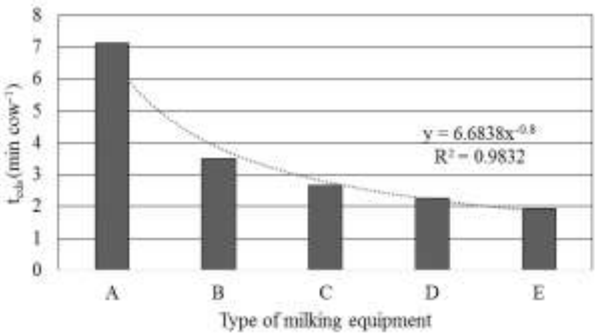

Figure 5. The specific time of single milking includes preparation, washing, milking, cleaning, etc. per lactating cow (min cow^{-1}).

Determining final average values of the overall resulting capacity Q_h of milking equipment, the real capacity Q_{LS} of milking equipment, the working capacity W_{dh} of one milker and the need of human labour t_{rc} for one milking of one dairy cow, summarized from all examined milking facilities and divided into groups according to of the type of milking equipment are given in Table 3. From these calculated results of parameters characterizing milking processes, a significant difference is evident, especially between milking inside the cowsheds (BM and PLMS) and milking in milking parlours.

The average values of the overall resulting capacity Q_h of milking equipment reached a relatively small value of 12 cows h^{-1} in the case of TMP, which is mainly due to longer preparation before milking (15 min preparation of milker and 15 min preparation of milking parlour) and longer the time required for the final activities after milking (40 min cleaning, washing and disinfection of the milking equipment). This may explain the reason why this parameter is lower for this milking parlour than for milking by the PLMS system, where it reached 19.67 ± 7 cow h^{-1}. The largest overall resulting capacity Q_h of milking equipment is 49.46 ± 37.57 cow h^{-1} reached in SBSMP, but from the statistical evaluation, it is clear that there are large differences between the examined milking parlours (large variance of values) which in some cases significantly reduces this parameter.

Real capacity Q_{LS} of milking equipment provides a better idea of the actual performance of milking equipment. A mutual comparison shows that milking parlours (TMP, HBMP and SBSMP) perform better than milking inside cowsheds (BM and PLMS). Also, according to this parameter, 71.7 ± 44.9 cow h^{-1} SBSMP achieves the best results, but again there is a large variance around the average value. Furthermore, there is the influence of a larger number of milkers working in these milking parlours, which can increase this performance.

For a more objective assessment of technical possibilities and operational results, the working capacity W_{dh} of one milker and the need for human labour t_{rc} for one milking of one dairy cow are interesting. The highest average value of the working capacity W_{dh} of one milker is 27.8 ± 9.5 cow h^{-1} in the HBMP, a little lower this value is 26.2 ± 8.5 cow h^{-1} in the SBSMP and significantly the lowest is 9.5 ± 4.2 cow h^{-1} in BM.

The calculated values of the need for human labour t_{rc} for one milking of one dairy cow also correspond to these results. This information indicates the real need for human labour for all tasks and work operations that the milker must perform during milking. This shows the importance of the milking parlour which reduces the need for human labour, facilitates the handling of the milking equipment, and in addition, provides better hygienic conditions for milking. Due to certain differences between farms in milking system equipment and milking facilities as well as different work intensities of individual milkers, there is considerable variance around the average values in individual groups of milking parlours. The lowest need for human labour 154 ± 46 s cow^{-1} is in HMP, slightly higher is 163 ± 61 s cow^{-1} in SBSMP and the largest is 462 ± 118 s cow^{-1} in BM.

Specific direct costs of milking system per cow and year $^{u}C_{MP}$ divided according to Equation 7 into three components ($^{u}C_W$, $^{u}C_P$ and $^{u}C_S$) are presented in Figure 6. The comparison of specific labour costs shows that the most expensive (269 EUR cow^{-1} year^{-1}) is the labour in cowsheds with BM. The lowest specific direct costs per cow and year (115 EUR cow^{-1} year^{-1}) are in the cowsheds with SBSMP.

The need for human labour is reflected in specific labour costs $^{u}C_W$. Overall, these specific labour costs can be assessed as quite high, especially in comparison with the results achieved e.g. (Chiumenti et al., 2020). A more detailed analysis of the technical solution and operating conditions has shown that there is a discrepancy between the technical equipment and the results achieved on many farms. E.g. on small farms (only 6, 8, or 15 lactating dairy cows) equipped with BM, 2 milkers work and the milking time is quite long. Only 1 milker would be enough.

Similar shortcomings can be found in some other farms, equipped with HBMP. What is the current number of milkers on the farm n_{df} and what should be n_d concerning technical equipment and achieved milking time shows a comparison of the number of milkers in Figure 7. It can be seen from the figure that in most farms the number of milkers is higher than optimal. Improved organization of farm work and better use of technical facilities especially in milking parlours would reduce the number of milkers and thus lower labour costs. Workers could work on other necessary work activities on farms in the saved time.

The specific costs of technical equipment for milking technology $^{u}C_P$ correspond to the given situation and because MPs are used for larger farms, the specific costs are slightly lower than for milking in the cowsheds (BM and PLMS). The specific costs of $^{u}C_S$ of supplies are influenced mainly by the extent and frequency of washing, cleaning and disinfection of milking facilities as well as the thoroughness of preparation, including cleaning of dairy cows before milking and disinfection after milking. These specific costs are the highest at MPs, mainly HBMP and especially SBSMP. These PMs are used on larger farms and farmers pay more attention to washing and disinfection than on small farms.

Figure 8 shows the specific direct costs of a milking system per cow and year uC_{MP} divided according to Equation 7 into three components (^uC_W, ^uC_P and ^uC_S) after changing the number of milkers (in most milking systems to a lower number of milkers) to better match the technical and capacity capabilities of the milking system on each farm. It can be seen from the figure that the biggest savings could be achieved with BM, PLMS and HBMP.

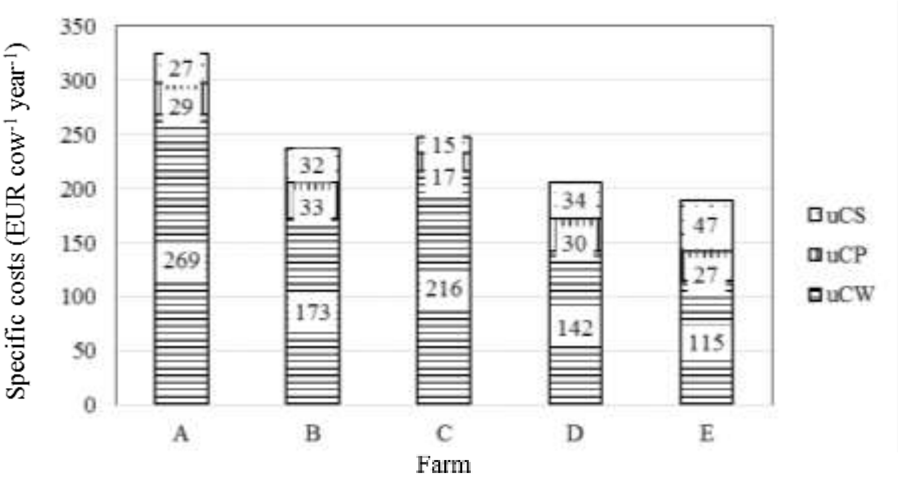

Figure 6. Specific direct costs of a milking system per cow and year $^uC_{MP}$ (EUR cow^{-1} year^{-1}) in the current situation in farms.

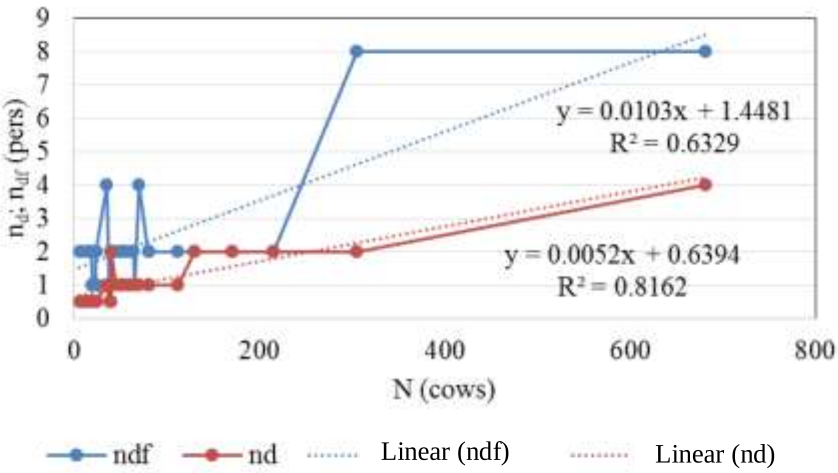

Figure 7. Current number of milkers on the farm n_{df} and optimal number of milkers n_d (pers).

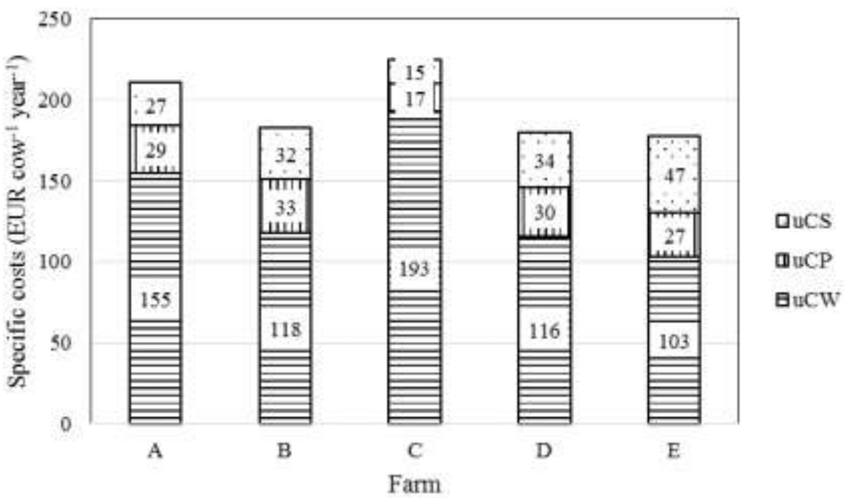

Figure 8. Specific direct costs of a milking system per cow and year $^uC_{MP}$ (EUR cow^{-1} year^{-1}) in farms with a reduced number of milkers according to the model calculation.

4. Conclusions

Based on the performed research and the results of the model calculation the following conclusions can be drawn:

- Greater capacity of dairy farms gives preconditions for increasing milk yield;
- Greater capacity of the dairy farms enables the application of progressive milking techniques in separate milking parlours;
- Greater capacity of the dairy farm allows to keep more young cattle and possibly cattle for fattening;
- The selection of a suitable milking technique should be evaluated in the light of the prospective development of the farm, including increased capacity;
- In particular, two criteria should be considered for the selecting a suitable milking technique, i.e. the total time required for milking and the final direct specific costs;
- When choosing a milking technique, it is appropriate to use a model for optimization calculations enabling the analysis of expected technical and economic results;
- Evaluation of existing milking systems would improve the milking process and operations from the point of view of either technical improvement or improved activity of milkers.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	M.D.	P.K.	B.D.	G.A.K.G.
C	25	25	25	25
D	25	25	25	25
S	25	25	25	25
DCP	25	25	25	25
DAI	25	25	25	25
L	25	25	25	25
W	25	25	25	25
CR	25	25	25	25
SR	25	25	25	25
PM	25	25	25	25
FA	25	25	25	25

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of this article produced using data before 2019.

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