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Design of algorithms for evaluating the efficiency of labour and variability of some group milking parlour parameters

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ABSTRACT

The first objective of this paper was to develop a series of algorithms for sizing group milking parlours (herringbone and parallel) that guarantee the best approximation to maximum efficiency and allow the variability of some important design parameters to be considered. The maximum efficiency was defined as that achieved when the total milking time worked by milkers was minimised given recommended milking duration. The main parameters considered were milking routine time, milk extraction time and milking duration. The second aim was to study the effect of variations in these parameters on parlour efficiency. To this end, the number of milking units and milkers required was determined for various combinations of cow number (40–240), milking routine times (30–100 s) and milk extraction times (250–600 s), considering the effects of each option on the duration of milking and total time worked. The results showed that the achieved efficiency varies as a function of the different combinations of values tested, and that using these algorithms, it is possible to establish an approximation for maximum efficiency for each combination. The best approximations are obtained when the milking duration is lower. Our study of the influence of parameter variability on efficiency found two models of farms: the first model combined a slow routine, low production and high inter-cow variability in production, and the second model combined a quick routine, high production and low variability. In the first model, the efficiency of labour is very close to maximum; even when using a large parlour or more workers, the performance in cows per hour will remain relatively stable, and no improvement is observed compared with using smaller parlours or fewer workers. For this reason, the increase in parlour performance can only be obtained by improving farm management, including milking routine times or grouping cows. In the second model, an increase in the number of milkers and milking units usually leads to a decrease in milking duration, but this comes at the cost of substantially increasing the total time worked; this case needs a detailed study to achieve the best efficiency. These results show that optimisation of parlour performance and approximation to maximum labour efficiency should be addressed differently depending on the characteristics of the farm; in some cases, an improvement in management activities is necessary. In others, a detailed study of the number of milkers and milking units is needed.

1. Introduction

The performance and efficiency of group milking parlours depends on the parameters of cows, milking management, milking facilities and labour, and the combination

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thereof. It is also necessary to take into account the organisation of farm work as it determines the total hours of parlour use, another factor to consider (Smith et al., 1996). Therefore, the study of milking parlours is broad and includes aspects such as working-time measurement, the influence of various parameters on performance and simulations of their operation.

Simulation models include combinations of parameters that are intended to represent parlour operation. Thomas et al. (1996a, 1996b) have indicated steps for achieving this objective and presented a simulation model to assess the effects of parlour size, parlour design, operating characteristics of the milking system, parlour management strategies and herd milk yield. Previously, Chang et al. (1994) defined an object-oriented model, and Nitzan et al. (2006) subsequently developed a stochastic model that considered the type of parlour, herd size, number of milking stalls, labour quality and individual cow characteristics, such as individual milking times, to obtain the duration of the milking process.

Another simulation approach employed by Reneau and Chastain (1995) using a rule-based model evaluated the effect of prep-lag time and milk flow rate on throughput. Reinemann et al. (2006) prepared a spreadsheet that estimated milking centre costs and performance, and Fernández et al. (2009) developed an algorithm for defining the number of milking units and milkers with parameters related to milking management and milk extraction time.

One of the most important evaluative parameters is the individual milking time of cows; however, because it is a function of many factors, its variability is difficult to estimate (Bade et al., 2009; Magliaro and Kensinger, 2005; Rasmussen et al., 1992; Stewart et al., 2002; Tančin et al., 2006; Thomas and DeLorenzo, 1994). Other key aspects to consider are the activities required to milk each cow; hence, the milking routine is one of the most influential variable parameters on parlour performance (Armstrong et al., 2001; Smith et al., 1997). The milking routine is analysed using time and motion studies, leading to models of routine times (Armstrong and Quick, 1986; Burks et al., 2006).

In addition to the above parameters, which are used for sizing the parlour, it is also necessary to consider the time spent on milking (milking duration), which varies depending on the organisation of work and the available work force. Additionally, the recommended time that cows spend in the holding pen and the parlour should be considered. The time of labour employed in milking is a parameter related to parlour efficiency and should be considered when sizing.

The efficiency of the parlour is usually assessed on the basis of the ratios of cows milked per hour, cows per stall per hour, cows per milker hour, cows per labour hour, turns per hour or kilos of milk output per stall, per hour or per shift (Armstrong et al., 2001; Smith et al., 1997, 2003; Thomas et al., 1996b). The efficiency was considered to be maximal in this work when the time worked is the minimum needed (maximum efficiency of labour), given use of the recommended milking times; these parameters allow us to provide a different approach to parlour efficiency.

The first objective of our study was to develop a series of algorithms for sizing group milking parlours (herringbone and parallel designs) that guarantee the best approximation to maximum efficiency and allow the variability in some important parameters of design to be assessed. The main parameters considered were milking routine time, milk extraction time and milking duration. The second aim was to study the influence of variations in these parameters on parlour efficiency.

2. Methodology

Four stages were used. First, we defined the parameters and their values, which were input as data and used in subsequent calculations. Second, we established working hypotheses and constraints between the parameters to be used in performing the calculations.

Third, combinations of parameter values (hereafter also called parameter group) were used to determine the possibility of achieving maximum efficiency. This approach simultaneously satisfies two conditions: the duration of milking should equal the recommended value and the milking time worked by all milkers should be at the minimum. An algorithm was developed that relates the parameters and allows testing of various combinations of parameter values. The results of these combinations were studied to determine the limits for achieving the two aforementioned conditions.

The fourth step was to perform the combinations of parameter values that get close us to real conditions, considering the variability in the values of the parameters. To design the group milking parlour and evaluate its performance, milk extraction time (T_{ME}) was usually introduced as a constant value. However, in real situations, T_{ME} varies cow to cow and, therefore, there is a different T_{ME} in each group. In addition, not all groups entering the milking parlour occupy all the milking units; it is not unusual for groups to have fewer cows than available milking units. Thus, to calculate the milking duration and the milking time worked by all the milkers, more than one value of T_{ME} should be used. Another algorithm was developed to obtain T_{ME} for each group. Later, the milking duration and the milking time worked by all the milkers were determined by employing an algorithm previously developed by the authors (Fernández et al., 2009) for parlour sizing. Using these algorithms, a number of parameter value combinations or parameter groups were investigated. The results were analysed to determine the effect of design parameter variability on parlour performance.

These four stages are described in greater detail below, and the methodology is outlined in Fig. 1.

2.1. Parameters

The following parameters were used (Fig. 1, step 1):

- N: Number of milked cows. We performed simulations for values of N between 40 and 240.
- M: Number of milking units in the milking parlour.
- M_W: Minimum number of milking units by each worker, i.e., the minimum number of units that a milker must manipulate to achieve the recommended milking duration.