

A DAIRY HERD DYNAMIC MODEL AS A BASIC TOOL IN SIMULATION OF DAIRY HUSBANDRY TECHNOLOGICAL ADVANTAGES

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Abstract. Dairy Management System (DMS) is an inalienable part of modern technology of milk production. There are many publications in scientific press about different aspects of computerized herd management and using of milking parlours equipment. At the same time, a problem of appropriate software tools development and using is discussed not enough. In this article described a mathematical model of dairy herd and milking and auxiliary technological device. This model is based on a lactation curve of every cow in a herd. This has a tuned head of livestock (up to more than 1000 head of cattle) and dedicated to the simulation of different kind technological advances on a dairy-farm. The variants of its application are milk production planning, veterinary measures planning, daily calculation of required food and other resources. Dairy management software is developing with this model. Needful properties of this software can be improved with a herd model, too.

Keywords: dairy herd, software simulator, DMS.

Introduction

An automation of milk production in the dairy farm includes not only technological data registration and each cow in a herd personal keeping, but treatment of final information, working process results and state of all the cows, too. This last defines cattle herd information processing as the most labor-consuming to be automated. Its efficiency factors are next these:

- Precision of registration of primary technological data like yield, milk conductivity, cow's activity, body weight etc;
- Sufficiency of set of technical- and economic indices;
- Ease of control of dynamic indices in time intervals from one day shift to more than a year;
- Ease of portion-wise control of large data arrays like one thousand cows' records.

For example, daily 600 head of cattle data array includes 490-505 yields per shift, 1-6 calvings, dry-off launchings and rectal researches. So, unfriendly user's interface can descend an efficiency of dairy management automation. Development of the DMS software can be having more sense of purpose with using of a dairy herd software simulator.

Materials and methods

The kernel of dairy herd simulator is improved Wood model [1] of lactation curve

$$y(t) = \begin{cases} a_1 t^2 + b_1 t + c_1, & 1 \leq t < t_m \\ a t^b e^{-ct}, & t_m \leq t \leq t_f \end{cases} \quad (1)$$

where $y(t)$ – daily milk yield in day t of lactation, kg;

$t = 1, 2, \dots, t_{f-1}, t_f$ – day of lactation;

t_m – day of maximum yield (usually 40...50);

t_f – last milking day before dry-off period (useful value is 305);

a, b, c, a_1, b_1, c_1 – coefficients depending of ascent and slump of a curve.

It is quite correct to suppose a shape of lactation curve the similar from prior lactation to next lactation. So, daily milk yield $y(t)$ in lactation I can be calculated as

$$y(t) = M(t) L_I^M \quad (2)$$

where $M(t)$ – daily milk yield in day t of lactation M , kg;

L_I^M – ratio of total yield of lactation I to lactation M .

Value of L_I^M for every M and L in range of 1...10 can be obtained with multiplication or division an appropriate neighbour ratios from table 1 (calculated from materials of [2]).

Table 1

Ratio of current total milk yield to prior lactation milk yield

2:1	3:2	4:3	5:4	6:5	7:6	8:7	9:8	10:9
1.133	1.082	1.032	1.021	1.020	1.000	1.000	0.960	0.940

Figure 1 shows a shape of lactation curve model calculated by (1) in comparison with simple Wood model (t_i is the end of experimental yields data). Coefficients in (1) were obtained with the least squares method. The lactation curves of 170 cows were having similar shapes as shown in Figure 1. Every curve was built with 100...150 daily milking yields beginning since a calving date.

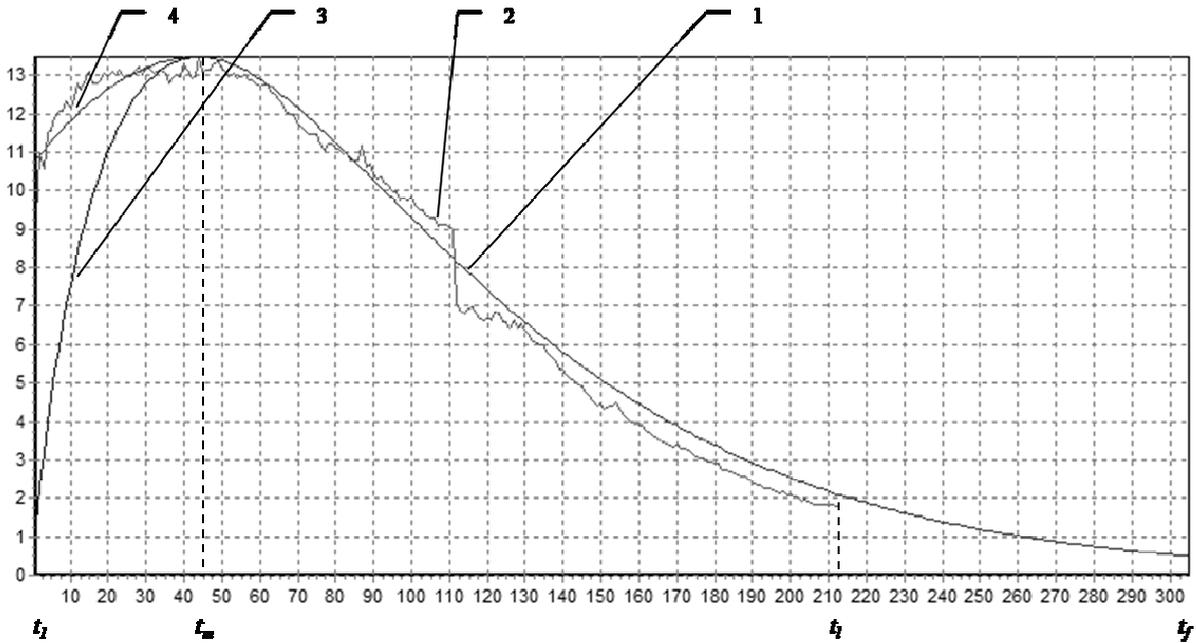


Fig. 1. Shape of lactation curve model:

- 1 – Wood model after the day of maximum yield; 2 – trend of real lactation curve; 3 - Wood model before the day of maximum yield; 4 – improved Wood model before the day of maximum yield

One more useful option in a dynamic herd model is a shape of milk flow rate curve in single cow’s milking (Fig. 2). It is useful to simulate milk flow at least to develop a seeking procedure of milking cases with multimode shapes of milk flow rate as shown in Figure 2.

Real-time milking data

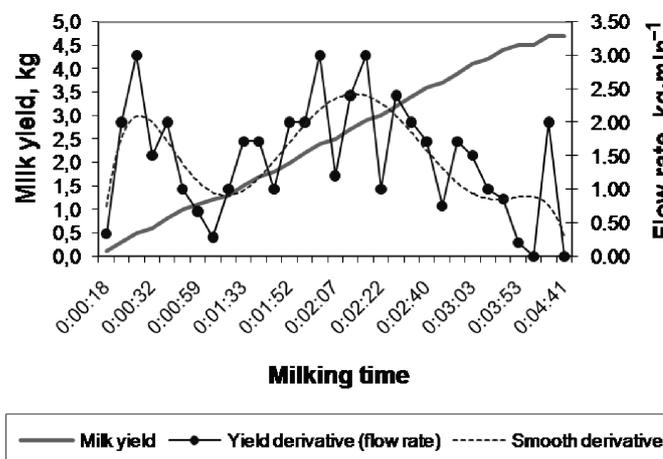


Fig. 2. Diagram of the real-time milking process

The target function of model is a set of technological data for every cow in cattle herd in every day of range from a begin date *A* to an end date *B* which includes next main members:

- Number of lactation;
- Milk yield for every milking in a shift (morning, day, evening);
- Begin time and duration of every milking in the shifts above (randomized in cows' queue);
- Real-time milk increase for every milking in a shift (optionally).

It is required a middle duration of service-period and dry-off period to obtain dates of inseminations, rectal researches and calvings for every day in modelling date range, too. Figure 3 shows a typical view of cow's lactation in modelling range of dates.

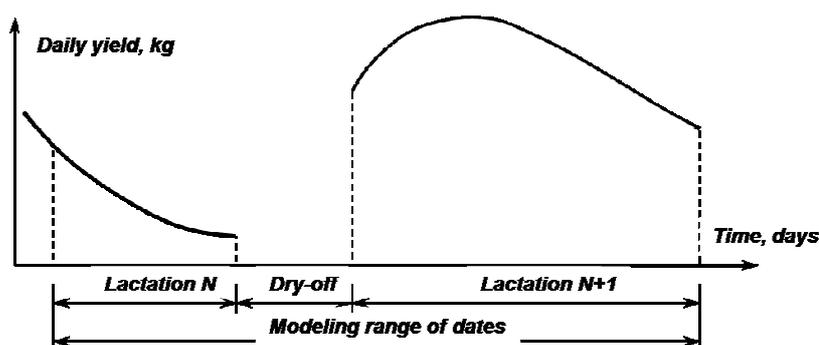


Fig. 3. Typical view of modelling range of dates for single cow

The modelling results must be kept in a database to be combined and researched with necessary different SQL-operators.

Results and discussion

Calculation of coefficients in (1) takes less than 1 second for one cow. There are good visual precision with using milking yield values since begin of lactation in range of 100 and more days.

The calculation time of modelling data depends on internal Microsoft Jet Database Engine processes behaviour. Typical values for a notebook with 1.6 GHz CPU and 1 GB RAM by Windows Vista OS can be seen from Table 2. It is possible to improve an algorithm of computer program to decrease the calculation time by large length of modelling range of dates.

Table 2

Calculation rate of modelling data for 600 cows

Length of modelling range, days	Calculation time, sec
1	1-2
14	8-15
720 (2 years)	About 300
1440 (4 years)	About 600

Finally, calculated technological data were used in an external farm device software simulator such milking parlours, selection gates, feeding stations for long-time testing on critical failure and fail-safe operation, debugging and exhibition DMS software. For these cases the farm device software simulator must be equipped with model-time generator to obtain daily data shortly. The modelling data can be used successfully for simulation to check some workshop factors like these:

- Milk production value on the farm with current cows in herd;
- Productive capacity of milking parlours;
- Failures of RFID parlour system to fix milk yields from cows with absent, lost or unreadable transponders less or more properly;
- Influence of external unfavourable events and reasons such a microclimate in cow-sheds;
- Ability of veterinarian or livestock expert specialist for helpful using DMS software in their daily work.

Conclusions

1. Main helpful usage of dynamic herd model is DMS software with friendly user's interface development. It is very important to give the specialist a powerful tool to easy strict monitoring a cattle herd and every cow state in dynamic of time, especially in livestock of 600 or more cows.
2. A given method lets use different formulas for lactation curves in the same model. Model (1) describes visually an experimental data more closely than simple Wood model in range from begin of lactation to the day of maximum yield. It is advisable to develop a method of getting individual coefficients in model formula for different terms less than 100 days of appointed lactations and test every case with statistical control.
3. Mathematical model (1) can be used in DMS software for forecasting and estimating yields of every cow in herd to be grouped. It is advisable to develop and check a program procedure for forecasting of milking production of whole cattle herd for different terms and initial data such middle length of service-period and cows' yearly yield.

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