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TEST DATA BASED EVALUATION OF LACTATION CYCLE CONTROLLING RULES WITH A GENERATED SIMULATION MODEL

András TANKOVICS[1], Mónika VARGA[2], Sándor BALOGH[2], Linda EGYED[3], Béla CSUKÁS[2]

[1]Videoton Elektro-PLAST Ltd, H-7400 Kaposvár, Izzó u. 3.
[2]Kaposvár University, Faculty of Economic Science, H-7400 Kaposvár, Guba Sándor u. 40.
[3]Fino-Food Ltd, Kaposvár, H-7400 Kaposvár, Izzó u. 9.

ABSTRACT

Economic effectiveness of a dairy farm operation is determined mainly by the produced milk and the costs of fodder, as well as of the fertilization and medication of cows. The whole system is characterized by the stages of production cycle, comprising several steps from the calving to the dry period. In line with these steps, there are respective groups of cows in separated stables. In addition, the ill animals are treated separately during their medication. Accordingly, the production cycle can be characterized by the time-based regular and event-based additional cyclic movement of the cows between the above groups. Considering the requirements for the common representation of the underlying balance model with the movement controlling rules and with the event-driven additional movements, in our study a case specific application of a generated programmable structure in sense of Direct Computer Mapping (DCM) of process models has been applied. The model is automatically generated, programmed and parameterized by the recently developed methodology of Research Group on Process Network Engineering. The test data for a representative set of animals, as well as the (optionally modifiable) rules were given from SmartDairy® Management Systems and from the management of Bos-Fruct Agricultural Cooperative. In the realistic data based hypothetical simulation tests we prepared to study the effect of the feasible changes in the conditional rules on the produced milk and on fodder consumption.
Keywords: dairy farm management, Direct Computer Mapping (DCM), modelling and simulation

INTRODUCTION

Dairy farming is a highly dynamic and integrated production system that requires continuous decision making from the management (*Cabrera*, 2012). Nowadays the routine production control tasks of dairy farms are supported by up-to-date tools of Information Technology (*Pietersma et al.*, 1998; *Teschner*, 2014).

Some widely used management information systems that are also utilized in Hungary are the following: SmartDairy® Management Systems, HerdMetrix™ Herd Management Software, RISKA Herd Management System, ALPRO® Herd Management System (*Vojtela et al.*, 2011). In most cases, these advanced information systems provide good basis for the effective management and control by the detailed recording of data, as well as by some specific capabilities (e.g. simple embedded calculations, automatic warnings, etc.) of the various subsystems.

However, in spite of the frequently collected detailed datasets, there are still some open questions in the operational decisions of the production cycle. In lower scale control, selection of "optimal" life cycle is a key point (*Delgado*, 2015) that determines not only the lifetime performance of the cow, but the profitability of the dairy farm. In a higher scale control, utilization of the accumulated data in a trans-sectorial transparency system would be a straightforward initiative (*Varga et al.*, 2012; *Dabbene et al.*, 2014; *Tankovics et al.*, 2014) to achieve whole chain transparency. Solution of both questions could be effectively supported by the combined utilization of the accumulated data and farmers' knowledge with computational models.

Accordingly, in the present paper we introduce the first steps towards the development of a simplified dynamic simulation model, where we utilize the detailed data and heuristic rules of a dairy farm for the testing of the alternative solutions.

METHODS AND APPLIED DATA

Applied modelling and simulation methodology

The basic idea of Direct Computer Mapping (DCM) (*Csukás*, 1998, *Csukás et al*, 2011) is that we let the building elements and the structure of process models map onto the elements and connections of a computable program code, directly, without their representation in any single, specific mathematical apparatus. On the contrary, the individual brief programs can be executed by a cyclically repeated algorithm, similar to an operational system.

The recently used method automatically generates programmable structures for the simulation models from a network structure and from the meta-prototypes of the state and transition elements (e.g. *Varga et al.*, 2016, *Varga et al.*, 2017). In the graphical (GraphML) model the locally programmable prototypes may be edited from the prototypes. The initialised and parameterised structural model is prepared for the common consideration of "model specific conservation law based" additive measures and of the "over-writable" signals. The general interpreter first generates the case-specific declarative model database, next executes the dynamic simulation. In the applied transition oriented model representation, all of the causally coordinated consequences of the functionalities may be processed together. This feature supports the robust execution of the multiscale models by a general purpose core program. It makes also the unified, common generation and execution of the balance-based and the rule-based sub-models possible.

Recently the methodology has been experimentally implemented for simulation based problem solving of various agri-food systems (*Varga et al.*, 2012; Varga and *Csukás*, 2015).

Modelled dairy plant and implemented data

Our example system, BOS-FRUCHT Ltd. dairy farm Kazsok, is one of the largest and most modern dairy farms in Central and Eastern Europe with almost 2000 dairy cows. The cows are milked 3 times a day on 72 stall Boumatic rotary parlor. The herd is all year calving, high genetics holsteins. They spend the majority of their time indoors in modern, well ventilated and insulated light cattle sheds.

The management of the farm use Smart Dairy® and Herd Metrix™ softwares. These two softwares collect all of the necessary information from individual cows.

Some of the most important data are shown in the *Tables 1-3*.

The cows are fed with Total Mixed Ration (TMR). One side of the TMR's components are home-grown. the other side is purchased. The amount of the TMR depends on the grouping of the cows. Some TMR recipes are shown on *Table 4*.

Table 1

General information for a cow from Smart Dairy®

Name	**WILMA 63**	**Condition**	**2,8**
Mother	585	HU3281805858	WILMA 63
Sire	19238	19238	BUCKEYE
Maternal grandsire	17655	17655	RAMOS
Calving date	2014.02.07.	Lactation number	3
State	Pregnant	Lactation days	187 days
Insemination	2014.04.24.	Excpected drying off date	2014.12.01
Bull	Kapt	Expected calving date	2015.01.26

Table 2

Example lifeway of a cow from Smart Dairy®

Reproduction				
Description	**Date**	**Days**	**Interval**	**General**
BORN	2009.09.16.			
CALVING	2011.10.17.			
AI	2011.12.17.	61		22257 MORPHEOUS
AI	2012.01.02.	77	16	22409 BEACON
AI	2012.02.24.	130	53	22409 BEACON
AI	2012.04.20.	186	56	22285 EMPHASIS
CALVING	2013.01.30.			
AI	2013.04.25.	85		24044 DREAMER
POSITIVE +	2013.06.24.	145		
DRYING OFF	2013.11.20.			
CALVING	2014.02.07.			
AI	2014.04.24.	76		24524 Kapt
POSITIVE +	2014.06.23.	136		

Table 3

Lactation information for a cow from Smart Dairy®

Calving	Two	Age	DIM	Milk kg	Fat %	Prot. %	Fat kg	Prot. kg
2011.10.17.		2.01						
			305					
2013.01.30.	471	3.04	294	9602	4.23	3.13	406.3	300.7
			305	9809	4.26	3.14	417.5	308.4
2014.02.07.	373	4.05	136	6768	2.83	2.98	191.7	201.8
			305	13285	2.84	3.07	376.7	407.4

Table 4

The applied TMR recipes for the different groups

Prep		High	
Corn silage	0.51502	Corn silage	0.4291
Lucern silage	0.08583	Lucern silage	0.11976
Corn	0.02145	Corn	0.05389
Melavit	0.0171	Melavit	0.01996
Hay	0.06438	Hay	0.01996
Straw	0.01716	Straw	0.01397
Beet slice	0.12875	MS rape	0.01996
Wet CGF	0.04291	Dairy conc	0.13373
Prep conc	0.10729	Beet slice	0.09980
		Wet CGF	0.08982
Low		**Dry**	
Corn silage	0.42914	Straw	0.24437
Lucern silage	0.11976	Lucern silage	0.18649
Corn	0.05389	Hay	0.1157
Melavit	0.01996	Dry conc	0.43729
Hay	0.01996	Rest of TMR	0.0160
Straw	0.01397		
MS rape	0.01996		
Dairy conc	0.1337		
Beet slice	0.09980		
Wet CGF	0.08982		

The relatively wide range of the group changing rule is determined heuristically by the dairy farmer. which is one of the most important managerial questions of the operation. considering the trade off between the length of milking period and the life cycle performance of the cow. An example set of rules is represented in *Table 5*.

Table 5

Entry and exit conditions of group changing

Entry condition	Group	Exit consequence
Before first calving cow enters from the pregnant heifers group. X_1	Temporary group	X_1+(25-30)
X_1+(25-30)	High performing group before insemination	X_1+(52-62)+(n*(20-24))+30+30
X_1+(52-62)+(n*(20-24))+30+30	High performing group after insemination	X_2-(50-65)-(18-25)
X_2-(50-65)-(18-25)	Low performing group	X_2-(50-65)
X_2-(50-65)	Dry period group	X_2-(14-28)
X_2-(14-28)	Precalving group	X_2
X_2	Temporary group	X_2+(25-30)
Cows can randomly enter from any group.	Sick group	Cows can randomly leave this group.
Cows can randomly enter from any milking group.	Mastitis group	Cows can randomly leave this group.
Calculation for further calvings: $X_n=(X_{n-1}+(52-62)+(n*(20-24))+30+30)+217$ n=random number between (1-16)		

RESULTS AND DISCUSSION

The flowsheet of lactation cycle and the changing groups can be seen in *Figure 1*.

The respective programmable structure of the model. representing the modelled part of the dairy plant is shown in *Figure 2*.

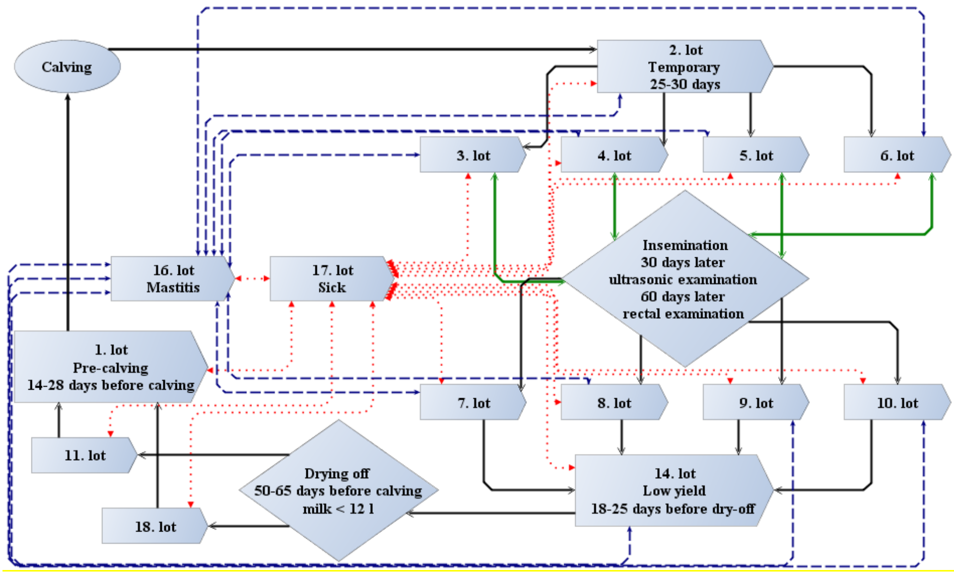
In course of model development. in line with the principles of DCM method. we described the underling processes of the dairy farm in the form of states (signed by ellipses in *Figure2* that represent the various storages. fodders. groups of animals. etc.) and transitions (signed by rectangles in *Figure 1* that determine the changes of states. considering also the prescribed environmental effects). These elementary building blocks communicate with each other. and with their environment via connections.

Both state and transition elements contain so-called "slots" for the storage of inputs. parameters and outputs.These slots are signed by small circles in *Figure2*.

In general. model building starts from the listing of the building elements. In the present version of the applied DCM method. structure building is supported by automatic generation from a simple "from" – "to" description of the underlying state and transition elements.

Figure 1

Process flow chart of changing group and lactation cycle



After the automatic generation of the structure. the next step is the formulation of the calculating expressions. Accordingly. beyond the graphical visualization of the model. the developed GraphML description contains also those functionalities that calculate the model outputs in every prescribed time step. For the parameterization of the model we utilized the test data from HerdMetrix™ system.

The actually applied state and transition elements can be summarized as follows.

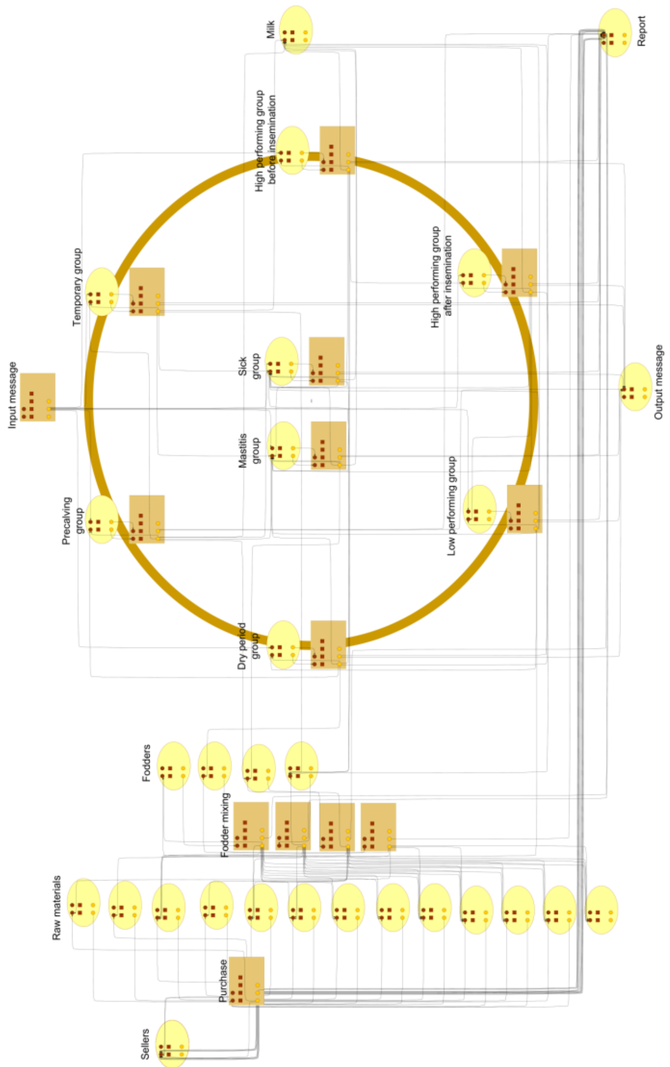
The first state elements are the sellers. In this situation we consider the home-grown fodders as purchased components. The Sellers sell the fodder components for the farm and then move into the buyer storages with purchase transitions. Thereafter we use this raw material for the TMR during the TMR mixing process. Each group has an own TMR recipe. The mixer wagon allocates the TMR to the cows.

Individual cows move from group to group according to their life cycle. Accordingly. cows are represented by the following eight groups in the model:

- Temporary group
- High performing group before insemination
- High performing group after insemination
- Low performing group
- Dry group
- Precalving group
- Sick group
- Mastitis group

Figure 2

The programmable structure of the modelled milking cow breeding



In the individual groups actual cows are identified by their ID. age. date of last calving. dedicated fodder per day. as well as by their daily milking performance.

The compositions of groups are changing from time to time. in line with their individual life cycle. The connecting transition elements are responsible for the "moving" of the cows from one group to another. according to the changing rules.

Via "Input message" element we can add the specific events to the model (e.g. got sick. mastitis. etc.). "Output message" elements stand for the automatic warnings. while "Report" elements are responsible for the monitoring of output data.

The test results of the implemented model are illustrated in *Figures 3-7*.

Figure 3

Purchas of fodder ingredients along a year

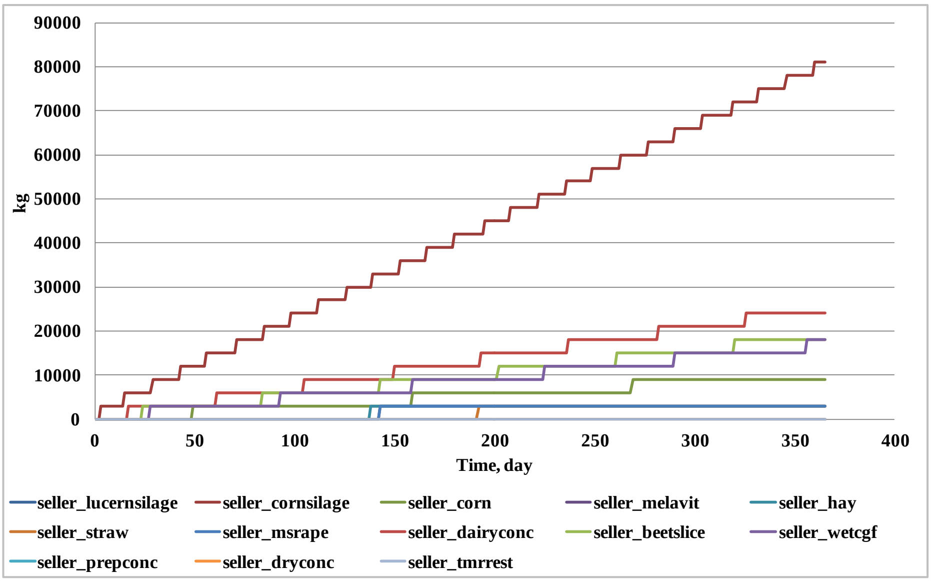


Figure 4

Changes in the amount of fodder storages

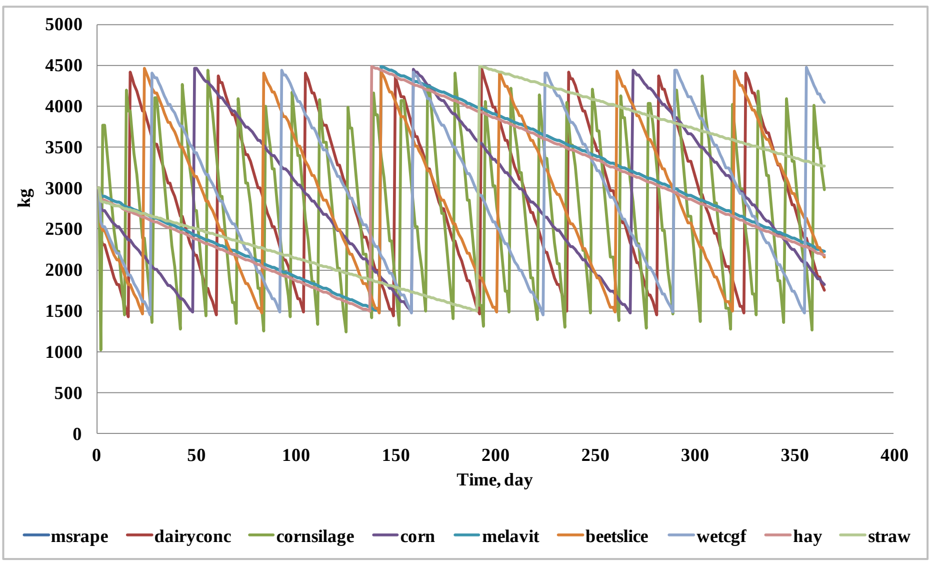


Figure 5

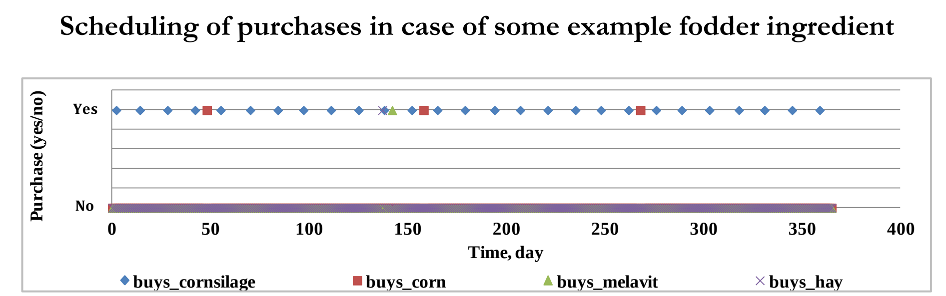


Figure 6

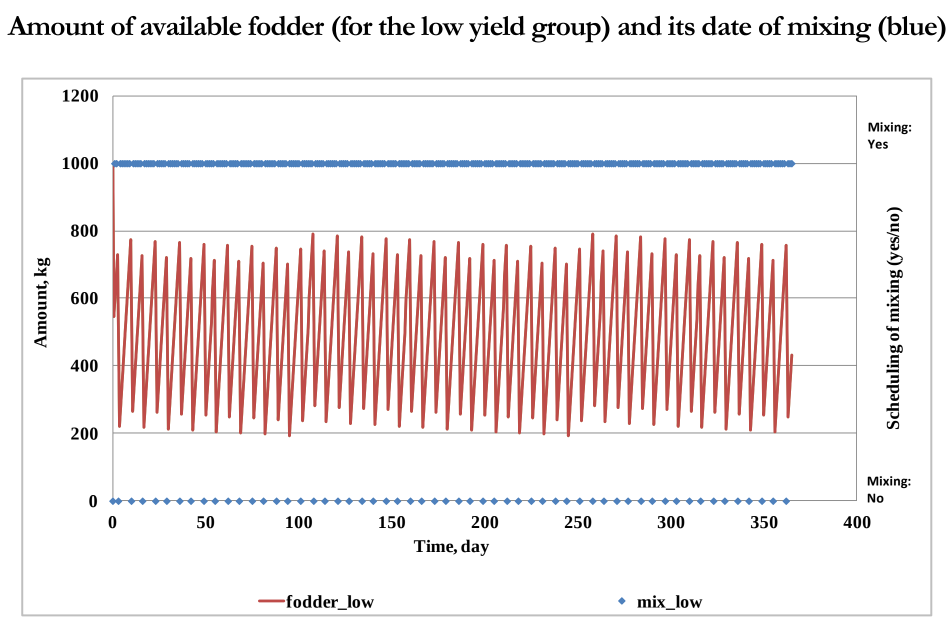
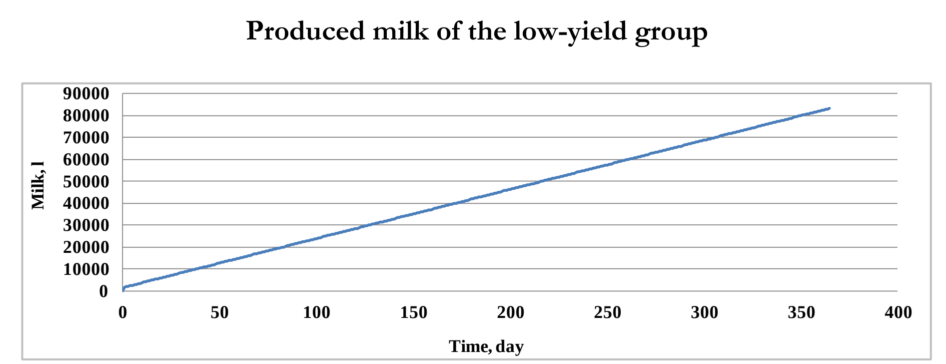


Figure 7



CONCLUSIONS

As a first step towards the simulation assisted evaluation of lactation cycle controlling rules. the respective process model of a dairy farm has been implemented. using the method of programmable structures. The developed dynamic model of lactation cycle has been tested with a limited set of example data. According to the preliminary results. the methodology can be applied for the solution of the investigated problem.

The suggested computer interpretable technological flowsheet might help to utilize the available data from the up-to-date software tools in the improved farm management. including the analysis of milk production of individual cows with various life-cycle.

The developed dynamic balance model can also contribute to implement trans-sectorial transparency modelling in the future.

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Corresponding author:

András TANKOVICS
Videoton Elektro-PLAST Ltd
H-7400 Kaposvár, Izzó u. 3.
e-mail: tankovics.andras@gmail.com