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The most efficient solutions of forage distribution on modern dairy cow farms

A. Saliņš, M. Freimanis, R. Truhanovs and J. Priekulis

Institute of Agricultural Engineering, Latvia University of Agriculture, J.Čakstes bulv. 5, LV-3001, Latvia; e-mail: ansis.salins@gmail.com; maris.freimanis1987@inbox.lv; Juris.Priekulis@llu.lv

Abstract. The most efficient technological solutions of forage mix preparation and distribution on modern farms with herds of 100 to 600 cows have been investigated. Seven different technologies were compared – technologies applying mobile equipment and those applying forage distribution robots.

Technological versions were evaluated by specific labour intensity and specific operational costs. For this reason a mathematical model was worked out, using computer simulation programme *MatLab Simmulink*. Calculations were based on the timekeeping data of the technological lines of forage preparation and distribution obtained on the farms included in the research.

It was ascertained that it is more efficient to apply technologies that propose all operations to be performed by a single mobile technological unit. If the number of cows in the herd does not exceed 370, it is efficient to use a tractor unit with a frontally hooked scoop for loading silage and with a forage mixer-distributor hooked on the backside, but in the case of more cows, it is more efficient to use a unit of self-propelled type. Forage distribution robots can compete with mobile distributors if concentrated feed is included in the feed mix and if separately arranged stations are not used for this purpose.

Key words: cow feeding, mixed feed, mobile feed distributors, robotic feed distributor, economic evaluation.

Introduction

Construction of new dairy cow farms and modernization of the existing ones has restarted during last years. For instance, according to the data of Ministry of Agriculture of the Republic of Latvia, in the year 2011 about 200 farms were subsidized for this purpose.

Modernization of dairy production has resulted in rapid growth of herds being handled on farms. While 10 years ago farms were planned mainly for 100–300 cows, now a dairy farm for 2000 cows is being constructed in Latvia and even bigger one is being designed.

On all modern farms up-to-date technological solutions are being implemented: loose handling of cows, milking in halls with high-productivity milking equipment or automatic milking systems (AMS), total mixed ration (TMR) or usage of precise feeding technology, automatic clearing out of manure etc.

Introduction of all these different technological solutions is possible due to the wide diversity of machinery offered by different companies. However, selection of the

technology is left to the consent of agricultural advisors and farm professionals, and for them the decision is not easy to be made.

According to our previous investigations (Salins et.al., 2011; Priekulis, 2000), selection of efficient technology and equipment largely depends on the amount of animals being handled on the farm, cow feeding features, lay-out of the barns, kind of work organization, required capital investments, production costs and lots of other factors.

The right cow feeding is of great importance in dairy cow farming, as the cow productivity depends on it. Presently mainly mobile tractor traction mixers-distributors are used for forage distribution on big farms. However, self-propelled distributors as well as robotic forage distributors are gradually being introduced.

In Latvia the first robotic forage distributor was assembled and put into motion in the year 2002 but now they have been introduced on eight farms already. Since 2010 introduction of mobile forage mixers-distributors of self-propelled type has started.

Therefore, our investigations aim to find out the most efficient technological versions of forage distribution on modern dairy cow farms depending on the number of cows being handled and on the organizational solution of forage distribution, taking into account the Latvian situation of Economics.

Materials and methods

Seven technological versions of forage mixing and distribution have been selected to compare them among themselves. In three cases all the operations are performed with the help of mobile forage mixers-distributors, in four cases – by using also robotic forage distributors or additionally even silage distribution stations (Table 1).

Table 1. Characteristics of the compared forage distribution versions

Tech-nology no.	*Mix preparation*	*Mix distribution*	*Silage distribution*	**No. of wor-kers**
A	Tractor unit with a frontally hooked scoop with passive knives and a forage mixer-distributor hooked on the backside. During silage loading the tractor is unhooked from the mixer-distributor. Concentrated feed is admixed to the feed mix.			1
B	All operations of feed mix preparation and distribution are performed with the help of self-propelled mixer-distributor. Concentrated feed is admixed to the feed mix.			1
C	Tractor unit with a hooked forage mixer-distributor. Concentrated feed is loaded with the help of a separate tractor unit with a scoop with passive knives. Concentrated feed is admixed to the feed mix.			2
D1	Feeding robot being refilled from stationary dosing containers. Grass fodder is filled into dosing containers with the help of a tractor unit, the scoop volume of which is 1.5 m^3.		Concentrated feed distribution stations installed in the barn.	1
D2			Together with the feed mix.	1
E1	Mobile tractor traction mixer-distributor. Separate silage loader.	Feed robot being refilled from a stationary dosing container.	Concentrated feed distribution stations installed in the barn.	1
E2			Together with the feed mix.	1

In order to compare the technological versions, a special mathematical model was worked out operating in the environment of the computer simulation programme *Lab Simmulink* (Fig. 1).

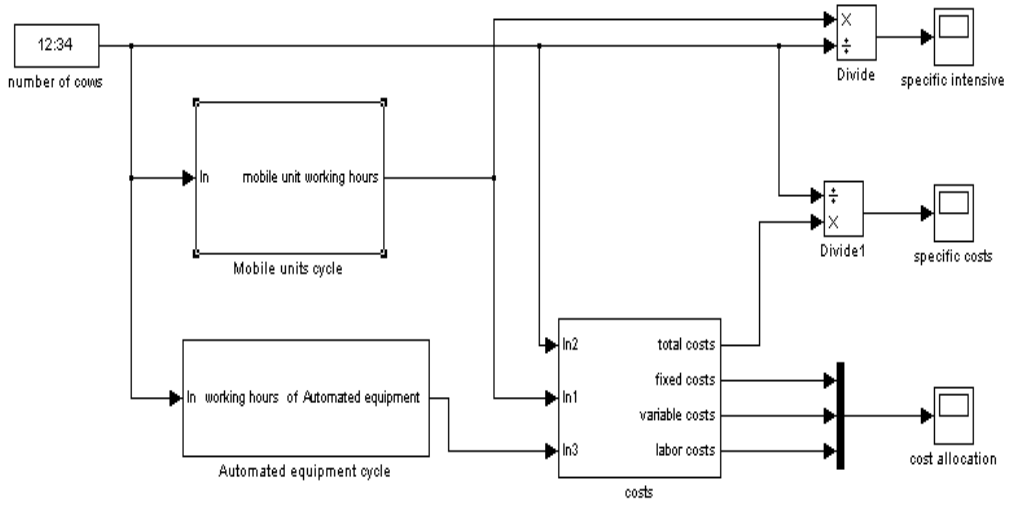

Fig. 1. Block scheme of the mathematical model of forage mix preparation and distribution worked out for operating in the environment of computer simulation programme *MatLab Simmulink.*

In the mathematical model both the number of cows being handled on the farm and parameters of each technological version were used as basic values: the selected technological machinery, number of workers involved, loading time, mixing and delivery time of separate feed components, fuel consumption and price, labour costs etc. In order to work out the mathematical model of machinery costs, methods available in the literature (Priekulis, 2000; Priekulis & Gulbis, 2008; Priekulis & Strautnieks, 2000) were used.

The main basic data were obtained by timekeeping the forage distribution on nine Latvian farms with herds of 120 to 430 cows. Afterwards the most characteristic and typical versions were selected that are summarized in Table 1.

On the basis of data obtained on the farms, the following theses were created and additional mathematical correlations were worked out, connecting separate basic data needed for calculations:

- On all farms cows are divided into two feeding groups according to their milk yield. It was presumed that the average milk yield of the more productive group is 8000 kg per year, but the less productive group – 6,000 kg per year. The rations of each feeding group are different; they were calculated according to the given milk yields.
- 75% of the total number of cows belong to the more productive group, and 25% – to the less productive one.
- In the simulation process the number of cows was changed from 100 to 600 animals.

- Forage preparation and distribution with the help of mobile mixers-distributors is performed twice a day, but with the help of robots – four times a day.
- The volume of the forage distributor container of the tractor traction unit is 2.5 tons, that of the self-propelled one – 5.0 t, of the robot – 1.0 t.
- Labour costs were calculated according to the standard of 2.5 LVL per hour.
- Productivity of the feed loading machinery labour was calculated by timekeeping data.
- Universal machinery used in forage distribution, for instance, forage loading tractors, is used to perform other operations as well, so that its operation time is 8 h per day.
- If a mobile tractor or a unit of self-propelled type is used, time needed for mixing the feed is 6 minutes, for distribution – 3 minutes (that corresponds average timekeeping data). But the delivery way of a feed distribution unit move depends on the number of cows being handled in the barn and calculated according to the relevant mathematical coherence.
- Operational efficiencies of the machinery, evaluating the performance of auxiliary operations when working with mobile units, were calculated according to the timekeeping data and are as following: for technology A=1.4; for B=1.05; for C and D = 1.05.

Sequentially the specific labour efficiency was calculated – labour hours per cow in a year; the specific costs of forage preparation and distribution technology lines – LVL per year, and the structure of forage distribution costs were ascertained.

Results and discussion

Calculation results are summarized in Fig. 2, Fig. 3 and Fig. 4. As it is shown in Fig. 2, labour expenditure required for forage mix preparation and distribution depends both on the technology version and on the number of cows on the farm. The larger the number of cows, the more the labour expenditure is reduced, calculated per one cow. Besides, the highest labour expenditure is determined when two tractor units (version C) are used in the technological process, but the lowest – when feed distribution robots are used (versions D and E).

Labour expenditure is also relatively low when feed mix is prepared and distributed with the help of a self-propelled unit (version B), as it is also equipped with silage loading milling cutter, enlarged mixing container and it is characterized by better manoeuvring possibilities. Moreover, in this case all operations are performed by a single worker.

Fig. 2 shows that the specific labour efficiency graphic representations do not curve regularly. At a definite number of cows the curves perform irregular ascend. It is caused by the fact that our basic data presume each kind of feed mixer to have a definite volume of the container. For instance, it is 2.5 t for a unit hooked on the tractor, 5.0 t – for a self-propelled unit, and 1.0 t – for a robot. Therefore, at a definite number of cows such volume of container appears to be not sufficient for forage mix distribution in one run of the transportation unit, but every new run causes increase in labour costs.

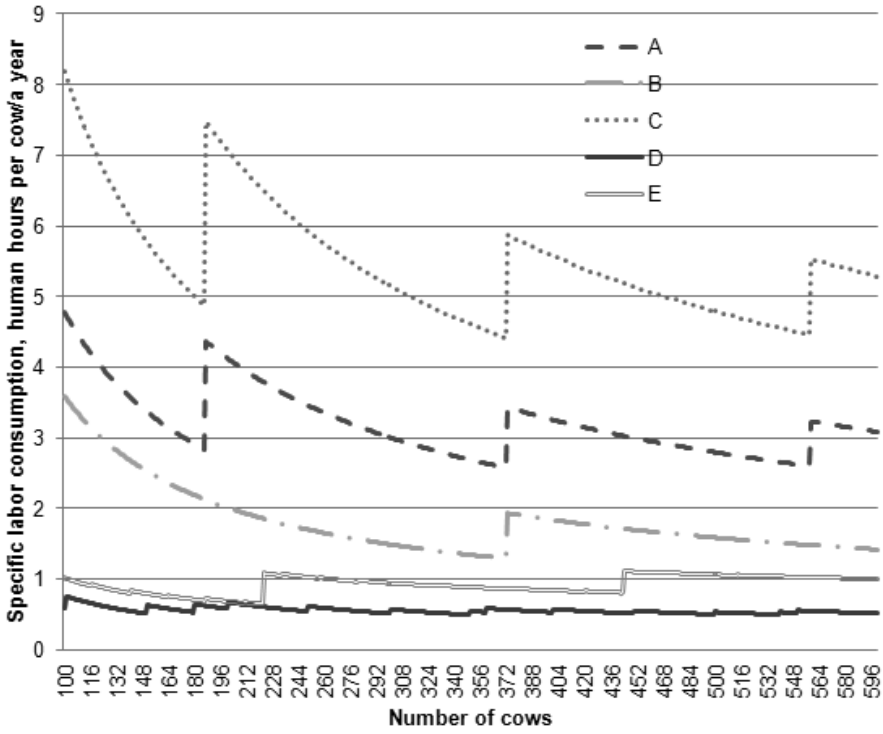

Fig. 2. Specific labour efficiency, labour hour/cow/year, depending on the number of cows being handled on the farm and on the technology version.

Specific operational costs of mixed forage preparation and distribution are shown in Fig. 3.

The figure allows making a conclusion that the highest specific costs are in the case when forage distribution robots and concentrated feed distribution stations are used. If the concentrated feed is admixed to the feed mix, the specific costs of the technologies are reduced by about 30% (versions D2 and E2), and if the number of cows is not large, the usage of robots is even cheaper than the usage of self-propelled mobile units (version B).

However, the efficient usage zone of forage robots is essentially influenced by the volume of their feed container. In this case it is assumed that up to 1.0 ton of forage can be filled into the container. As it can be seen from Fig. 3, in such conditions in the case of five feeding times up to 260 cows can be fed with the help of one robot. If the cow number rises, two or even three forage distribution robots are required on the farm, which surely increases the specific costs of feed distribution accordingly. Therefore, the large farms should think of feed distributing robots that have sufficiently large feed containers to handle all the animals being handled on the farm with the help of one feed distribution robot.

The most inexpensive version of feed mix preparation and distribution is the usage of A technology. It is characterized by the fact that all operations are performed by a single worker with the help of one tractor unit. If the number of cows exceeds

about 375, technology B that uses self-propelled units for feed distribution appears to be more inexpensive.

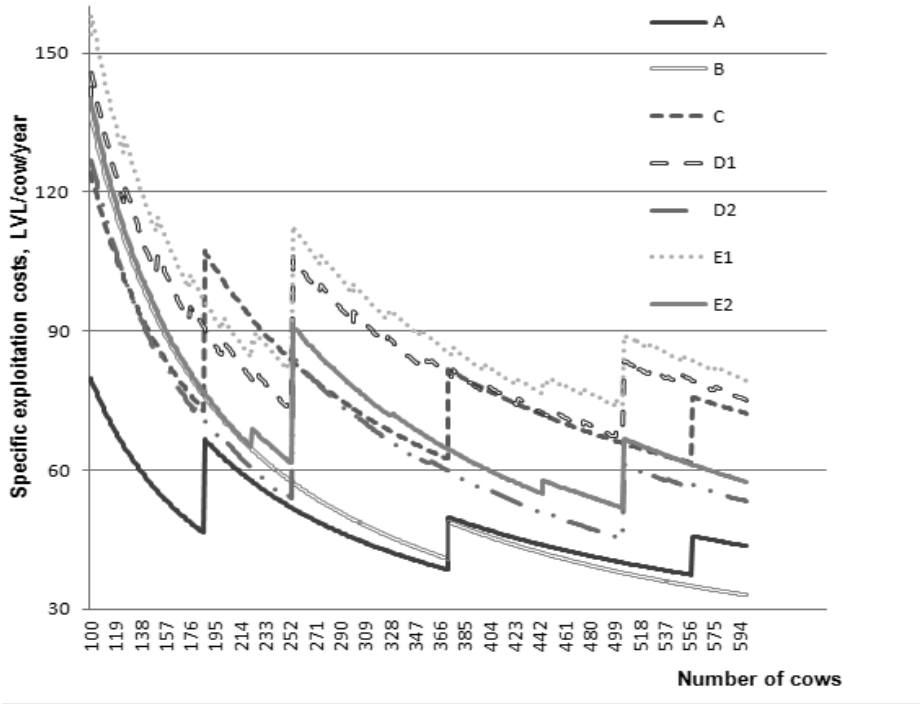

Fig. 3. Specific costs of forage mix preparation and distribution, LVL/cow/year, depending on the cow number in the herd and the applied technological solution.

The structure of operational costs of the technological lines of forage mix preparation and distribution for a herd of 200 cows is shown in Fig. 4.

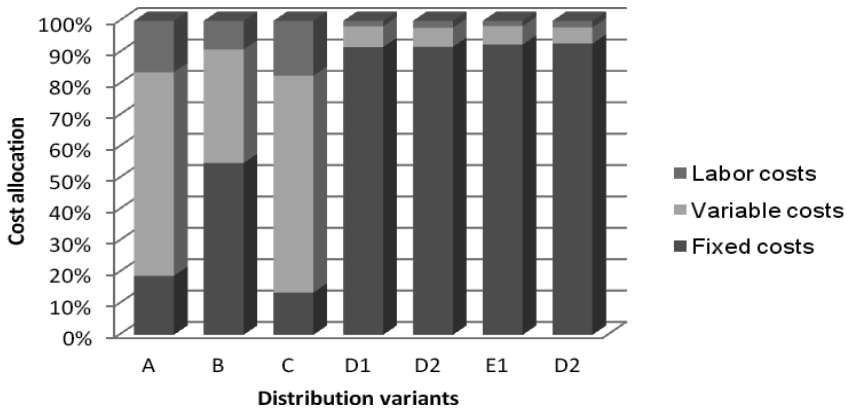

Fig. 4. Structure of operational costs of the technological lines of forage preparation and distribution for a herd of 200 cows, LVL/year.

It can be seen from the figure that the structure of operational costs of the technological lines depends on the applied technology. When feed distribution robots are used, the fraction of constant machinery costs make up approximately 90% of the total operational costs, but the fraction of variable machinery costs and labour costs – only 10%. It can be explained by the fact that technologies using feed distribution robots are featured by relatively low electricity costs and a reduced fraction of labour costs as well.

If mobile machinery is used for feed preparation and distribution, the variable machinery costs and labour costs increase essentially. It is caused by fuel expenses and payment to mobile unit operators (tractor drivers).

It should still be mentioned that it was presumed in the calculations that universal machinery applied in mixed forage preparation and distribution, for instance, forage loading tractors, is also used for other operations, in average being operated for 8 hours per day. This decreases constant costs of the technologies insignificantly, and does not change the structure of operational costs essentially.

Conclusions

1. The most efficient forage mix preparation and distribution technologies are those using one mobile unit if all the operations are performed by a single worker. When the number of cows does not exceed 375, in the aspect of operational costs it is reasonable to use a tractor unit with a frontally hooked scoop for silage loading and with a feed mixer-distributor hooked on the backside. In order to lift silage from the ditch, the tractor is unhooked from the mixer-distributor. When the number of cows exceeds 375, it becomes more efficient to use a unit of self-propelled type with a silage loading milling cutter.

2. If a robot is used for forage mix distribution, fodder should be admixed to the feed mix. If separately installed stations are used for fodder feeding, the specific costs increase by approximately 30%, and considering these specific costs, they cannot compete with mobile forage mixers-distributors.

3. It is not efficient to use two feed distribution robots on a farm. Therefore, the robot should have a container of sufficient volume and productivity in order to feed all animals on the farm, ensuring the prescribed feeding times per day. For example, if the volume of the robot container is 1.0 tons and the feed has to be distributed four times a day, a single robot of this kind can handle a herd of up to 260 cows.

4. When feed distribution robots are used, the specific labour expenditure does not exceed 0.9 labour hours per one cow in a year. If a self-propelled unit is used for forage mix preparation and distribution, the specific labour expenditure doubles or trebles, but, if a mobile unit is used for this purpose that is operated by one or two workers, the specific labour expenditure multiplies 3 to 5 or even 5 to 8 times.

5. When feed distribution robots are used, the fraction of constant machinery costs makes up approximately 90% of the total operational costs, but the fraction of variable machinery costs and labour costs – only 10%. If mobile machinery is used, the variable costs and labour costs increase essentially.

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