Abstract - Modern milk industry has the tendency of automating all its segments, the highest requirements being those in the area of the feeding quality control, which are impossible to be met with the conventional methods of supplying the food.

This paper deals with the system of an automated feeding of milch-cows, the feeding with refreshing fodder in medium-sized farms. The advantages of the system over the conventional ways of supplying the food are a better food usability, an increased milk production due to the fact that each head gets an optimal quantity of food, control over the quantity of food eaten and the possibility of controlling the feeding of each head for health reasons, with no need for heads to be physically separated from others.

The system is controlled by a PC and a microcontroller system, and heads are identified by using the RFID technology.

I. PROBLEM DESCRIPTION

The present ways of feeding cows on farms where heads are not tied but are free to move are those of manual or mechanized shaking refreshing fodder out into the feeding trough. The feeding mostly takes place twice a day.

This is a usual and a well-established way of feeding, though it has significant faults.

The biggest fault is the fact that a great amount of food is shaken out in front of a large number of heads so some of them take more food than they really need, while some do not get enough.

The next fault is too big an amount of food eaten in a single portion due to the fact that the heads are fed only twice a day, which results in a poor digestion, leaving an amount of food non-digested at all.

Heads being in calf for 7 months and more must not be fed with refreshing fodder, but with voluminous one, meaning they have to be separated from others, which implies extra costs and extra working labour.

There may be a change in the chemical structure of refreshing fodder, caused by mixing the fodder with the maize or hay silage. Consequently, the nutritional value of the fodder is reduced, which otherwise would not happen in the cow's stomach, due to its anatomy.

Apart from the problems being directly related with feeding, the demands for reducing costs of feeding and working labour are also set.

The development of industrial electronics, i.e. microcontroller systems, has come up with some great ideas realized in plant automation, applicable to cattle-breeding too. An automated feeding system provides solution to all the problems mentioned so far and assures optimal feeding.

II. SOLUTION TO THE PROBLEM

The basic idea was to design a feeding system and to make it available to all heads in a cowshed. Each head has its own identification device and there is a reader of the device identifying each head when approaching the feeding system. The feeding system has a fodder container holding a mechanical dozer controlled by a microcontroller which shakes the fodder out into the feeding trough. Each head, being physically different, has different food demands. A program in a PC calculates the quantity of food intended for each head and there is a possibility of disposing the food manually. The PC is also used for monitoring the cows' milk yield and food consumption, storing each cow's health index-card, keeping statistics and making profit considerations of each head and the farm in total. The feeding system and the PC are connected by a serial connection and the system has the ability to work independently in case of the computer failure. Taking into consideration the time when the animals are not active (at night), the system may successfully feed up to 60 heads, which makes it suitable for small and medium-sized farms. The system's software has the ability of being easily upgraded.

There are 9 microelements contained in each food portion which mostly influence the milk production and the cow's health: the quantity of dry substance, energy factor, raw proteins, digestive raw proteins, raw fibers, calcium, phosphorous, sodium and magnesium. There is another set of microelements influencing the cow's milk yield and its health, but at a lower degree, so it can be neglected.

Each sort of food contains all these elements or at least the majority of them, in different proportions. The proportions of all microelements are known for each sort of food available on the market today.

The computer makes the best choice of food to use and the quantity to spend to get an ideal refreshing fodder. The system instructs the user which sorts of food to use (among those available) and in which proportions to mix them to get an ideal refreshing fodder. The fodder mixed that way is placed into the feeding system (manually or by a machine) and a microcontroller subsystem prescribes a dose for each head, depending on each head's need for food.
The idea of "ideal fodder" is based on several sorts of food mixed the way that each microelement contained is present in a proportion demanded for each head respectively.

Each head has different needs for different microelements. The needs for the microelements are determined by the weight of the animal, its physical activities, the length of lactation, quantity of milk given daily, the amount of fat contained in the milk, the daily growth of the cow (if it is still growing) and the phase the cow in calf is in (the phase the calf in its womb is in).

The needs for microelements can be divided into two groups: sustaining needs and milk producing needs.

The sustaining needs for microelements refer to those the cow feels for sustaining its organism and its embryo. The needs are determined by the weight of the animal, its physical activities, its daily growth and the phase the cow in calf is in. The data for each head is entered into the computer which uses it as the basis for calculating the sustaining needs.

The producing needs for microelements refer to those the cow feels for producing milk. Various chemical elements are composed and form a new substance in the animal's organism. The features milk is recognized by are the amount of milk fat, proteins, etc. The milk producing needs are determined by the length of lactation, the quantity of milk given daily and the amount of fat contained in the milk.

The cow's total needs for microelements are a sum of sustaining and milk producing needs. It is necessary to emphasize that meeting the sustaining needs has the priority over meeting the milk producing needs. For only the surplus of microelements not used for sustaining needs is used for milk production. If the cow is not fed properly, the amount of milk produced is determined by the cow's mass, and for the milk producing needs it is the amount of milk fat determined by the cow's mass, its physical activities, and for the milk producing needs it is the amount of milk fat in, whereas the milk producing needs for minerals are determined by the amount of milk produced.

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As the feeding system functions the way that a controlled amount of refreshing fodder is given to each head, there is a need for each head to have a unique tag and being used as the interface for the user.

The system consists of three basic units (Figure 1): - RFID tag – each head carries an RFID mark holding a unique number written in a 64-bit binary code, placed under the skin, in the ear or around the neck - feeding system controlled by a microcontroller, containing a food dozer and the RFID tag reader - PC processing the systems and proportions of food contents, calculating the quantity of refreshing fodder for each head, and being used as the interface for the user

The center of the feeding system control is an 8-bit microcontroller made by Atmel, typically marked as AT89C52, which controls the electronic part and communicates with the RFID reader and the PC (Figure 2).
An I²C bus connects the microcontroller to an EEPROM memory card holding the data of the food eaten during the day, of the food eaten for the last 3 hours and of the quantity of food a head should eat during the day.

![Figure 2. Hardware block diagram](image)

The identification subsystem consists of 2 basic units:
- RFID tag (Figure 3) - a miniature device holding a unique 64-bit code. The tag may take the form of a 12 mm long glass shell of about 3 mm diameter, which may be implanted under the animal's skin or may be integrated in the collar. The glass shell has a great mechanical endurance - 500 N to axial and radial load. When under the skin, it cannot be destroyed unintentionally, being as such resistant to environmental impulses. It also does not affect the health of the animals.

![Figure 3. RFID transponder block diagram](image)

The transfer of the information from the RFID tag is based on the induction connection between the antenna of the reader and the antenna of the tag (Figure 4). The antenna of the reader is constantly maintained by a high voltage with a frequency of 125 kHz. If in a circle of 80 cm from the reader, the antenna of the RFID tag receives enough electricity, rectifies it and the voltage obtained is used for power supply.

![Figure 4. Signal on coils](image)

The tag sends a 64-bit code, with no title. Once the signal has been registered by the reader, it is demodulated and the data received that way is then sent to a microcontroller via the RS-232 port. The voltage levels do not conform with the RS-232 speci-fication, but the state if the logical unit represents the voltage of +5V, and the state of the logical zero represents the voltage of 0V, which is an ideal situation for connecting with the microcontroller (Figure 5)

![Figure 5: Connecting the RFID reader](image)

The feeding system is connected to a PC via the RS-232 interface. The system allows the PC not to be in the vicinity of the feeding system, but it can be placed several tens of meters away, in a separate room. This is a very good point since the environment the cows live in is not favourable for sensitive electronic devices.

There is a database in the PC holding the information on all the elements contained in each sort of food at its disposal. The computer calculates the proportions of particular sorts of food and concentrated addings necessary to meet the cows' needs for all elements. Since all heads are fed with the same sort of refreshing fodder, the proportions calculated are based on the input data average of all heads. When the contents of food are known the amount of food to be given to each head in the following 24 hours is calculated. The amounts calculated are sent to by the PC to the EEPROM memory card placed on the feeding system, via the RS-232 port. The procedure is repeatedly done every 24 hours and the user may initiate the calculation himself.

The computer indicates the proportions of all contents of refreshing fodder, expressed in percentage, which helps the user to be well informed about the entire farm as well as about each head in particular, about its health, the profit considerations, etc.

If a head has not eaten the prescribed amount of food it may imply a health problem or a problem in the system functioning. In that case the user is informed about it via the computer interface.

The computer indicates the proportions of all contents of refreshing fodder, expressed in percentage, which helps the user to prepare the fodder out of basic contents. The fodder is prepared in a blender and then transported to a container placed above the feeding system.

When a head approaches the feeding place, the RFID tag is read and the microcomputer checks the amount of food
already eaten that day, the amount of food eaten for the last 3 hours and the maximal amount of food to be allowed that day (Figure 6.).

![Flowchart](image)

**Figure 6. Flowchart**

The feeding system was designed to allow only one head at a time to approach the place the food is shaken out into. A dozer supplies 100 g portions to the head being at the feeding place at the moment and registers it in the memory.

There is a good reason why the microcomputer checks the amount of food eaten for the last 3 hours: to prevent the animals from eating too much refreshing fodder in a meal. This is the way how to increase the level of the animal’s digestion.

III. MEASUREMENTS

The system was first tested on a farm of milch cows in Velika Peratovica. There are 48 milch cows, 12 being of the Siemental breed and 36 being of the Holstein breed.

The cows were first being fed in a conventional way for 2 months, and then the automated feeding system was applied.

During testing, the amounts of refreshing and voluminous fodder eaten were measured. Their prices and contents were also registered. The record of the level of milk production was also kept. This data was the basis for calculating the total profit of the cowshed.

The measurements were made in the period between June 6th 2005 and September 30th 2005.

The diagram in Figure 7 shows that the quantity of the fodder eaten over the observed period was increased. During the first two months of testing the cows were fed with the usual quantity of food. During the third and the fourth month they were fed in an automated way. There was a significant drop in the amount of food eaten when the automated system was applied. The drop was due to the fact that the cows had been fed more than it was really necessary for the amount of milk they produced. Applying the automated feeding system caused the increase in the food quality, resulting in the reduction of the quantities of food eaten. As the time passed by the cows, being fed with a high quality food, started producing more milk. The prices of refreshing fodder were not changed.

![Diagram](image)

**Figure 7. Quantity of the eaten fodder**

The diagram in Figure 8 shows the increase in milk production only a few days after the automated feeding system was applied. The increase in the amount of milk produced could not be noticed at once, but a few days later, due to a relatively tedious cow’s digestion. It is also obvious that the prices of milk were not significantly changed.

![Diagram](image)

**Figure 8. Milk production**

The diagram in Figure 9 shows the total profit of the farm gained in the period the testing was done. The total profit was influenced by the price of refreshing fodder, the mass of refreshing fodder, the milk price and the amount of milk produced.

![Diagram](image)

**Figure 9. Profit**
IV. CONCLUSION

There was a significant improvement in milk production made by applying scientific methods of specifying the feeding technology of milch cows together with a computer navigated feeding system. A series of tests was run indicating that the system has a great potential in modern cow breeding. The results of testing indicate the increase in the daily profit by 23.45% per head.

There was a significant increase in profit caused by the increase in milk production and milk prices. Using high quality refreshing fodder and supervising strictly the amount of food being eaten by each head resulted in a better milk quality, which caused a significant increase in milk prices. The balanced feeding is the main advantage of the automated feeding system over the traditional one.

Since the system is a computer based one, its functions may be altered, allowing the possibility to be still improved and advanced, especially when it comes to removing errors that have not been detected in testing so far.

It is possible to improve the system by applying better methods in calculating the contents and the amount of fodder, i.e. by using more reliable equations for calculating the sustaining and milk-producing needs of each head.

The automated feeding technology is not restricted to cow breeding only, but it can be applied to cattle breeding in general.

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