Scientia Agricola

Note

Dairy cow monitoring by RFID

Stevan Stankovski[1]*, Gordana Ostojic[1], Ivana Senk[1], Marija Rakic-Skokovic[1], Snezana Trivunovic[2], Denis Kucevic[2]

[1]University of Novi Sad/Faculty of Technical Sciences, Trg Dositeja Obradovica 6 – 21000 – Novi Sad – Serbia.
[2]University of Novi Sad/Faculty of Agriculture, Trg D. Obradovica 8 – 21000 – Novi Sad – Serbia.
*Corresponding author <stevan@uns.ac.rs>

Edited by: Gerson Barreto Mourão

Received May 07, 2010
Accepted September 05, 2011

ABSTRACT: Dairy cows identification and monitoring on small cattle farms are usually based on the utilization of barcode technology. This kind of identification technology is unsuitable for dairy cows milking and feeding process automation. Radio Frequency Identification (RFID) technology is a better solution in this case. This paper describes the research and implementation of the milking cycle´s automated monitoring with the use of RFID tags conducted on a small cattle farm in the Republic of Serbia. This solution is based on RFID system which consists of two parts. First part includes control box, two Ultra High Frequency (UHF) RFID readers operating at frequency of 915 MHz and RFID tags glued onto the dairy cow ear labels. Second part includes software modules for acquisition and collecting data from RFID tags to build up an archive due to supervision and analysis of the milking cycle. Reading accuracy of RFID system in the observed period was 99.8 % in average. A group of dairy cows having a settled milking cycle within an interval of 12h ± 5 % had a 1.5 % better yield and a 0.08 better quality in comparison with a group of dairy cows having a milking cycle variance higher than 20 %. RFID system implemented in described way can be easily integrated into a new or existing farm management system in order to have better production results which depend on several factors including settled milking cycles.
Keywords: identification technology, automatic scanning, cattle farm, milk yield

Introduction

Currently developed identification systems are based on electronic technologies that allow automation, instead of traditional systems based on visual identification. An automated system that uniquely identifies each animal should: (i) identify the origin of each animal; (ii) trace the path of each animal from location to location; (iii) trace each animal exposed to disease; (iv) eradicate or control an animal health threat; (v) retrieve information within hours of an outbreak and implement intervention strategies; (vi) improve consumer confidence; and (vii) provide assurance to buyers regarding the animal's life history (McKean, 2001; USDA, 2009).

Several animal identification systems were developed and implemented on farms (Artmann, 1999; Eradus and Janssen, 1999; Klindtworth et al., 1999; Ntafis et al., 2008; O'Connor, 2009; Samada et al., 2010) and other animal habitat (Balch et al., 2004). Radio frequency identification (RFID) technology was implemented in many systems as well. Since it became a global trend, in 1994 the International Organisation for Standardisation (ISO) defined a standard for radio frequency animal identification devices, which ensures compatibility between systems of manufacturers.

One of the most important goals of the system implemented and presented in this paper is the possibility of integrating it with an already developed farm management system (Voulodimos et al., 2010), and the possibility to function autonomously. Fulfillment of these goals is based on the application of Ultra High Frequency (UHF) RFID tags, which can be used for various farm management functions. Another goal that the RFID system for data collection and monitoring should achieve is the possibility to transfer data regardless of whether the data transfer is wired or wireless. Furthermore, over a short period of time the RFID system should prove that its installation is justified by various benefits, above all to the owners of small farms, which hold the majority of the livestock pool used for the case study conducted in Serbia.

Materials and Methods

Cattle identification on the territory of the Republic of Serbia is obligatory. It is performed within 20 days after the birth or before leaving the birth farm, by double ear labels on both ears fixed through the auricle. The ear labels have a unified code for the identification of each calf individually. This code is in the form of barcode with the structure represented in Figure 1. The first two letters represent the country code, while the ten-digit number represents the unique number assigned to the particular animal. The first digit is the country code (seven - Serbia), the second digit is the cattle breed code (one - cow), the third digit is a control digit assigned by the Central base, and the remaining seven digits are the animal identifier.

In the research carried out on the farms, barcode identification proved inefficient for many reasons, e.g.: (i) to identify the animal; as barcode reading is possible only on short distances, the animal should be approached physically which disturbs it; (ii) the farm worker spends his working time in data reading, which directly influences the farm's productivity and expenses; (iii) errors occur during the manual data input to the PC; (iv) since

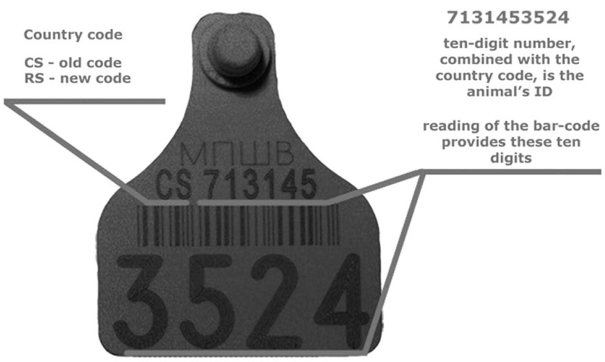

Figure 1 – Ear label with unique identification number in form of barcode.

the animals live in a muddy environment, the ear labels are often mud-covered or dirty which cause difficulties in animal identification as more reading attempts are required; (v) recording changes about the individual animal data is not possible locally as barcode lacks memory for data storage. Instead, it is necessary to modify the data in a unified database which can be inaccessible for different reasons (no adequate infrastructure, etc), and also requires additional involvement of the user; (vi) animal barcode can be used only once as data modification is impossible; and (vii) barcode can easily be duplicated which opens the possibilities of its abuse.

Taking into account the fact that the identification of cattle (dairy cows) is obligatory, and that it is performed in the above described manner, as well as the problems noticed on the farms, the idea came up to use RFID technology for identification and milking cycle tracking for each calf (dairy cow), due to the importance of regular milking cycles. This is one of the key influencing parameters for achieving a better and higher quality milk yield. Monitoring milking cycles can bring benefit to the following: (i) milk quality can be influenced by monitoring the entering sequence of cows to the milking facility. It is possible to monitor whether healthy animals come first, or the animals with suspicion of disease, or the ill animals or animals under therapy, whether the younger or the elder animals come first, etc.; (ii) with the reports on the milking cycle, animal control can be optimized by arranging the sequence of bringing the animals to the milking facility and avoiding their crowding at the entrance. This can reduce stress and agonistic interactions between the cows while they wait to enter the milking facility which leads to their better overall welfare, reduces the risk of hurting between the animals, etc; (iii) if the animal is fed with concentrated meals, then the amount of food for each animal can be optimized according to the report of the time spent in the milking facility and its production.

RFID is one of the most fundamental technologies that enable wireless data transmission (Dowla, 2004). It consists of RFID tags, RFID readers/writers, RFID barcode scanners, RFID smart sensors and RFID controllers (Lahiri, 2007). In Feb. 2009, an RFID-based dairy cow monitoring system was implemented on dairy farms with three hundred and five cows of all Holstein-Frisian breed categories in the municipality of Vrbas in the Republic of Serbia. It was used until May 2009 for the purpose of this experiment. After that period it is accepted as regular operation. This system is used not only for the identification of each cow, but also for monitoring the entire milking cycle.

Milking system is herringbone and each cow is admitted through an entrance gate. The cows are washed under the sprinkler systems and each cow enters an individual box. This system provides safe and correct cow positioning so there is a good visibility of the animals under the milker. Also, it is important to mention that the cows are provided with feed concentrate, and the milker is wiped with cloth and put on the milking cluster. All cows are milked twice daily and the samplings are taken for each cow outcome by milk meters (Metatron 12), according to ICAR (International Committee for Animal Recording) rules. On the farm, the milk samples are collected ones in four weeks, but the experiment milk samples were collected each day and carried in Novi Sad. These samples represent the 24 h milking period. Analyzes of the chemical components of milk samples (milk fat (MF), protein (P), lactose (L), dry matter (DM)) are done by routine methods. Also, the total bacteriological count (TBC) is obtained by the method – flow cytometry using BactoScan (Foss Analytical equipment). Statistical analyses (average values, standard deviation and t-test) were carried out through software Statistica 9.1 (from StatSoft, Inc.).

The advanced RFID system is implemented in the milking facility. The RFID system comprises the following major hardware components: (i) Control box, containing a computer connected to a system of uninterruptible power supply; (ii) Two UHF RFID readers operating at frequency of 915 MHz (Figure 2a) and Figure 2b), and (iii) Two hundred and ten RFID tags glued onto the dairy cow ear labels (Figure 3). The UHF RFID readers are placed at the entrance and the exit of the milking facility above the door so that they do not hinder in any way the entry/exit of dairy cows, nor the workers carrying out tasks in the facility.

The maximum length at which a reliable UHF RFID tag data reading can be performed is 10 m. The protocol according to which data is collected from the RFID tags is the ISO 18000-6B. The communication between the computer in the control box and the RFID reader is conducted by an RS232 interface, while the maximum cable length is 10 m. The bit rate between the computer and the RFID is 115,200 bps. Since the UHF RFID technology allows longer distances for tag recognition (even up to 10 m), the installation of RFID readers in the existing facilities is easier and does not affect to a larger extent the already established movement of cows within the room where the identification is conducted (in this particular case: the milking facility).

The computer in the control box is primarily used for data acquisition from the RFID tags placed onto the

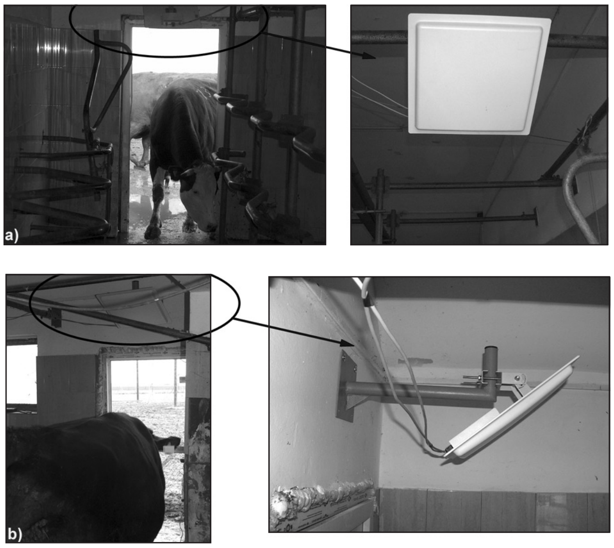

Figure 2 – a) Ultra High Frequency Radio Frequency Identification (UHF RFID) readers placed at the entrance to the milking facility. b) UHF RFID readers placed at the exit from the milking facility.

Figure 3 – The Radio Frequency Identification tag placed on the existing ear label.

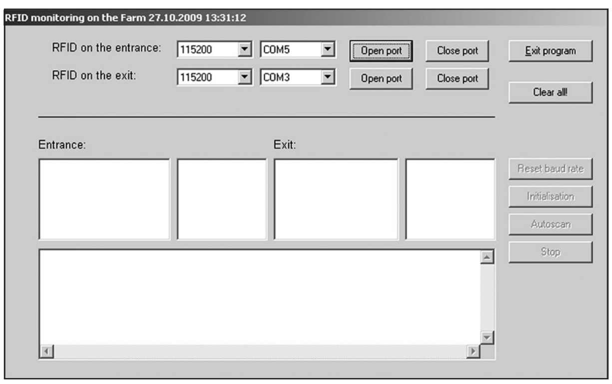

Figure 4 – Dialog box of the developed application for communication between computer and Radio Frequency Identification readers.

ear labels and archive data on the hard disc of the computer. The following software components are installed in the computer: (i) an application which communicates with the RFID readers, and collects data from the RFID tags (UID – Unique Identifier, a single number for each card); (ii) an application for the analysis of the data collected from the RFID tags for the purpose of identifying the milk cycle of each dairy cow. These two applications enable monitoring, data acquisition, archive and analysis of a milk cycle of each dairy cow. In the text bellow, the software components are presented individually.

The software application communicating with the two RFID readers (installed at the entrance to - and the exit from the milking facility) has been developed for data acquisition from the RFID tags of dairy cows. An image of the application interface is presented in Figure 4. This application enables setting up a connection between the computer and the RFID reader (Figure 2) via RS232 interface. It further enables the communication between the reader and the interface according to the protocol specified by the manufacturer of the RFID reader. After the initiation, by pressing the "Autoscan" button, the application enters into the mode of automatic scanning of tag presence within the reader's field. In this mode, the application sends to each reader within certain time intervals a command to read all tags within the field and the command for the UID (Unique Identifier) identification of the tags within the reader's field.

When a certain tag is read within the field of the entrance reader, its UID is entered into the "Entrance" list. The actual (system) time is recorded simultaneously and linked to the UID. By the same token, when a certain tag is read in the field of the exit reader, its UID is entered into the "Exit" list and linked to the actual time. Since the scanning is performed within short time intervals, one tag is scanned several times while in the reader's field. Thus, when entering a UID into a particular list, it is first checked whether it has already been there. If it has, the UID is not entered again. The time when the UID is entered into the list is also checked and compared with the actual time. If it is established that more than five minutes have passed from entering the UID into the list, the UID is linked again to the actual time. This turned out to be necessary since the dairy cow sometimes spends up to 20 min in front of the entrance before entering the milking facility. At each entry to or exit from the milking facility, the data (entry/exit, UID and the actual time) is entered into an appropriate XML file. Each day, a separate XML file is generated, and the name of this file is created based on the date. Thus, a database of files for further information analysis is created.

The data acquisition by software application for communication with the RFID readers and data acquisition from RFID tags represent the basis of milking cycle analysis of each dairy cow. The application of the analysis of data acquired from the RFID tags is shown in Figure 5. The application's pilot version consists of three tabs. The first tab enables the selection of milking data

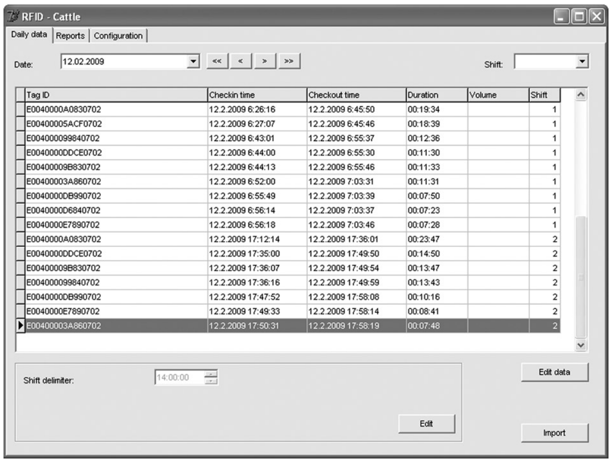

Figure 5 – The starting screen of the application for the analysis of the data collected from the Radio Frequency Identification tags.

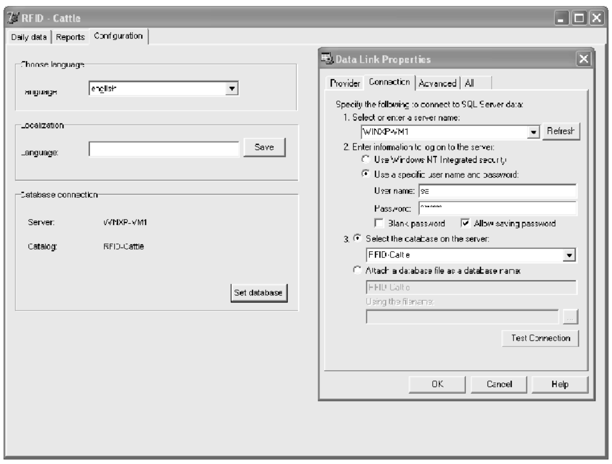

Figure 6 – Preview of the application for the analysis of the data collected from the Radio Frequency Identification tags configuration tab.

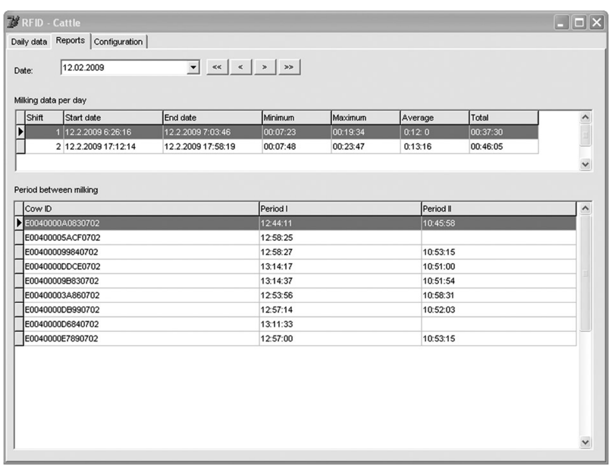

Figure 7 – An example of milking data analysis.

on a particular date, whereby it is possible to see the animal's (in this case the dairy cow's) label, the time of entry into the milking facility (check-in time), the time of exit from the milking facility (check-out time), as well as the number of milking cycles within the selected date. The duration is calculated as the difference between the entry and the exit time. The data can be presented entirely for a particular day or filtered for a particular milking (by choosing the appropriate values from the drop-down list entitled "Shift").

Generated XML files were interactively loaded into the database using the application. By selecting the "Import" button, the access to the XML file containing the data, as well as their import into the database is enabled. Database connection configurations, as well as further configurations pertaining to the application itself are enabled by the third tab entitled "Configuration". A preview of this tab with the open box for database configuration is shown in Figure 6.

The second tab entitled "Reports" shows the statistical data pertaining to milk within the days necessary for the milking cycle analysis. An example of reports is shown in Figure 7. This tab shows two data groups. The first part contains the milking statistical data: cycle start time, i.e. when the first animal entered into the milking facility; cycle end time, i.e. when the last animal left the milking facility; the minimum, maximum and average time in the milking facility, as well as the total duration of a milking cycle. The second part of the data shows the time periods between two consecutive milking for each dairy cow. "Period I" is the time passed from the last milking of the previous day until the first milking of the currently selected day, while "Period II" is the time passed between two milking during the same day.

Results and Discussion

The experimental period at the farm lasted 85 days. The owners of the small cattle farm could follow every step of the field trials, and thus, they understood the procedure. The benefits of the system were easily recognized. They include simple installation, replacement of the handwritten records with electronic ones, and possibility to analyze larger amount of valuable information for dairy cows.

The results collected on the small cattle farm enabled the determination of behavioral patterns, i.e. it was possible to determine the order in which the cows entered the milking facility. Changes in this order happened stochastically, which influenced the milk quality and yield of each dairy cow. Cows having a settled milking cycle within an interval of 12h $\pm$ 5 % (group 1) had a 1.5 % better daily milk yield and a 0.08 better quality in comparison with the cows with a milking cycle variance higher than 20 % (group 2). Average value $\pm$ standard deviations of daily milk yield and milk quality are shown in Table 1. Low values of daily milk yield in the group with a milking cycle variance higher than 20 % (group 2) are

Table 1 – Average value ± standard deviation of milk yield (MY), milk fat (MF), protein (P), lactose (L), dry matter (DM), total bacteriological count (TBC) and statistical probability (*p*).

Group	MY	MF	P	L	DM	TBC
	kg	%				
1	27.1 ± 5.35	3.573 ± 0.558	3.201 ± 0.323	4.300 ± 0.346	12.302 ± 0.743	42589 ± 8423
2	26.7 ± 5.62	3.571 ± 0.700	3.198 ± 0.490	4.297 ± 0.269	12.211 ± 1.182	42591 ± 9280
p	$p < 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$

Table 2 – Results of the reading accuracy in the experimental period.

Reading accuracy during experimental period	Minimum per day	Maximum per day	Average per period
	%		
Period A (first week)	94.8	98.6	97.3
Period B (the rest of the period)	99.2	100	99.8

in accordance with other research findings (Davis et al., 1999; Hale et al., 2003; Hassabo, 2009; Tagelsir, 1991).

Circulatory and nervous system play an important role in milk synthesis, secretion and let down which is affected by neurohormonal effect and synchronization (Tagelsir, 1991). Thus, once a day milking or skipping milking is not acceptable with high producing dairy cows under intensified dairy system, while twice a day milking interval of 10-14 h and 12-14 h is acceptable, while three times a day milking will increase milk up to 12-15 %. Furthermore, four times a day milking will increase milk production from 8-12 % over, (Hassabo, 2009). Once-daily milking (ODM) of ruminants results in loss of milk production. The loss of milk production can vary considerably among cows but in recent short-term trials, on average, the loss was 13 % (Davis et al., 1999). Milking frequency can be increased in a manner that minimizes additional labour by employing unequal milking intervals (Hale et al., 2003). Total bacteriological count was in accordance with 39 % of the best samples of Cassoli et al. (2010).

During the experimental period, no serious problems were detected. Animals responded well to tag application and no effect on the animals´ welfare was observed. Moreover, the animal's health status was not affected by the devices because the UHF RFID tags were glued onto the dairy cow ear labels (Figure 3). The only problem was related to the RFID reading accuracy. In the Table 2 the results of the RFID reading accuracy are presented. To remove the faults due to the reading accuracy of the RFID reader or loss of ear tags, four additional ultrasonic sensors and four limit switches were placed. Each cow was located in a separate box and before the milking started, the signal from the matching limit switch proved that the box was closed. Afterwards, the presence of the cow in the box was identified and the cow was enumerated by the ultrasonic sensor.

At the end of the milking cycle, the data about the enumerated cows from the RFID system and from the sensor system were compared. In the case when these numbers do not match, the system generates a list of cows that were not identified by using the RFID system. During the first week of the experiment (Period A, Table 2), the problem with the RFID reading accuracy was observed and necessary adjustments of the RFID readers were performed. After this period (Period B, Table 2), the variations of the RFID reading accuracy were settled.

Conclusion

The animal identification process using UHF RFID technology ensures that the cow is unaware of the whole procedure, so the stress is avoided as well as a negative influence on the yield and quality of milk. This is not the case with the other identification methods, i.e. the manual or the automatic method which uses bar codes. Another advantage of the implemented system is that it can work autonomously, and, if required, it can be easily integrated into the new or existing complex farm management system.

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