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# Development of a new automatic water intake measurement and recording system to monitor individual water drinking behaviors of cattle

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ABSTRACT

Water is the most vital nutrient directly affecting the production performance and comfort of cattle. Sufficient amount of clean water must be provided in order to obtain the optimum yields in milk and meat production. Measuring individual water intakes of cattle on a farm is not commonly practiced because it requires huge amount of human work. Determining daily water drinking behaviors of cattle can give information about their welfare, health and inadequate farm practices. The aim of this study was to develop a new automatic water intake measurement and recording system giving an opportunity to monitor individual water drinking behaviors of cattle. The developed system consists of three main units: mechanical unit, electronic unit and data storage/processing unit. The mechanical unit holds different components together and provides durability with its installation to the ground. The electronic unit collects the RFID tag number and the amount of water intakes for cattle during a day and sends wirelessly them to the data storage/processing unit during each drinking event. Data storage and processing unit saves the data to its database and makes necessary calculations. A field test with dairy cows was done to determine the performance of the developed system. The cows had 80.55 to 164.41 liters of daily free water intakes, 581 to 2870 seconds of daily water intake durations and 13 to 40 of daily drinking events.

Keywords:
Precision livestock farming
Animal monitoring
Internet of things
Data acquisition

## Sığırların bireysel su içme davranışlarının izlenmesi için yeni bir otomatik su alımı ölçüm ve kayıt sisteminin geliştirilmesi

ÖZET

Su, sığırların üretim performansını ve konforunu doğrudan etkileyen, yaşamsal öneme sahip bir besindir. Süt ve et üretiminde optimum verimi elde etmek için yeterli miktarda temiz suyun temin edilmesi gerekmektedir. Çok yüksek miktarlarda insan emeği gerektirdiği için çiftliklerde sığırların bireysel su alımının ölçümü yapılmamaktadır. Sığırların günlük su içme davranışlarının belirlenmesi, sığırların refahı, sağlığı ve uygun olmayan çiftlik uygulamaları hakkında bilgi verebilir. Bu çalışmanın amacı, sığırların bireysel su içme davranışlarını izleme imkanı verecek yeni bir otomatik su alımı ölçüm ve kayıt sisteminin geliştirilmesi olmuştur. Geliştirilen sistem; mekanik ünite, elektronik ünite ve veri toplama/işleme ünitesi olmak üzere üç ana üniteden oluşmaktadır. Mekanik ünite farklı parçaları birlikte tutmakta ve yere montajıyla dayanım sağlamaktadır. Elektronik ünite, her bir su içme olayı için su içen hayvanın RFID küpe numarasını ve içtiği su miktarını toplamakta ve kablosuz olarak veri depolama/işleme ünitesine göndermektedir. Veri depolama/işleme sistemi gelen verileri veri tabanında saklamakta ve gerekli hesaplamaları yapmaktadır. Geliştirilen sistemin performansını belirlemek için süt ineklerinin kullanıldığı saha denemesi yapılmıştır. Her bir ineğin 80.55 ile 164.41 litre aralığında günlük su alımı, 581 ile 2870 saniye aralığında günlük su içme süresi ve günlük su içme sayısı 13 ile 40 aralığında olmuştur.

Anahtar Sözcükler:
Hassas hayvansal üretim
Hayvan izleme
Nesnelerin interneti
Veri toplama

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## 1. Introduction

Increasing availability and decreasing cost of electronic components on market present opportunities for the collection and evaluation of various data related to animals and their surroundings to make timely and precise decisions about livestock production (Banhazi et al., 2012; Halachmi and Guarino, 2016). Precision Livestock Farming (PFL) is a term used to state the applications of information technologies for all stages of animal husbandry. Collecting electronically various data related to daily activities, surroundings and physiology of each animal with various measurement systems is the first step of PFL.

Water is a vital nutrient for cows since their body weight is 56 to 81 % water (Murphy, 1992) and their raw milk is 87.3 to 88.1 % water (Wijesinha-Bettoni and Burlingame, 2013). Sufficient amounts of clean water must be provided to dairy animals to retain the maximum yield in milk production since there is a significant correlation between the amount of water intake and milk yield for dairy cattle (Murphy et al., 1983). Insufficient water supply imposes adverse effects on animal performance and welfare (Meyer et al., 2004). Determining the daily drinking behaviors of each cow on a farm can provide unique information to maintain its production efficiency and to proactively identify its possible health and comfort problems. Daily water intakes of cows are occasionally measured by determining the change of water volume or weight in a trough (Meyer et al., 2004; Morris et al., 2010). There is a need for an automatic system which can operate all day long to monitor the drinking activities of cows without any human interruption. The objective of this study was to develop a new automatic water intake measurement and recording system to monitor the daily water drinking behaviors of cows in terms of daily amount of water intake, daily drinking duration and number of daily drinking events.

## 2. Material and Methods

*2.1. The automatic water intake measurement and recording system*

The automatic water intake measurement and recording system is expected to perform the following duties:

-It reads the RFID number of the cow coming to drink water,
-It records the beginning and ending time of each drinking event,
-It measures the amount of water drunk by a cow at each drinking event,
-It sends wirelessly the data to the data storage/processing unit,
-It calculates the daily total amount of water drunk by each cow,
-It calculates the daily total duration of water drinking for each cow,
-It counts the daily total number of active drinking events for each cow,
-It stores raw/processed data and presents them via internet.

It consists of three main units: mechanical unit, electronic unit and data storage/processing unit.

*2.1.1 Mechanical unit*

The mechanical unit holds different components together and provides durability with its installation to the ground. It consists of side barriers which permits only one cow to drink water at a time, a bowl drinker with muzzle paddle, plumbing fixtures, a storage box in which the electronic unit and a battery are kept under locked and a RF antenna pole with a power supply cabinet (Figure 1).

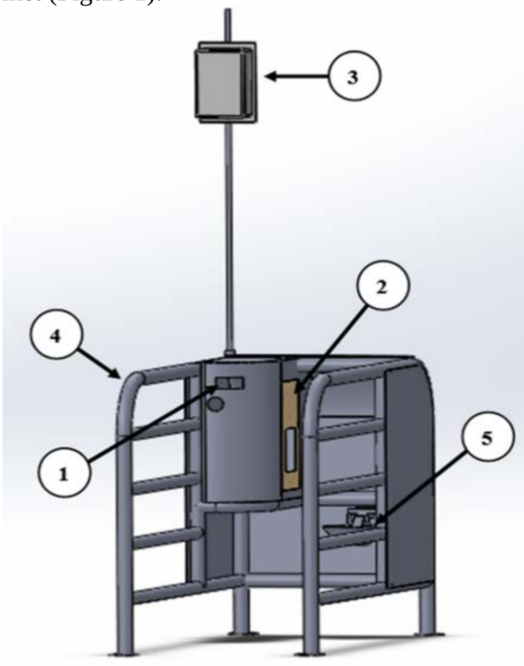


Figure 1. Mechanical unit (1. storage box, 2. RFID reader, 3. RF transmitter pole and power supply cabinet, 4. side barriers, 5. bowl drinker with muzzle paddle).
*Şekil 1. Mekanik ünite (1. Depo kutusu, 2. RFID okuyucu, 3. RF verici direği ve güç kaynağı kabini, 4. yan bariyerler, 5. dilli suluk).*

*2.1.2 Electronic unit*

The electronic unit collects the RFID tag number and the amount of water intake for each cow during a day and sends wirelessly them to the data storage/processing unit during each drinking event. The electronic unit consists of a microcontroller-based electronic circuit card, a RFID reader, a water flow sensor, a RF transceiver, a battery, a power supply and a battery charge circuit.

The microcontroller-based electronic circuit decodes the RFID number sent by the rfid reader, counts the pulse sent by the water flow sensor, displays the measurement results simultaneously on the 16x2 lcd display and wirelessly communicates with the data storage/processing unit through a rf transceiver (Figure 2).

Figure 2. Microcontroller-based electronic circuit
*Şekil 2. Mikrodenetleyici tabanlı elektronik devre kartı*

The microcontroller was selected based on the following requirements: sufficient accuracy, sufficient I/O ports, support of a serial interface (supports RS485 to communicate with RFID reader), at least two 16 bit timers / counters, sufficient computational speed, sufficient program and data memory capacity, 96 Kbyte of flash program memory, 1Kbyte of EEPROM, a watchdog timer and to be able to work under harsh environmental conditions in the barn. Microchip PIC18F4685 microcontroller having a RISC CPU with maximum clock frequency 40 MHz and maximum speed of operation up to 10 MIPS was chosen. An 11.059.200 Hz crystal oscillator was chosen to obtain higher UART baud rates when needed.

RFID ear tags attached to the ears of animals were used to identify each cow drinking water. A RFID reader working on ISO11784 / 11785 standards and RS485 communication protocol was chosen. The RFID reader read the RFID ear tag number in a distance of up to 40 cm. The RFID reader and the bowl drinker were installed in such that the RFID ear tag number could be easily read during drinking (Figure 3).

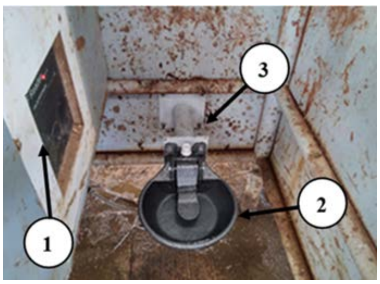


Figure 3. Positions of The RFID reader(1), the drinker with muzzle paddle(2) and the mounting arm (3)
*Şekil 3. RFID okutucu(1), dilli suluk(2) ve montaj kolu(3) konumları*

The water flow sensor selected for this study was an integrated magnetic Hall Effect sensor that output an electrical pulse with every revolution. It had a capacity range of one to thirty liters per minute and ½ inch tubing (YF-S201, Sea, China). Wireless data transfer from the electronic unit to the data storage/processing unit were made by a transceiver ( Lora HM-TRL-R-D-433).

The microcontroller was programmed based on a special algorithm (Figure 4).

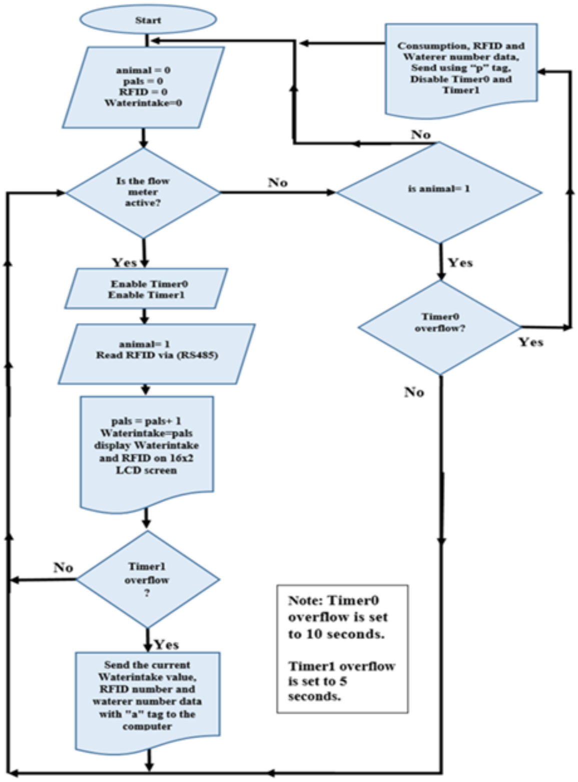


Figure 4. Flow chart of microcontroller program algorithm
*Şekil 4. Mikrodenetleyici programı algoritması akış diyagramı*

As shown in Figure 4, the initial variables are set to zero and Timers are disabled immediately after start. When an animal enters the stall, its RFID tag number is read. The flow sensor plays a key role in the operation of the algorithm. The flow sensor is connected to the external interrupt pin of the microcontroller. When the flow sensor starts sending pulses (an animal started drinking water in the stall), the microcontroller starts counting every pulse and enables the timer0 and timer1 and reset them on each pulse. Timer0 is set to 10-second interval to trigger an interrupt on overflow. When timer0 overflows, the interrupt occurs. It means that flow sensor is not active and has not been sending any pulse for ten seconds, then microcomputer sends the RFID tag number by means of the rf transceiver to the data computer unit in the milking parlor building along with the total pulse counts. After sending the data, the program turns to beginning and the initial variables are set to zero and timers are disabled and the microcontroller starts listening the flow sensor again. As long as the microcontroller receives pulses, it sends the current RFID tag number and pulse count in every five seconds to the data processing unit. For this purpose, timer1 is set to five seconds interval to trigger an interrupt on overflow.

*2.1.3 Data storage and processing unit*

Data storage and processing unit consists of a pc and a rf receiver connected to it. The task of this unit is to save the data wirelessly sent by the electronic units to its database and makes necessary calculations.

*2.2 Calibration*

The system was calibrated by passing two, four, six, eight and ten liters of water through flow sensors (Figure 5).

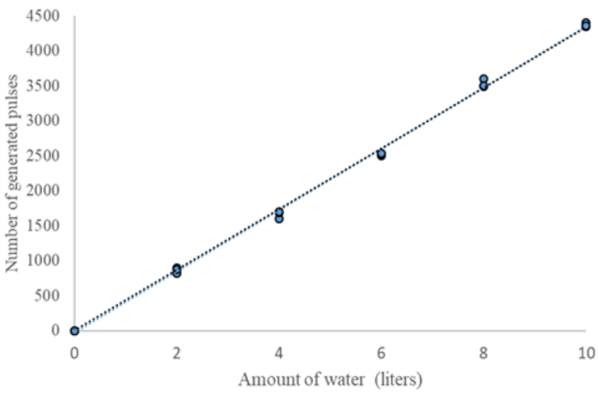


Figure 5. Calibration curve of water flow sensors.
*Şekil 5. Akış ölçerlerin kalibrasyon eğrisi*

The flow sensors generate averagely 428 pulses per liter of water passed through them ($R^2$=0.9980). One pulse is equal to 0.00234 liter of water. The number of pulses counted and sent by the microcontroller-based electronic circuit card for each drinking event of cows is converted to the volumetric amount of water drunk by multiplying it by 0.0234.

*2.3. Data processing*

The amount of water for all drinking events of a cow during a day is summed up to find the daily water intake for that cow. In addition, the time of the first pulse and the time of the last pulse received by the data storage and processing unit for each drinking event are recorded and used to calculate the duration of that drinking event. When there is a time interval more than 10 s between the times of last two pulses received, the drinking events of these pulses are considered as separate drinking events. The durations of all water drinking events of a cow during a day are summed up to find the daily drinking duration of that cow. All separate water drinking events of a cow during a day are counted to find the number of daily water drinking events of that cow. All these calculations are done by an application developed with C#.NET programming language.

*2.4. Field test*

The precision automatic water intake measurement and recording system consisting of three mechanical units, three electronic units and one data storage/processing unit was manufactured and installed on a dairy farm (Figure 6). One data storage/processing unit were able to communicate with more than one electronic units on the same time.

Figure 6. Overview of field test
*Şekil 6. Saha denemesinin genel görünüşü*

Water drinking behaviors of three Holstein-Friesian cows were automatically followed during four consecutive days. The cows were milked three times a day (morning, afternoon and night). They were fed with the mixture of corn silage, alfalfa hay and concentrate feed after every milking and had ad libitum access to water.

## 3. Results and Discussion

The data about the water drinking behaviors of cows are shown in Table 1. The daily water intakes of three cows range from 80.55 to 164.41 liters per day. It was reported that the daily water intakes of cow had ranged from 23.9 to 130.4 per day (Axegärd, 2017). The large variations among the daily water intakes of cows on a farm occur since they have different body weight/size, milk yield even though they are cared with the same farm practices. Dry matter intakes of cows are correlated with their body weights and milk yields (Anonymous, 2001). The daily water intakes of cows are correlated with dry matter intakes and milk yield. As a result, the cows having larger body size and higher milk yields consume more feed and water (Meyer et al., 2004). The data about the lactations and milk yields of three cows are shown in Table 2. The milk yields range from 21.1 to 37.43 liters per day. The third cow has higher milk yields than the other two cows since because of its much bigger body weight/size than the others based on visual observation. The milk yields are mainly affected by the lactation length and the live body weight/size of cows (Berry et al., 2007; Vijayakumar et al, 2017).

Table 1. Drinking behavior measures belonging to three cows
*Çizelge 1. Üç ineğe ait su içme davranışı ölçütleri*

| Cow Number | Day Number | Daily Water Intake (liters) | Daily Water Intake Duration (seconds) | Number of Daily Drinking Events |
|---|---|---|---|---|
| 1 | 1 | 88.49 | 581 | 14 |
| | 2 | 98.55 | 636 | 13 |
| | 3 | 80.55 | 601 | 20 |
| | 4 | 89.34 | 618 | 18 |
| 2 | 1 | 86.81 | 845 | 19 |
| | 2 | 91.15 | 873 | 22 |
| | 3 | 81.21 | 915 | 26 |
| | 4 | 86.64 | 978 | 25 |
| 3 | 1 | 139.67 | 1262 | 27 |
| | 2 | 164.41 | 2870 | 40 |
| | 3 | 142.21 | 1331 | 24 |
| | 4 | 150.87 | 1354 | 22 |

Table 2. Lactation and milking data belonging to three cows
*Çizelge 2. Üç ineğe ait laktasyon ve süt verisi*

| Cow Number | Day Number | Number of Lactation | Lactation Day | Daily Milk Production (Liters) |
|---|---|---|---|---|
| 1 | 1 | 3 | 296 | 22.57 |
| | 2 | 3 | 297 | 21.99 |
| | 3 | 3 | 298 | 22.3 |
| | 4 | 3 | 299 | 21.1 |
| 2 | 1 | 1 | 88 | 25.41 |
| | 2 | 1 | 89 | 23.06 |
| | 3 | 1 | 90 | 24.68 |
| | 4 | 1 | 91 | 22.80 |
| 3 | 1 | 2 | 146 | 37.43 |
| | 2 | 2 | 147 | 29.26 |
| | 3 | 2 | 148 | 35.14 |
| | 4 | 2 | 149 | 35.46 |

The daily water drinking durations of range from 581 to 2870 seconds and their number of daily drinking events range from 13 to 40. In one study, the numbers of drinking events are reported to be 10 to 60 and the daily water drinking durations of cows are reported to be 7.4 to 69 minutes (Axegärd, 2017). The daily water drinking durations found in this study stay within the range reported in the literature (Axegärd, 2017). The drinking behavior of the same cow shows some variations day to day. The reasons of these variations can be random variations associated with feed consumptions and milk yields or uncontrolled delays or advances in milking times. Most cows drink water immediately after each milking. 75% of cows in one study (Cardot et al, 2008) and 90% of cows in another study visited a drinker within 2 hour of post milking ( Wieclaw et al., 1973). The cows drink water and feed in a sequential manner. Cows are reported to have 7.3±2.8 visits to a drinker (drinking bouts) per day (Cardot et al, 2008). The number of daily visits to a drinker are effected by feeding method (grazing pasture vs. feeding a total mixed ration) (Jago et al., 2005) and lactation stage of cows (Huzzey et al., 2005). The average number of daily visits to a drinker increase from 6.6±0.4 in the pre-calving period to 9.5±0.4 in the post-calving period (Huzzey et al., 2005). In the current study, the number of active drinking event were counted. A cow may drink water more than once at each drinker visit as seen in this study. The drinking behaviors of are affected by various factors including their physiological conditions, climatic conditions and social ranks. The low ranked cows spend less time at the drinker and their number of drinking events are relatively less than the high ranked cows (Axegärd, 2017).

## 4. Conclusions

A new precision automatic water intake measurement and recording system were developed and successfully tested on a dairy farm. It provided information related to daily amount of water intake, daily drinking duration and number of daily drinking events of each cow on a farm. This information can be used to monitor any unfavorable change in cows' health and comforts. Early detection of these unfavorable changes reduces treatment costs and production losses by starting medical treatments for sick cows earlier. This system can be used by researcher and farmers to observe drinker behaviors of their cows under different conditions and treatment.

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