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HAYVAN İZLEMEDE RADYO FREKANSLI TANIMLAMA SİSTEMLERİNİN KULLANIMI

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Özet

Son yıllardaki teknolojik gelişmelerin artmasıyla birlikte, geçmişi 1940'lı yıllara dayanan radyo frekanslı tanımlama sistemlerinin (RFID) uygulamaları oldukça popüler hale gelmiştir. Okuma mesafelerinin artması ve boyutlardaki küçülme, RFID teknolojisinin çok farklı uygulamalarda kullanılmasına sebep olmuştur. Hayvan tanımlama, izleme ve takip sistemleri, bu teknolojinin hırsızlık ve hileyi önlemede, verilerin toplanması ve depolanmasında etkin olarak kullanıldığı alanlardan bazılarıdır. Son zamanlarda, aktif RFID etiketlere sıcaklık ve pH sensörleri eklenerek elde edilen ve hayvanların rumenine yerleştirilebilen bolus tipi etiketler ile hayvanların vücut sıcaklığı ve rumen pH değerlerinin uzaktan ölçümünü içeren çalışmalar sunulmaktadır. Bu çalışmada ilk olarak literatür ve pratik uygulamalar taranarak RFID tekniklerinin nasıl kullanıldıkları özet karşılaştırmalarla gösterilmiş, son olarak da önerilen sistemlerin problemlere hangi oranda çözüm olabilecekleri tartışılmıştır. Kullanılan yöntemlerin avantaj ve dezavantajları belirtilerek, hayvanların takibinde ve tanımlanmasında RFID teknolojisinin kullanımı ortaya konulmaya çalışılmıştır.

Anahtar kelimeler: RFID, aktif RFID etiketi, bolus, sıcaklık sensörü, pH sensörü

USE OF RADIO FREQUENCY IDENTIFICATION SYSTEMS ON ANIMAL MONITORING

Abstract

With enhancement of technological advances in recent years, radio frequency identification (RFID) applications, whose history begins in the 1940s, has become quite popular. Decrement of their size and increment in their reading distance has led to the use of RFID technology in different areas commonly. Animal monitoring, tracking and identification systems are some of the application areas where this technology is used effectively to prevent theft and fraud, to increase efficiency and to collect and store essential data. Recently, some studies that involve remote measurements of the body temperature and rumen pH values of animals with bolus type-tags placed in rumen by adding temperature and pH sensors to the active RFID tags have been presented. In this study, firstly having literature search and practical application designs, it was presented that how RFID techniques used in this area with brief comparisons and finally discussed that proposed systems whether or not could be a solution. Indicating the advantages and disadvantages of the application methods in the field, it is tried to express use of RFID technology, in the monitoring, tracking and identification of animals.

Key Words: RFID, active RFID tag, bolus, temperature sensor, pH sensor

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1. INTRODUCTION

As a birth, RFID technology has entered to the scientific world in order to be used to ascertain the friendly and enemy aircrafts in World War II (Landt, 2005). Today, RFID technology can be used in the recognition of all kind objects from a distance without contacting in various areas and it is irreplaceable for identification and tracking systems. While it widely used in the product and inventory tracking, it is also used for monitoring and identification of animals. Because GPS systems have some difficulties indoor and hided areas (Bekkali et al., 2007), RFID systems become forefront in identification and tracking of animals (Lui et al., 2007, Farid et al., 2013, Gu et al., 2009).

Mad cow disease, bird flu, tuberculosis and brucellosis are common diseases seen in animals. These diseases have increased interest to the health of food production and animal husbandry (Marchant, 2002). This increased interest, in many countries, has led to take strict precautions to identification and tracking of animals. With these precautions what is aimed is to prevent the spread of diseases to other locations and to identify quickly the origin of diseases (Chang et al, 2010). United States Department of Agriculture (USDA), in USA, after the occurrence of mad cow disease published a plan. This plan includes the identification animal by RFID tags. Also it has put different databases that include information of animals. Monitoring of the record deliveries and disease control can be considered as the purpose of these systems (Grubb, 2010). European Parliament Regulation No: 1760/200, establish a system labeling of beef and their products and identification of animals. This system includes “cattle passport” and national computerized database (European Commission, 2009). With the same regulations by keeping records of animals using RFID tags and include that recording meat and meat products database have been emphasized. Australia, Canada, Japan and many other developed countries, have established RFID-based systems for monitoring and identification of animals and animal products. These countries have also begun to implement strict follow-up policies (Feng et al., 2013).

RFID technology is not limited only to identification of animals, especially using the advantages adding sensors to the active tags have been used to monitor body temperature and ruminal variables. In this paper, RFID system and use of animal monitoring were investigated and the products on the markets were evaluated.

2. RFID

RFID technology used radio waves for object identification. This technology is different from automatic data collection technologies which we know like barcode bars and optical signal forms. RFID and barcode technologies are different, but sometimes they are confused. Although in barcode systems reader has to see barcode to read it, but it is not necessarily in RFID systems. Unlike barcode, even if there is not any visual contact between the tag and reader, reading can be achieved rapidly and precisely. Because data can be transmitted in an encrypted form and have many other features, RFID technology much more secure than magnetic cards as well (Hunt et al, 2007, Wu et al, 2006).

RFID usage is a quite old technology and dates back to the Second World War years. Firstly, at the beginning of 1940s it was used in the identification of friendly and enemy aircrafts in the UK. This was followed by nuclear material tracking applications in 1970s, commercial applications began in 1990s. This technology has been used in Italy, France, USA, Portugal and Norway for 20 years on the remuneration of transition in highways and bridges, monitoring of livestock, controlling and monitoring nuclear materials inventory and monitoring the vehicles in automobile assembly-line production. But the high cost and difficulties of use of tags, made RFID technology unsuitable for mass commercial activities for a long time (Karaca, 2010). It was used very limited in enterprise applications so far; because, this system was so expensive. In recent years when compared to other identification systems, because it provides ease of use, product tracking accuracy, which ensures accuracy and performance in the production and storage bands, RFID technology has become more prominence. In identification with radio frequency (RF), radio waves can be spread through many non-metallic surfaces. Therefore, the RFID tag in a package, or tags that protected to prevent damage from bad weather conditions or contained in the packaged products can also be read easily. Another reason why using RFID in product tracking and control systems is inevitable because the serial numbers in microchips in labels are unique (Hoşoğlu, 2010).

2.1. Architecture of a RFID System

RFID tags and readers are the most critical components of this technology and also RFID printers, RFID antenna, and software can be added. The system consists of three main components:

- Tag (sometimes transponder) consists of a semiconductor chip and an antenna basically. It can be passive or active working type.
- Reader; comprises antenna, RF electronics module and electronic control module.
- Controller (sometimes host or middleware), which consists of a database and control software running on a PC or workstation.

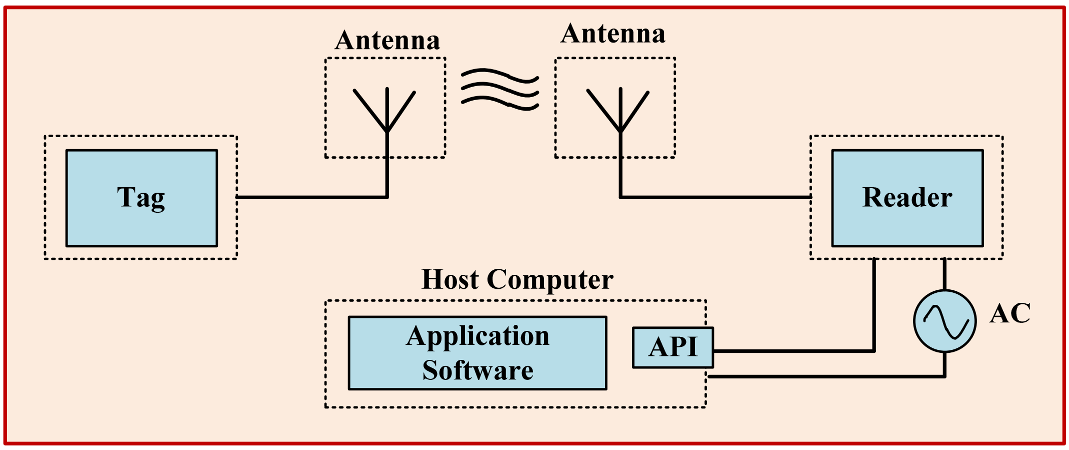

Figure 1. RFID System Components

Each tag has a unique identification number, in system shown in Figure 1. Reader propagates electromagnetic (EM) wave signals to identify RFID objects. Information and energy transfer are provided without any contact between the RFID reader and RFID tags. Tags which have entered the reader's radio frequency field, receive the required energy of EM waves for communication from this area. When tag receives the required energy, carrier signal is modulated according to the stored information. The modulated carrier signal is sent from tag to reader. Reader detects the modulated signal, deciphers its password and reads it. Finally, received information is transmitted to the computer database. RFID tag is a portable or mobile module, when it enters to the effect field of the reader; it sends data to the reader. Tags can be produced in various forms as shown in Figure 2. The most widely used type of tags are the ones whose surrounding looks like an antenna and whose size about a credit card size. They can be embedded or can be attached in any type of product.

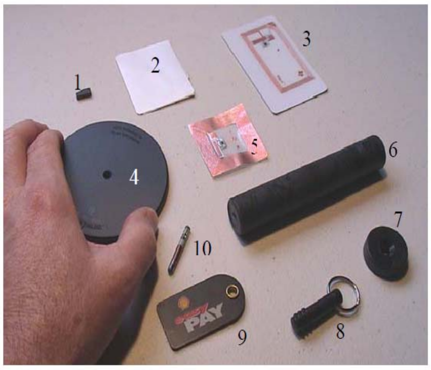

Figure 2. RFID tag types

Tags are divided into three different groups according to their functions:

- **Active tags:** As seen Figure 3(a), they use an inner battery to communicate with the reader, to keep the information and to deliver required energy which runs the microchip. In terms of read range quite successful but the cost is quite high. Therefore, they are used the identification of expensive items and monitoring (Domdouzis et al., 2007)
- **Passive Tags**: There is no energy source inside. This is why they provide the needed energy from readers. The reader sends radio signal to the antenna. The tag receives this signal with its antenna (coil) as seen on Figure 3(b). So it obtains needed power to operate its chip. Tag, using the received energy from the signal, performs the function of verifying the information transferred to the reader. As a conclusion, passive tags' communication distance is relatively low. It can be used in many systems due to its affordable cost (Roberts, 2006).

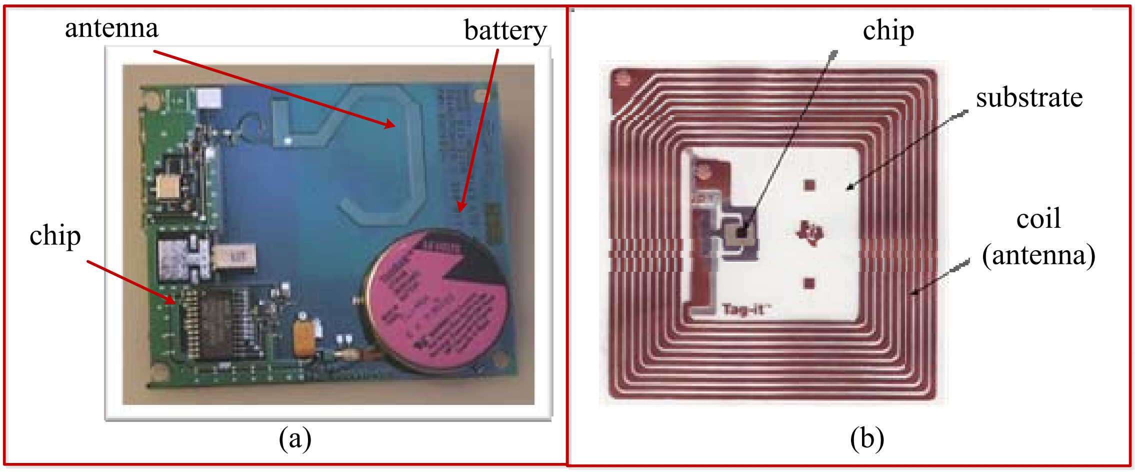

Figure 3. a) Active and b) passive RFID tag

- **Semi-active tags**: Although they have their own power sources this source are only used to energize the chip. Reading operation is performed through EM fields emitted from reader like passive tags. They do not broadcast like active tags (Karaca, 2010).

Another distinguishing feature of RFID tags is operation frequency range. The operation frequency of RFID tags is shown in Table 1 (Hoşoğlu, 2010). Today widely used tags' frequency range is mostly high frequency (HF). The cost of a tag not only depends on whether it is active or passive but also varies according to the operating frequency.

Table 1. Operation frequency of RFID tags and used countries.

Band	Frequency	System	Country/Area
LF	125-134 KHz	Inductive	USA, Canada, Japan, Europe
HF	13.6 MHz	Inductive	USA, Canada, Japan, Europe
UHF	433-434 MHz	Propagation	USA, Japan, Europe
UHF	865-868 MHz	Propagation	Middle East, Singapore, Africa, Europe
UHF	866-869 MHz 923-925 MHz	Propagation	Korea, Japan, New Zealand
UHF	952-954 MHz	Propagation	Japan
Microwave	2.4 and 5.8 GHz	Propagation	USA, Canada, Japan, Europe

Another categorizations of RFID tags by their frequency and their power consumptions listed in Table 2 (Garcia, 2011).

Table 2. Categorizations of RFID tags by frequency and their allowed field strength.

Band	Common Used Frequency	Type of Tag	Communication range		Allowed field strength transmission power
			Typical	Max.	
LF	125-134.2 KHz	Passive	20cm	100cm	72dB µA/m max.
HF	13.56 MHz	Passive and semi-passive	10cm	1.5m	60dB µA/m max.
UHF	433 MHz	Active	3m	10m	10–100 mW
	860 and 915 MHz	Active and passive	3m	15m	0.1–4 W
Microwave	2.4 and 5.8 GHz	Active and passive	3m	30m	0.5 – 4 W

2.2. Usage areas of RFID Systems

By providing accurate information at real time and having the control and safety elements, it has become a very important factor and brought a new dimension to the management. RFID usage is limited by imagination. RFID, has the ability to provide remote management and control in many areas such as defense industry, food industry, logistics and automotive. Usage areas of RFID are so many and is increasing every day. Outstanding applications can be summarized as follows (Kuru, 2010);

- container tracking in the shipping field,
- tracking of products in the production line,
- monitoring patients, doctors and drugs in hospitals,
- vehicle tracking on motorways,
- precise tracking of ammunition in the military field,
- preventing products theft and unauthorized use (such as vehicle locking system),
- input and output controls in all areas,
- animal identification and tracking,
- baggage tracking at airports,
- monitoring and safety in library books,
- monitoring and security documents in archives.

Usage areas of RFID are hard to count and their numbers have been increasing every passing day. Thus RFID has endless solutions. Namely, every application analogy creates its own RFID architecture.

3. RFID IN ANIMAL SCIENCE

Identification of livestock is essential to modern farming and successful farm management. Various methods and types of identification for application under different circumstances have been developed. Animal owners developed sophisticated systems in the earliest times. Many tribes used identification system include skin color and patterns. Developed systems in recent times have used in order to animal identify also track food products (FAO/WHO, 2004).

RFID systems have been used in agriculture for a long time. These areas are animal traceability, farm management etc. RFID applications in animal identification and tracking systems have begun 1970s (Eradus and Jansen, 1999). With improvement and miniaturizations in electronic component in the 1980s, it has become possible producing smaller RFID tags. The first RFID tags used in animals were secured with a neck collar (Rossing, 1999). Later, ear tags and leg bands were seen. Implantable and bolus type tags followed this generation (Castro et al., 2010). Rumen bolus and ear tag technologies have been used commonly today. When compared to the traditional methods, RFID based systems have many advantages (Voulodimos, 2010, Stankovski et al., 2012 and Ting, 2007). These advantages are

- storing more data about animals,
- monitoring animals from birth until slaughter by unique labels,
- tracking animal disease and easy to determine their origin,
- recording the transportation of animals,
- opportunity to follow animals without distressing them,
- allowing quick and multiple data readings,
- no need to be within line of sight of the RFID reader,
- improving the confidence.

On the other hand, RFID systems have various constraints which are mechanical damage, environmental damage (excessive cold/hot, dust etc.), tag collusion, reduction in print (circuit) quality, effect by static electricity and surrounding electronic devices (Mennecke and Townsend, 2005). Solving the hardware and software problems of RFID based systems by evolving technology provides improvements in most of the problems mentioned above and it is shown that the tags can also work in very harsh environment (Chandrud et al., 2008). In a study, it has been designed RFID tags which can operate between -20 to 200°C (Nicholson, 1997). After the introduction of RFID-based systems in animals, manual record errors and labor costs have been decreased, automation has been achieved and herd health and productivity has been increased (Samad, et al., 2010). Beyond these, using RFID systems in animal world will take effect all food sectors sequentially. Important matters in these systems can be expressed as follows; rapidness, cost and accuracy for data, protection against the theft, etc. (Trenkle, 2000, 2006).

In line with the increasing needs, public health, animal health and protection of the consumer require secure animal identification and monitoring systems. These systems help to limit producer losses due to disease, prevent the spread of animal disease and reduce the control costs and decrease trade loss (Marchant, 2002). Also these systems will provide management more animals, reducing theft and more confidence (Garcia, 2011). RFID systems seem to be ideal solution to these problems. Accurate identification of livestock will provide very important facilities in buying, selling and monitoring of them (Dziuk, 2003). The need for animal identification has been increasing, because there is need for quality control and animal welfare. Also effects of animal disease into the environment reveal need of true effective animal identification systems (Voulodimos, 2010). That's why, many countries are trying to trace livestock by building RFID systems to animal checkpoints. In Australia, LF RFID systems have been used for a long time as attaching RFID tags at the animal checkpoints to obtain their information which passing through (Ketprom et al., 2011). Also, Australia's National Livestock Identification System (NLIS) was started in 2004. According to this system all animals must be labeled with RFID tags. These tags can be ear type or bolus type (Mennecke and Townsend, 2005). Canadian Cattle Identification Program has made identification process using ear tags since 2001. Common animal identification and tracking systems are listed below in some countries, on Table 3 (New Zeeland Ministry Agriculture and Foresty, 2009).

Table 3. Animal identification and tracking systems in some countries

Country	Mandatory	Species
Australia	Yes (States)	Cattle
United Kingdom	Yes	Cattle, sheep and other livestock
Canada	Yes (Provinces)	Cattle, sheep, pigs
USA	Initial Voluntary	Cattle, production livestock
South Korea	Yes	Cattle, agricultural products
Japan	Yes	Cattle
European Union	Yes	Cattle and other livestock
Argentina	Yes	Cattle
Brazil	Yes	Cattle

Different RFID tags have been used in animal tracking systems. RFID tag types for animals which are used in the researches and in practical applications have been summarized as follows. ***Ear type tags*** are commonly used ones shown in Figure 4(a). They are suitable for operation in different frequencies and are used at all frequencies bands. Although they are very economical way of labeling in the animal identification, they have some several weaknesses like open to outside interference (strike, theft, replacement, etc.). ***Ring type tags***, shown in Figure 4(b), are label formats used in especially follow-up of bird species, the larger of them is attached to feet of farm animals and is used in the monitoring of their activity. ***Bolus type tags*** are passive and active RFID tags and mostly placed the secondary stomach of ruminants (reticulum). RFID boluses that currently being sold in the market as plastic or ceramic packaged are being used extensively and their most important property is tamper proof structure. Thus, they are more advantages than other types of labels in where security is essential. Moreover, since these type of tags make it possible to access parameters and so, many parametric specifications is easy to be measured and followed, this type of tags will be more attractive in the future. Bolus type tags can also be put to stomach of animals directly by the apparatus shown in Figure 4(c) by swallowing. ***Injection type tags,*** shown in Figure 4(d), are passive tags used for pets like dogs, cats, fish etc. at LF and HF band. Generally, glass coated tags, smaller than a grain of rice, are injected into animals.

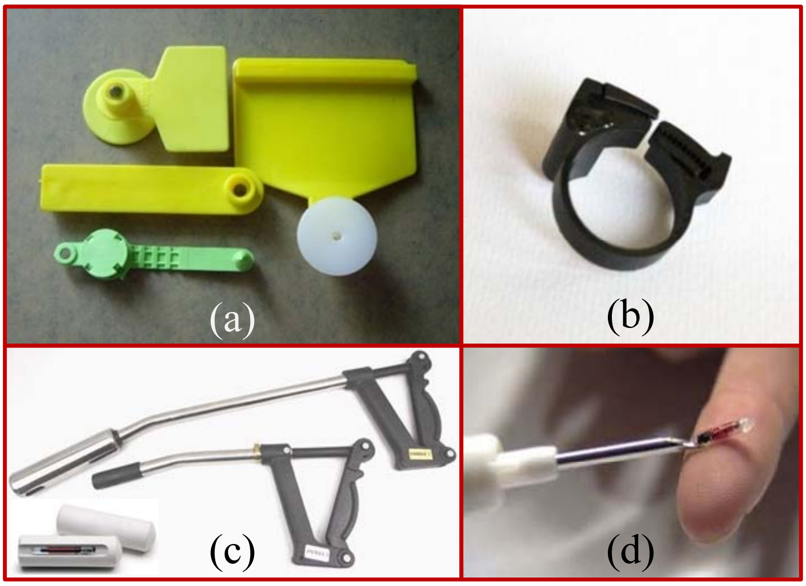

Figure 4. (a) Ear, (b) ring (c) bolus and (d) injection type RFID tags

If problem is only identify or tracing animal, in this situation passive tags are sufficient. But if sensor applications are necessary, active or semi-active tags must be used in these applications (Chandrud et al., 2008). There are significant advantages and disadvantages of different types of tags in the tag design. Foot and ear tags are easy and intuitive to use, but foot tags are more vulnerable, and ear tags can drop easily. On the other hand, tags that can be injected and rumen type tags are less vulnerable by outside effects, but they are relatively more complex (Hong, 2012). In injected tags there is possibility merging into food when animal is slaughtered. So developers design alternative electronic label. This label called rumen bolus is packaged with a ceramic or steel material (Fallon, 2001). In many studies rumen boluses have shown more superior features than other tags (Rossing, 1999; Hong, 2012; Varese et al., 2008). In IDEA Project joined Germany, France, Italy, Ireland, Netherlands, Spain and Portugal, used about one million RFID tags constitute %72 bolus type tags (Rossing, 1999; Wismans, 1999). Injectable (implantable) RFID tags especially preferred in small animal tracing, with integrated sensors to these tags is trying to trace various parameters (blood pressure, body temperature etc.) belong to animal (Volk and Jansen, 2012, Catarinucci et al., 2012). The European Union Regulation CE 21/2004 established identification of ovine animals with an ear tag. Also in identification system must be use a second device. Each member state can be select proper device. Spain government selected bolus type tags (Fallon, 2001). The electronic bolus type tags is proven to be most reliable devices against the lost and displacement (Volk and Jansen, 2012). Bolus tags are packaged with an acid-resistant material. They are designed in accordance with animal's stomach (Finkenzeller, 2003). Bolus type tags are given orally to animals by means of a bolus gun apparatus. In order to be permanently settled bolus in the rumen are used different techniques. Foremost among these come in rumen bolus' opened wing structure after placement and different weight materials (Kılıç, 2010). One of the main reasons why rumen boluses are used commonly is because they provide an identification protected against outside effects and by the sensors that will be combined they also enable various parameters in rumens associated with animal diseases to be measured.

Animal husbandry sector is facing very important economic losses. These losses related health problems in animals. Until now if any animals have some health problems, it can be understand only this illness has visual symptoms. After these symptoms with a rectal thermometer can be determined animal's body temperature. In this case, the animal will not be disturbed if it is not ill. With RFID systems body temperature of animal can be detected from far. In this way if animal is disease it can be understood before disease symptoms appear. So this technology will increase all of performance about the animals. (Dye et al., 2007). Temperature and pH sensors come at the beginning of the sensors can be attached to the rumen bolus. In animals, rumen pH level is very important parameter for animal nutrition. Also it is indicator for sub-acute ruminal acidosis (SARA) illness. Veterinarians and animals' owners by determining the pH level are trying to get rid of the negative effects of this disease (Nogues, 2013; Mottram et al., 2008). When unwanted pH value reduces performance about the animals, it can cause economic losses in undesired ratio (Nogues, 2013). It has been demonstrated that the SARA caused very high economic losses (recently US$500 million to US$1 billion per year) in USA (Philips et al., 2010). Rumen pH measurement in animals began long time ago. Currently with receiving oral rehydration and rumenocentesis (fluid taken from the stomach through the syringe) methods continues to be measured by using a pH meter. Then the animals were cannulated with surgical operations and rumen's content can be monitored dynamically. And also monitoring the rumen helps nutrition and detect to calves (Mottram, 2010). Recently, cannulated animals have been used some research purposes. These researches carried out that pH level in animal's rumen is between 5.5 and 7 when animal is healthy. pH values in animal's rumen measured by sensors. Measured data are recorded externally devices (Mottram et al., 2008). Because of cannulated animals only can be used in researches and using cable system can restrict behavior of animals, emerged the idea adding pH sensor to rumen bolus tags. With these sensors can be measured true results for 40 days periods (Gasteiner et al., 2012). Although it is seen a negative situation that data have a certain error in a longer time, with the development of sensor technology is expected to be much higher than this time. So, pH value in the rumen of animals can be easily measured as a wireless remote in a dynamic way is foreseen. A lot of studies has taken place about ruminal boluses what kind of direction will make an impact on the health of animals (Castro et al., 2010; Antonini et al., 2006; Ghirardi et al., 2006; Garin et al., 2003; Eardrop et al., 2008; Ghirardi et al., 2006; Cappai, and Pihra 2014) and in consideration of all these works, bolus type RFID tags have not negative effect on milk production, not side effects on fertility, not effect on weight gain/loss, have no leading to death (Ghirardi et al., 2006; Garin et al., 2003).

Studies have been made both in cattle; sheep and goats, and bolus type tags can be given in a very short time after animal born. This process is indicated to cause any adverse event (Ghirardi et al., 2006; Garin et al., 2003). Used bolus type tags have been evaluated in terms of parameters like size, weight, volume and specific gravity; the effects of these parameters have been examined for the retention rate of the bolus tag (Ghirardi et al., 2006). In animals, the weight rather than age has been shown to be an important parameter to use bolus (Ghirardi and Caja, 2006). Bolus type RFID tag structure is a ceramic or plastic which may also be used with weight materials (Ghirardi et al., 2006). The impact of these materials on the operating frequency has been the subject of various studies. Magnetic material, also makes the task of collecting accidentally ingested metal particles in animals, have been shown to lead to a shift in operating frequency of the tag according to the terms of the settlement (Eardrop et al., 2008). Bolus type tags designed new generation RFID tags at 433 MHz frequency are newly introduced to the market by different companies. These types of labels, especially active types, owing to allow inserting sensors are considered to be very popular in the future (Doğan, 2012). Recently a few technological firms have begun to produce RFID bolus with temperature and pH sensors (for example eCow bolus and Well Cow bolus).

RFID and other wireless systems can be used in many applications together. In various studies, GPS, sensors and RFID combinations have been proposed, the identification process by RFID, location information by GPS, body temperature and image information is provided by the sensors (Kim et al., 2010). In a study by combining RFID and wireless sensor networks (WSN) technologies, management of a breeding farm is planned by the RFID tags and sensors placed at various points, identification process is made and various parameters of animals could be observed (Congguo et al., 2011). The Argos System was developed to track animals in their habitats about 850 km areas. This study is an integration of RFID and WSN (Pereira et al., 2008). Identification and monitoring animals in zoos, RFID technology is seen an outstanding system. Identification of animals in zoos is made by using RFID and WSN. Because RFID can be integrated with WSN systems easily, visitors can access to various information about animals both before and after their visit (Karlson et al., 2010).

4. CONCLUSIONS

The vast majority of existing applications on animals have been made using passive type tags at LF and HF. Selecting low frequency leads to be relatively short reading distance, and which is causes the inability to perform multiple read from long distances. Besides these, it is thought to be higher frequencies have some disadvantages in the liquid medium and cost issues. Yet LF and HF band RFID equipment has been widely used for tracking and identifying livestock traditionally.

The use of active tag in VHF and microwave band, especially bolus type active tag, has been increased in animals recently. With added sensors to the bolus type tags the animal's body temperature which is a very important term in health can be monitored in real time. Thus, at the beginning of disease, opportunities increase to start appropriate treatment. Another an important characteristic related with to the animals is pH value of rumen. pH value that directly related with nutrition and animal health provides to evaluate the effect of food type on animal health and more rational nutrition. Common oral rehydration and rumenocentesis methods have been currently used to measure pH of rumen that are discomfort and difficult. However, with added pH sensors to the active bolus type RFID tags, all these process can be done much easier and faster which affects the health of the animal and nutrition format positively.

As a result, using RFID tags in animal tracking and monitoring for any purpose has become compulsory by international regulations. Especially, aiming multi-benefits, active RFID tags with sensor applications have been popular productions to run providing animal health monitoring and secure tracking in recent years. But progressive studies should be taken place in novel projects to solve deficiencies when current products were examined experimentally.

REFERENCES

Antonini C., Trabalza M., Franceschini R., Mughetti L., Acuti G., Asdrubali G., Boiti C., 2006, In vivo mechanical and in vitro electromagnetic side effects of a ruminal transponder in cattle, JANIM SCI, vol. 84, no. 11, p. 3133-3142.

Bekkali A., Sanson H., Matsumoto M., 2007, RFID Indoor Positioning based on Probabilistic RFID Map and Kalman Filtering, Third IEEE International Conference on Wireless and Mobile Computing, Networking and Communications.

Cappai M.G and Pihra W., 2014, Long term performance of RFID technology in the large scale identification of small ruminants through electronic ceramic boluses: Implications for animal welfare and regulation compliance, Small Ruminant Research, Volume 117, Issues 2–3, Pages 169–175.

Castro N., Martín D., Castro A., Arguello A., Capote J., Caja G., 2010, Suitability of electronic mini-boluses for early identification of goat kids and effects on growth performance and development of the reticulorumen, JANIM SCI, 88:3464-3469

Catarinucci L., Colella, R., Mainetti, L., Mighali, V., Patrono, L., Sergi, I., Tarricone, L., 2012, An Innovative Animals Tracking system based on Passive UHF RFID technology, International Conference on Software, Telecommunications and Computer Networks, p:1-7.

Chandrud W., Wisanmongkol, J., Ketprom U. 2008. RFID for Poultry Traceability System at Animal Checkpoint, Proceedings of ECTI-CON, p.753-756.

Chang C., Han W., Kuo L., 2010, Application of Radio Frequency Identification (RFID) Technology in Dairy Herd Electronic Management, http://www.afita.org /graph/web_structure//files/ Seminar%20(12)-01.pdf (Accessed date: 27.08.2015)

Congguo MA, Yeqin W., 2011, The pig breeding Management system Based on RFID and WSN, 4th International Conference on Information and Computing, p.30-33.

Doğan H., 2012, PhD Seminary, Suleyman Demirel University, Graduate School of Natural and Applied Science.

Domdouzis K., Kumar B., Anumba C., 2007, Radio-Frequency Identification (RFID) applications: A brief introduction, Advanced Engineering Informatics 21:350–355.

Dye T., Richards C.J., Burciaga-Robles L.O., Krehbiel C.R., Step D.L., Fulton R.W., Confer A.W., 2007, Rumen Temperature Boluses for Monitoring health of Feedlot Cattle, Oklahoma State University Agriculture Experiment Station

Dziuk P., 2003, Positive, accurate animal identification, Animal Reproduction Science 79: 319-323

Eardrop S., Wounchoum, P., Phongcharoenpanich C., Torrungrueng D., 2008, Effects of ruminal magnets in the vicinity of a bolus Tag of an LF-RFID System, Proceeding ECTI-CON.

Eradus W and Jansen M, 1999, Animal Identification and Monitoring, Computers and Electronics in Agriculture, 24: 91-98.

European Commission Directorate General for Health and Consumers, 2009, Study on the introduction of electronic identification (EID) as official method to identify bovine animals within the European Union, Final Report.

Fallon R.J. 2001, The development and use of electronic ruminal boluses as a vehicle for bovine identification, Revue Scientifique et Technique Office International, 20(2), 480-490.

FAO/WHO, 2004, Animal Identificiation Practices.

Farid Z., Nordin R., Ismail M., 2013, Recent Advances in Wireless Indoor Localization Techniques and System; Journal of Computer Networks and Communications Volume 2013, Article ID 185138.

Feng J., Zetian F., Zaiqiong W., Mark X., Xiaoshuan Z., 2013, Development and evaluation on a RFID-based traceability system for cattle/beef quality safety in China, Food Control (31),314-325.

Finkenzeller K., 2003, RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification, John Wiley & Sons, Inc. New York, NY, USA

Garcia L.R., 2011, The Role of RFID in agriculture: Applications, limitations and challenges, Computers and Electronics in Agriculture 79: 42–50

Garin D., Caja G., Bocquier F., 2003, Effects of small ruminal boluses used for electronic identification of lambs on the growth and development of the reticulorumen, J ANIM SCI 81, p.879-884.

Gasteiner J., Guggenberger T., Häusler J., Steinwidder A., 2012, Continuous and long term Measurement of reticuloruminal pH in Grazing Dairy Cows by an Indwelling and Wireless Data Transmission, Veterinary Medicine International Volume 2012.

Ghirardi J., Caja G., Garín D., Hernández M., Ribó O., Casellas J., 2006, Retention of different size of electronic identification boluses in the forestomachs of sheep, JANIM SCI 84:2865-2872.

Ghirardi J., Caja G., Flores C., Garı´n D., Herna´ndez M., Bocqui F., 2006, Suitability of electronic mini-boluses for early identification of lambs, J ANIM SCI 85:248-257.

Ghirardi J., Caja, G., Garín, D., Casellas, J., and Hernández M., 2006, Evaluation of the retention of electronic identification boluses in the forestomachs of cattle, Journal of Animal Science, 84(8), 2260–8.

Grubb J., 2010, A Low Cost Automated Livestock Tracking System, Master Thesis, Appalachian State University, Department of Computer Science. https://libres.uncg.edu /ir/asu /f/Grubb,%20Jason_2010_Thesis.pdf (Accessed date:04.08.2016).

Gu Y., Lo A., 2009, A Survey of Indoor Positioning Systems for Wireless Personal Networks, IEEE Communications Surveys & Tutorials, Vol. 11, No. 1.

Hong-Da W., 2012. Application of Radio Frequency Identification (RFID) in Diary Information Management, Journal of Northeast Agricultural University, vol 19. P:78-81.

Hoşoğlu M., 2010, RFID Mifare Reader Design, Karadeniz Tecnique University, Graduate School of Natural and Applied Science, Master Thesis.

http://www.ecow.co.uk/rumen-monitoring-with-the-ebolus/ (Accessed date: 22.02.2016).

http://wellcow.co.uk/bolus/ (Accessed date:22.02.2016).

Hunt V., Puglia A., Puglia M., 2007, RFID: A Guide to Radio Frequency Identification, Wiley Inderscience, Edition 1, April 10, 2007.

Karlson J., Ren K., Li H., 2010, Tracking and Identification of animal for a Digital Zoo, IEEE /ACM International Conference on Green Computing and Communications, p:510-515.

Karaca S., 2010, Personal Tracking System with RFID, Maltepe University, Graduate School of Natural and Applied Science, Master Thesis.

Ketprom U., Mitrpant, C., Makhapun, P., Makwimanloy, S., Laokok, S., 2011, RFID for Cattle Traceability System at Animal Checkpoint, Annual SRII Global Conference, p.517- ,521.

Kılıç U. 2010, Use of Wireless Rumen Sensors in Ruminant Nutrition Research, Science Alert an Open Access Publisher.

Kim S. H., Kim, D. H., Park H. 2010, Animal Situation Tracking Service Using RFID, GPS and Sensor, Second International Conference on Computer and Network Technology, IEEE Computer Society, p.153-156.

Kuru M., 2010, RFID Technology in Auto-Identification Systems and Its Application, Marmara University, Graduate School of Natural and Applied Science, Master Thesis.

Landth J., 2005, The History of RFID, Potentials, IEEE, Volume 24, Issue:4.

Liu H., Darabi H., Banerjee P., Liu J., 2007, Survey of Wireless Indoor Positioning Techniques and Systems, IEEE Transactions on Systems, Man, and Cybernetics—Part C: Applications and Reviews, vol. 37, no. 6.

Marchant J, 2002, Secure Animal Identification and Source Verification, JM Communications UK.

Mennecke B. and Townsend A., 2005, Radio Frequency Identification Tagging as a Mechanism of Creating a Viable Producer's Brand in the Cattle Indutsry, MATRIC Research Paper 05-MRP 8.

Mottram T, 2010, Is a life time Rumen monitoring Bolus Possible?, The First North American Conference on Precision Dairy Management.

Mottram T., Lowe J., McGowan M., Phillips N., 2008, Tecnical Note: A wireless telemetric method of monitoring clinical acidosis in dairy cows, Computer and Electronics in Agriculture 64: 45-48.

New Zeeland Ministry Agriculture and Forestry, 2009, Approval of National Animal Identification System, p:8.

Nicholson M., Morahan B., 1997, www.google.com/patents/US5973599. Accessed date: 30.01.2016.

Nogues A, 2013, Commercial Benefits of Routine Monitoring of Rumen pH in Dairy Cows in South West England.

Pereira D.P., Dias W., Braga M., 2008, Model to integration of RFID into Wireless Sensor Network for tracking and monitoring animals, 11th IEEE International Conference on Computational Science and Engineering, p.125-131.

Philips N. and Mottram T., 2010, Continuous Monitoring of Ruminal pH using Wireless telemetry, Animal Production Science, 50:72-77.

Roberts C.M., 2006, Radio Frequency Identification (RFID), Computer&Security, Vol.25, 18-26.

Rossing W, 1999, Animal Identification: Indtroduction and history, Computers and Electronics in Agriculture, 24: 1-4.

Samad A., Murdeshwar P., Hameed Z., 2010, High credibility RFID based animal data recording System Suitable for Small Holding Rural Dairy Farmers, Computers and Electronics in Agriculture 73: 213-218.

Shanan C. and Kernon B., 2009, A Framework for beef tarceability from farm to slaughter using global standarts: An Irish Perspective, Computers and Electronics in Agriculture vol.66 p:62-69.

Sorrells P., 2000, Optimizing read range in RFID systems, ww1.microchip.com/downloads/en /market_communication/optedn_ps.pdf. Accessed date:30.01.2016.

Stankovski S., Ostojic G., Senk I, Skokovic M.R., Trivunovic S., Kucevic D., 2012, Dairy cow monitoring by RFID, Sci. Agric. v.69, n.1, p.75-80

Ting J.S.L., 2007, A Dynamic RFID –based Mobile Monitoring System in animal Care Management over a Wireless Network, International Conference on Wireless Communications, Networking and Mobile Computing, WiCom 2007, p:2085-2088.

Trenkle A., 2000, Experience with an electronic Identification System for Cattle, Beef Research Report Iowa State University.

Trenkle A., 2006, Evaluation of Rumen Boluses as an Electronic Identification System for Cattle in an Automated Data Collection System, Iowa State University Animal Industry Report.

Varese E., Buffagni S., Percivale F., 2008, Application of RFID Technology to the Agro Industrial Sector: Analysis of some case studies, Journal Commodity Sci. Tech. Quality, 47(I-IV), 171-179

Volk T, Jansen D, 2012, Implantable RFID sensor platform to monitor vital functions of small animals controlled by network based software, European Conference on Smart Objects, Systems and Technologies (SmartSysTech), Proceedings of 2012, 1-6.

Voulodimos A. S. 2010, A Complete Farm Management System Based on Animal Identification Using RFID Technology, Computers and Electronics in Agriculture 70, 380–388.

Weis S.A., RFID: Principles and Applications,www.eecs.harvard.edu/cs199r/readings/ rfid-article.pdf. Accessed date:30.01.2016.

Wismans W.M. 1999, Identification and registration of animal in the European Union, Computers and Electronics in Agriculture, 24:99-108.

Wu N.C., Nystrom M.A., Lin T.R., Yu H.C., 2006, Challenges to global RFID adoption, 2006, Technovation 26:1317–1323.