Application of RFID tags for the overall traceability of products in cheese industries

R. Pérez-Aloe, J. M. Valverde, A. Lara, J. M. Carrillo, I. Roa and J. González

Abstract— **The industrial sector of cheese production with specific quality protection occupies a relevant position in the industrial context of the European Union. In order for the sector to improve the competitiveness, solutions with emphasis in technological innovations should be done which increases the automation and quality control in the productive process. Moreover, the laws regulating the food industry in Europe establish that "the food traceability in all the production, transformation and distribution stages has to be guaranteed".**

Nowadays, the sector has no a procedure that exhaustively guarantees a proper traceability throughout the cheese ripening due to the fact that the surrounded conditions such as humidity, temperature, product handling (turning) and mold growing avoid the individual labeling of the products. Is for this that the production and quality control are performed by batches and the data storage is doing manually by the company personnel.

This paper deals with the possibility of carrying out an individual and by batches quality control of the product in cheese industries. By means of RFID tags a complete traceability is performed improving the cheese fabrication process monitoring and production control.

I. Introduction

THE current laws which regulate the food security in the European Union establish the principles and general requirements of the food legislation. In the article 3 of the Regulation 178/2002 the traceability is defined as the "possibility of carrying out the tracking throughout the production, transformation and distribution stages of a food, feed or animals or substances used for food production" [1]. Besides, "the food traceability must be guaranteed in all the stages described above: production, transformation and distribution stages" which implies the obligation of being able of identifying every product in the company providing a complete information about it.

Depending on the activity in the food chain three different types of traceability can be distinguish [2]:

1) Back traceability, called *"suppliers traceability"* as well, refers to the possibility of having knowledge of what products are coming into the company, where are they coming from as well as who are their suppliers.
2) Internal traceability or *"process traceability"* refers to the information about what is made, from what it is made, how and when it is made and the identification of the product.
3) Forward traceability or *"client traceability"* means the possibility of knowing what products delivers the company, when and for whom they have been provided.

Although the law imposes a generic obligation of traceability, it is not mentioned the way in which the companies can achieve that goal.

Nowadays, the sector of cheese production has no a procedure that exhaustively guarantees a proper traceability throughout all the fabrication stages. The main problem is the cheese ripening which is done is special chambers as shown in Fig. 1. The surrounding conditions in these chambers, such as humidity, temperature, product handling (turning) and mold growing avoid the individual labeling of the products. Is for this that the production and quality control are performed by batches and the data storage is doing manually by the company personnel.

Fig. 1. A traditional ripening chamber

This work was supported by the Junta de Extremadura, Consejería de Infraestructuras y Desarrollo Tecnológico under Grant PDT2005A042 with the financial collaboration of European Union (FEDER).

R. Pérez-Aloe is with the Electrical, Electronic and Automatic Engineering Department, University of Extremadura, Badajoz, 06071 Spain (phone: +34-924-289-594; fax: +34-924-289-601; e-mail: raquel@unex.es).

J. M. Valverde, A. Lara and J. M. Carrillo are with the Electrical, Electronic and Automatic Engineering Department, University of Extremadura, Badajoz, 06071 Spain. I. Roa and J. González are with the Technological Institute INTAEX of Extremadura, Badajoz, 06071 Spain

I. Roa and J. González are with the Technological Institute INTAEX of Extremadura, Badajoz, 06071 Spain

Obviously, the use in this type of products of "smart cards" allows obtaining the benefits that come from the fact of providing the product with a "certain kind of intelligence", such as:

- to have only one identity.
- be able to communicate with his environment in a efficient way.
- be capable of obtaining and retaining the information about itself.

In this work, a system which deals with the use of RFID tags as the physical support for storing the information required to perform a "complete traceability" in a cheese industry is presented. The application performs the three types of traceability mentioned before (back, internal and forward) as well as an individual register of analysis and controls done in all the production stages (milk reception, storage, fabrication, ripening, quality and yield control and pH measures). We propose to increase the collected data corresponding to the process conditions (humidity, temperature, pressure, ventilation) as well as microorganism, biochemical and pH analysis and the connection of these data with the products provided by the different suppliers.The traceability then will be granted, both on cheese batches and on individual cheeses, so cheese batch tags as well as individual tags are provided which allow an automatic management of the traceability. This contributes to assure and certificate the quality, making easier the location, immobilization and in some cases the effective and selective withdrawal of the products when problems arise.

In this point, it is worth to mention also the main advantages that the RFID tags solution offers versus the "traditional" bar code which can be summed up as follows:

- huge number of data in a reduced physical space.
- automatic writing/reading in either individual or by batch mode which could be performed thanks to the use of anti-collision algorithms allowing the reading of several RFID tags without interferences.
- bar code needs visibility to work properly and the information stored can not be changed using the same tag.
- bar code identifies a type of object. The RFID tag identifies an only object in an only way.
- bar code is easily damaged in wet environments like are the ripening chambers where mold growing exists. In this case a RFID tag can be wrapped, for example, by *biofilm* without affecting the reading/writing process.

II. System Implementation

Two complementary systems have been developed in this work. One is based on a personal computer (PC) and the other one in a PocketPC (PPC). The PocketPC application was implemented as an alternative to the PC due to the portability. The PC system includes the S6350 midrange reader and the gate antenna series 6000, both supplied by Texas Instrument [3-4]. The reader operates at 13.56 MHz and is able to communicate with tags that accomplish ISO 15693 protocol.

The communication to the reader is done through a PC serial port, using a RS-232 data transmission protocol, with one bit start, 8 data bits, 1 stop bit and no parity. Several speeds can be selected within the range from 9600 bps to 57600 bps. PC starts the communication with the reader, through a pair of request/response sequences that accomplish ISO 15693 standard, which establishes the request stream format as well as the fields size. Some of the commands supported by the reader can be used with addressing, i.e. read, write and lock. If addressing is used, the command will be sent to a single tag, and in the other case, the command will be broadcasted to all tags in the reader visible range.

The system is also able to detect errors in such a way that if an error occurs during the communication, the reader will send an error code in the response stream to the PC. Some errors are tags not found in the vision range, a read-only block write attempt or an addressing to a non existing block.

The PPC system consists of:

- PocketPC 2003.
- Compact Flash ACG reader and a built-in antenna [5].

The hardware interface runs also at 13.56 MHz. Both ASCII and Binary transmission modes are supported for the reader, but only ASCII mode has been developed because it simplifies the process. The transmission protocol is ASCII mode at 9600 bps. The PocketPC and the PC version of the application are entirely compatibles so a tag written by one application can be read with the other. The software was implemented with Microsoft Embedded Visual C++ environment, and the source code includes the library supplied by the reader manufacturer. All the data stored in a tag are accessed and read in just 8 seconds. Fig. 2 shows a simplified block diagram of the PC and PPC systems developed.

The tags HF-I ISO 15963 have been selected due to their characteristics of thinness and flexibility [6-7].

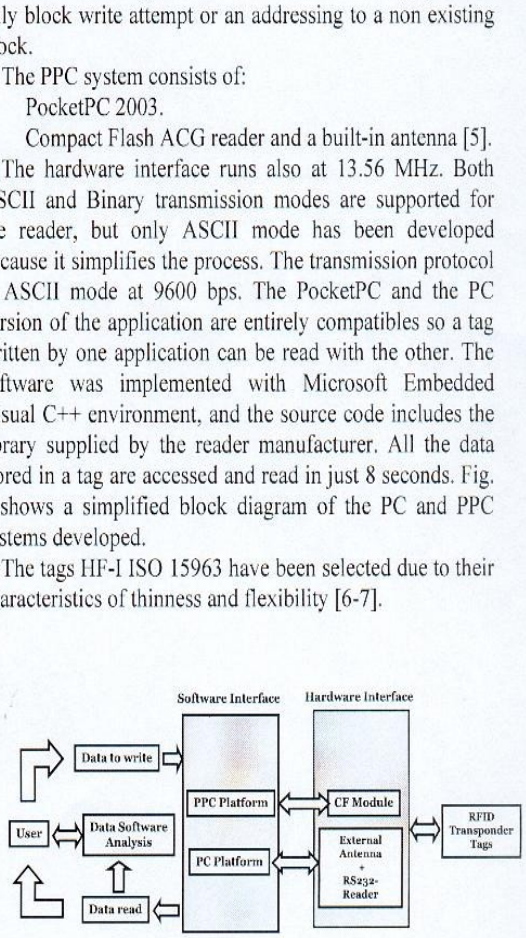


Fig. 2, A simplified block diagram of the two implemented systems.

The tags have a 2kBs user memory organized in 64 blocks x 32 bits as shown in Fig 3 (a). Tags can contain read-only data (ROM) and read/write data (R/W). The stored data on blocks can be locked on factory or by the user on an irreversible process, so data can not be modified any more. In other cases, tags can be reused for future utilizations. All the tags have a locked field, the individual identification code UID which is a 64 bits code, provided by the manufacturer and defined in ISO 15693 standard. AFI and DSFID code allow store the type of application. Both of them are 1 byte block.

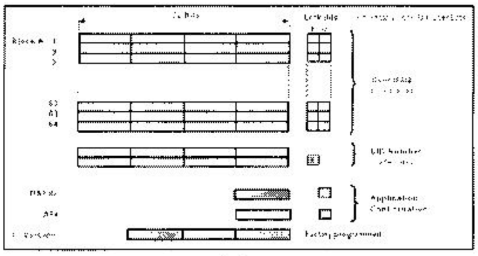
The HF-I tags commands list is seen in Fig. 3 (b). Basically, two modes of reading/writing tags are available: single and multiple tag operation. In single tag operation, the first action is to detect a single tag, then the reader identifies the UID tag, and the subsequent reading/writing commands refer exclusively to it. On the other hand, in the multiple tag operation the information is broadcasted to all the tags in the reader range.

The "writing tag" command transmission sends 9 bytes data in ASCII mode, so first byte indicates the block to write and the next 8 bytes are the data to write in the corresponding block. However, the "reading tag" command transmission does contains just 1 byte, concerning to the number of block to read. The reader has a 512 bytes buffer, so once the command is sent and the reader receives the data, the application can extract the required word from the buffer. The 512 bytes size allows the hardware to read all the tag blocks.

Regarding the data to be recorded in the tags, the writing process has to be optimized in order to store as much as possible cheese production parameters. Fields that will be saved on tags can contain numerical values (temperature, fat, etc.), alphanumerical values (kind of milk, manufacturer, batch, batch qualification, etc.) and data concerning key dates (elaboration, reception, ripening, etc.). Numerical data will be codified in binary, differentiating between integer and decimal part. The number of bits required for each part depends on the range of values and the precision used. In some cases, a data manipulation is performed. For example, if a variable varies from 3 to 5, for a value of 4.57, the integer and the decimal part are codified separately. Effective range of integer part has only 3 values (3 .4 and 5), and an offset of 3 is subtracted, so only 2 bits are needed (0 to 2) instead of the 4 bits needed if offset is not considered (0 to 5).

On the another hand, alphanumerical values will be stored as a simple database, that is, assigning a numerical value to each data, i.e., type of milk can contain 4 values: "null", "cow", "goat" and "sheep", that will be linked to numerical values 0, 1, 2 and 3, respectively.

Once all the fields and its associated number of bits are defined, the next step is to organise the whole tag. The purpose is that each stage of the production process will be associated with a collection of blocks. Around two hundred variables related to the parameters involved in the different phases of the cheese fabrication can be recorded in a tag. Some of them appear in Table I.



(a)

Request	Request Code	Request Mode: Inventory	Addressed	Non-Addressed	Select	AFI
ISO 15693 Mandatory and Optional Commands						
Inventory	0x01	✓	-	-	-	✓
Stay Quiet	0x02		✓	-	-	
Read_Single_Block	0x20	✓	✓	✓	✓	✓
Write_Single_Block	0x21	-	✓	✓	✓	-
Lock_Block	0x22	-	✓	✓	✓	-
Read_Multi_Blocks	0x23	✓	✓	✓	✓	✓
Write_Multi_Blocks	0x24	-	-	-	-	-
Select Tag	0x25	-	✓	-	-	-
Reset to Ready	0x26	-	✓	✓	✓	-
Write_AFI	0x27	-	✓	✓	✓	-
Lock_AFI	0x28	-	✓	✓	✓	
Write DSFID	0x29	-	✓	✓	✓	-
Lock DSFID	0x2A	-	✓	✓	✓	-
Get_System_Info	0x2B	✓	✓	✓	✓	✓
Get_M_Blk_Sec_St	0x2C	✓	✓	✓	✓	✓
TI Custom Commands						
Write_2_Blocks	0xA2	-	✓	✓	✓	-
Lock_2_Blocks	0xA3	-	✓	✓	✓	-

✓ Implemented
- Not applicable

(b)

Fig. 3, Characteristics of the tags used.
(a) Memory organization. (b) List of commands

TABLE I
SOME PARAMETERS STORED IN THE TAGS

Variable	Range
General Data	
Product Code	1000-2000
Lot	010111-311299
Volume	500 lts-2500 lts
Pieces	50 uds-300 uds
Fit for consumption?	yes/no
Number of tags	000000-999999
Specific data for the different stages	
Reception date	01/01/11-31/12/99
Raw milk supplier	Alphabetical
Tank	Alphanumerical
pH	4,00 upH-7,00 upH
Acidity	13,00 °D-18,00 °D
Temperature	02,0 °C-12,0 °C
Chemical analysis	
Fat	3,00 %- 8,00 %
Protein matter	2.50 %-7,00 %
Lactose	3,00 %- 6,00 %
sodium chloride	0,80 %-2,20 %
Microbiological analysis	
Listeria monocytogenes	yes/no
Salmonella spp.	yes/no
Staphylococcus aureus	0-20.000 ufc/gr
Yield control	
Lot weight	50,0 kgr-400,0 kgr
Lot yield (Volume/Weight)	4,00-12,00
Average unit weight	750 gr-1400gr
Clients control	
Client Reference	Alphanumerical
Order number (units/kgr)	1-300/0.80-400

Data are sent to the tags by means of a software application. This application is easy-to-use so any employee of the company will be able to use it without difficulties. The routine includes a "format tag option" which store zeros in all blocks in order to the tag be reused for future activities. The software has been developed using Microsoft® Embedded Visual C++. A scheme representing the mode in which data are stored in the tag memory and the data appearance on the PPC screen can be observed in Fig.4.

III. Experimental Results

The two developed systems have been tested in the industries that collaborate in this work. Previous to place the prototypes in the companies, exhaustive tests in tags were done in the laboratory in order to prove proper working under identical operation conditions than in factory. The simulated conditions were temperature, humidity, biological contamination, acid corrosion, ammoniacal gases, mold growing (Fig. 5) and immersion on saline solutions, inhibiting substances, sugars, colorant pigments, preservative substances and oils action.

Besides, physical tests have been also made which include friction and flexibility because in ripening chambers cheeses with its corresponding tags are subject to turns, shelving changes, frictions and personnel manipulations. In all these cases, no significant negative effects have been reported in communication with tags, with the exception of data reading with metallic materials in the range of the reader which reported erroneous reading.

Finally, in order to confirm that tags were suitable to be attached to the products from the start to the end of the production, some tags were stuck to the cheese surfaces at the beginning of the production phase. As can be seen on Fig. 6, tags remained fixed to the product until the end without reporting errors in the reading/writing process.

Regarding the signal range, for the PC application the system is able to read/write tags inside a radius of around 20 cm, whereas the PPC reader has a limited range of around 10 cm, in both cases, enough for our purposes.

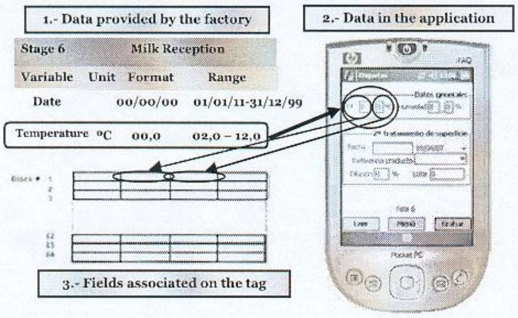


Fig. 4, Data recorded in tag and its representation on the PPC screen.

Fig. 5, Tags test in laboratory with mold growing

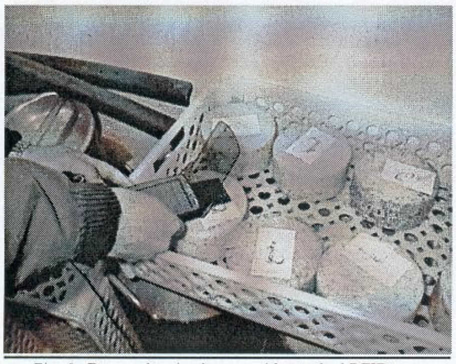


Fig. 6, Data update in cheeses with attached RFID tags

IV. Conclusion

Two different systems that perform the reading/writing task with RFID tags in a cheese industry have been implemented One of them is based on a Personal Computer whereas the other solution uses a PocketPC providing the application with the required portability. The main objective has been to make available to the factory the complete traceability of the products, in individual and by batches mode.

The tags have been tested under different conditions of temperature, humidity, acid corrosion, ammoniacal gases and immerse in saline solutions with inhibiting substances, sugars, colorant pigments, preservative substances and oils. Besides, physical tests have been also made which include friction and flexibility. In all the situations, no significant negative effects have been reported in communication with tags, excepting for metallic materials in the range of the reader.

Around two hundred variables related to the parameters involved in the different stages of the cheese production can be stored in the tag which improve considerably the quality and yield control of the production plant.

REFERENCES

[1] Regulation nº 178/2002 of European Parliament that establishes the principles and general requirements of the food legislation.

[2] Guide for the application of traceability in food companies. Spanish Agency for Food Security. 2004.

[3] HF Reader System Series 6000. S6350 Midrange Reader Module. TI_RFID. September 2002.

[4] HF Reader System Series 6000. Gate Antenna. TI_RFID. September 2002.

[5] CF RFID Reader Card Compact Flash Card With Integrated High Frequency RFID, Reader/Writer for PPC. Socket Communications, INC. USA.

[6] Tag-it (TM) HF-I Pro Transponder Inlays Miniature Rectangle. Texas Instruments, December 2005

[7] Tag-it (TM) HF-I Pro Transponder Inlays Rectangle Large. Texas Instruments, 2002