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ELECTRONIC TRACKING AND TRACING IN FOOD AND FEED TRACEABILITY

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ABSTRACT. Automatic identification and Electronic Data Interchange (EDI) are two most applicable electronic tools for food and feed traceability. This work has presented the main features of printed graphic identifiers, radio frequency identifiers, and electronic data interchange protocols that have potential for the traceability of food and feed.

Two-dimensional printed graphic identifiers offer cheaper electronic identification alternative to radio-frequency identifiers (RFID), and may be the best alternatives until such time that existing difficulties with RFID application to food substances, originating from attenuation, are addressed fully and properly.

Preliminary results from an experiment aimed at the evaluation of UHF RFID application to the identification of modified atmosphere packaged meat show that to attain a probability of detection of approximately 0.67 (two-third) with a system that employs three antennae requires an effective radiated power of not less than 700 mW and distances of at most 0.2m. Linearly polarized antennae performed better than circularly polarized, especially at longer distances. Presence of bone in the meat samples is observed to have positively affected readability, although further experimentation is necessary to verify this phenomenon.

The lack of a single road-map to electronic data interchange (EDI) leaves the choice open to a few alternatives that may fall into two broad classes, namely internet based EDI enabled and traditional EDI based. Cost considerations make the former is an attractive choice and there are still developments in the area, perhaps with the new protocol, ebXML, leading the way.

Key words: food, feed, traceability, barcodes, RFID, EDI.

INTRODUCTION

Traceability, in relation to food, may be defined as the ability to follow a product batch and the ingredients of the product batch forward through the production process via the distribution chain to the immediate customer and backwards to the supplier of the ingredients, services and packaging, and processes (see Figure 1). In terms of input to the food chain, these products refer to food, feed for consumption by food-producing animal, food producing animals or substances through all stages of production and distribution [Cheftel, 2005, Schwägele, 2005, The European Commission, 2002, FSA-UK, 2002]. While authentication of products and processes are best carried out using biometric and bio-analytical methods [Schwägele, 2005, Prache et al., 2005], operational efficiency and accuracy of information handling is best served using automatic identification and data capture (EIDC). This is implemented using electronic identification tools and related data interchange infrastructure [Schwägele, 2005].

A functional traceability system must identify units or batches of all ingredients and products gather and properly organize temporal and spatial information on moved and transformed products,

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and consists of a system linking these data [FSA-UK, 2002]. As voluntary and mandatory labeling information expands mainly as a result of widening traceability requirements by legislation and consumer preference [Cheftel, 2005], so does the information to be recorded, transmitted, and stored for further use. The implication is that the data carriers need to match the requirement through larger sizes and/ or greater complexity [Zebra Technologies, 2004] with the accompanying higher costs.

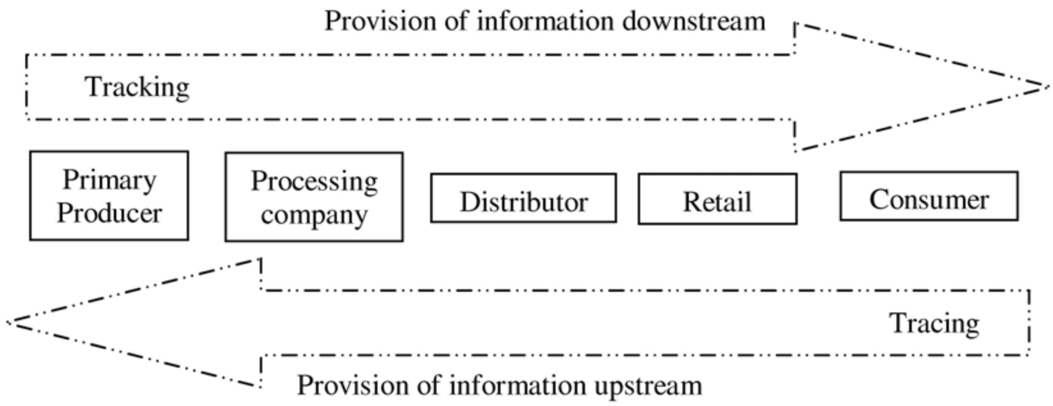


Fig. 1. A simplified view of information flow in traceability [Schwägele 2005].
Rys. 1. Uproszczony schemat przepływu informacji w trakcie procesu śledzenia towaru [Schwägele 2005].

Desirable features of electronic traceability systems are conformance to existing global identification and communications standards in order to improve accuracy and speed of traceability information [FSA-UK, 2002] and smooth operation in the system, unique identification internationally [EANI, 2002], overall cost-effectiveness and data security.

Technologies enabling traceability may be categorized into automatic identification and data management in the tracking and tracing of animals, food and feed, water, and the tracing of food/ and feed (where appropriate) ingredients to their sources. Previous reviews [FSA-UK, 2002] and studies (such as IDEA Project Team [2001]) show that electronic identification (EID) and electronic data interchange (EDI) are the best tools in delivering individual animal and product traceability.

Although technologies are developing quickly and new ones may still be in development like the ZigBee [ZigBee Standards Organization, 2005], Finkenzeller [2003] and Swartz [1999] identify one- and two-dimensional barcodes (referred hereafter as printed graphic identifiers, PGIs), optical character recognition, magnetic stripes, RFID (smart cards included) and automatic biometrics (such as voice recognition, finger printing, and retinal scanning [Marchant, 2002]) as the most outstanding automatic identification technologies. Of these, PGIs, retinal scans, and RFID have direct relevance to food traceability [Schwägele, 2005]. Although retinal scans are proven to be an effective automatic identification tool [Marchant, 2002], they can only be practically used for identity verification purposes, as their operation requires checking against an existing database of retinal vascular images. This leaves PGIs and RFIDs for use in the tracking of food and feed products.

This study reviews the features of major electronic identification and electronic data interchange tools used or which have potential of being used in traceability of food and feed, and a brief description of an ongoing study on the application of a UHF RFID system to meat traceability.

AUTOMATIC IDENTIFICATION DATA CARRIERS

Printed graphic identifiers

This section deals with PGIs that are known with the generic name barcode. PGIs are constrained by the conflicting requirements of high-density information, reliable code reading, minimal cost of printing and minimal cost of reading equipment [Pavlidis et al., 1990], and accordingly various codes exist to satisfy one or more of these requirements.

PGIs are attributed with merits such as low-cost (less than a cent); being accurately readable by machine with different symbologies offering differing levels of error detection/ protection; encoding possibilities for numeric, alphanumeric ASCII, and other characters; being well established; existence of different code forming materials and techniques such as metals, in addition to printed media; fast, line-of-sight readability with a wide range of equipment available catering for reading distances from direct contact to several metres; availability of wide range of symbol formation and printing software and hardware. Disadvantages of PGIs are low-capacity, typically less than 100 characters (linear codes) and at most 2335 alphanumeric characters (Data Matrix codes), dependence on symbology; requirement of line-of-sight; warping of label, and damage of symbol by hostile environmental factors such as moisture and friction; and being read-only [Acuity CiMatrix/Siemens, 2006; AIM, 2005; Jalaly and Robertson, 2005a, 2005b; Finkenzeller, 2003].

Linear barcode symbologies

In use for over a quarter of a century [AIM, 2005], and more than a hundred encoding schemes, linear barcodes are still the most widely used PGIs. Linear barcodes encode information along one dimension with varying widths of parallel light and dark patterns. A linear barcode would typically contain guard bar patterns at its ends to enable the reader identify the beginning and end of a code, and to enable bi-directional reading. For the EAN-13 symbology, for instance, it is bar-space-bar (101) [Pavlidis, 2000] on both sides. The reader illuminates the code symbol and measures the reflected light, from which it determines the pattern in width and brightness variations and decodes based on the encoding table for that particular symbology [Zebra Technologies, 2006].

The most common linear barcodes are Code 39, pioneered by the defense and automotive industries; the Universal Product Code (UPC), first employed by the supermarket industry in 1973 and adopted by the EAN-13 (European Article Numbering) in 1976 for applications in the grocery industry; Codabar, used in high safety requirement applications such as blood banks and other medical/clinical fields; Interleaved 2-of-5 (ITF), used in automotive industry, goods storage, pallets, shipping containers and heavy industry; and Code 128 (which is the parent set of the EAN-128 code structure [Anonymous, 2004d]). Bar codes may encode only numeric data (e.g. UPC/EAN-13 and ITF), or all or part of the ASCII character set (e.g. Codes 39 and 128) [AIM, 2005, Finkenzeller, 2003]. The advantages of linear barcodes are simplicity and cheaper readers, whereas their major disadvantage is that they have limited data storage capacity, and hence their function only to carry indices to databases - in a number plate fashion. Also too small and/or low-resolution printing can challenge readability [Pavlidis, 2000]. Detailed structures and encoding techniques employed for selected linear barcodes are given in Pavlidis et al. [1990].

Two-dimensional (2D) symbologies

There are two types of 2D symbologies - stacked and matrix type. The stacked symbols (e.g. Code 49 and PDF417 (see Figure 2) are structured in the form of a rectangular block consisting of numbers of rows, each of which is like a linear barcode. The matrix-type symbols (e.g. DataMatrix see Figure 2), Maxicode, and QR code) are made of an array of binary (black or white) cells placed in a grid. Individual matrix symbologies differ in the way input data is converted to a binary pattern, the way the pattern is placed on the grid, the grid size, and additional features needed to help locate the particular symbol in the field of view [Hahn & Joung, 2002]. 2D symbologies help overcome the analogue nature of encoding information in linear barcodes, by localizing the points where information is to be stored and only have to decide whether a location is black or white. They also offer greater data density compared to linear symbols. Furthermore, with some additional overhead, varying levels of immunity to error can be achieved [Acuity CiMatrix/Siemens, 2006, Anonymous, 2006]. 2D symbologies make the data density of PGIs more competitive to those of RFIDs (dealt with below), with a significantly lower cost [Pavlidis, 2000]. In this regard, 2D symbologies may be considered as the figurative mid-way house between linear barcodes and RFIDs, as they offer the sought data density at competitive price. Although other 2D symbologies also exist [Kato & Tan, 2005, Pavlidis, 2000], the PDF417 code (owing to its wide-spread use Pavlidis [2000]) and the Data Matrix code (as a representative matrix code) will be briefly discussed below.

Fig. 2. The word "traceability" encoded in PDF417 (left) and Data Matrix (right) Codes.
Rys. 2. Słowo „śledzenie” zakodowane kodem PDF417 (z lewej) oraz Data Matrix (z prawej).

The PDF417 Code

PDF417 (where PDF stands for portable data file, a name attributed to 2D symbologies) is the most widely used 2D symbology. This symbology is a stacked code designed to provide significantly higher density than linear barcodes while keeping most of their advantages [Pavlidis, 2000; Kato & Tan, 2005]. It consists of redundant information in its many code words. This allows stitching of partial scans (using laser scanners), which enables not only error detection but also error correction. As this level of error correction capability (and hence level of redundancy) is set by the user, one can say that this symbology has an embedded facility for security versus density trade-off [Pavlidis et al., 1992]. Up to 50 % of the label of PDF417 may be damaged or torn while maintaining readability [Anonymous, 2006]. The maximum data capacity of a PDF417 symbol is 1108 bytes, which is equivalent to 1850 ASCII characters (approximately 500 English words), or 2710 digits, and actual capacity is limited by the resolution of the scanner. As this symbology can also encode binary data it can be used to encode data like biometrics [Pavlidis, 2000], which is of a great significance in traceability.

The Data Matrix (DM) Code

The DM symbol has been used in many sectors of industry not so much for replacing other kind of graphic symbols, but extending barcode applicability to new areas [Acuity CiMatrix/Siemens, 2006]. DM codes can store up to 3116 numeric characters, 2335 alphanumeric characters, or 1555 bytes of binary data. Advantages of the DM symbology is encoding of data in real digital format and hence better tolerance to errors due to low-contrast printing, very high-information density, no need of predetermined orientation of code in relation to camera, and built-in error-correction capability. Information in DM codes can be retrieved from codes, parts of which have been damaged by as much as 20 %. In one study [Hecker, 2006] the DM code provided 99.74 % readability, including missed reads resulting from dirty tags, on over 1.5 million reads on reusable plastic containers. Added benefit of the DM code is that it is physically extensible within a wide range of sizes [Acuity CiMatrix/Siemens, 2006]. There is also a potential for further increase in data density if a multi-color DM code is adopted as proposed by Tarassenko et al. [2003].

Application of PGIs in traceability

The FoodTrace system [Anonymous, 2005], that is proven to be an effective traceability system in the industry, at least in Ireland, is based on the EAN-128 code and Application Identifiers "AI"s (an application identifier may be considered as a description of the content of what follows it in an EAN-128 barcode structure) defined by GS1. EAN-UCC standards on traceability of beef specify protocols, using part of their internationally accepted numbering and bar coding system, in the traceability of beef. In the EAN-UCC standard document [EANI, 2002] the AIs have been defined for reference source identity (ear-tag number, for instance), country of origin, country of initial process, country of processing, and approval number of processor. In addition, AIs for country of birth, country(ies) of fattening, country of slaughter and approval number of slaughterhouse, approval number of first cutting hall, approval number of second cutting hall, approval number of third to ninth cutting hall, either ear tag number for individual cutting or batch number of cuttings have been defined and recommended by GSI [Anonymous, 2005] for inclusion on carcass labels.

Radio Frequency Identification

Radio Frequency Identification (RFID) systems are characterized by the contactless transfer of power and data between the reader (a.k.a. interrogator) and the tag (a.k.a transponder) [Finkenzeller, 2003]. For that reason, while a line-of-sight is necessary for barcode scanning, RFID scanners can read even when the tag is embedded for either aesthetic or security reasons [Want, 2004]. Another disadvantage associated with barcodes is that they are not re-programmable and are of limited storage capacity [Finkenzeller, 2003], although there is an improvement in this regard in 2D PGIs [Hecker, 2006]. It is believed that RFIDs overcome these disadvantages and would bring about automatic tracking of assets. The operation of an RFID system is as follows. An RFID reader transmits a radio-frequency electromagnetic field, the tag receives the field, and uses part of the absorbed energy (Such RFID tags are called passive tags, as opposed to active tags where they have on-board power sources) to identify itself by changing the load on the reader (for low (LF), and high frequency (HF) systems), or the field pattern around it (UHF systems) in such a way as to send a pre-programmed code, which in turn is decoded by the reader (LF, HF, and UHF refer to RFID standards in the wave bands of 9 - 135 kHz; 6.78, 13.56, and 27.125 MHz; and 433.920, 869.0 and 915.0 MHz, respectively. Microwave (> 3 GHz) tags also exist (Finkenzeller, 2003)). A software compiles and collates the ID with other collected information on a database [Kampers et al., 1999; Scharfeld, 2001].

RFID tags are also classified according to their specification. Class-0 RFID tags have, by definition, the following required functions [Auto-ID Center, 2003]:

- being factory programmed with an electronic product code (EPC) (The EPC is the core identification segment of an RFID data; has internal sub-segments called the EPC version number, domain manager number, object class number, and serial number; and has sizes of 64, 96, 256, and up to 496 bits (in Class 1 Generation 2 tags), 24-bit kill code (a code to disable the RFID tag to stop tracking), and CRC (cyclic redundancy check, an error checking component),
- being read by the reader,
- being selected as part of a related group of tags,
- being individually destroyed,
- not containing re-writable memory.

EPCglobal also defines other four RFID tag classes based on the base class called Class-1. Class-1 identity tags are passive-backscatter tags with the minimum features of [Anonymous, 2004b]:

- an electronic product code (EPC) identifier,
- a tag identifier (TID),
- a kill function,
- optional password protected access control,

- optional user memory.

Class-2, Class-3, Class-4 or higher class tags do not, by specification, conflict with the operation of, nor degrade the performance of Class-1 tags located in the same RF environment [Anonymous, 2004b]. Class-2 tags possess higher functionality, and are passive tags with the following features above and beyond those of Class-1 tags:

- an extended TID,
- extended user memory,
- authenticated access control,
- additional features to be defined in Class-2 specification.

Class-3 tags are semi-passive tags with the following anticipated features above and beyond those of Class-2 tags:

- an internal power source,
- integrated sensing circuitry.

Class-4 tags are active tags with the following anticipated features above and beyond those Class-3 tags:

- tag-to-tag communication,
- active communications,
- ad-hoc networking capabilities.

Table 1. Comparison of linear barcodes with RFID systems [Finkenzeller 2003]
Tabela 1. Porównanie liniowych kodów kreskowych z systemem RFID [Finkenzeller 2003]

System parameter	Barcode	RFID systems
Typical data quantity (bytes)	1-100	16-64k
Data Density	low	very high
Machine readability	good	good
Readability by people	limited	impossible
Influence of dirt/dampness	very high	no influence
Influence of optical covering	total failure	no influence
Influence of direction and position	low	no influence
Degradation /wear	limited	no influence
Purchase cost	very low	medium
Operating costs (e.g. printer)	low	none
Unauthorized copying/modification	slight	impossible
Reading speed (including handling of data carrier)	low, ≈ 4 s	very fast, ≈ 0.5 s
Maximum distance between data carrier and reader	0-0.50 m	0-5 m
Additional features provided	none	temperature

Źródło: Kumar & Budin, 2006.

Table 1 contrasts linear barcodes with RFIDs. Although the technology is highly promising and there are desirable features for a traceability system such as security and high data capacity suitable for traceability information, they are still to be verified in situations where the effect of lossy and reflective materials must be reliably circumvented. The case in point is the fact that most, if not all food materials consist of lossy, moist contents, and/or conducting packages such as tins. Improvements attained with 2D symbologies have, at lease partially, overcome some of the setbacks listed in Table 1, especially regarding data quantity and data density.

Application of RFIDs in traceability

RFID has been considered the most important identification tool for the establishment of an effective traceability system [Wang et al., 2006]. RFID tags allow a manufacturer of food items to have an audit trail of moments of the retail unit's life, monitoring correct handling, storage, transportation and delivery. Some tags also have the capability to monitor temperature-controlled product on a per unit basis, hence allowing manufacturers to find out exactly where a temperature abuse occurred [Kumar & Budin, 2006].

The comparison of applications of Hazard Analysis and Critical Control Points (HACCP) on one hand, and RFID tracking on the other, for the purpose of reduction of recalls and the subsequent impact in the processed-food industry shows [Kumar & Budin, 2006] that:

- long history, long-time understanding among experts, prevention of food contamination by identifying potential hazard in the food processing chain are strengths of the HACCP; while being most advanced technology, ability to track units of sale to the cash register and product traceability being those of RFID,
- the perception of being bureaucratic, and frequent misunderstanding are the weaknesses of HACCP; while the facts that micro-organisms take time to manifest themselves, and that in-plant control capabilities not as clear apply in case of RFID,
- potential for further improvement, and re-training of workers are opportunities existing in HACCP; while the potential to change the retail practice, and direct consumer tracking in the event of an emergency in the case of RFID,
- eventual obsolescence in the wake of improved technology is a threat to HACCP; while system crashes, risk of hacking and loss of data are threats to RFID.

Hecker [2006], on the other hand, argues that RFID promises to solve problems associated with linear barcodes by enabling item-level automatic tracking throughout the supply chain, but this promise has been tempered by accuracy problems, high costs, and environmental limitations when used around metals and liquids. Therefore, he argues it might be prudent to slow down a bit, until such time that these issues are fully addressed. This issue is even more important to the food and feed industries as such features are dominant in food and feed items.

Another application of RFID technology in traceability is its use in animal identification. The radio frequency animal identification standard (ISO 11784/85) is a well tested [IDEA Project Team, 2001] application where animals are tagged and identified automatically, as required. The frequency of operation this standard specifies is 134.2 kHz [Kampers et al., 1999], owing to the low absorption rate, high penetration depth in non-metallic materials and water at this frequency [Finkenzeller, 2003]. The tag may be attached to the animal in one of three modes, namely ear tags, subcutaneous injection, or ruminal bolus (only applicable to ruminants). The bolus has been identified as the best tamper proof (99 % retention rate, and 100 % recovery rate) animal identification tag provided it is implanted at the right age and weight of animals [IDEA Project Team, 2001; Fallon et al., 2002].

THE EFFECTS OF DISTANCE, ANTENNA POWER, AND TYPE OF MEAT ON THE READING EFFICIENCY OF AN UHF RFID SYSTEM

Glidden et al. [2004] gives the theoretical range (m) of detection for tags as:

$$R \le \frac{\lambda}{4\pi}\sqrt{\frac{1.64 \cdot ERP_{reader} G_{tag}}{P_{tag}}} \qquad (1)$$

where P_{tag} is power required at the tag antenna output, G_{tag} is the tag antenna gain, ERP is the effective radiated power, and λ is the wavelength of the RF carrier (all in the MKS system of units). Want [2004] puts the dependence of signal strength as a function of the inverse cubic of distance. Either way, distance is a crucial factor for RFID operation. As actual P_{tag} cannot be directly measured the only means available is the monitoring of tag operation by placing it at different distances from the reader.

RFIDs depend on the interaction of EM waves with their surroundings (tags included) for their operation. As a result, material properties inside and around the actual medium of interest (such as a pack of meat) affect readability. An experiment is currently being conducted to verify the readability of class 1 Generation 1 UHF RFID (also applicable to Generation 2, as the operating frequencies are similar [Anonymous, 2004b]) system as applied to beef and pork samples. A brief account of the experiment, and the preliminary results is provided below.

MATERIALS AND METHODS

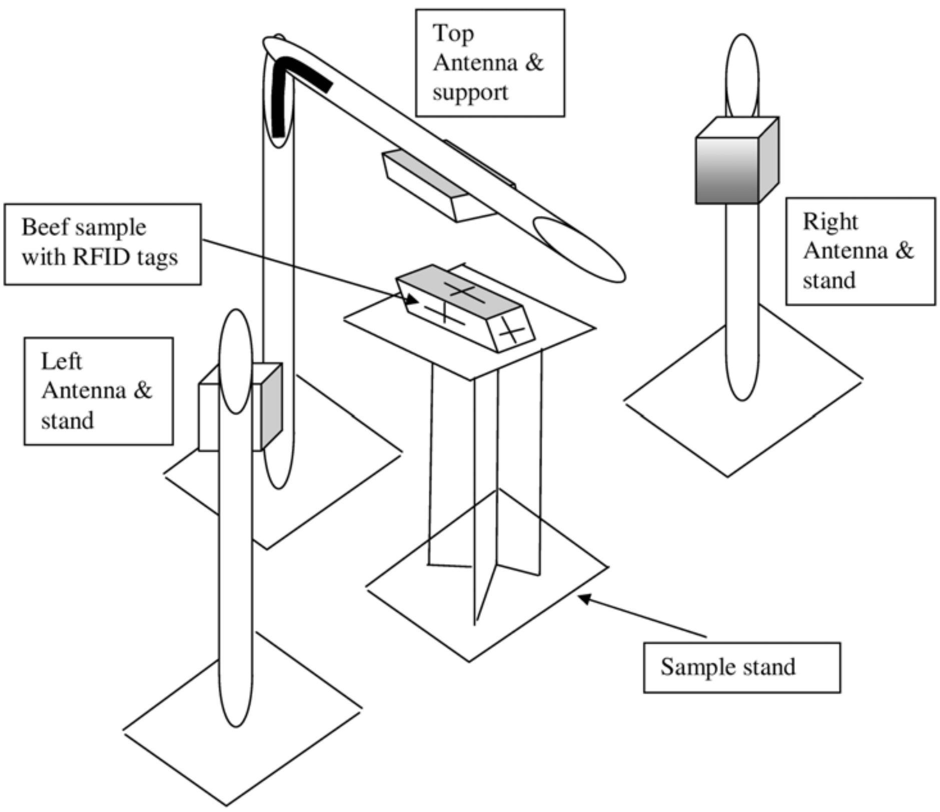


Fig. 3. Schematic representation of the physical arrangement of RFID readability test apparatus (this study).
Rys. 3. Schemat testowego urządzenia RFID.

Figure 3 is a schematic representation of the physical arrangement of RFID readability test apparatus developed in this study. The RFID system consists of a CAEN (Construzioni

Apparecchiature Electroniche Nucleari (C. A. E. N.) S.p.A., Sede Sociale, Uffici e laboratori: Via Vetraia, 11 - 55049 VIAREGGIO, Italy) UHF Class 1 Generation 1 RFID Development Kit, with sets of 3 antennae (linearly polarized, or circularly polarized), a perspex-made sample seat 1 m high and 0.2 m x 0.2 m top platform. PVC are pipes used as support for antennae, each of which was connected to the UHF RFID reader. A PC running a CAEN reader software was used to control the RFID system and acquire tag IDs.

Two modified atmosphere packaged beef and pork samples of roughly equal weight (ca. 1.1 kg), one from each meat type with bone and another without bone were used for the experiment. Two Class 1 Generation 1 UHF RFID tags of the Philips U-code type were bonded on each surface of each sample (12 in total), one tag always parallel to the ground and the other bonded perpendicular to it (shown in Figure 3).

Three antennae were used in each trial, and their distances from the sample were adjusted from a minimum of 0.2 m to a maximum of 1.2 m. The Effective Radiated Power (ERP) was adjusted between 101 to 2200 mW using the software provided.

A tally of total tags detected out of 12 was made after each reading procedure (with the omission of replicate detection), and this plotted against ERP and antenna distance.

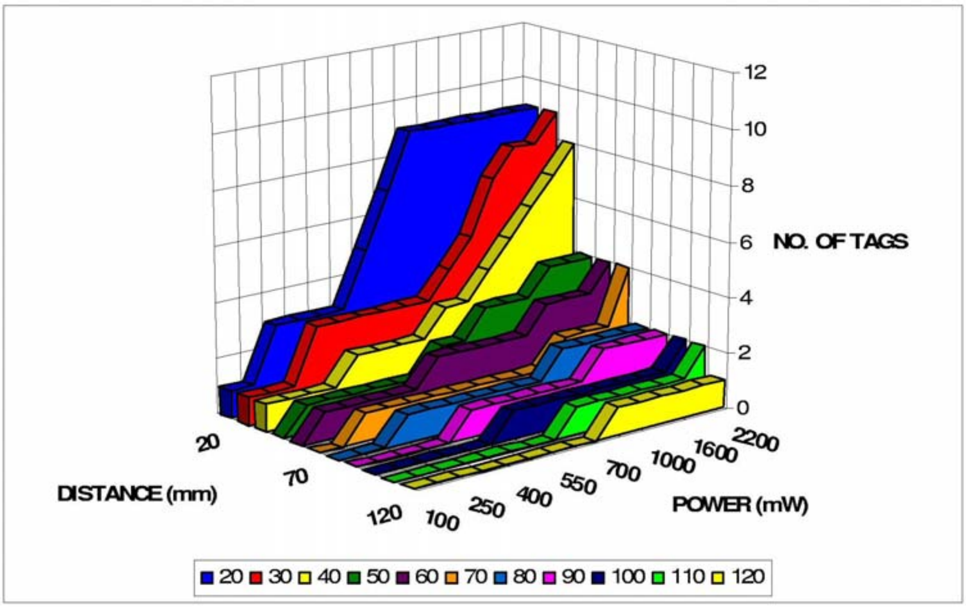
RESULTS AND DISCUSSION

Figures 4 and 5 show the number of tags detected as a function of antenna power and distance. Comparison of circularly polarized and linearly polarized antenna operation shows that use of linearly polarized type antennae yielded higher reading rates over larger distances (up to 1.2 m), whereas the performance of the circularly polarized type antennae declined dramatically at distances over 0.8 m.

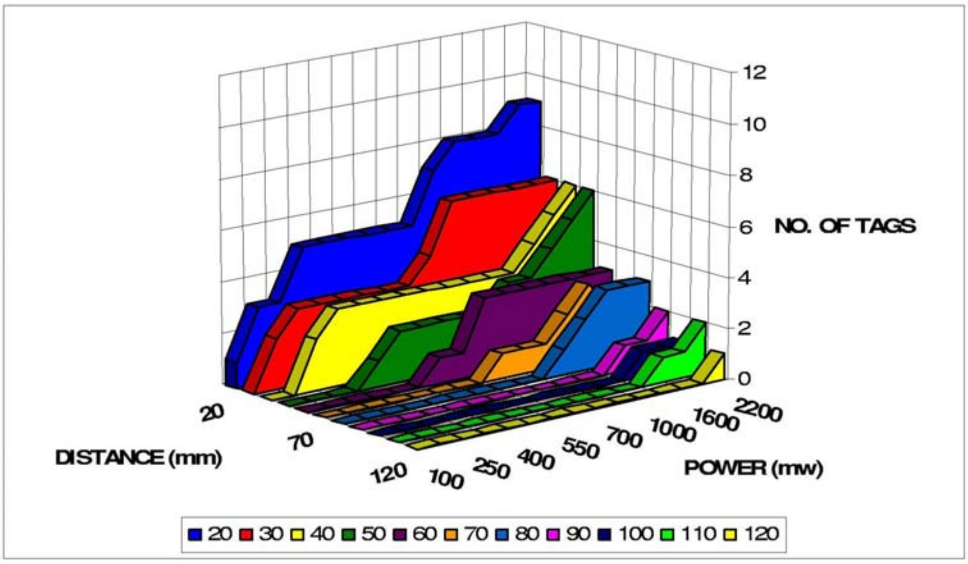
Also, as the ERP was increased the number of tags detected, at a given distance, increased - a trend common in both antenna types. The distance was also shown to be an important factor in that the number of tags detected decreased as the distance between tag and reader increased for a constant ERP. Preliminary results also suggest that the presence of bone in meat samples improved readability over longer distances regardless of antenna type used. This may be attributed to the lower loss caused by bone than meat [Pethig, 1987] (dielectric constants and conductivities for bone and muscle tissue are, respectively, 4.9 & 55, and 0.15 & 1.45, at 915 MHz), and perhaps due to a reflection at the interfaces between them.

These results also suggest that no significant difference exists between linearly polarized and circularly polarized antennae up to a distance of 0.5 m. However, read efficiency of circularly polarized antennae decreased after this point, while the linearly polarized antennae continued to detect tags up to a maximum of 1.2 m.

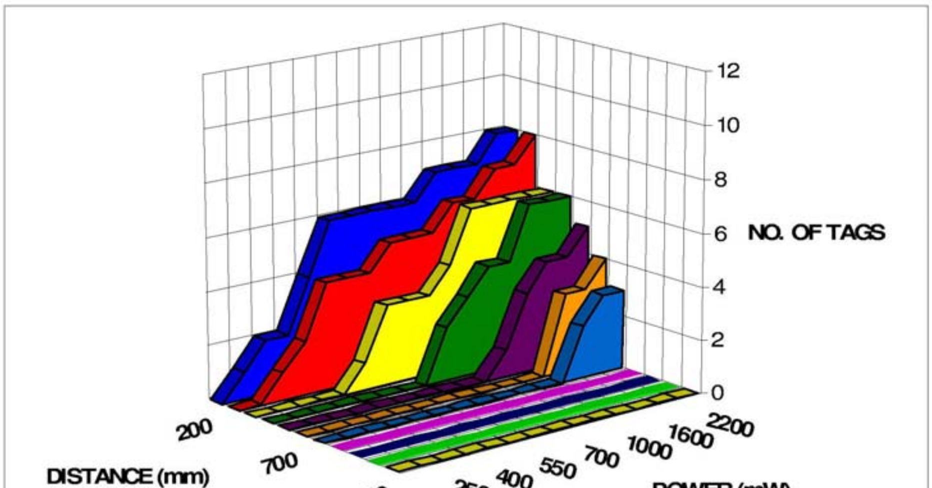
Again from these preliminary results, it can be said that linearly polarized antennae performed generally better than circularly polarized antennae, which may be attributable to the fact that for a perfectly aligned tag and reader antennae, a linearly polarized antenna delivers more RF power than its circularly polarized counterpart [Finkenzeller, 2003]. It is too being seen in Figure 3 that for each of the three linearly polarized antennae in the vertical direction (along the supports shown), there exist 4 tags in the plane of polarization. Also it can be seen that 2/3 (66.7 %) of tags were read with power levels of at least 700 mW and distances of at most 0.2 m.


12
10
8
6
4
2
0
NO. OF TAGS
20
70
120
DISTANCE (mm)
100
250
400
550
700
1000
1600
2200
POWER (mW)
20 30 40 50 60 70 80 90 100 110 120

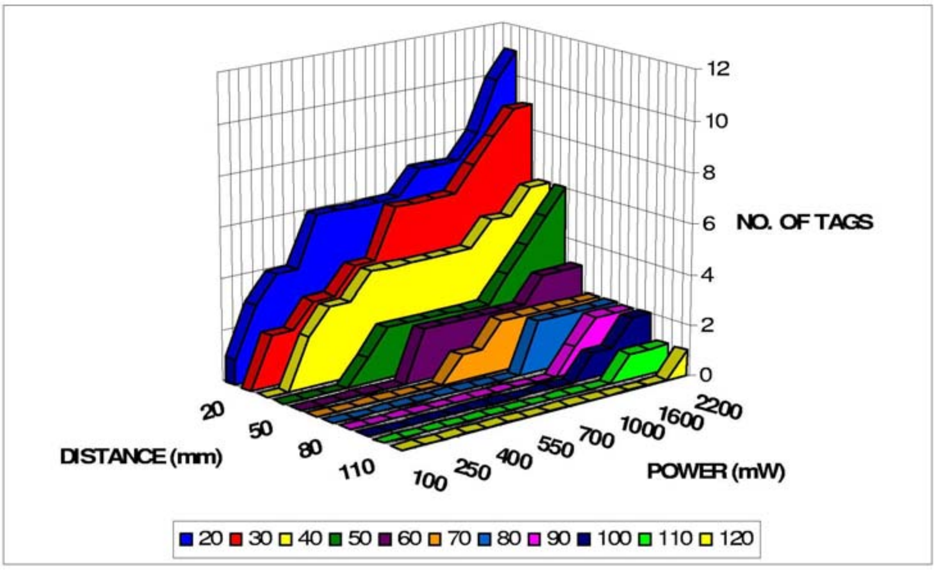
(a)


12
10
8
6
4
2
0
NO. OF TAGS
20
70
120
DISTANCE (mm)
100
250
400
550
700
1000
1600
2200
POWER (mw)
20 30 40 50 60 70 80 90 100 110 120

(b)


12
10
8
6
4
2
0
NO. OF TAGS
200
700
1200
DISTANCE (mm)
100
250
400
550
700
1000
1600
2200
POWER (mW)
200 300 400 500 600 700 800 900 1000 1100 1200

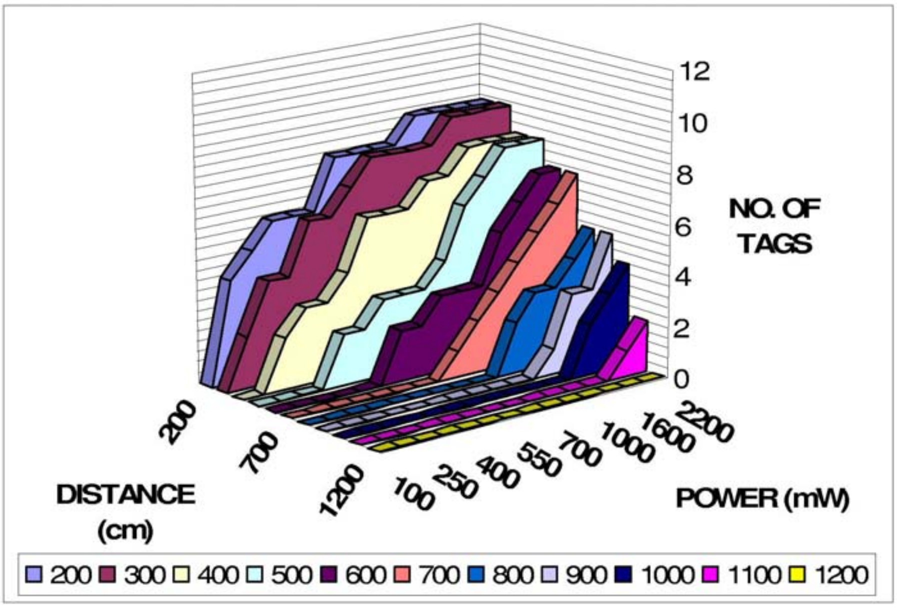
(c)



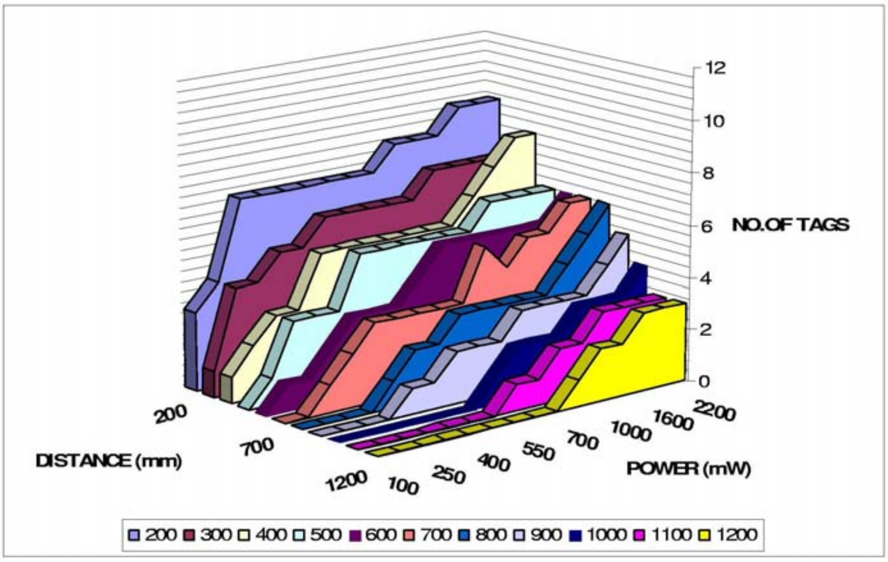
(d)

Fig. 4. Preliminary results from RFID readability test: (a) beef with bone, circularly polarized antenna, (b) beef with bone, linearly polarized antenna, (c) beef without bone, circularly polarized antenna, and (d) beef without bone, linearly polarized antenna (this study).

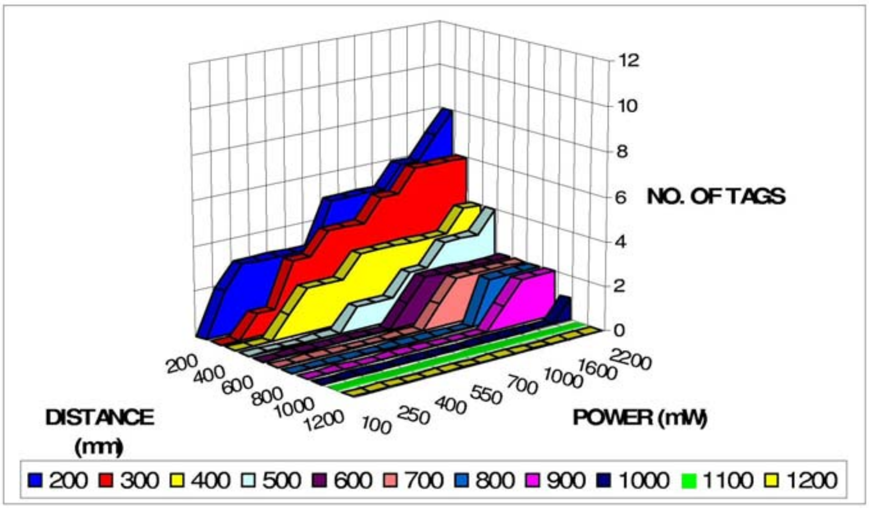
Rys. 4. Wstępne wyniki testu czytalności RFID: (a) wołowina z kością, antena spolaryzowana kołowo, (b) wołowina z kością, antena spolaryzowana liniowo, (c) wołowina bez kości, antena spolaryzowana kołowo, (d) wołowina bez kości, antena spolaryzowana liniowo.



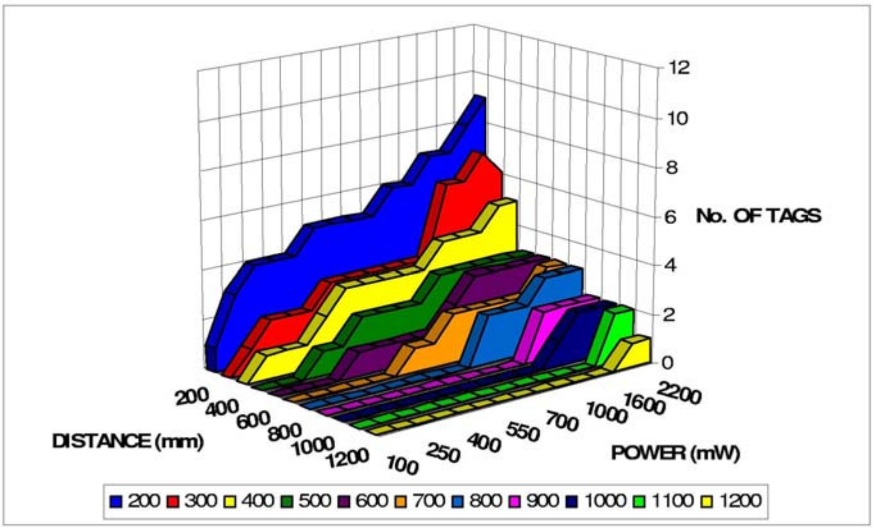
(a)



(b)



(c)



(d)

Fig. 5. Preliminary results from RFID readability test. (a) pork with bone, circularly polarized antenna, (b) pork with bone, linearly polarized antenna, (c) pork without bone, circularly polarized antenna, and (d) pork without bone, linearly polarized antenna (this study).

Rys. 5. Wstępne wyniki testu czytalności RFID: (a) wieprzowina z kością, antena spolaryzowana kołowo, (b) wieprzowina z kością, antena spolaryzowana liniowo, (c) wieprzowina bez kości, antena spolaryzowana kołowo, (d) wieprzowina bez kości, antena spolaryzowana liniowo.

ELECTRONIC DATA INTERCHANGE

Traceability data management methods range from paper based records to information technology enabled systems, for which there are different systems in the food industry [FSA-UK, 2002]. Technically, Electronic Data Interchange (EDI) is a reliable means for the exchange of traceability data. It comprises of computer-to-computer exchange of structured information, by agreed message standards, from one computer application to another with a minimum of human intervention. One typical application of EDI is the automated purchase of goods and services. EDI makes data transfer independent of transmission technologies like the Internet or private networks. Two major standards exist, namely the UN/EDIFACT (The United Nations rules for Electronic Data Interchange For Administration, Commerce and Transport) and the ANSI ASC X12, the latter being more popular in North America while the former is more so in the rest of the world [The Free Encyclopedia (http://en.wikipedia.org)]. UN/EDIFACT comprises a set of internationally agreed standards, directories and guidelines for the electronic interchange of structured data, and in particular that related to trade in goods and services between independent, computerized information systems [UNECE, 2006].

Formal document and transmission standards inherent in EDI combined with adequate bandwidth permit large transaction volumes [Gunasekaran et al., 2002]. However, high cost and non-flexible nature of dedicated EDI systems, is turning SMEs and large business alike to implement Internet based technologies compatible with EDI messaging protocols [Gunasekaran et al., 2002], or irrespective of compatibility [Themistocleous et al., 2004] for their electronic commerce activities. The XML/EDI (visit www.xmledi.org) integrates XML (The Extensible Markup Language -visit www.w3c.org, www.xml.org for details) with EDI to provide business, irrespective of size, and is a cheaper system to carry out electronic transactions with any trading partner worldwide. This model provides lower costs, compatibility with ANSI ASC X.12 and UN/EDIFACT, suitability for short-term trade relation, improved global accessibility, and easy integration with existing systems. The major cost is that EDI messages were four to eight times larger [Lu et al., 2001). Another XML-based messaging protocol is being developed by the ebXML Initiative, which aimed to develop a single global electronic market based on an open public infrastructure enabling the global use of electronic business information in an inter-operable, secure and consistent manner by all parties (www.xml.org).

E-mail-attached UN/EDIFACT messages have been implemented during the research phase of the IDEA Project [IDEA Project Team, 2001], with success. Therefore, one can say still the use of EDI messaging, in whatever the means of communication be, is an attractive option for the exchange of traceability information. Another development that may be effective in the transfer of data from a scattered farming community to central databases is through the use of mobile phones. In one application, farmers can register calf-births using their mobile phones (Mr. Alan King, Personal Communication, Department of Agriculture, Food and Rural Development, Ireland). The EANCOM, owned by GS1global is an EDI that is a subset of the UN/EDIFACT and incorporates the GS1 (EAN-UCC) numbering system. It allows to integrate the physical flow of goods with related information sent by electronic means [EAN International, 2005].

The EPCglobal Network (formerly the EPC Network) is intended to improve asset visibility and help ensure product safety and integrity across the supply chain, through the delivery of seamless, efficient, and secure business transactions. The EPC Network enables trading partners to track and trace items identified by the electronic product code (EPC) throughout the supply chain [Anonymous, 2004c]. In addition to operational efficiency, the EPC Network provides with applications that address counterfeiting, tampering, terrorism, and regulatory compliance - which are all requirements of a food traceability system [Anonymous, 2004a].

According to the above discussion regarding EDIs, there is not a single roadmap to EDI and this leaves the choice open to the alternatives that may fall into two broad classes, namely internet based EDI enabled, and traditional EDI based. The former may be led by the ebXML as heavyweight players such as the UN/CEFACT and ANSI are behind it (visit www.ebxml.org). This poses an opportunity as well as a challenge, and perhaps it is time that the Governmental bodies and the food/feed/agricultural industry look into standardization of EDI for the purpose of traceability.

Also, as stressed in FSA-UK [2002], there is a great element of trust being expected from partners, as there is no inseparable physical link between the information being recorded and the food item being traced. From this point of view, the accuracy of traceability information is limited by that of what is entered into the tracking and tracing technologies [EANI, 2002].

CONCLUSIONS

Although many applications outside the food industry have been reported and the future of RFID as a dominant tool for traceability seems assured, there still remain issues like operation in high-attenuation environments and cost, and an immediate adoption seems doubtful. The additional cost of RFID in traceability can add to the reluctance of the industry to adopt them. An incentive to the food-related sectors to share costs associated with traceability among all concerned sectors may help the food industry to adopt RFID systems.

2D PGIs have developed to the extent that they can be used to store traceability information such as biometrics of an animal, for instance, on board the product to be sold, and perhaps will serve in the medium term before the cost of RFID tags fall to an attractive cost level, and technical difficulties related to attenuation are decisively overcome. Linear barcodes on the other hand, being widely adopted by all major sectors including the food industry are likely to remain serving the function of holding the index to the database.

Given the multiple choices existing regarding EDI technologies, perhaps it is time Government bodies and food/feed/agricultural industry looked into the standardization of EDI as applied to food and feed traceability.

Preliminary results from a study on readability of a UHF RFID system show that a reliable automatic identification of beef and pork items in the supply chain requires further study with the hope to improve performance in detection.

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ELEKTRONICZNE ŚLEDZENIE PRZEBIEGU PRODUKCJI WYROBÓW MIĘSNYCH

STRESZCZENIE. Narzędzia elektroniczne, najczęściej stosowane w celu śledzenia partii żywności lub paszy to automatyczna identyfikacja oraz elektroniczna wymiana danych (EDI). Praca przedstawia podstawowe cechy drukowanych graficznych identyfikatorów, identyfikatorów wykorzystujących fale radiowe oraz protokołów elektronicznej wymiany danych, które mogą być stosowane przy śledzeniu partii żywności i pasz.
Zastosowanie dwuwymiarowego drukowanego graficznego identyfikatora jest tańszym sposobem elektronicznej identyfikacji w stosunku do identyfikatorów opartych na falach radiowych i wydają się być najlepszych rozwiązaniem do momentu rozwiązania problemów, jakie obecnie występują przy zastosowaniu identyfikatorów radiowych do śledzenia partii żywności.
Wstępne wyniki badań nad opracowaniem aplikacji wykorzystującej fale radiowe UHF do identyfikacji mięsa pakowanego w zmodyfikowanej atmosferze wykazują, że uzyskanie prawdopodobieństwa wykrycia równego 0,67 (dwie trzecie) przy zastosowaniu sytemu z trzema antenami wymaga efektywnej mocy nadawczej nie mniejszej niż 700 mW oraz odległości najwyżej 0,2 m. Zastosowanie anteny spolaryzowanej liniowo daje lepsze efekty niż spolaryzowanej kołowo, szczególnie na większych odległościach. Obecność kości w mięsie poprawia zdolność odczytu, jednak potwierdzenie tej obserwacji wymaga kolejnych badań.
Brak jednego rozwiązania umożliwiającego elektroniczną wymianę danych (EDI) prowadzi do wyboru jednego z kilku dostępnych rozwiązań, które można zaklasyfikować do jednej z dwóch grup: EDI oparte na usługach internetowych oraz EDI oparte na rozwiązaniach tradycyjnych. Ze względów kosztowych pierwsze rozwiązanie wydaje się atrakcyjniejsze. Obecnie trwają nadal badania nad rozwojem w tym kierunku, między innymi nad nowym protokołem ebXML.

Słowa kluczowe: żywność, pasza, śledzenie partii, kody kreskowe, RFID, EDI.

ELEKTRONISCHE VERFOLGUNG DES PRODUKTIONSPROZESSES VON FLEISCHWAREN

ZUSAMMENFASSUNG. Automatische Identifizierung und elektronischer Datenaustausch (EDI) sind zwei der am häufigsten anwendeten elektronischen Werkzeuge für die Verfolgung von Lebens- und Futtermitteln. Diese Arbeit zeigt die Eigenschaften der gedruckten Kennzeichnungen, RFID und elektronische Datensaustauschprotokollen, die Potential für die Verfolgung von Lebens- und Futtermitteln haben. Zweidimensionale, gedruckte Kennzeichnungen bieten eine billige Alternative zu RFID. Sie sind solange eine Alternativen bis zu dem Zeitpunkt, an dem die existierenden Schwierigkeiten mit der Anwendung von RFID auf Lebensmitteln entstehend gelöst worden sind. Erste Ergebnisse eines Experiments, das die Bewertung der Anwendung von UHF RFID zum Ziel hatte, gezielten, dass für eine Wahrscheinlichkeit der Erkennung von 0,67 drei Antennen gebraucht werden sowie eine effektiv ausgestrahlte Energie von mindestens 700 mW bei einer Entfernungen von höchstens 0.2 m. Linear polarisierte Antennen sind dabei besser als kreisförmig polarisierte, besonders bei größeren Entfernungen. Das Vorkommen von Knochen in den Fleischproben wirkt sich positiv auf die Lesbarkeit aus, dennoch sind weitere Experimente notwendig, um dieses Phänomen zu überprüfen. Der Mangel an einem einheitlichen Standard im elektronischen Datenaustausch (EDI) lässt die Wahl zwischen zwei Klassen von Alternativen; entweder internetbasiertes oder traditionelles EDI. Kosten-Überlegungen machen das erstgenannte ist eine attraktive Wahl und es gibt weitere Entwicklungen in diesem Gebiet, vielleicht sogar mit dem neuen Protokoll, ebXML.

Codewörter: Lebensmittel, Futter, Verfolgbarkeit, Barcodes, RFID, EDI.

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