Agris on-line Papers in Economics and Informatics

Volume II Number 2, 2010

Food Tracing and Interoperability of Information Systems in the Hungarian Meat Industry

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Abstract

The manufacture, distribution and retailing of foodstuffs became an extraordinarily complex business activity. The complete food chain must provide for the implementation of the strictest quality standards and safety regulations. Problems of food safety can be solved by keeping (and enforcing) applicable regulations, by introducing modern quality assurance systems, by making possible the traceability of products and their identification. The safety of product lines and tracing of products cannot be solved without using information systems of a certain level. During our research, it came to light that, generally, agrarian traceability struggles with many more problems. Companies try to live up to expectation, but they often apply different solutions with totally different approaches, while serving several different market aspects, depending on their customers. The conception of the Digital Business Ecosystem (DBE) has come, to build an Internet-based environment in which businesses will be able to interact with each other efficiently. The DBE solutions based on community philosophy are able to create applications, which can solve most of food traceability problems.

Key words

Quality management, information systems, meat industry, food tracing, Digital Business Ecosystem.

Introduction

Increasingly, consumers tend to worry about the safety and origin of foods. Recent scandals related to the safety and origin of foods, sometimes overreacted to by the press, have fundamentally shaken consumer confidence in foodstuffs available at shops (Lakner et al., 2005). The manufacture, distribution and retailing of foodstuffs became an extraordinarily complex business activity. This extraordinary complexity makes it necessary to develop overall controlling processes that are indispensable if we want to safeguard the quality product of safe and excellent foodstuffs (Lang and Heasman, 2004). With a background like this, the complete food chain must provide for the implementation of the strictest quality standards and safety regulations. Therefore, in every phase of the food chain, from the purchase of raw material through manufacture, distribution and sales, whether we examine a retail shop or a supply unit, the quality demands up to the actual products, processes and handling methods should be fulfilled. At the same time, since consumers do not really have an overlook of the technology and circumstances of product, only confidence in a manufacturer can help in choosing his food. Problems of food safety can be solved by keeping (and enforcing) applicable regulations, by introducing modern quality assurance systems, by making possible the traceability of products and their identification - beyond any doubt. The safety of product lines and tracing of products cannot be solved without using information systems of a certain level (Schiefer, 2008). In any case, one could greatly improve the level of food safety and the information supply by installing the newest technologies and informatics facilities at every participant in a product line in the meat industry. For SMEs it is very difficult to keep up with challenges of the mentioned problems. The agri-food companies especially the SMEs are underprivileged. In commodities and especially in food commodities, the establishment of tracking and tracing capabilities meets many barriers that have prevented their broad based use beyond what is legally required (Fritz and Schiefer, 2009). The conception of the Digital Business Ecosystem (DBE) has come, to build an Internet-based environment in which businesses will be able to interact with each other efficiently. The DBE is supported by the new hardware and software technologies, network topologies. The open source and component-based software, the collaborative environment, development and the popular and quick developing network technologies can establish the extensive use of DBE.

Objectives

Our research focused on the IT support and development of quality management systems in the Hungarian meat industry (as refers to meat industrial product enterprises, the poultry industry is also involved) especially food tracing systems, utilized identification systems and those which may become applicable in the future. We also studied information technology tools and examined the establishment of domestic meat industry enterprises. On the basis of the results of our examinations, we set out to elaborate a cost-efficient device and to offer a system that might assist meat industrial enterprises to choose an applicable quality system, while ensuring effective product identification and tracing, taking into consideration the advantages of introducing such a device. More specifically, the aims of our research were:

Regarding to regulations, standards referring to product qualification and product identification, we set the following targets: to treat and systemize the standards and specifications applied primarily in meat industrial product chains, as well as to determine which of these are relevant. First, we considered which of the composite Hungarian and EU standards, directives and orders are pertinent to our areas of study. We assumed that the up-to-datedness of the applied quality control system must be connected with the economic development of the company, its place in the product chain and its market position.

The types of identification technologies and their supporting technological systems may differ within a specific product chain, depending on the nature of e.g. manufacturing from raw materials to the point in time when one has produced a finished article. Moreover, the ways such technologies may be applied might be influenced by any number of factors. These include the environment, economic factors, the quantity of to-be-stored information connected to the product or e.g. systems of product and manufacture. Our objective is to explore, systemize and analyze those identification technologies applicable for meat industrial product lines which may serve as the basis for further research.

As a next objective, we wished to explore the requirements of product tracing, the levels of tracing, its organizational-economic background and its realization at the various steps of the meat industrial product line. Of the steps on the product line, we wish to focus first of all on the following phases: tracing of forages, questions of livestock tracing and the area of processed products. Among all these, we primarily wish to analyze meat plants, based on questionnaires, personal visits at plants and deep interviews.

Among our objectives, we developed a research portal on the Internet connected in part with the above-mentioned areas of interrogation, and in part with the aim of gathering information and publishing the results for use by plants and experts. Furthermore we created a conception of DBE application which can support the companies in their food traceability methods.

The research portal

In the framework of our research, we developed a research portal that is meant to support research work applied in the meat industry, specifically pertaining to planned modern quality control and tracing systems and to the publication of the knowledge base connected with the topic (http://nodes.agr.unideb.hu/kutatas/fi/).

In preparing a portal, we had quite a few aims. On the one hand, we wanted to summarize at one place the most important knowledge concerning the topic- especially that which is difficult to access in Hungary or which otherwise would require significant research in the literature and in the Internet. On the other hand, the questionnaire which we compiled and sent to meat industry enterprises could be filled in an electronic way through the portal. Indeed, the results of the survey can be viewed there, too.

On the portal, information can be found in many topics:

- **Technologies.** Under this menu, we gathered the most relevant articles concerning identification techniques (one part of it is available only in English, unfortunately) as well as information materials, companies dealing with the solutions, and a further collection of professional portals in the field of identification.

- **Issues.** A collection of publications and literatures referring to the topic. By means of the presented books, anyone can access detailed information about quality management, tracing, food safety and modern identification techniques. Selecting among the publications is assisted by a short summary of every literature item, located next to the basic data.
- **Publications.** On this site, we listed the publications of the Department of Economics and Agricultural Informatics issues in this subject, as well as the papers and thesis handed in to scientific students' conferences.
- **Regulations**. A site comprising a collection of standards, orders and regulations. Here can be found links necessary to cognition of compulsory, voluntary respectively commercial standards referring to meat industry and references to pages comprising detailed descriptions.
- **Links.** It comprises of the availability of organizations and authorities acting in domestic and international meat and food safety.

Identification technologies in meat industry product chains

A full traceability of products can be realized by the adaptation of numbering and bar code systems, as well as by electronic and biological marking systems, on the basis of their appropriate combination. The regulations of identification provide for the continuity and reliability of tracing among independent partners (a common language and compatibility of information are necessary). In order to assure that the tracing from producers to consumers effectively works at each step, the information referring to the product must be forwarded together with other attaching information. Through the quick development of computer technology, a number of new and innovative methods have been elaborated to solve this problem (Podgornik et al., 1994).

In the course of our questionnaire, we also examined product identification technologies that are most often a factory number or a series or bar code. There was no undertaking with radio frequency identification among those replying (although I know of a company using this technology); therefore, we draw the conclusion that incidence of the technology is low at present.

In order to compare the identification technologies, we have to consider several factors. While there are numerous advantages and disadvantages for each solution in comparison with the other techniques, we still cannot unanimously choose the one that conforms to the requirements of the meat industry product chain the best, as there are different challenges on each step of the product chain. We performed the comparison of the identification technologies on the basis of different characteristics (Figure 1). Of the examined technologies, the figure does not feature Bokode- (Mohan et al., 2009) and DNS-based systems, because we cannot call these fully- developed technologies - they are only at an experimental level.

Spreading of the new identification technologies are set back by two major factors:

- One of these is the obviously high cost. The price of biological identifiers RFID and of DNS-based identifiers decreased in a significant way in later years. The cost of identifiers per product (sometimes per kg) would allow for their usage, but meat industry enterprises are often unable to pay the required investments connected with them beyond the costs of identifiers attached to the products. Therefore, we also need decoding of information and the development of an infrastructure able to decode, and to prepare the information systems and develop human resources. Consequently, with respect to the present income relations of the branch, the investment return time is too long.

	Linear bar codes (EAN/UPC)	Multi-dimensional (2D) bar codes	RFID labels (active)	RFID labels (passive)
Price	Very low	Relatively low	Very high	High
Operational costs	Low	Low	High	Relatively high
Writing tolerance limit	High	Average	Cannot be interpreted	It cannot be interpreted
Reading tolerance limit	High	Average	None, or possibly at some frequencies	None, or possibly at some frequencies
If the scanner is damaged	Cannot be restored	It can be restored by using an error-correcting algorithm	It cannot be restored (although it is well protected)	It cannot be restored (although it is well protected)
Things necessary for scanning	Any visual scanner	CCD scanner	Antenna, scanner, energy source	Antenna, reader
Size of ID to be stored	Relatively small	Small	Large	It depends on the given type
Database dependence	The information cannot be interpreted without the database	The information cannot be interpreted without the database	Automatically transmitted information	Directly available information
Level of standardization	Totally standardized	128 characters (ISO 646)	There are currently several standards	There are currently several standards
Main areas of usage	In all areas of the supply chain	Mainly in industrial fields	Mainly for identification systems	In many fields, in theft protection
General costs	Relatively small	Relatively low	It is currently very high	It is currently very high

Figure 1: Comparison of identification techniques (based on Erabuild, 2009).

- On the other hand, modern identification techniques allow significant advantages over traditional solutions, if their usage accompanies the whole product chain. At present, the most different solutions are being used on those steps of the chain which are mostly incompatible. The systems cannot be harmonized or only difficultly, and often there is a need for a new coding.

New standards are needed. The modern identification techniques have to increase the efficiency of processes in a way that the fit the information systems of both the enterprise and its partners. Currently, there could even be several parallel standards for a given ID. The penetration of these techniques greatly depends on the uniformization of standards, which would make interoperability through the entire product chain possible.

The integration of mobile and wireless technologies is important (Szilágyi and Herdon, 2006). Mobile phones and other portable devices greatly help RFID technology becoming widely known. By using a wireless connection, we can always accurately log and – if needed – modify product information (by scanning an RFID label or a bar code), no matter where we are in the product chain.

Tracing foods

To be able to withdraw the product in question from a market in the case of a food problem, one has to dispose of appropriate information, referring to each ingredient and the manufacturing processes. In the course of a questionnaire, we examined what kinds of data Hungarian enterprises have about their products (Figure 2). The results show us that the largest defect in the re-traceability chain is in the traceability of forages, 29 per cent of the inquired firms do not dispose of any information about forages of the livestock. A FeedTrace system could help to reduce the lack of information (Cebeci at al., 2009). During our research, it came to light that, generally, agrarian traceability struggles with many more problems. In the cases of the other ingredients, one can talk about the present levels, since an effective product withdrawal only exists if every participant in the product chain has a clear picture about the origin of his products.

The number of product withdrawals increases towards the end of a product chain (Table 1). This is nevertheless not a surprising result. On the one hand, problems with a foodstuff can be sensed most often by the consumers; on the other hand, the more ingredients a certain product has, the more manufacturing processes it has undergone and, therefore, the greater the chance of various problems is.

We came to an interesting result when we defined the depth of tracing data. 53 percent of Hungarian firms dispose of traceability data displayed for certain products, the registration of which is without any doubt the most expensive, but a product withdrawal can cost much less since one only has to withdraw those products with a problem from the market and not a greater amount. However, in my experience, this number may be fairly high, so the question has not been understood properly.

Information systems at meat industry enterprises

It becomes clear from our survey done in Hungarian meat industry enterprises that integrated management systems may only be affordable for companies with high revenues. The licensing and introductory budget of these (e.g. infrastructure, training shaping) in most cases cost 10 Million Hungarian Forints. Obviously, this is practically unaffordable for small companies and would mean an extremely long cost recovery period. It is univocal from our survey how many from the total meat industry enterprises use individual and/or integrated systems (Figure 3). We can see that companies using part modules and island solutions are in the majority. This is why I considered it important to analyze the quality management, tracing and information systems of small enterprises.

We examined how, in Hungary, the usage of information systems at meat companies changes according to revenues (Figure 3). Based on the results, less information systems will be used in the category of least revenues, 63.6 percent of companies do not have a system at all. In companies above 1 Billion Hungarian Forints, this number hardly exceeds 10 percent; in such cases, integrated company management is used to a great extent (half of the repliers). In the other groups, mixed results were obtained, but generally we can state that using individual island solutions is frequent in various types of companies. These will rather be used in the fields of stock economy and finances. For usage of integrated company management, the picture is fairly complex, too. Mainly Microsoft Navision and CSB systems are characteristic, while some run programs they themselves developed. From other systems, one can mention one or two examples.

The domestic agriculture economy urgently needs innovation processes, as well as fundamental and supporting innovation processes that would improve its positions among competitors, which have shattered in the last few years. Dealing with the topic is repeatedly reasoned by the fact that the 2007-2013 development policy of the EU may decisively influence the long term result of the race among nations and community of nations (Husti, 2007). This is the reason why we inquired how much the enterprises spend from their yearly revenues on the improvement and maintenance of their informatics systems, and if they are planning such investments, what the volume of the investment is.

Solutions for interoperability

Interoperability is one of the key concerns in the enterprise domain. It is a multidimensional problem that can concern different layers of the enterprise. One of the difficulties enterprises are facing is the lack of interoperability of systems and software applications to manage and progress in their business. Organizations are looking for new methods of work and business relationships, and the exchange of information and documents with new partners is often incapable of being executed automatically and in an electronic format. This is mainly due to problems of incompatibility in the information representation and in the software application methods adopted (Jardim-Goncalves at al., 2006). Several approaches have been developed

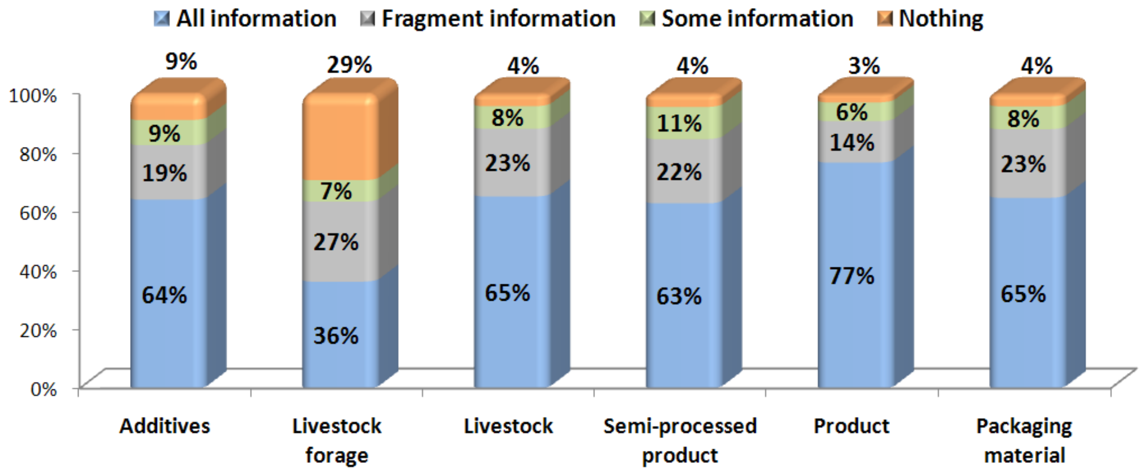

Figure 2: Available information of meat products.

	Stock-raising	Livestock buying up	Slaughtering	Food processing	Distributing of owen ready products
Never	71,43%	66,67%	72,22%	56,94%	35,29%
Sometimes	28,57%	29,17%	25,00%	40,28%	58,82%
Several times	0,00%	4,17%	2,78%	2,78%	5,88%

Table 1: Proportion of food withdrawals at certain levels of a product chain in meat industry.

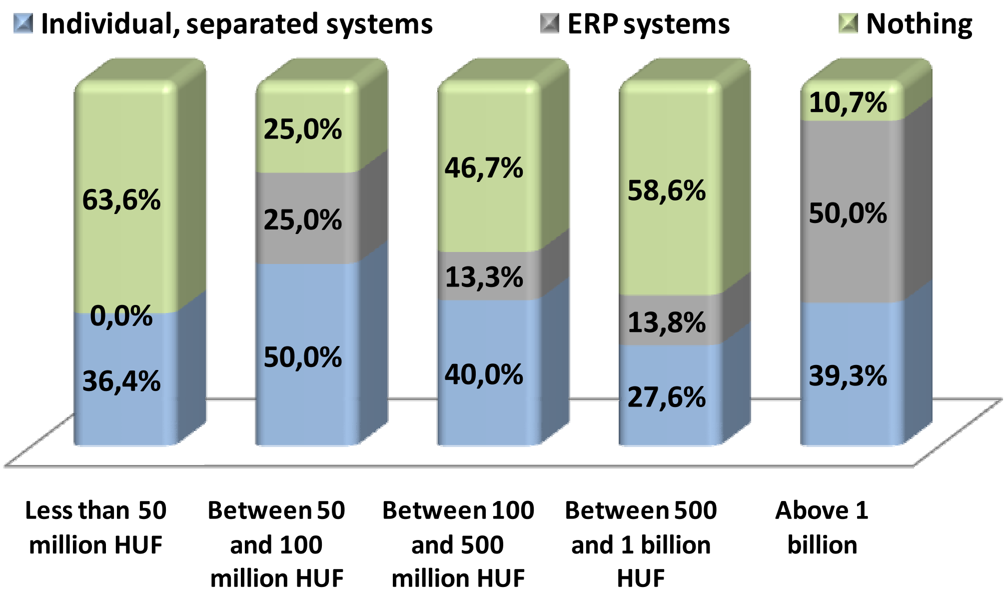

Figure 3. Usage of information systems according to revenues.

for collaborative network. However, their focus is mainly on technical aspects related to inter-organizational communication. The service-oriented architecture (SOA) as ‘‘a set of components which can be invoked, and whose interface descriptions can be published and discovered’’ does not consider the services architecture. Technical interoperability concerns technical issues related to e-communication, e.g., issues on linking applications and services addressing aspects related to: interfaces; ICT platforms; information integration; exchange and accessibility; security, standards; services. But this is not enough in the business applications. Information /knowledge interoperability has to focus the following aspects: information/knowledge representation and management, learning ability, rights to access information, knowledge sharing, aspects related to the adaptation and recombination of knowledge in a collaborative network during its life-cycle (Chituc at al., 2009).

The Framework for Enterprise Interoperability (FEI), currently under standardisation (CEN/ISO 11354) defines a classification scheme to categorise knowledge for interoperability according to three dimensions: interoperability barriers, interoperability approaches, and enterprise levels (Naudet at al.). The technical architecture of KodA is based on SOA and subsequently consists of the three basic layers: business process management layer, business services layer, business application layer. The KodA focuses on the supply chain for processing food products which was communicated and discussed at different forums. This has resulted in establishing the agriXchange group that has the objective to harmonize agricultural data exchange at a European level (Wolfert at al., 2009).

The Digital Ecosystem Concept

The DE is: unlike a client-server architecture, where the communication is centralized and which acts as a command and control environment; unlike a Peer-to-Peer architecture, where, at any time, each agent has a well defined role, i.e. can only be client or server, but not both; unlike a Grid architecture, which stitches partners together for resource sharing but cannot avoid counter free riding; unlike a Web service network, where brokers are centralized and service requesters and providers are distributed in a hybrid architecture that does not guarantee trust and QoS. A Digital Ecosystem instead is an open community, and there is no permanent need for centralized or distributed control or for single-role behavior. In a Digital Ecosystem, a leadership structure may be formed in response to the dynamic needs of the environment. An agent in a Digital Ecosystem can be a client and a server at the same time. In the same message, agents may offer a service to others as a Server and request help as a Client. There is no centralized control structure or fixed role assignment. There is no preconfigured global architecture, where the communication and collaboration is based on swarm intelligence: Unlike traditional environments, digital ecosystems are self-organizing systems which can form different architectural models through swarm intelligence, where local interactions between agents determine the global behavior.

A prototype tracing solution based on DBE Consept and Toolset

IT solutions of the food chain traceability could be based on DBE solutions. One of the most important properties of this method that all data is stored in the owner database and the data is served if it is requested by the authenticated DBE server. All connected nodes have own database are stored in their own database server. Forasmuch many organizations have exiting information system (ERP) , where they store the neccessary data . We assure possibility to connect other existing systems to the DBE by XML technology (Figure 4). (We use the portability property of the XML).

The database structure is available for download and use. In case of the traceability the XML file contains the following information: Company name, TRU (Traceable Resource Unit) identification number, Output id., Input id. In addition, we need a web server where the portal software is running. The portal prepaired with open source tools according to DBE principles. The prototype system is suitable for both top-down and bottom-up tracking and traceing. The working methods are the follows:

Top-down: You can see a text field on the website. You can type or scan the barcode by the help of a barcode scanner. The web server can identify the producer by the barcode. Certainly, it works only if the company has joined the community and their barcodes are stored in the database. We can reach

```xml
<?xml version="1.0" encoding="ISO-8859-2"?>
<product>
<productname>húspép</productname> /*name of the ingredient*/
<tru>12434567889</tru> /* Traceable Resource Unit id*/
<inp>kz ltd</inp> /* Supplier company id*/
<outp>xy company</outp> /* Customer company id*/
</product>
```

Figure 4. Portable data in XML.

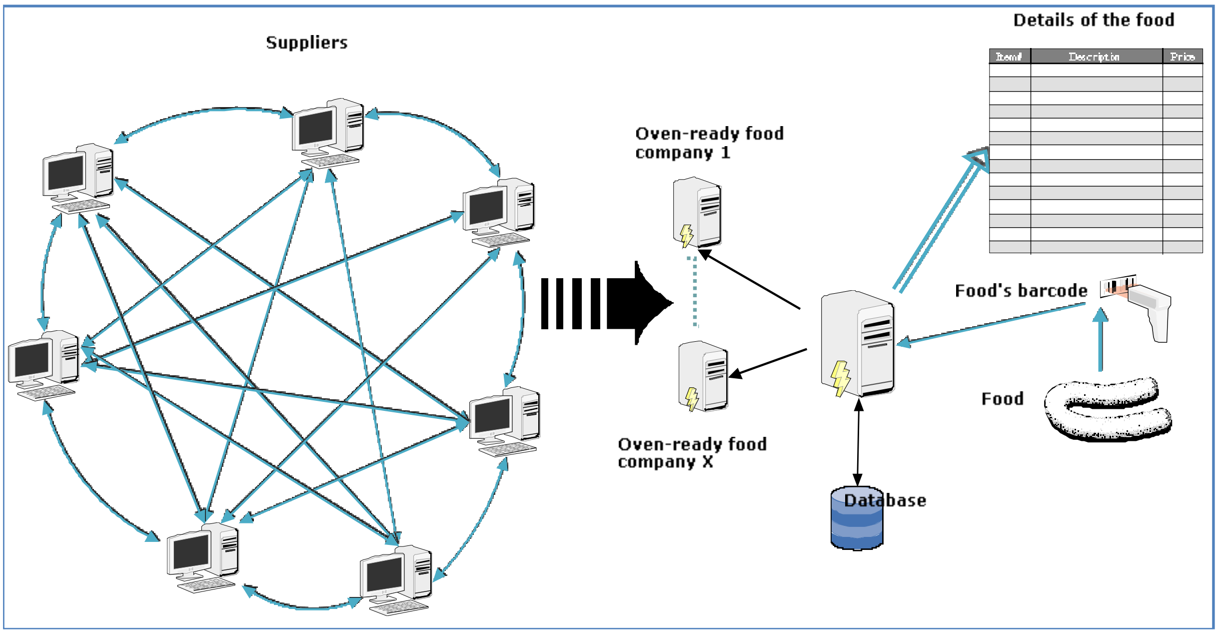

Figure 5. DBE community.

the data wich are strored in the ERP system by the product's barcode. The data show us the ingredients of the product. Inputs displayed on this page, so that the input supplier of the database searches the details of ingredients and send to the server for further processing and display, and then recursively to the product suppliers to get the similar information. We can reach the bottom level of the supply chain. It looks like a tree-structure.

Bottom-up: The knowledge of the barcode of lowest level of basic ingredient we can get besides of the basic details we can know the place of the deliveries as well. Then,either of the products manufactured by the companies which are on the N-1st level will be choosen which contain the ingredient of the company on the Nth. level. This goes on, until we reach the top level. Where we get the oven-ready products, which contain the basic ingredient.

With this prototype We have an opportunity to trace the full path of life of the product, if only all participant have been joined to the community (Figure 5). The above solution can greatly facilitate the precise monitoring the flow of substances occurring in food. Thus, the appearance of any food safety hazard we have opportunity to achieve rapid and efficient product recall.

Conclusions

The use of quality management systems does not show any great fluctuation in the given areas, except for ISO, GXP and the systems used in trade, which depends on the levels of product processing. The bar code technique is currently the absolute leader in the sector. Although modern solutions provide numerous advantages, their profitable application is not possible for the time being. Our results provide a suitable basis for the participants of the product chain to get to know and select the technology suitable for them. We drew the following conclusions in relation to the penetration of identification technologies: Hungarian enterprises most often use some serial number, lot number or bar code; The high cost level needed for building up the whole infrastructure puts obstacles in the way of the introduction of new technologies (RFID, DNS); The penetration of these techniques greatly depends on the uniformization of standards, which would make interoperability through the entire product chain possible. The biggest rupture of the traceability chain exists in the tracing of forages, 29% of interviewed enterprises have no information about the feeding of live animals. Companies try to live up to expectation, but they often apply different solutions with totally different approaches, while serving several different market aspects, depending on their customers. The special needs arising in the food industry can only be satisfied by an integrated ERP system, as it is important to cover each step of the sector and not to have holes in the production chain. We established that enterprises spend less than 1% of their income on information technology investments (the average of the entire food sector), which is a very little amount spent on the implementation of developments and modernization. For this very reason, partial solutions are rather frequent at enterprises, while the ratio of using new technologies is low. One of the main problem is the lack of capital in this sector that is why the open source technologies might help to implement new solutions in the meat industry.

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