University doctoral (PhD) dissertation abstract

INFORMATION TECHNOLOGY TOOLS AND SYSTEMS IN THE QUALITY ASSURANCE OF MEAT PRODUCT CHAINS

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1. OBJECTIVES

In addition to the IT support and development of quality management systems in the meat industry (as refers to meat industrial product enterprises, the poultry industry is also involved), my research focused on food tracing systems, utilized identification systems and those which may become applicable in the future. I also studied information technology tools and examined the establishment of domestic meat industry enterprises (Figure 1). On the basis of the results of my examinations, I 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 my research were:

1. As the subject of this research is defined by regulations, standards and orders referring to product qualification and product identification, I 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, I consider which of the composite Hungarian and EU standards, directives and orders are pertinent to my areas of study. As a hypothesis, I 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.

2. Identification technologies make the traceability of a product in a product chain possible and their use is relevant during almost every phase of the product line, as it is necessary to provide for the unambiguous identification of each individual product. 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. My 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. I presumed that the applied identification technologies are mostly based on the

traditional numerical and bar code systems, but in the more developed plants, the more up-to-date RFID-based identification technologies are already in use.

3. As a next objective, I 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, I 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, I primarily wish to analyze meat plants, based on questionnaires, personal visits at plants and deep interviews.

4. The next target of my research is the exploration of information systems at meat industry companies. More specifically, I examine the question of product tracing there. In the cases of medium and larger meat industry companies, the running of information systems (integrated information systems) is essential. In my dissertation, I primarily focus on that circle of companies and enterprises where product tracing functions have been integrated. Research of central (national, sectoral) information systems providing for food safety, food chain supervision and the realization of withdrawal of products is indispensable in my paper and so is their link with different steps of any chain of products. Investigation of these links comprises livestock identification, central registers linked with the field of breeding, as well as most importantly with the Rapid Alert System for Food and Feed.

5. During my research, it came to light that there are very few publications and little knowledge available about this topic in Hungary. Among my objectives, I 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. This portal can also assist B.Sc. students in the Department of Informatics and Administration, majoring in Agricultural Engineering, when they study the subject of IT possibilities of quality assurance.

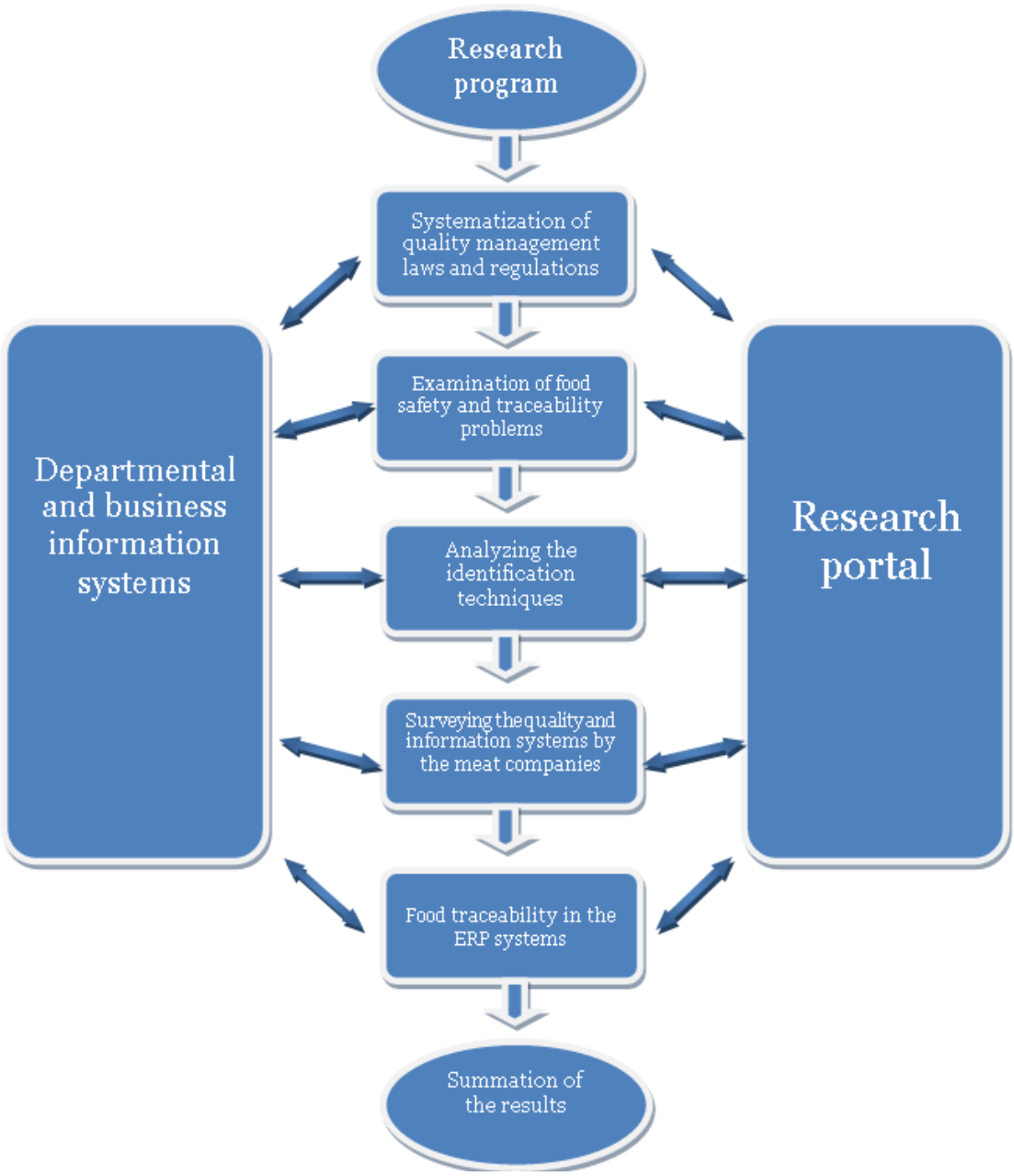

Figure 1: Structure of research work

2. ANTECEDENTS AND THE APPLIED METHODS

2.1. Antecedents

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. 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. 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. 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.

2.2. Applied methods

I began to research food safety and tracing systems and to explore identification technologies, as well as to analyze product tracing through information systems, by examining the literature. During this “desk” research (secondary research), I surveyed publications and expert studies on the topic. I gathered knowledge and purveyed results referring to my field of research out of these. In spite of the fact that secondary research is the major starting-point of the investigation, thorough professional interviews and consultations were indispensable, in order to produce the case studies. I visited many meat plants to test the

solutions used in the sector in practice. In the course of the deep interviews, I familiarized myself with the applied technologies and systems, I gained information on the thematic of the research portal and I held dialogues with quality assurance and IT experts about questions of content and the methodology of the questionnaires. They can supply priceless background information for understanding several key questions. In this manner, a portion of the primary, qualitative research was also used as the basis for determining the significance of the information.

During my research work, it was necessary to consistently describe all the tasks to be done by the enterprises with their contentual and temporal dependences. For this purpose, I used the ARIS business process modeling and planning software system to analyze the business (production) processes and to describe them in my study. ARIS is a general, widely used methodology for the unique modeling, description and documentation of the operation of enterprises. The aim of this methodology is to use uniform objects and models within a uniform framework. Of the methods available, I used an extended Event driven Process Chain (eEPC) diagram to demonstrate the processes. More specifically, there are two general methods for the realization of process chains. “Lean” modeling plots only the temporal and logical process aspects in an eEPC. On the contrary, extended modeling integrates functions and data, as well as the static correlations between products/services and organizational view into eEPC; therefore, I chose this modeling type. In the model, the linkage of tasks is done on the basis of their triggering events or those that occurred as a result of completing a given task. The process chains can be defined on different detail levels and abstract planes.

During my research work, I used ARIS Designer ver. 7.0 to model processes and to determine and describe the main control points of product tracing.

The Internet version of the questionnaire was prepared by a Limesurvey software system. The software offers a solution with a full value, open code of source, and with a “php web” administration surface in 50 languages, by which we can create an infinite number of questions and choices of replies in twenty different types of questions. I stored the questionnaires and the data in a MySQL data base, and then converted the answers using the application into a form that can be processed by the SPSS program packet. The evaluation was made the same way. For presentation of the results and preparation of diagrams, I used Microsoft Office Excel 2007. Methods of comparing analysis have been used by system

selection, and by comparing the evaluation of different identification and tracing techniques. I followed the method in which I compared the theories explored in the first part of the paper, as well as the experience I gained from the plant visits, interviews and surveys. I therefore attempted to comprise generally valid statements and show the trends of information technology support of quality management systems (inductive apprehension).

3. MAJOR CONCLUSIONS OF THE DISSERTION

3.1. Professional information service of the research portal

In the framework of my research, I made 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. (Figure 2)

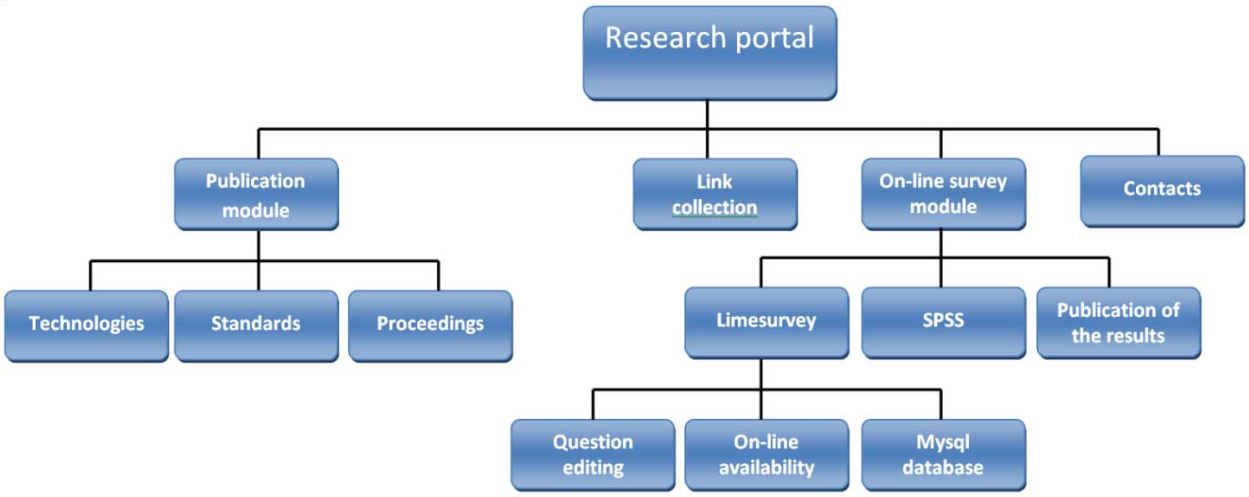

Figure 2: Sketch of the research portal

In preparing a portal, I had quite a few aims. On the one hand, I 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. As far as I know, any similar initiative can only be found on the portal: nyomonkovethetoseg.hu. Unfortunately, the content of the page has been the same for years. It will hardly be expanded by a couple pieces of new information. On the other hand, the questionnaire which I 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, I 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, I listed the publications of the Department of Economics and Agrarian 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.

I measured attendance using Google Analytics. As concerns attendance, since its launch in 2009, its turnover has doubled every month, excepting April 2009. It has been looked up from 28 different computers and 624 visits of the site have been registered. (Figure 3) The site has been accessed mostly indirectly (due to the fact e.g. that the we provided the availability in the questionnaire, too), but hits by Internet searchers is also growing (50) and also 10 external web sites refer to the portal. The enquirers viewed 2,22 pages on average and 57,65 percent was the proportion of returnees, i.e. the proportion of those returning to the site. For the time being, only a Hungarian version of the portal exists, but I am planning its translation into English language, as well as expansion of the content. Consequently, the site will be mostly visited from Hungary, mainly from Debrecen, Budapest, Szeged and other large cities.

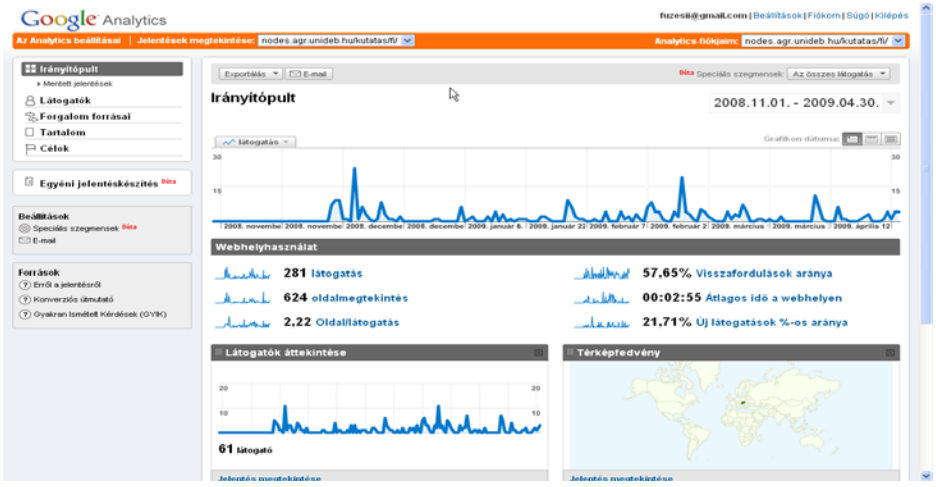

Figure 3: Screen of the Google Analytics control unit

3.2. Usage of quality management systems

Today, we can say that all food companies in Hungary have introduced a system of quality management. I considered it relevant to examine which systems will be use by meat industry

enterprises in Hungary at specific levels of product lines (Table 1). By introducing the systems, one can produce goods of better quality. Furthermore, there is strong pressure from food companies on suppliers to meet the expectations and regulations of the European Union, which is also not incidental. This can be seen from my survey: each of the companies on the product line from those inquired disposes of an HACCP, although this result is not surprising, since its application became compulsory in 2002. Usage of GXP regulations and commercial standards depends greatly on the level of product chain where the firm can be found. Generally, one can also say that usage of TQM and ISO 22000 systems is very low, unfortunately.

Table 1 Usage of quality management in the product chain

	HACCP	GMP, GHP reference books	ISO 9000 regulations	BRC, IFS	TQM	ISO 22000
Stock-raising	100%	7%	40%	13%	7%	7%
Livestock buying up	100%	12%	36%	28%	4%	8%
Slaughtering	100%	8%	27%	27%	3%	11%
Food processing	100%	11%	35%	30%	3%	7%
Distributing of oven-ready products	100%	0%	47%	37%	0%	11%

Applying quality management systems does not show a great variation at the steps of meat industry product line, excepting a few cases:

- At companies acting in breeding (as well) application of systems (IFS, BRC) in use in trade is obviously low, because mostly they are not directly connected with trade chains unless they have other activities which make the establishment of such a relationship necessary. In parallel, by increasing the processed level, this usage will grow.
- At companies dealing with the sale of ready-to-cook articles, usage of ISO standard is growing; in the same way, this will cease usage of GXP systems used in product.

I found it interesting to explore the proportion of applying quality management according to revenue, since introduction and audit might be costly, so firms may be influenced by them. The result is as I had expected: we can state that with an increase in revenue, the number of systems in use also increases (Figure 4), although in cases of companies with revenues of 100 and 500 Million Forints, a repeated setback can be experienced. This phenomenon requires

further examination. (Inside the certain revenue category, the number of answers was distributed fairly moderated, so variation of fit cannot explain unexpected results.)

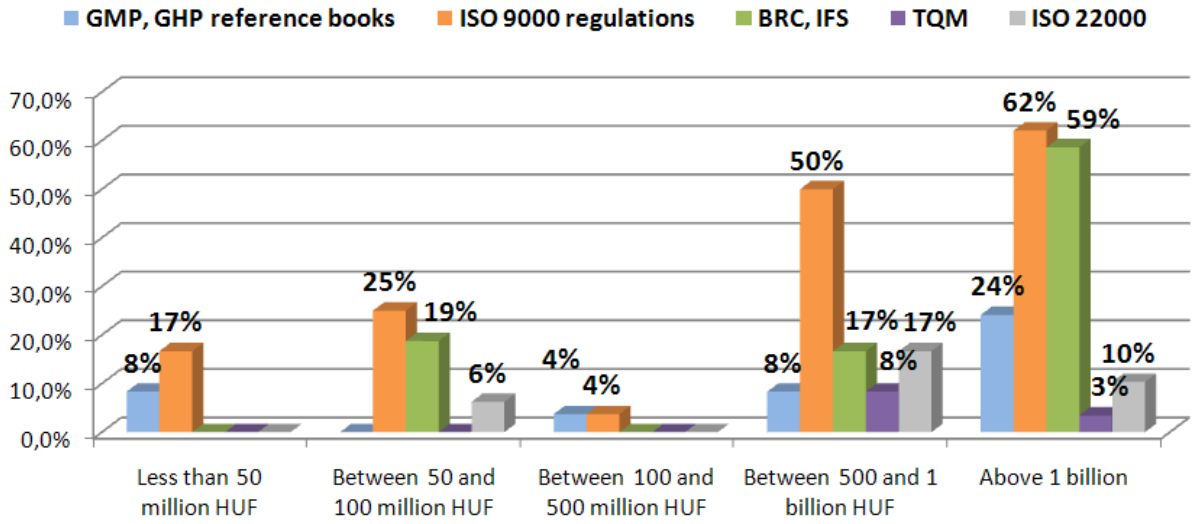

Figure 4: Usage of quality management systems according to revenue

3.2.1. Microbiological databases and models

Most food industry end products are rather complex and it is very difficult to determine or even to classify their components and, therefore, the dynamics of the microbe population found in them. It is a further difficulty to survey the possible microbiological reactions, as there are many variables and the outcome of this effort would be rather doubtful. The number of possible variations of microbe characteristics (e.g. growth rate, germination time) greatly increases with the increase of response time. In order to solve problems such as this, the ComBase database was developed at the conference called “Predictive Modeling in Foods”, which was held in Paris in 2003. ComBase is very useful in a sense that it established precise (mathematical and quantitative) bases for further microbiological research projects. Many researchers, risk assessment experts, offices, food producers and their related lab heads use it, as the published data can be quickly and freely obtained. Moreover, it is a useful tool in estimating predictive microbiological results. Currently, it contains 40 thousand kinetic data series about the growth, survival and inactivity of bacteria that can be found in foods. The majority of data illustrate a curve that is based on laboratory food medium or food observations, using a living germ number. Users compare their observations to the independent prognoses included in the software package; therefore, they can draw conclusions as to the expected results. ComBase is a microbiological database that is regularly used by the risk assessors of different countries; therefore, we can consider it to be an internationally acknowledged test centre. As a matter of course, we have come across several

microbiological databases and identification systems on the Internet. Links to these sources can be found in Table 2.

In recent years, other areas have developed significantly, as well. Information technology revolutionized the methods of analyzing diseases of food origin. We can come across several free software products dealing with the processing of epidemiological data (e.g. Epi Info or Epidata). In most countries, observation data of infectious diseases are collected from physicians in electronic form, using some kind of standard format. These systems are much more effective and they provide more information than paper-based reports. Therefore, IT tools can contribute to the development of sensing tools and, consequently, to the realization of food-induced epidemics. Furthermore, GIS systems provide opportunities to epidemiologists to regionally circumscribe infections.

The PulseNet system is a good example of genetic databases for pathogens of food origin. This system was developed by the CDC (Centers for Disease Control and Prevention). The network was established in the Unites States in 1996. The aim of this nationwide computer network which connects public health laboratories was to make it possible to quickly identify pathogens that are present in foods. Due to the success of this network, many similar systems have been established to-date, e.g. in Canada in 2000, in the Pacific Ocean area of Asia in 2002, and in Europe and in Latin America in 2003. These networks cooperate with each other under the aegis of PulseNet International, in order to provide common solutions to the increasing problems concerning food-induced diseases and bioterrorism. The international network currently has six independent networks with a total 81 member countries. The network contributes to the more efficient global information exchange between international laboratories and food safety experts about the molecular characteristics of pathogens. Therefore, it becomes possible to realize events connected to food consumption in time and to operate an early warning system through the laboratory system. For example, the system classifies the branches of Salmonella and E. coli that cause human diseases and it stores the results in a so-called “Bionumerics” database, the data of which are used by laboratories that participate in the program. With the help of this database, several large food infection epidemics could be stopped and the DNA directory compiled on the basis of the samples could serve as a reference for further cases.

On the Internet, we can also find other databases that serve in comparing the genetic make-up of pathogens. The virus database of the Health Protection Agency in the United Kingdom was a good example for this, as it contains the data of all viral branches that caused infections during the last ten years. These databases can be efficient tools in determining the sources of food infections and in identifying tendencies.

Table 2: Main microbiological databases on the Internet

Name	Area of usability	Links
Combined Database for Predictive Microbiology	Microbiological research	http://www.combase.cc/
PulseNet	Genetic databases	http://www.pulsenetinternational.org/
Health Protection Agency	Genetic databases	http://www.hpa.org.uk/HPA/
EPI Info	Processing and analysis of epidemiological data	http://www.cdc.gov/epiinfo/
EPIdata	Processing and analysis of epidemiological data	http://www.epidata.dk/
Food Safety Network	Information centre for food infections	http://www.foodsafetynetwork.ca/
Promed	Information centre for food infections	http://www.promedmail.org/

3.2.2. Software support of the use of quality management systems

For most enterprises, it is difficult and expensive to conform to compulsory quality management systems. Quality management software products could help them in this process. These softwares can be classified into several categories; there are a large number of applications that can help companies to more easily and quickly take care of numerous food safety and quality management processes:

- They provide a uniform framework for quality management.
- They provide continuous compliance with standards and regulations (e.g. ISO, HACCP, IFS, BRC).
- They reduce the administration time concerning food safety issues. Documents can be simply stored, it is easy to update and print them.
- Protocols are integrated into the software. This means that users continuously get instructions and notifications about their pending tasks; the application guides them through the steps of introducing the quality management system.
- Information can be stored, edited and observed at several locations, even through remote connection.
- It is easy to identify and categorize threat sources, components and processes.
- Paper-based administration will be significantly reduced. All information and reports are stored in one system which is easily available and modifiable.
- The system automatically alerts workers to perform their pending tasks. These tasks could be to fill out electronic forms, to make a journal entry, to perform maintenance jobs, to participate in a call back process, or to examine unusual cases.

- After setting the levels of responsibility, those responsible will have a view of all the quality management activities belonging to them.
- Due to the web-based character of the application, any data and information can be queried with a browser from anywhere.
- Most systems already support mobile solutions, so the mentioned tasks can be performed by a Smartphone, table PC or a PDA.

There are software products that introduce these systems and those that help users master them. By using them, we can plan and introduce our quality management system. For example, an HACCP instructional software helps us to easily and quickly put together the HACCP plan of an enterprise, in conformity with the food safety requirements. Furthermore, we can identify the necessary processes in accordance with the individual business processes of the company. Therefore, the HACCP software and the model-like procedures significantly shorten the time needed for introduction.

3.3. Adaptation of 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.

In the course of my questionnaire, I 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, I 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. I performed the comparison of the identification technologies

on the basis of different characteristics (Figure 5). Of the examined technologies, the figure does not feature Bokode- and DNS-based systems, because we cannot call these fully-developed technologies - they are only at an experimental level.

	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
Overall				
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 5: Comparison of identification techniques

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 recovery time is too long.

- 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. 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.

3.4. Tracing foods

When examining the tracing techniques that can be applied during the product processing steps, I observed the tracing system of Debreceni Hús Plc., taking the production processes of a specific product as a basis. By using this system, one can identify production lots and daily production quantities per product type. Therefore, the so-called internal tracing will be realized. I used ARIS business process modeling and planning software system to map the process.

The described system is capable of the entire traceability of products within the enterprise; both basic and auxiliary materials can be traced for a certain delivery. During the examination of meat industry product chains, we can find relatively few examples for this. Nevertheless, in this examined case, it can be a problem that the recording of documents (data) serving traceability is done manually, which poses the risk of human error and the damaging of tags. In order to solve these problems, it would be worth using more modern identification and data storage concepts (bar codes, RFID) and establishing a central database that would improve the transparency of the system. It would also be practical to use a computerized registry system covering everything (the current solution only covers certain areas). In a system such as this, data would be built on each other, recorded next to each other; therefore, they could be easily accessed if necessary.

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, I examined what kinds of data Hungarian enterprises have about their products (Figure 6). 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. During my 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.

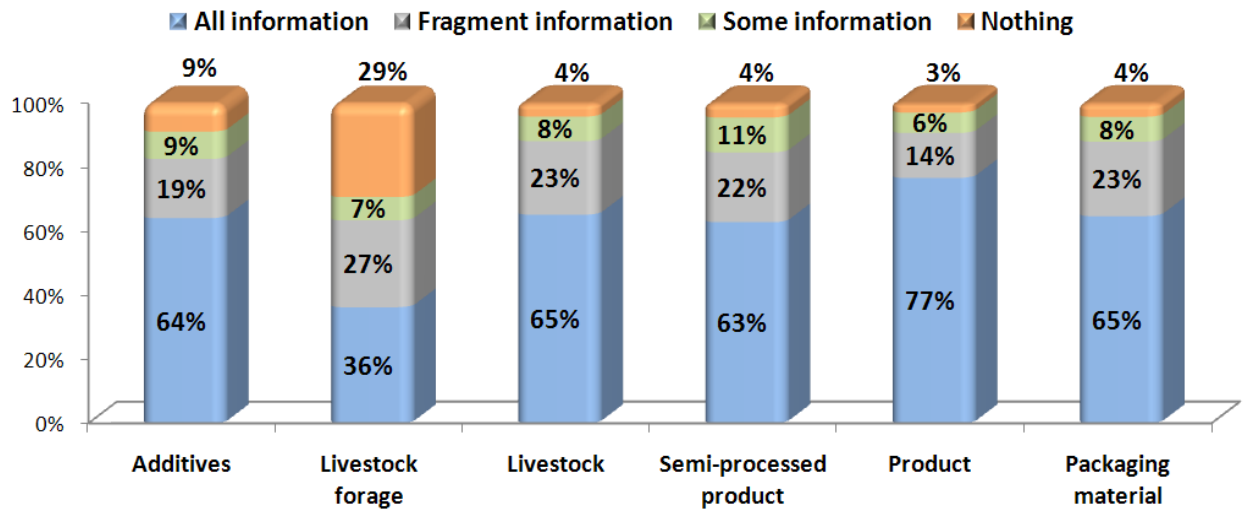

Figure 6: Available information of meat products

The number of product withdrawals increases towards the end of a product chain (Figure 7). 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.

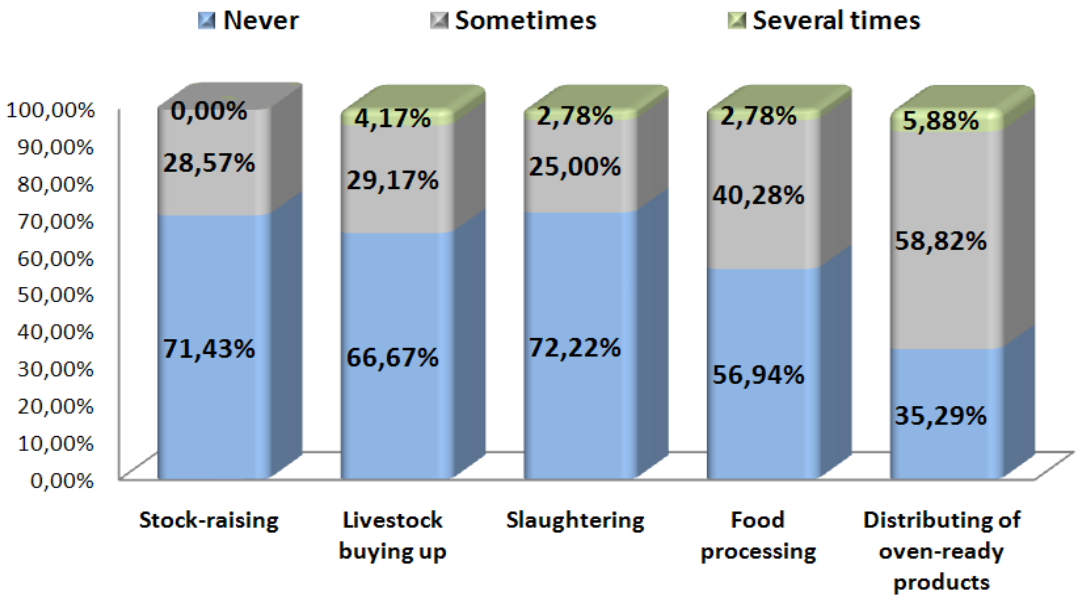

Figure 7: Proportion of food withdrawals at certain levels of a product chain in meat industry

I came to an interesting result when I defined the depth of tracing data (Figure 8). 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.

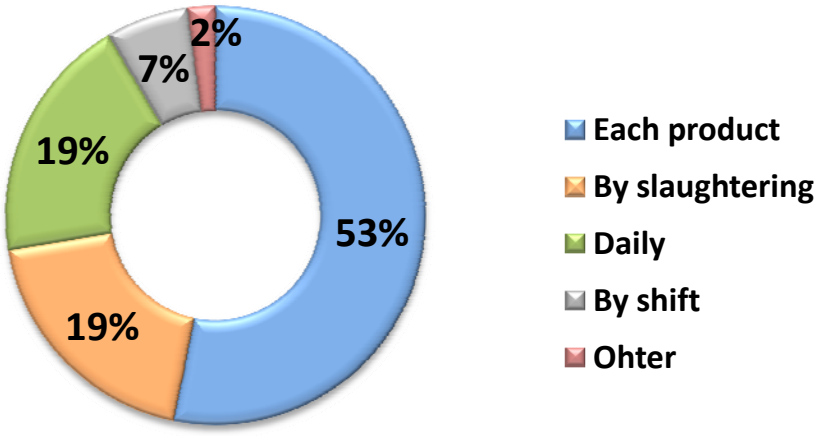

Figure 8: Depth if the tracing data

The economic aspects of traceability are rarely examined. In my study, I examine the organizational and general economic aspects of the traceability of multi-component foods. A multi-component food is a product that is produced from the combination of different

agricultural goods (or products processed in different ways). Their general feature is that they are produced on the basis of a particular method and the quality of the end product is highly dependent on the quality of each component. Today, we can come across many multi-component products in shops. The tracing of these products in the product chain is a rather complex coordination problem; new measures had to be taken in order to take care of them.

There are many companies in the food chain that perform different activities in different areas. Due to the globalization, the range of these companies continuously grows and so does the complexity of the food network. It follows from this that horizontal and vertical correlations of different strengths could develop in all points of the supply chain. The other feature of food production and processing is heterogeneity, which significantly influences the coordination of activities. The three levels of the simplified three-step model (Figure 9) are producers, intermediate processing units and the last processing unit of the product.

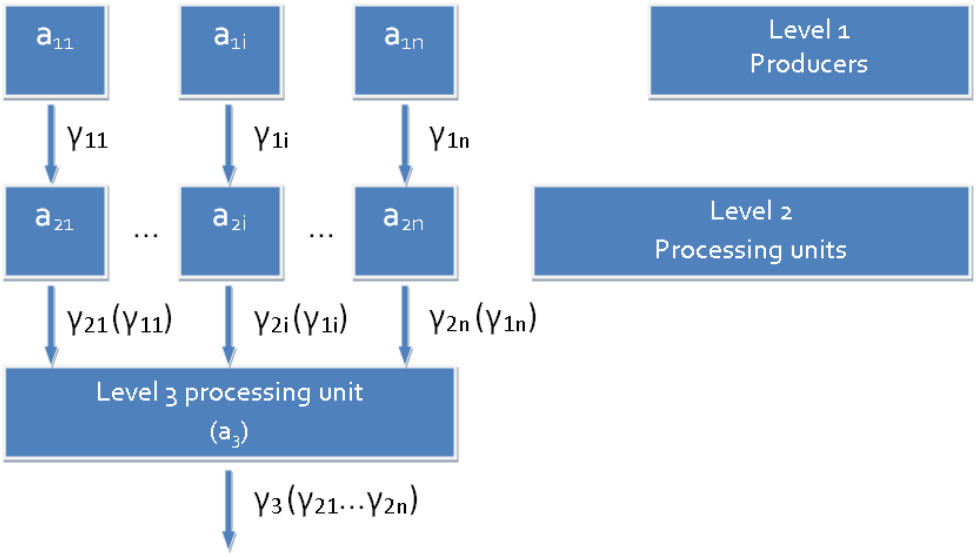

Figure 9: The three-step model of food processing

The enterprise on the third level can be considered the producer of the multi-component product, as this unit purchases half-finished products from the processing units on the second level. In order to produce the half-finished products, the second level acquires base materials from the first level. We can find specialized enterprises on the first two levels, as they only have one output and the related information. The companies of the second level depend on the inputs they are provided by their sole suppliers; therefore, each company has only one contact within the network structure. For example, if a_{11} produces farm paprika, it will only sell the product to processing unit a_{21}, as we assume that this is the only processing unit which uses the paprika as input. (We should reckon companies on the first level to be like small enterprises, or the organizational units of the processing unit.)

Several conclusions can be made on the basis of the model:

- In the case of multi-component food industry chains (as is the case for most meat industry products), the determination of the economicalness of traceability on each step of the product chain is rather complex, which then depends on increasingly more factors around the end of the chain.

- The key issue of the usability of the model is that the customer is willing to pay for the traceability of products. This statement is reinforced by several mentioned studies, but its extent and sustainability is not assured within the strained relations we have today (especially in Hungary).

- It follows from the previous statement that total and global traceability cannot be realized or that it would only possible if there were perfectly optimal circumstances, e.g. if the whole production process could be done by one enterprise or a group of enterprises.

3.5. Usage of information systems at meat industry enterprises

It becomes clear from my 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 Forints. Obviously, this is practically unaffordable for small companies and would mean an extremely long cost recovery period. It is univocal from my survey how many from the total meat industry enterprises use individual and/or integrated systems (Figure 10). 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.

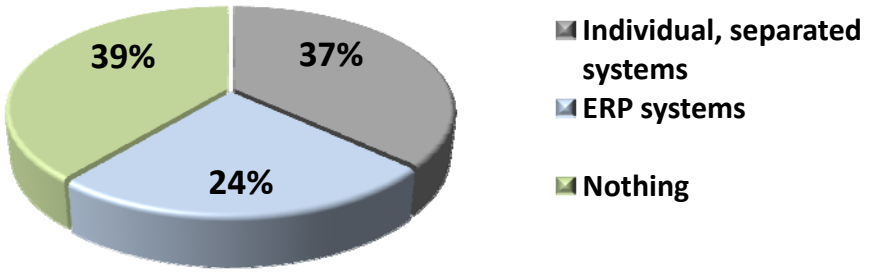

Figure 10: Using information systems in Hungarian meat industry

I examined how, in Hungary, the usage of information systems at meat companies changes according to revenues (Figure 11). 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 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 Navision and CSB systems are characteristic, while some run programs they themselves developed. From other systems, one can mention one or two examples.

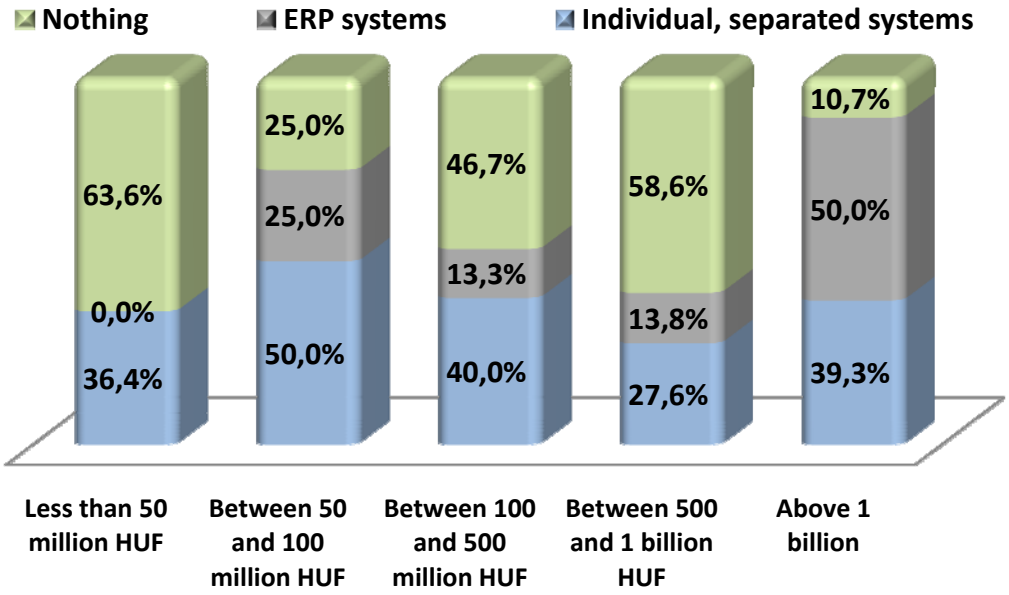

Figure 11: Usage of information systems according to revenues

The domestic agrarian 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. This is the reason why I 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. I made this analysis using an SPSS program.

It could be seen at the start that, among repliers, there are outstanding cases where some of the companies are willing to spend even 7 to 10 percent of their yearly revenue on their informatics system and its development (their number was not significant in either case).

Obviously, they are such extreme and "everyday life" cases, that when considering final numbers, they were not taken into account. These failures probably came from a wrong filling in of the questionnaires or a misinterpretation of the question.

It can be seen from the table (Table 3) that the sum spent on informatics and their maintenance is around 0,6 percent of revenue and, if they plan investments or improvements, their values are somewhat less. This proportion is extremely low, for the sake of improving the competitiveness of the branch, these investments should be enhanced by any means.

Table 3. Sum spent on present and planned systems of informatics in proportion of the revenue

	Sum spent on present systems of informatics in proportion of the revenue	Sum spent on planned systems of informatics in proportion of the revenue
Mean	**0,63%**	**0,61%**
Median	**0,20%**	**0,10%**
Variance	**0,74%**	**0,73%**
Minimum	**0,00%**	**0,00%**
Maximum	**3,00%**	**3,00%**

In order to get a more accurate picture of the technological preparedness of the meat industry, I considered it necessary to examine the circumstances of the European food industry in general, from the aspects of its use of information and communication technologies (ICT). I conducted my examinations on the basis of the database of e-Business W@tch. The examination was begun by the European Commission and the Industry Directorate General in 2002. Their aim was to determine the extent to which electronic business solutions have penetrated the industrial sectors of the countries that joined the European Union. Statistics were compiled on the basis of interviews, case studies and surveys, and these data were provided by the decision-makers of EU companies.

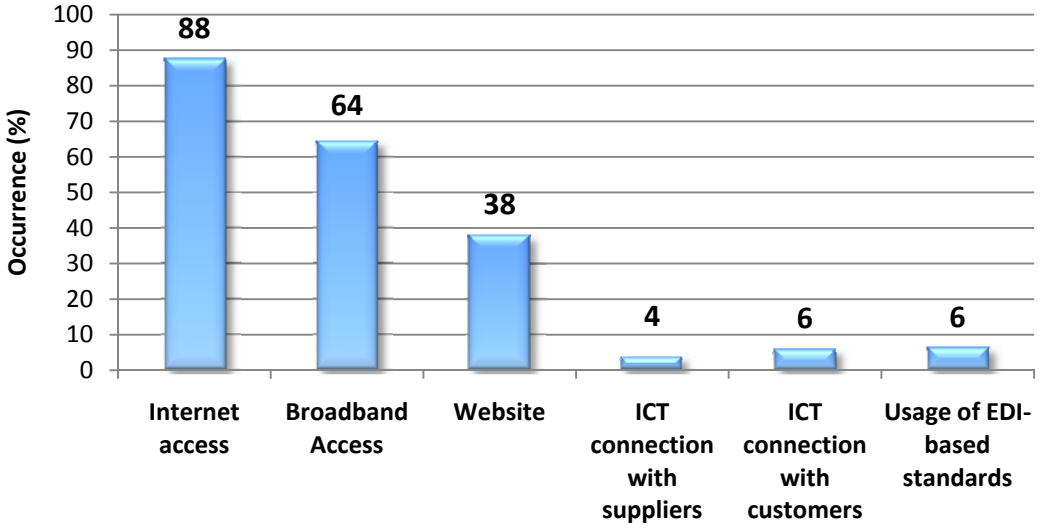

Figure 12: IT preparedness in the food industry

It is clearly shown in the results that the majority of food industry companies already have Internet access, most of which are broadband connections (Figure 12). Nevertheless, only 38% of companies have their own websites and the ratio of those in electronic connection with their suppliers and customers is even lower. As for the applied information system, we can state that almost three quarters of enterprises use some standard software packages. The number of accounting software products and systems that are used to receive orders is also high: their ratio is around 60%. Nevertheless, the number of CRM and integrated corporate management systems is rather low, whereas the proportion of software products applied for the initiation of ICT sales is also rather moderate on B2B and B2C markets (Figure 13).

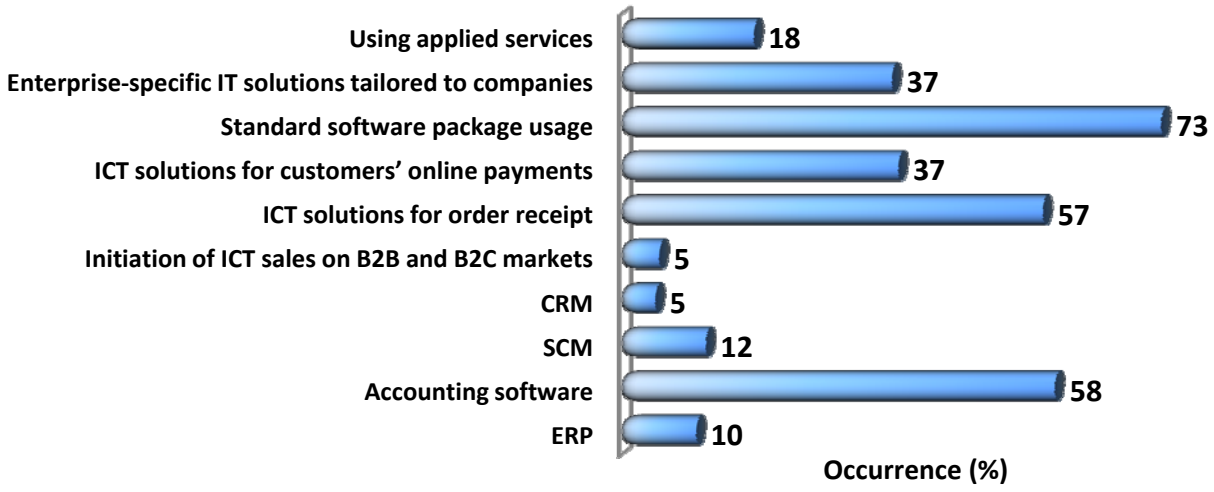

Figure 13: Ratio of using software in the food sector

The selection, introduction and operation of an integrated company information system have several difficulties and problematic points. Around 40% of ERP projects are not carried out as planned. Utmost care has to be taken while choosing a system, as a system's introduction calls for significant resources. This is especially true for those enterprises operating in the food sector, due to the necessity to satisfy specific needs. I analyzed the service of the Technology Evaluation Center from this aspect, focusing on what opportunity it provides for enterprises in choosing the right software.

Unfortunately, there are no such independent evaluation systems available for users in Hungary. The portal "erp.lap.hu" contains several links concerning the food industry, but contains minimal information on enterprises. Tünde Rózsa and Zsigmond Gábor Szalay dealt with selecting and evaluating ERP systems during their research work.

3.6. National and international systems of informatics in quality management

In Hungary, we can find many national registration systems that try to harmonize with those regulations requiring registrations. Registrations concerning livestock, and their system of connections, can be seen in Figure 14.

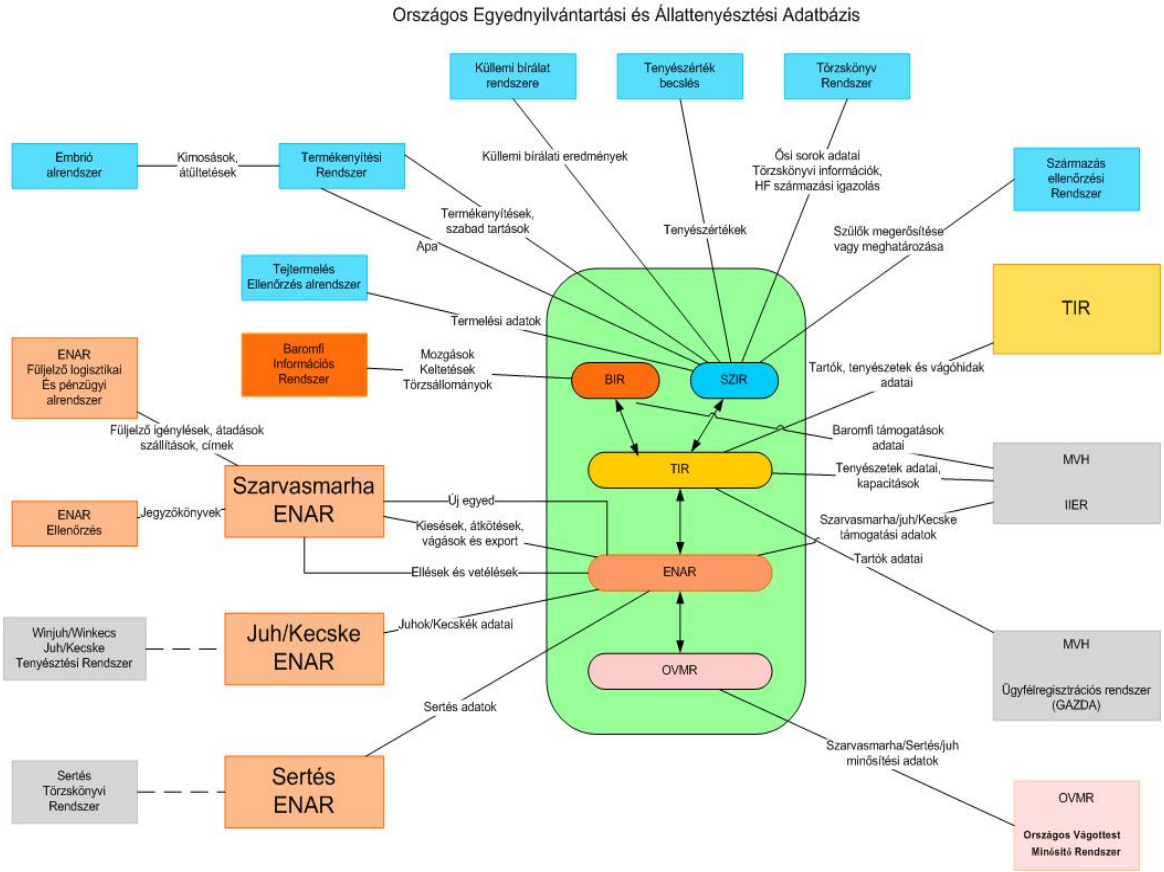

Figure 14: National databases and their systems of connections of individual registration

In the branch, many informatics systems serve for authority checking and in quality management tasks. I studied these systems in MgSzH, at companies and at authorities. According to rank, they can be classified into two groups:

a) The National Veterinary Information System (OÁIR) and its subsystems.
b) The information systems of breeding in the center of Central Agricultural Office.

These systems work mostly independently and are older developments, yet they still are able to fulfill their tasks properly. Assuring interoperability of systems integrating systems and their technical and technological development is continuous. For a couple of years, the Rapid Alert System for Food and Feed (RASFF) has been used, and of course Hungary has also joined EU. The RASFF came into being on the basis of regulation 178/2002/EK.

On the basis of a report of member states, the RASFF immediately decides whether the objected event or goods have only got an informatics value or whether the authorities have to be alarmed. In every case, the RASFF states the name of the suspicious company and generally its location, so upon forwarding, the alarm raised by the MEBIH (Hungarian Office for Safety of Food), i.e. the competent Hungarian authorities, means that the infringing parties are located immediately. The RASFF center has to be informed of those steps taken, of who sent the report about how the issue was resolved and this report must be accepted. Although compulsory use of the RASFF system for member states is fairly new, the database and service have been working for 30 years, since 1979. In the beginning, information was relayed by telex and fax, too. A genuine jump occurred through the online electronic system. Since its foundation, the number of events has expanded rapidly. By 2008, 7,000 registered records had already been made. This naturally does not mean that foodstuffs happen to be less safe, but the system will be used by more and more countries for handling various food safety incidents. Its disadvantage is that only those problems will be recorded that enter the borders of EU member states; it would be necessary to use a similar system of publication on a national level.

To survey food safety risks pertaining to Hungarian meat industry products, I used the RASFF online searching database. Searching is possible on the basis of five filter conditions: data of record, date, reporting country, type of alarm and products. In my examination, I dealt separately with cases in Hungary and products from Hungary.

One can conclude from the cases in Hungary that the number of alerts and reports decreases continuously from 2005. The number of reports regarding meat industry products shows the same tendency every year.

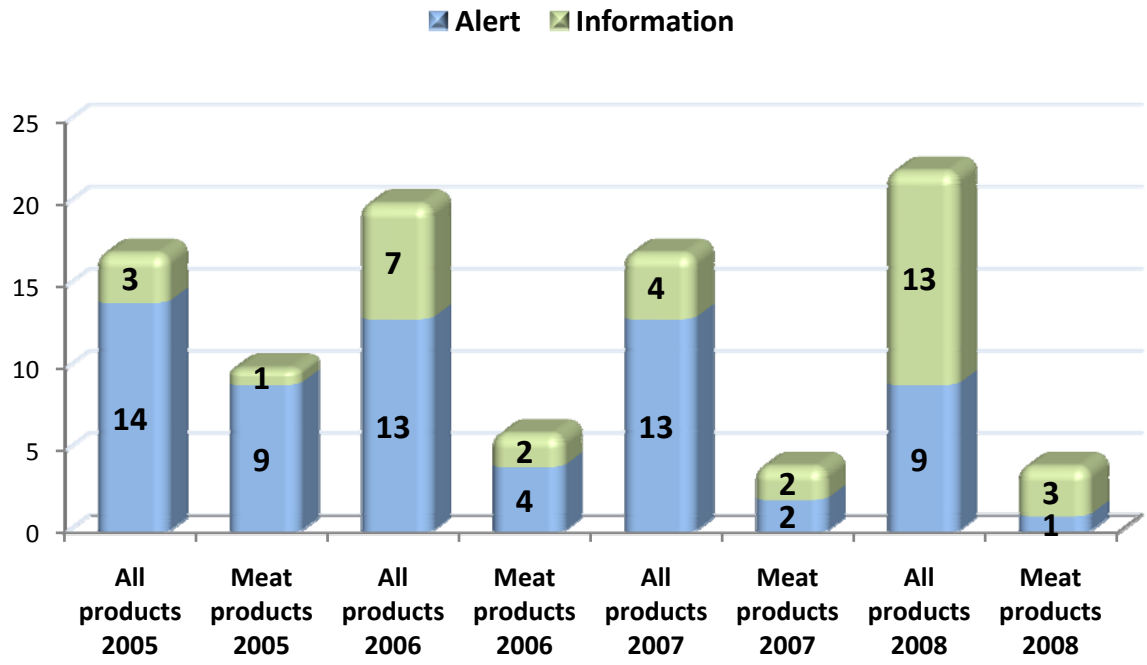

Figure 15 Alerts and information about Hungarian products

Cases reported of Hungarian products are more or less steady in number, and their figure also includes the number of meat industry products (Figure 15). One single exceptional case was in 2005, at that time, 60 percent of the reports of products from Hungary came from the meat industry. After further examination, it came to light that 8 of 10 cases refer to the poultry industry, whose products were infected by Salmonella and were reported 90 percent from Italy.

Furthermore, I examined the perception proportion of food products in relation to all foodstuff products. About the results, we can say that the number of explored cases corresponds to the Union average. In many cases, this figure is even under the average. In the case of products manufactured in Hungary, this number is a multiplication of the average. This situation is due to a very great number of poultry product infections in 2005. This number can also be regarded as being high in the other examined years; nevertheless, there is no single year where the number of reports exceeds six, thus it cannot be regarded as a serious problem.

4. NEW AND NOVEL RESULTS OF THE DISSERTION

The basic objective of my research work was to explore IT alternatives supporting the safety and traceability of meat industry product chains, as well as the technological, organizational and economic aspects of their application. I surveyed solutions available on different levels of the supply chain, as well as the factors influencing their application. Modern quality management and IT solutions could significantly improve the level of food safety and information supply of all participants of the meat industry product chain. This view is reinforced by my research results, on the basis of which I would highlight the following key statements:

1) **I developed the research portal called "Information technology systems and tools in the quality management of meat industry product chains".** The development of this portal was necessitated by the fact that I had not found any similar initiation aiming at the comprehensive examination of the quality management and the information technology background of the meat industry product chain. By developing the portal, I achieved the following results:
    - **I managed to publish professional information about the meat industry product chain which had not or had only partially existed previously. The portal provides information about identification technologies, standards and publications dealing with this area and relevant organizations.**
    - **The online questionnaire survey system on the portal supported my research and I was able publish its results with the help of the portal**.
    - **The portal can be used to perform further research, it can be developed and it is possible to publish additional professional materials, which can be widely used in enterprises and education.**
2) I examined which systems are used by Hungarian meat industry enterprises at each step of the product chain. **Based on these examinations, I established that 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. Furthermore, I collected and analyzed the foreign online microbiological databases and models available and the software solutions supporting quality management systems that cannot be found in the Hungarian sector.**
3) **Based on my survey, I established that 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. My results, which I published on the portal, provide a suitable basis for the participants of the product chain to get to know and select the technology suitable for them.**

    I 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.**

4) The results of my survey showed that 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. As for the other components, there is a similar degree of information supply, but I consider it to be important to improve the current levels, as efficient product recall only exists if all participants of the product chain are aware of the origins of the components of their products. Based on the three-step model of food processing, I established that the determination of the economicalness of traceability on the steps of the product chain is rather complex and that total and global traceability cannot be achieved, or it can only be done if circumstances are perfectly optimal.
5) **Based on my examinations, it can be concluded that 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. I 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.**
6) In sector management, several information systems serve authority supervision and quality assurance tasks. I observed these systems at the Hungarian Food Safety Office, the Central Agricultural Office, enterprises and supervisory boards. My statements about the systems are the following: **The sectoral systems work independently and they were developed some time ago. These can handle the necessary tasks on the proper level, but it is necessary to provide for the interoperability of these systems, due to both professional and organizational reconstructions, as well as to integrate systems and to perform technical and technological developments. Furthermore, it would be important to make a wider range of data public for the enterprises and users active in the field.**

5. PRACTICAL USABILITIY OF THE ACHIEVEMENT

The research portal may help experts in the meat industry in the field of quality management (Figure 16). On the one hand, it summarizes the most important material of knowledge referring to the subject; on the other hand, they can compare their own systems and preparedness, and can rank their company compared to other Hungarian enterprises. The portal can also be useful for B.Sc. students majoring in informatics and agricultural engineering, or those specializing in farm business administration, when they study "IT tools of quality management," which also covers the structure of the portal in detail. The description of new technologies and the achievement of the survey can be used by participants in sector administration, too.

Figure 16: Research portal

6. PUBLICATIONS IN THE TOPIC OF THE DISSERTION

Chapter of scientific book in Hungarian language

1. **Füzesi I.** (2009): Termék nyomon követés Informatikai eszközei, pp. 326-341. In: Herdon M. (szerk.): Informatika agrárgazdasági alkalmazásokkal, Szaktudás Kiadó Ház ZRt, Budapest 355 p. (megjelenés alatt) 0,15

Hungarian language scientific journals with foreign language abstract

2. **Füzesi I.** (2005): Élelmiszerbiztonság és termékazonosítás napjainkban, Agrártudományi Közlemények, 2005/16. különszám pp. 339-345. HU ISSN 1587-1282 0,2
3. **Füzesi I.** - Herdon M. (2006): RFID-rendszerek perspektívái a húsiparban, A Hús, 2005/4. szám pp. 229-234. HU ISSN 1215-0665 0,1
4. Herdon M. - **Füzesi I.** - Rózsa T. (2006): ERP rendszerek szektorspecifikus funkcionális követelményei az élelmiszerláncban, Acta Agraria Kaposváriensis, Vol 10 No 3. pp. 223-231. HU ISSN 1418-1789 0,066
5. **Füzesi I.** (2008): Elektronikus adatcsere technológiák alkalmazása az élelmiszer nyomonkövetésben, Agrártudományi Közlemények, 2008/29. különszám pp. 69-74. HU ISSN 1587-1282 0,2
6. Herdon M. - **Füzesi I.** (2009): Információtechnológiák a húsipari termékpályák minőségmenedzsmentjében, Acta Agraria Kaposváriensis, HU ISSN 1418-1789 (megjelenés alatt) 0,1

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7. **Füzesi I.** - Herdon M. (2008): RFID az élelmiszerek nyomonkövetésében, Térinformatika online, 2008. május 16. http://terinformatika-online.hu/index.php?option=com_content&task=view&id=225&Itemid=84, 12 p. 0,05

Conference full papers published abroad in foreign language

8. **Füzesi I.** (2006): Product tracing in meat industry, Information systems in agriculture and forestry, XII. European Conference Prague, CD-ROM kiadvány, 7 p. ISBN 80-213-1494-X 0,3
9. Herdon M. - **Füzesi I.** (2006): Quality control and product tracing in ERP systems, Computers in Agriculture and Natural Resources, Proceedings of the 4th World Congress, Orlando Florida, pp. 518-521. ISBN: 1-892769-55-7 0,15
10. Szilagyi R. - Lengyel P. - **Füzesi I.** (2006): Mobile Internet in Agri-logistic, XV. Agrarian Perspectives Conference Prague, Conference Proceedings. 4 p. ISBN-80-213-1531-8 0,1
11. **Füzesi I.** - Rózsa T. (2006): Interoperability of information systems and the food tarceability, XV. Agrarian Perspectives Conference Prague, Conference Proceedings. 5 p. ISBN-80-213-1531-8 0,15

12. Herdon M. - Rózsa T. - **Füzesi I.** (2006): Food traceability solutions in information systems, 3rd HAICTA International Conference in Information Systems in Sustainable Agriculture, Agro-environment and Food Technology, Volos-Greece, Conference Proceedings. pp. 187-195. ISBN: 960-8029-42-2 (set), 960-8029-43-0 (Vol. A) 0,1

13. Salga P. - **Füzesi I.** (2007): Mobile traceability systems, Information systems in agriculture and forestry XIII. European Conference Prague. Conference Proceedings 5 p. 0,15

Conference full papers published in Hungary in foreign language

14. **Füzesi I.** (2006): Economic aspect of traceability systems in the meat industry, Summer University on Information Technology in Agriculture and Rural Development, CD issue, pp. 158-162. ISBN-13:9789638736604 0,15

15. **Füzesi I.** - Herdon M. (2006): Traceability requirements for information systems in the agro-food sector, Summer University on Information Technology in Agriculture and Rural Development, CD issue, pp. 152-157. ISBN-13:9789638736604 0,075

16. **Füzesi I.** - Herdon M. (2007): Printed electronics in product identification and tracing, AVA3 International Conference on Agricultural Economics, Rural Development and Informatics, Conference Proceedings. pp. 220-228. ISBN 978-963-87118-7-8 0,075

17. Salga P. - **Füzesi I.** (2007): Edi and barcode based mobile traceability system in food industry, AVA3 International Conference on Agricultural Economics, Rural Development and Informatics, Conference Proceedings. pp. 229-236. ISBN 978-963-87118-7-8 0,075

18. **Füzesi I.** - Herdon M. (2007): EDI-XML standards and technologies in the agri-food industry, In: Herdon M, Szilágyi R (szerk.) Summer University on Information Technology in Agriculture and Rural Development - SU2007. Konferencia kiadvány, Debrecen, Magyar Agrárinformatikai Szövetség, pp. 122-131. ISBN:978-963-87366-1-1 0,075

19. Salga P. - **Füzesi I.** (2007): What are the main difficulties in traceability?, In: Herdon M, Szilágyi R (szerk.) Summer University on Information Technology in Agriculture and Rural Development - SU2007. Konferencia kiadvány, Debrecen, Magyar Agrárinformatikai Szövetség, 22 p. ISBN:978-963-87366-1-1 0,075

20. **Füzesi I.** - Mezőszentgyörgyi D. - Herdon M. (2009): Application of modern traceability systems and data storage technologies by Hungarian meat companies, AVA4 International Conference on Agricultural Economics, Rural Development and Informatics, pp. 876-883. ISBN:978-963-502-897-9 0,05

Conference paper published in Hungary with a foreign language abstract

21. Salga P. - **Füzesi I.** (2008): A nyomonkövetés technikái, Informatika a felsőoktatásban Konferencia Debrecen, Konferencia kiadvány 10 p. ISBN 978-963-473-129-0 — 0,05

Conference papers published in Hungary without a foreign language abstract

22. **Füzesi I.** - Herdon M. (2004): Élelmiszeripari termékek minőségbiztosításának információtechnológiái, Agrárinformatikai Nyári Egyetem és Fórum, SZIE Gödöllő, CD-ROM kiadvány, 8 p. ISBN 963 472 767 0. — 0,025
23. **Füzesi I.** (2005): A termékazonosítási technológiák fejlesztésének jelentősége az élelmiszeriparban XI. Ifjúsági Tudományos Fórum, VE Georgikon Mezőgazdaságtudományi Kar Keszthely, CD-ROM kiadvány. 6 p. — 0,05
24. **Füzesi I.** - Herdon M. (2005): Az élelmiszer termékláncok harmonizálásának információtechnológiai lehetőségei AVA2 Konferencia, Debreceni Egyetem Agrárgazdasági- és Vidékfejlesztési Kar, CD-ROM kiadvány, 14 p. — 0,025
25. **Füzesi I.** - Moldvay J. (2005): A minőség-ellenőrzés és termékkövetés IT támogatásának lehetőségei a baromfi termék feldolgozási láncban, Agrárinformatika 2005 Debrecen, 6 p. ISBN 963 219 023 8 — 0,025
26. **Füzesi I.** - Herdon M. (2006): Húsipari termékek nyomonkövetését biztosító információs rendszerek és azonosítási technológiák alkalmazásának gazdasági előnyei, 4. Gazdaságinformatikai Konferencia, Győr, pp. 45-47 — 0,016
27. Bencsik A. - **Füzesi I.** (2007): Az RFID technológia alkalmazásának lehetőségei egy pecsenyecsirke tartással foglalkozó mezőgazdasági vállalkozás esetén, AVA3 Konferencia, Debreceni Egyetem Agrárgazdasági- és Vidékfejlesztési Kar, Konferencia kiadvány, 13 p. — 0,025
28. **Füzesi I.** (2008): RFID az agrárlogisztikában és a terméknyomonkövetésben, „Tér és idő a logisztikában" Konferencia, Budapest, Konferencia kiadvány 17 p. — 0,05

Total (KPÉ): **2,657**