PRINTED ELECTRONICS IN PRODUCT IDENTIFICATION AND TRACING

István Füzesi – Herdon Miklós
University of Debrecen, Centre for Agricultural Sciences, Faculty of Agricultural Economics and Rural Development
Department of Business- and Agricultural Informatics

Summary

Food and livestock traceability and tracking are now very hot topics because of severe threats to health and the need to comply with stringent new legislation. The traceability of products and components has received critical attention over the past few years. The requirements from the individual segments of the food industry may vary. The solutions of these problems are the introduction of modern quality assurance systems, traceability and identification of products.

Introduction

Evolution of information technologies can assure new possibilities in agriculture and food industry. With using Internet, GRID systems, mobile communication systems and modern ICT traceability become more and more simpler. The traceability of products and components has received critical attention over the past few years. The requirements from the individual segments of the food industry may vary. They do have one thing in common, however: they share the need for seamless documentation of the path a product takes from producer, to supplier, up to the consumer.

The good news is that (a) there are now many more good reasons why electronic features will be valued; and (b) a whole new toolkit of electronic components is available that comprises radically cheaper, thinner and more robust options. Driving the increased use of electronic and electric smart packaging are factors such as the increasing percentage of aging people in the population, more demanding consumers, new laws on traceability, recycling, and the zeal of the consumer goods industry to get costs down and sales up.

Without question silicon chips have had a massive impact on our lives since their invention almost sixty years ago. However, there are many applications where their cost, fragility and time to market mean they are not viable. For such applications, a new disruptive technology is emerging which could ultimately have an even bigger impact to humankind than silicon had. This is the ability to print electronics and electronic components, using inks and conventional printing techniques.

Food and livestock traceability and tracking are now very hot topics because of severe threats to health and the need to comply with stringent new legislation. For example the latest avian influenza outbreaks have twice the kill percentage of smallpox and the World Health Organisation warns of a repetition of the pandemic in 1918 when 20-40 million died. Bioterrorism is another challenge and timely and accurate detection, tracing and action are central to dealing with these problems.

Traceability in the chain

At the beginning of the 21st century the matter of food safety plays an accentuated role in the food industry. Important issues in this topic are the risk of bioterrorism, impurities in the food chain and the ascendancy of customer needs. The solutions of these problems are the introduction of modern quality assurance systems, traceability and identification of products.

In primary production, traceability has been defined as the ability to trace the history of the product through the supply chain to or from the place and time of production, including the identification of the inputs used and production operations undertaken (British Standards Institute PAS 85:2000).

In Europe, traceability has been mainly motivated by regulations, while in the US it tends to be motivated by economic incentives. There are several different systems of traceability in agro-food industries. The systems can be characterized by three dimensions: depth (how far up and downstream the system goes), breadth (how many attributes are traced), and precision (e.g., to what extent the origin is correctly identified). There is no single best way to introduce traceability and there is a large variability in the characteristics of systems within and across industries, depending on specific attributes of products or motivations to introduce traceability.

Traceability costs are associated with system implementation (e.g., changes in procedures, decreased flexibility, and increased levels of automation, inventory, personnel, and documentation) and maintenance (through auditing). The benefits include increased transparency, reduced risk of liability claims, more effective recalls, enhanced logistics, improved control of livestock epidemics, possible positive effects on trade, easier product licensing, and possible price premiums.

We look at the big picture in terms of the major issues within the food industry where traceability will have a major positive impact:

- Animal disease. Major disease outbreaks, such as BSE, cost the industry billions of dollars. Traceability can help contain these outbreaks and prevent spread of disease.
- Food scares. Traceability assists food residue surveillance schemes and minimizes the cost involved in a product recall event.
- Food poisoning. 32 million children under five die of food related illness every year (WHO). The technology is available now to prevent this and track the source of problems.
- Consumer confidence and public health. A transparent industry is needed to maintain consumer trust and loyalty. Traceability goes a long way to achievement of a secure and safe food supply chain
- Cold chain management. Up to 20 per cent of perishable food is expired on reaching destination (FDA). RFID provides unprecedented visibility that makes the food chain much more efficient. RFID technology with sensing can prevent breaks in the cold chain.
- Bioterrorism. The threat of an attack via our food chain is a real one and the only way to circumvent an incident is by enforcing food chain traceability. The new US Bioterrorism Act 2004 and EU legislation in 2005 go a long way to doing this.

Automated monitoring of food condition throughout the supply chain will take it further.
- Global trade. Today international trade is massive and if companies want to keep market access to, for example, the European Union EU they must be able to prove traceability.

Technologies of identification

Traceability can not be solved without high level identification. The identification of food items is based essentially upon two categories of identifier:
- Primary identification (based on the use of biological markers and feature extraction based upon anatomical, physiological, biochemical or molecular, including DNA, methods of identification).
- Secondary or data carrier-based identification techniques in which a number or alphanumeric string is used for identification purposes and may be accompanied by other data or information for traceability or process support purposes.

A secondary identifier may also be linked to a primary identifier, particularly where the primary identifier is held as a data template in a data carrier or database. Meta-data may be used to distinguish data types and assist in automatic identification and handling of source data concerning the item or items being processed or handled.

A wide range of reader-supported data carriers are now available for use in structuring and developing process support systems and traceability. The predominant carriers include:

Linear bar code symbols

Linear bar codes have been used extensively in retail and supply chain logistics for many years, as an effective means of machine-readable identification and data transfer. A range of symbologies is available to satisfy a variety of data encoding needs, a symbology being the rules determining the way the bar-space symbols are structured to encode character sets. A number or alphanumeric character string encoded within a bar code symbol is used as a means of identifying an item and / or associated information held in a database or other storage facility. Linear bar codes may also carry meta-data identifiers and a limited amount of standalone information, such as expiry date or weight.
- Multi-row bar code symbols, matrix code symbols, composite symbols

A range of two-dimensional, multirow bar and matrix data carriers is now available, featuring attributes that are complimentary to linear bar codes. Of particular significance in this respect is the ability to carry substantially more data than linear bar code symbols or the same data in smaller space. This capability is engendered in what is generally referred to as the 'portable data file' concept, wherein data is carried as stand-alone machine-readable files. Carrying data in this way constitutes a radical vehicle for process improvement, where opportunities are recognised. They also provide a platform for alternative solutions to data carrier problems that would be difficult or impracticable to satisfy using linear bar codes. Two-dimensional data carriers share some of the features of linear bar codes including read-only capability, line-of-sight reading and low cost data carrier format.

Radiofrequency identification data carriers

RFID is a transponder technology which is set to play an increasingly important role in the field of logistics alongside existing automatic identification systems such as barcodes. RFID transponders are already in successful use for identifying animals and containers, as part of access control systems, in vehicle immobilizers and in automated production. But the retail and service industries as well as procurement, production and distribution logistics see extended fields of application being opened up by RFID technology, bringing with it greater efficiency in monitoring and controlling supply chains, whether it be in the reduction of stock levels, the optimization of just-in-time processes, the regulation of traffic control systems in ports and airports, the tracking of shipments or in the monitoring of mechanical or climatic influences on goods during shipment. It is assumed that the greatest potential will be in those sectors that have the highest demands on quality and process reliability, such as the pharmaceutical, chemical and automotive industries. Unlike with barcodes, RFID transfers data between for instance a package (equipped with a transponder) and a data capture unit (reader) with no need for contact or a direct line of sight. It is also possible to capture the data from several different data carriers simultaneously and to read the information through a range of different materials. Furthermore, the data can be tracked in realtime in defined areas. RFID is based on electromagnetic waves with frequency ranges from long wave through to microwave. The technology involves a data capture unit or reader reading the data from a transponder (data carrier with an integrated antenna - also known as a "tag") and/or writing new or additional data to the tag. (http://www.tis-gdv.de/tis_e/verpack/rfid/rfid.htm)

Smart packaging

Smart packaging can involve primary, secondary or tertiary packaging that becomes smart. Examples include primary packaging that automatically lets the bad gases out to preserve meat; secondary packaging that is radio tagged for automated traceability and data capture; and tertiary packaging, radio tagged as an automated tamper alert.

The packaging is the favoured location for radio tags because they could affect the working of the product itself, and it is not feasible to tag food, drink, medicines, chemicals and seeds directly. Indeed, consumers with privacy concerns are pleased to throw away the package and thus the tag after purchase.

Technology of printed electronics

October 16, 2005 A world first in volume printed integrated electronics circuits was exhibited at the recent Plastics Electronics trade fair in Frankfurt. The Institute for Print and Media Technology at Chemnitz University in Germany has developed a new process that enables electronic circuitry to be produced with mass printing technology. The new process will enable the mass production of very cheap integrated circuitry in paper and cardboard and can be expected to have massive consequences in manufacturing, the future of RFID and the blurring of the line between printed objects and the virtual world.

The technology includes being able to print a range of electronic and electrical components - such as transistor circuits, displays, sensors, power, interconnects and even sound actuators. These will eventually be printed using similar materials on similar printing equipment and have another advantage of being flexible where required (making them more robust) and being able to make every device different where digital printing is used.

Most development work is being done using organic semiconductors - plastics which can be used to make transistors and other components. Unlike silicon wafers which need to be etched - a subtractive process - organic semiconductors can be added to a substrate in order to build up the component. Printing is the preferred choice of developers because it can be done very quickly, manufacturing can be dispersed, and it can be very low cost. Others are also working on non-organic metallic based inks which can be printed to build various components and even carbon nanotubes.

None of these terms alone are suitable in describing this vast enabling technology. For example, although companies are developing printed electronics, not all work today uses printing as the deposition method. One advantage of the technology is that it can be flexible, but again a lot of the work today is done on glass or other rigid substrates. Others refer to the topic as organic semiconductors but this ignores non organic non silicon semiconductors and conductors, such as metal particle based versions.

Many other areas of printed and potentially printed electronics are being relatively neglected. Take batteries. Most potential applications of printed electronics call for batteries, preferably of low cost and flexible. The technical requirements vary greatly between the different applications, yet we are stuck with a handful of suppliers who either offer carbon zinc with its limited life, power storage and rate of delivery or lithium technologies with their problems of cost and environmental credentials.

A similar question can be asked about large printed memory - from kilobytes to gigabytes. So few companies are working on this that AMD has about 80% of the patents for potentially printable, thin film versions, yet large memory will be needed for a high proportion of applications involving printed transistors.

Using of printed electronics

Printed electronics instead offer the possibility of using electronics in applications where the cost of silicon would have made it impossible or where silicon properties – such as size or rigidity – are inadequate. Suitable applications include either “small area” electronics such as the electronic sensors and the changing use-by date on a pack of meat or medicines; “large area” electronics such as billboard size electronic displays, solar cells, lighting and sensors; or where flexible circuits are needed, for example: displays for computers, signage and posters where the flexibility of the display adds much needed robustness.

The two key benefits of printed electronics are:

1. Materials and manufacture costs are very low
2. Circuits can be deposited onto flexible substrates such as plastic film and foils.

Several major companies, including Electrolux in Germany, are developing smart refrigerators and freezers. They will help commercial restaurants to save money and reduce errors; they will monitor the RFID tags in the packs inside to make sure they are used before expiry and they never run out. Proponents believe that the payback on commercial smart fridges and freezers will be rapid, though the case for the equivalent in the home is less clear.

Another example of current applications of printed electronics are new smart skin patches from Power Paper that replace the delivery package for cosmetics and drugs. These product-impregnated patches are shipped direct from the manufacturer and are applied by the patient. Using a printed battery and a conductor pattern, the patches deliver the substance by making the skin porous. A variant gives young people a tattoo that lasts four months—just enough to terrify moms!

Also available for trial are printed electronic time/temperature recording labels that use printed electrochromic displays. The labels go on food and blood bags and show the words "Expired" when appropriate, signaling back the temperature history. A chip is used at present, so the labels are not yet fully printed, but the battery and antenna are printed and combine an RFID function.

Bioett AB of Sweden, along with international frozen food business Findus and a Swedish dairy chain, has successfully tested a completely printed inductor/capacitor/biosensor that signals time/temperature characteristics. At very high volumes, it is estimated that a cost of 15 cents is achievable. No silicon chip is needed.

July 13, 2006 IBM and Marnlen RFiD are collaborating on enabling consumer privacy protection for RFID tags -- the potential production of smart radio frequency identification (RFID) labels using IBM Research's Clipped Tag privacy technology. Clipped Tag technology allows consumers to tear off a section of the tag which in turn reduces the tag's read range to just a few inches, protecting consumer privacy while maintaining the benefits of the technology, such as product authentication or recalls. The Clipped Tag puts privacy protection into the hands of the consumer as it gives the consumer a visual confirmation of the tag's modification.

As the implementation of RFID tagging of pallets and cases for the retail supply chain proceeds, attention is being given to the possibility of RFID tagging for individual retail items. The sale of tagged retail goods gives rise to measures to enhance consumer privacy. Ultra-high frequency tags may be read by wireless means of distances up to around 30 feet (10 meters). High frequency tags also may be read wirelessly, but generally at a shorter range.

Mechanisms have been proposed to address enhanced consumer privacy upon the introduction of item-level tagging. One of them is the use of “Blocker Tags” proposed by RSA Laboratories, a security and privacy organization. These tags interfere with the reading of other RFID tags. They must be carried by the consumer. Another mechanism is the EPCglobal Gen2 protocol “Kill” command which deactivates tags permanently. The Kill command is executed by the retailer at the point-of-sale. Killed tags cannot be revived.

Price of printed electronics

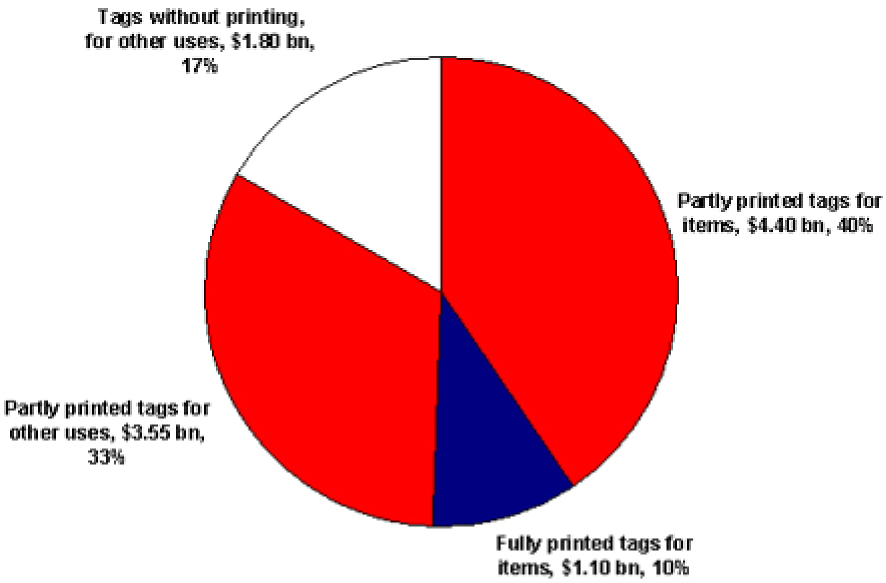
This is even truer of their use with items such as packaging, labels and other formats. The circuits are usually too bulky, too fragile and, most importantly, too costly. It is a rule of thumb in packaging that, if you offer a valued feature at $1, you will be lucky to sell 1 million a year. If you provide features that cost just a few cents apiece—for instance, holograms or anti-theft tags—many billions will be sold yearly. Printed electronics factories cost under ten million dollars and produce products in 2-3 days whereas silicon chip factories cost at least one billion dollars and still cannot produce products in less than 2-3 months.

Conclusion

It is hoped that in the future, conventional flexographic, lithographic and other existing printing technologies may be used. After all, the bar code is usually free of charge because it is applied as part of normal printing. Hopefully, the same will eventually be true of RFID tags and many other forms of electronics on packages, products and so on. But do not hold your breath: That may take until 2020.

The market for organic and printable electronics is expected to reach $300Bn in 2025 - larger than the size of the silicon industry today. The future electronic fabrication plants will be printing presses. Enormous markets will be created where conventional silicon chips cannot go today because they are too costly, large and brittle. A full range of electrical and electronic components will be printed - from transistor circuits to displays, power and even speakers.

Below is the IDTechEx projection for the global market for RFID in 2016 in billions of dollars with the impact of printing technology.



1. figure IDTechEx projection for the global market for RFID in 2016 (source: IDTechEx)

References

Buhr, B. L., (2003): Traceability and Information Technology in the Meat Supply Chain: Implications for Firm Organization and Market Structure. Journal of Food Distribution Research 34(3):13-26.

Elise, G. (2000): Economics of Food Labeling, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 793.

Falus, G. (2002): Napjaink prioritása: az élelmiszer-biztonság, Available at: http://www.pointernet.pds.hu/ujsagok/agraragazat/2002-ev/09-szeptember/agrarag-11.html

Furness, T. (2003) Cross-Supply Chain Traceability from an ICT Perspective, FoodTrace Conference Sitges,

Golan, E, B. Krissoff, F. Kuchler, K. Nelson, G. Price, and L. Calvin, (2003): Traceability forFood Safety and Quality Assurance: Mandatory Systems Often Miss the Mark. CurrentAgr., Food, & Resource Issues 4:27-35.

Golan, E., B. Krissoff, F. Kuchler, K. Nelson, G. Price, and L. Calvin, (2004): Traceability in the U.S. Food Supply: Economic Theory and Industry Studies. Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 830. March.

Gracia and Zeballos, (2005): "Attitudes of retailers and consumers towards the EU traceabilityand labelling system for beef." Journal of Food Distribution Research 36(3):45-45.

Herdon, M. (2006): Innovatív információtechnológiák a térségfejlesztésben, A térségfejlesztés vezetési és szervezési összefüggései, Debreceni Egyetem AVK ISBN 9639274968 146-151

Hobbs, J. E., (2002): Consumer Demand for Traceability. Paper present at the International Agricultural Trade Research Consortium Annual Conference, Monterey, CA, 15-17December.

Hobbs, J. E., (2004): "Traceability in the Canadian Red Meat Sector: Do Consumers Care?". Agribusiness 20 (4) 397–415.

Hobbs, J. E., Bailey, D., Dickinson, D. L., and Haghiri, M., (2005): "Traceability in the Canadian Red Meat Sector: Do Consumers Care?" Canadian Journal of Agricultural Economics 53 (2005) 47–65.

Hofstede, G. J., (2002): "Transparency in Netchains" Review Paper for KLICT v. 1.6. Wageningen University Information Technology Group, KLICT 3949.

Jansen-Veullers, M. H., van Dorp, C. A., and Beulens. A., (2003): " Managing Traceability Information in Manufacture" International Journal of Information Management 23 (2003) 395–413.

Meuwissen, M. P. M, A. G. J. Velthuis, H. Hogeveen, and R. B.M. Huirne, (2003): Traceabilityand Certification in Meat Supply Chains. Journal of Agribusiness 21(2):167-181.

Moe, T., (1998): Perspectives on traceability in food manufacture. Food and Science Technology, 1998(9), 211–214.

Natural Resources Institute, (2003): Food Management and Marketing Group, Available at: http://www.nri.org/about/fmmg.htm 2003

Sendula, T. CSB-System. Inc, (2000): Vállalatirányítási információs rendszerek Magyarországon, CSB System International webpage Available at: http://www.csb-system.com

Souza Monteiro, D. and J. A. Caswell, (2004): The Economics of Implementing Traceability inBeef Supply Chains: Trends in Major Producing and Trading Countries. Paper presentedat NAREA Annual Meeting, Halifax, Nova Scotia, Canada.

Starbird, S. A. and V. Amanor-Boadu, (2004): Traceability, Inspection, and Food Safety. Selected Paper for the AAEA Annual Meeting, Denver, Colorado.

Trienekens, J. H., and Beulens, A. J. M., (2001): The implications of EU food safety legislation and consumer demands on supply chain information systems, International Food and Agribusiness Management Association, Proceedings of the 11th Annual World Food and Agribusiness Forum, Sydney, Australia.

Vernede, R., Verdenius, F., and Broeze, J., (2003): "Traceability in food Processing Chains: State of the Art and Future Developments". Wageningen University, Agrotechnology and Food Innovations bv., KLICT Position Paper, Version 1.0.

Printing the Electronic Future
http://www.idtechex.com/printelecreview/en/articles/00000449.asp

Tracking food and livestock
http://www.idtechex.com/products/en/articles/00000148.asp

A Step Change in Printing and Electronics (Feb 01, 2006)
http://www.idtechex.com/printelecreview/en/articles/00000426.asp

OLED lighting and large area signage (Apr 20, 2006)
http://www.idtechex.com/printelecreview/en/articles/00000466.asp

Active RFID Attracts More Big Money (Dec 11, 2006)
http://www.idtechex.com/printelecreview/en/articles/00000511.asp

Printed Electronics - the Missing Fragments (Jan 25, 2007)
http://www.idtechex.com/printelecreview/en/articles/00000519.asp