View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by SZTAKI Publication Repository

Kemény, Zs., Ilie-Zudor, E., Szathmári, M., AIP CORNET—Battling Losses in European Food Supply Chains. Proc. of the 12th International Conference on the Modern Information Technology in the Innovation Processes of the Industrial Enterprises (MITIP 2010), 29–31 August 2010 Aalborg, Denmark, pp. 44–53

AIP CORNET—BATTLING LOSSES IN EUROPEAN FOOD SUPPLY CHAINS

Kemény, Zsolt; Ilie-Zudor, Elisabeth; Szathmári, Marcell

Research Laboratory on Engineering and Management Intelligence
Computer and Automation Research Institute, Hungarian Academy of Sciences

Address—Kende u. 13–17, H-1111, Budapest

Hungary

E-mail: {kemeny, ilie, szmarcell}@sztaki.hu

Abstract:

The paper gives an overview of major challenges appearing in supply chains conveying fresh food products over an extended range. Typical problems of different supply chain stages are presented, followed by a listing of technologies able to deliver solutions in response. The problem of fresh food supply chains is, furthermore, placed into a European context, and related objectives—especially IT-relevant efforts—of the recently started AIP-CORNET project are summarized.

Keywords:

Food supply chain, tracking and tracing, active packaging, intelligent packaging, RFID

1. INTRODUCTION

A significant trend witnessed in numerous regions worldwide is the change of customers' expectations regarding food quality. Trends of converting to lighter food can be observed, and growing customer concerns are experienced regarding preservatives, additives, microbial contamination and nutrient deterioration due to processing, storage or transportation conditions. Driven by these tendencies, customers now turn more and more towards fresh food with little intervention in its raw materials. While such food has a lengthy record of cultural tradition in countries like Japan, it is now also becoming appealing in regions so far dominated by processed food.

This shift in consumer preference not only induces changes in food production, it also calls for adaptation of the supply chain due to the sensitivity of fresh food to spoilage. Without such adaptation, losses would occur due to adverse ambient conditions, or inappropriate handling policies of goods due to a lack of process transparency [11],[13]. Improvement can be effected in two ways: *i)* making transportation, storage, dispatching and replenishment processes and conditions suitable for fresh products, and *ii)* employing special packaging that presents a better match for the conditions and requirements of the supply chain [4].

Meant to give initial insight about AIP-CORNET, a European R&D project dedicated to this problem domain, this paper examines key issues of bringing fresh food to customers from a specific European point of view, especially in the context of information services and their availability to typical participants in European food supply chains. The paper is organized as follows: first, major stages of the food supply chain are summarized, along with describing requirements and problems that are typical for the given stage (see also Figure 1 for an overview). This is followed by a systematic presentation of selected technologies and possible solutions that can meet the previously explained challenges. Finally, the European situation is characterized, outlining the tasks to be solved by AIP-CORNET.

2. CHALLENGES IN THE FOOD SUPPLY CHAIN

2.1. Production

When it comes to assessing production, the production processes themselves receive most attention, i.e., the transformation of raw material into the desired product. While fresh food does present special requirements for processing conditions, etc.—potentially requiring adaptation of the facilities and introduction of tighter production scheduling policies—another class of technical challenges may call for more thorough transformation and initial investment: readying the packaging of goods for their progress through the supply chain [4].

As explained in subsequent sections, packaging of fresh food may be far more advanced: it may contain conditioning agents or indicators that need to be specifically handled and initialized during the packaging process. Also, loss prevention measures in perishable supply chains may require more transparent handling of production information, calling, e.g., for reporting steps in the facilities that were not a critical requirement for other types of food, in addition to the food traceability measures already required by today's legislation [6].

2.2. Transportation

As perishable goods proceed from the producer over the logistics network to the final point of sale, spoilage—resulting in undesired or dangerous degradation of the product—must be prevented. For transportation, this implies two measures to be taken: i) reducing transportation time and ensuring suitable handling conditions, and ii) providing information about the shipping process itself (both transportation progress and ambient conditions).

Making transportation better suited for fresh products can thus require the use of more advanced transportation assets that ensure proper ambient conditions and grant observability, as well as improved organizing measures like flexible re-routing and more intelligent assignment of resources to transportation tasks [13].

2.3. Warehousing

The intermediate storage of fresh food shares many problems with transportation: notably, the time lag must be within limits, and ambient conditions must fulfill the requirements. A given degree of observability must possibly be ensured during storage as well. However, warehousing may also involve a re-organization of the goods: shipments can be broken up and recombined, joining different goods with varying tolerances in handling conditions [11]. Also, responsible decisions must be taken when goods of the same type but different remaining shelf life are present. Large facilities present another challenge: locating the goods [8] in reasonable time—it is enough to think of direct and induced losses and safety threats posed by spoiled food that may infest other products sharing the same storage space.

2.4. Sales

While points of sale inherit several requirements generally applying to the entire food supply chain (those related to handling conditions and transparency), this stage introduces further special challenges since sales is where fresh food (both on an item-by-item scale and generally as an assortment of merchandise with implied or pending consumer decisions) comes in contact with the consumer. Some stock-keeping policies practiced in stores can easily be found analogous to those in warehouses, and have basically the same purpose: maintaining stock quantities and qualities that are matching the outbound requirements, minimizing spoilage losses but disposing of material that is already expired. There are, however, some major differences that set sales apart from warehousing:

- Sales facilities present a most heterogeneous selection [3]: some are large supermarkets with state-of-the-art equipment for keeping fresh food in good condition for a lengthened period of time and are more likely to have access to modern check-out equipment and information technology, while the same type of product may also end up in a small shop with very limited technological background and refrigerating capacity.
- The behavior and perspective of consumers differs largely from that of operators meeting picking decisions in warehousing and logistics. Consumers meet locally optimal decisions for a small amount of goods, while they may have limited or no access to any extensive information flow established for the rest of the supply chain. More conscious consumers may wish to be exactly informed about the freshness of the product, while others are concerned about the price alone. Also, consumer decisions are often bounded-rational [9] (reasoning is only practiced up to certain limits, and habitual patterns or emotional influence may take over at a point), and sales facilities can manipulate consumer behavior by carefully selecting what product information is disclosed and how it is presented (well-noted, vendors often wish to have firm control over this aspect, presenting a demand that certainly has to be recognized when offering solutions).

2.5. After-sales issues

While points-of-sale are generally considered to be the end of the food supply chain, it is still important to extend the scope of our examinations one step further into the phase of storage with the consumer prior to its consumption. This is recommended for two reasons: i) consumer confidence, an important factor in a competitive market, also depends on the persistence and transparency of product quality after its sale, and ii) especially with food and beverages, it is important to keep the consumer shielded from health risks posed by food that is contaminated or spoiled without making the latter noticeable to the consumer [6]. While trying to meet these requirements, it is important to note that the home of the typical consumer is possibly the most “low-tech” point in the entire chain. An average home may have limited technical means for keeping the goods under suitable ambient conditions, and the lack of advanced reading or measurement devices may leave a mere visual check as the only option when it comes to assessing the freshness of an unopened package.

3. TECHNOLOGICAL BACKGROUND OF SOLUTIONS

While solutions to the above challenges rely on a wide range of theoretical advances and technologies, the present survey is restricted to some selected areas within the scope of the AIP-CORNET project, namely, active and intelligent packaging, and tracking services. The main focus of the paper is centered around information technologies; however, related domains of the project’s scope will be mentioned as well to complete the picture.

3.1. Advanced packaging technologies

Active packaging—this term is generally used for solutions that actively interfere with the deterioration processes of fresh food to prolong its shelf life without altering the composition of the product itself. Two fundamental classes are recognized here: i) those that absorb chemical agents allowing or accelerating spoilage (most commonly oxygen [12]), and ii) those that inhibit the growth of microbes effecting spoilage (antimicrobial packaging [2]).

Active packaging can be implemented either in the form of sachets accessing the (usually hermetically sealed) head space of the product, or added to the polymer matrix of the packaging material itself, depending on the active agent and the type of product. Also, it may need activation at the time of production, either by removing a protective hull or by triggering a specific chemical or physical process. Active packaging accompanies the product through the entire supply chain and can meet challenges present in all stages the product passes.

Intelligent packaging—these are solutions with an indicator for assessing an estimated shelf life or supply information on actual freshness [4],[5]. Two basic principles can be followed:

1. The remaining shelf life or freshness is not measured directly but is estimated using a simplified model. This can be either an electronically implemented mathematical model (a clock ticking at constant or variable speed), or any process that runs in parallel to actual food degradation but can be measured more easily (e.g., ink diffusing through a tissue, or an indicator field that changes its color over time). Depending on what is displayed, one can distinguish pure time indicators (assuming that ambient conditions do not vary too much to compromise the time estimation) from those that vary their progress rate depending on ambient conditions, such as temperature (time-temperature indicators in the given case). The latter allow more flexible product handling policies (e.g., the same product can have a longer permitted shelf life if it is kept refrigerated, or, it can be stored at higher temperatures if it is consumed faster). This could prevent losses of usable food being discarded due to rigid handling prescriptions. In addition to estimating remaining shelf life, similar indicators can also signalize if handling conditions have remained within required tolerances throughout the supply chain.
2. Product quality is directly monitored, relying on the presence of certain compounds or microbes appearing with the progress of degradation. Referred to as freshness indicators, these solutions can be based on chemical or physical processes effecting visible changes of an indicator, but conversion to electrically measurable signals (in the fashion of an “electronic nose”) is also known as an alternative. While freshness indicators may also fail to provide truthful information, this solution is commonly regarded to be more in keeping with the degradation processes really taking place, the more so as they detect the effects of processes occurring in the entire volume of the product, while time-temperature indicators may be deceived by changes near the packaging surface that are too volatile to penetrate the bulk of the product.

Two classes of indicator implementations are commonly distinguished:

1. *Electronic sensors*—key parameters are converted to electric signals that can be registered and evaluated electronically. Integrating such solutions into the packaging has become technically feasible due to the development of low-power devices that are either battery-powered, or are tapping electromagnetic waves. Sensor-equipped RFID tags could prove efficient, especially due to the contactless data transmission, reducing time lags of checking product quality or ambient condition records at checkpoints in the supply chain [1]. However, decisions about introducing sensor-equipped RFID must be taken in awareness of limiting factors, such as i) possible restriction of measurement

times due to interrupted power supply, ii) limitation of data transfer to reader-equipped places and potential exclusion of consumers not having suitable reading devices (e.g., NFC phone sets), iii) the need for pre-processing raw data to keep the burden of an information flood within limits [10], and iv) the costs of an underlying infrastructure that still continue to hamper massive spreading of sensor-equipped RFID solutions.

2. *Optically readable indicators*—here, optical properties of the indicator materials undergo well-defined changes in response to the indicated processes. While RFID does promise more versatility in the decades to come, the present is dominated by optical indicators due to their low cost, their relatively low environmental impact, and their easy observation and interpretation (mostly intuitive even for first-time consumers) [11]. However, one major disadvantage limits their integration into automated solutions: the circumstantial way of coupling them with any digital processing. The latter is not entirely impossible, as the indicators can be read with a scanner or camera. However, due to the analog nature of the indicators, calibration must be reliable and robust, and standards for interpreting the analog information must be agreed on throughout the scope of the supply chain. Also, reading optical indicators may need more human assistance than RFID, since indicator labels must be properly positioned in the field of vision of the capturing sensors, either implying higher labor costs, or limiting the volume of feasible data acquisition (e.g., to some selected items within an entire shipment).

Various forms of intelligent packaging may be beneficial in all stages of the food supply chain, however, criteria may be conflicting from stage to stage. Large-throughput facilities may prefer RFID for efficient handling of massive data and can better meet an implied major initial investment. Small-scale vendors and consumers, on the other hand, do not reject manual inspection, and optical indicators would better fit their technological limitations.

3.2. Tracking in the supply chain

Counteracting and indicating spoilage with advanced packaging are only one way of reducing losses in fresh food supply chains. In parallel to these efforts, it is also possible to improve the throughput and efficiency of supply chains as material streams. Both surveys and practical experience suggest that much supply chain efficiency is lost due to sub-optimal decisions taken without proper knowledge of the materials handled. This, again, is the result of imperfect transparency of the processes involved, and a major step of remedy can be taken by introducing tracking services providing reliable data without much time lag.

Tracking is the process of keeping track of selected properties (most commonly physical location) of the material in question, and requires the following requisites to be provided [11]:

1. *Unambiguous identification of the material* is a key for recording and retrieving tracking information, therefore, uniqueness must be granted to ensure consistency of records and retrieved results. Nowadays, many processes in the supply chain (especially stock keeping policies) still observe pure material count (stock level, also referred to as the *account-based* perspective), rendering these solutions incapable of differentiated material handling, e.g., based on varying expiry dates. Thus, unique identification has to reach at least the level where differences in estimated product quality occur (e.g., production batches with different dates of output, or lots that have historically taken a different path through the supply chain). When decisions about the desired granularity of uniqueness are taken, one should also observe the drawbacks of differentiation being overdone: an information flood can be a serious burden to operation efficiency.

A wide spectrum of technologies is now available for physical implementation of unique identification. Traditionally, material was identified entirely manually, with human operators passing on relevant information on paper (hence the term *paper-based*). While requiring almost no initial investment, high labor costs and high error rate will only justify its future application as a fallback measure. Optical identifiers (such as bar code) can be read automatically or semi-automatically with an optical device and can be implemented at a very low cost, justifying its most widespread use among all the AutoID (automatic identification) technologies that make identity-based material tracking economical. Optical identifiers do, however, have their limits: most of them are not re-writable, and the numbering space of some of them is insufficient for unique identification to a desired granularity. Although its current cost still limits its penetration, RFID is more versatile as it can be read even more efficiently than optical identifiers (no direct line of sight needed; this may spare the effort of breaking up packages for inspection). Also, RFID can be combined with sensors, offering seamless integration of sensing product properties and processing them in tracking activities [1],[11].

2. *Establishment of information services* to record and retrieve tracking data. In supply chains, this means a network of communicating acquisition/retrieval end points and data repositories where material are maintained and shared with a sufficient level of reliability (e.g., transaction consistency) and security (secure communication channels, differentiated access control). Future tracking services are certain to cross corporate borders, calling for easy access by new participants and occasional users, and protection of operators from unauthorized parties possibly attacking the open network.

   Product variability implies a wide variety of data that has to be properly interpreted by all parties concerned. For cross-company transparency, mutually accepted data modeling and interpretation conventions are essential. The industry is already moving towards the latter, as indicated by the appearance of standard top-level ontologies and data or process modeling practices (see, e.g., UN/CEFACT) [11].

Tracking services can be beneficial for all stages of the food supply chain but are especially useful where fast and precise decisions must be met about a greater stream of goods: during routing of transportation and stock management in warehouses and points of sale. Accessibility must be assessed observing that smaller participants are, least equipped for accessing tracking networks—this may call for compromises or fallback measures as simplified access points or double implementation with human-readable copies of labels.

4. THE EUROPEAN SITUATION—CONDITIONS AND CHALLENGES

European food supply chains and local regulations differ from those in regions where active and intelligent packaging are massively deployed (notably Japan and North America). The following issues prevent AIP technologies (and partly also today's mainstream tracking solutions) from being directly adopted in European fresh food supply chains:

- As opposed to relatively few large companies, both production and replenishment of food is dominated by SMEs in Europe. The practices of large-volume supply chains of other regions may prove unsuitable as SMEs have limited resources to invest in new technologies and have sporadic access to expertise needed for their adoption. The heterogeneity of SMEs presents special challenges for tracking infrastructures as well.
- European regulations are not well-prepared for direct adoption of packaging techniques used in other regions [7]. Some solutions, such as separate sachets with agents, are

currently not permitted in food packaging, requiring either the elaboration of suitable technologies or the reassessment and modification of corresponding regulations.

- A significant part of European consumers is very critical towards certain technologies employed in high-performance food supply chains, the more so as local trade of fresh food often remains a popular—and reasonable—alternative. Especially in Western Europe, consumers are growing conscious about products with less health risks and no excessive environmental threat (see, e.g., the almost unanimous rejection of genetically modified crops attempted to push into production without proper testing). Environmental and health issues [5],[6] will surface in the case of packaging, and they must be addressed before a large-scale roll-out. Tracking services may prove more appealing: they can reduce spoilage-related environmental impact and better transparency improves consumer confidence. Most consumers in Eastern Europe present another challenge by being extremely price-sensitive due to their poor financial situation. Chances are that this will limit the Eastern European market of packaged fresh food to a narrow range of premium products for a considerable time.

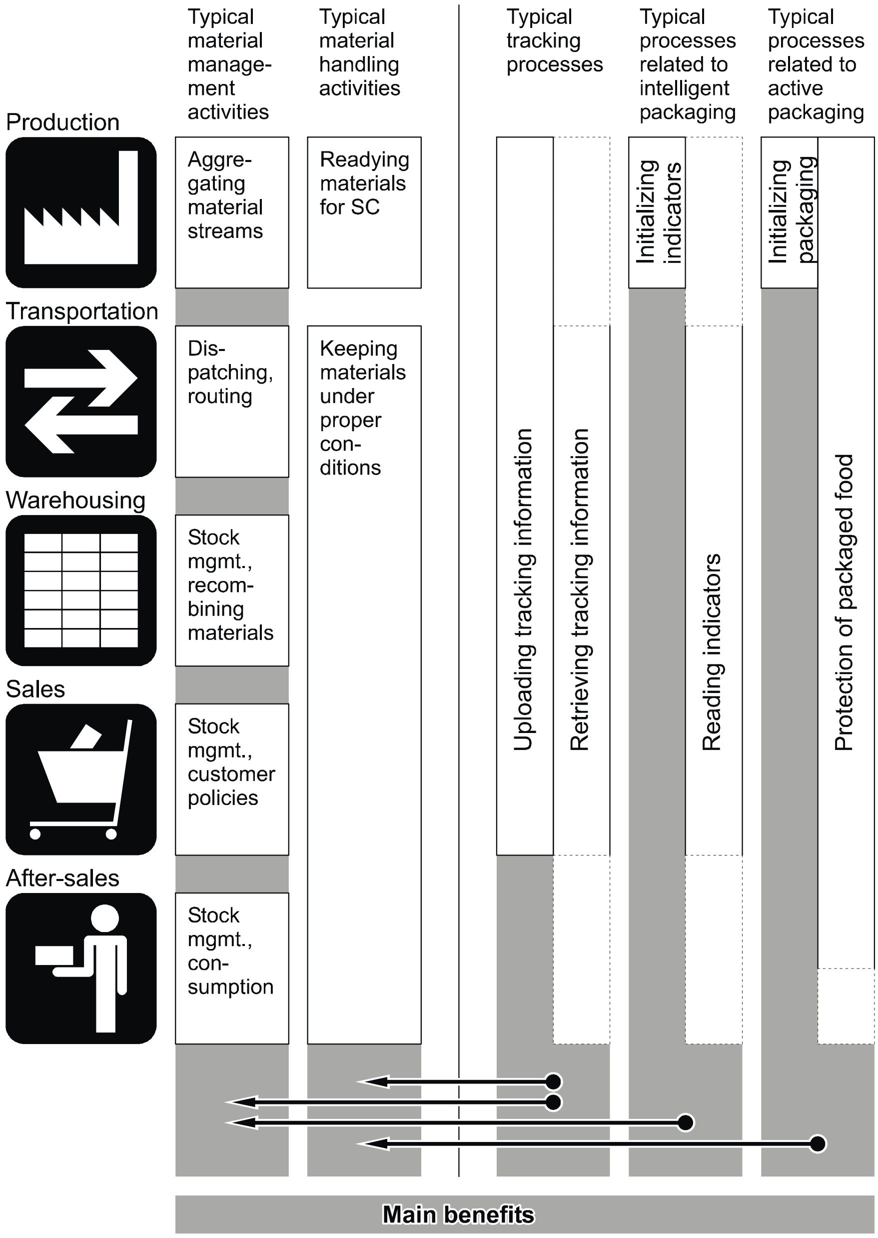

Figure 1: Key activities and processes in various stages of the fresh food supply chain (left), shown in parallel with processes of tracking and use of active and intelligent packaging (right). The application interrelations resulting in benefits are highlighted at the bottom.

5. MEETING THE CHALLENGES WITH AIP-CORNET

Started September 2009, the two-year European R&D project AIP-CORNET (*Active and Intelligent Packaging (AIP) Competence Platform*, http://www.activepackaging.eu/) aims to overcome the aforementioned burdens by two types of efforts exerted in parallel: i) the channeling of vital information especially to technological stock holders, prospective users and standardization/legislative bodies, and ii) elaboration of new technologies that better suit the European conditions of application. The consortium of AIP-CORNET joins a wide range of expertise, as it includes stock holders from the packaging and food industry, R&D partners in chemical/biochemical research, as well as members with IT expertise and SME-friendly tracking resources at hand. Although the brief duration of the project limits the observation of long-term impact, ongoing and frequent consultation with targeted user groups will ensure that the identification, evaluation and integration of suitable solutions meets the European needs, especially of small-scale members of perishable supply chains. A systematic view at the addressed problems and targeted solutions is summarized in Figure 2. Here, the IT-relevant tasks will be presented in detail.

5.1. Channeling of knowledge

Collecting and presenting knowledge is a highlighted challenge due to the nature of a major part of the targeted audience: SMEs that may not even have a rough picture of the given scientific and technological domain and are thus left without any initial orientation. This calls for a systematic organization of knowledge resources for both fast and directed search (to specific criteria), as well as browsing that guides the inexperienced user through the structures of the domain and gives a good first impression of “where to locate” a given answer.

Most suitable for this purpose are topic maps that can place a structured conceptual index on a pool of information resources. As the project has limited time and resources for establishing such a structure, a “lightweight” implementation of the topic map concept with somewhat restricted flexibility will be built. This is still easy to handle for those populating the repository as well as those using it.

5.2. AutoID and machine readability

It is well-understood by the consortium that RFID, despite all efforts of pushing it into practical use, will experience limited penetration in supply chain applications of the next years. Therefore, AIP-CORNET is seeking possible alternatives in the optically readable domain. This includes two parallel branches of progress: i) developing optical indicators that work reliably enough for automatic acquisition and processing, and ii) development of suitable methods and technologies (protocols, selected devices, etc.) for automated acquisition and interpretation of optical indicator readings.

5.3. Tailoring of tracking services

Within the AIP-CORNET consortium, considerable expertise is present regarding tracking services with small-scale members of high variability [13]. An already implemented solution platform presents a solid basis for mastering specific tasks of fresh food supply chains with the inclusion of small-scale or occasional users as SMEs. As the identity-based tracking platform is independent of the particular choice of physical ID carrier, it can also serve as a test bed for assessing a variety of prospective labeling and identification technologies.

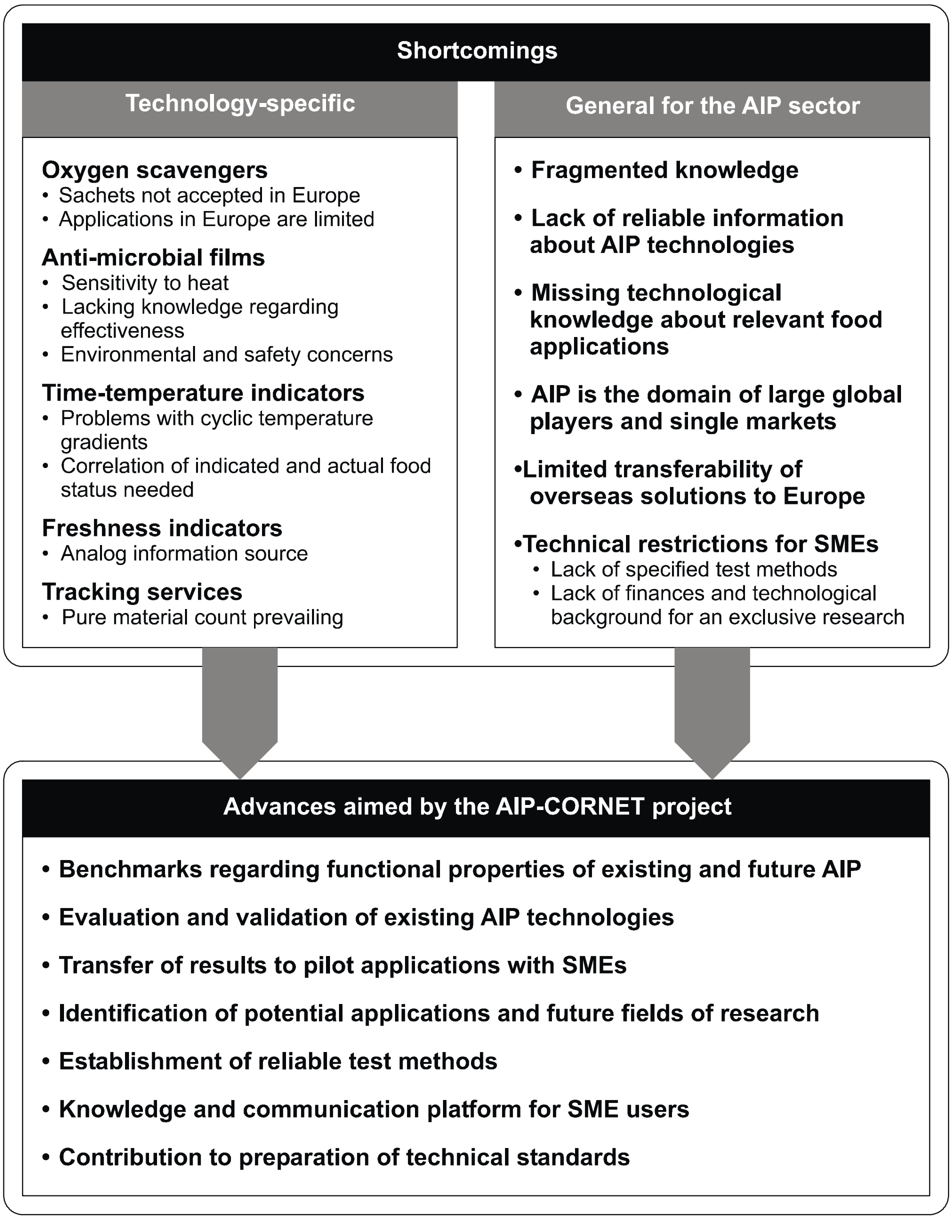

Figure 2: Problems addressed and goals pursued by the AIP-CORNET project

6. CONCLUSIONS

The paper presented the key challenges of supply chains conveying fresh food products over an extended range. Active and intelligent packaging, as well as tracking services were named as feasible solutions for attaining longer shelf life, more precise information about current product quality, and improved information transparency in dispatching and replenishment processes. The paper pointed out that these solutions, although commonly used in other regions of the world, can meet obstacles in Europe due to a different legislative framework, a different composition of market players and critical user expectations. Finally, the paper summarized steps to be taken by the recently started project AIP-CORNET to overcome these obstacles by channeling of expert knowledge and developing technological alternatives that are better suited for a roll-out in Europe.

7. REFERENCES

[1] Albright B. (2008). *RFID Sensor Platform from GE Breaks New Ground.* RFID Update news report, October 15, 2008, http://www.rfidupdate.com/articles/index.php?id=1691&from=rss

[2] Appendini P., Hotchkiss H. (2002). “Review of antimicrobial food packaging”, *Innovative Food Science & Emerging Technologies*, 3 (2): 113–126

[3] Bardaki C., Pramatari K., Doukidis G.I. (2007), “RFID-enabled Supply Chain Collaboration Services in a Networked Retail Business Environment” *BLED 2007 Proceedings*, Paper #51, pp. 1–16. http://aisel.aisnet.org/bled2007/51

[4] Brody A.L. (2002). “Action in Active and Intelligent Packaging”, *Food Technology*, 56(2): 70–71.

[5] Chiellini E. (Ed.), (2008). *Environmentally compatible food packaging, Woodhead Food Series No. 161*, Woodhead Publishing, ISBN 1-84569-194-6

[6] European Union (2002). *Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety*, http://europa.eu/

[7] European Union (2004). *Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Dirs. 80/590/EEC and 89/109/EEC*, http://europa.eu/

[8] Han J., Gonzalez H., Li X., Klabjan D. (2006). “Warehousing and Mining Massive RFID Data Sets”, *LNCS*, 4093/2006: 1–18

[9] Jager W., Janssen M. (2002). “The need for and development of behaviourally realistic agents”, *LNCS Proc. of the 3rd int. conf. on Multi-agent-based simulation II*: 36–49.

[10] Jedermann R., Ruiz-Garcia L., Lang W. (2009). “Spatial temperature profiling by semi-passive RFID loggers for perishable food transportation”, *Computers and Electronics in Agriculture,* 65: 145–154

[11] Kemény Zs., Ilie-Zudor E., Kajosaari R., Holmström J., van Bolmmestein F. (2007). *State of the Art in Tracking-Based Business (survey deliverable D3.1)*, Technical report, EU 6th FW Specific Targeted Research Project TraSer (contract Nr. IST-033512)

[12] Miltz J., Perry M. (2005). “Evaluation of the performance of iron-based oxygen scavengers, with comments on their optimal applications”, *Packaging Technology and Science*, 18(1): 21–27

[13] Monostori L., Kemény Zs., Ilie-Zudor E., Szathmári M., Karnok, D. (2009). “Increased transparency within and beyond organizational borders by novel identifier-based services for enterprises of different size”, *CIRP Annals—Manufacturing Technology,* 58(1): 417–420