# New Methods for Improving Food Product Safety and Communication

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## Abstract

*When purchasing food products, consumers have to be confident that the products are safe and fresh. Most food products are packed and the product package should give all the necessary information and, at the same time, promote the product and the brand. In addition, new tendencies towards to new renewable and biodegradable packages that reduce the use of oil-based raw materials and restrain the continuously worsening littering call more sustainable packaging solutions. These requirements represent challenges for the food production chain and new methods for improving product safety, communication and authenticity guarantee have to be developed. This paper presents new methods that have been developed for these specific purposes for the food production chain. These methods include new kind of barrier layer for decreasing leakage and migration of substances (through the package and from the packaging material), inkjet printed leakage indicator for detecting if the package containing modified atmosphere that protect the packed food has been leaking thus causing food spoilage, and markings done directly on food products in order to improve authenticity, traceability and thus product safety [1, 2].*

## Safety, communication and authenticity needs of food products

Typically product safety issues are linked to food contact materials, e.g. food packages. All materials comprising the final food package (substrate and its different layers and ink) and the whole manufacturing process have an effect on the product safety of final food packages. So, for example, printing process parameters (e.g. amount of ink per unit surface area, printing speed and drying or curing energy) which are known to interact with each other may affect significantly on safety of food packages.[3,4]. Therefore, wherever changes are made, either in the production process or in the raw materials, testing of the product safety with e.g. migration tests is necessary. In the end the one who combines food and packaging, the manufacturer of the final food package or article, has the responsibility to ensure that the package is suitable for food [5].

One aspect of product safety is spoilage of food products. Food spoilage is caused by chemical and physical reactions and actions of micro-organisms and enzymes. The shelf life of a food product depends on a number of factors, such as the quality of the raw material, processing conditions, packaging and storage conditions. External factors that determine spoilage are the initial quality of the product and hygiene, storage time, storage temperature, gas atmosphere and humidity, lighting conditions and packaging. Thus, the spoilage of packed food can be controlled by restricting the time of use, monitoring the temperature, detecting package leakage and detecting substances produced by spoilage. Spoilage of food products can start because of breakage of the product package or wrong storage conditions during transportation, at the retail store or at home, thus affecting the lifetime of the food product. By monitoring food product quality, it is possible to get more reliable information about the status of the product than with use-by-date or production date information.

During the last decade, consumer attitudes towards packages have become more positive, because packages increase shelf life and reduce food waste. Consumers consider information content, convenience, easy opening and environmental friendliness as the most important properties of packages. It is important that the package communicates correctly and looks appealing. Legislation defines what information is required in food product packages. In addition, brand owners want to include marketing messages. Elements of package communication can be divided into graphical and structural elements. By modifying these elements according to the needs of the target group, package communication can be enhanced.

Counterfeiting is an increasing problem. In early 2013 there were several cases reported in Europe where beef products contained horse meat although not listed in the ingredients. Horse meat was used in production instead of beef since it is considered less expensive. However, horse meat might present health concerns because of antibiotics used for medicating horses that have not been originally intended for use in food products. World Customs Institute estimates that the counterfeit food industry is worth about 49 billion US dollars (approximately 35 billion euros) [6]. There is now evidence that counterfeiters are moving into product lines where the effect is not only economic, but it can put lives at risk. Such product areas include also food, and consequences from fake food include unsafe or out-of-date food as well as repackaged food. Typical means to fight counterfeiters is to put safety elements onto product packages. In addition to marking and customising product packages, there is also a need to directly mark the packed products in order to guarantee their user safety, authenticity and tracking. For example, one aspect of counterfeiting is to replace genuine products with pirated ones, but retain the genuine package. In this regard, it is important to guarantee both the authenticity of the product and the package.

Traceability of the food product is also important e.g. with product recalls or when dealing with liability issues. Since 2002, traceability has been obligatory in the European Union for all food and feed businesses. Studies have shown that the information loss from one link in the chain to the next is huge, in some industries documented to be 80-95% [7].

 

## Some methods for improving food safety and communication

There are several ways for improving food safety and communication. This paper focuses on recent studies about food quality indicators, barrier layers and direct marking that can separately or together significantly improve food safety and communication.

### *Barrier layers*

Leakage and migration of certain components into and out of food packages are aspects of product safety. They can be controlled by adding special barrier layers on packaging substrates. Barriers are added by coating methods during or after the substrate manufacturing process. Typical barrier properties required in packaging applications are water vapour, oxygen, grease and aroma resistance. Different food products have different requirements for water vapour and oxygen permeability of barrier layers because of e.g. storage requirements. VTT has developed, amongst others, a thermoplastic starch dispersion barrier with a glass transition temperature range of 40 to 150 $^oC$, which could be suitable for poultry packages. Dispersion barriers can be applied by traditional liquid paper coating methods and by some printing techniques, such as flexographic printing. The use of thermoplastic starch supports the shift from oil-based barrier materials to renewable bio-based materials.

One recent safety fear on the packaging market is the migration of technical grade mineral oil compounds into packaged food. The mineral oil compounds, typically saturated (MOSH) and aromatic (MOAH) mineral oil hydrocarbons, can either originate from recycled fibre (e.g. containing printing ink residues) or from printing inks not intended for food packages or from the surroundings, e.g. transport box made of corrugated board [8,9]. Typical synthetic extrusion barriers on the market today are made of mineral oils themselves and thus pose a risk if monomers or additives are left free in the polymer matrix. This calls for packaging barriers which are not made up of mineral oil components. In addition, since the paper and paperboard recycling rate in Europe reached a record high of 68.9% in 2010 with the voluntary target of recycling 70% by 2015, the risk of mineral oil migration will increase further. Thus new effective barrier materials that prevent also the migration of mineral oil compounds from packaging materials are needed in the future.

The developed thermoplastic hydroxypropyl starch acetate dispersion has been double-coated commercial Food Service Solid Bleached Sulphate Board in order to achieve 8+8 $g/m^2$ coating. A laboratory-scale coating equipment was used. Table 1 lists the measured values from the coated samples.

**Table 1. Results for the hydroxypropyl starch acetate coated on base board. All measurements are done in 23 $^oC$, 50 % relative humidity.**

| Property | Method | Result | Analysis |
|---|---|---|---|
| WVTR (water vapour transmission), normalized 20 µm | TAPPI T448 | 55 ± 7 $g/m^2$ | Medium level (PET board=11 in C. Laine et al. / Industrial Crops and Products 44 (2013) 692– 704) |
| PPS roughness | ISO 8791-4 | 3.7 ± 0.5 µm | Smoother compared to base board |
| Air permeance | LW air permeance tester | <0.265 ml/min | Impermeable to air |
| OTR (oxygen transmission), normalized 20 µm | ASTM D3985 | 556 ± 28 $cc/m^2/day$ | Medium level (PET board=288 in C. Laine et al. / Industrial Crops and Products 44 (2013) 692– 704) |
| Coating thickness | SFS-EN ISO 536 | 6-19 $g/m^2$ (16 $g/m^2$ as the target) | Much variation |

The coated sheets still need improvement to show good enough barrier properties, but they have been successfully converted into tray packages (Figure 1). The use of starch acetate barrier layer is shown to improve product safety based on the measured barrier properties.

*Figure 1. Barrier coated carton board converted into tray package.*

### *Food quality indicators*

Food quality indicators are one solution for increasing package communication and product safety. These indicators monitor a certain property inside the product package, such as headspace gas composition, humidity or temperature, and communicate relevant changes as visual colour changes of the indicator. Food quality indicators for indicating humidity, oxygen, i.e. leakage, food freshness and ethylene have been developed. Inkjet printing has been chosen as the manufacturing method because of low material consumption. Another benefit of inkjet printing is that indicators can be directly attached to the product package during packing thus enabling activation of the indicator at the correct time.

In order to evaluate the performance of the developed barrier layers, but also to evaluate the performance of the whole packing process in the final food package, an oxygen indicator has been developed. The indicator shows if the package is leaking as a result of improper sealing, malfunctioning barrier layers and/or defects caused by handling steps or transportation.

The oxygen indicator for indicating leakage of vacuum and MA (Modified Atmosphere) packaging developed at VTT is based on reduced redox dye. The indicator is attached inside the package and a visual colour change can be read from outside the package. The reactivity of the indicator has to be tailored for a specific product packaging, in this case a poultry package. An inkjet printable indicator ink has been developed to meet the requirements of the indication process, food compatibility, the adhesion on plastic substrates and printability properties.

An inkjet-printable, working oxygen indicator solution consists of an alcohol soluble polymer binder (c. 10 wt-%) for adhesion on plastic substrates, dye and active agents (3 wt-%) and organic solvent. Good adhesion has been achieved on reverse side of various types of multi-layer PET sealing films i.e. inside the food package. For inkjet printing both laboratory scale (DMP-2831 by Fujifilm Dimatix) and industrial type of inkjet printers (Nova AAA printheads by Fujifilm Dimatix) have been used. The principle of the working indicator is presented in Figure 2. This shows a clear colour change from yellow to blue for leaking package.


*Figure 2. The principle of the developed oxygen indicator.*

The developed oxygen indicator concept can be used in poultry packages for detecting potential leakage and it increases package communication with the consumer. As an inkjet printable solution the indicator can be added to the package and activated at the correct time during packing and sealing for improved product safety.

## Direct marking

Digital direct marking methods, laser marking and inkjet printing, where a marking is made directly on the product surface without a separate label, have been mainly used for product decoration purposes, but they offer a huge potential also in product safety applications. These direct marking methods offer a solution that does not contaminate the product and with laser marking no additives are added to the product. Small details such as 2D bar codes, short texts and striking logos are possible to be added directly on the product itself. Compared to traditional stamping-type of methods these direct marking methods can be easily automated, are suitable for mass production, offer possibility for customised markings and can be integrated into existing production lines.

Direct marking of different type of food products with laser marking and inkjet printing have been studied. A pulsed $CO_2$ laser (200 W pulsed $CO_2$ laser with scanning optics f100/f200) and commercial edible inkjet ink (Tapestry$^{TM}$ FEC cyan ink, E133 colorant) have been used, respectively. A comparison between these two marking technologies has been made based on visual quality and small scale sensory tests. Also, the effect of direct marking on food product quality has been investigated with SPME GC-MS (Solid Phase Micro-Extraction Gas Chromatography Mass Spectrometry) and visual analysis. Laser marking settings were pulse ratio 10-30 %, scanning speed 200-2000 mm/s, pulse frequency 10-20 kHz, power 72-191 W and pulse length 5-30 µs depending on the marked sample. In inkjet printing 80 pl printhead (SE-128 from Fujifilm Dimatix) with 300 dpi resolution and 150 mm/s printing speed was used. Figure 3 shows the marking equipment used.

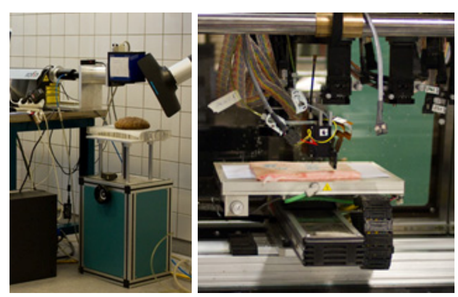

*Figure 3. Laser marking and inkjet printing setups used in the direct marking studies.*

Some samples of marked food products are in Figures 4 and 5. The experiments showed that the most potential product sectors for direct marking are meat products, bakery products including breads and cookies, cheese, and sweets, such as candies, chips and chocolate. Fruits and vegetables are a challenge since inkjet inks do not adhere on them well and laser might accelerate degradation due to locally thinner skin. With inkjet printing, products such as meat and cheese products, which are stored in a refrigerator, might also present challenges because of moisture and condensate water that trigger ink spreading.


Figure 4. Laser marked edible products: on top from left crisp bread, sausage and potato chip; on bottom medical tablets and capsules.


Figure 5. Edible products marked with inkjet printing: on top from left apple, sausage and crisp bread; on bottom medical capsules.

Bread and ham were used as the two case products when studying the effect of direct marking on quality of food products. The products were marked with both laser marking and inkjet printing and processed into final products. In the case of bread this meant marking the dough, moulding and baking the product. The idea was that the marking would disappear during processing thus making it invisible for consumers. This concept is for improving traceability inside bakeries. In the case of pre-baked bread the marking would be visible for consumers and the marking is done after pre-baking, but before final baking. The idea is to improve brand promotion and product safety. In the case of ham the raw meat skin was marked and cooked afterwards. The idea is to improve traceability and guarantee authenticity for consumers. Figures 6 and 7 present some samples of the case products.

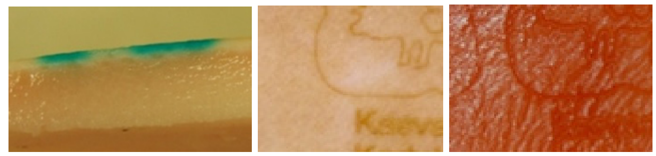

Figure 6. Examples of ham with direct marking. From left: inkjet ink penetration into ham skin after two weeks cold storage, laser marking before cooking, laser marking after cooking.

Based on visual analysis of the ham samples the laser marking speed had a clear effect on the darkness of the marking i.e. the lower the speed the darker the marking. Dipping of ham into salt water washed the burned colour almost entirely away thus leaving only the engraving that was not that visible anymore. Inkjet markings were very clear after printing and salting, but after two weeks in vacuum packs at 4 $^{o}$C the markings were spread thus making them difficult to read. The inkjet ink didn't, however, penetrate very deep into the product – only into the skin. Based on small-scale sensory analysis neither laser marking nor inkjet printing affected the smell of the products.

Figure 7. Examples of bread with direct marking. From left: inkjet ink visible after moulding and baking of dough, inkjet ink after baking of pre-baked bread, laser marking on pre-baked bread after final baking.

Based on visual analysis all the markings on dough and bread were clearly visible after marking and frozen storage. Laser markings disappeared easily during moulding and no traces of the marking could be found in visual evaluation of bread slices. Disappearance of inkjet markings required a lot of work and still after baking traces of markings could be found in bread slices. Based on small-scale sensory analysis neither laser nor inkjet markings caused any smell or taste defects. On pre-baked bread both markings were clearly visible after baking. Inkjet ink didn't penetrate into the bread and caused no smell or taste defects. Laser marked areas, however, smelled and tasted slightly burned.

The case product studies showed that both laser marking and inkjet printing are suitable methods for improving traceability, product safety and brand promotion. Laser marking can also be used for making markings that disappear during further processing thus making them visible only to logistics and retail store- and invisible for consumers.

The edible ink used in this study has been accepted by FDA and EU for use on food products and inkjet printing is already used for decoration purposes on edible products. The same evaluation has not been done for laser yet although industrial examples of laser marking on edible products already exist. For this reason the potential suitability of laser marking for food products was evaluated by using SPME GC-MS that analyses volatile compounds. Laser marked samples were compared with heat treated samples and unmarked samples. Heat marking was done using a soldering iron. Analysis samples were scraped from the marked surfaces of dough and meat. Unmarked surfaces served as non-treated reference samples.

SPME GC-MS tests showed that heat treatment and laser marking increased the amounts of several volatile compounds when compared to non-treated reference samples. However, heat and laser marking had the same kind of effect on the volatile compounds thus indicating that the same compounds were formed with the both methods. Only the amounts of the volatiles varied a bit. This shows that laser has the same kind of effect on the volatile compounds compared to heat treatment that is commonly used for food decoration.

## Conclusions

Migration and leakage of MAP packages have a critical effect on food product quality and thus on product safety. These can be controlled by using new kinds of barrier layers, such as thermoplastic starch. Furthermore, leakage can be monitored by using oxygen indicators that give more precise information about the quality of the food product than use-by-date information. Inkjet printing is a suitable manufacturing method for food quality indicators, because it enables application of the indicator at the point of packaging. Inkjet printing can also be used for improving communication in the food production chain with the help of direct marking and printed quality indicators. Package communication is important to consumers, but when dealing with authenticity and traceability, marking of the actual product in addition to package markings is beneficial. Inkjet printing and laser marking are potential direct marking methods that enable customisation of the information content thus providing traceability, product safety and authenticity in addition to brand promotion.

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