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Case study
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The possibilities of RFID and NFC tag implementation in dairy segment

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Abstract

With the help of printed electronics, the product-consumer relationship can be further evolved and explored, thus enabling the building of a deeper emotional connection. The growing implementation of online connectivity – Internet of things, is one of the important driving factors for the printed electronics market. The goal of our study was to estimate implementation options of printed electronics into the packaging of dairy products according to the type of packaging with considering the approximation of the cost per unit. Knowing that the dairy segment is mainly a commodity, we assume this implementation will have a big influence on the product price. Our research showed that the added value in the commodity segment is too low to be able to cover the cost of implementation of the RFID tag. Printed electronics and, generally speaking, smart packaging has found its place in a segment where a need for security elements or the product is higher priced and the extra cost of a tag does not represent a high burden. There is a great potential in the packaging of pharmaceutical and cosmetic products, where the product's identity is key. There is also a potential in a food segment where food safety is crucial; these are nutritional products for children, for example, baby milk. The main obstacles of printed electronics and smart labels, in general, are in the high unit price per product because the uses are mostly carried out on luxury goods and those are smaller in quantities. Taking it into consideration the printed electronics providers cannot achieve large quantity productions and therefore lowering of price because the economy of scale is insufficient. Until there are no implantations in the segments where the quantities are high, the RFID tag has lesser chance to get its price lowered.

Keywords: smart packaging, consumer interaction, aseptic packaging, food packaging

1. Introduction

Printed electronics (PE) enables the implementation of new types of packaging and product features outside classic static printing technologies. This allows the owner of the brands, manufacturer or retailer to stimulate and persuade the consumer in the purchase activity. The longer the potential consumer is in the emotional phase, the actual purchase is more likely to happen (Achar, et al., 2016). Printed electronics enables to gain the customer attention and keep him in a deeper connection with the product. At the same time, the use of PE enables communication directly to the consumer in real time; for example, it can offer customized solutions, discounts and promotional prizes. The expanding collection of connected things and the growth of Internet of things (IoT) is showing a need for new technology and development of PE. According to the new report, PE was valued at USD 3.13 billion in 2015 and is expected to reach USD 12.10 billion by 2022, at a compound annual growth rate (CAGR) of 22.38 % between 2016 and 2022 (MarketsandMarkets, 2016). By increasing the volume of the economy, the price of PE will drop, and this will ensure its broader use.

Most common usage of PE on the packaging is the use of radio-frequency identification (RFID) tags and sensors for inventory management, tracing in logistics, and monitoring of temperature regime. The PE usage in the marketing, advertising and point of sale is strongly oriented into the usage of near-field communication (NFC) tags. The PE is also essential to promote customer loyalty and retention. Many consumers carry many loyalty cards, and with PE this becomes economical and at the same time feasible to turn them into smart cards. They can store data and enable wireless interaction. When a

consumer enters the store, makes it easier to communicate promotions and other features that make it possible to adjust shopping experience. At the same time, from a producer or trade point of view, PE are also crucial, as the applicable technologies provide security against counterfeiters and fraudsters (Vanderroost, et al., 2014). Communication possibilities are not yet introduced in commodity goods due to yet not analyzed reasons – which are the basic goals of this study.

The advantages of using RFID technology in retail are obvious, as vendors can monitor their goods throughout the store and thus have instant information, in a case when a product on the shelf is running out. This greatly enhances the precision of the inventory and reduces the management of stocks. It is also possible to maintain lower inventory and at the same time to manage purchasing statistics, thereby simultaneously reducing costs (Kaur, et al., 2011; Swedberg, 2013). The cost, on the other hand, is also dramatically reduced by the more effective anti-theft protection offered by the aforementioned system. The payment process itself at the end of the purchase is much faster, as there is no need to scan each product separately. Moreover, the purchase can be simultaneously added to the buyers account during the purchase time and is displayed on the shopping cart.

Looking at the implementation of RFID and NFC tag, we looked also on the main differences. The RFID is a one-way process in the discussed field since information is transmitted from an encrypted memory chip (known as a "smart tag") via the antenna to the RFID reader itself. Active RFID tags contain an energy source so they can emit a signal up to 100 meters, but passive RFID tags do not have their own power source and a RFID reader activates them. This allows them to be used for short reading domains, up to 10 meters. Passive RFID tag uses one of three frequency ranges; low frequency (LF), high frequency (HF), and ultra-high frequency (UHF). The NFC operates as a passive RFID HF tag. High-frequency NFC reads smart tags and also has a read-write mode like RFID. If comparing RFID and NFC, last mentioned has the advantage of exceeding the RFID's one-way limitation (reading only information on a chip, not able to write new information) with two-way communication: card emulation or peer-to-peer (P2P) communication. For example, a smartphone that has the ability to use NFC technology, and today most of them have this feature, can also transfer information back and forth to another device which has an NFC protocol – e.g. contactless payment is an example of the way the cards emulate.

Due to the rise of PE use in packaging on general and the possibility of prolonging consumer interaction, we analyzed the possibility of implementing an RFID and NFC tags in the food-packaging segment, more precisely in the dairy segment. This segment was selected because of its specifics being in lower added value segment where the increasing of the costs can be more influential than in case of products with higher added value, like non-commodity products, mainly as indulgent, premium, bio-products, alcoholic beverages, and in general higher-priced products, like chocolate, coffee, cheese and champagne.

We made an approximated financial estimation of the implementation and analyzed its impact on the product. In this paper, we present the main possibilities of implementation of RFID and NFC tags on three different types of product with different types of packaging and we investigated what kind of technical and financial effects can this application bring.

2. Methodology

2.1 Information collection and analysis

In order to get an outlook on the possible implementation of PE, in our case RFID and NFC tags, we looked upon the different types of temperature control policies, and took three different types of packaging and products, where we decided on the products with different added values, for which the quantities are higher and the types of packaging are widely used in the region (even in Europe). The products of interest were a long-life product (UHT milk), a fresh product (yogurt) and a frozen product (ice cream). The price analysis was performed on a general assumption of population size and dairy production data in Slovenia. Because the production costs information is a trade secret, we made estimation according to publicly known data. To estimate production costs (EPC), we calculated the average shelf price (ASP) collected on the field and online retail stores, deducted it with the current average market price (AMP) of the main ingredient, i.e. milk, and average retail margins (ARM):

$$EPC = ASP - AMP - ARM \quad [1]$$

We used this calculation knowing that the milk consists of 100 % percentage of the main ingredient, in yogurt little less and in ice cream the difference from 100 % has only minor effect – while this is a product with higher added value, consequently there is less impact on the final result. The implementation options were reviewed according to the type of packaging and an indicative calculation to consider what it means regarding the approximation of the cost per unit. Knowing that the dairy segment is mainly in a commodity sector and with that lower added value, we assumed that implementation of an RFID tag will have a big influence

on the production price. The implementation possibilities were examined from the packaging structure point of view, considering also the packaging manufacturing process where the process itself can influence the tag functionality.

According to the three types of products and packaging, i.e. long-life milk, fresh yogurt and ice cream, we examined the technical possibilities and cost-effectiveness of the RFID or NFC tag application. Long-life milk has, for the purpose of the safety, also a layer of aluminum, which may cause interference in the signal when the tag is read. According to different providers, these problems are solved with an added secure protective layer on the back or in the last layer of the tag; this either prevents or reduces the interference. Fresh products do not need aluminum layer and there are no such restrictions. However, taking in consideration that the products are filled in a relatively wet environment, the problems may also occur when the tag is in contact with water, but this is only in case when the tag is applied to the outside of the packaging and is actually exposed to external influences. There are possible solutions to this, adding protection layers to the tag, and this may partially or fully solve the wet environment problem. In the case of a long-life and fresh product, the application would be most suitable on the top of the layer of paper, so the tag is protected against the water with a layer of polyethylene. In the case of ice cream, or frozen products, in general, the problem is that low temperatures needed for maintaining the cold regime of frozen products must be less than −18 °C, mostly on average below −24 °C. The currently known RFID technology is ensuring the tags are in full operational in no less than −22 °C.

2.2 Monitoring a typical dairy product – a long-life, fresh and frozen product

A typical process of dairy product tracking and different temperature regimes needed according to the type of product were examined to see to possible solution for implementation of a smart element. In the production of milk and dairy products, all input materials, from raw materials (milk) to all packaging components (paper, caps, foils), need to be traced. Our interest was to see how the traceability of the finished product is carried out. Mostly the production is tracked by using the GS1-128 and EAN-13 code. When the primary packaging is filled, packaging also receives a printed date of production, and on the pallet, the series or batch of the production is also indicated. The pallets are transported to storage under a proper cooling regime and from there transported to the buyer and their successful delivery is recorded. When handling a food product that needs to be cooled, special care must be taken to ensure that the cold chain is not interrupted. Modern refrigerating and freezing transports already have computer-controlled systems, whereby the controller can easily find out what was happening with the product. In the event of system failure or prolonged power failure, the stored products are carefully inspected and usually eliminated from the sale. If the products are left in unfavorable conditions, their temperature rises and microorganisms have better conditions for development and growth. Consumers perceive the development of microorganisms as a process of deterioration, changing the taste, smell and consistency; in short, the product becomes different from the customer expectations. In respect to the cold chain principle and the appropriate storage conditions there are two cooling modes that ensure food safety and quality. For fresh products, the temperature of the cooling must not rise above +8 °C, and when we have frozen products, the temperature must not be above −18 °C.

2.3 Packaging structure

2.3.1 Long-life and fresh product

For long-life product, we examined the aseptic packaging, which basic structure is composed of 6 layers (Tetra Pak, n.d.). From inside out they follow as:

- layer 1 – polyethylene (closes the package at the side facing the contents, liquid);
- layer 2 – polyethylene (connecting the first layer of polyethylene and aluminum, layer 1 and 3);
- layer 3 – aluminum (oxygen and light barrier);
- layer 4 – polyethylene (connecting layer 3 and 5);
- layer 5 – paper, which is the carrier of the strength and stability of the package and at the same time the print media;
- layer 6 – polyethylene (last outside layer protects against external moisture in the production process).

The paper layer is the most important for the hardness of the package and is also the surface that determines the print quality. The polyethylene protects the packaging against external moisture and allows the paper to be laminated on a layer of aluminum. The aluminum protects the product against oxygen and light to maintain its nutritional value and taste at daily temperature. The aseptic package differs from the fresh package in aluminum layer, which is oxygen and air barrier and not needed for shorter shelf life products. However, taking recycling into account, the packaging producers are working on the development of new aseptic packaging without the aluminum layer, replacing it with other high-barrier materials. For example, first mentioned was the use of Toppan GL film – a transparent high-barrier film with the same degree of barrier performance as that of aluminum foil (Steeman, 2014).

2.3.2 Frozen product

The packaging of ice cream cup, so-called thin-walled packaging made of polypropylene is made on the principle of "in-mold" technology. Namely, with the help of a robot, a label is inserted into the tool during the process of plastic injection; in our example a cup and a lid. The label is made from the same material as the injected mold, so it is a perfect fusion of both materials and the temperatures in the process are exceed the temperature of 200 °C.

2.4 Restrictions of printed RFID tags

There are some restrictions of printed RFID tags. The operating frequency of printed antennas can reach a HF (13.56 MHz) and even an UHF (433–960 MHz) range that meets the requirements that the RFID tag can operate. However, the current problems that hinder the development of the printed market of RFID tags lie in the printing of transistors that could replace the microchip, because the printed transistors can only operate at a very low frequency, which is incompatible with the working frequency of the testers (Kaur, et al., 2011). In addition, only hundreds of transistors are printed based on current printing techniques, while about 10 000 integrated transistors are required in a normal RFID tag. When it comes to dairy products, the problem of water occurs as the functionality could be lost if water is in contact directly with metal parts of the tag. The higher the frequency of a tag, the more problems arise in the RFID system, these can accrue and finally cause that the tag has lower ability to be read. In general, passive UHF tags are intended for use on dielectric materials (non-conductive), such as cardboard, non-carbonic plastics and general non-metallic surfaces typical for use in logistics or production (Stark, 2011).

When used on or near metallic or metallic-dielectric material, signal disturbance can be generated. To reduce the interference, the non-conducting material (spacer) is added between the label and the substance; this significantly reduces the interference. It can be also solved if we place the tag physically away from the metal surface, and in packaging, this is neither practical nor possible (Roberti, 2012).

In the case of multilayer packaging, which has an aluminum layer in its composition, the tags on the inner part are protected, this way we can avoid the disturbance of the signal during the tag reading. In the case of an unprotected back layer of the tag, the reading signal is caught between the layer of aluminum and the tag, so the tag can transmit a poor signal or even not emit. For example, metal can reject RF energy from the tag, which greatly reduces the powering of the antenna, thus preventing good communication with the reader.

When we are thinking how to implement the tag we have to consider sustainability and recycling issues as well. It is difficult to separate and recover multilayered packaging, even without RFID tags, besides the fact that it represents a more energy intensive process. At developing packaging equipped with RFID tags, packaging designer should design products that are fit for recycling, and make it easier to separate out potential contaminants (Pullman and Boyd, 2017). Even if RFID tags have no impact on the recycling process, they do have an impact on the processing costs and/or the quality of products, material loss and the recovery rate (Schindler, et al., 2012). According to Benton (2017), acting policy director at environmental thinktank Green Alliance, the main challenge is in ensuring that new inks and NFC chips do not contaminate the recycling process, or enable a reuse loop. Inks are a major reason for down cycling, and NFC chips are essentially unrecyclable as they contain too little metal to separately collect but contain too much metal to not mess up traditional plastics, glass or paper recycling streams. Benton also pointed out the need for communication between packaging designers and recycling bodies, to ensure the products are suitable for recycling; to design the packaging in a way that the potential contaminants could be easier to separate out. To tackle the recyclability issue, the NFC tag producer, ThinFilm, is avoiding the use of silicon in its tags, and they instead invested in a new method of printing on to recyclable strips of thin steel, of a thickness of a human hair (Pullman and Boyd, 2017).

3. Results

In the results we will show first the economical surroundings and the primary elements for monitoring typical dairy products – a long-life, a fresh and a frozen product, following the differences in the packaging structure for all three type of products, ending with the application of RFID and NFC tags.

3.1 Products and their economical surroundings

For estimation of the production and packaging cost, the average shelf price was reduced for the average retail margin and main ingredient – milk. The price of milk was taken from the August 2017 and was indicated at 0.31 euro per liter (SURS, 2017). We have to take into consideration that the milk price differs according to the fluctuation of the milk market during seasons and demand. The average margins in Slovenia are approximately 30 % and they vary according to the different segments (Križnik, 2012). In Table 1 data is collected for average shelf prices of 1 l packaging, reduced for the average margin and for the cost of the main ingredient, milk.

Table 1: Average shelf prices of selected products, net price, and price reduced for the cost of milk

Products	Average shelf price of 1 l (in euro)*	Net price (reducing the average shelf price for 30 % margin, in euro)	Production and packaging cost (net price reduced by milk price, in euro)
Long-life milk	0.80	0.62	0.31
Yogurt	1.70	1.31	1.00
Ice cream	4.50	3.46	3.15

* Information gathered with the research of the prices in the retails in Slovenia.

3.2 The possible applications of RFID and NFC tags

The product tracking in loading and transporting process is easy, and existing systems are well implemented using barcodes GS1-128 and EAN-13. The main cause of misplaced product or shipment is usually a human error when products can be loaded onto another truck or remain in the warehouse.

At the moment, human error is also the only direct economic reason for the introduction of the RFID or NFC tracking system, because it is not enough that only one user is equipped with the aforementioned technology, but it is recommended that the whole chain would be included in the system; manufacturers, logistic transport companies, and final customers. The connected supply chain can contribute to rationalization and can offer a lot of transparency and, most importantly, quick access to information. The contribution would be even greater if the system would be introduced at the point of sale itself and would replace existing barcodes with RFID or NFC technology.

Going a step further, your intelligent refrigerator could detect when the product needs to be replaced with a new one. The most recommended and optimal implementation of the RFID or NFC tag is directly in the packaging and in the case of long-life and fresh product directly between the layers. This requires the cooperation of the packaging provider, the RFID or NFC technology provider and the manufacturer of the product. Currently, the cost of RFID and NFC tags per unit of product for primary goods (commodity goods) is too high to have enough impact and have enough advantages of their use.

3.2.1 Application on the long-life and fresh products

The possible application of an RFID or NFC tag on long-life milk and fresh products were reviewed together while there is a difference in only one layer when it comes to packaging structure – long-life product has additional layer of aluminum.

If we look at our three cases, we are interested in the approximation of the application cost. For the approximation of the tag price, we needed a yearly quantity of tags. When we talked to different manufacturers and RFID technology providers, nobody wanted to explicitly quote the prices, because the price is highly dependent on long-term cooperation, possibilities for implementation, and cooperation with the packaging provider. In fact, it was important to them what kind of business model is behind and for what purpose the tag is used. It is interesting that technological solutions exist; the problem is an economy of scale and thus high price. As we have already said from a hypothetical point of view, passive RFID tag costs roughly 0.10 euros (depends on the specific characteristic or needs) when talking about the quantity of more than 10 million tags per year according to Zorlu (2017), vice president and head of sales for industry segment at Smartrac. For easier estimation of the RFID or NFC tag quantities, we took the production quantities in the Slovenia in 2016 and divided them with three major Slovenian manufactures of dairy products.

This way we came up with an estimation of the production quantities and the possible tag order, in long-life milk, which is around 40 million, and yogurt with estimation quantities below 10 million (SURS, 2017b).

Table 2: Percentage of RFID and NCF tags cost per 1 l unit on the selected products

Products	Tag cost of net price per 1 l unit (in %)	Tag cost of production and packaging costs per 1 l unit (in %)
Long-life milk	16.1	32.3
Yogurt	7.6	10.0
Ice cream	2.9	3.2

In Table 2 the percentage of a tag cost per 1 l unit and current net (or production and packaging) costs for the selected products are shown. From the standpoint of 1 l long-life milk, the cost of a tag represents more than 16 % of the cost of the net price and more than 32 % of the cost of the production and packaging. From the point of view of 1 l of fresh yogurt, the tag cost is approximately 10 % of the production and packaging costs. We did not take into account the cost of research for the implementation of a tag in the packaging, as well as the additional costs of investment in the marketing. A question arises whether the manufacture will be willing to pay at a higher price, which this in milk represents the increase of 17.5 % price, and in yogurt 7.6 % and in ice cream 2.8 % (Table 3) and the answer is no, because the benefits of using the new technologies are yet not well explored from all parties involved to bring the proper return on the investment.

For price comparison, according Kantola, et al. (2009), Coca Cola said that they would not consider using RFID tags until the price decreased to 0.01 dollar per tag (approx. 0.0085 euro), so even big manufacturers concluded that the price of RFID should be much lower.

It would be necessary that the packaging supplier and the tag provider join forces and by increasing the volume of production, they could jointly act on the market and thus offer already final solutions to the consumer. This could bring the acceleration of usage and drop of tag cost. New smart technologies in the low added value segment are difficult to enter, despite the fact that large volumes are provided, and large volumes are lacking in the segment of luxury goods where added value is high.

3.2.2 Application on the frozen product

Unfortunately, we did not get the data for ice cream, but according to the consumption, we can assume that its numbers are even lower. In the case of ice cream, the value added is higher for the mentioned product, and therefore the price of the tag per unit is much smaller, i.e. just above 3 % of the production and packaging costs. However, according to the information from the tag provider (Zorlu, 2017), this normally works in temperature higher than −22 °C, and these products are stored at lower temperatures, which excludes the possibility of use of a tag in frozen goods segment. The tag can be placed on the outside of the packaging and due to temperature fluctuation, the moisture condensation can appear, which additionally makes the use impossible; or we should use tags with a water protection layer, which only further increases the costs. In the market, there are RFID tags specifically for in-mold technology, i.e. Diobond RFID (Inotec, 2017), which consist of a label and UHF inputs. Due to special surface treatment, they are highly resistant to wear, UV light, cleaning agents, weak acids, and chemicals and also higher in price. The tag is attached to the lid or cup during the injection process so that its surface remains smooth. This means that dirt or moisture cannot get under the label, which is essential. This solution is suitable for identifying returnable buckets, which could possibly be used in larger fillings (e.g. 10 liters) such as milk or sour cream for the catering industry, where the pack sizes are larger and can bear the costs.

4. Conclusions

Looking at the growth forecast of PE, a very high growth (MarketsandMarkets, 2016), more than 20 % per year is predicted. The question is in which segment this will become the reality. For commodity goods, like dairy segment, consumers are very price sensitive so that manufacturers cannot hold up to 17 % increase in costs if we look upon long-life product where the quantities are substantial for the lower tag price. Based on our research the added value in the commodity segment is too low to be able to cover the cost of implementation of the tag only for the marketing use, as prolonging the connection with the consumer. Furthermore, many supermarket chains use dairy products, mainly milk, as a dump product to attract customers. This is also the reasons why we do not see uses in the dairy or on general commodity food sector. If we look further from the consumer point of view, the dairy segment already has a very well structured product monitoring (EU region). We see a potential of RFID or NFC tags use for optimization of logistics process to ensure the tracking of different temperature regimes and at the same time to simplify the traceability process. While this means the

Table 3: Price structure of selected products with implemented tag

Products	Cost of the product (production, packaging, milk and tag cost in euro)	Cost of the product with 30 % margin (in euro)	Difference in price to the average shelf price (in %)
Long-life milk	0.72	0.94	17.5
Yogurt	1.41	1.83	7.6
Ice cream	3.56	4.63	2.8

need of reorganizing and building a system where all parties will be involved – from the producer of packaging, filling machine, manufacturer, logistic company and retailer to consumer – the direct cost effect is harder to predict, but packaging companies are already tackling this issue.

In our opinion, even if we are in a commodity business, the dairy segment has its differences while here security is still and a very important factor and consumers wish to know about the origin of the product (i.e. traceability). The cost of a tag in comparison to the benefits should bring the positive effect even if it is more than 0.01 dollar per unit as in Coca Cola case. In our opinion, it could hold up to 0.05 dollar per unit (depends on added value; it means milk consequently less, yogurt more), which is still the half of current tag cost.

Printed electronics and, generally speaking, smart packaging has found its place in a segment where security is key or the product is higher priced and the extra cost of a tag does not represent such a burden. By using smart packaging and thus also PE, there is a great potential in the packaging of pharmaceutical, cosmetic products, where the product's identity is key and also added value much higher. In addition, the aforementioned technology is already used by recognized brands of beverages, clothing, and toys in order to protect their products from counterfeiters while at the same time allowing for greater connectivity with the consumer. There is also a potential in a food segment where food safety is crucial; these are nutritional products for children, for example, baby milk. The main problem of PE and smart labels is generally in the high unit price per product. The current uses of RFID are mostly carried out on luxury goods and those are smaller in quantities. Taking it into consideration, the PE providers cannot achieve large quantity productions and therefore lowering the price because the economy of scale is insufficient. Until there are no implementations in the segments where the quantities are high, the RFID tag has lesser chance to get its price lowered. We found ourselves in a circle and good long-term partnership between producers, packaging and smart solution providers can bring a quicker lowering of the cost of an RFID tag and from this widespread use also in a segment more sensitive to the cost increase.

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