NEAR FIELD COMMUNICATION (NFC) TECHNOLOGY IN THE PACKAGING INDUSTRY

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Abstract: *Packaging that supports NFC technology is generally designed to be reusable, thus by reducing the environmental impact of packaging, consumers and businesses are presented with more opportunities to be more sustainable. The important thing here is that a company can be creative and add information about a product or company without a significant financial investment. For example, if a customer is interested in a product on the shelf, they can be granted information about the origin of the product or links to provide some feedback on social networks. Furthermore, sales can be promoted by offering the customer a discount, coupon, or added value to the buyer.*
NFC technology can offer many benefits when used with packaging, ranging from interactivity to product security validation.
NFC labels have unique identifiers that can be embedded in packaging to make consumers more interactive, secure, and more efficient in tracking, allowing packaging companies to offer better customer service and product safety.
The aim of this work is to perform a comprehensive literature review of the application possibilities of NFC technology and develop a methodology for the application of NFC technology to promote product sales efficiency.

Key words: NFC, smart packaging, food packaging, mechanical impact

1. INTRODUCTION

In today's complex retail market, brands and retailers must find new and innovative ways to engage with customers. In spite of the fact that 90% of smartphone owners use their devices in-store to search for products through search engines and online stores, companies need to recapture customers' attention through new technologies, says Gillian Ewers (2018). While millennials and Gen Z spend an average of 3:44 hours a day spend on their smartphones, 67 percent of them still prefer to shop in-store (Sterling, 2017), so there is a clear need to change the traditional retail marketing to a new approach that builds a bridge between the digital and physical worlds (Ewers, 2018).
For brand owners and retailers, NFC offers opportunities to develop direct engagement and increase customer loyalty. Such interaction is possible because NFC tags have unique identifiers per item, not just product type, therefore the content can be targeted and dynamic (different before and after purchase). These tags are small and can be integrated into the packaging without affecting the brand identity. NFC technology is also more resistant to cloning because the unique identifier prevents counterfeiting and allows the brand owner or customer to confirm the product's authenticity (Ewers, 2018).
Based on the researchers' insights, it was decided to analyse existing NFC technologies in the packaging industry. There are different types of NFC stickers on the market, and thus it is essential to analyse their potential and applicability to packaging. It is also relevant to investigate how the information written in the NFC tag's memory is read after certain performance factors, such as cold, heat, humidity, mechanical abrasion, or other, would affect the NFC sticker. After the analysis, tables with the types of NFC stickers and their parameters have been compiled and grouped for further experiments. The selected information will be further recorded, the readability will be checked against a benchmark and the readability of the information after mechanical impact on the NFC sticker will be checked against the benchmark.

2. THEORETICAL BACKGROUND

Nowadays, there is an increasing trend to use diverse wireless technologies to retrieve miscellaneous types of data / various data. One of them is Near Field Communication (NFC) technology.
It is important to understand and analyse the applicability and trends of NFC technology for today's generation of consumers. One of the studies conducted by Noah Mooiman, Simon Andersson analyses (2022) the results obtained from a sample of N=5 Generation Z living in Sweden. They have focused on five themes that were identified: (1) Added value, (2) Brand image, (3) Ease of use, (4) Right product, and (5) Environmental concerns. During the experiment, the participants' identities were kept anonymous, and their names were labelled Participant A through Participant E. The researchers give more demographic information about the sample in Table 1 (Mooiman & Andersson, 2022).

Table 1: Participants' demographic information (Mooiman, Andersson, 2022)

	Age	Gender	Occupation
Participant A	24	Male	Self-employed
Participant B	21	Male	Employed
Participant C	22	Male	Employed
Participant D	22	Female	Self-employed
Participant E	20	Male	Student

In this experiment, to ensure that the participants could answer the given questions, they were informed about NFC and its use cases through a short presentation. In addition, use cases of NFC in product packaging were presented to the participants. The demonstration was done since the product packaging industry has not widely adopted NFC, and the participants were most likely not familiar with the topic. The presentations were, however, strategically placed after specific questions to give room for the interviewees to comment and present their knowledge of the phenomena first (Mooiman & Andersson, 2022).
From the data gathered through the interviews, a thematic analysis of the researchers was carried out, and five main themes were defined. These themes mentioned earlier were: added value, brand image, ease of use, right product, and environmental concerns. The results show the need for the NFC to add value for the customer, which might be seen as evident, but it is the key aspect that will enable brands to use NFC to strengthen their relationships with their customers. This view was repeated multiple times by all participants in the study. The user's experiences with an NFC-enabled product package will reflect the associated brand's image. The results suggest that a positive interaction would benefit the brand's image but also that a negative interaction would harm it. One of the critical things that a brand must get right to succeed in creating a good user experience is to match the right interaction with the right product. The increased ease of use features through NFC was seen as one of the main benefits enabled by the technology. Although there were some positive sides mentioned in association with the environment, this was also the main drawback mentioned in the interviews (Mooiman & Andersson, 2022).
In another article (Lathiya & Wang, 2021), the evolution of NFC transaction values between the years 2014 and 2024 was presented (Figure 1).

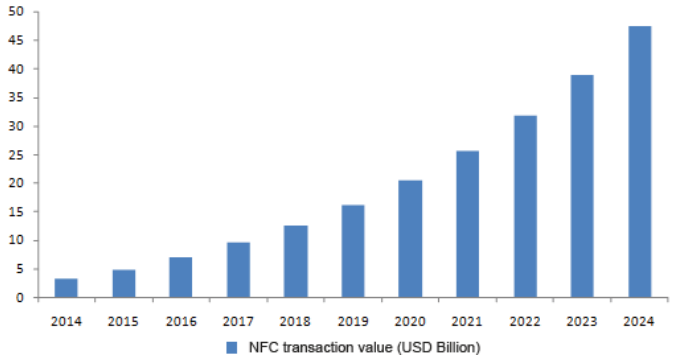


Figure 1: Global NFC Market, 2014 - 2024 (USD Billion) (Grand View Research, Inc., 2016)

In this article, the author states that from 2010 onward, new interesting applications of NFC were launched every year in the communication sector by technology giants such as Google, Apple, Samsung, NXP, etc. The industry players are constantly introducing new advances and improved technologies in NFC-enabled devices, which have taken the global market to 4.80 billion USD in 2015 and are expected to reach 47.42 USD billion by 2024 (Lathiya & Wang, 2021; Grand View Research, Inc., 2016).
The future of NFC technology is growing rapidly, as shown by the research data presented. This is due to the technology's easy applicability in areas ranging from the healthcare sector to the packaging industry. The following is a review of the research conducted on the application of NFC technology in packaging.
The researchers Zhong Ma and ect. (Ma et al., 2018), claim that the applications in detecting food spoilage, where the sensor with a high sensitivity that acts as a switch for a NFC tag needs to be developed, still remain a challenge. In this article, they developed a nanostructured conductive polymer-based gas sensor with high sensitivity of ΔR/R0 = 225% toward 5 ppm ammonia NH3 and unprecedented sensitivities of 46% and 17% toward 5 ppm putrescine and cadaverine, respectively. The gas sensor plays a critical role as a sensitive switch in the circuit of the NFC tag and enables a smartphone to read out about meat spoilage when the concentration of biogenic amines exceeds a set threshold. Furthermore, the authors envision the broad potential use of such intelligent sensing for food status monitoring applications in daily life, storage and supply chains. Reprinted with permission from ref. (Ma et al., 2018).

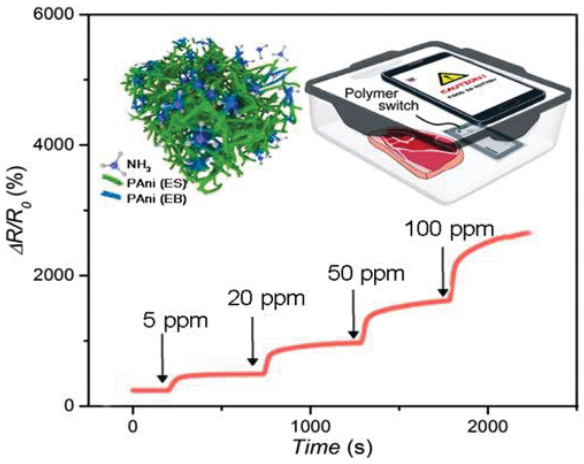


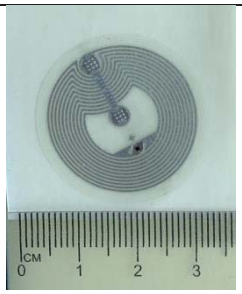
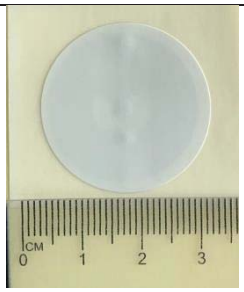
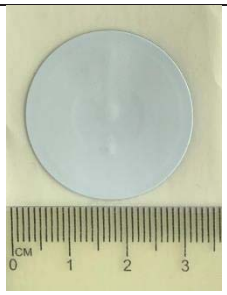
Figure 2: Food safety monitoring. Reprinted with permission from ref. (Ma et al., 2018)

The researchers (Ma et al., 2018) presented a novel NFC tag (Figure 2) for food spoilage detection with the advantages of a highly sensitive, printable nanostructured conductive polymer. Pablo Escobedo and ect. (Escobedo et al., 2020) have investigated a flexible strain sensor integrated with an NFC tag that can be better integrated into the packaging to detect food spoilage. The researchers (Nguyen, Tran, Chung, 2019) have developed a 2.5 cm × 2.5 cm sensor tag for a new method to read temperature and air pressure data and monitor the freshness of different types of food such as pork, chicken and fish during storage.
In the other article, author Jane Merchant (2022) analyses the NFC technology embedded into coffee packaging. The author says that many packaging manufacturers now use NFC as an interactive customer engagement tool. A customer can scan their coffee bag to access the detailed product information, as well as verify whether the product is authentic and has not been tampered with. This could be particularly useful for roasters and coffee shops, as transparency and origin information are aspects of specialty coffee that customers often look out for (Merchant, 2022).
The use of NFC technology in the packaging market is growing steadily. Therefore, the applicability of NFC stickers in packaging is very relevant. As research shows, NFC technology can not only provide information about the product/manufacturer (Merchant, 2022; Đurđević et al., 2019), directing us to a discount page but also provide information about the product's suitability for use (that is especially relevant in the case of food products) (Ma et al., 2018; Merchant, 2022).

3. RESEARCH PROCESS AND RESEARCH METHOD

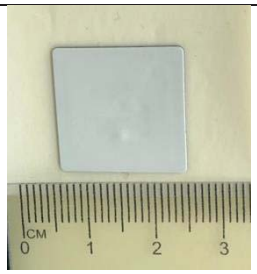
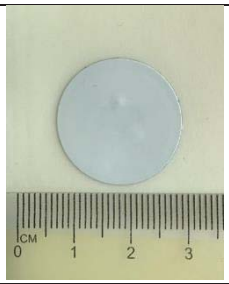
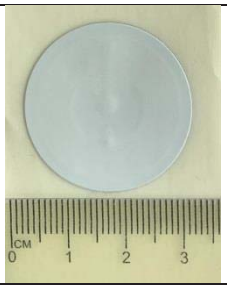
There are many reasons to use NFC technology in the packaging industry. Firstly, packaging in the modern world is becoming more minimalistic, and manufacturers strive to use as little material as possible for packaging (from packaging material to printing). Therefore, NFC technology can be used instead of printing to convey product information (product quality, freshness and etc.).
Secondly, NFC technology allows interactive communication with the customer. This is particularly relevant for today's Generation Z, which is mainly interested in games and promotions.
Thirdly, environmental friendliness. By moving away from printing on the packaging and using NFC technology to convey information.
Moreover, during the Covid 19 pandemic, many things have moved into the digital space, so using NFC technology for packaging can convey not only textual information about the product but also provide visual, more informative data.
It is, therefore, very important to analyse the possibilities and features of NFC stickers. To this end, a table of the technical characteristics of the stickers available on the market has been drawn up and classified into groups according to certain parameters.
1. The first combination of NFC stickers consists of samples that have the same chip NTAG213 and diameter of 29 mm, but are produced on different substrates. More detailed information is provided below in Table 2.

Table 2: The data about the NFC stickers for the first experiment

Properties/NFC sticker type (product code)	ST710 Clear	ST711 White	ST706 On-metal
Picture			
Purchase from	Seritag	Seritag	Seritag
Diameter	29 mm	29 mm	29 mm
Label form	Circular	Circular	Circular
NFC chip	NXP NTAG213	NXP NTAG213	NXP NTAG213
Standard	ISO 14443A	ISO 14443A	ISO 14443A
Frequency	13.36 MHz	13.36 MHz	13.36 MHz
Data transfer (chip)	106 kbit/s	106 kbit/s	106 kbit/s
Memory (chip)	180 byte	180 byte	180 byte
User memory (chip)	144 bytes	144 bytes	144 bytes
Max URL Length (chip)	136 characters	136 characters	136 characters
Thickness	0.136 mm (upgrated)	0.19 mm	0.47 mm +-0.05 mm
Antenna Size	25 mm circular	25 mm circular	25 mm circular
Face Material	Clear PET Plastic	White PET Plastic	White PET Plastic
Adhesive	Acrylic, permanent	Acrylic, permanent	Acrylic, permanent
Water Resistance	Low	Low	Low
Water Rating	Water Resistant	Water Resistant	Water Resistant
Operating Temperature	-25C to 70C	-25C to 70C	-15C to 70C

2. The second combination of NFC stickers consists of samples that are all made for on-metal surfaces but are in different sizes and formats. More detailed information is provided below in Table 3.

Table 3: The data about the NFC stickers for the second experiment

Properties/NFC sticker type (product code)	ST730 On-metal	ST868 On-metal	ST706 On-metal
Picture			
Purchase from	Seritag	Seritag	Seritag
Diameter	19x19 mm	22 mm	29 mm
Label form	Square	Circular	Circular
NFC chip	NXP NTAG213	NXP NTAG213	NXP NTAG213
Standard	ISO 14443A	ISO 14443A	ISO 14443A
Frequency	13.36 MHz	13.36 MHz	13.36 MHz
Data transfer (chip)	106 kbit/s	106 kbit/s	106 kbit/s
Memory (chip)	180 byte	180 byte	180 byte
User memory (chip)	144 bytes	144 bytes	144 bytes
Max URL Length (chip)	136 characters	136 characters	136 characters
Thickness	0.48 mm	0.32 mm	0.47 mm +-0.05 mm
Antenna Size	16x16 mm	19 mm	25 mm circular
Face Material	White PET Plastic	White PET Plastic	White PET Plastic
Adhesive	permanent	permanent	Acrylic, permanent
Metal Surfaces	Yes	Yes	Yes
Real ScanStrength	21 mm – 25 mm (non metal) 6 mm – 10 mm (metal)	21 mm – 25 mm (non metal) 11 mm – 15 mm (metal)	21 mm – 25 mm (non metal) 16 mm – 20 mm (metal)
Water Resistance	Low	Low	Low
Water Rating	Water Resistant	Water Resistant	Water Resistant

Reference (Electronics notes, n.d.) states that there are four different types of NFC tags. The definition of each type is provided below:

Tag 1 Type: The Tag 1 Type is based on the ISO14443A standard. These NFC tags are read and re-write capable and users can configure the tag to become read-only. Memory availability is 96 bytes which is sufficient to store a website URL or other minor data. However, the memory size is expandable up to 2 kbyte. The communication speed of this NFC tag is 106 kbit/s. As a result of its simplicity, this tag type is cost-effective and ideal for many NFC applications (Electronics notes, n.d.).

Tag 2 Type: The NFC Tag 2 Type is also based on ISO14443A. These NFC tags are read and re-write capable and users can configure the tag to become read-only. The basic memory size of this tag type is only 48 bytes, although this can be expanded to 2 kbyte. Again the communication speed is 106 kbit/s (Electronics notes, n.d.).

Tag 3 Type: The NFC Tag 3 Type is based on the Sony FeliCa system. It currently has a 2 kbyte memory capacity, and the data communications speed is 212 kbit/s. Accordingly, this NFC tag type is more applicable for more complex applications, although there is a higher cost per tag (Electronics notes, n.d.).

Tag 4 Type: The NFC Tag 4 Type is defined to be compatible with ISO14443A and B standards. These NFC tags are pre-configured at manufacture, and can be either read / re-writable or read-only. The memory

capacity can be up to 32 kbytes, and the communication speed is between 106 kbit/s and 424 kbit/s (Electronics notes, n.d.).
From the definitions of the different NFC tag types, it can be seen that type 1 and 2 tags are very different to type 3 and 4 tags, having different memory capacity and makeup. Accordingly, it is expected that there is likely to be overlap in their applications (Electronics notes, n.d.).
Type 1 and type 2 tags are dual state and may be either read/write or read-only. Type 3 and Type 4 tags are read-only, data being entered at manufacture or using a particular tag writer (Electronics notes, n.d.).
The next stage of the study is to conduct mechanical experiments on different NFC stickers on selected packaging, taking into account the above-mentioned types of NFC tags:

1. Cold/heat resistance;
2. Moisture resistance;
3. Mechanical abrasion resistance.

The aim of the study is to analyse the readability of recorded information in NFC stickers after they have been subjected to specific mechanical properties. To investigate the transfer of information from stickers to a smart device after exposure to cold, moisture and mechanical abrasion. It is very important to investigate the speed of scanning and the accuracy of the information, as the Z-generation focuses the attention for a very short time. If the information takes a while to scan, the user will lose interest.

4. DISCUSSION AND CONCLUSIONS

Research shows that interactive and intelligent communication is essential for Generation Z. According to researchers, around 90% of smart device owners use them to access product information.
In addition, the packaging industry is increasingly using NFC technologies (more than 10 times between 2014 and 2024) to provide information about the product being purchased, from the product's composition to information about the product's fitness for use.
After the literature review and the development of the methodology, the next step is to investigate the readability of NFC stickers when exposed to certain mechanical properties (humidity, cold, mechanical abrasion). The parameters were chosen considering the most common problems encountered during the transport and/or storage of the products.

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