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CHALLENGES OF FOOD PACKAGING MATERIALS

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Abstract

The present paper is a study on the adaptability of packaging materials to the new pandemic context. Producers of packaging materials for the food industry must ensure the safety and quality of food products. Therefore, there are two problems: if the new biomaterials can ensure food stability, the barrier to pathogens and if the different edible films can provide food coverage. A solution for monitoring changes induced in the packaging could be biosensors. These biosensors can identify changes in pH, which often indicate product alteration. Biosensors could also be used to display various contaminants (bacteria, moulds, viruses). In the process of biomaterials selection, two parameters must be monitored: the food product to be packed with all its properties and the entire food traceability chain. This action should be done in detail. Thus, the system: food product - packaging - the external environment must be analyzed in detail, considering all its valences. All these changes to packaging and the emergence of intelligent bio-packaging must be regarded throughout the food chain. The benefits of these biomaterials used in the food industry would have a beneficial environmental impact. The challenge for packaging manufacturers is to adapt quickly to all the food chain changes, from the factory delivery to the consumer's table as the final link.

Keywords: pandemic context, food packaging, biomaterials, biosensors, edible coating

1. Introduction

In addition to other important aspects of the quality of life, well-being is also influenced by alimentation. Therefore, the main goal in the food industry is to keep food safe. It must be protected from various sources of contamination to ensure traceability. Moreover, since December 2019, people's lives have been turned upside down by the new SARS-CoV-2 virus, so packaging must have additional protection against it. Numerous changes have appeared in this pandemic context. Some will probably be temporary, but the others will be profound, and they will fundamentally change the way the packaging industry works. Several solutions to adapt to it are proposed in the present paper.

We can consider two stages of existence found in all fields of activity: the period before and after SARS-CoV-2. Adaptation to the new life (in the presence of this virus) was quickly made at all levels.

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This paper reviews the aspects that have been affected by the new virus from the perspective of packaging, which needs to be designed now to avoid contamination with SARS-CoV-2.

Packaging is the key to the safety and quality of food products in the food industry, protecting them from chemical or biological contamination. This must adapt to the properties of food. Its main role is preserving food quality during storage and extending food shelf-life (Guillard *et al*., 2018). The second one is to communicate the ingredients and, of course, market the products (Shaikh *et al*., 2021). Another important aspect is to minimize food loss and waste (Coffigniez *et al*., 2021), which is related to the previous two or derived from those. To realize the abovementioned packaging functions, the literature has been proposed some mathematical models. One of them was used in fresh fruits and vegetables packaging. It has two objectives: to prevent physical damage and mould growth. These were realized using a PET punnet and a lid (Cagnon *et al*., 2013). Based on that model, the strawberry active packaging was improved to increase shelf-life, incorporating HXAL in a cellulose pad coated with polyamide on both sides (Heras-Mozos *et al*., 2021). Another model was used to reduce microbial growth (Guillard *et al*., 2017).

Unfortunately, this type of packaging is a non-biodegradable plastic, and biodegradable polymers or biopolymers should replace it. These are extracted from biomass, and the microorganisms are used to produce it (Shaikh *et al*., 2021). Their use has two important advantages: minimizing the consumption of flexible plastics such as films and foils used as packaging materials and reducing the surface contamination of food. The last one is accomplished by introducing bio-based polymers in which various natural compounds with antimicrobial potential can be incorporated.

Some bacteria, such as psychrophilic, lactic acid, or *Enterobacteriaceae*, suffered a developmental slowdown due to the gelatin film incorporated with lemongrass essential oil 25% (w/w). This type of package is from the active packaging category and was used on sea bass for 12 days in conditions of 4ºC (Ahmad *et al*., 2012). Nowadays, this is included in the smart category, a package created from active and intelligent components with essential roles in food safety: it assures protection from UV and microbiological contamination, extends food shelf-life etc. (Nikolic *et al*., 2021). Thus, CO_2, O_2 or ethylene are removed, and the active components like antimicrobial or antioxidants are released (Yildirim et al., 2018). These are developments in the food industry, transferring substances to the "outside world".

Some problems appear in the bulk food system, where the role of the active substance may be affected. To find a better solution for antimicrobial protection, "trays by baking cassava bagasse with polyvinyl alcohol with the incorporation of clove or oregano essential oils were made. Two methods were used in this approach: surface coating or direct incorporation. The first one is best in food protection against gram-positive, gram-negative bacteria, yeast, and moulds". This antimicrobial action is very used in active packaging (Debiagi *et al*., 2014). Another antimicrobial method was proposed for Staphylococcus aureus and *Escherichia coli* by incorporating zinc oxide and oregano essential oil in a very thin "bio-paper" made by PHBV (Barrett, 2020).

Food packaging materials are an essential element in maintaining safety and human health. Given the aspects mentioned above and the SARS-CoV-2 virus, the interest in suitable packaging materials is beginning to grow, increasing due to the pandemic. In a period of global economic and health uncertainty, packaged food is necessary.

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2. Packaging in pandemic crisis

SARS-CoV-2 pandemic has generated many changes in people's behaviour; most of them are found in the food sector, related to food purchase and packaging. One of the adapted solutions was home delivery during this period, thus increasing packaging use (many non-biodegradable). This has a negative impact on waste management (de Oliveira *et al*., 2021). The large production of non-recyclable or non-biodegradable packaging is also a consequence of the fears caused by the new virus that has led to an increase in demand from food banks. This increase was about 20% during the current pandemic, compared to 28% in 2008 in Canada during the economic recession (Britneff, 2020).

Various solutions have been proposed to reduce the non-biodegradable packaging, pursuing two main objectives: environment protection and people protection from coronavirus infection. The virus survival on surfaces represents another problem. It can be carried by food packaging, an example being the Chinese case of the Brazilian chicken (IPC, 2020; Spring and Mano, 2020). Center of Disease and Control Prevention sustained that the virus could survive on surfaces as follows: for at least three hours in aerosols (air droplets); up to 4 days on wood; up to 72 hours on hard, shiny surfaces such as plastic, stainless steel, and glass; up to 24 hours on fibrous and absorbent surfaces such as cardboard, paper, fabric; up to 4 hours on copper (Sharafi *et al*., 2021). So, the major concern is now to produce recyclable, biodegradable packaging that reduces contamination. As mentioned in the previous section, the solution is smart packaging (de Oliveira *et al*., 2021), with active components and nanotechnology. Incorporating various antimicrobial agents ensures food safety and affects food preservation.

To implement it, the research has already been initiated by several start-ups and scaleups. At the same time, packaging production has been simplified using 3D printers and robotic packaging. The most important 20 start-ups which have innovated the packaging industry are those in figure 1. The packaging is made smart by some key elements: QR codes, radio frequency identification tags or some Internet of Things (IoT) sensors that can detect food spoilage and a real-time food consumption platform (StartUs Insights, 2021). This information may permit the renewal of low stocks and the withdrawal or recovery from other places of products approaching their expiry date. The most widely used bio-packaging is based on starch, cellulose, PLA, polyhydroxy butyrate (PHB), polyhydroxyalkanoates (PHA), and other biopolymers. In addition, herbal packaging (sugar cane, coconut, hemp, and corn starch) is used. Replacing plastic packaging reduces the impact on the environment, representing a good economical solution for the industry (StartUs Insights, 2021).

As an integral part of the system, the packaging must provide a chemical, biological and physical barrier to the environment. Bio newly designed materials provide a barrier-free of moisture, oxygen, carbon dioxide, light, radiation, foreign odours and microbial safety (Bandyopadhyay *et al*., 2018).

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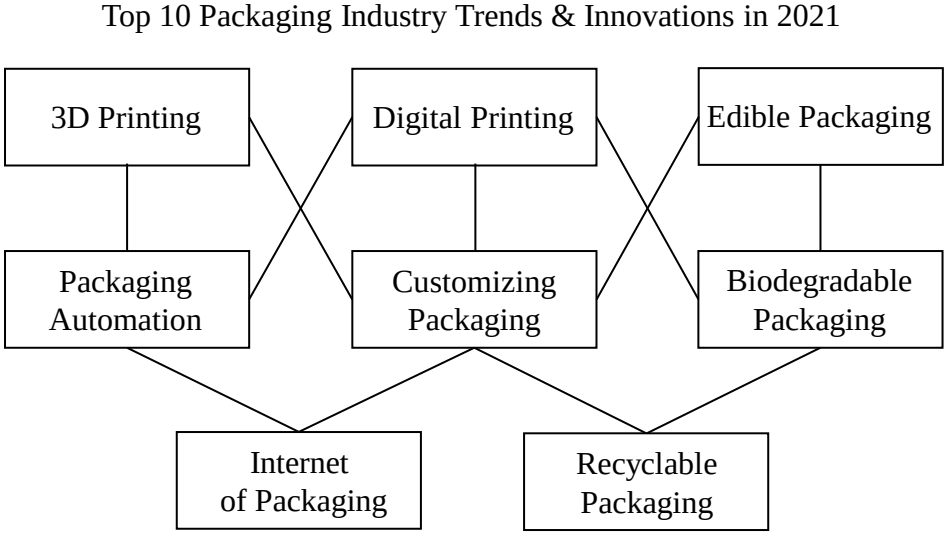

Figure 1. Packaging Innovations from 2907 Start-ups & emerging companies analyzed, June 2021 (adapted from StartUs Insights, 2021)

The Internet of packaging provides security, authentication and connectivity, making the packaged product accessible to a data medium, a digital tool to identify the actual state of a food by incorporating sensors. This system is very important, especially in emergency cases. It has a centralized structure and a list of data (de Oliveira *et al*., 2021). Other start-ups offer anti-counterfeiting solutions that allow product authenticity by developing platforms that ensure real-time traceability (StartUs Insights 2021). The proposed solutions by the start-ups mentioned above are beneficial also in terms of food traceability.

Studies on trust in the traceability system in China have been carried out, and it has been shown that people do not trust this system, so they are not willing to pay more for traceability. For this purpose, a blockchain food traceability system (BFTS) was launched to ensure data transparency (Hu *et al*., 2021). We consider that studies are necessary for other countries as well.

3. Problems and solutions

Nowadays, there are four important aspects in the food industry in the SARS-CoV-2 pandemic: food security in lockdown, bioactive ingredients, sustainability and food safety. (Galanakis 2020).

In this crisis, the fear of SARS-CoV-2 contamination is extensive, and people protection is a significant concern. So, the food system represented in figure 2 must address four elements:

– increase immunity and maintain a healthy body through balanced food consumption with bioactive ingredients;
– preservation of uncontaminated food throughout the food chain from producer to consumer, so the packages must be very carefully produced, with active components, to assure food protection against SARS-CoV-2;

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– when the lockdown was installed, and people had to stay in their houses, the food security issue has emerged; some companies proposed specific software for monitoring the food delivery;
– sustainability – the system should minimize food waste, ensuring healthy lives.

The society suffered and had to find quick ways to adapt for survival. Lifestyle changes lead to issues such as: increasing the demand for pre-packaged processed food products; creating the habit of consumers to store food; food banks have grown again, with increasing demand; identification of new opportunities for restaurants - home delivery services; rapid purchase of packaging equipment for the industrial branch (Ohl 2019).

These changes came with some important changes in the food industry: a product that was previously sold in bulk must now be pre-portioned to accommodate consumer retail sizes, causing supply chain disruption; the need to use disposable bags to avoid contamination during handling; automation of packaging processes to reduce staff coming into contact with packaging (with some advantages: economy, efficiency, safety, accuracy); time management in favour of research and innovation projects in large companies that are currently facing a reduction in activity; increasing the consumption of craft coffee; food products packaged in a modified atmosphere, to extend the shelf life (Modified Atmosphere Packaging).

In summary, there are three main problems identified in this period of SARS-CoV-2: contamination through surfaces and packaging, which can be solved by discouraging the use of reusable bags; cross-contamination having the solution of withdrawal of unpackaged products; abolition of product showcases unsafe packaging. The last one has a solution too: replacement with active packaging (antibacterial, antiviral).

The active components are excellent in cross-contamination reduction. These include organic ingredients, like resveratrol or myricetin, and some metals such as zinc, silver or copper (de Oliveira *et al*. 2021).

The packaging as a coating or spraying solution has the main advantage of incorporating various compounds with an antimicrobial role, intelligent packaging, freshness indicator for pH, humidity or gas sensor, and conductometric nano biosensor (Ludwicka *et al*. 2020). This could be a solution if a natural compound is identified that does not sensory affect the food but could be used as a barrier between the product and any contaminants of a microbiological nature, including target even SARS-CoV-2.

4. Conclusions

To identify optimal solutions, the entire pandemic context should be analyzed. The rapid spread of this virus has completely changed the way of life, with new strains adapted to varying conditions developing rapidly. The quick solution to avoid food contamination is the packaging. Whether intelligent or not, we believe that food must be packaged in as variable quantities as possible. Trade-in foodstuffs should only be allowed where traceability can be ensured. This would mean the introduction of packaging and labelling in wholesale or bulk markets. We also consider that a study is needed to centralize population consumption trends by geographical area. In this way, the optimum quantity of basic foodstuffs to be individually packaged could be determined more precisely to avoid waste from bulk sales. In the future, new packaging techniques in a modified atmosphere can be developed to identify pH changes or possible defects in handling. Packaging must provide sealing and a protective barrier to the outside

environment. Start-up competitions at local, national and international levels are beneficial solutions for adapting life to the new conditions and updating food packaging and traceability.

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