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REVIEW ARTICLE

Food packaging and the new coronavirus: challenges and opportunities for the packaging industry post-Covid-19

Embalagens para alimentos e o novo coronavírus: desafios e oportunidades para a indústria de embalagens pós-Covid-19

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Abstract

Health authorities such as the World Health Organization and the US Centers for Disease Control and Prevention state that while SARS-CoV-2 contamination from surfaces such as food or its packaging is possible, it is not seen as the primary way of contagion. In studies addressing virus survival on surfaces, the virus is no longer detected on porous objects such as corrugated cardboard and fabric after 2 and 5 days, respectively, and also on non-porous surfaces such as plastic and stainless steel for periods longer than 7 days. It was also observed that this persistence depends on environmental factors such as temperature, relative humidity and solar radiation incidence. The Coronavirus Disease-2019 (Covid-19) pandemic also had an impact on food industries, whereby digitalization trends increased, as well as the packaging industry with the expansion of e-commerce, consumer demand for packaging that is easy to disinfect and the development of more environmentally responsible packaging. On the other hand, taking into account the fear of contamination by the virus, consumers felt safer handling disposable products or single-use packaging instead of reusable packaging, which goes against the progressive ban on disposable packaging in regions, such as the European Union (EU). In the post-pandemic, concerns regarding the usage of plastics will be resumed, and in the long term, a reduction in the use of single-use packaging and a growth in recyclable waste generation rates similar to those predicted before Covid-19 is expected.

Keywords: Covid-19; Food packaging; SARS-CoV-2; Recycling; Pandemics; Virus survival.

Resumo

Autoridades sanitárias como a Organização Mundial da Saúde (OMS) e o Centro para Controle e Prevenção de Doenças dos EUA (CDC) afirmam que embora seja possível a contaminação de superfícies pelo SARS-CoV-2, tais como alimentos ou suas embalagens, esta contaminação não é vista como a principal via de contágio. Estudos sobre a sobrevivência do vírus em superfícies, indicam que o vírus deixa de ser detectado em objetos porosos, como papelão ondulado e tecido, após dois e cinco dias, respectivamente, e em superfícies não porosas, como plástico e aço inoxidável, após períodos superiores a sete dias. Foi verificado também que a persistência depende de fatores ambientais, tais como temperatura, umidade relativa e incidência de radiação solar. A pandemia de Covid-19 também teve impacto nas indústrias de alimentos, com aceleração das tendências de digitalização, bem como nas indústrias de embalagens, com expansão do *e-commerce*, exigência do consumidor por embalagens de fácil desinfecção e desenvolvimento de embalagens ambientalmente mais responsáveis. Em contrapartida e levando-se em conta o temor com a contaminação pelo vírus, os consumidores se sentiram mais seguros em manusear produtos descartáveis ou embalagens de uso único em vez de embalagens reutilizáveis, o que vai na contramão do banimento progressivo das embalagens descartáveis em determinadas regiões, como a União Europeia. Para o pós-pandemia, a preocupação em relação ao uso dos plásticos será retomada e, em longo prazo, espera-se uma redução do uso de embalagens de uso único e um crescimento das taxas de geração de resíduos recicláveis semelhantes às previstas antes da Covid-19.

Palavras-chave: Covid-19; Embalagens para alimentos; SARS-CoV-2; Reciclagem; Pandemia; Sobrevivência viral.

Highlights

- The SARS-CoV-2 virus showed lower persistence on porous surfaces
- The development of more sustainable packaging will have to be balanced with the sense of safety
- Throughout pandemics, disposable plastics were preferred over reusable ones

1 Introduction

The Food and Drug Administration (2023) website shows that currently there is no scientific evidence that food, food containers, or food packaging are associated with the transmission of SARS-CoV-2, the virus responsible for the Coronavirus Disease-2019 (Covid-19) pandemic. However, the entity claims that as with other viruses, it is possible that the Covid-19 virus can survive on surfaces or objects. The organization recommends that sanitary measures such as cleaning the packaging with soap and water after purchasing it or quarantining this material can be adopted as preventive actions. The Centers for Disease Control and Prevention (CDC), part of the US Department of Health and Human Services, and the World Health Organization (WHO) follow these same lines and point out that the coronavirus family is transmitted from person to person by respiratory droplets sprayed when someone coughs or sneezes. Although the authority claims that a healthy person can be contaminated after contact with food or food packages that have received a viral load by the droplets, this is not seen as the main mechanism of contagion. They also say that so far, there has been no documentation of any case of contagion associated with contact with food, food packaging, or shopping bags. Still, considering the scenario of new variants possibly emerging especially where the vaccination indexes are yet not high enough, attention should be maintained to this route of contamination. Although there are cases in which food industry workers have contracted the disease, there is no evidence of consumer contamination when handling food or packaging previously handled by these workers. Although several species of bacteria manage to develop in food, viruses necessarily need a living host to multiply (Centers for Disease Control and Prevention, 2020; World Health Organization, 2020).

This literature review aims to present research studies for the SARS-CoV-2 virus survival on common surfaces, such as plastics, metals, and paper, among others, under different environmental conditions and after contact with several sanitizers. In addition, it also gathers information regarding the changes in people's consumption habits, the sustainability issues raised by the Covid-19 pandemic, and some observed trends, all for food packaging.

2 Survival of SARS-CoV-2 on inanimate surfaces

In the study published by van Doremalen et al. (2020), the stabilities of SARS-CoV-1 and SARS-CoV-2 were evaluated, respectively, responsible for the 2002 coronavirus epidemic (Severe Acute Respiratory Syndrome (SARS)) and for the coronavirus pandemic that started in 2019. Their stabilities were evaluated on plastic (polypropylene), stainless steel, copper, and corrugated cardboard surfaces for 7 days at 21 °C to 23 °C and 40% of relative humidity (RH). The viral load decay was exponential, expressed in $TCID_{50}$/mL (Tissue Culture Infectious Dose, which represents the dose to infect 50% of tissue culture). Moreover, detailed data about the periods from which the viruses were no longer detected in their viable forms are shown in Table 1. Under the experimental conditions studied, both viruses showed similar stability on plastic, but different stabilities on the other surfaces studied. In the latter materials, the viruses were no longer detected from 8 hours to 4 days, and in plastic and stainless steel they happened after 4 and 3 or 4 days, respectively. The study concluded that the epidemiological differences between these two viruses are more related to factors such as viral load in the upper respiratory tract and transmission capacity by asymptomatic people since the epidemic caused by SARS-CoV-1 was much milder (8,098 confirmed cases) (Wallace, 2020) than the current epidemic (281,808,270 confirmed cases by 29/12/2021) (World Health Organization, 2022).

In another study, the stability of SARS-CoV-2 was evaluated on surfaces such as stainless steel, plastic, glass, ceramic, wood, cotton fabric, paper, latex gloves, and surgical masks at room temperature for a period of 7 days (Table 1) (Liu et al., 2021). The choice of materials aimed to simulate common surfaces in homes and hospital facilities susceptible to contamination by the virus. The authors found that after seven days the virus remained viable on all surfaces, except for cotton fabric and paper. On the plastic surface, for example, the reduction in viral load went from $10^{5.83}$ $TCID_{50}$/mL (beginning of the experiment) to $10^{2.06}$ $TCID_{50}$/mL after 7 days (the total period of the experiment) remaining viable. The virus viability on the different surfaces at the end of the experiments is described in Table 1. In a third study, the authors evaluated the viral activity of SARS-CoV-2 on printer paper, tissue, wood, fabric, glass, banknotes, stainless steel, plastic, and surgical mask at 22 °C and 65% RH for 7 days. The results showed surface persistence ranging from 3 hours for printer paper to 7 days (total period of the experiment) for plastic, stainless steel, and surgical mask, and are presented in detail in Table 1 (Chin et al., 2020). In general, the studies showed lower persistence of the virus on porous surfaces when compared to impermeable surfaces. According to Chatterjee et al. (2021), this occurs because the spreading of droplets in the first materials is favored by capillary effects, thus increasing the surface area of the liquid phase in contact with the atmosphere (virus survival medium), leading to evaporation.

Table 1. SARS-CoV-1 and SARS-CoV-2 viability results on different surfaces, according to recent studies, regarding the periods in which they were no longer detected in their viable forms.

Studies	van Doremalen et al. (2020)[a]		Liu et al. (2021)[c]	Chin et al. (2020)[e]
Virus evaluated	SARS-CoV-1	SARS-CoV-2	SARS-CoV-2	SARS-CoV-2
Experimental conditions	21 °C to 23 °C and 40% of RH		Room temperature No reference to RH	22 °C and 65% of RH
	Viral load not detected from	Viral load not detected from	Viral load not detected from	Viral load not detected from
Copper	24 hours[b]	8 hours[b]	-	-
Corrugated cardboard	24 hours[b]	48 hours[b]	-	-
Plastic	4 days[b]	4 days[b]	>7 days[b]	7 days[b]
Stainless steel	3 days[b]	4 days[b]	>7 days[b]	7 days[b]
Ceramics	-	-	>7 days[b]	-
Latex gloves	-	-	>7 days[b]	-
Paper	-	-	6 days[b,d]	3 hours[b,f]
Fabric	-	-	5 days[b]	2 days[b]
Glass	-	-	>7 days[b]	4 days[b]
Surgical mask			>7 days[b]	>7 days[b]
Wood	-	-	>7 days[b]	2 days[b]
Banknote	-	-	-	4 days[b]
Tissue paper	-	-	-	3 hours[b]

[a]Detection limit: $10^{0,5}$ $TCID_{50}$/mL for plastic, stainless steel and corrugated board, and $10^{1,5}$ $TCID_{50}$/mL for copper. [b]Experiment duration: 7 days. [c]Detection limit: $10^{1,5}$ $TCID_{50}$/mL. [d]Unspecified paper type. [e]Detection limit: 10^{2} $TCID_{50}$/mL. [f]Printer paper.

In the latter study, the authors also evaluated the virus inactivation by different sanitizers (domestic bleach (1:49 and 1:99 ratios), hand soap solution (50%), ethanol (70%), povidone iodine (7.5%), chloroxylenol (0.05%), chlorhexidine (0.05%) and benzalkonium chloride (0.1%)) after 5, 15 and 30 minutes of contact. Except for the hand soap solution, which showed an undetectable viral load only after 15 minutes of contact, all the sanitizers studied showed this reduction in viral load after 5 minutes of contact (Detection limits: 10^3 $TCID_{50}$/mL for the hand soap and for the chloroxylenol assays; 10^3 $TCID_{50}$/mL for the tests with povidone iodine, chlorhexidine and benzalkonium chloride; and 10^2 $TCID_{50}$/mL for the others).

The variation between the results of the studies may be associated with factors such as the intrinsic variability of the same material tested (presence of additives in plastics, impurities in metal alloys, type of glass, etc.); the strain of the viruses; the loss of viral viability in the drying process after application of the solutions containing it to the surfaces before the exposure times and in virus recovery; and to environmental factors such as solar incidence, RH and temperature. In addition, a lack of standardized methods for this kind of test may also be a reasonable cause of data heterogeneity (Mihucz et al., 2022), which makes it difficult for one to compare the results from different studies. However, some tendencies may still be verified, such as the propensity of lower persistence periods of the SARS-CoV-2 onto porous surfaces as discussed earlier.

The effect of simulated solar radiation incidence was evaluated using a xenon lamp according to Ratnesar-Shumate et al. (2020) at three different intensities, representatives of three periods of the day and year, after applying SARS-CoV-2 on stainless steel. The study showed that wavelengths in the range of 280 to 315 nm (UVB), compatible in intensity with those present in natural solar radiation, may be responsible for the rapid deactivation of the virus on the evaluated surface. After applying SARS-CoV-2 via artificial saliva, a 90% reduction in viral load was observed every 6.8 minutes to the equivalent of solar intensity at 40°N latitude on the summer solstice, and 14.3 minutes for a solar intensity equivalent to the same latitude but winter solstice. Although the data suggests rapid viral deactivation against radiation in the range of 280 to 315 nm, extrapolation to the real scenario is hampered by factors such as the location in the world, meteorological conditions, time of the year, and experimental limitations, such as the chemical composition of the vehicle used for depositing viral cells on surfaces.

The effects of temperature and RH were investigated in the study done by Biryukov et al. (2020), where the persistence of SARS-CoV-2 was evaluated in stainless steel and on a nitrile rubber glove under controlled conditions of temperature, which ranged from 24 °C to 35 °C, and RH, which ranged from 20% to 80% RH. The authors did not observe any significant statistical difference between persistence on stainless steel and on nitrile rubber gloves. Half-life, which is the period necessary for the virus concentration to fall to half, decreased for increasing values of RH and temperature. These two variables were shown to be statistically determining factors for virus persistence on metal and nitrile glove surfaces, which can probably be extrapolated to other materials. Chin et al. (2020) evaluated the persistence of SARS-CoV-2 in a viral culture medium for a period of 14 days at temperatures of 4, 22, 37, 56, and 70 °C. The same behavior of increasing viral viability reduction with increasing temperature was observed. For the lowest temperature studied, after 14 days the reduction in viral load was slight, from 6.10^8 $TCID_{50}$/mL to 1.10^8 $TCID_{50}$/mL, while for the other temperatures the virus was no longer detected, respectively, after 14 days, 2 days, 30 minutes and 5 minutes (the detection limit was 10^2 $TCID_{50}$/mL). Although the inverse correlation of temperature and viral viability has been observed in these studies, further investigations are needed, as for some authors this correlation is not true (Kratzel et al., 2020).

Concern about the possibility of maintaining SARS-CoV-2 active on surfaces at low temperatures and detecting it in frozen food packages from other countries by the Chinese government led the country to suspend the import of frozen products such as chicken from Brazil and shrimp from Ecuador. Although detection of the virus's genetic material is a warning sign, an investigation into the ability of the virus to infect a person after being subjected to such low temperatures must be investigated.

Recently, the pandemic scenario opened the discussion on the risk of using reusable plastic materials, regarding the possibility of contamination by the new coronavirus, due to the insufficient cleaning of this type of material. Governments in cities and countries that have restricted the use of single-use packaging and disposable plastic bags have come under pressure to relax these measures. The American *Bag the Ban* campaign includes a letter from the Plastics Industry Association to the US Department of Health and Human Services, which alleges that viruses and bacteria remain on surfaces for up to 3 days and can be carried by these sanitized plastic materials inappropriately (Hale & Song, 2020).

An interesting fact about the studies used to encourage the *Bag the Ban* campaign is that none of them assessed the viability of the Covid-19 virus or any other virus of the coronavirus family and the work aimed to assess cross-contamination of food in reusable bags. In the first study, led by Repp & Keene (2012), the authors investigated the contagion of 9 soccer players with a type of norovirus, which causes gastroenteritis, after contact with the first infected individual with a returnable plastic bag and packaged food. In this study, the authors could not determine whether the contagions were associated with product consumption or packaging handling. In the second study, in addition to not evaluating the exposure of workers and consumers in a supermarket to the studied viruses by handling reusable bags, the pathogens were found only in low concentrations, when found (Barbosa et al., 2019). In the latter, researchers also assessed the potential of dirty clothes stored in bags as sources of pathogens (Williams et al., 2011), by evaluating the growth of some bacteria inside of them. Since none of the three studies have evaluated the viability of any coronavirus-type pathogen, there is no guarantee that the data may be extrapolated to the persistence of the Covid-19 virus. Even though these founds highlight that some microorganisms can survive on reusable bags for days, a single-use bag may also get infected in-store during handling or transport to consumers' houses. Having that said, the only way to minimize the chances of contamination is by strict hygiene measures, especially after using the bags, whether they are made of single-use plastics or reusable materials.

A literature review carried out by Kampf et al. (2020) evaluated 22 studies that showed existing data on the persistence of various viruses on inanimate surfaces and against disinfectant agents. The work does not include SARS-CoV-2 but includes other coronaviruses such as those responsible for the SARS and the Middle East Respiratory Syndrome (MERS) epidemics; the latter started in 2013. They concluded that the studied viruses remain active on the evaluated surfaces for up to 9 days and that 0.1% sodium hypochlorite or 62-71% ethanol solutions were sufficient to reduce viral activity on the evaluated surfaces after exposure to the sanitizers for 1 min. Higher temperatures, such as 30 °C and 40 °C, reduced the persistence times of the studied coronaviruses on inanimate surfaces. However, at 4 °C the persistence of some coronaviruses reached more than 28 days. RH also influenced the persistence of coronaviruses, that is, the persistence was greater at 50% than at 30% of RH. The studies evaluated with different coronaviruses showed viability that ranged from 1 to 9 days depending on the material studied (Table 2).

Table 2. Viability of different coronaviruses in materials.

Materials	Time (days)	Evaluated virus	References
Steel	2 to 5	MERS-CoV	van Doremalen et al. (2013)
		229E coronavirus	Warnes et al. (2015)
Wood	4	SARS-CoV-1	Duan et al. (2003)
Paper	1 to 5	SARS-CoV-1	Duan et al. (2003) Lai et al. (2005)
Glass	4 to 5	229E coronavirus	Warnes et al. (2015)
		SARS-CoV-1	Duan et al. (2003)
Plastic	2 to 9	MERS-CoV	van Doremalen et al. (2013)
		229E coronavirus	Warnes et al. (2015)
		SARS-CoV-1	Duan et al. (2003)
		SARS-CoV-1	Chan et al. (2011)
		SARS-CoV-1 229E coronavirus	Rabenau et al. (2005)
Ceramics	5	229E coronavirus	Warnes et al. (2015)

3 Pressure on packaging design

Packaging design focuses on product protection functions, communication with the consumer regarding product promotion and instructions on how to use it, as well as allowing for greater convenience with packaging for ready-to-use products. These demands, already imposed by the market, will have to consider other needs in the post-pandemic period.

More sustainable narratives are one of these demands, eliminating unnecessary parts of the packaging and communicating with the consumer about environmental issues, for example, how to make recycling more appropriate. The Life Cycle Assessment (LCA) of materials enables us to estimate which changes generate a smaller environmental footprint and, if contextualized with the consumer, can lead to greater acceptance of the product.

In this line of sustainability, other measures that will have to be taken into account are related to the improvement of design, with innovations in materials and the movement towards monomaterials and packaging that facilitate recycling.

According to Lingle (2020), the concern with Covid-19 contagion through food packaging was significant for two-thirds of the American population, whereby more than 40% of this group used disinfectants to clean the packaging. These numbers can interfere with the manufacturer's choice of material, as the virus remains active for different periods in different materials.

The consumer demand for packaging with closing and use systems that allow the user to consume the product while moving or practicing physical activity is growing. However, these packages often require the consumer to handle the food or the region of the package that comes into contact with the mouth with their hands, which will have to be rethought in the design of these packages. An alternative to this problem may be delamination technologies, where the consumer removes the outer layer of the package, exposing a surface free of viruses and microorganisms. This last point raises the question of how to inform the consumer that food and drink are safe in this type of packaging while avoiding them being rejected by associating protection with the unnecessary use of materials.

A Brazilian survey regarding the eating habits of 1,108 people over 18 years of age during the Covid-19 pandemic revealed that 68% of respondents use food delivery services. The concern with packaging that can be sanitized when received at home, proved to be the most preferred choice for 61% of respondents compared to 21% who prefer economical family-size packaging and 18% who opt for individualized packaging for the products. Delivery, a resource widely used by restaurants for business survival during the quarantine period imposed by the Covid-19 pandemic, as well as e-commerce, requires packaging with specific requirements. This is a great opportunity for innovation, as only 26% of consumers fully agree that this type of packaging is suitable for maintaining the temperature and texture of food. In addition, 51% of respondents say they have stopped buying from a restaurant by delivery because of packaging problems, such as lack of seal and product leakage. In the post-pandemic economic recovery, 41% of respondents said they will use the ready-to-eat food delivery service more, especially in higher economic classes. Thus, the improvement of packaging, such as the use of crimpable devices, and QR codes, which are easy to sanitize and maintain the temperature of the food and its integrity, should accompany this growing demand, thus improving the consumer experience (Galante & Carioba, 2020).

Opportunities for technological development in food delivery packaging cannot leave aside the approval of materials for this application, taking into account the types of food (aqueous, fatty, acidic, etc.) and the conditions of use (brief or prolonged contact, room or refrigerated temperature, etc.). Thus, the risk of food contamination due to the migration of unwanted packaging components is reduced, ensuring consumer safety. Some of the factors that must be considered are the type and temperature of the packaged food, the contact time, the conditions of use and instructions to the consumer on how to sanitize, use and dispose of the packaging (Brasil, 2010).

E-commerce, in expansion mainly during and post-pandemic, requires packaging that protects the product, increases productivity and improves the consumer experience. A trend that has been emerging in this sector is the combination of primary and secondary packaging, which makes direct logistics for the consumer feasible, with a reduction in the number of packaging. The use of flexible multi-material packaging can be more efficient for e-commerce as they provide the necessary protection for the product while minimizing the weight during transport (Feber et al., 2021). In many cases, these packages are difficult to recycle in existing recycling systems, and therefore there will be a need to establish policies to support new recovery options for these packages, including collection, separation and reprocessing of these materials.

All these topics of concerns about packaging hygiene, digital commerce, delivery, and environmental issues of waste generation and incorporation of recycled material must be considered for the product to be accepted by the final consumer (Feber et al., 2021).

4 Sustainability considerations and Covid-19

Due to the concern with hygiene to avoid possible contamination by SARS-CoV-2, the use of packaging and disposable products gained ground again in the market. This position runs counter to the progressive ban on disposable packaging in the European Union (EU), whose general objectives are to avoid environmental contamination by plastics, and improve resource efficiency and the circularity of plastic packaging. Among the goals are to achieve 60% reuse and recycling of all plastic packaging in 2030 and 100% reuse, recycling and/or recovery of all plastic packaging in EU countries in 2040 (Plastics Europe, 2018).

In October 2018, more than 350 organizations (such as consumer goods producers, raw material producers, recyclers, governments, etc.) signed the Global Commitment for the New Plastics Economy at the World Economy Forum in Davos, Switzerland (United Nations, 2019). The objective of this Global Commitment is to reduce waste and plastic pollution at the source and is focused on the circular economy. Specifically for plastic packaging, six characteristics were defined, among which it is worth mentioning that all plastic packaging must be 100% reusable, recyclable, or compostable. Many of these companies have high recycling targets for 2025. Thus, reflections should be made about the pandemic to achieve these targets.

Currently, packaging reuse has not been prioritized due to consumer concern about the risk of contamination by the coronavirus, as mentioned above. Probably, reusable packaging will happen more on an industrial scale, where this packaging is cleaned on the premises of the industries before being reused. This practice reduces the risk of consumer contamination due to package handling by different people (Felton, 2020).

On the other hand, recyclable packaging, at least in the most critical periods of the pandemic, was not being recycled, as the collection and separation of recyclable materials were interrupted to avoid contamination of workers involved in the recycling chain. Material separation for this purpose continued to operate only in places where the separation is carried out mechanically, such as the city of São Paulo and other big cities around the world. Thus, separating packaging materials for recycling through optical sensors and the use of robots (automation) should grow in the post-pandemic world scenario as it reduces human labor side-by-side and helps to improve the separation stage (Felton, 2020).

The reduction in using post-consumer recycled plastic was also observed in other countries. The temporary suspension of the ban on disposable plastic bags and reusable bags with post-consumer recycled plastic (PCR) content has been adopted in some countries aiming to reduce Covid-19 contamination by workers who handle the bags and the reusable containers (Packaging Insights, 2021). These actions negatively affected the PCR supply and production chain. Thus, products that used PCR started to be made with virgin resin.

According to a global survey on the effects of the pandemic carried out by the consulting company AMI, which focuses on the thermoplastics market around the world, 68% of companies showed a reduction in activities in the first half of 2020, while 61% had reduction greater than 10%; and 40% showed a reduction greater than 20%, as shown in Figure 1. Regarding the time to recovery from activities, 94% of respondents expect to reach the same levels of pre-pandemic activity by the end of 2022 (Walter, 2020).

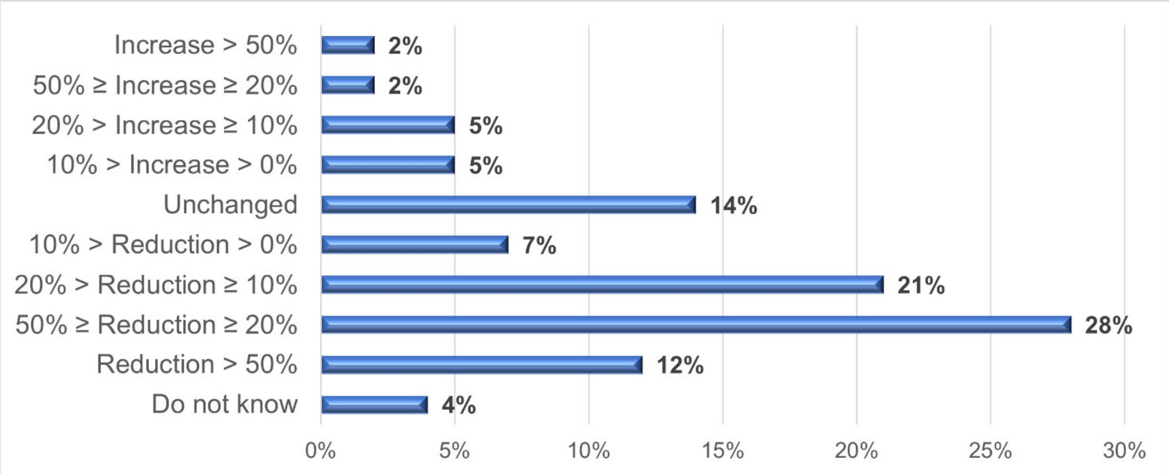

Figure 1. Effect of the pandemic on business activity in the first half of 2020 (Walter, 2020).

For 46% of companies operating in the rigid plastic food packaging segment, the pandemic did not affect the importance of recycling and sustainability for business, while for 17% of companies, these aspects have become more important (13%) or even much more important (4%) (Walter, 2020).

Considering the impact of Covid-19, the forecast for the plastic industry for 2030 is:

- Growth of the waste stream: the volume of waste available for recycling will influence the levels of recycled production. There was an initial decline followed by a sharp recovery and long-term waste volume is expected to grow at rates similar to those predicted before Covid-19;
- Influence of the cost of virgin resin on the cost of recycled: there was a decrease in the cost of virgin resin during the pandemic period, as the price of oil fell. This low cost implies a reduced cost of recycled products, which harms the economy of recycling. Reducing this impact depends on legislative actions, commitments made by the main brands, and consumer pressure;
- Consumer behavior: during the pandemic, plastic was used in many applications associated with hygiene (masks, face shields, etc.). However, the concern regarding the use of plastics reappears when the quarantine is relaxed, which should provide the growth of recycling at the rates expected before the pandemic;
- Expectation of a permanent reduction in the global production of plastics: recycling rates will be associated with a lower volume of material produced (in absolute numbers) and, therefore, the mechanical plastics recycling market should show recovery with growth lower than previous projections to the pandemic (Walter, 2020).

5 Trends for the post-Covid-19 food packaging market

Throughout the pandemic, packaging producers´ attention was focused on three minimum requirements: maintaining sustainable trends in material reduction, design considering the hygiene aspects of packaging, and the demands required by growing e-commerce. Some of the trends in the packaging market are listed below (Feber et al., 2021):

- The trend towards the development of more sustainable packaging, whether due to thickness reduction, optimized design, or the search for non-fossil polymers that were adopted before the pandemic, will have to be balanced with issues related to sanitation. The latter may prevail over environmental issues, but the search for more sustainable packaging will continue to be one of the main consumers demands;

- Restrictive measures taken to promote social isolation have boosted e-commerce consumption, which grew around 30% in the year 2020 in the United States compared to 2019 (Palmer, 2021). The trend is for an ever-greater scope of the portfolio of products sold by this type of business, which requires adequacy of packaging design so that their specific requirements are met;
- The pressure on converters, driven by pressure on the margins of consumer goods companies will become even more intense. This can reaffirm the need for cost savings by design optimization;
- The trend towards digitization of the entire value chain was further accelerated with the arrival of the pandemic. This catalyzes the use of artificial intelligence to optimize processes and the integration of packaging tracking technologies using Radio Frequency Identification (RFID) and Near Field Communication (NFC).

It is worth mentioning the change in the areas of activity of some companies, nationally and internationally, to meet the great demand for hygiene and protection items, such as alcohol-based hand sanitizer, individual masks, aprons, gloves, etc., which had an impact on packaging production. For example, the use of squeezy HDPE (High Density Polyethylene) bottles with flip top caps, normally used for sports activities, is now aimed to be used as a dispenser for alcohol-based hand sanitizer (Packaging Insights, 2021).

The increase in making and consuming meals at home and the increase in consumer concern for health and hygiene products also had an impact on the profile of the packages produced. The longer consumers stay in their homes, the more they become aware of their consumption and disposal patterns (Felton, 2020). In other words, the food waste that was generated in restaurants is now produced in consumers' kitchens. In addition, delivery purchases arrive at homes with large amounts of packaging, which were normally discarded in stores, out of sight of the consumer. Thus, the amount of packaging discarded in consumers' homes has increased and, therefore, their awareness should grow with the impacts of consumption and disposal. Possibly consumers can become more environmentally aware and concerned about materials that cannot be recycled easily.

Thus, there is a trend towards greater emphasis on eco-design, the expansion of technologies and processes for greater recovery and/or reuse of packaging, as well as guidance on disposal and recycling for consumers.

6 Final thoughts

Persistence studies of SARS-CoV-2 on surfaces reveal that the virus can remain active for periods ranging from a few hours to more than seven days in materials present on common surfaces. However, some standardization of the methods used must be encouraged to facilitate comparisons of data from different studies.

The pandemic had a relevant negative impact on the use of reusable packaging and the recycling rate of materials. Even though the global economy is expected to recover, the global production of plastics is likely to reduce permanently. Automation of the separating processes using optical sensors and robots in the post-pandemic is also seen as a tendency since it reduces human labor side-by-side and helps to improve the separation stage.

Specifically for food packaging, the design will have to address a balance between convenience and contamination risks; the rise of food delivery and e-commerce, along with the challenges associated with them; the development of more sustainable structures (bio-based materials, thickness reduction, optimization, etc.); pressure on the margins of consumer goods companies; and digitalization of the entire value chain.

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