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THE STATE OF **PACKAGING** 2024

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Trends in Packaging

Innovations in the domain of packaging have emerged in two major segments. One that involves altering the composition of the packaging material - this includes new materials, modification in existing materials, composites and so on. The other aspect where innovation are dense involves the application of emerging technologies in other fields to improve the functionality of packaging. For example, use of digital coding technologies, Internet of Things (IoT), novel design concepts and so on. After analyzing various research activities, vision statements, forums, etc., we concluded that the following innovations trends will be in the limelight in the near future -

1. Nano-composite Packaging

2. Smart Packaging

3. Circular Packaging

4. Thermal Packaging

1. Nano-Composite Packaging

Nano-composite materials are being researched to improve the mechanical and barrier characteristics of packaging material in an economical manner. A good amount of research has happened in this space and some players have received license for commercial pilot production. Patent analysis shows that large number of innovations are focused on using Polyolefin and PLA as base materials. Further, largely researched topics include biopolymers, monolayer packaging films, and functional advancement of material.

2. Smart Packaging

Active, Intelligent and Connected Packaging are trending in Smart packaging domain. This is because Active and Intelligent packaging have the capabilities to meet sustainability goals by reducing food & water wastage. Meanwhile the user base of Connected packaging has increased. “AI & Machine Learning”, “Sensors & Indicators”, “Holograms” are few segments that are coming up in the technological space of this domain. Further, Nano-composite materials are being explored in Active and Intelligent packaging. While Connected packaging is focusing on anti-counterfeit packaging solutions.

3. Circular Packaging

Recyclable and Bio-based packaging are two types being focused under this domain. Asian countries have shown more willingness in adoption of these solutions. In addition global consumer sentiment and push from various governments around the world is also boosting this domain. With applications in the field of F&B, Cosmetics, medical domain, more interest is inclined towards bio-based packaging. Here the use of Cellulose and Chitosan based packaging material is on a rise with focus towards improving their performance characteristics.

4. Thermal Packaging

Thermal packaging designed to maintain temperature for temperature sensitive products (such as pharmaceuticals, seafood, chocolates, meat, wine, cosmetics, etc.) has seen keen interest from pharmaceuticals and food industries. Asia-Pacific has shown the highest growth interest in such packaging. This is because of the focus of regulatory bodies towards ensuring that the products from these domains have been kept within approved temperature ranges during transit. Interestingly, recent innovations have been focused towards bringing in recyclability to thermal packaging solutions.

Nano-composites are made by embedding nanoparticles (particles with size of the order 10^-9m) in a polymer matrix (structure) in a continuous or discontinuous pattern. These particles are capable of improving the mechanical and barrier characteristics of the polymer as they strengthen the base polymer's mechanical properties by reinforcing its elasticity (regain original shape after deformation). Apart from that, nano-composites are economically more feasible than most other options available to develop similar properties in packaging.

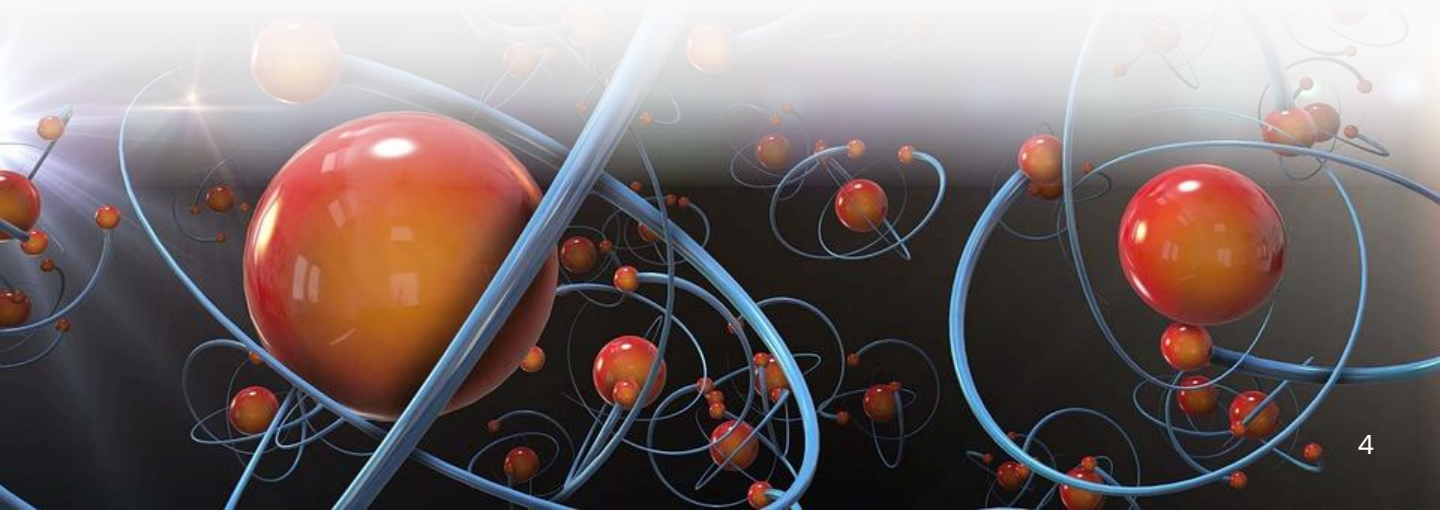
Applications of nano-composite packaging

Speaking about applications, nano-composite packaging have a wide range of uses -

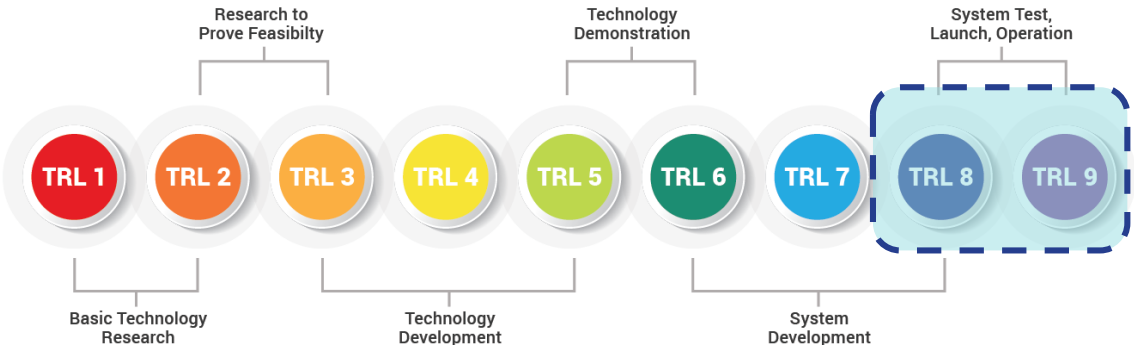
- **Food Safety -** One of the major applications is to enhance the shelf-life of the perishable contents such as fresh vegetables, fruits, fish, and meat products.
- **Recyclability -** To improve recyclability of the packaging product by using monolayer films.
- **Self-healing Packaging -** Application where nano-enabled packaging is increasingly being utilized for self-healing packages (Source).

What is technology readiness level of "Nano-composites for Food Packaging"?

There is a global push towards improved food safety and use of alternative packaging materials which can replace plastic. However, food contact packaging requires heavy regulatory clearance for use in commercial products as it concerns the health and safety of the consumers. So, we see that there is high density of **early research and exploratory studies** in this field across the globe.

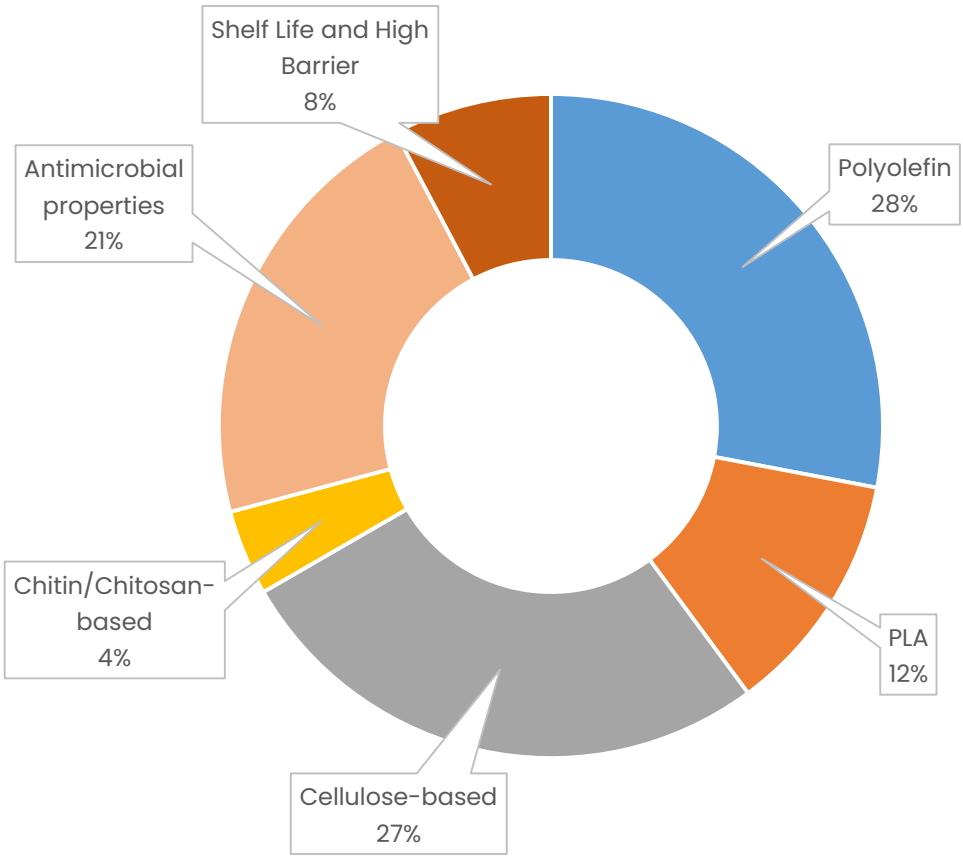


Further, we observed that the European Commission and the Government of UK have shown keen interest in funding research collaborations for the development of nano-composites-based packaging. We see that **research maturity stage** has been reached by many Europe-based projects due to adequate funding and technology sharing among various entities along with regulatory support. Also, a few startups have released **pilot products** based on nano-composites. For example, Melodea (an Israel-based startup) has acquired FDA license to start production of Nano-cellulose barrier coating for the U.S. market (Source). **This has led to the conclusion that this trend is concentrated on research maturity stage, although some players have received license for commercial pilot production.**



Which entities are researching at various research stages of "Nano-composites for Food Packaging"?

What type of research is happening in the space of "Nano-composites for Food Packaging"?



Patent analysis shows that the highest number of innovations are targeted towards Nano-composites with Polyolefin and PLA as base materials.

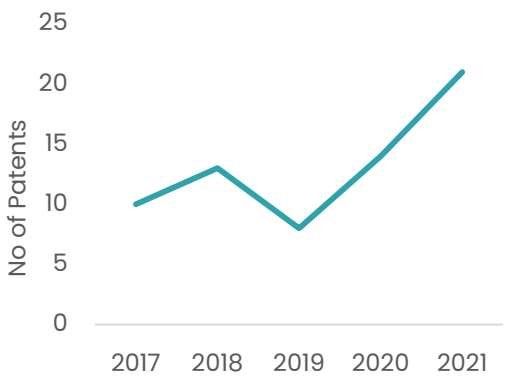
Almost at par are patents on nano-composites which have cellulose as a component. Here, focus has been on Nano-cellulose in the recent years.

Further, when we explored the regulatory environment, funding for projects and the market activity in this domain, we were able to understand that the patent filings for antimicrobial properties, high barrier function, and improving shelf-life of the products correspond to the demand for such properties in food packaging.

Driving Factor

Patent Filing Trend

Recently, there has been growing research interest in creating food packaging that can preserve the contents and prevent oxidation as well as spoilage. We can observe the growing research interest in this domain in the following publications trend: -



Consumer Perception

In a survey carried out across 5 countries, 87% people responded that they would want to have a label on food products containing Nano-materials (Source).

Further, a study done by University of Otago, New Zealand showed positive response of consumers towards nano-composites based packaging. The value addition in the form of improvement in food safety, quality enhancement, reduced deterioration rate and so on created a positive response to this technology among consumers (Source).

Government Response

In response to the growing use of Nano-composites for food packaging, governments and regulatory authorities around the globe have established tests, evaluation methods and other regulatory steps to validate such products for commercial sale.

- Canada has sought early applications for regulatory clearance regarding food packaging products using nanotechnology. They encourage applications during the development phase itself (Source).

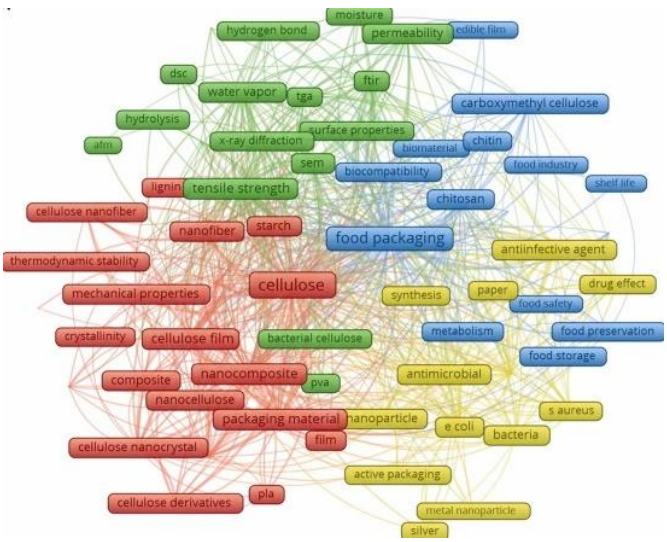
- In March 2020, the European Commission adopted a new Circular Economy Action Plan for a green future and "European Green Deal", which is a step to achieve climate neutrality by 2050, is a priority for 2019-2024 (Source).

Trending Topics

The focus of nano-composites has been on improvement of biodegradability so that post-consumption management of packaging material is simplified and does not cause adverse environmental impact.

Biopolymers

Research in nano-enabled packaging was initially focussed upon Ag (Silver) and TiO2 (Titanium dioxide) nanoparticles in polymer matrices of LDPE (Low density Polyethylene), PVC, and so on. However, in the recent years, research has shifted to **bio-based nanoparticles** such as Nano-cellulose and chitin/chitosan-based nanoparticles to form nano-composites with desired properties.



The heat map from the study showcases the same trend of growing interest in nano-composites over the years (Source).

A research study was carried out to determine the evolution of packaging using cellulose analysed publications over a period from 2012 to 2020. It was observed that there was a **shift from using cellulose as the main component to using nano-cellulose and nano-crystals and nanofibers of cellulose** as reinforcement in nano-composites (Source).

Monolayer Packaging Films

There is a growing interest and funding for innovation projects that seek to develop monolayer packaging films as multiple layers prevalent in present packaging products complicate the recycling after consumption (Source).

Functional advancement

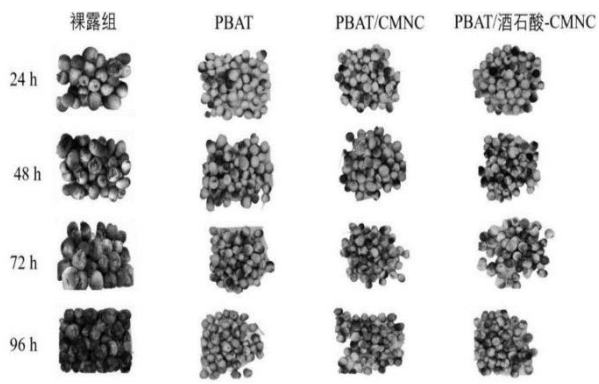
Another aspect that has gained significant focus from researchers and companies innovating in this field is functional advancement of the material. Barrier properties, strength, resistance to logistic stresses are some of the sought after qualities, especially in food and beverage packaging.

Nano-composites are receiving great attention in the domain of food packaging innovations from institutions across the globe. They offer a green alternative to plastics, improve the functional qualities of the packaging material, and are cost effective solutions.

Example of some researches

Esterified nano-composite film with preservative properties

Researchers from Shanghai Ocean University have developed an esterified nano-composite film that has preservative properties. The material contains modified carboxymethyl nanocellulose (CMNC) which has bacteriostatic oxidation resistance. So, it **inhibits the growth of microorganisms and prevents the loss of nutrition in food**. The base material in their innovation is a poly butylene adipate/terephthalate (PBAT) degradable material which endows the film with antibacterial and antioxidant properties. Moreover, it is environment-friendly, safe and reliable. (Source)

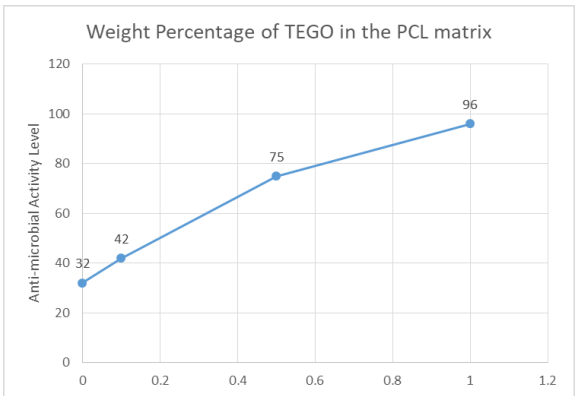


They recorded (figure above) the effects of different packaging film composition on straw mushrooms over 4 days.

TEGO-PCL matrix based nano-composite with high moisture absorption capacity

A researcher from Birla Institute of Technology has innovated a material for food packaging that has thermally exfoliated graphene oxide (TEGO) dispersed in polycaprolactone (PCL) matrix. The resulting nano-composites was found to have **better moisture absorption** along with antimicrobial properties. It is clearly evident from the graph below that the antimicrobial activity increases as the wt% of TEGO increases in the composite film. (Source).

WT% OF TEGO IN THE COMPOSITE FILM	ANTIMICROBIAL ACTIVITY
0	32
0.1	42
0.5	75
1	96



Who are some other entities working on Nano-composites for Food Packaging?

Core companies

BASF We create chemistry

parkside

WELLS PLASTICS LIMITED

haydale

Recycling Technologies

Nanocor

Non-core companies

dunbia

PEPSICO

MITSUBISHI GAS CHEMICAL

Startup

Metalchemy

NeoEnpla

TORAPHENE

fre energy

Melodea Bio Based Solutions

CAMBRIDGE NANOMATERIALS TECHNOLOGY LTD

University

SHANGHAI OCEAN UNIVERSITY 1912

1865 THE UNIVERSITY OF MAINE

PRIFYSGOL BANGOR UNIVERSITY

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI

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Which entities have collaborated for research in Nano-composites for Food Packaging?

Core companies

Haydale & NeoEnpla

Haydale is supplying functionalized Graphene Nano-platelets (GNPs) to NeoEnpla for creating food storage zipper bags and biodegradable plastic bags (Source)

Non-core companies

Nanocor & Mitsubishi

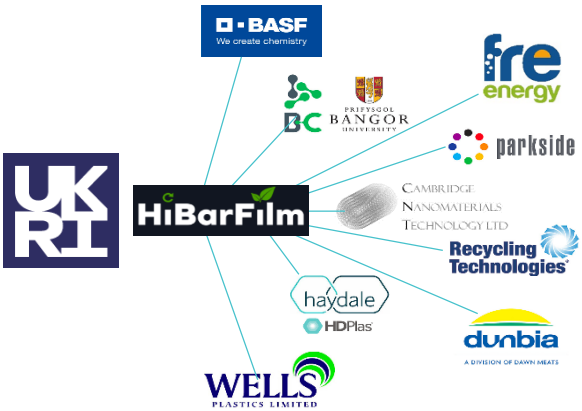
Nanocor and Mitsubishi Gas Chemical Company have collaborated to develop nylon nano-composites to be used as a barrier layer for multi-layer PET bottles with potential for packaging liquors like beer and small carbonated soft-drink beverages (Source).

Startup

University

Do You Know?

Government of UK is funding innovations in Nano-composite mono-material with high barrier properties for food packaging applications



United Kingdom has an agency to promote innovation called "Innovate UK". It funds and supports business organizations for developing new products and services (Source).

Innovate UK funded a project called HiBarFilm2. This project started in March 2022 as a consortium of 9 entities came together to innovate next gen high barrier films using plasma functionalized nanomaterials for food packaging applications.

The consortium was funded to build upon the feasibility study project on the same research topic named "HiBarFilm". This consortium is led by Haydale Composite Solutions and includes some of the most prominent companies from Europe- BASF, Cambride Nanomaterials, Dunbia, Parkside Flexibles, Fre-Energy, Wells Plastics, Recycling technologies and Bangor University.

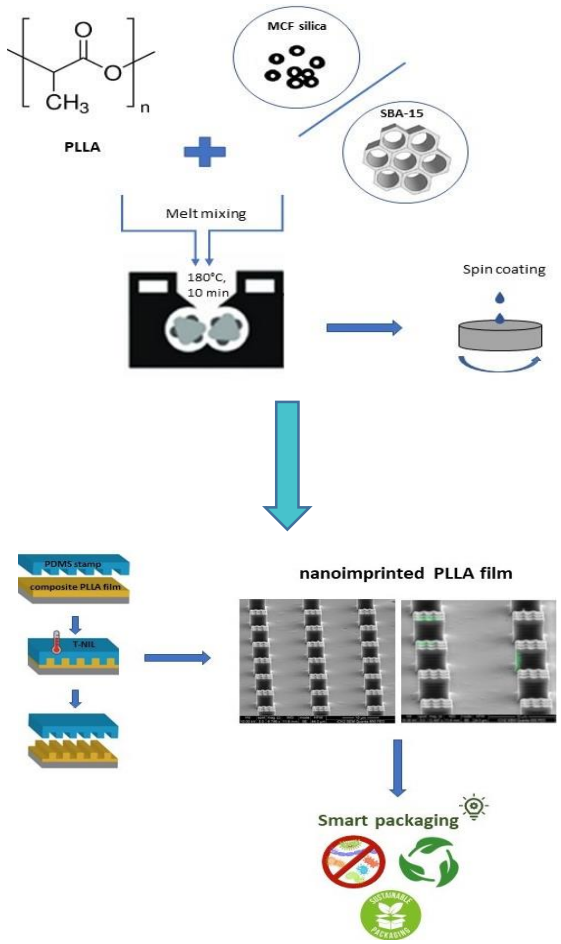
They are working to achieve the barrier performance of multilayer films in a mono-material polyolefin film. For this, they have devised two directions: -

- By mixing the nanomaterial into the polyolefin before filming to impart the barrier property into the film itself. This will also help tackle the issue of film contamination with leftover fats and blood.
- By dispersing the nanomaterials into a barrier coating to be applied on polyolefin substrate.

The two solutions they are working on may be combined to achieve higher barrier performance as desired. Moreover, since these films would be mono-material, recyclability will improve and create value addition(Source).

European Union is funding research in packaging technologies using Nano-enabled bio-based materials to upscale them for market applications

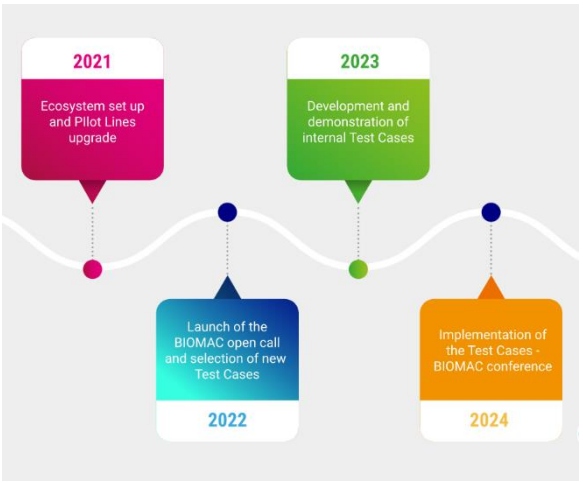
BIOMAC (European Sustainable BIO-based nanoMAterials Community) is working on a test case for food packaging application. It is a bio-based PLA film which is reinforced with bacteria nanocellulose, nanolignin, and biochar and coated with nanofibrillated cellulose. This film would be 100% compostable as claimed by the study. Further, it would have high oxygen barrier properties along with increased storage and life. Using vacuum thermoforming, the study seeks to develop biocompostable food containers using the material (Source).



They have received funding from the European Union's Horizon 2020 Research and Innovation Programme (Source). In line with their research interest, they have published a series of research papers on modifying PLA using nanolignin.

- In 2021, their research was focused on studying the applications of Polylactic Acid (PLA) as polymer. They worked on Nanoimprinted PLA composite for smart packaging (Source).
- In 2022, their research has been concentrated upon PLA-lignin composites (Source). They experimented with both lignin and nano-lignin to see the properties of the resulting composite. The young's modulus and tensile strength, along with UV blocking and antioxidant properties of the PLA-NL composites showed enhancement. The study concluded that the composites would be well suited green alternatives in the food packaging industry (Source).

BIOMAC intends to implement and demonstrate the present test cases (which includes the nano-composites for food packaging) and implement them in 2024. At present, it has called for taking up more test cases (Source).



2. Smart Packaging

Smart packaging increases the consumer and business utility by increasing the simplicity of accessing and tracking the information surrounding products and companies. Based on the functionalities, three trending things within Smart Packaging domain are –

- Active packaging: The package interacts with product inside with a goal to increase the product's shelf-life.

- Intelligent packaging: Contains sensors to determine the condition (e.g., freshness or temperature) of the product

- Connected packaging: Allows consumers to interact with a product through a code on the package that can be activated with a mobile device.

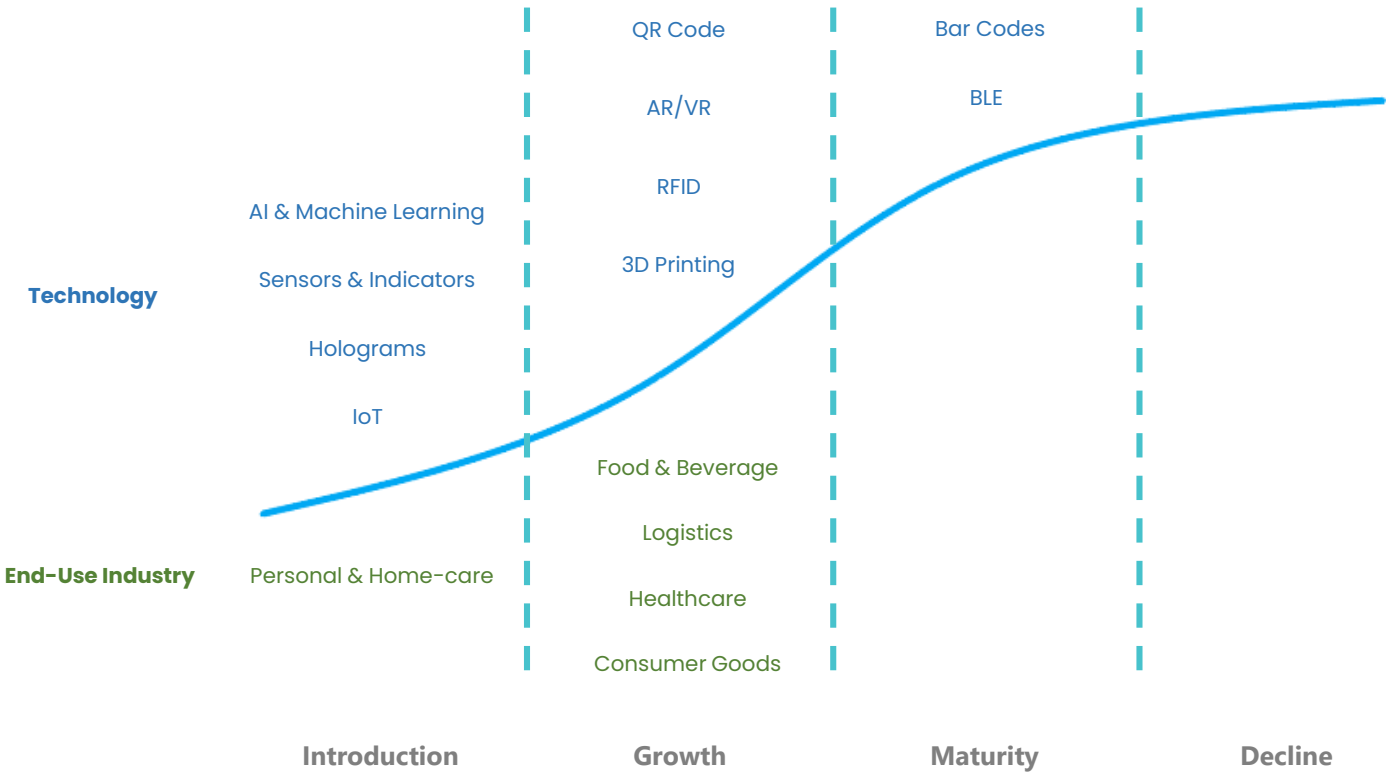
Out of the identified trending topics, Active and Intelligent packaging are trending because of their capability to reduce food & water wastage (by 1.1 Million Tons and 314 Billion Gallons). Whereas Connected packaging is in demand as its user base increases from 54% (in 2022) to 81%. In depth analysis showcase Active and Intelligent packaging is focussing on using nano-composites as material for improving the shelf-life of consumables. Meanwhile Connected packaging is focusing on anti-counterfeit packaging solutions.

In terms of technological advancements, "AI & Machine Learning", "Sensors & Indicators", "Holograms" are few segments that are coming up in the technological introduction space of smart packaging. Whereas the industry which has focused the most to inculcate these packaging solution has been Food & Beverage industry (leading with 19% share).

What is the technological stage as well as maturity of "Smart Packaging technologies"?

Our analysis shows that "Bar Codes" and "BLE" have reached the technological maturity in the area of "Smart Packaging". And, further growth drivers in the area would be from "QR Code", "AR/VR", "RFID", etc.

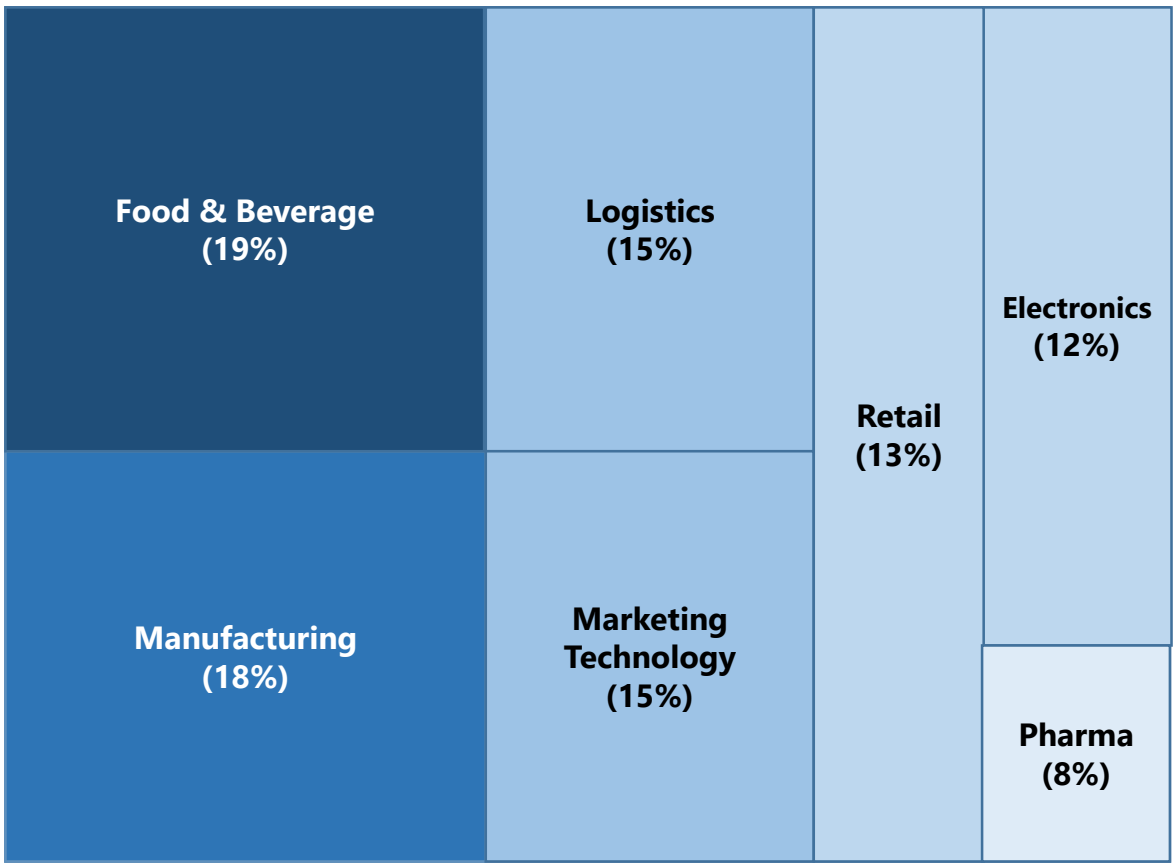
Along with this, a few segments are coming up in the technological introduction space. These are "AI & Machine Learning", "Sensors & Indicators", "Holograms".



We believe that the introductory technologies as well as growth drivers would be the main areas of research focus in this space. And, these areas are likely to receive more activity, both in terms of investments as well as commercial launches in the near future. (Source)

Where is the focus of research in the space of "Smart Packaging"?

Food & Beverage industry has focused the most towards "Smart Packaging" than other industries. This is due to the reason that Smart food packages improves transparency into food conditions and extend shelf-life. Additionally it also functions as an effective marketing medium for brands, thus improving customer engagement. This makes food industry as the most predominant customer of smart packaging.(Source)



These stats point towards "Food & Beverage" and "Manufacturing" as the two most important innovation areas within "Smart Packaging". Innovations are likely to follow in these area in the near future, and various commercialization activities are also expected.

Driving Factor

Smart packaging have found their use in food, beverages and pharmaceutical products. For these domains Active, Intelligent and Connected packaging are being used.

Here, Active and Intelligent packaging solutions have focused on improving the monitor-ability and shelf-life of packaged food & beverage products. Whereas Connected packaging has focused towards providing information and reducing counterfeiting in packaged materials (with more focus towards pharmaceutical products).

Further, let's understand the factors which are driving the growth of these packaging solutions.

Active and Intelligent packaging

Studies state that using active and intelligent packaging solutions can help divert **1.1 million tons** of food waste and save **314 billion gallons** of water. (Source) Additionally it can also prevent the emissions of around **2.43M Metric Tons of CO2e**. (Source)

Environmental impact of active and intelligent packaging

The importance of these numbers increases drastically when looking at UN food waste index. It states that **900 Million tons** of food is wasted causing **24%** of greenhouse gas emissions. In this wastage a lot is contributed by incapability to extend the shelf-life requirements of stored food.

Looking further into the stats showcases how active and intelligent packaging can help overcome some of these prevailing problems –

- **60%** of food waste produced from UK households is from products that weren't used in time. While **30-40%** of food waste in America is generated because of expiration date being reached. (Source).

- **20%** of fruit and vegetable wastage comes from production. While **28%** of wastage is due to how products look on the shelf.

- **20-40%** of all fruit and vegetables are wasted by retailers based on the appearance of product on shelf.

- **30-50%** of food entering consumer's homes are thrown away because of labeling, including "best before" and "use by" dates. (Source)

- **33%** of people working in bakeries believe that a short shelf-life is one of the major contributing factor for wastage of bread. (Source)

- **5%** seafood is lost during processing and packaging while **9.5%** is lost at the distribution and retail level. (Source)

Connected Packaging

Just to see how much connected packaging has been in the demand, following stats showcase its importance in packaging industry –

- **97%** executives agreed that data from connected packaging could improve the evidence-based culture in their organization. (Source)

- **81%** used connected packaging as a brand (compared to only 54% in 2022)

- **57%** deemed connected packaging as a sustainable way to connect with consumers. (Source)

- **92%** consider connected packaging to be important for packaging industry for next 12 months and beyond. (Source)

From huge global brands to small and medium-sized firms, product makers are adopting connected packaging to be customer-relevant. With the requirement to achieve supply chain resiliency while also advancing sustainability, companies are using connected packaging as an extension of their products. This packaging is also additionally creating valuable data driven insights and delivering growth.

Applications

In terms of applications –

Active packaging is used to extend the shelf-life and quality of the packaged product by inculcating various technologies such as –

- O2-scavengers and antioxidant releasing systems can be used with O2-sensitive products to extend their shelf-life.
- Desiccants have been used with dried and mold-sensitive foods.
- C2H4-scavengers are used in horticultural produce industry,
- and antimicrobial release systems can be used with bakery foods, cheese and other products. (Source)

Intelligent packaging solutions are used in applications where there is a need to monitor the condition of either the packaged food or the food environment inside the package. To keep track of these properties, it uses various mechanisms such as time-temperature indicators, oxygen sensors, freshness indicators etc.

Connected packaging is generally used for addition of 'triggers' to physical packs, enabling consumers to access digital content from digital devices, giving brands a chance to provide product experience to consumers. This is done with the help of technologies such as AR, NFC, QR codes and image recognition. Additionally they have found their use in anti-counterfeiting industry as well.

Trending Topics

When looking at the innovations which lead the smart packaging domain, certain areas are being focused under active/intelligent packaging and connected packaging. This is where the focus in these domains have been -

Active and intelligent packaging

Research in this domain is focused on using **nano-composites for improving the shelf-life of consumables**. This is due to the fact that this material can easily be modified to provide required properties to packaging layer which in turn helps with improving shelf-life and storability of consumables.

These packaging solutions are also trending as **governments push to use such solutions** to reduce food wastage. This can be seen from recent developments of standards which package manufacturing industry has to follow while developing such solutions –

- International Organisation for Standardisation (ISO) is developing standards specifically for active and intelligent packaging (**ISO/CD 6608-1, ISO/AWI 6608-2**). These standards are still under development and are expected to be released soon. (Source 1, 2)

- European Food Safety Authority (EFSA) has developed guidelines for active/intelligent substances present in active/intelligent materials and articles intended to come into contact with food (**Regulation (EC) No 450/2009**). (Source)

Connected packaging

Connected packaging solutions have recently focused towards **countering the increasing threat posed by counterfeit products** in the market.

This shift came after Food/Beverages and pharmaceutical domain recently started getting hit by increased counterfeit products. In order to see how adversely these domains have been affected, here are some stats –

- In Europe, **one in eight** food products seem to be counterfeited. (Source)
- Recent survey on food fraud incidents from 164 countries were analyzed. It was noted that fraud with meat products were most frequently reported (**27.7%**), followed by milk products (**10.5%**)
- Most of the food fraud was related to expiration date (**58.3%**) followed by tampering (**22.2%**) and mislabeling the country of origin (**11.4%**). (Source)
- For pharmaceutical industry, it suffers an annual loss of around **$150 billion** due to counterfeiting of real medications. (Source)
- Europol analyzed that in 2020 counterfeit medications were the **seventh** most commonly seized counterfeit product, whereas in 2019 they were tenth. (Source)
- As per US customs, counterfeit pharmaceutical goods accounted for **46.6%** of total seized goods. (Source)

With such a huge amount of loss related to counterfeit products, anti-counterfeit packaging has become a trending topic in connected packaging domain.

Let's look at some of the innovations taking place in these packaging domains –

ACTIVE AND INTELLIGENT PACKAGING

Nano-Silica reinforced pH response label for food and beverage packages

Researchers from the Northeast Forestry University have innovated a food label to keep a track of freshness of packed food contents (such as meat and seafood).

It consists of nano-silica reinforced pH response label film containing specific plasticizers (such as starch, carrageenan, nanowhiskers of cellulose, nano silicon dioxide, etc.). The nano silicon dioxide was found beneficial as a shield against UV light.

The results showcased that the developed film exhibited enhanced optical properties (such as high haze and light transmittance) which can result in better identification of the color change in the intelligent film. Mechanical properties (such as the tensile strength, elongation at break, barrier property and water vapor transmission) also showed significant improvement as well (Source).

Photonic crystal assembly of nano colloid particles forming time-temperature tag for cold chain packages

Researchers from Shenzhen Institute of Advanced Technology of CAS (China) have innovated a temperature controlled self-destructive photonic crystal tag with adjustable trigger temperature and color-changing time. This tag can change color when a certain temperature barrier is breached.

The innovation comprises of two materials in a liquid photonic crystal assembly of mono-disperse micron/nanometer colloid particle. When the environment temperature crosses the phase change temperature of the first material, the second material melts and comes in contact with it. This damages the ordered arrangement structure of the assembly. As a result the structural color is irreversibly altered. This ensures that product safety is maintained and the stakeholders in the supply chain are notified in case the contents may be exposed to unsafe temperatures.(Source)

CONNECTED PACKAGING

UV technology based hologram labels for anti-counterfeit packaging

Holostik (India-based hologram making company) has developed a product range consisting of holograms for anti-counterfeiting functions. It has a 3D label for packaging sensitive products. In order to ensure that hologram label cannot be copied, it uses embossing and UV-technology so the product authenticity may be tested using their packaging labels. Their product has a wide application for nutraceutical and protein powders industry where fake products have caused large damage to the industry (Source).

Ai-based anti-counterfeiting system

Researchers from National University of Singapore innovated an anti-counterfeiting technology called DeepKey which comprises of a 2D material tag and AI-based software for authentication. Their tag for packaging materials has high durability and they are resilient against environmental conditions such as extreme temperatures, UV exposure, moisture, and chemical spills. They have filed a patent for their system (Source).

Who are some other entities working on Smart Packaging?

Core companies

Non-core companies

Startup

University

Which entities have collaborated for research in Smart Packaging?

Core companies

Non-core companies

AMD & Skipso

Launched "AMB D2BD," an innovation program focused on startups that are developing solutions for smart packaging, and improved shelf-life quality. (Source)

Startup

WayCool & IIT

Signed a 3-year MoU to enhance shelf-life of food packaging material by using biopolymers. WayCool will invest close to $25,000 over a period of 3 years of this association. (Source)

University

Do You Know?

Governments across the world are funding smart packaging projects

A lot of funding activity is taking place in smart packaging domain. Governments such as USA and European Union have been pushing the development of these packaging solutions because of their positive environmental impact.

European Union's GLOPACK proposal

GLOPACK proposes to support users and consumers' access to packaging solutions which can enable the reduction and circular management of agro-food, including packaging, wastes. The proposal focuses on increasing the TRL of the three main food packaging area:

(1) Bio-circular (biodegradable materials issued from agro-food residues conversion) packaging materials

(2) Active packaging to improve food preservation and shelf-life without additives.

(3) RFID enabled wireless food spoilage indicator as new generation of self-adjusting food date label.

EU has contributed **€ 5 560 785,47** for the proposal who's total cost comes around **€ 6 658 650,36** (Source)

US Department of Agriculture's Clean Label Active Packaging to Reduce Food Waste

The overall goal of the proposed research is to reduce food waste and loss by developing a new, scalable method to produce active packaging materials. The research aims to take a multidisciplinary approach (consisting of expertise in stakeholder engagement, food science, active packaging, polymer chemistry, social science etc.).

In order to meet this objective it has proposed to develop reactive extrusion methods to produce thermoplastic active packaging resins. Based on the developed solutions, it is subjected to efficacy of the new active packaging materials in authentic food systems where performance, safety, environmental impact, and pilot scalability will be tested. (Source)

3. Circular Packaging

In packaging solutions, circular economy is encouraged to meet sustainability efforts. Areas of focus under this technology has been mainly towards -

- Recyclable Packaging – Packaging material capable of being recycled to be used again.

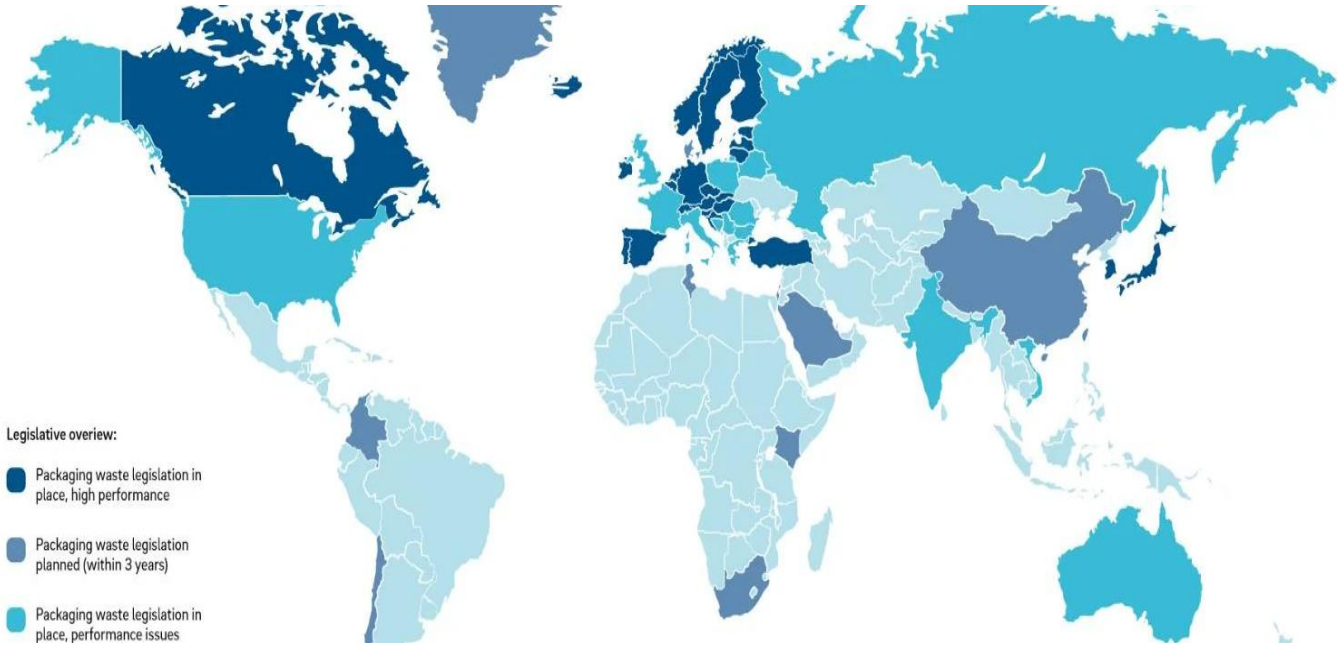
- Bio-Based Packaging – Packaging material based out of natural bio raw materials that are easy to decompose.

These packaging solutions are readily being pursued by Asian countries (like China, Japan, South Korea, etc.) as they have shown more willingness as well as concerns towards packaging sustainability. With consumer sentiments (83% of younger consumers willing to pay more for sustainable packaging) and governments around the world (such as USA, Canada, Europe) implementing regulations and policies to promote circular packaging, this domain will be growing further.

With wide range of applications in the field of F&B, Cosmetics, medical domain which are consumer oriented, consumers are more aligned towards using bio-based packaging solutions (45%). Further in bio-based packaging, Cellulose and Chitosan based packaging are on a rise. Here the focus is towards improving their performance characteristics (such as mechanical, thermal and barrier properties).

How is the global focus in initiatives related to "Circular Packaging"?

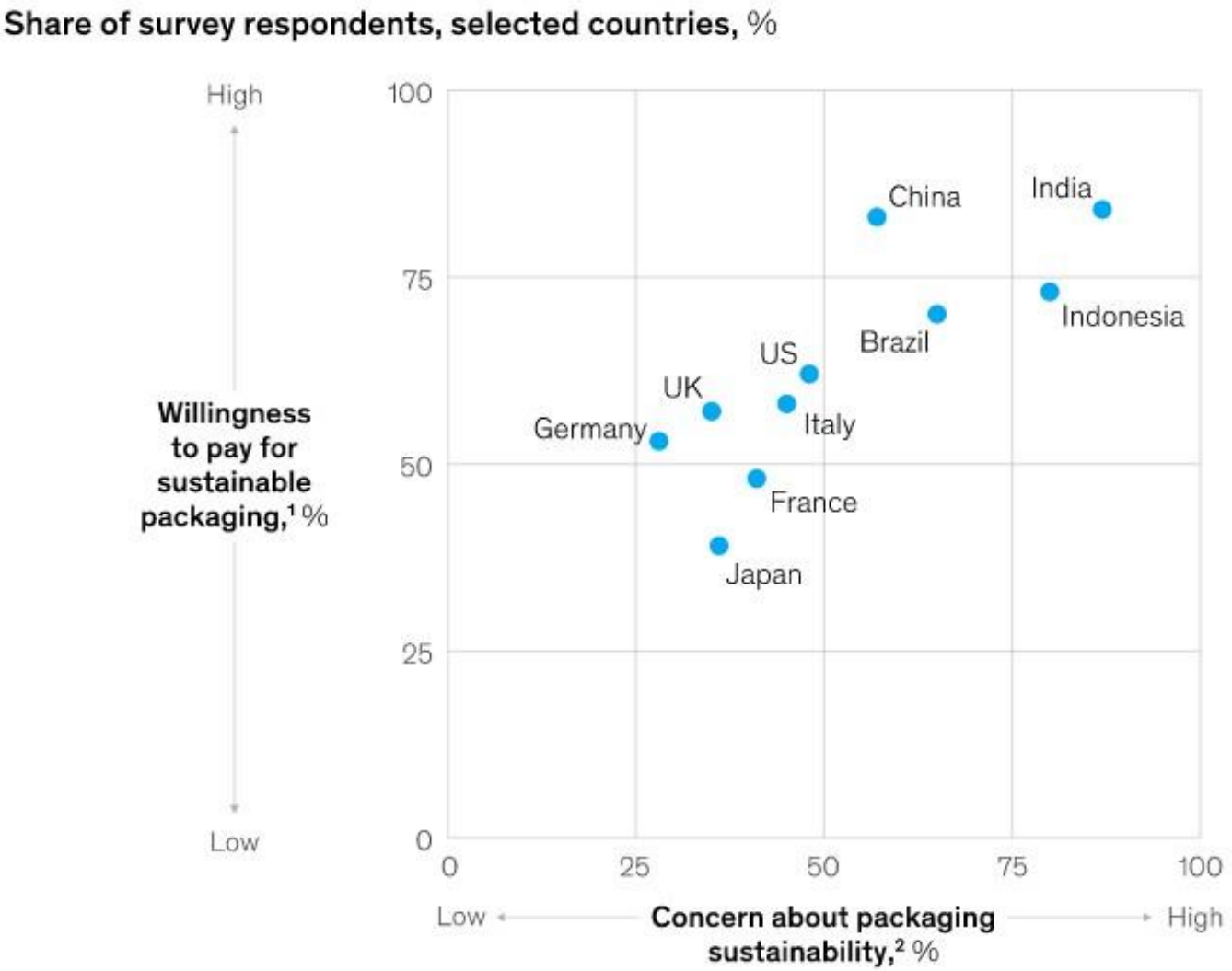
Analysis of geographic locations illustrates that government legislations in Asian nations (like China, Japan, South Korea, etc.) are far ahead in terms of planning as well as execution as compared to developed western economies (like USA, UK, France, etc.).



Companies/startups working in these geographies are more likely to receive active interest from governmental agencies. This will help in setting up infrastructure as well as scaling up of operations for these companies/startups. (Source)

Consumers from which geographic areas are most concerned about “Circular Packaging”?

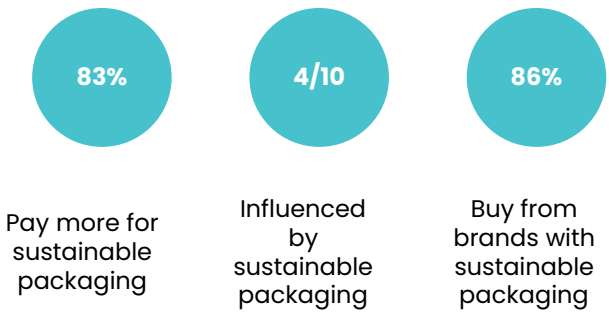
Analysis showcase that Asian countries are the forefront in willingness as well as concerns about packaging sustainability. These countries are far outpacing the European/American players in this domain, and big developments are expected from these geographies in the near future. (Source)



Driving Factor

Consumers mindset indicates that they are becoming more aware of the negative impact of plastic waste on the environment and are demanding more sustainable packaging options. Following are some of the stats pointing out the same –

- **83%** of younger consumers are willing to pay more for sustainable packaging.
- **4 out of 10** online shoppers stated that sustainable packaging influenced their online shopping decisions. (Source)
- **86%** consumers are more likely to purchase a product from a brand or retailer if the packaging is considered sustainable. (Source)



In addition to consumers, many governments around the world are implementing regulations and policies to promote circular economy practices, including circular packaging. This includes mandates for companies to reduce their plastic waste and increase their use of recycled materials in packaging –

- European Union has drafted **European Green Deal**. It ensures reusable packaging options along with getting rid of unnecessary packaging. It aims to bring packaging sector on track for climate neutrality by 2050. In order to meet this deadline the deal is also working on preventing packaging waste, boosting reuse and refill, and making all packaging recyclable by 2030. (Source)
- **Canadian Government** has introduced Single-use Plastics Prohibition Regulations (the SUPR) to meet its target of zero plastic waste by 2030. (Source)
- **U.S. Environmental Protection Agency** (EPA) published the National Recycling Strategy and reaffirmed the goal to increase the U.S. recycling rate to 50% by 2030. (Source)

This push from consumers and governments around the world is due to the growing concern over the environmental impact of single-use packaging. It is driving the demand for more sustainable packaging solutions to overcome the environmental concerns which come along such packaging. This has made Circular packaging becoming increasingly popular in this industry due to its positive impacts.

Applications

Some of the applications of circular packaging include –

- Food packaging: It can be used for food packaging, such as containers and wraps, that are made from materials that can be recycled or composted, reducing waste and the use of single-use plastics.

- Beauty and personal care products: Used in the beauty and personal care industry to reduce waste from products such as shampoo and soap bars, which can be packaged in reusable or compostable containers.

- Consumer goods: It can be used for a variety of consumer goods (such as electronics, toys, clothing etc.) by using recyclable materials that can be repurposed or upcycled after use.

- Medical packaging: Used in the medical industry to reduce waste from single-use medical supplies, such as syringes and sterile packaging, by using recyclable materials that can be safely sterilized and reused.

Overall, the applications of circular packaging are diverse and can be applied to a wide range of industries and products, with the goal of reducing waste and promoting sustainability.

Trending Topics

In circular packaging domain, analysis indicate towards bio-based packaging technology being on the rise. This can be seen in consumer survey which states that around **45%** consumers are inclined towards biodegradable packaging solutions. (Source)

Consumer base inclined towards biodegradable packaging

Further analysis highlights that Cellulose and Chitosan based packaging are being focused. Around **30%** of the patents are focusing on this form of bio packaging. This is also due to fact that these materials are readily available, easily mass produced and have good biodegradable properties.

However Cellulose and Chitosan based packaging solutions need massive improvements in their performance characteristics (such as mechanical, thermal and barrier properties). The further analysis of patents reveal that around **40%** of patents are focused to achieve this goal with these materials.

Following are some of the innovations taking place in this domain -

Cellulose nanocrystal barrier coating for paper-based food packaging

Melodea, (an Israel-based company) has developed a system for extracting cellulose nanocrystals (CNC) from the waste sludge of paper and pulp industry.

The obtained CNC is found to be capable of withstanding high humidity while protecting the contents from oil, grease, water and oxygen. It is used as an alternative to plastic and aluminum while manufacturing paper-based packaging products. Their main offering would be paper-based food packaging products with non-toxic barrier coating of cellulose nanocrystals. For the next step, the company has plans to open a manufacturing unit in US. (Source).

Cellulose-based screw cap for beverage packaging

Blue Ocean Closures (Sweden based ocean biodegradable packaging product manufacturer) and Glatfelter (USA based paper manufacturer) have collaborated to use renewable wood fibers and create cellulose-based screw caps. They have achieved optimum leakage protection using cellulose based material and vacuum press forming technique. Their innovation has captured the attention of Absolut (a Sweden-based alcohol maker) and they have partnered to design a natural cellulose-based cap for Absolut Vodka's iconic bottle.(Source).

Chitosan grafted with catechins for antioxidant packaging

Researchers from Yangzhou University (China) and Anhui Agricultural University (China) have collaborated to form packaging films with antioxidant properties using chitosan grafted with different catechins. Their analysis compared the effect of four catechins for achieving optimum antioxidant level for packaging edible oil. Of the four, the chitosan-catechin-g-CSs films were found to be ideal for the purpose of antioxidant packaging material for edible oils (Source).

Chitosan-Lignin-Ramie fiber composite for antioxidant property

Researchers from Shandong University and Qingdao University (China) have jointly researched on Chitosan-Lignin-Ramie fiber composites for improving the tensile strength and thermal stability of packaging film for meat. They observed that the addition of ramie fiber (20 wt%) increased the tensile strength (by 29.6%) and the addition of lignin (20 wt%) increased the antioxidant activity of the film (by 288%) and reduced the water absorption (by 41.2%). The composite was proved to be ideal for meat packaging (Source)

Who are some other entities working on Circular Packaging?

Core companies

Revolution

CNG CHARTER NEXT GENERATION

SCIENTEX

Non-core companies

سابك sabic

FPA Flexible Packaging Association
Connecting. Advancing. Leading.

Startup

greenback advanced plastic recycling

BIOOM

NOTPLA

University

WAGENINGEN UNIVERSITY & RESEARCH

Brunel University London

UF UNIVERSITY of FLORIDA

Which entities have collaborated for research in Circular Packaging?

Core companies

Scientex & SABIC

Developing packaging material based on advanced recycled ocean-bound plastics (OBP) using SABIC certified circular polypropylene (PP). (Source)

Non-core companies

Startup

University

Flexible Packaging Association & University of Florida

Developing the Regenerative Robust Gasification process that converts difficult-to-recycle packaging materials into methanol for use as feedstock. (Source)

Do You Know?

With Governments funding circular packaging initiatives, is the Government-Private association on the cards?

Govt. of Canada is investing $8.2 million to help food packaging companies scale-up their sustainability operations.

Friendlier (a sustainable food packaging solution provider) has received $500,000-Government of Canada investment. Using this, the company will standardize its reusable takeout packaging system through a network of businesses across Canada.

Unified Flex Packaging Technologies (UFPT) has received a $4-million Government of Canada investment. The company will increase manufacturing of its recyclable films used for food packaging and pouches.

Omnia Packaging has received over $3.7-million Government of Canada investment that will be used to produce 100 percent compostable/recyclable paper/plastic trays for the food packaging industry. (Source)

The U.S. Department of Agriculture (USDA) has announced an investment of $9.5 million to support the scale-up of sustainable bio product manufacturing in the United States.

Virginia Polytechnic Institute and State University (USA) has been awarded for a project that proposes to convert food waste into biodegradable, polyhydroxyalkanoate (PHA)-based bioplastics that can be used for a variety of consumer plastics, including flexible and rigid packaging and containers for food and beverages. (Source)

Innovate UK, part of UK Research and Innovation, will invest up to £2.5 million from the Smart Sustainable Plastic Packaging Programme for early-stage and mid- stage projects. (Source)

All these government initiatives across the continents show the keen interest they are taking in moving towards circular packaging. More govt.-private partnerships in this domain are expected in the near future.

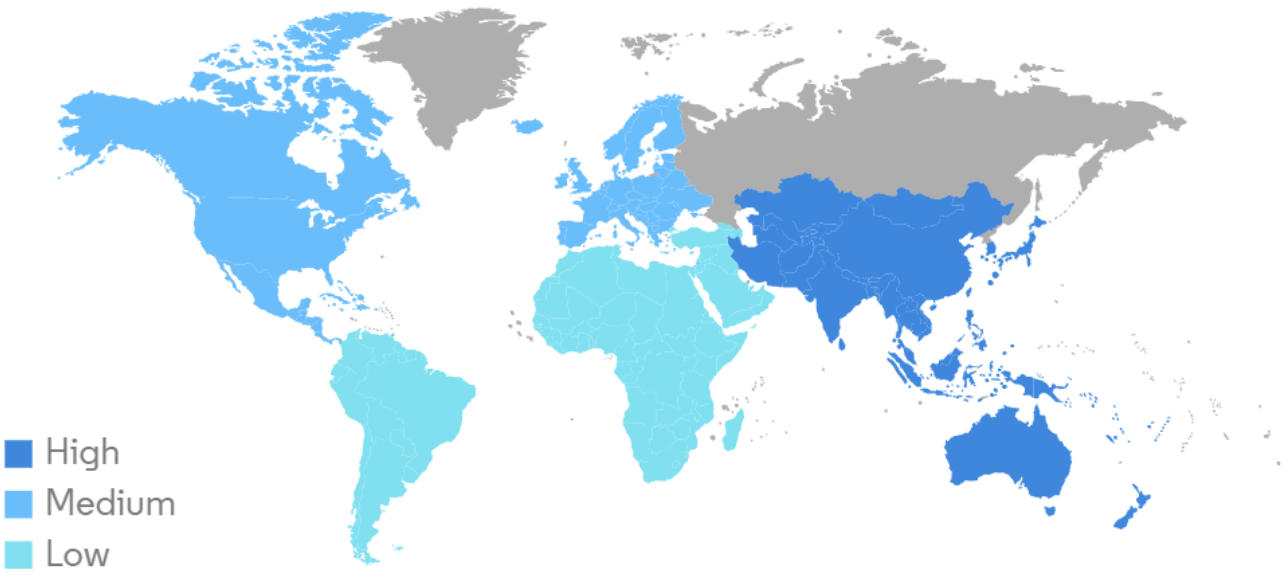
4. Thermal Packaging

Thermal packaging is designed for temperature sensitive products (such as pharmaceuticals, seafood, chocolates, meat, wine, cosmetics, etc.) that require a defined temperature to be maintained for end user. In terms of region, Asia-Pacific has shown the highest growth interest in insulated packaging. Whereas in terms of industrial adaptation, pharmaceuticals and food industries would be the highest adopters of insulated packaging. This growth in these sectors is because of regulatory bodies stressing on ensuring that the food and pharmaceutical products comply with the norms and have been kept within approved temperature ranges during transit.

This focus on F&B and Pharmaceutical industries is also backed by innovations taking place in these domains. 67% patents in thermal insulation packaging focus in F&B sector while 30% patent focus towards Pharmaceutical and medical domain. However it is interesting to see that recent innovations have been focused towards bringing in recyclability to these thermal packaging solutions (such as Smurfit Kappa and Mindful Chef's recyclable insulation packs, Dufaylite's recycled paper honeycomb based thermal insulation packaging).

Which geographical areas hold the highest growth rate for “Thermal packaging”?

Asia-Pacific region would receive the highest growth interest in insulated packaging. However, The United States is expected to dominate the insulated packaging market. This is due to the presence of major giants such as Amazon and Walmart, which have significantly changed the buying trends of grocery shoppers in the U.S. Also, the ability to prevent damage to temperature-sensitive products like pharmaceuticals, foods, and cosmetics, insulated packaging commands a noticeable presence in several high-growth industries in the country like healthcare, food, beverage, etc.



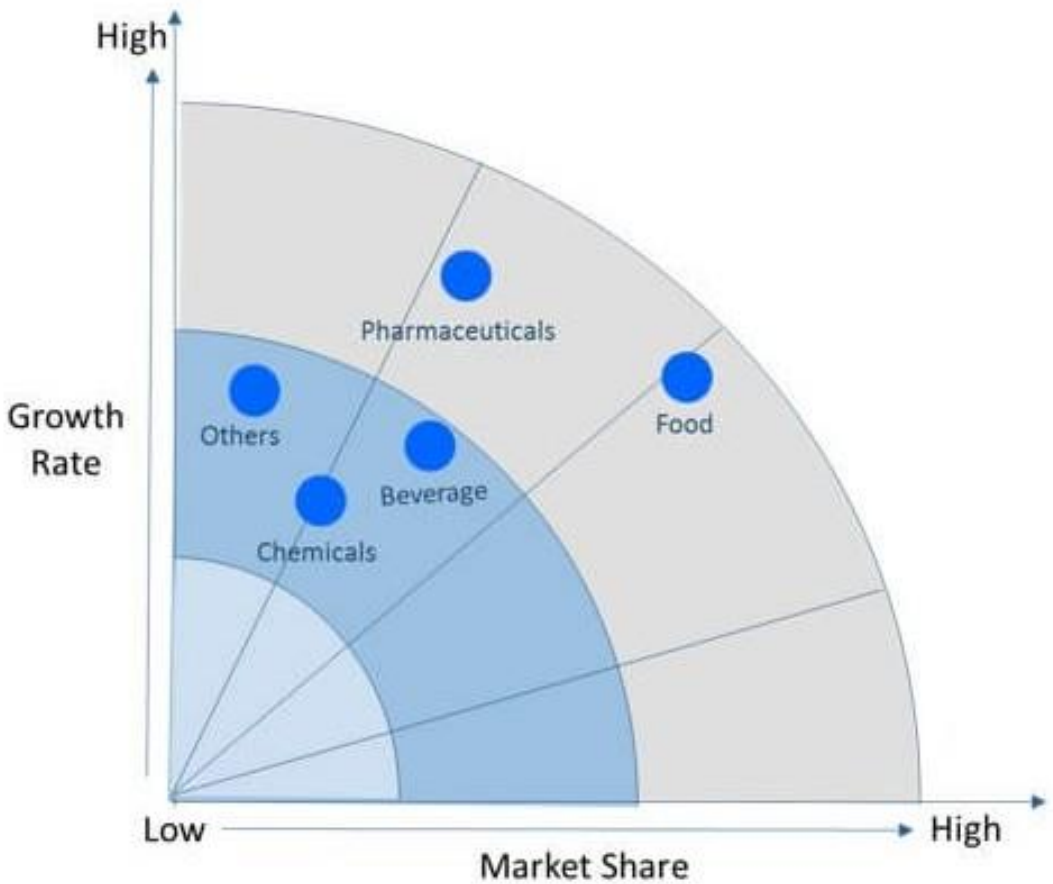
The government regulations in various geographies would also play a big role in the adoption of food-contact insulated packaging sector. With food/pharmaceutical being one of the most sensitive products to transfer and store, the regulations are expected to considerably promote the adoption of insulated packaging, such as insulated food bags. (Source)

Which industry's adoption of "Thermal packaging" would be the highest?

Analysis have made it evident that pharmaceuticals and food industries would be the highest adopters of insulated packaging.

Comparing the growth rate and market share for food and pharmaceutical industry, it is seen that:

- The annual growth rate for insulated packaging in pharmaceutical and food industry is expected to be 10% and 8% respectively.
- Interestingly, in terms of market share, food industry is expected to account for more than half of global passive temperature controlled packaging solutions. (Source)



Driving Factor

Multiple factors are driving the growth of thermal packaging solutions -

- Healthy eating has spurred the demand for global food products without nutritional decay. Consumption of high-end food across geographies increases the need for thermal insulation packaging to sustain the freshness of the food products.

- Regulatory bodies are stressing on ensuring that the food and pharmaceutical products are complying with the norms and have been kept within approved temperature ranges during transit. This has led to stricter regulations and high visibility across the supply chain, which makes temperature monitoring a must for pharmaceutical and food manufacturers.

- Growing demand for e-commerce has propelled the demand for thermal insulation packaging. For e-commerce food delivery partners, temperature control of perishable goods such as fresh produce, dairy products, and meat helps in preventing monetary losses due to product quality degradation and enhances customer satisfaction.

Applications

In terms of applications, thermal packaging solutions have found their application in various industries –

- **Food & Beverage** - Food articles need to be insulated during shipment or till the time it reaches customer. This insulation is required to prevent any texture or chemical changes in the product. (E.g. - Milk, Chocolates, Cheese, Confectionaries, etc.)

- **Cosmetics** - Cosmetics items may undergo chemical changes as well as physical properties (such as viscosity, etc.). These changes may affect the feel of the product and could possible alter the results from application. (E.g. - Lipsticks, Eyeliners, Serums, etc.)

- **Pharmaceuticals** - Vaccines, drugs and other medical items require temperature controlled environment, so as to prevent any changes in the efficacy of the product. So, thermal insulation is very important aspect in pharmaceuticals. (E.g. - Insulin, Vaccines, etc.)

Trending Topics

Innovations in thermal packaging domain are distributed towards food & beverages, medical and pharmaceutical domain. This can be seen from patent analysis post 2020–

- Around **67%** patents focus towards food & beverage related thermal insulation solutions.
- Around **30%** patents in thermal insulation focus towards medical and pharmaceutical domain.
- Other patents focus towards cosmetic domain.

Patent distribution clearly indicate that thermal insulation packaging solutions focus towards food and beverage industries.

Here are some of the innovations in this domain –

Thermal insulated pet bottle cover to keep beverage warm for longer time

Pearl Metal company (Japan) is researching on a PET bottle cover capable of retaining heat which has vacuum insulation structure. This provides PET bottle with the capability to keep beverages present inside it warm for longer periods of time.

In terms of the setup, the PET bottle containing a beverage has its spout exposed, and has a vacuum insulation structure. Whereas the second opening in spout is there for exposing the mouthpiece of the bottle with bottom configured to be attachable to and detachable from the first opening. It is characterized in that the arranged vacuum portion extends from the side surface of the PET bottle to a position above the diameter-reduced portion connected to the drinking mouth of the PET bottle.
By adopting such a configuration, it has become possible to keep hot beverages in PET bottles warm for a long time. (Source)

Temperature control beverage container

Novelis Incorporation (USA) is working on development of aluminum beverage can which can also control the temperature of the beverage present in it.

This is achieved through a setup consisting of a beverage container that

includes a container body and a container end. The container body includes an outer wall and an inner wall. The outer and inner walls define an outer and inner cavity with an opening at a top end of the container body. The inner wall is positioned within the outer cavity such that between the top end and a bottom end of the container body, the inner wall is spaced apart from the outer wall within the outer cavity. The container end is joined to the top end of the container body and covers the opening of the inner cavity.

This space between outer and inner wall reduces thermal conductivity thus helping in controlling temperature of beverage. (Source)

Who are some other entities working on "Thermal Packaging"?

Core companies

SOFRIGAM

Cryopak
The Perfect Degree of Protection

COLD CHAIN TECHNOLOGIES

Non-core companies

CATHAY PACIFIC

Logmore

B medical systems

Startup

ALUTIX INSULATIONS

Metsä

AEROPOWDER

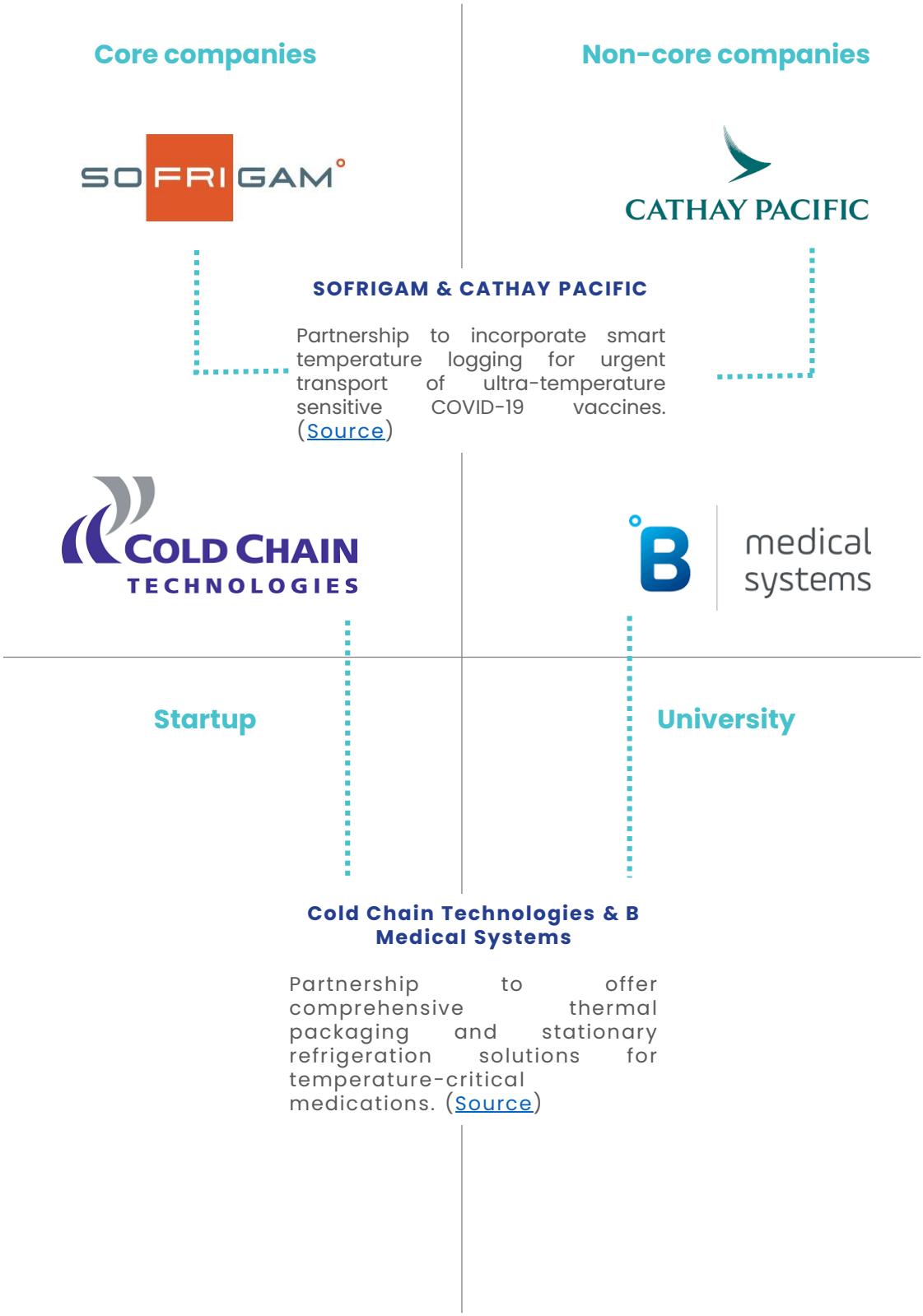
University

SHANGHAI JIAO TONG UNIVERSITY 1896

WEIHENSTEPHAN · TRIESDORF
University of Applied Sciences

MICHIGAN STATE UNIVERSITY Founded 1855

Which entities have collaborated for research in "Thermal Packaging"?



Do You Know?

Focus in thermal insulation packaging has recently shifted towards "recycling"

Analyzing the focus of patent publications in this domain, around **60%** of the total patents filed in this domain are aiming towards recycling properties.

This is mainly due to increasing demand and focus towards sustainability and overcoming global pollution caused by packaging industry.

Here are some recent developments taking place –

Smurfit Kappa collaborates with Mindful Chef on recyclable insulation packs

Smurfit Kappa (Leading European packaging company based in Ireland) and Mindful Chef (London based meal kit retailer) have collaborated to develop recyclable corrugated cardboard insulation packs.

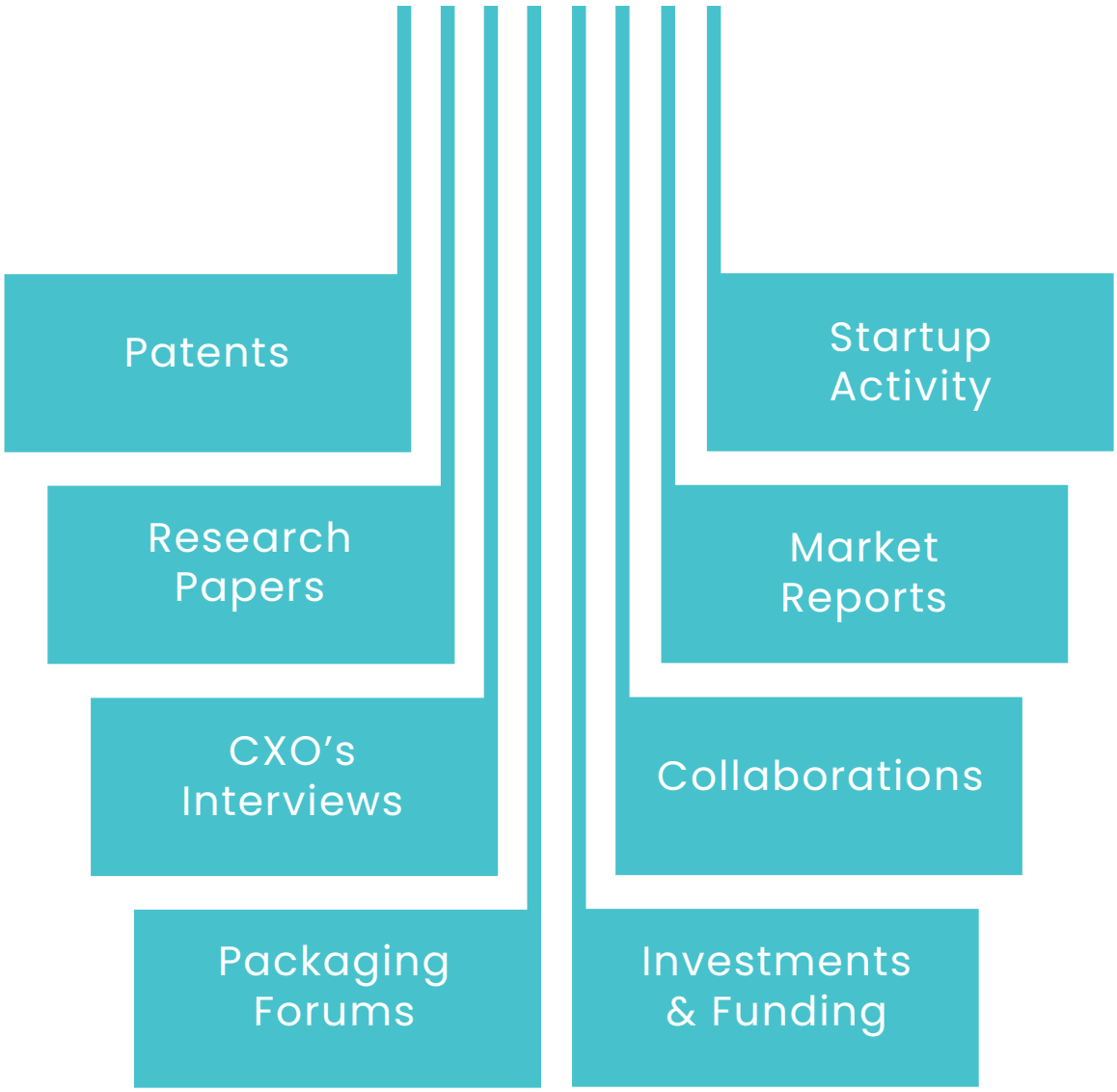
The developed insulation pack is 100% recyclable as per Smurfit Kappa's Experience Centre. Further the developed solution maintains the required temperatures over an extended period (under 8oC for over 30 hours) while providing a 30% reduction in carbon footprint compared to the previous packs. (Source)

Dufaylite's new thermal insulation packaging using recycled paper honeycomb

Dufaylite (UK based packaging solution company) has developed thermally-insulated box liners and inserts made from recycled paper honeycomb. The developed insulation packaging solution is able to deliver "excellent" thermal properties by keeping the contents cool for 24-48 hours. (Source)

Why we think these trends are going to be the big thing for 2024?

To spot out the themes that could become trends in the coming year, we explored various recent data sources and then analyzed them to highlight the themes which are commonly occurring in most of these sources. This provided us with a list of innovation trends which are targeted by entities in various areas (such as patents, research papers, vision statements, textile forums, etc.). And, these themes have a very high probability of becoming main-stream trends in new future. Below are the parameters we considered for figuring out these trends -



About GreyB:

We help companies solve their most pressing innovation challenges

Who could be your next competitor? What breakthrough tech will change your industry next? What are your competitors doing in their research labs?

And what should be the next step in your business and research strategy?

Don't let such questions bother you in your strategic meetings and steal your sleep at night. We constantly help our clients tackle their innovation challenges, people who are at the edge of what they do. We can surely help you find answers as well. Let's get in touch and uncover the secrets of your industry.

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