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FROM PLASTIC TO PAPER: A SUSTAINABLE REVOLUTION IN FOOD PACKAGING

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Abstract:

This technical paper explores the shift from single-use plastic to paper-based alternatives in sustainable food packaging. It discusses the environmental impact of single-use plastic, highlights the benefits and types of paper packaging, addresses challenges and considerations, and examines collaborative efforts and industry examples. The paper also emphasizes the importance of consumer choices, behavior, and innovation in driving the adoption of paper-based packaging solutions for a more sustainable future.

Keywords: Sustainable Packaging, Health Considerations, Public Opinion, Environmental Concern, Durability

1. Introduction:

In recent years, the detrimental effects of single-use plastic on the environment have become increasingly apparent. Plastic waste, particularly in the form of food packaging, has contributed significantly to pollution, marine degradation, and landfills overflowing with non-biodegradable materials. To combat this issue, a shift towards paper-based alternatives has gained momentum.

Figure 1

This paper delves into the importance of replacing single-use plastic with paper (Figure 1), with a particular emphasis on sustainable food packaging solutions

1. The Environmental Impact of Single-Use Plastic: Single-use plastic poses a severe threat to our planet. It takes hundreds of years to decompose, leading to long-term pollution and damage to ecosystems (Figure 2). Plastic waste in oceans endangers marine life and contaminates the food chain. By transitioning to paper-based alternatives, we can significantly reduce these adverse effects.

Figure 2

2. The Rise of Paper-Based Food Packaging:

a. Benefits of Paper Packaging:

- Biodegradability and recyclability: Paper is derived from renewable resources and can decompose naturally, making it an eco-friendly choice.
- Reduced carbon footprint: The production of paper generates fewer greenhouse gas emissions compared to plastic, especially when using recycled paper.
- Health considerations: Unlike certain plastics, paper-based materials are generally safer for food contact, minimizing potential health risks.

b. Types of Paper-Based Food Packaging:

- Cartons: Paper cartons, often made from recycled fibers, are commonly used for packaging milk, juices, and other beverages.
- Boxes and trays: Paper boxes and trays offer excellent alternatives to plastic containers for food takeout and delivery.
- Wrappers and pouches: Paper wrappers, such as those used for sandwiches or snacks, can effectively replace plastic packaging.
- Coffee cups and sleeves: Paper cups lined with a thin biodegradable layer are increasingly utilized, along with paper sleeves for insulation.

Here are a few more ways paper can be used as an alternative:

1. Shopping Bags: Instead of using plastic bags, opt for paper bags when you go grocery shopping or visit retail stores. Paper bags are biodegradable and can be recycled.
2. Food Packaging: Look for food products that use paper-based packaging instead of plastic. Items like paper cartons, boxes, or wrappers can be used for packaging various food items.
3. Straws: Instead of plastic straws, consider using paper straws. They are often biodegradable and can be a better alternative for single-use purposes.

4. Takeout Containers: Many restaurants are shifting towards using paper-based takeout containers rather than plastic containers (Figure 3). These containers are typically made from recycled or compostable paper materials.

Figure 3

5. Coffee Cups: Some coffee shops offer paper cups that are lined with a thin layer of biodegradable material instead of plastic. These cups are more eco-friendly and can be recycled in certain recycling facilities.
6. Wrapping Paper: Instead of using plastic wrapping for gifts, use recyclable or compostable paper-based wrapping paper. This helps reduce waste and promotes sustainability.

3. Challenges and Considerations:

a. Waterproofing and grease resistance: One significant challenge in food packaging is ensuring that paper-based materials remain durable and resistant to moisture or grease. Innovations in water-based coatings or compostable films are being developed to address this concern (Figure 4).

Figure 4

b. Recycling infrastructure and consumer awareness: To maximize the sustainability of paper-based packaging, proper recycling infrastructure must be in place. Additionally, educating consumers about the importance of recycling paper products is crucial to promoting effective waste management practices.

Greaseproof paper market 2023-2033

The global greaseproof paper market has experienced significant growth, reaching a valuation of US$1.27 billion in 2022. It is projected to grow at a compound annual growth rate (CAGR) of 5.5% and reach US$2.1 billion by 2033. Greaseproof paper plays a crucial role in food storage and packaging due to its ability to repel grease, making it suitable for long-term food preservation. The demand for greaseproof paper is expected to rise in the coming years, primarily driven by the food packaging sector's high requirements. Additionally, as the world witnesses a surge in online food delivery and cloud kitchens, the packaging material industry is re-evaluating the efficiency, cost-effectiveness, and environmental impact of food packaging materials.

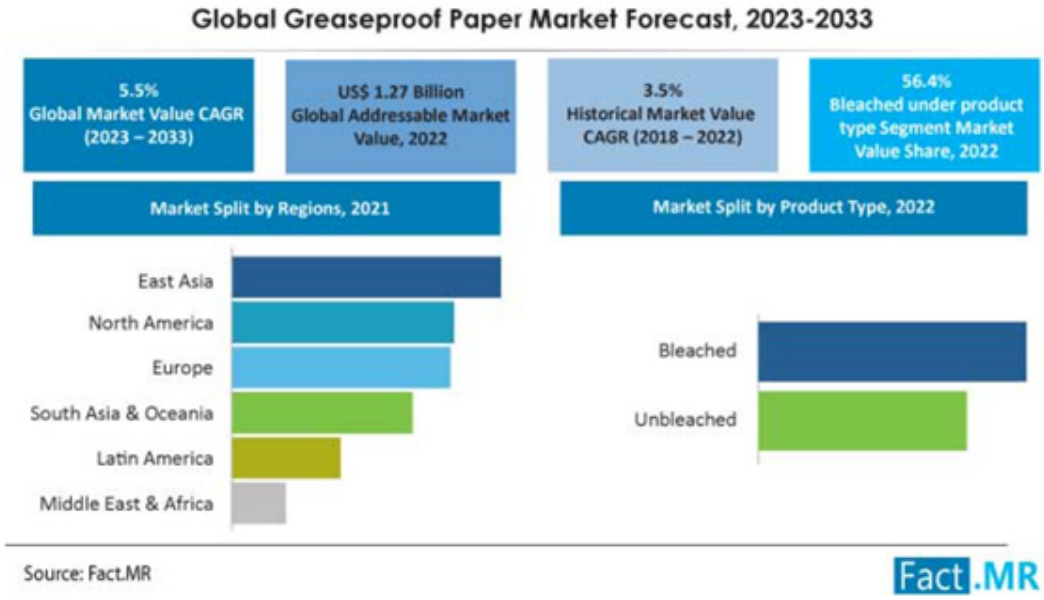

Figure 5

Previously, plastics were widely used in the packaging and transportation of food products such as confectionaries, baked goods, and poultry items. However, due to concerns over plastic waste generation, there has been a significant shift from plastic to paper-based materials. Greaseproof paper, being a cost-effective alternative to conventional packaging papers like plastic and parchment paper, has gained popularity. It is often mistaken for baking paper, although the presence of a silicone layer on baking paper makes it heat-resistant. Greaseproof paper can also be used in the baking process with some additional precautions.

The demand for food packaging materials has increased exponentially with the rise in online home food delivery post-pandemic. Governments' stringent regulations on plastic usage have further boosted the demand for greaseproof paper. As greaseproof paper is more affordable than baking paper, there is a high likelihood of increased product demand in the near future. Additionally, growing consumer awareness about reducing plastic consumption and sustainability concerns, along with innovations in packaging materials, will greatly impact the overall food paper packaging industry.

In conclusion, the greaseproof paper market is poised for growth due to its crucial role in food storage and packaging. Factors such as increased demand for online food delivery, government regulations on plastic usage, cost-effectiveness, and sustainability concerns are driving the demand for greaseproof paper as a preferred packaging material.

Characteristics For Greaseproof Paper and Board

Ecological Material's	***Suited To Food Contact***
Papers are made with 100% pure virgin fiber, eco-friendly and optimized for waste recycling. Upon request this can be FSC or PEFC certified	These papers meet BFR 36 and BFR36/2 standard's, guaranteeing food contact safety
Greaseproofing	***Resistance To Temperature Variations***
Grease barrier treatment coatings are laid on the surface o in the body of the paper, avoiding any transfer to the packaging. Several levels of greaseproofing can be offered.	From freezing to cooking, these papers maintain their properties
Release Coating	***Wet Strength***
The formulation of our paper and cardboard means easy de-moulding for all baking applications	We can custom set the wet strength for different applications.
Respecting Flavor's	***Machinability***
Specific raw materials are handpicked to guarantee flavors are unaltered. All these papers and cardboards are tested against EN 1230-2 standard which certifies the absence of transfer from the packaging to the food	The paper and cardboard formulations are designed to optimize your production speeds

4. Collaborative Efforts and Industry Examples:

a. Government initiatives: Governments worldwide are implementing regulations to reduce single-use plastic waste, incentivizing businesses to adopt paper-based alternatives.

b. Industry shifts: Many food and beverage companies have embraced sustainable practices by transitioning to paper-based packaging. They recognize the importance of corporate social responsibility and meeting consumer demands for environmentally friendly options.

5. The Way Forward:

a. Consumer choices and behavior: As individuals, we can contribute to this movement by actively choosing paper-based alternatives, supporting brands committed to sustainability, and advocating for responsible packaging choices.

b. Innovation and research: Continued investment in research and development is essential for improving the durability, performance, and recyclability of paper-based packaging solutions.

Bio based materials for barrier coatings on paper packaging.

Due to growing environmental concerns about the use of some petroleum-based polymeric packaging materials and coatings as well as rising consumer demands for products with nutritive quality and prolonged shelf lives, research into alternative packaging materials is becoming more and more popular. Paper packaging materials can be treated with barrier coatings comprised of biopolymers that are organically renewable. These biopolymer coatings are strong oil and oxygen barriers that have the potential to replace the synthetic paper and paperboard coatings now used. They could also stop inadvertent moisture transfer in food products. Incorporating antimicrobial substances into coatings to produce active/functional paper-based packaging materials is a desirable way to limit the growth and spread of bacteria in food packaging.

Coating materials

As long as it can give the base paper the appropriate qualities after coating, it can be employed as a coating material. Basis weight, absorbtivity, gloss, opacity, water/gas permeability, smoothness, ink absorbency, brightness, and color are only a few of the attributes of paper that are affected by coating. Barrier characteristics, such as the permeability of water or gas, are of particular importance for packaging applications. Barrier coatings on paper-based packing materials aid in blocking the entry of air and water vapor. To do this, we must enhance the tortuosity based on the packaging application to lengthen the mean-free path of gases or molecules of water vapor. To control the barrier properties of paper, we typically use traditional petroleum-based materials like PVC (polyvinyl chloride), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polystyrene, polypropylene, polyethylene terephthalate (PET), chitosan, polymethyl pentane (PMP), polyesters, fluorine-based derivatives, and waxes. To manage the barrier qualities, non-traditional coating materials such lignin-based coatings, polyvinyl alcohol (PVA), alkene ketene dimer (AKD), and PVA and AKD combined are also employed.

Biodegradable polymers for high barrier paper coating

Coating material	Water vapor transmission rate (g or cc/m²/day)		Oxygen transmission rate (cc/m²/day)		COBB (g/m²)		Contact angle (°)	
	Uncoated	Coated	Uncoated	Coated	Uncoated	Coated	Uncoated	Coated
Polylactic acid	339	57		302	25.6	3.17	–	–
Polyvinyl alcohol/zein	826.0 ± 18.8	288.0 ± 14.5	–	128.0 ± 14.7	–	–	105.0 ± 0.0	98.8 ± 2.4
Cellulose nanofibers and nano clay	28.55 ±0.7	5 ± 0.2	–	6.7 ± 0.05	–	–	–	–
Chitosan + micro crystalline cellulose + protein	99.6	60.3	–	–	95.43	76.13	–	–

Coating material	Water vapor transmission rate (g or cc/m²/day)		Oxygen transmission rate (cc/m²/day)		COBB (g/m²)		Contact angle (°)	
	Uncoated	Coated	Uncoated	Coated	Uncoated	Coated	Uncoated	Coated
Chitosan	298.17 ± 3.34	280.69 ± 2.92	–	–	45.21 ± 2.75	39.74 ± 1.44	–	–
Chitosan	501.5 ± 3.4	594 ± 57.9	> 10,000	1.1 ± 1.3	–	–	–	–
Cellulose ester	566 ± 45	1805 ± 151	> 400,000	18,050 ± 1510	–	–	59.8 ± 2.4	66.4 ± 1.8
Bio-polyethylene	566 ± 45	4 ± 1	> 400,000	11090 ± 986	–	–	59.8 ± 2.4	97.6 ± 2.9
Polylactic acid	566 ± 45	52 ± 6	> 400,000	386 ± 37	–	–	59.8 ± 2.4	77.2 ± 1.1
Cellulose undecanoyl ester	622.4 ± 21.4	192.0 ± 8.1	–	–	–	–	0–10	100–110
Chitosan-graft -Poly(dimethylsiloxane)	~ 1200	~ 800	–	–	~ 35	~ 15	70	120
Zein	~ 1200	~ 500	–	–	~ 35	~ 25	70	90
Poly(dimethylsiloxane)-Zein	~ 1200	~ 400	–	–	~ 35	~ 5	70	100
Chitosan-Zein	~ 1200	~ 1300	–	–	~ 35	~ 30	70	90
Poly(dimethylsiloxane)-Chitosan-Zein	~ 1200	~ 1000	–	–	~ 35	~ 20	70	120
Polylactic acid and Polycaprolactone	~ 800	~ 600	–	–	~ 5	~ 4	68	72
Semi-crystalline Polylactic acid	–	–	–	–	~ 25	~ 5	62	79
Corn starch	297.36	234.12	–	–	–	–	64.47	117.93
Natural rubber latex and alpha-1,3 glucan	–	–	–	–	~ 160	~ 30	53.8	94.2

Table 1 Different types of bio-based coating materials along with their water vapor and oxygen transmission rate, contact angle, and COBB values for uncoated and coated paper substrates

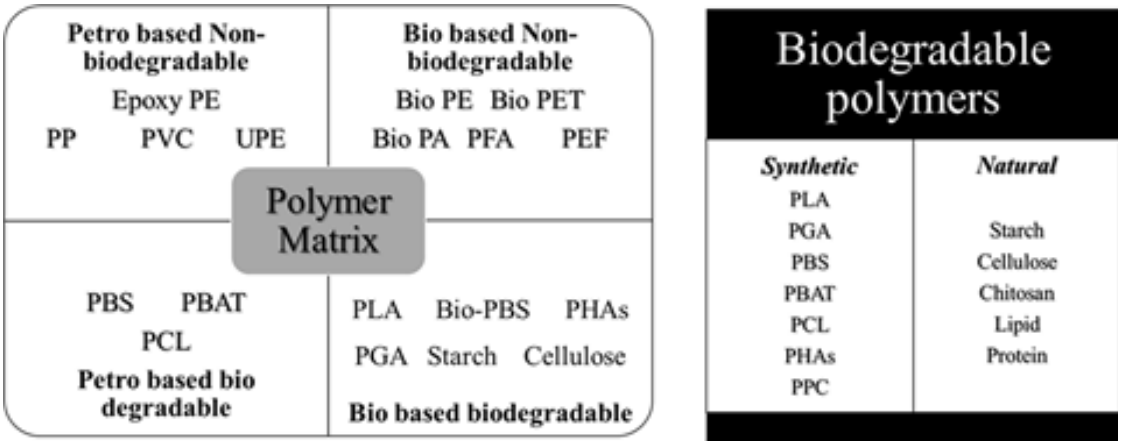

Table 2 : Classification of different kinds of polymers, such as biodegradable and non-biodegradable and classification of biodegradable polymers based on origin, such as synthetic and natural

Different barrier properties

Barrier properties of paper are crucial in packaging applications as they help maintain the quality, freshness, and shelf life of products. The two primary barrier properties that are particularly important in packaging are the water vapor transmission rate (WVTR) and the oxygen transmission rate (OTR). These properties determine the ability of the paper to resist the penetration of water vapor and oxygen, respectively.

Water Vapor Transmission Rate (WVTR):

Water vapor transmission rate refers to the rate at which water vapor passes through a material over a specific time period. For packaging, it is essential to minimize the transmission of water vapor to prevent moisture exchange between the packaged product and its surroundings. Excessive moisture can negatively impact the quality, taste, texture, and shelf life of various food and non-food products.

Coating paper with barrier materials can significantly reduce the WVTR. Barrier coatings create a thin layer that acts as a barrier against moisture, preventing water vapor from permeating the paper and reaching the packaged product. This helps maintain the product's freshness, crispness, and overall quality over an extended period.

Oxygen Transmission Rate (OTR):

Oxygen transmission rate measures the amount of oxygen that can pass through a material in a given time. In packaging, it is crucial to minimize the oxygen transmission to prevent oxidation and spoilage of oxygen-sensitive products. Oxidation can lead to loss of flavor, color deterioration, rancidity, and reduced shelf life, particularly in food and beverage products.

Barrier coatings applied to paper can significantly reduce the OTR, forming a protective barrier that limits the ingress of oxygen into the packaged product. By minimizing oxygen exposure, barrier-coated paper helps preserve the product's freshness, flavor, nutritional value, and overall quality, ensuring a longer shelf life.

In the illustration, the "before" image of the paper substrate may show a regular uncoated paper surface. This uncoated paper has limited barrier properties, allowing

water vapor and oxygen to permeate easily. The "after" image demonstrates the paper substrate after applying a barrier coating. This coating forms a thin, impermeable layer on the paper surface, significantly reducing the transmission rates of water vapor and oxygen. The result is a paper substrate with enhanced barrier properties, providing improved protection for the packaged product.

It's important to note that the specific barrier materials used for coating paper can vary depending on the desired properties and packaging requirements. Common barrier materials include polymers, resins, laminates, or even combinations of these materials, which are chosen based on their effectiveness in minimizing WVTR and OTR.

By enhancing the barrier properties of paper through coating, packaging solutions can effectively protect and extend the shelf life of various products, ensuring their quality and freshness for consumers.

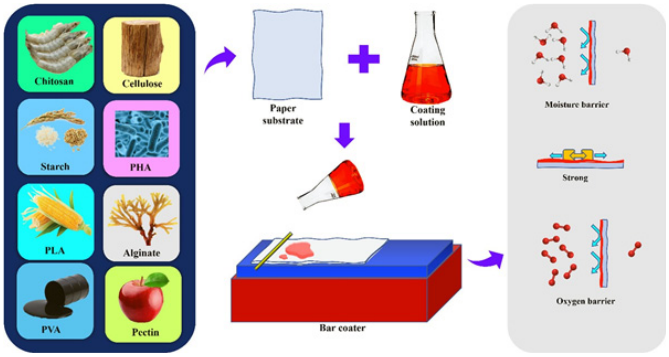

Figure 6

Different sources for biopolymers and their effect on improvement of barrier properties upon coating on paper substrate

Coating methods for paper substrate

Different coating methods have been explored and reported in the literature for imparting barrier properties to paper. These methods involve applying a barrier material onto the paper substrate using various techniques. Here are brief explanations of some commonly mentioned coating methods:

Bar Coating:

Bar coating, also known as Mayer bar coating or rod coating, involves applying a layer of coating material onto the paper surface using a bar or rod. The coating material is typically dispensed onto the paper, and the bar or rod spreads and levels the coating evenly across the surface. This method allows for precise control over the coating thickness and uniformity.

Spray Coating:

Spray coating involves spraying a fine mist or spray of the coating material onto the paper surface. This method is commonly used when the coating material is in a liquid form. Spraying creates a thin and even layer of coating on the paper, providing effective barrier properties. Spray coating can be done using air-assisted or airless spray systems.

Knife Coating:

Knife coating, also known as blade coating, utilizes a sharp-edged knife or blade to apply the coating material onto the paper. The coating material is typically supplied onto the paper, and the knife or blade spreads it uniformly as the paper passes through the coating station. Knife coating is known for its precise control over coating thickness and is often used for high-quality coatings.

Dip Coating:

Dip coating involves immersing the paper substrate into a bath or tank containing the coating material. The paper is dipped into the liquid coating material, and upon withdrawal, excess coating is allowed to drain off, leaving a thin, uniform layer on the paper surface. Dip coating is suitable for coating small areas or specific sections of the paper.

Each coating method has its advantages and may be selected based on factors such as the nature of the coating material, desired coating thickness, production speed, and the specific requirements of the application.

It is worth noting that advancements in coating technologies have led to the development of more specialized and advanced coating methods, such as slot-die coating, gravure coating, and roll-to-roll coating. These methods offer improved precision, speed, and efficiency in applying barrier coatings to paper substrates, further expanding the range of options available for achieving desired barrier properties.

Overall, the selection of the coating method depends on factors such as the properties of the coating material, desired coating thickness, production requirements, and the specific needs of the packaging application.

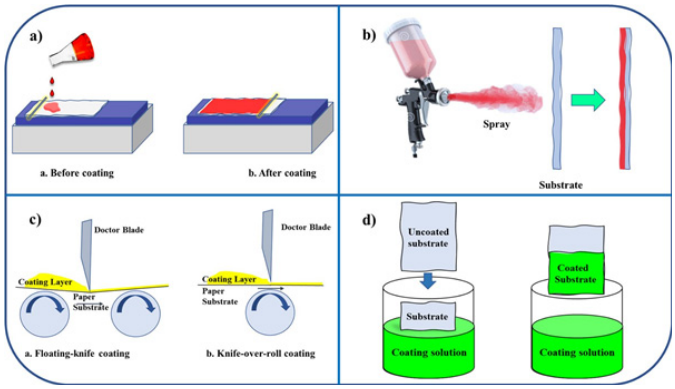

Figure 7

Different methods for coating on the paper substrate: a bar coating. b Spray coating. c Knife coating. d dip coating

Public opinion

Public opinion regarding the replacement of single-use plastic with paper in the food industry is highly positive, with a growing awareness and support for more sustainable packaging alternatives. Here are some common sentiments and perspectives:

Environmental Concern: Many individuals are increasingly concerned about the environmental impact of single-use plastic, particularly in the food industry where packaging waste is significant. They recognize the need for sustainable solutions and view the shift to paper packaging as a positive step towards reducing plastic pollution, protecting ecosystems, and preserving natural resources.

Health and Safety: Consumers often perceive paper-based packaging as safer for food contact compared to certain types of plastic. Paper is considered a more natural and non-toxic material, alleviating concerns about potential chemical leaching from plastic packaging into food. This perception enhances the acceptability of paper alternatives, particularly for food items.

Aesthetics and Perception: The visual appeal and feel of paper packaging can evoke a sense of authenticity and sustainability. Consumers appreciate the natural, earthy look of paper, associating

it with eco-friendliness and a more eco-conscious brand image. The tactile experience of handling paper packaging also adds to the positive perception of such alternatives.

Recycling and Waste Management: Paper is widely recognized as a recyclable material, and consumers appreciate the ease of recycling paper-based packaging compared to certain types of plastic. The ability to recycle and contribute to a circular economy aligns with the values of many environmentally conscious individuals.

Functional Considerations: While paper-based packaging has its advantages, some consumers express concerns about its durability and resistance to moisture or grease. They may worry about potential issues such as leakage or loss of food freshness. Addressing these functional considerations through innovations in water-resistant coatings or compostable films can help increase consumer confidence in paper alternatives.

Figure 8

Education and Awareness: Consumer sentiment is often influenced by awareness campaigns, educational initiatives, and transparent labeling. Effective communication about the benefits of paper packaging,(Figure 8) its environmental impact compared to plastic, and the importance of proper recycling can help shape positive attitudes and encourage acceptance of these alternatives.

It is essential to note that public opinion can vary across different regions, demographics, and cultural contexts. Some individuals may still prefer the convenience or specific functionalities of plastic packaging. Therefore, a comprehensive approach to sustainable packaging should involve a balance between consumer preferences, environmental considerations, and industry innovation.

Conclusion:

Replacing single-use plastic with paper-based alternatives, especially in food packaging, is a critical step towards a more sustainable future. By utilizing paper cartons, boxes, wrappers, and cups, we can significantly reduce plastic waste and its detrimental effects on the environment. However, it is vital to address challenges like waterproofing, improve recycling infrastructure, and raise consumer awareness. Through collaborative efforts and conscious choices, we can create a world where paper becomes a viable and eco-friendly substitute for single-use plastics.

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