STRUCTURAL AND BARRIER/RESISTANCE PROPERTIES OF PAPER

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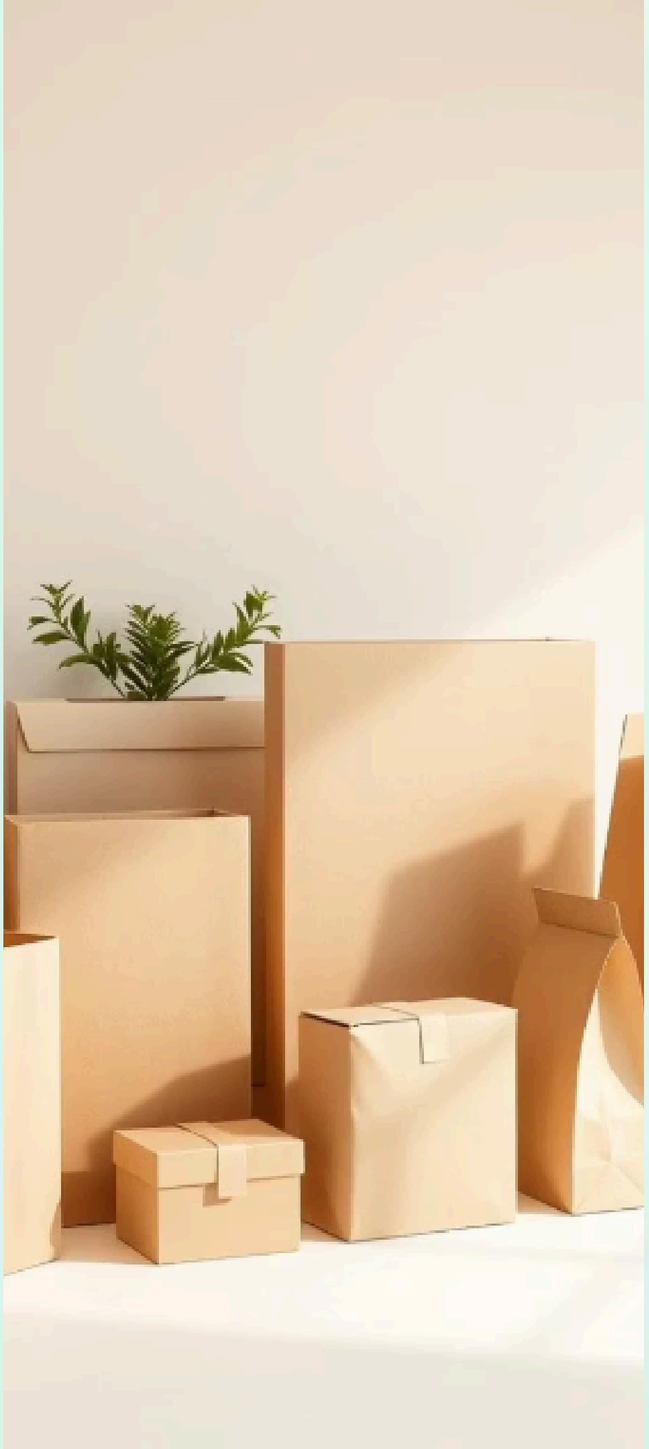


Introduction: Paper in Packaging

- Paper is one of the most versatile, sustainable, and widely used materials in the packaging industry. Its adaptability, printability, and eco-friendly profile make it a preferred choice for a broad range of applications, from food service to retail and industrial packaging.
- The microstructure - **a mesh of cellulose fibers** -is what gives paper its basic mechanical strength.
- Fillers and additives are used to tailor the paper's appearance and performance
- Surface treatments and coatings further enhance functionality for specific uses (printing, packaging, barrier properties).

VERSATILITY

Used for wrapping, cushioning, protecting etc for goods efficiently.

SUSTAINABILITY

Biodegradable, recyclable, and increasingly replacing plastics.

COST-EFFECTIVENESS

Lightweight and easy to customize for diverse packaging needs.

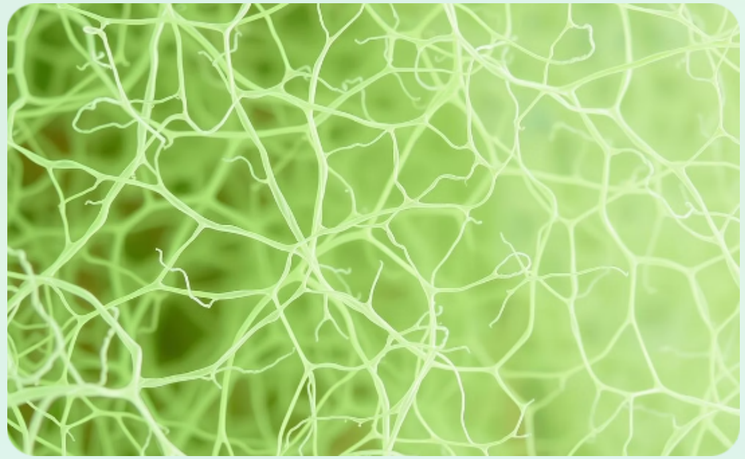
Structure of Paper

Surface Coatings (Optional)
print quality, gloss, or barrier properties

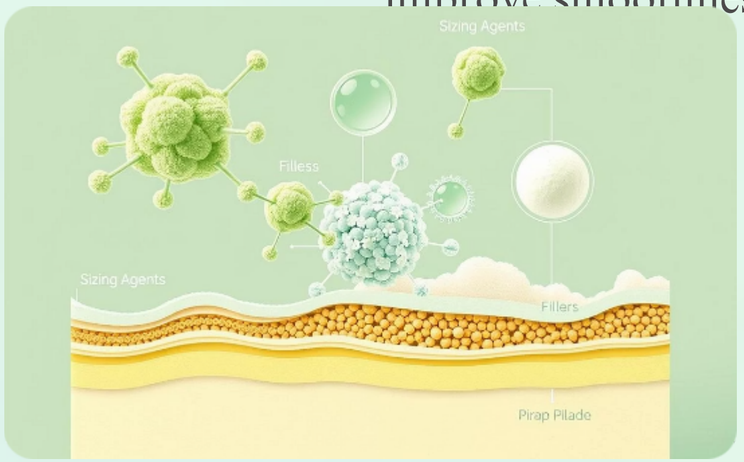
Additives and Sizing Agents
of absorbency
d resistance to
netration

Filler Materials
improve opacity, brightness, and smoothness

Fiber Network
Interlaced cellulose fibers form the core structure. Softwood fibers add strength; hardwood fibers improve smoothness



Fiber Network

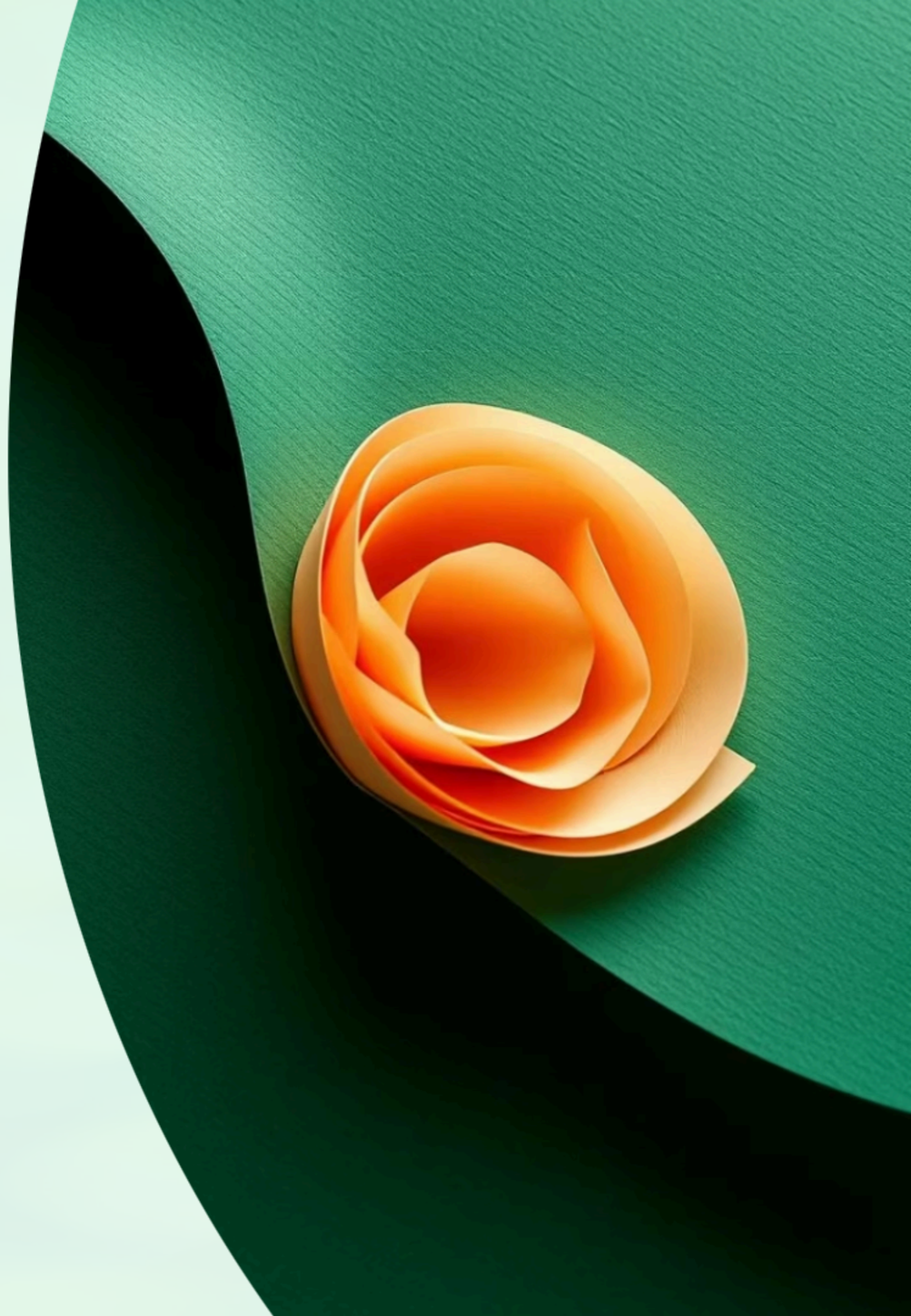


Additives

Surface Properties

Basic Structural Properties of Paper

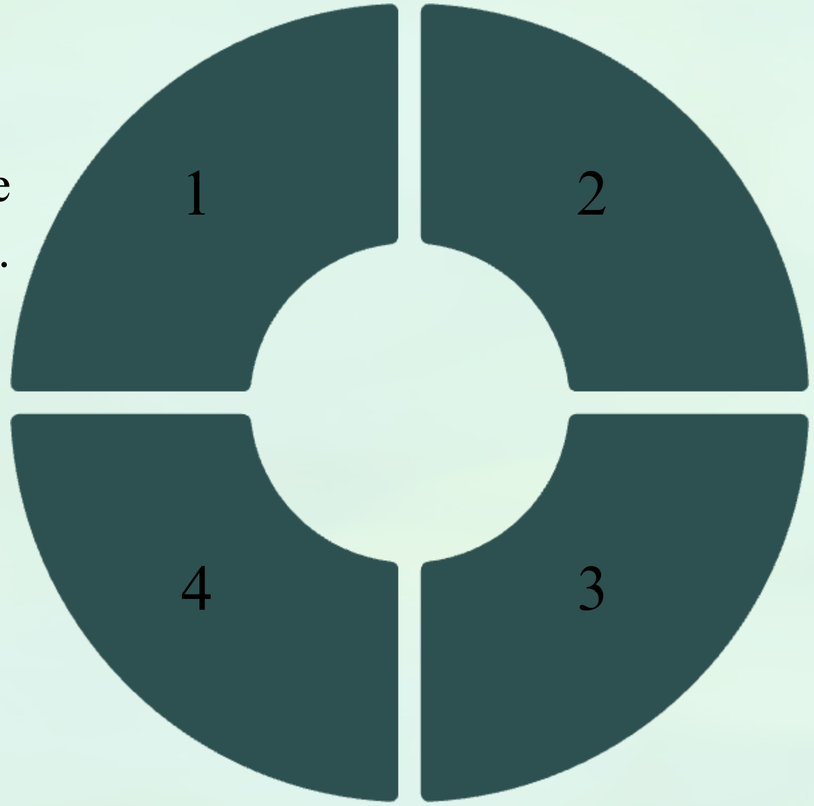
Fiber Bonding	resistance
Porosity	printing quality
Fiber Orientation	and folding behavior
Thickness & Compressibility	ability of paper



Basic Barrier Properties of Paper

Moisture Barrier

Paper absorbs water easily, therefore coatings are done to improve resistance.



Gas Barrier

Untreated paper is highly permeable to gases, therefore it is laminated/coated to enhance protection.

Mechanical Barrier

Papers generally have poor tensile and tear strength. Therefore, heavy papers are used to protect against physical damage

Eg: Corrugated box

Oil & Grease Resistance

Untreated paper readily absorbs oils/grease. Therefore, coatings are done to prevent staining and weakening of the paper structure.

Enhancing Paper Barrier Properties

Laminate Layers

Metallized films boost gas barrier but may affect the process of recyclability.

Surface Coatings

Wax, polymers, and biobased coatings improve moisture and grease resistance.

Eco-friendly Innovations

Development of water-based and biopolymer coatings to reduce environmental impact.

Functions of packaging:

1) **Containment**
2) **Protection**
3) **Convenience** during storage and consumption
4) **Communication** of the relevant information to consumers including its marketing aspects

Plain paper is insufficient because of

- Poor barrier properties
- Low heat sealability

- Thus, it is impregnated with **some additive or laminated with aluminum or plastic** to improve its functional properties.
- Recently, the trend in bio-based coatings has been growing rapidly due to the increasing demand for environmentally friendly and sustainable alternatives to traditional synthetic coatings
- Offers several benefits like **biodegradability, lower toxicity, and reduced carbon footprints.**

Method of Paper Production

Pulping

- Process of separating wood fibres using mechanical, chemical, thermal treatments or any of these in combination.
- Lignin is dissolved to produce individual fibres.

Bleaching

- Bleaching treatment is applied to improve the whiteness of chemical and mechanical pulp using chlorine, chlorine dioxide or hydrogen peroxide.

Beating and Refining

- Involves the mechanical treatment of pulp for its conversion into a sheet on paper machine.
- Beating treatment increase the surface area of the fibres thus increasing their water holding capacity and creating additional bonding opportunities for fibers.
- Refining process is similar to beating process. Used for improving the physical properties of the finished sheet.

Paper Making

- During the paper forming process the fibrous material (containing approximately 99% water) is passed through rollers or wire mesh to remove water and form the paper web.

Final Treatment

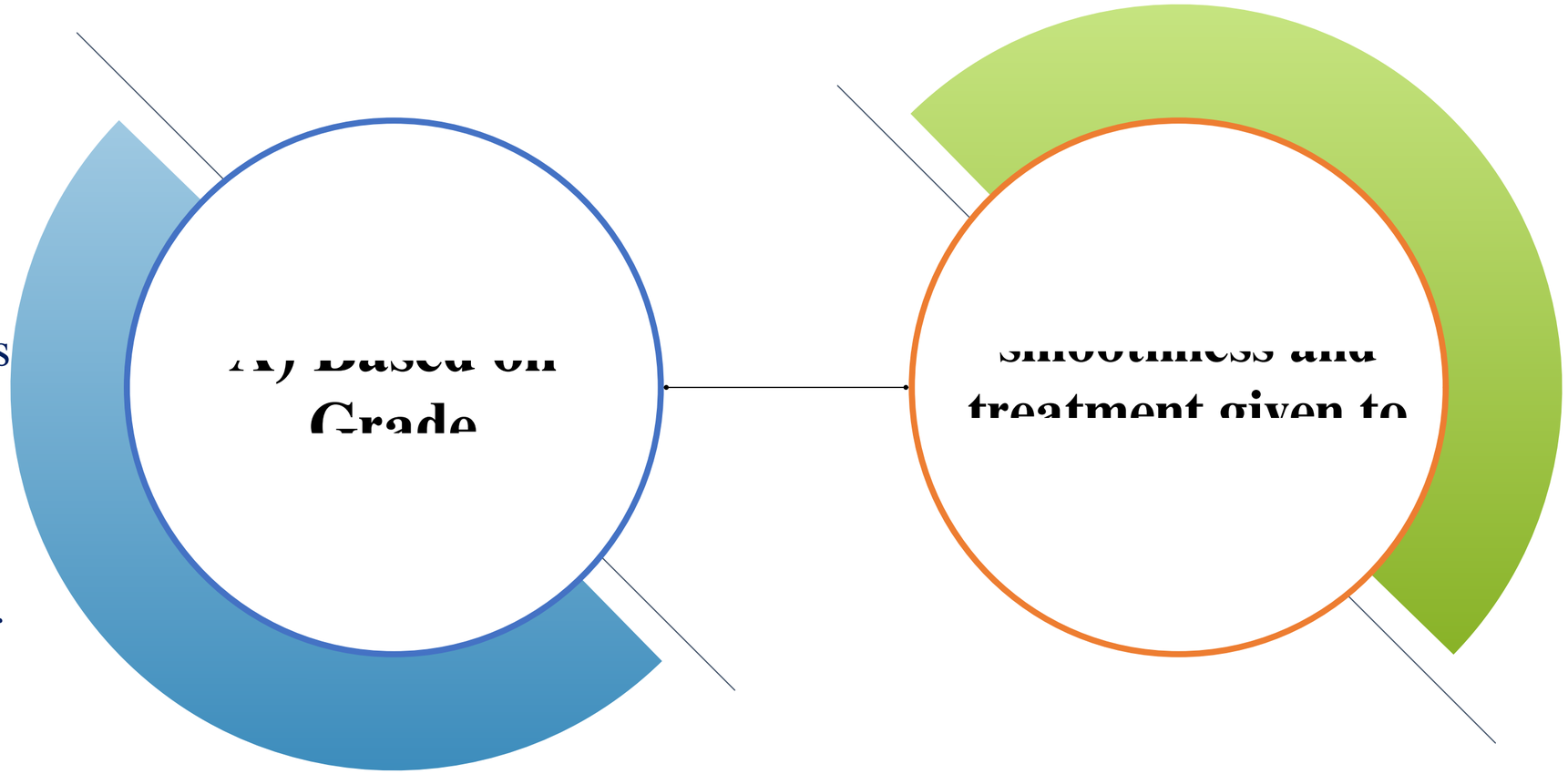
- Final treatments include calendaring, supercalendering, sizing, laminating, impregnating or saturating the developed paper as per the requirement of the industry or the product to be

Chemicals Used in Paper Manufacturing

Category	Key Chemicals	Function	Safety Considerations
Pulping	Sodium sulfide (Na_2S), Calcium hydroxide	Fiber separation	Corrosive - requires PPE
Bleaching	Chlorine dioxide (ClO_2), Hydrogen peroxide	Whitening	Toxic gases - closed systems
Sizing	Rosin, Alkyl ketene dimer (AKD)	Water resistance	Food-grade variants required
Strengthening	Epichlorohydrin, Cationic starch	Wet strength	Potential allergen control

Classification of Paper

- Processed paper from raw wood pulp is called as **virgin paper or virgin grade paper**.
- Recycled paper is the paper obtained after reprocessing of virgin paper, recycled waste or their combination.



- Paper used for printing, labelling, writing, books etc. are made of bleached pulp and called as **fine paper**
- Paper used in packaging of food materials which is made of unbleached pulp is called as **coarse paper**

According to FSSAI, only **virgin grade packaging material** should be used for **direct food contact** (FSSR 2011).

Paper Types for Food Packaging

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Types of Paper

KRAFT PAPER

- Prepared from unbleached pulp
- Known for its strength
- Available in 3 grades
- Grade 1: virgin-kraft
- Grade 2: semi - virgin-kraft
- Grade 3: non - virgin-kraft
- Used in packaging **flour, sugar, and dried fruits.**

KRAFT PAPER

Structural Properties of Kraft paper

Composition

- Kraft paper is made from **long, strong cellulose fibers, typically derived from softwood pulp** through the kraft process.
- This results in a dense, **robust fiber network with high mechanical strength**.

Thickness & Grammage

- Common grammage ranges from **50–90 g/m²** for wrapping and packaging, with specialty food-grade kraft papers available from **30–60 g/m²**.

Tensile Strength

- Kraft paper exhibits superior **tensile strength** compared to other papers, with values around **47–62 MPa** and **tearing strength** up to **100 kN/m.**
- This strength is attributed to its **long, tightly bonded fibers and low porosity**.

Surface Morphology

- The **fibers are well bonded**, with **low porosity and increased sizing content, enhancing both strength and surface integrity.**
- The surface roughness and friction increase after aging, but the paper remains tough and tear-resistant

Color

- Available in natural brown or bleached white, depending on the intended application

Barrier Properties of Kraft paper

Moisture Resistance

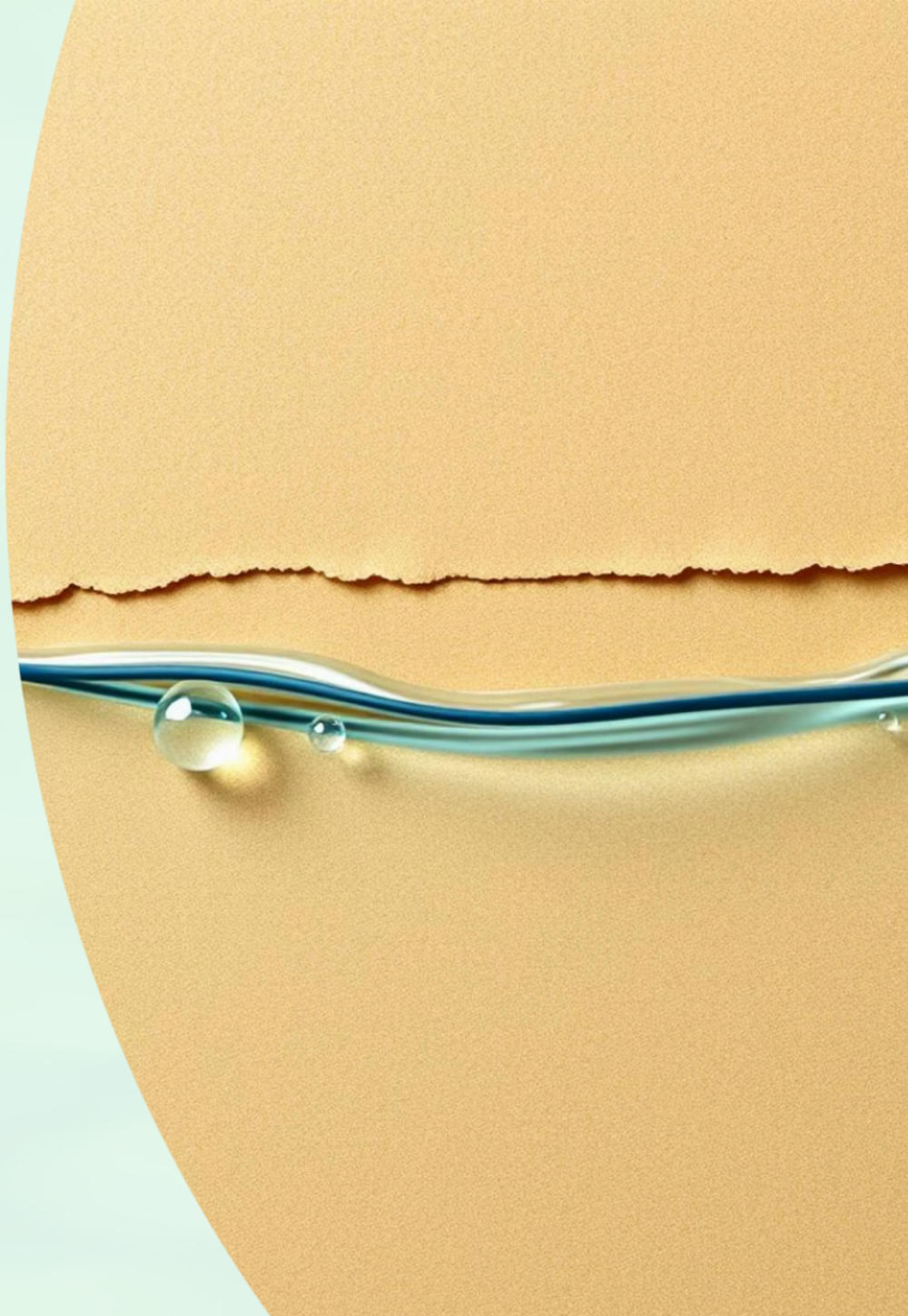
- Standard kraft paper has **moderate moisture resistance** due to its dense fiber structure and sizing agents. However, it is **not inherently waterproof**.
- Food-grade variants may be further treated or laminated with **wax, polyethylene, or biopolymer coatings** to improve barrier properties against water vapor, grease, and oil

Grease Resistance

- **Greaseproof and parchment kraft papers** are specially processed to enhance resistance to oils and fats, making them suitable for direct food contact.

Breathability

- Kraft paper maintains some breathability, which can be advantageous for packaging certain foods that require air exchange.



Application in food industry

Bakery and Confectionery

Used for secondary packing of bread, cake, and muffin liners

Fast Food and Takeaway

Secondary packing of fried chicken rolls, roast food packaging, sandwich wraps, and food bags

Dry Goods Packaging

Suitable for flour, sugar, dried fruits, and other dry food products due to its strength and breathability

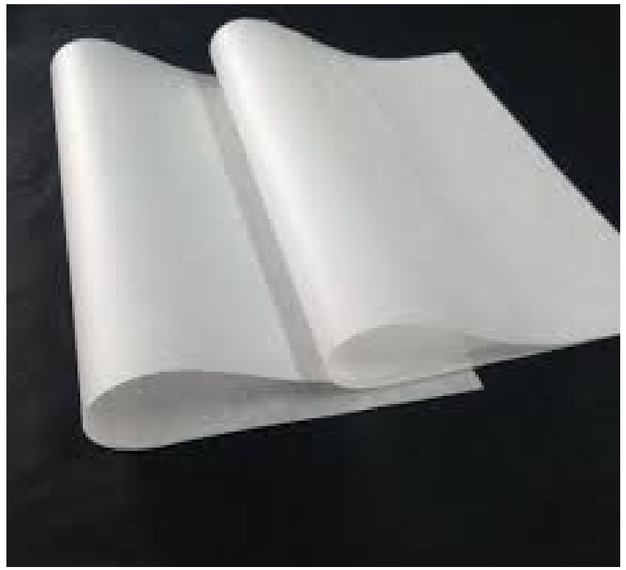
Greaseproof Variants

If the kraft paper is made grease resistant then it can be employed for packaging foods with higher oil or fat content, such as pastries and cheeses

Types of Paper

BLEACHED PAPER

BLEACHED PAPER



- Bleaching reduces the strength of paper making it soft, expensive, and white
- Used when the focus is on appearance rather than its strength. The eco-friendly approach had been developed- the use of **ligninolytic enzymes including xylanase, laccase, and manganese peroxidase**
- Used in **sugar, fruits and vegetables**.

Structural Properties of Bleached Paper

Composition

Bleached paper is typically made from virgin pulp that has undergone **chemical bleaching**, resulting in a brilliant white appearance and high purity

Strength

The bleaching process, combined with the use of strong cellulose fibers, gives **bleached kraft paper** excellent tensile strength, durability, and rigidity-often stronger than traditional brown kraft paper

Surface Quality

It offers a **smooth, uniform surface that enhances printability** and is suitable for high-quality graphics and branding

Caliper & Grammage

Available in a wide range of thicknesses, commonly from **30 to 150 gsm** for food applications, with caliper ranging from **0.5 to 4.7 mil**

Finishes

Offered in **machine glazed** (MG), **machine finished** (MF), and **smooth finished** (SF) grades, providing options for gloss, smoothness, and runnability

Barrier Properties of Bleached Paper

Moisture Resistance

- Standard bleached paper has **moderate moisture resistance**. For food applications, it is often coated (e.g., with **polyethylene, wax, or biopolymers**) to improve its barrier to water vapor and grease

Grease Resistance

- Specially treated or coated variants provide excellent resistance to oils and fats, suitable for packaging greasy foods

Breathability

- Maintains some breathability, which can be beneficial for packaging dry foods

Applications in food Industry

Bakery & Confectionery

Used for wrapping bread, cakes, and pastries, as well as for muffin and cupcake liners

Dry Goods Packaging

Ideal for flour, sugar, grains, and other dry food products due to its strength and purity

Fast Food & Takeaway

Employed for sandwich wraps, burger wraps, and food service bags, especially where a white, clean appearance is desired

Greaseproof & Butter Paper

Coated or treated bleached paper is used for butter, cheese, and other fatty foods, offering grease resistance and food safety

Types of Paper

TISSUE PAPER

- Food-grade tissue paper is mainly used as **bakery product liner**, **sandwich wrap**, and **box liner**.
- The tissues are widely used for **tea and coffee bags** which is used for their porosity, light weight, and long fibers

TISSUE PAPER

Structural Properties of Tissue paper

Composition

Tissue paper is a lightweight, soft paper made primarily from wood pulp, either virgin or recycled

Basis Weight

Food-grade tissue paper typically **does not exceed 25 g/m²**, making it extremely thin and flexible

Absorbency

High absorbency is a hallmark of tissue paper, allowing it to soak up moisture, oil, or grease efficiently

Surface Texture

It is delicate, slightly translucent, and can be creped (wrinkled) for added softness and flexibility

Strength

While tissue paper is not as strong as kraft or bleached paper, it is engineered for adequate wet strength, especially in food-grade variants

Applications

Wrapping

Used for wrapping sandwiches, burgers, bakery items, and fried foods to absorb excess oil and maintain hygiene.

Napkins/Placemats

Functions as disposable napkins or placemats in food service settings.

Decorative Uses

Adds visual appeal to food presentations, especially in gourmet packaging

Lining

Serves as liners for trays, baskets, and boxes to keep food clean and presentable.

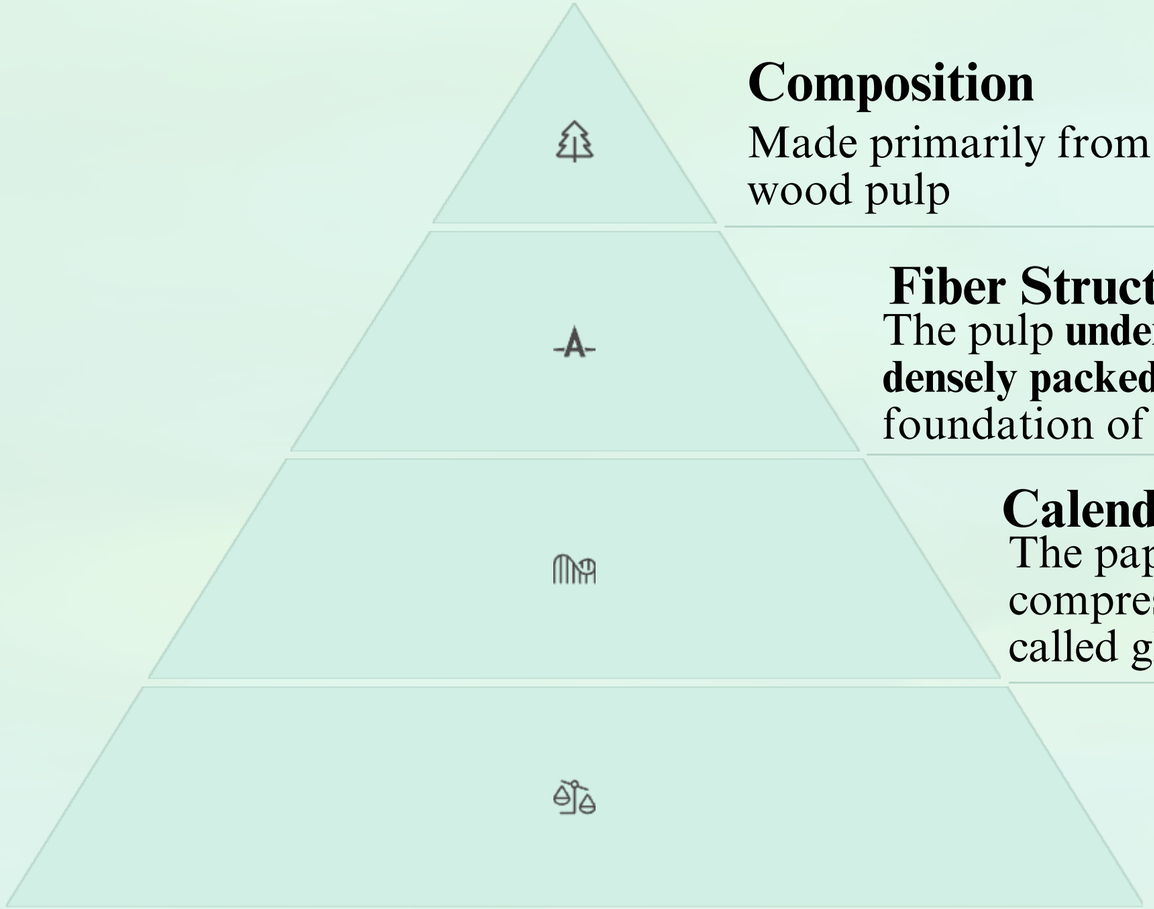
Types of Paper

GREASEPROOF PAPER

GREASEPROOF PAPER

- Greaseproof paper is translucent and hydrated to give oil and grease resistance.
- Used **for packing butter and other fat-containing food products.**
- Greaseproof paper can also find its application as an inner liner of the microwave double bag food container with an outer layer comprising of paper and an integral microwaveable heating element.

Structural Properties of greaseproof paper



Composition

Made primarily from refined cellulose fibers sourced from wood pulp

Fiber Structure

The pulp **undergoes intensive refining**, producing **very fine fibers** that are **densely packed**. This **creates a tight, low-porosity structure**, which is the foundation of the paper's grease resistance.

Calendering

The paper is calendered-passed through high-pressure rollers-to further compress the fibers, resulting in a smooth, glossy, and dense sheet (often called glassine).

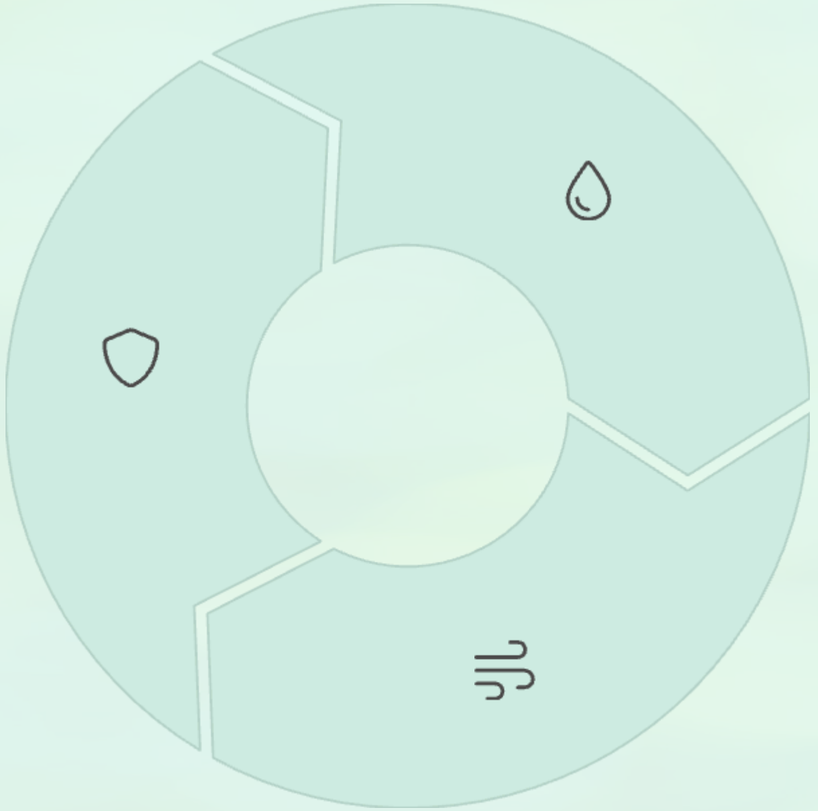
Density & Thickness

Typically **ranges from 30 to 52 g/m²**, making it lightweight but mechanically strong

Barrier Properties of greaseproof paper

Grease Resistance

- The dense, non-porous structure prevents grease and oil from penetrating the paper, making it ideal for wrapping oily or fatty foods.
- This property is often enhanced by surface treatments with **food-safe agents like starches, alginates, or carboxymethyl** cellulose (CMC), which fill any remaining pores and further repel fats.



Moisture Resistance

- While not fully waterproof, greaseproof paper offers **moderate resistance to moisture**, helping maintain food texture and freshness during storage and delivery.

Breathability

- Despite its barrier properties, it retains **slight breathability**, which can help prevent sogginess in foods

Applications in food industry

Wrapping
Used for sandwiches, burgers, pastries, and greasy bakery items to prevent oil transfer and maintain presentation.

Lining
Common as basket or tray liners in fast food, takeout, and delivery to keep packaging clean and food appetizing.

Baking
Sometimes used as a non-stick surface for certain baking tasks (not suitable for high-temperature baking).

Dairy & Cheese
Ideal for wrapping cheese and butter due to its resistance to fat and oil migration

Types of Paper

VEGETABLE PARCHMENT PAPER

- Vegetable parchment paper is extensively used as a layer between **slices of pastry or meat** because its grease resistance and wet strength properties make it easily removable from food contact surfaces.
- **Labels and inserts for products with high oil** or **grease** content are often made from parchment paper.
- **High fat-containing cheeses** coated with food-grade mold inhibitors can also be wrapped with vegetable parchment paper.

VEGETABLE PARCHMENT PAPER

Structural Properties of Vegetable Parchment Paper

Composition

- Made from highly refined, chlorine-free plant fibers (usually wood pulp), vegetable parchment paper is produced by **passing the base paper through a bath of sulfuric acid**.
- This process **partially gels the cellulose fibers**, creating a dense, uniform, and translucent sheet that mimics traditional animal-based parchment.

Surface Quality

- The **acid treatment** results in a **smooth, glassine-like surface** with high uniformity and low porosity, giving the paper a semi-transparent appearance and excellent release properties.

Density & Thickness

Typically ranges from **40 to 100 g/m², with 45 g/m²** being common for food wrapping applications.

Strength

The parchmentizing process imparts high wet strength and stability, allowing the paper to maintain its integrity even when exposed to moisture or heat

Barrier Properties of Vegetable Parchment Paper

Water and Oil Resistance

Vegetable parchment paper is **inherently waterproof** and highly resistant to fats and oils, making it ideal for wrapping greasy or moist foods. Its oil resistance can reach high KIT values (up to 12 or above), and it does not allow oil or water to penetrate easily.

Heat Resistance

It can withstand high temperatures, making it suitable for baking, oven, and microwave use without melting or releasing harmful substances.

Breathability

Despite its barrier properties, it **retains a degree of breathability**, which helps **maintain food humidity and prevents over-drying** during cooking.

Odorless

Remains odorless even when wetted for a long time, preserving food aroma and taste

Applications of Vegetable Parchment Paper

Bakery & Confectionery
Widely used for baking cookies, cakes, pastries, and bread due to its non-stick, heat-resistant, and greaseproof properties.

Butter, Cheese, and Margarine Wrapping
Ideal for packaging fatty foods, as it prevents oil migration and maintains product freshness.

Meat and Ham Packaging
Used for wrapping processed meats, providing a barrier against grease and moisture.

Food Wrapping & Separators
Suitable for wrapping fried foods, separating food layers, and as liners in food trays and boxes.

Freezer and Oven Use
Can be used for freezing and baking, maintaining integrity and non-stick performance at both low and high temperatures

Types of Paper

WAXED PAPER

WAXED PAPER

- The wax layer not only acts as an adhesive but also provides heat sealability.
- Wet-waxed, dry-waxed, and wax-laminated are the different grades based on the thickness of the wax coating.
- **Bread, biscuits, dairy products** (UHT milk and cream), **sandwiches, cakes**, sunflower oil, and breakfast cereals are most commonly packed using waxed paper.
- Waxed paper containers are extensively used for the **distribution and consumption of fruit juices and milk.**

Structural Properties of Waxed Paper

Base Material

Cellulose-based paper from virgin or recycled wood pulp

Coating Thickness

Wax layer constitutes **10–25% of paper's weight** (5–10 μm)

Surface Texture

Smooth, slightly glossy, and non-stick surface

Strength

Increased tensile strength and elastic modulus

Waxed paper is made from cellulose-based paper, often from virgin or recycled wood pulp, coated with a thin layer of wax-commonly **paraffin, beeswax, soy wax, or other food-safe waxes**.

The **wax coating increases** the **tensile strength** and **elastic modulus** of the paper, while decreasing its elongation at break, resulting in a more durable and less stretchable material

Barrier Properties of Waxed Paper

Moisture Resistance

- The wax layer forms a waterproof barrier, making waxed paper highly resistant to water vapor and moisture ingress

Non-stick Properties

- The waxed surface prevents food from sticking, making it ideal for wrapping sticky or greasy foods

Grease Resistance

- Waxed paper is excellent at repelling fats and oils, preventing grease from penetrating and keeping food fresh and packaging clean

Breathability

- While the wax layer blocks moisture and oils, it allows some breathability, preventing sogginess in wrapped foods

Applications

Wrapping

Used to wrap sandwiches, burgers, deli meats, cheeses, pies, and baked goods, preventing sticking and grease transfer.

Lining

Common as a liner for food baskets, trays, and boxes, especially for fried or oily foods.

Storage

Used for wrapping cookies, candies, and other confections to maintain freshness and prevent moisture loss.

Microwave Use

Can be used to cover food in the microwave to prevent splatters

Summary

Paper Selection Criteria

Choose packaging paper based on food type, barrier requirements, and intended use. Consider moisture, grease, and heat resistance needs.

Regulatory Compliance

Ensure selected papers meet local food safety standards and migration limits for direct food contact applications.

Sustainability Factors

Balance performance requirements with environmental considerations like recyclability, compostability, and biodegradability.

Paper Type	Key Properties & Structure	Barrier Properties	Typical Uses	Advantages	Limitations
Kraft Paper	Strong, coarse, brown (can be bleached); made from chemical pulp (kraft process)	Moderate moisture resistance	Packaging, bags, wrapping, food trays	High strength, eco-friendly, versatile	Not greaseproof or non-stick
Bleached Paper	Refer to highly bleached/washed paper for purity	Varies (depends on treatment)	Specialty packaging, medical, or filter uses	Purity, tailored properties	Not a common food packaging paper
Greaseproof Paper	Dense, hydrated cellulose, translucent; surface treated to close pores	Grease, oil, and moderate water resistance	Wrapping greasy foods, baking, pan liners	Grease/oil resistance, compostable, recyclable	Not heat-sealable, moderate wet strength
Vegetable Parchment Paper	Chemical pulp treated with sulfuric acid; dense, strong, uniform, oil-resistant	Grease, oil, high wet strength	Baking, separating pastries, wrapping cheeses	Non-stick, high wet strength, oil resistant	Not heat-sealable, poor gas barrier unless coated
Tissue Paper	Thin, soft, absorbent; made from lightweight pulp	Low (highly absorbent)	Wrapping, interleaving, hygiene, crafts	Soft, biodegradable	Not moisture/grease resistant, fragile
Waxed Paper	Any base paper coated with paraffin/soy wax; smooth, glossy	Moisture, grease, oil resistant	Wrapping fatty foods, lining trays, bakery items	Non-stick, moisture/grease barrier, flexible	Not heat-resistant, wax melts in oven

Conclusion & Future Outlook

Understand Paper Structure

Optimize fiber networks and paper microstructure for strength

Improve Barriers

Use coatings and laminates to enhance moisture and gas resistance

Focus on Sustainability

Develop eco-friendly treatments balancing performance and recyclability.

Innovations will expand paper’s role as a versatile, green packaging solution