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A Review of Natural Fibre Composites for Automotive Interior Applications

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Abstract: *The auto industry uses natural fibers for interior panels to reduce carbon emissions, promote sustainability, and increase fuel economy. Global environmental issue: inside panel composite disposal. Unsustainable disposal of synthetic fiber and plastic interior panels is common. Panel removal frequently entails air-polluting burning. Natural fiber composites' automotive performance is examined here. This study examines natural fibers' mechanical qualities, endurance, moisture absorption, insect assaults, and fiber failure prevention. Natural fiber composites are biodegradable and simple to dispose of, making them promise for automobile use. Synthetic composites cost more than natural ones. Unfortunately, natural fibers absorb moisture and attract termites and fungi. To meet criteria, natural fibers need further study on bacterial resistance, moisture absorption, and durability.*

Keywords: Natural Fibre Composites, Automotive Interior Panels

I. INTRODUCTION

Automotive sector affects global economy. The world produces 80 million cars [1]. This number rises annually. Europa manufactures 50 million cars yearly, 30% of the world's [2], [3]. Removing used automobile components may be difficult. The inner panels may be hard to recycle. Car components are discarded globally at around 10 million tons [2]. Interior panels generate 20 kg of waste every vehicle [4].

Buyers prioritize automobile interior style and functionality. It evokes emotions, identifies brands, and provides security, comfort, and utility [5]. Internal panels usually burn [6]. Inner panel disposal pollutes air. Renewable interior panels. Sustainability extends beyond recycled and bio-composite [7]. Plastics and composites replace wood and metal interior panels for cost, safety, and aesthetics [8]. Polymer composite automobile interior panels improve toughness, corrosion resistance, durability, and design flexibility.

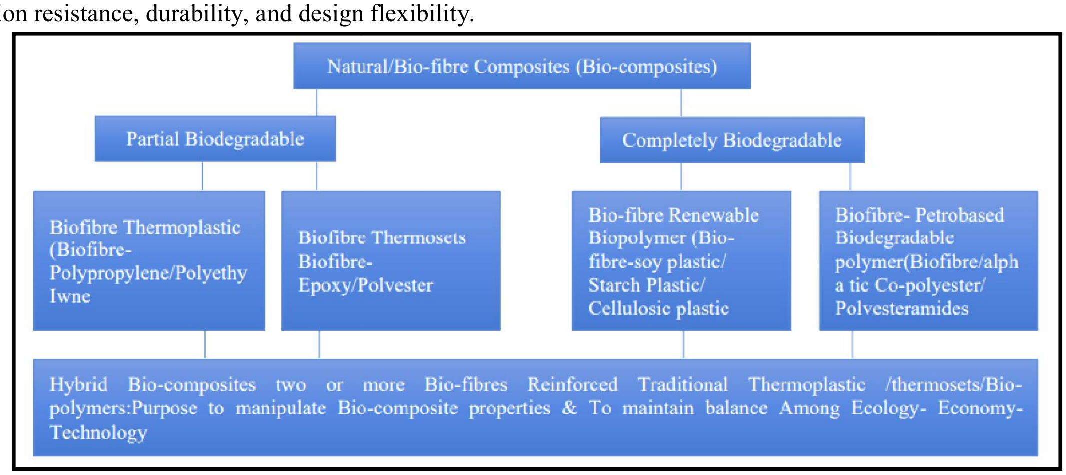

Fig. 1 Natural fibre biodegradable classification [17]

Composite materials are strong, lightweight, and affordable [9]. Incinerating automobile interior panels releases mercury, dioxins, and polychlorinated biphenyls yet is recommended [6]. Burning PVC releases toxic halogens and causes global warming [10]. Burning these plastic components pollutes the air and damages humans, animals, and the ecosystem [11–13]. Synthetic-free auto interior composites reduce pollutants and improve sustainability [14]. Autonomous driving, lightweight automobiles, fewer emissions, connectivity, and mobility services have transformed the auto business. Car suppliers must change their materials owing to these concerns. [14], [15].

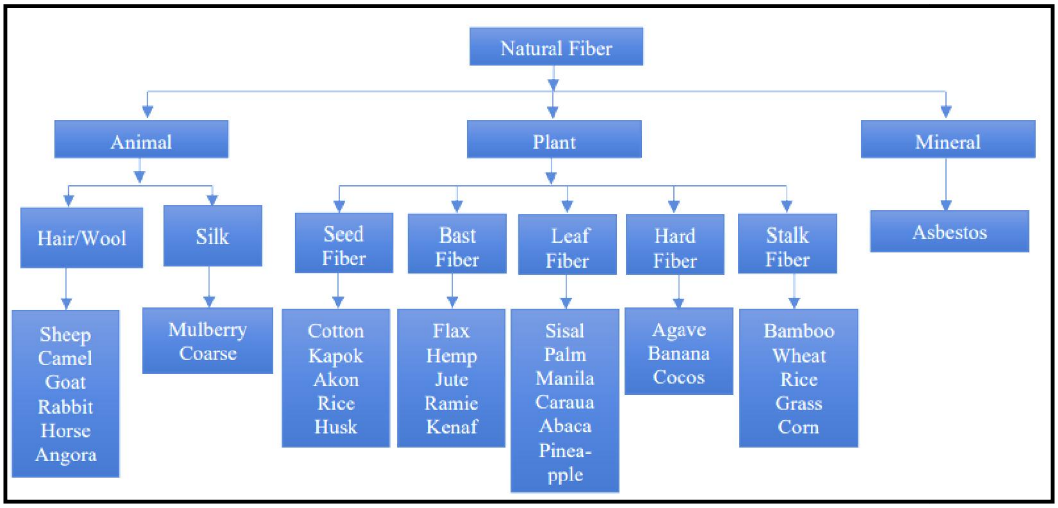

Fig. 2 Natural fibres classification [24]

Automakers are developing bio-composite interior panels because to their mechanical strength and lightweight [4]. Manufacturing technology has advanced thanks to hybrid bio-composites, which blend biological and petrochemical elements.

Research is focused on eco-friendly bio-composites made of plant fibers and agricultural polymers due to their low carbon footprint[16]. Evidence suggests biodegradable materials might be used in automobile interiors. Figure 1 depicts bio-composites' wide categorization. Reusing disposable plastics for composite mixing reduces the need for virgin petroleum-based resources [16].

The compatibility of waste and recycled resources with other composite materials for improved mechanical performance and interface presents significant scientific hurdles. Research has shifted to natural fiber bio-composites due to the difficulties of recovering petroleum-based components.[16]

Natural Fibres

Natural fibers are affordable, sustainable, and ecologically benign, making them ideal for composite reinforcement in polymeric matrices. Natural fibers are used in construction, automobile, and soil conservation. Naturally occurring fibers are the major source of cellulose. [18]. Mechanical and electrical characteristics of natural fiber composites are verified [19]. Natural fibers are also thermally and acoustically insulated and crack-resistant [19].

Table 1. Mechanical properties of natural fibres

Fibres	Tensile strength (MPa)	Young's Modulus (GPa)	Elongation at break (%)	Density (g/cm3)
Abaca	400	12.00	3.00-10.00	1.50
Bagasse	350	22.00	5.80	0.89
Bamboo	290	17.00	-	1.25
Banana	529-914	27.00-32.00	5.90	1.35
Coir	220	6.00	15-25	1.25
Cotton	400	12.00	3.00-10.00	1.51
Curaua	500-1150	11.80	3.70-4.30	1.40
Flax	800-1500	60.00-80.00	1.20-1.60	1.40
Hemp	550-900	70.00	1.60	1.48

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Jute	410-780	26.50	1.90	1.48
Kenaf	930	53.00	1.60	-
Pineapple	413-1627	60.00-82.00	14.50	1.44
Ramie	500	44.00	2.00	1.50
Sisal	610-720	9.00-24.00	2.00-3.00	1.34
E-glass	2400	73.00	3.00	2.55
S glass	4580	85.00	4.60	2.50
Aramid	300	124.00	2.50	1.40
Hs Carbon	2550	200.00	1.30	1.82
Carbon (std PAN-based)	4000	230.00-240.00	1.40-1.80	1.40

Natural fiber manufacture consumes 17% less energy than glass. [20]–[22]. Animal, plant, and mineral fibers exist. Seed, bast, leaf, stalk, cane, grass, and reed fibers are vegetables. Wool and silk are animal fibers. Finally, asbestos and fibrous brucite are mineral fibers. These biodegradable, eco-friendly fibers reinforce composites better than synthetic fibers and may be used for numerous purposes. Electric resistance, thermal conductivity, and acoustic insulation of plant-based composites are unknown [23]. Plant, mineral, and animal fibers are shown in Figure 2. Renewable fiber production consumes less energy. CO_2 use releases oxygen. Its simplicity and low cost make it popular. Biodegradation removes natural fibers from the environment. Incineration may generate energy [25]. Synthetic vs. natural fiber tensile values [23].

Benefits of Natural Fibres in Automotive Industry

Interior panel composites made with natural fibers are 10% lighter than typical materials [26]. This weight decrease may boost fuel economy by 7%. A vehicle that loses 1 kilogram of weight saves 20 kg of carbon dioxide [26].

Short-coming of Natural Fibres in the Automobile Industry

Automotive natural fibre composites have moisture absorption, durability, mechanical strength, and fibre-matrix interfacial adhesion concerns. [27]. Furthermore, bio-composites deteriorate in nature. Modes of environmental degradation are in Table 2. These include mechanical, water, weather, biological, and fire damage. Bio-composite degrades by organisms. First, organisms digest hemicelluloses by hydrolysis. [30]. Poor fibre-matrix interaction weakens bio-composites. Enzymes reduce and oxidize during biodegradation. It may be chemically removed from fibers. [31]. Water degradation is another bio-composites issue. Natural hydrophilic fibers absorb water. Vacuum and non-crystalline natural fibers absorb water. [30].

Table 2. Degradation of mechanical properties [28], [29]

Environmental Attack	**Means of degradation**
Biological degradation	Hydrolysis, reduction, and oxidation
Mechanical degradation	Stress, fracture, abrasion, stress
Water degradation	Swelling, freezing, shrinking, and cracking
UV degradation	Impact resistance, Mechanical integrity, Ductility, Tensile strength
Thermal degradation	Hydrolysis, oxidation, and dehydration

Bio-composites exposed to water and moisture sometimes have wetter and drier patches, causing differential swelling and cracking [30]. Bio-composites absorb water, weakening their interfacial binding and mechanical strength [32].

Moisture Regain of Natural Fibres

Lignocellulosic and hydrophilic fibers absorb water. Macromolecules may create hydrogen bonds in fiber cell walls. Natural fibers' hydroxyl groups form hydrogen bonds with water. Table 3 shows natural fiber moisture recovery.

Wicking moves moisture through fabric. Wet fiber swelling reduces matrix interface bonding. This produces matrix cracking, composite dimensional instability, and poor mechanical characteristics. [21]. Natural fibers must be treated to prevent moisture absorption. Chemicals may remove hydrophilic hydroxyl groups from natural fabrics, lowering moisture absorption. [22]. Couplers and chemicals may limit moisture recovery [37].

Chemical Treatment of Natural Fibres

Natural fiber cellulose molecular structure is frequently modified with NaOH [38]. Amorphous fibers result from NaOH treatment, which reverses the firmly packed crystalline cellulose structure [38]. Helps chemical penetration.

The amorphous zone gaps created by cellulose macromolecule separation are filled by water. Dismantling alkali-sensitive hydroxyl (OH) groups lets water molecules react and leave the fibre structure. Between cellulose chains, reactive molecules form fibre-cell-O-Na [38]. Thus, hydrophilic hydroxyl groups decrease, enhancing fiber moisture resistance. Also removed: hemicelluloses, lignin, pectin, wax, and oil-covering substances [39]. A clean fiber surface.

Thus, microvoid removal uniformizes fibre surfaces, facilitating cell stress transfer. This treatment decreases fiber diameter and boosts aspect ratio. Increased fiber surface area improves matrix adhesion [40]. This method enhances composite mechanical and thermal characteristics. Alkali concentrations beyond the optimal threshold may delignify, weaken, or damage fibers [41]. Treated fibres have less lignin, wax and oil cover components are reduced, and crystalline cellulose order is disrupted. Table 4 shows the latest mechanical and thermal alkali treatment findings.

Table 3. Moisture regain of natural fibres [33]–[35][36]

Natural fibres	Moisture absorption (%)
Abaca	5.0 - 10.0
Bamboo	11.7
Banana	2.0 - 3.0
Coir	0.2 - 10.0
Cotton	7.5 - 20.0
Flax	7.0 - 12.0
Hemp	6.0 - 12.0
Jute	10.0 - 13.0
Ramie	7.5 - 17.0
Sisal	10.0 - 22.0

Table 4. Chemical treatment of natural fibres

Fibres matrix composites	Applied treatment methods	Results mechanical and thermal properties	Reference
Flax-epoxy	Alkali treatment	Pectin removal results in a 30% improvement in tensile strength and modulus.	[39]
Sisal-polyester	0,5,1,2,4,10% NaOH treatment a room temperature	Maximum tensile strength properties were reported after 4% alkali treatment.	[39]
Hemp non-woven mat with euphorbia resin	0,16% NaOH for 48 h.	Tensile strength was increased by 30% and doubled the shear strength properties.	[42]
Jute-vinyl ester	5 % NaOH for 4,6 and 8h	4h alkaline treated composite accounted 20% and 19% increase in flexural strength and interlaminar shear strength properties.	[43]

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Sisal-polycaprolactone composite	10% NaOH for 1,3,24 and 48h	Increased elastic modulus with the increased reaction time.	[43]
Hemp fibre	8% NaOH treatment	There was a 4% increase in thermal stability.	[38]
Coir-polyester	5% NaOH treatment for 72 h	Flexural and impact strength was increased by 40%.	[44]

Table 5. Application of natural fibres in the automotive industry [49], [50]

Company	Model	Natural fibre	Matrix /Resin	Application
Audi	A2, A3, A4, A6, A8, Roadster, Couple, Q7	Wood Fiber, Flax, Sisal	PP, Epoxy, PUR	Seat backs, side and back door panels, boot lining, hat rack, spare tire lining.
BMW	3,5 and 7 series	Kenaf, flax, hemp, wood fibre	PP	Door trim panels, Headliner panel, boot lining, seat backs, noise insulation panels, dashboard.
Citroen	C5	Wood Fiber, flax	Epoxy	Interior door panelling
Fiat	Punto, Brawa, Marca, alfa ROMEO,146,156	Flax, sisal, hemp, cotton, coconut fibres	PP	Door cladding, seatback linings and floor panels, seat bottoms, back cushions and head restraints.
Diamler Chrysler	Sebring	Flax, sisal, Abaca	PP	Door panel, seat cushion, head restraint.
Ford motors	Ford Flex, Ford Focus BEV	Wood fibre, wheat straw, coconut fibre	PP, PUR	Interior panel bin, load floor, Foam seating, headrests, headliners.
General Motors	Cadillac Deville, Chevrolet Impala, GMC Envoy, Trailblazer, Terrian, Opel Vetra	Wood, kenaf, Flax, Cotton	PP Polyester	Seatbacks, trim, rear shelf, Cargo floor, Door panels, Package trays, Acoustic insulator, Ceiling linear.
Honda	Pilot	Wood fibre	N/a	Floor area parts
Land rover		2000, others	Kenaf	Insulation, Rear storage shelf/door panel, seat backs.
Lotus	Eco elise	Hemp	Polyester	Body panels, Spoiler seats, interior carpets.
Mazda	5 hydrogens RE hybrid	Corn	PLA	Console, Seat fabric
Mercedes Benz	A class, C class, E class, M class, R class, S class	Abaca/banana, Hemp, Flax, sisal, Jute	PUR, PP, Epoxy	Door panels, seat cushions, head restraints, underbody panels, seat backs, spare tire covers, Engine and transmission cover.
Mitsubishi	Concept car	Bamboo	PBS	Interior components
Peugeot	406	Hemp, Flax	PP, PUR	Seat backs, parcel shelf
Renault	Clio, Twingo	Jute, Coir	PP, PUR	Rear parcel shelf

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SAAB	9 s	Flax	PP	Spare wheel, Door panels
Toyota	Lexus CT 200h, Prius, Raum	Kenaf, Bamboo, Corn, Starch	PET, Sarona, EP	Luggage compartment, speaker, floor mats, instrument panel, air conditioning vent, spare tire cover, shelves.
Volkswagen	Golf, Passat, Bora flux, Touareg	Flax	PP	Door panel, seat back, boot lid finish panel, boot liner.
Volvo	C70, V70	Flax	Polyester	Seat padding, Natural form

Application of Natural Fibres in the Automotive Industry

Natural fibers in automobile composites are being studied [45, 46]. Energy-efficient natural fibers outperform synthetic [47]. Natural fibers reduce health concerns, absorb impact, and perform better. Natural fibers have replaced synthetics in 1.5 million US autos since 2005. Germany utilized 160,000 tons of natural fibers for vehicle composites [48].

Table 5 shows automakers employ natural fibers for interior panels. Battery trays, brake shoes, spare tire covers, cowl screens, tank shields, air cleaning housing, trim pieces, and splash shields are new exterior applications. Biocomposites might reduce vehicle weight by 25%, saving 250 million barrels of oil. Carbon dioxide emissions may decrease with weight loss. Toyota will employ natural fiber interior composites instead of plastic [51, 52].

This company trims doors using kenaf and polypropylene [53]. Seat backs were 65% kenaf, 35% polypropylene. Its mechanical strength was lower than synthetic fiber composites. Durable for automobile door trims. It was cheaper to produce [54]. For ceiling liners and acoustic insulation, GM employs cotton and kenaf. Flax reinforces Chevrolet Impala rear shelf polypropylene. Flax-kenaf Saturn L300 door panels and trays. Wooden Cadillac DTS seat backs and Chevrolet Trailblazer and GMC Envoy cargo flooring [21]. Soy and bio-based polymers made Ford seat cushions and backs recyclable. Ford Electrical flooring is coconut fiber and polypropylene (Bajwa & Bhattacharjee, 2016). Coconut shell composite guides are on Ford F-250 pickups. Natural fibers saved North American automakers $4.5 million. To improve sustainability, F-150 electric stiffness replaced talc in 2014 with rice husks [55]. NEW: recycled cotton fiber carpet insulation, soybean oil seat cushions, and recycled tires underbody shields.Volvo uses more natural fiber composites. Volvo-molded polyester load trays. Volvo used flax load floor mat composites [56]. Volvo chairs use soy-based, natural-fiber foam. About 85% of Volvo interior components are recyclable [49]. Mazda makes seat coverings and interior panels using polylactic acid and kenaf.

II. CONCLUSION

Due to their sustainability and environmental benefits, automobiles will use more natural fibers. Synthetic fibers with better mechanical properties. However, car synthetic fiber disposal and manufacture hurt the environment. Natural fibers are cheap and biodegradable, unlike synthetics. Failure results from excessive moisture absorption, endurance, termite, and fungal attacks. Solar UV radiation weakens mechanical properties. Impregnating natural fibers with an alkaline fungus and termite barrier may solve these problems. While keeping mechanical properties, bio-composite interior panels may absorb moisture better than degraded ones. Bio-composite's advantages will keep it popular. Researchers exploring automotive biocomposites should develop mechanical, chemical, and biological treatments to improve durability and fibre–matrix bond strength. Natural fibers might save automakers money and create employment. Natural fibers are abundant and might enhance Africa's economy.

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