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Automotive Applications of Animal and Plant Fiber Based Thermoplastic Composite: A Review

AbduljeleelKehinde Issa[1*], Abdu Salihi[2], Abubakar Baba Aliyu[3]
[1]Department of Mechanical Engineering, Federal Polytechnic, Mubi. Adamawa State, Nigeria
[2&3] Department of Mechanical Engineering, Bayero University Kano, Nigeria
Postal address:P.M.B 35 Mechanical Engineering Department, Federal Polytechnic, Mubi. Adamawa state.

ABSTRACT: *One of the most fast-growing industries is the Automotive Industry. This industry is always challenged with innovation of automotive materials that will best suit some important fundamental requirements. The most important requirements considered in automotive materials are light weight, cost, safety crashworthiness, corrosion resistance, recyclability and life cycle consideration. Steel or various metal alloys have been the traditional materials used in the production of automotive components because of its strength and reliability but it is prone to corrosion and has higher noise vibration harshness and damping, higher tooling and assembly cost, and most importantly, considerable weight. This did not stop the application of steel but it prompted researchers to find its replacements in some part of the automobile in order to satisfy the first fundamental requirements of automotive material that is light weight. This work discuses major reasons for reducing automotive weight, the techniques employed and major properties' requirements of automotive materials. Likewise, itspells out the type of composite materials and fiber length used in automotive industry. Furthermore, ithighlights the achievement made by natural fiber most especially plant fiber thermoplastic composites in the automotive industry. Lastly, it recommends the need to use more animal fiber specifically horn fibers to reinforce thermoplastic composite for automotive parts due to their inherent and potential mechanical and chemical properties possessed.*

Keywords: *automotive, density, fiber, natural, thermoplastic.*

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I. INTRODUCTION

Plastic materials have been discovered for long and have been used in automotive industries but insufficiently worked out technology limited its application to automotive decorative parts due to inability to incorporate fibre well into the plastic. Of recent, the high need to replace conventionally used metal and its alloys with polymer composites (thermosets or thermoplastics), has arisen due to the legal regulations established by the Corporate Average Fuel Economy (CAFE) – regulations in the United States, endorsed by the U.S. Congress in 1975 and mandated in July 2011 by the U.S. Government. [1][2]. Automotive producers have no choice than to comply with this new regulation in order to reduce vehicle emission, fuel consumption and improve the efficiency of the car. Therefore, abiding to this regulation becomes a necessity for automotive industry. It has been established today that Thermoplastic Composite (TPC) has demonstrated the ability to fulfil the fundamental automotive material requirement, even the perception that thermoplastic composite cannot satisfy the crash performance requirement because of its brittleness has been unveiled [3]. A good number of automotive lighter weights have been produced using TPC. Nowadays, Light weight composite materials are commonly referred to as fibre reinforced plastic [4]. Therefore, this work present review of automotive application of animal and plant fibre based thermoplastic composite.

II. MOTIVES OF COMPOSITE IN AUTOMOTIVE INDUSTRY

2.1 Principal reasons for reducing automotive weight

Center for automotive research [5] spelt out the benefits of automotive light weight: reduction in fuel consumption and CO_2 generation, improves the noise and vibration of a car. Along with decrease in energy

required to accelerate the vehicle, reduction in rolling resistance at speed, smaller powertrains, Lighter chassis and brake components, smaller gas tanks and smaller wheels and tires.
Studies have shown that a 25% weight reduction in current US vehicles alone could save 750,000 barrels of oil per day, reduce the yearly domestic fuel consumption by 13% and prevent 101 million tons of CO_2 from being emitted into the atmosphere each year [6]
Many researches have been conducted to establish the relationship between mass and fuel consumption and CO2 reduction using empirical techniques. Summarily, their results show 10% reduction in vehicle weight provides a 6-8% reduction in fuel consumption and 8% reduction of CO_2 emissions [7]. Furthermore, an average fuel reduction factor has been calculated for a series of conventional light-duty internal combustion engine (ICE) system as 0.69 l/100 km for every 100 kg of weight save [8].Presently, this industry has seen composite materials as the best alternative to substitute many conventional materials employed in car production because of the following reasons:

- Latest environmental issues associated with global climate change and greenhouse gas emissions [9].Due to this, a legal regulation was established which automotive industry has to fulfill, because they are one of the major generators of carbon emission. This prompts them to look inward on how to reduce the weight of the car so that fuel consumption will be minimized and emission of greenhouse gases will be reduced. Similarly, environmental problems that arise due to non-recyclability of conventional materials can be resolved. This now lead to appreciation of composite materials.
- Safety and impact strength: impact strength is a measure of the amount of energy that a material can absorb before fracturing under a high rate of deformation. High impact strength material is highly needed for cars in order to protect the integrity of back passenger space, fuel tank, side and front structure and roof construction. This can also be achieved through composites [10].
- Improvement of car design and appearance: application of composites allows different complicated shapes to be designed easily for different car components than conventional materials. Also, Composite materials can be used to produce both exterior and interior parts of cars, which will be corrosion-free and has a very nice aesthetic look than traditional material.

Furthermore, Hovorun et al. [11] listed the benefits of weight saving of a car apart from fuel consumption and emission reduction to include decrease in the inertia of a car and its acceleration, improve the braking system and reduce the load on the suspension parts. They also confirmed further that employing composite, most especially polymer matrix; also reduce the cost of manufacturing of automotive components.

2.2. Techniques of reducing automotive weight

Majorly there are three (3) techniques of reducing the weight of automotive: Vehicle size, vehicle redesign and content reduction, and material selection. Material selection is the most convenient and effective technique because it allows new and advance material to be incorporated into the vehicle without going deeply into new design for entire size and content of vehicle. Furthermore, it consumes less time and energy [5].
Baseline weight of six major classifications of automotive parts and their percentages are shown in table 2.1 below. It can be seen from the table that, body and structure system carry highest weight of 47%. Therefore, for weight of a car to be reduced effectively and meaningfully, materials substitution in the body and structure should be selected [7]

Table 2.1 Automotive system and weight percentage [7]

System	Baseline Weight (kg)	%
Body and structure	722	47
Chassis	316	21
Powertrain	293	19
HVAC and electrical	72	5
Others	122	8
Total	1525	100

2.3. Major properties' requirements for automotive materials

The 10 top criteria considered in the production of automotive components using NFRPCs from year 2000-2016 in product design specification (PDS) by researchers are cost, density, tensile strength, Young's modulus and elongation at break. Others are water/moisture absorption, thermal conductivity, fracture toughness and ease of manufacturing [12]. The most prominent important factor for automotive design are lightweight, economic effectiveness, (i.e. the cost), safety that is ability to absorb impact energy and lastly recyclability of materials [10] [13].

2.4. Automotive classification of composite

According to automotive industry, composites can be categorized into three as depicted in fig. 2.4. Thus High Performance composite (HPC), Intermediate Performance composite (IPC) and Low performance composite (LPC).

- High Performance composites: In this type, fiber reinforced composites are designed and constructed in order to carry primary loads and commonly have a reinforcement volume fraction greater than 35%. They are normally restricted to low volume structural applications, such as in racing cars.
- Intermediate Performance composites: Fiber reinforced composites here are designed to transmit secondary loads and have volume fraction less than 35%. They are used for semi structural applications often used as under body.
- Low Performance composites: Fiber reinforced composite are not designed to transmit any load and have volume fraction 20%. They are employed for cosmetic parts such as inlet manifolds, floor panels, roof panels, dash boards, door trims, interior components and light housings are manufactured with high dimensional precision [14].

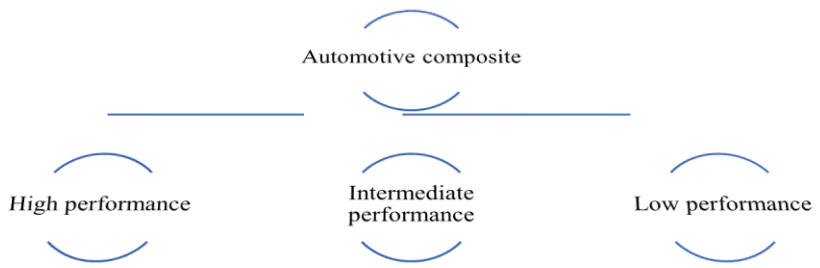


Fig 2.4: classification of composite in automotive industry

2.5. Fiber length in automotive composite materials

Colucci, Simon, Roncato, Martorana and Badini [15] studied the effect of recycling on mechanical properties of glass fiber reinforced propylene composite. This composite has already been used for automotive component. The length of this glass fiber length is >1mm. Also, Hassan, Zulkifli, Ghazali, and Azhari [16] reported the length of bastand core fibers that have been used for developing composite for automotive component to be 2.32mm and 0.74mm respectively. Development of short carbon fiber reinforced polypropylene composite for car bonnet was carried out by Raxaei [17] when he used carbonfiber of length 2, 5 and 10mm. The developed composites were compared with standard steel that are used for car bonnet. The result shows that this composite are viable alternative for steel car bonnet. Sumaila and Ibhadode [6] produced bumper from Lalloh plant fiber reinforced Epoxy composite. The length of lalloh fiber used is 25mm. Furthermore, Ayrilmis, Jarusombuti, Fueangvivat, Bauchongkol, and White [18] developed Coir Fiber Reinforced Polypropylene Composite Panel for Automotive Interior Applications. The coir fiber length used was 15-17mm. these lengths of fiber fall within the range of Short fiber which reported in literatures to be either typically less than 1 mm long in length [19] or lie in the range 0.1 - 10 mm [11] or less than or equal to or less than 50mm [21].

III. THERMOPLASTIC COMPOSITE AND AUTOMOTIVE

3.1. Thermoplastic composites for automotive application

Automotive industry is one of the major consumers of bulk engineering materials. Their need keeps on changing based on customer and environmental request. The basic material requirement for automotive design are (i) lightweight, which is the determinant for vehicle emissions generation and fuel efficiency; (ii) economic effectiveness, (i.e. the cost), that determines whether any new material has an opportunity to be selected for a vehicle component; (iii) safety, which determines the ability to absorb impact energy through controlled failure modes and mechanisms and guarantee protection for the passengers and car users, (iv) recyclability of their products and life cycle considerations [10].

Thermoplastic composite has demonstrated ability to fulfill the requirement of automotive because it has distinctive advantages of polymer matrix composites such as high weight savings, energy absorption, corrosion resistance, high strength, high stiffness, and parts integration. Furthermore, they are durable, recyclable, and viable for automated high-volume processing with a potential for fast and low manufacturing cost [22].

Mallick [19] listed the advantages of thermoplastic composite over thermoset as recyclable, higher ductility and impact resistance, weldability with different welding techniques, such as resistance welding, vibration welding and ultrasonic welding and lower processing time because it does not involve any chemical reaction in the mold [23]i. In addition, thermoplastic composite part can be easily installed [24]. Also, it gives a very nice aesthetic appearance and comfort to the car user without compromising the passenger safety that is reason why automotive industry rely on it [25] [10].

Researchers mentioned the drivers and motivations of automotive industry to thermoplastic composite: weight saving, co_2 emission, automotive fuel consumption, Noise vibration and Harshness (NVH) and acoustic, cost, aesthetic, legislation, safety and environment [26]. Park, et al. [27] also enumerated the attractive benefits offer by thermoplastic composites to automotive industry as cost reduction, economically recyclable and re-used, enhanced environmental, moisture and corrosion resistance; tailored product forms and methods to accomplish the requirements of the application, eradication of exothermic reactions, toxic or solvent emissions, thereby making them environmentally benign; adaptability to manufacturing for low as well as high volume, low tooling costs and rapid cycle times; improved assembly and joining methods. Hold to this, the most commonly used polymer materials in automotive industry nowadays are thermoplastics [28]. The automotive industry also confesses that substitution of metal parts with TPC is feasible for future automotive materials [21].

Application of thermoplastic composites in the automotive industry started with only body interior but nowadays it has covered many other automotive components such as automotive exterior, automotive fuel and electrical system and automotive engine components and powertrain. Components such as exterior panels trim, and bumper fascia, as well as interior trim panels, window encapsulation, headlamp housings, manifolds and valve covers, electronic/electric parts and components, wiring harnesses, steering wheels, insulation, dampening and deadeners, upholstery, mechanical parts and components, safety glass, and many other have been produced using thermoplastic composites [25].

The achievement of thermoplastic composite in replacing traditional material in automotive can never over emphasized. Glass reinforced poly propylene composite has been developed to replaced cast aluminum frame lid that support rear axle in Volvo vehicle V70XCAWD. This fiber reinforced component achieved improvement in strength apart from weight reduction to about 27% and the component manufacturing time was less than 240 seconds as compared to cast aluminum. The bumper of BMW M3 used E glass /nylon 6 Tow flex as a structural material gained higher energy absorption and 60% reduction in weight [14]. Likewise, Shigeru kudo [29] produced Resin rear door to replace steel sheet rear door using short glass fiber reinforced propylene resin through injection molding. Then weights of the two were compared. 30% weight reductions were successfully achieved by Resin rear door. Besides, a glass fiber reinforced thermoplastic to replace steel bumper was developed a higher factor of safety of 64%, cost reduction of 80% and weight saving of almost 54% was accomplished when compared with steel bumper [30, 31].

3.2. Plant fiber thermoplastic composites for automotive applications

Previously synthetic fibers such as glass, carbon, aramid fibers were used to reinforce thermoplastic composites because of their significant mechanical important properties such as high stiffness and strength, high corrosion and wear resistance, long fatigue life, thermal insulation and conductivity, lastly low density as compared to metal. However, these fibers have some severe drawbacks such as high cost, high density (as compared to plant), and poor recycling and non-biodegradable properties. Composite parts made with these fibers turn out to be wastes at the end of their life which brings about serious environmental issues of land filling and air pollution if burnt. This led to research for the replacement of these fibers. Over the last few years plant and animal fiber reinforced thermoplastic composites are increasingly gaining attention as viable alternative to synthetic reinforced thermoplastic composites (SRTPCs) because it covers the deficiency of glass fiber [32]. Table 3.1 shows the comparison between Synthetic and plant fiber. Abdullah [33] listed eight (8) environmental benefits of using plant and animal fiber reinforced thermoplastics as Biodegradability, reduction of greenhouse gas emission, enormous variety of structural fibers available throughout the world, creation of employments in rural areas, development of non-food agricultural/farm-based economy, low energy consumption, low cost, and low energy utilization. Similarly, Food and Agriculture Organization of the United Nations [34] also itemized thirty (30) principal advantages of plant and animal fiber composites. Among these advantages are: viable replacement for man-made fiber, reduced demand for petroleum-based products, substitution of solid wood with plastic reinforced wood thus reducing deforestation, providing a new source of income and raw-materials to the rural areas farmers, lower cost when compared to man-made fibers; environmentally friendly during production, and at the end of life, renewability, lower density, relatively good mechanical properties and reduction in green-house gases.

Table 3.1 Comparison between Synthetic and Natural Fiber [35]

Sources	Synthetic Fiber	Natural Fiber
Renewability	Non-renewable	Renewable
Resources	Infinite	Limited
CO_2 neutral	No	Yes
Biodegradability	Non-Biodegradable	Biodegradable
Recyclability	moderate	Good
Nature of abrasiveness	High	Low
Mechanical property	High	Moderate
Thermal sensitive	Low	High
Moisture sensitive	High	Low
Density	High	Low
Consumption of energy	High	Low
Cost	Higher	Lower
Toxicity	Toxic	Non-toxic

Similarly, it is also noted that plant fiber gives mechanical properties close to glass fiber as shown in Table 3.2. It can be seen from that table that tensile strength and Young's modulus of glass fiber are higher than Plant-based fibers. Nevertheless, the specific tensile strengths and specific Young moduli of both types of fibers are comparable apart from the benefit of lower density values of the plant-based fibers as compared to glass fiber. This is a key aspect for automotive industry where weight reduction is a main concern [36]. Therefore, NFRPCs should be used as best alternative to glass fiber to avoid non-biodegradability and other environmental hazards caused by synthetic fibers apart from cost [37]

Table 3.2 Comparison between plant Fiber and Glass Fiber. [36]

Fiber	Density(g/cm^3)	Diameter (**µm**)	Tensile strength (MPa)	Stiffness/Young's modulus(GPa)	Specific tensile strength(MPa/g/cm^3)	Elongation at break (%)	SpecificYoung's modulus
Flax	1.38-1.52	5-600	343-1830	27-100	227-1220	1.2-3.2	18-53
Kenaf	1.2	12-36	295-930	22-60	246-993	1.6-6.9	18-50
Jute	1.23-1.5	5-200	187-800	10-55	140-610	1.16-3.1	7.1-39
Hemp	1.35-1.51	10-500	550-1110	30-70	210-740	1.6-4.5	20-47
Ramie	1.44-1.55	18-80	400-938	44-128	258-620	1.2-4	29-85
Coir	1.1-1.46	7-460	130-580	4-62	92-180	15-40	3.3-5.2
Sisal	1.2-1.5	7-200	468-855	9-28	55-610	1.9-7	6-20
E glass	2.5-2.55	15-25	200-3500	68.9-73	666-1400	2.5-3	29

NFRPCs have been successfully used in various fields of application including automotive. The leading motivating forces for car –makers to substitute Synthetic fiber reinforced polymer composites with NFRPCs are depicted in Fig. 3.1. Peças, Carvalho, Salman and Leite [38] reported some studies that have quantified the cost and weight reduction achieved by the natural fiber composites to be 20% and 30% respectively for automotive parts

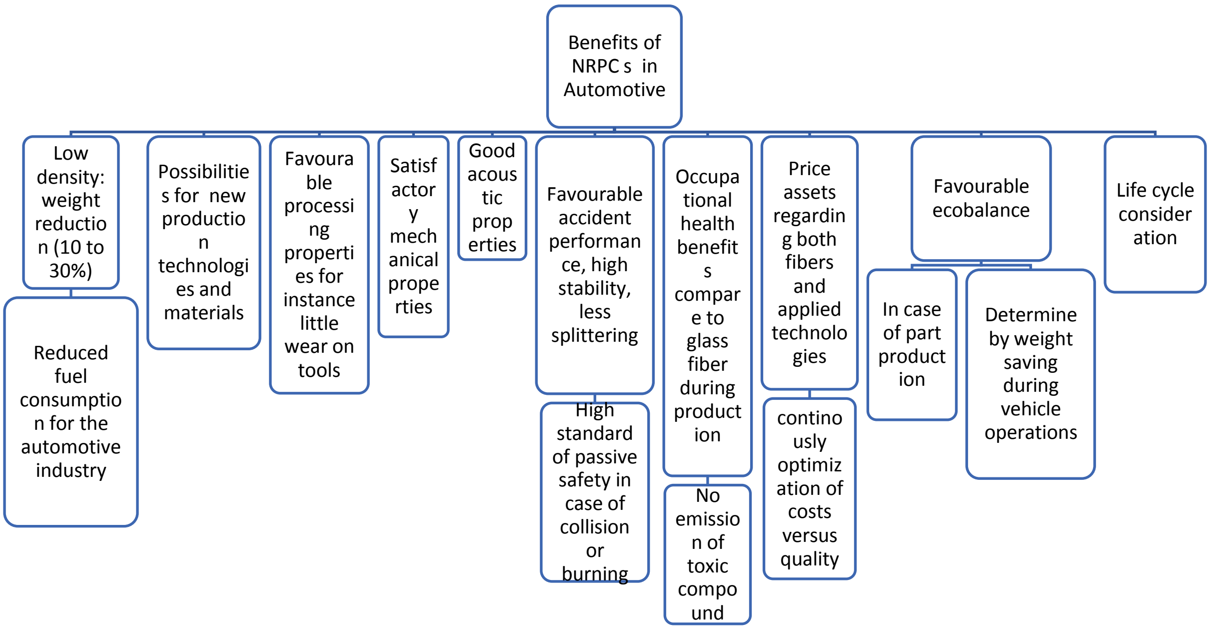


Fig. 3.1 Benefits of NFRPCs in Automotive [36]

Researchers have identified major contributing factors for selecting NFRPC materials in automotive industries to be physical, mechanical and environmental properties. Other factors such as chemical, maintenance, thermal and acoustic insulating properties are considered by minority of the researchers [12]. Several plant fibers have been employed in the production of automotive part. The names plant fibers together with thermoplastic matrix and the automotive parts fabricated from them are shown in Table 3.3 and 3.4

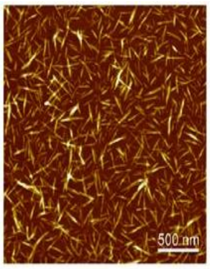
Table 3.3: Plant Fibers, Resin and Automotive Applications

S/N	Plant Fiber	Thermoplastic Resin	Automotive Component	References
1	Wood fiber	Acrylic resin dispersion	Instrument panel, door panel, air channel, bolster, low and mid-segment car	[39] [38]
2	Needle felt wood fiber	Acrylic resin dispersion	Instrument panel, door panel, seat back panel low and mid-segment car	[39]
3	Hemp/kenaf fiber bundles	Polypropylene	Seat back panel, door panel, middle-segment cars	[39] [34]
4	Wood powder and fibers extruded sheets	Polypropylene granules,	Door panels, inserts, low- and middle-segment cars	[39]
5	Fibro wood recyclates	Polypropylene Granules	Plastic retainer for seat back panel, all segments.	[39]
6	Palm kernel(hybrid)	Recycled polyethylene	bumpers	[30]
7	Kenaf(hybrid)	Poly propylene	Bumper beam	[40]
8	Coconut fiber	Poly propylene	Automotive interior	[18]
9	Jute, flax, hemp, kenaf and wood	Poly propylene	Automotive exterior and interior	[41][38]
10	Kenaf	Poly propylene	Door panel	[42]
11	Kenaf	Poly lactic acid	Spare tire cover	[42]
12	Bamboo	Polybutylene	Interior automotive components	[42]
13	Flax	Polyethylene	Engine and transmission cover, underbody panel	[5]
14	Cotton	Polypropylene/Polyethylen eterephthalae	Sound proofing, trunk panel, insulation	[43]

Table 3.4: Plant fibers and automotive components

Plant	Fiber	Automotive Parts	Sources

Hemp 			[44]
		 	[38]
Sisal 		 	[44][42]
Jute 		 	[41] [44] [45]
Flax 		 	[41]
Kenaf 		 Spare Tyre Cover	[42]
Coir 			[45][46]
Cotton 			[45]

Banana 		 Under floor protection trim Of Mercedes	[41][42]
Wood Plant 	 	  	[41][42]

3.3. Animal fiber thermoplastic composites for automotive applications

Animal fibers are protein based and possess some distinct characteristics which make them different from plant fiber. Table 3.5 shows the differences between animal and plant fibers

Table 3.5: Comparison between Animal and Plant Fibers

Characteristics	Protein fiber	Cellulose fiber
Susceptibility to moth	Greater	Less
Susceptibility to fungi and mildew	Less	Greater
Susceptibility to chemicals	More likely to be damaged by strong alkali chemicals and chlorine, but less vulnerable to acid chemical	less likely to be damaged by strong alkali chemicals and chlorine, but more vulnerable to acid chemical
Susceptibility to hot water shrinkage	Greater	Less
Susceptibility to wrinkling	Less	Greater
Insulation value and comfort	High insulation value, generally more comfortable in cool weather	Low insulation factor, more comfortable in warm weather
Fire resistance	Greater	Less
Resistance to wear and abrasion	Greater	Less
Moisture absorbency and wicking ability	Greater	Less
Fiber elasticity	Much greater	Much less
Fiber strength	Less	Greater

Some animal fibers have been reported to reinforce thermoplastic composites: A comparative study of animal and plant fibers reinforced thermoplastic composites was carried out by Alam, Beg, Shubhra and Khan [47]. Silk was selected as animal fiber and jute as plant fiber, both are used to reinforce polypropylene. Compression molding method was used to fabricate the composites, thenTensile strength (TS), impact strength (IS), bending strength (BS), bending modulus (BM), and young's modulus (YM), of the composites were measured. The comparative study makes it obvious that mechanical properties of silk/PP composites are greater than those values of jute/PP composites. Also, Ofora et al [48] carried out a study on Effects of Organic Fillers on the Physical-Mechanical Properties of Low-Density Polyethylene when chicken feather, cow hide and cow hoof were used as fiber to reinforce low density polyethylene and the composite was produced through injection molding. Mechanical properties such as, tensile strength, elongation at break, compressive strength, flexural strength and surface hardness were tested. The result shows that hoof fiber exhibit the best mechanical properties, then cow hide and least was found in chicken feather.

Besides, the Influence of Chemical Treatment on the Mechanical Behaviour of Animal Fiber-Reinforced High-Density Polyethylene Composites was conducted by Oladele, Olajide and ogunbadejo [49]. Cow hair and chicken feather were used as fibers to reinforce high density polyethylene. Two samples were prepared. The fiber in one of the samples was treated with NaOH while the other was not. Hot compression method was used for the production of the composite; it was observed from the result that the chemically treated cow hair and chicken feather fiber gave the best flexural properties than the other.

Furthermore, the empirical model for estimating the mechanical properties and morphology of recycled low-density polyethylene/snail shell bio-composites was investigated by Atuanya et al [50]. The snail shell of different particle sizes and weight percentage were used to reinforce recycled polyethylene (RLDPE) and compressive molding technique was used to prepare the composites. The composites were then subjected to mechanical testing such as tensile, flexural and impact energy. Results obtained showed that the higher the weight percentage of fiber, the higher the properties till it reaches 15% weight of fiber. Consequently, the developed composite was recommended for fabrication of indoor and outdoor structural parts.

3.4. Horn fiber thermoplastic composites for automotive applications

Literature shows that some animal horns have been used for composite reinforcement. A case of buffalo horn fiber reinforcing Vinyl Easter was reported. This composite was developed using hand lay technique. It was noticed that buffalo horn fiber improved the modulus of the composite than the pure polymer and lower density was obtained [51]. Oxen horn fiber was also employed to reinforce polypropylene to produce thermoplastic composites. It was observed that the fiber was able to increase tensile yield strength and modulus, flexural strength and flexural modulus. Consequently, the composite was recommended for automobile, computers, construction, and house ware application [52]. Likewise, Oxen horn fiber was treated and used to reinforce epoxy resin and the tribological and mechanical properties of the treated horn composites and those of the untreated were investigated. It was noted that the treated horn composites displayed better properties than the untreated. It was therefore suggested to be used for frictional applications like brake pads and clutches [53, 54]. In addition, the feasibility study of developing cattle horn reinforcing polyester was carried out. Besides design analysis and optimization of cattle horn-plastic chair seat was also investigated [55]. Furthermore, Mogaji, Abioye and Ohuruogu [56] developed Epoxy resin composite reinforced with cow horn and cassava particle using powder methodology process. Mechanical properties such as hardness, tensile and flexural strength were investigated for different constituent's composition. The results revealed that hardness, tensile and flexural strength of the developed composites were increasing with the increment of cow horn and cassava particle till it reached a certain composition. Finally, the compositions where these mechanical properties are optimal were found to be suitable for car dash board applications. Similarly, the cow horn was used as a filler material to reinforce epoxy resins using hand-lay-up technique. The results show that the fiber was able to improve the flexural and impact properties of the polymers even with the incorporation of the fiber in no particular order and reduced the tensile property at lower curing temperature, but at higher curing temperature a better tensile strength was obtained [57].Table 3.6 shows the chemical composition of cattle horn. The major elements are sulphur, Molybdenum and Calcium

Table 3.6: Elemental composition of cattle horn [58]

S/N	ELEMENT	PERCENTAGE (%)
1	Sulphur	51.1 - 81.90
2	Molybdenum	23.0 - 32.0
3	Calcium	2.5 - 8.32

4	Zinc	1.20 - 2.4
5	Potassium	0.4 - 1.5
6	Copper	0.24 - 0.34
7	Rhenium	1.7 - 3.2
8	Indium	0.3 - 1.0
9	Selenium	0 - 2.70
10	Silicon	0 - 0.33
11	Aluminum	0.4 – 0.78

Mechanical properties of cattle horn Sheath are compared with that of plant fibers and glass fiber as shown in Table 3.7. It can be observed from the table that properties of these three fibers are not the same. Nevertheless, cattle horn fiber can be tested to reinforce thermoplastic composites for automotive applications, because various plant fibers that have been used already in these regards are having different mechanical properties too and also as compared to glass fibers, are not the same.

Table 3.7 Comparison of Mechanical Properties of Synthetic, Plant and Cattle Horn Fibers [38] [36]

Fibers	Young's modulus (GPa)	Tensile strength (MPa)	Moisture/water content (%)
E-glass	68.9-73	200-3500	
Bamboo	17-89	270-862	11-17
Coir	6	175	10
Cotton	6-10	287-597	33-34
Flax	50-70	343-1035	7
Hemp	30-60	580-1110	8
Jute	20-55	187-773	12
Kenaf	22-60	295-930	6.2-12
Sisal	9-22	507-855	11
Cattle horn (Sheath)	0.815-2.34	39.72-154	19-0

IV. CONCLUSION

Natural fiber reinforced thermoplastic composite has demonstrated its qualification to serve in automotive industrial capacity, Most especially the plant natural fiber. Animal natural fiber has not been involved judiciously and practically in producing automotive composite despite its potential ability and in-built properties explained above.From the review of animal fiber above, it can be concluded that, animal natural fiber particularly horn fiber can also be used intensively to reinforce thermoplastic materials for automotive application.

V. RECOMMENDATION

Based on this review, the following recommendations are made:

1. Researchers should exploit more of animal waste for fiber production of composite materials
2. The government should support researcher in providing machines and equipment required in turning out animal and plant waste to wealth.

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