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Journal of Cleaner Production 15 (2007) 1032−1040

Journal of Cleaner Production

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Curauá fibers in the automobile industry − a sustainability assessment

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Accepted 28 May 2006
Available online 13 November 2006

Abstract

Replacing glass fibers with natural fibers in the automobile industry can yield economic, environmental and social benefits. This article evaluates the prospective environmental impacts of automobile applications of curauá fiber (*Ananas erectifolius*), which nearly equates the physical properties of glass fibers. The study identified economic and social advantages of applying curauá fiber composites in car parts. Besides costing 50% less than fiber glass, the use of curauá fibers can promote regional development in the Amazon region. In order to realize significant environmental benefits, however, the curauá-based composites would have to be lighter than their glass fiber-based counterparts.

Keywords: Natural fibers; Curauá; Composites; Passenger cars; Life Cycle Assessment (LCA)

1. Introduction

1.1. Background

The use of plastics in passenger cars has doubled over the last 25 years. One reason for this is the trend towards lighter weight and more complex car parts, but economic considerations have also mattered [1]. In order to improve the structural properties of plastics, glass fibers have been embedded into the polymer matrix. Nowadays, composite materials can be found in various automobile parts, such as interior panels, car bumpers and fuel tanks [2]. Since compounds containing glass fibers cannot easily be separated they are difficult to recycle. According to Directive 2000/53/EC, the European Community requests member countries to reuse and recover at least 95% by 2015 [3] for all end-of-life (EOL) vehicles. In contrast to glass fibers, by burning natural fibers the energy can be recovered. Consequently, the application of natural fiber composites is rapidly increasing in the automobile sector [4] with annual growth rates above 20% [5].

1.2. Natural fibers for automobile applications

Natural fibers and sawdust are perhaps the oldest products added to plastic composites. Their use dates back to the original plastic, bakelite, in which they were used to provide impact resistance, reduce cost, and control shrinkage. Eastern Germany's Trabant (1950−1990) was the first production car to be built from natural fibers. It was equipped with a chassis made of cotton within a polyester matrix. Until recently, car manufacturers used thermoplastics enforced by mineral products or fiberglass. Today, European car manufacturers are again applying natural fiber composites in interior parts such as door panels, trunk liners, instrument panels, parcel shelves, interior roofs, head rests and upholstery [6]. Exterior applications are more critical, where the components must be able to withstand extreme conditions such as wet weather and not splinter due to mechanical impacts (technically called 'chipping') [4]. Nonetheless the first exterior applications are already on the market (flax reinforced engine/transmission covers, Mercedes-Benz Travego Coach). The future trend of extreme light-weight car design [7] will further enhance the application potential of natural fiber composites eventually leading to the ultimate vision of cars that grow on trees [8].

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doi:10.1016/j.jclepro.2006.05.036

1.3. Characteristics of natural fibers

Table 1 compares the physical properties of natural fibers that have been used in composites [6, 9–11]. Major disadvantages of natural fibers are their highly variable quality, depending on unpredictable agricultural conditions, their moisture absorption properties, which complicate exterior applications, their restricted maximum processing temperature, and their lower strength properties. Glass fibers exhibit a tensile strength which is two to three times higher than that of natural fibers. However, due to their low specific weight, they can reach a specific strength and stiffness comparable to that of glass fibers. Other material properties such as Young's modulus and elongation at break are comparable with glass fibers. However, due to the low cost of some fibers (jute, coir, sisal and curauá), their application is very interesting economically.

1.4. The curauá fiber

One of the most promising fiber plants is curauá (*Ananas erectifolius*) due to its combination of suitable material properties and low price (see Fig. 1). The curauá plant is well-known in the Amazon Water Basin in the western region of Para State (Brazil), where the first commercial plantations started [9]. This fiber costs the same as other natural fibers in Brazil, whereas its tension and flexural strength are much higher than those of coir, sisal or jute, reaching nearly the physical properties of the expensive flax fiber and of glass fibers. Curauá-based composites also perform better than other natural fiber/polypropylene composites, as they are being used in the automobile industry (Table 2).

In contrast to most bast fibers that have a strange odor, the leaf fibers from curauá are odorless, which is a major advantage for interior car applications. Curauá/polypropylene composites, therefore, have the potential to replace glass fiber/polypropylene composites for sound insulation and for structural parts mainly in the interior of the car. However, widespread application of curauá in car manufacturing also bears risks. Examples are the negative impacts on ecosystem quality caused by curauá cultivation or the dependency of the car manufacturer on the variable quality and availability of a natural product.

Although small-scale applications are very promising and curauá is already in use in the Brazilian automobile sector [12], it is yet an open question as to whether curauá composites can compete with traditional glass fiber composites with regard to all the environmental impacts that occur during the time from the cultivation of the curauá plant until the end-of-life of natural fiber composites.

1.5. Study goals

The goal of this study was to assess the ecological impact of using curauá composites for automobile applications, and compare it with the impact of traditional glass fiber composites over the whole life cycle of the product. The study was designed to assess the consequences of this design change for the overall sustainability of the automobile sector.

2. Methodology

To achieve the goals of this study, a comparative Life Cycle Assessment (LCA) was performed. LCA is the most appropriate approach for evaluating energy and material flows and their environmental impacts across the full life cycle ranging from raw material extractions to the end-of-life phase. The weakness of LCA lies in its restriction to environmental impacts. Methods such as Social Compatibility Analysis (SCA) or Life Cycling Costing (LCA) are more appropriate to quantify social or economic consequences. However, since the integrated quantitative evaluation of social, economic and environmental impacts is still methodologically controversial, this study focuses on the evaluation of environmental impacts. Social and economic aspects are discussed only qualitatively in the concluding part of this article (Section 5).

2.1. Functional unit

For the first part of the study, which deals with a single car part, the functional unit was defined as 1 kg of an interior car part made of glass fiber composites. Because various interior car parts are designed for different purposes and, therefore, optimized for different material properties, we defined three scenarios:

- *Equal stability:* The curauá composite (curauá/PP 70/30, 1.19 kg) has a similar stability and stiffness as the reference composite (GF/PP 30/70, 1.00 kg). This scenario is

Table 1
Comparative properties of selected natural fibers and glass fibers

Fiber	Fiber type	Density (g/cm^3)	Tensile strength (Mpa)	Young's modulus (Gpa)	Specific strength (Mpa/(g/cm^3))	Elongation at break (%)	Moisture absorption (%)	Price/kg raw (US$)	References
E-glass	Mineral	2.5–2.55	1800–3500	70–73	700–1400	2.5–3.0	0	1.3	[6,10,11]
Flax	Bast	1.4–1.5	345–1500	27.6–80	230–1070	1.2–3.2	7	1.5	[10,11]
Hemp	Bast	1.48	550–900	70	370–610	1.6	8	0.6–1.8	[10,11]
Jute	Bast	1.3–1.45	400–800	10–30	280–610	1.16–1.8	12	0.35	[10,11]
Ramie	Bast	1.5	400–938	44–128	270–620	1.2–3.8	12–17	1.5–2.5	[10,11]
Coir	Seed	1.15–1.25	131–220	4–6	100–190	15–40	10	0.25–0.5	[10,11]
Sisal	Leave	1.33–1.45	468–700	9.4–38	320–530	2–7	11	0.6–0.7	[10,11]
Curauá	Leave	1.4	500–1150	11.8	360–820	3.7–4.3	n/a	0.6	[6,9]

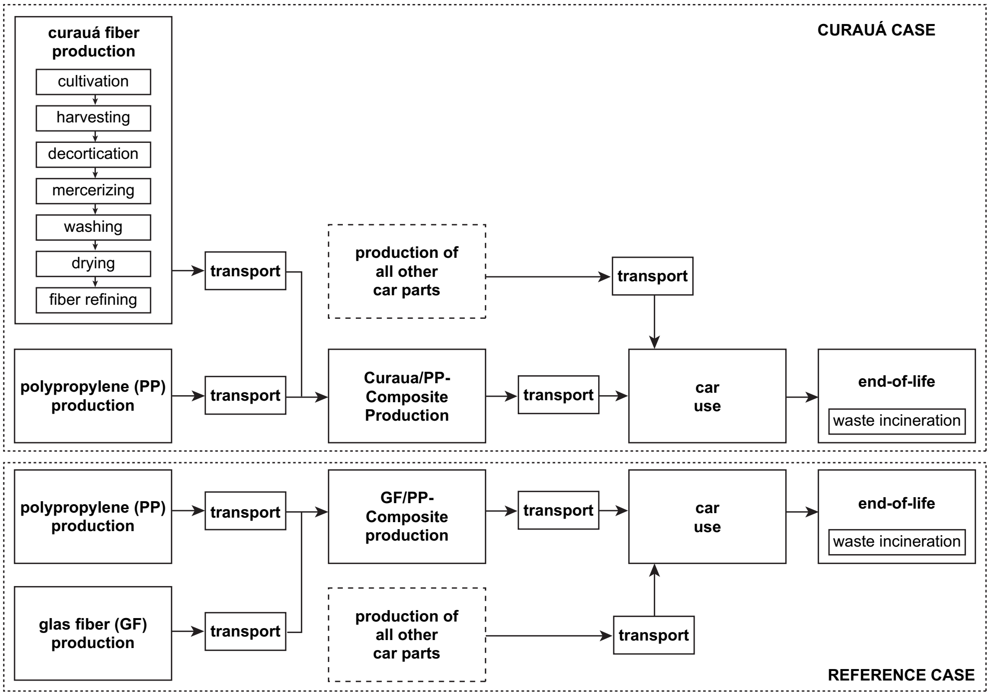

Fig. 1. Process steps included in this study for the production of curauá-based composites (curauá case) and for glass fiber composites (reference case).

relevant for car parts exposed to higher physical impacts such as parcel shelves.

- *Equal weight:* The curauá composite (curauá/PP 50/50, 1.00 kg) has the same composition and weight as the reference composite (GF/PP 50/50, 1.00 kg). This scenario is relevant to car parts where the look-and-feel of natural fiber composites is needed and the costs are critical. Examples are door panels or interior roofs.
- *Equal volume:* The curauá composite (curauá/PP 27/50, 0.77 kg) has the same volume as the reference composite (GF/PP 50/50, 1.00 kg). This scenario is relevant for filling materials where a weight reduction is supposed to be achieved such as for seat cushions.

For the second part of the study, which deals with the overall sustainability of curauá applications in the automobile industry, the complete life cycle of a car was taken as functional unit. As reference scenario, an average car (type Golf IV 1.4L), as it has been assessed by Spielmann et al. [13], has been used. In order to assess the future potential of curauá fibers we looked at the amount of natural fibers that could be used in a light-weight car mainly built from composites, as it has been defined by Schmidt et al. [14].

Table 2
Comparative properties of natural fibers/polypropylene composites in standard ratio of 50/50 [9]

Fiber	Tensile strength (Mpa)	Young's modulus (Gpa)	Flexural strength (Mpa)	Flexural modulus (Gpa)
Ramie	34.67	3.43	29.33	3.02
Jute	15.66	2.4	23.97	2.5
Curauá	46.58	3.78	33.1	2.51

2.2. System boundaries

For both parts of the study, the system included the complete life cycle from cradle to grave, i.e. from the extraction of raw materials and agriculture over different production processes and the use phase to the end-of-life of the car (see Fig. 1). The system boundaries included all transport processes as well as the infrastructure. In the first part, only the life cycle of the respective composite parts was taken into account. In the second part the system boundary is the life cycle of the complete car.

2.3. Environmental impact assessment

Since specific impact assessment methods for Latin American conditions are not available, the impact assessment in the study used all baseline impact categories, plus selected study-specific categories defined by the so-called 'CML methodology' [15]. These impact categories belong to the problem-oriented approach, described in "operational guide to the ISO standards" [15], established by the Center of Environmental Science of Leiden University (CML). Table 3 provides a list of the factors.

3. Inventory data

Standard inventory data on energy supply, transportation and standard industrial processes have been taken from the *Ecoinvent* life cycle inventory, which is nowadays the most comprehensive and harmonized source for life cycle inventory data [16]. These base data have been complemented with system specific data on curauá harvesting and processing.

Table 3
Characterization factors used in this study (according to the CML methodology [15])

Category	Abbrev.	Unit	Remarks
Baseline impact categories			
Depletion of abiotic resources	ADP	kg antimony eq.	–
Climate change	GWP	kg CO_2 eq.	Factors for GWP 100 years
Stratospheric ozone depletion	ODP	kg CFC-11 eq.	Factors for ODP steady state
Human toxicity	HTP	kg 1,4-DCB eq.	Factors for HTP infinite
Ecotoxicity			
Freshwater aquatic ecotoxicity	FAETP	kg 1,4-DCB eq.	Factors for FAETP infinite
Marine aquatic ecotoxicity	MAETP	kg 1,4-DCB eq.	Factors for MAETP infinite
Terrestrial ecotoxicity	TETP	kg 1,4-DCB eq.	Factors for TETP infinite
Photo-oxidant formation	POCP	kg ethylene eq.	Factors for high NO_x values
Acidification	AP	kg SO_2 eq.	Factors for average Europe
Eutrophication	EP	kg PO_4^{3-} eq.	Generic factors
Study-specific impact categories			
Ecotoxicity			
Freshwater sediment ecotoxicity	FSETP	kg 1,4-DCB eq.	Factors for FSETP infinite
Marine sediment ecotoxicity	MSETP	kg 1,4-DCB eq.	Factors for MSETP infinite

3.1. Curauá cultivation

Curauá (*A. erectifolius*) is well-known in the Amazon Water Basin in the western region of Para State (Brazil). The plant was cultivated already in the 1950s for producing ropes. Later, cultivation decreased due to the growth of polypropylene as raw material for ropes. In 1995 new cultivation was started around Santarem [12,17,18], initially funded by Daimler-Chrysler. In 2002 new production was begun in the Pematec Triangle of Brazil.

The fields need no irrigation as long as annual precipitation is greater than 2000 mm/y, which was assumed for the present study. The soil preparation consists of tillage and leveling using tractors (0.8 ha/h). Annual amount of fertilization is N = 400 kg, P = 100 kg, and K = 200 kg/ha. Additionally, 6 l/ha y of the pesticide *Diuron* (*N*-[3,4-dichlorophenyl]-*N*,*N*-dimethyl urea) have to be applied [18]. It has been possible, in recent years, to increase the yield remarkably, and now it is about 100 t leaves/ha y. After the manual harvesting and the transport from the fields to the farm house (10 km), the leaves need to be decorticated, i.e. the fibers have to be extracted from the leaves. This is done with a rudimentary machine (5 HP/machine) consisting of rotating knives that remove the mucilage from the leaves (500 kg per machine/day). After decortication, the fibers are mercerized for 36 h in water tanks, washed again to remove fragments of the mucilage, dried under canopies in the sun and rolled into bales. The raw fibers are blended with polypropylene. These non-woven mats are then transported by truck from Santarem to the automobile industry around São Paulo, which is 3500 km with each truck load holding 23 t of mats [18].

3.2. Composite production

The curauá/polypropylene car parts are produced in São Paulo in a molding-process. The mats are heated to approx. 190 °C, and pressed using cooled moldings. Pressing and cutting can be done in a single working step, e.g. for parcel shelves, or in two separate steps, e.g. for roof interiors [19]. The overall process is approximated with the thermoforming data from the ecoinvent database [20]. Afterwards, the car parts made from curauá are either used in the Brazilian car manufacturing process or they are transported to Europe, where they enter the usual process chain of car manufacturing.

It is assumed that the production of the reference parts (glass fiber/polypropylene) takes place at the European car production sites by injection molding. Data for the materials (glass fiber and polypropylene) and the production process were taken from Althaus et al. [20] and Kellenberger et al. [21].

3.3. Car production—use—end-of-life

For the first part of the study on the part level, the production of the remaining parts of the car is not taken into account. In the second part of the study, all data for the reference car (Golf) were taken from Spielmann et al. [22], and it was assumed (according to IENICA [6] and Suddell et al. [4]) that 12 kg of curauá fibers can potentially be used in this car, replacing the glass fiber amount as well as a part of the plastics. The data for a first hypothetical light-weight car, the LIRECAR, were taken from Schmidt et al. [14]. For this car, we assumed that 40 kg of glass fibers can be replaced by 40 kg of curauá fibers. A more advanced light-weight concept, the HYPERCAR, based on a different engine approach, has been added [7] for purposes of comparison.

For the use phase, we assumed a total of 150,000 km (10 years, 15,000 km/y) for all three types of cars, as has been suggested by Schmidt et al. [14]. Fuel consumption for the base case (Golf IV) was taken from the respective data set of the passenger car fleet in the year 2000, as reported in Ref. [22] (i.e. 20% diesel, 80% petrol). For the hypothetical light-weight cars, the study used information about fuel consumption from Ref. [14] for the LIRECAR and from Ref. [7] for HYPERCAR.

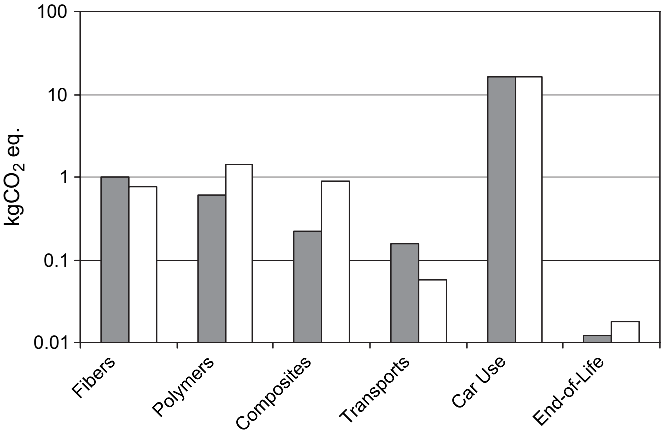

Fig. 2. Estimated impact of 1 kg of a composite on climate change (greenhouse warming potential measured as kg CO_2 equivalents) in the different life cycle phases. Dark = curauá composite and white = glass fiber composite.

Although processes for the recycling of composites have been recently developed [23], in the near future it will only be economically feasible to recycle expensive carbon fibers, not glass or natural fibers. Therefore, we assumed energy recovery in a modern municipal solid waste incineration (MSWI) plant as the only feasible option for the end-of-life of both cases – the curauá/PP and the glass fiber/PP part. The part-specific incineration data were calculated with the respective tools of Doka [24]. For the disposal of a full car, the assumptions and disposal data sets from Ref. [22] were used for all examined car types, i.e. for the Golf and the two light-weight cars.

4. Results

4.1. Part level

Fig. 2 shows the estimated impact on climate change of a composite part during different phases of its life cycle. The distribution is similar for all three scenarios; therefore, we show only the results for the scenario ‘‘equal weight’’. Obviously, the use phase dominates all categories of environmental impacts. For the curauá composite, 89% (84% for the glass fiber composite) of the impact on climate change comes from the use phase. For the full life cycle the curauá composite exhibits a 6% lower impact on climate change than a glass fiber composite with the same weight. If the use phase is neglected, the climate change impact of the curauá is 36% lower. Transport processes display low environmental impacts, with the curauá composite making a 0.9% contribution to climate change, and the glass fiber composite 0.3%. Although the general environmental impact of the end-of-life treatment is significantly lower for the curauá composite, the overall contribution of the end-of-life phase is <0.1% and, therefore, negligible. The results for all impact categories are displayed in Table 4. While the production and transport steps show high environmental impacts for the curauá composites the other processes' steps exhibit higher impacts for the glass fiber composite.

Fig. 3 shows the total environmental impacts of the three scenarios. Fig. 3a compares the environmental impacts of car parts having similar strength characteristics. For most environmental categories, the differences are less than 10% and not significant. The impact on eutrophication is 40% greater for the curauá composite, because fertilizer is needed for the cultivation of the curauá plant. Overall, the environmental impacts of the curauá composite are not significantly different from that of a glass fiber composite with similar stability.

Fig. 3b compares curauá with glass fiber composite of same weight. For many categories, the differences are not significantly different. However, the curauá composite shows significantly lower environmental impact for the four toxicology categories. In general, the curauá composite shows a slightly better environmental performance than a glass fiber composite with the same weight.

Finally, we compared a curauá composite with a glass fiber composite of the same volume (see Fig. 3c). Due to the low

Table 4
Environmental impacts of 1 kg of composite material at different stages of the product life cycle

		Acidification	Climate change	Eutrophication	Photochem. oxidation	Stratos. ozone depletion	Resources
Fiber production	Curauá	*7.95E−03*	*9.85E−01*	*4.16E−03*	*2.89E−04*	*8.71E−08*	5.13E−03
	GF	5.03E−03	7.67E−01	4.03E−04	1.84E−04	5.86E−08	*5.58E−03*
Polymer production	Curauá	6.15E−03	6.09E−01	4.00E−04	2.06E−04	1.52E−09	1.01E−02
	GF	*1.43E−02*	*1.41E+00*	*9.21E−04*	*4.78E−04*	*2.11E−09*	*2.36E−02*
Composite production	Curauá	1.15E−03	2.23E−01	8.89E−05	4.57E−05	1.06E−08	1.67E−03
	GF	*3.92E−03*	*8.83E−01*	*2.96E−04*	*1.82E−04*	*4.31E−07*	*7.31E−03*
Transports	Curauá	*2.36E−03*	*1.59E−01*	*2.42E−04*	*7.87E−05*	*1.78E−08*	*1.08E−03*
	GF	3.53E−04	5.65E−02	6.22E−05	1.40E−05	6.34E−09	4.01E−04
Car use	Curauá	6.54E−02	1.63E+01	1.07E−02	2.01E−02	1.89E−06	9.98E−02
	GF	6.54E−02	1.63E+01	1.07E−02	2.01E−02	1.89E−06	9.98E−02
End-of-life	Curauá	2.23E−04	1.21E−02	*6.92E−05*	*6.18E−06*	1.25E−09	7.86E−05
	GF	*2.68E−04*	*1.76E−02*	6.80E−05	4.13E−06	*2.42E−09*	*1.32E−04*

Units are explained in Table 3. Italicized numbers indicate the higher environmental impact for the respective two composites (curauá vs. GF).

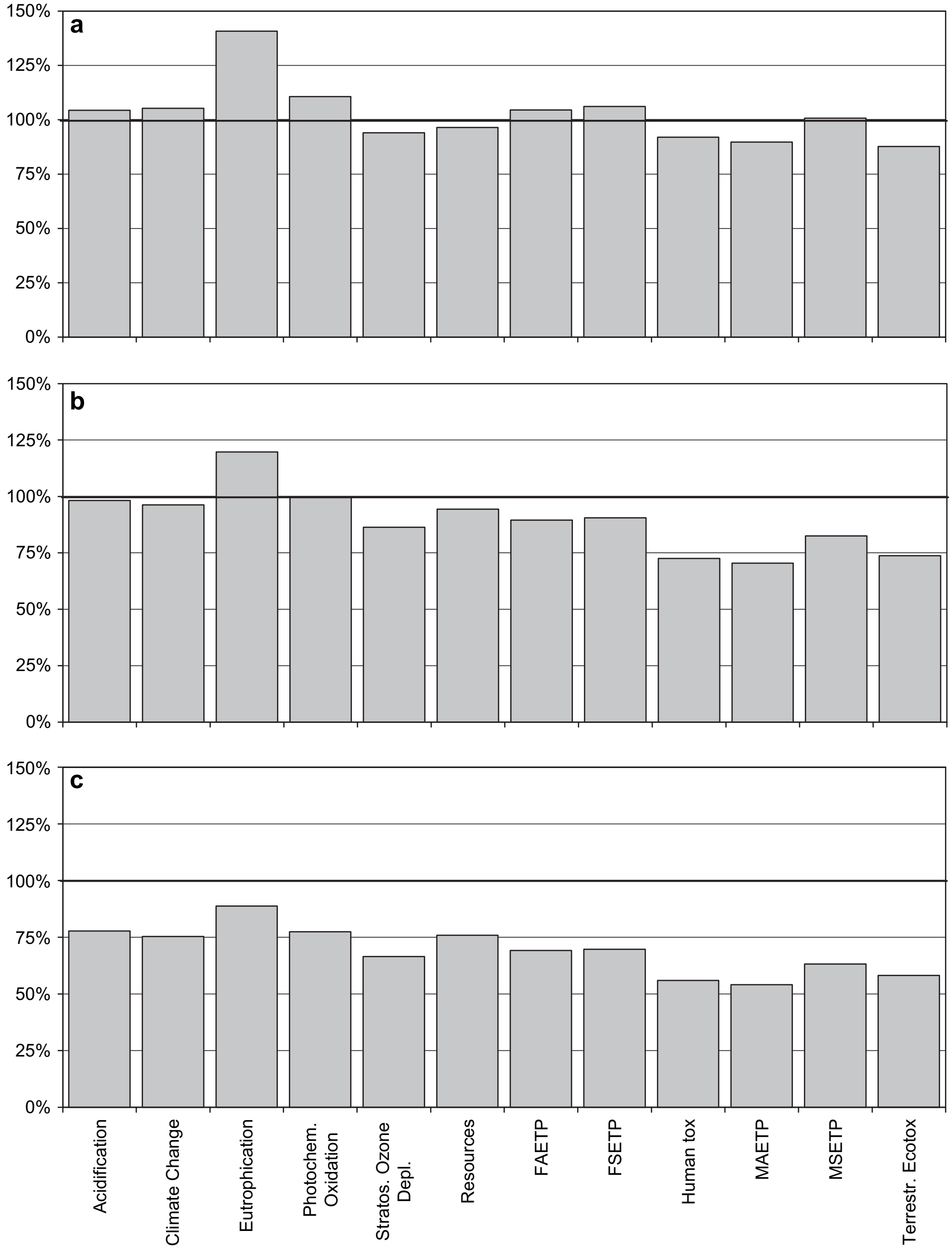

Fig. 3. Environmental impact assessment of curauá-based composites relative to glass fiber composites (100%) for the scenarios equal stability (a), equal weight (b) and equal volume (c).

density of curauá, this part is 25% lighter. Consequently, the curauá composite exhibits less environmental impact than the glass fiber composites for all categories. Overall, curauá composite presents a significantly lower environmental impact of approx. 30%.

The latter results showed that, due to the high importance of the use phase for the full life cycle of automobile parts, weight is the most influential parameter. Therefore in Fig. 4 we examined the influence of the weight on the environmental impact. With the exception of eutrophication, all other environmental impact categories display similar or better ecological performance, when the curauá composite has the same weight as the glass fiber composite (100% in Fig. 4). When the curauá composite is 15% lighter, even the more adverse impact on eutrophication is compensated for, but when the curauá composite is only 5% heavier, it has a higher impact on climate change than its glass fiber counterpart.

4.2. Car level

Compared with all environmental impacts during production, use and recycling of a complete car, the replacement of

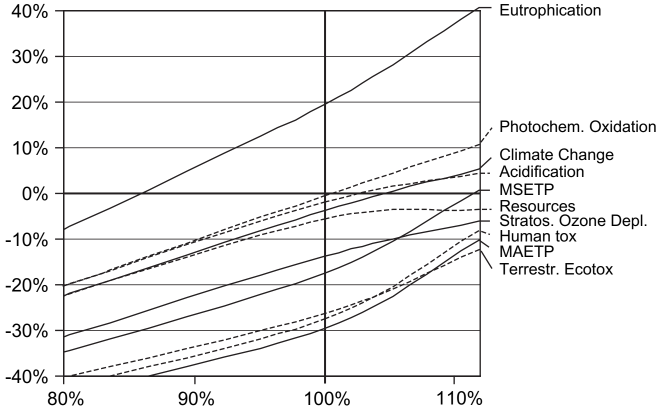

Fig. 4. Weight of curauá composite relative to glass fiber composite (horizontal axis) vs. relative difference in 10 different impact categories (vertical axis). A negative vertical value means that CU/PP is better than GF/PP − a positive value means the opposite. CU = curauá and GF = glass fiber.

glass fibers by natural fibers has a rather small effect (see Fig. 5), e.g. when using curauá fibers instead of glass fibers, the impacts on climate change for the full life cycle of the Golf reference car and the light-weight car are equal. This is mainly due to the fact that, again, the use phase is absolutely dominant throughout the overall life cycle of a car.

Thus, a much more pronounced effect could be achieved by switching to light-weight designs. Compared with a standard Golf, the environmental impact of the LIRECAR (described in Ref. [14]) is 10% lower in average (see Fig. 5). However, this is mainly due to its lower fuel consumption during the use phase. And in case a light-weight design is combined with fuel-saving (hybrids) power-trains, as has been done for the HYPERCAR concept from Ref. [7] the environmental impact can be reduced by more than 50% (see Fig. 5).

5. Discussion

Although the LCA applied in this study focused on the environmental impacts, the life cycle inventory revealed important social and economic consequences of using curauá fibers in automobile applications, summarized in Table 5.

5.1. Economic aspects

The main economic advantage of curauá is its low cost. Curauá fibers cost two to three times less than glass fibers [9], while production costs, maintenance costs and life time can be assumed to be equal. This leads to significantly lower total costs for curauá composites. Additional advantages on the car selling market could be gained if the environmental benefits of the curauá fibers were adequately marketed, as has been done for the VW Fox [12].

Consequently, the market for natural fiber/plastic composites is rapidly growing, in the U.S. at a rate of 54%/y [5], and many car manufacturers have started to use natural fiber composites for interior applications. The global market potential for natural fibers in the automobile industry is expected to be at around ∼800,000 t/y [4].

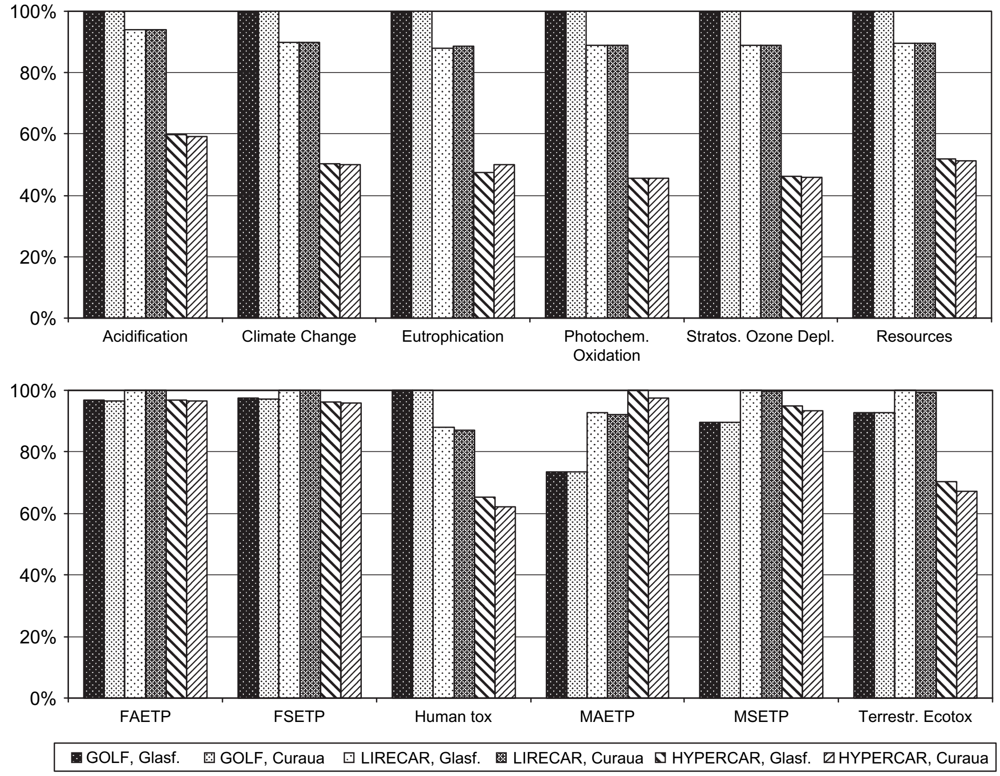

Fig. 5. Overall environmental impacts of passenger car life cycles.

Table 5
Opportunities, risks and potential risk avoidance strategies when replacing glass fiber composites with curauá-based composites

	Opportunities	Risks	Risk avoidance
Economic aspects	+ Low raw material costs + More agricultural business + Eco-marketing	− Variable quality and availability − Lack of production	→ Multiple suppliers; stock building → Building up production capacities
Environmental aspects	+ Slightly lower environmental impact compared to GF + Higher thermal recovery rate	− Higher weight than comparable GF parts − High environmental impacts by monocultures	→ Natural fiber optimization (e.g. by alkali treatment) → Reduce fertilizers/pesticides; mixed cultivation
Social aspects	+ Jobs for under-developed regions + Reduced health risks in production	− Unregistered workers usage	→ Cooperation with social development programs (e.g. POEMA)

The major economic risk for the wide-spread application of curauá is its availability. In contrast to the industrial production of glass fibers, curauá fibers are an agricultural product. The available yield depends on meteorological conditions and farmers could switch to more profitable crops. Car makers, therefore, need to carry a certain amount of stock and should collaborate with different suppliers in order to reduce the risk of being without sufficient supply (reg. Table 5).

Although the price of curauá as a raw material is competitive, it is traded as plates ready to be moulded, which are larger than the final product. The cost of logistics could, therefore, be minimized if the car parts were moulded close to the area of fiber production. This is the case for the VW Fox produced in Brazil.

5.2. Environmental aspects

This study demonstrated that the fuel savings caused by a weight reduction of the curauá composite totally dominate the environmental impact. The same effect has been demonstrated for other natural fibers. Wötzel et al. [25] calculated an LCA for a hemp/epoxy-car door panel, Schmidt and Meyer [26] have assessed the environmental impact of a hemp/PP-based car insulation and Corbière-Nicollier et al. [27] have done an LCA for a China reed-PP transport pallet. In all three studies the natural fiber composite part was approx. 20% lighter than the reference part, and all three authors came to the conclusion that natural fiber composites have environmental benefits over comparable designs with conventional materials.

However, conventional curauá/PP-composites exhibit slightly worse mechanical properties compared with glass fiber composites. To meet the physical standards required, car parts made from curauá or from other natural fibers have to be built heavier than their glass fiber counterparts. Therefore, in order to make light-weight curauá composites feasible, it is crucial to reinforce the strength of curauá composites. Alkali treatment, for example, can greatly increase the fracture strength of natural fibers [28]. When small amounts of glass fibers (5–8%) are added, the tensile strength of the composite can even outperform the strength of pure glass fiber composites [29].

In contrast to glass fibers, curauá fibers are biodegradable. This should lead to advantages in the end-of-life of the car parts, as the parts can be completely thermally used and the amount of residuals is smaller [8,10]. However, because the environmental impact of the end-of-life treatment of car parts makes up to <0.1% of the whole life cycle impacts, these advantages are negligible in the case of car parts.

As was expected, the environmental savings of switching to natural fibers are small in relation to the environmental impacts of the life cycle of a full car. The main reasons are that we assumed no weight savings, and that the amount of replaceable material (12 kg fibers in a standard car, 40 kg in a future light-weight car) is relatively small compared to the total weight of a passenger car.

The global market potential for natural fibers in the automobile industry could be grown on an area of 1600 km^2, which appears to be relatively small for the world consumption of the automobile industry. Current plantations around Santarem (Para, Brazil), where curauá is cultivated for Volkswagen and Daimler-Chrysler, are planted on former monocultures [30]. Some of them are now a mixture of crops that mimic many different levels of plant life in the rain forest (e.g. curauá with coconut trees). An increase in fiber crop cultivation could, therefore, be environmentally advantageous in the region of Santarem. Accordingly, Dornburg et al. [31] demonstrate that it is environmentally more favorable to use agricultural land for natural fiber cultivation than for the production of bioenergy (bio-ethanol made from sugar cane).

5.3. Social aspects

It has been stated that the main economic advantage of natural fibers may be found in their local availability [10]. This might be true when using natural fibers as building materials or for packaging purposes. For automobile applications, however, the transportation processes make up to <1% of the environmental impact of curauá composites, and local availability is neither an environmental nor an economic issue. The low impacts of the transport processes make curauá fibers a suitable export product for developing and transitional countries – a so-called "fair trade" product. All production steps from cultivation up to the mats ready for molding take place in the Amazon region of Northern Brazil and are supervised by the local research and development program "Poverty and Environment of the Amazon" (POEMA) [17]. The cultivation and fiber refinement are labor-intensive and based on traditional knowledge. A high added value is generated in an under-developed region (see Table 5). Additionally, handling curauá fibers instead of glass fibers causes fewer health risks for the people involved in the production and also for car users sensitive to skin irritation.

It is expected that approx. 10,000 new jobs will be created near the city of Santarem by the end of 2006 in the sector of curauá fiber production. In addition to earning a wage, employees and their families also gain access to schools and medical facilities, benefits that continue to be out of reach for a significant part of Brazil's population [12]. The introduction of curauá into the car manufacturing chain induces significant added value for an underdeveloped and rural region. Obviously, this is the main benefit of the automobile application of curauá fibers.

6. Conclusions

This study has shown that the replacement of glass fibers by natural fibers such as curauá is just a small step towards the sustainability of the whole automobile industry. However, due to the low costs of natural fibers, the automobile industry is already on its way to making this transition, which will bring many social advantages. In order to gain significant environmental benefits, however, the curauá composites have to be lighter than their glass fiber counterparts. This requires in future further optimization of the material properties of curauá fibers and the resulting composites.

Acknowledgements

The authors would like to thank Manoel da Silva Robson Marques of the Material Technology Center of Volkswagen in Anchieta/Brazil for the significant contributions to the data collection, to the students of the Volkswagen AutoUni for their engagement in the curauá case study and to Thomas Ruddy from the Technology and Society Lab at EMPA for improving the English of this paper.

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