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Effect of Recycling Cycles on the Mechanical and Damping Properties of Short Alfa Fibre Reinforced Polypropylene Composite

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Abstract: This paper aims at studying the effect of recycling on the static and dynamic properties of short alfa fibre reinforced polypropylene. For this purpose, alfa fibres reinforced composites were elaborated by an injection moulding process and were subjected to different mechanical recycling cycles. Then, non-recycled and recycled materials were subjected to static tests and Dynamic Mechanical Analysis (DMA) to evaluate the effect of recycling on their behaviour. Besides, the effects of alkali and salt water treatments on the static and dynamic properties of the alfa composite were also investigated. The obtained results show that tensile and flexural properties of alfa fibres reinforced composites decrease during recycling cycles. Moreover, the recycling induces a drop in the storage modulus and enhances the loss factor of these composites. The composites with alfa fibre especially the alkali treated composite show the same resistance to recycling as composites with hemp fibres. Further, SEM observations indicate a decrease in the fibres dimension with the recycling cycles, especially for alfa fibres, which can explain the decrease in the properties of the alfa composite during recycling operations.

Keywords: Alfa fibre; hemp fibre; eco-composites; recycling; mechanical properties; dynamic properties

1 Introduction

Currently, the new environmental regulation has prompted many industries such as automotive, aviation, sports and packaging industries to use ecologically friendly materials to reduce their environmental foot print. Accordingly, there has been a growing interest in employing natural fibre reinforced polymer composites. This choice was motivated by the multiple advantages offered by these fibres such as availability, renewability, biodegradability, low density and specially their recyclability [1-3]. This allows the reduction of the raw material cost which makes it a very interesting strategy to establish a sustainable development. Therefore, several works have analysed the effect of recycling on polypropylene (PP) which is one of the most used matrix in composite materials reinforced with natural fibres. For example, Echevarria et al. [4] showed that rheological and mechanical properties of pure PP remain practically unaffected during the first four recycling cycles. On the other hand, Bourmaud and Baley [5] found that, after seven recycling cycles of pure PP, the tensile modulus, tensile strength and elongation at break decrease by about 13.5%, 6.13% and 36.1%, respectively.

As to PP based eco-composites, it is generally expected to have less recyclability than the pure PP because of the heterogeneous and the inherent lower thermal stability of natural fibres. Despite these difficulties, several research works have been interested in recycling natural fibres reinforced polymer composites [5-9]. For example, Bourmaud and Baley [5] studied the mechanical and thermo-physical behaviour of recycled short hemp and sisal fibres reinforced PP. They showed that after seven recycling cycles of the PP-sisal composite, the Young's modulus and tensile strength decrease by about 10% and 17%, respectively, while those of PP-hemp composite remain approximately unchanged. The authors attributed this difference to the fact that the form factor of the sisal fibre decreases more rapidly with

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recycling than that of hemp fibre. In another work, Srebrenkoska et al. [6] showed that the flexural modulus of PP-hulls composites remains practically unchanged after two recycling cycles while that of PP-kenaf composite increases by about 20%. Arbelaiz et al. [7] found that after three recycling cycles the tensile properties of PP-flax composite showed a slight decrease compared to those of non-recycled ones.

For matters of comparison, Bourmand and Baley [5], found that the decrease in the mechanical proprieties of PP/hemp fibre with recycling is less important than in PP/glass fibre composite. In fact, after 7 recycling cycles, the tensile strength, tensile modulus and strain at break of PP/glass with 30 wt% changed by -52%, 40% and +34.2%, respectively. However, for the PP/hemp with 30 wt%, these properties vary only by +1.81%, -0.66% and +22.3%, respectively. Moreover, Colucci et al. [10] studied the effect of mechanical recycling on glass fibre reinforced polypropylene composite. As a result, they noticed that after one mechanical recycling cycle, their mechanical properties decrease by 8.5%, 23.8% and 27.5% for Young's modulus, tensile strength and flexural strength, respectively, with respect to the values of non-recycled material. In the light of these results, we can see that composite reinforced with natural fibres stands the mechanical recycling better than composite with glass fibre.

About alfa fibre reinforced polymer, few researchers studied the effect of recycling on their mechanical properties. To the author's knowledge, only one study was conducted by Hammiche et al. [8]. They showed that the tensile strength and Young's modulus of short alfa fibre reinforced polyvinylchloride were enhanced after four recycling cycles. The authors attributed this enhancement to changes in physical and chemical properties of the composites during the recycling process.

These studies showed that the recycling of natural fibres reinforced composites, in some cases, could be promising because their recycling causes low variations in their mechanical properties. Within this context the effect of recycling on the tensile, bending and dynamic properties of short alfa fibre reinforced PP were studied in this work. The purpose is to study how composite reinforced with alfa fibre will behave after several grinding and injection process that may damage the fibre. Therefore, polypropylene reinforced with alfa fibre was recycled up to four cycles. Then, the non-recycled and recycled composites were subjected to static and dynamic tests to evaluate their mechanical and dynamic properties together with their evolution according to recycling cycles. Besides, the effects of two alfa fibre treatments on the recyclability of alfa fibre composites were analysed. For comparison sake, a short hemp fibres reinforced PP composite was also studied in this work. For the reason that, it will be interesting to compare alfa fibre to one of the most widely used natural fibre as reinforcement in composites.

Table 1: Gathered mechanical properties of recycled composites from published literature

Matrix	Fibre Type	Recycling Cycles	General Behaviour	Reference
PP	-	5	Strain properties, Young's modulus and yield stress, were practically constant with reprocessing (maximum difference 120 MPa and 2.0 MPa, respectively).	[4]
PP	-	7	Tensile modulus: -13.5% Tensile strength: -6.13% Elongation at break: -36.1%	[5]
PP	Sisal (30 wt%)	7	Tensile modulus: -10% Tensile strength: -17% Elongation at break:+8.9%	[5]
PP	Hemp	7	Tensile modulus: -0.66%	[5]

	(30 wt%)		Tensile strength: +1.81% Elongation at break: +22.3%	
PP	Glass (30 wt%)	7	Tensile modulus: -40% Tensile strength: -52.5% Elongation at break:+34.2%	[5]
PP	Rice hulls (30 wt%)	2	Flexural strength:-10% Flexural modulus: -2%	[6]
PP	Kenaf (30 wt%)	2	Flexural strength: -5% Flexural modulus: +20%	[6]
PP	Flax	4	Tensile properties only showed a small decrease	[7]
PP	Glass	1	Young's modulus:-8.5% Tensile strength: -23.8% Flexural strength: -27.5%	[10]
PVC	Alfa	4	Tensile strength: +5.7% Young's modulus: +125%	[8]

2 Materials and Experimental Testing

2.1 Materials

Alfa is the Arab name of Esparto Grass. It belongs to the Graminacies family that is widely widespread in North Africa and the South of Spain. Its culture requires very little water and no insecticides or pesticides. The alfa fibre is principally used in the production of high quality papers and artisanal applications [11]. In the last years, a considerable focus has been laid on the use of the alfa fibre as reinforcement for polymer matrix because of its interesting mechanical properties. In fact, alfa fibre presents a Young's modulus of about 18.42 MPa to 24.92 GPa, a breaking strength of about 187.5 MPa to 565 MPa and a breaking strain of 1.5% to 5.8% [12-18]. Besides, the major component in alfa fibre is cellulose (43.8% to 47%), followed by hemicellulose and pectin (22.15% to 28.4%), then lignin (17.7% to 24%) [11,13-18]. According to these interesting properties, the alfa fibre can constitute a potential reinforcement of polymer matrix in North African countries as flax [19] and hemp [20] fibres in Europe. Thus, the alfa plant was collected during April from the Oujda region (East of Morocco). It was dried under the sun for three days in order to eliminate most of the moisture captured in the leaves and make them easier to crush. The alfa leaves are very hard to break; so with the standard mills, we got fibres either with large dimensions or an important quantity of dust. To avoid this problem, the dried leaves were manually cut to bundles of 4-6 cm length and crushed using a special mill. More details about this experimental protocol can be found in [21].

In order to improve the fibre-matrix interface, the effect of two treatments on the alfa fibre were studied. The first one consisted in soaking the fibres in salt water (35g/l) for 24 hours at a temperature of 60°C. Then they were washed several times with tap water and dried in an oven for 12 hours at a temperature of 105°C. In order to simplify the process and reduce its costs, the tap water was used until the fibre PH reached 7. This soaking allowed to remove wax, sand and dust that existed on the surface of the leaves. The idea of using salt water to treat alfa fibre goes back to the ancient craftsman in North Africa. In fact, in the past producers of alfa submerged the leaves in the sea water before using it in traditional manufacturing [11]. On the other hand, other works also showed the efficiency of seawater treatment in the case of other natural fibres such as hemp and flax [22,23].

The second treatment was similar to the one used in [21]. This treatment was carried out in several steps. First, alfa fibres were treated with salt water (35g/l; 60°C; 24 hours). Second, an alkali solution with 10% of NaOH was applied for 24 hours at room temperature. To eliminate the residual sodium hydroxide, alfa fibres were washed with tap water until their pH reached 7, and dried for 12 hours at a temperature of 105°C. 10% of NaOH was found to be the optimum concentration for alfa fibre to achieve a good adhesion with the matrix without causing fibre degradation during the treatment process [24].

On the other hand, the polypropylene composite reinforced with hemp fibre was directly received from AFT Plasturgie Company (Fontaine-Les-Dijon, France). The same company has provided us the PP under the commercial code P00205P2, in the form of pellets. No coupling agent was used in this study.

2.2 Specimens Preparation

For bio-composite made with natural fibres reinforced composite, it was shown that the 30wt% of fibres content was presumably the optimum in term of tensile properties as reported in [21,20]. Thus, only composite with 30 wt% were elaborated in this work. For comparison, the PP/hemp fibres composite with 30 wt% was also considered.

The mixture of alfa fibres and PP matrix was carried on a single screw extruder with a rotation speed of 28 revolutions per minute. The four zones of the extruder were heated up to 175°C, 180°C, 185°C and 190°C, respectively. Under these conditions, the thermal degradation of alfa fibres which started at 210°C was avoided [25].

To elaborate composite specimens, the obtained compounds were dried in an oven for 12 hours at a temperature of 105°C, then injected in a mould with normalized dimensions (ASTM D638-10 and ASTM D790). All tensile and flexural specimens were elaborated using an injection process with a two-cavity mould. The injection moulding process was carried out using a Sandretto Otto machine for thermoplastics. The parameters include an injection time of 0.8 s, screw rotation speed of 150 revolutions per minute, pressure of 70 bar, cooling time of 10 s and total cycle time of 30 s. To avoid the thermal degradation phenomena of the alfa fibre, the temperature in the three main zones of the equipment was set at 190°C, 185°C and 180°C, respectively. In order to evaluate the effect of recycling on the alfa and hemp fibre composites, the original composites obtained were mechanically grinded, and then injected up to four cycles under the same conditions as described above with no addition of virgin material (Fig. 1).

In the next sections, the PP polymer reinforced with alfa fibre treated by salt water and alkali solution will be designated by PP-A30-S and PP-A30-N, respectively. Similarly, the PP-hemp reinforced composite will be designated by PP-H30.

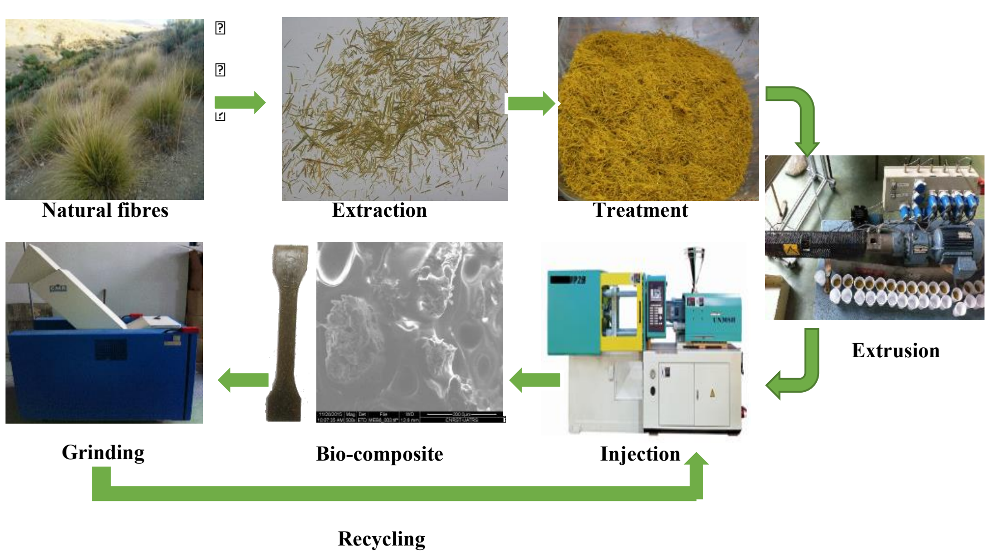


Figure 1: Elaboration and recycling processes of the studied bio-composites

2.3 Tensile and Flexural Tests

All tensile tests were conducted at room temperature according to the ASTM D638-10 standard, with a cross-head speed of 2 mm/min and a clip-on extensometer with 50 mm gauge length used to measure the longitudinal strain.

Flexural tests were performed using a three points bending set-up according to the ASTM D790 standard. The crosshead speed was 2 mm/min. The two support spans were 40 mm apart. For both testing configurations, the reported results were an average of at least five specimens.

2.4 Dynamic Mechanical Analysis (DMA)

Regarding the studied composites, the dynamic analysis was conducted using a DMA 242 (Netszch). All specimens were tested in three-point bending mode. Each sample is placed between two supporting edges 40 mm apart, a third central support applies a variable force of 8N maximum allowing motion only in the horizontal plane. The temperature scans were run at a rate of 2 °C/min from 30°C to 120°C and the tests were performed at two frequencies (1 Hz and 50 Hz).

2.5 Scanning Electron Microscopy (SEM)

In order to distinguish the different damage mechanisms triggered by recycling, the specimen fracture surfaces were examined using a Quanta 200 SEM. The sections observed were obtained by mechanically cutting the specimens transversely to the beam axes 4 mm away from the failed centre region. Then they were coated with a fine layer of carbone to enhence the electrical conductivity of the surface. An accelerating voltage of 25 KV has been used

3 Results and Discussion

3.1 Tensile Properties

Fig. 2 presents stress–strain curves of the non-recycled composites. After a linear behaviour, the curves present a substantial non-linear response which could be attributed to the matrix plastic deformation and damage of fibre-matrix interfaces. The effect of the salt water and alkali treatments on the tensile properties of alfa composites could be clearly seen particularly for the PP-A30-N material. The mean values of tensile modulus, tensile strength and strain at failure are depicted in Tab. 1. Compared to the untreated alfa composite PP-A30, the results show that the alkali treatment improves the Young’s modulus and the tensile strength by about 30% and 18%, respectively. However, the salt water induced only a slight increase of these two properties. This could be explained by the fact that salt water treatment has only removed wax and dust from the surface of the alfa fibre. On the other hand, the alkali treatment dissolved the amorphous organic components of alfa fibre such as hemicelluloses and lignin which led to the breakdown of the fibre bundle into micro fibrils [21]. Consequently, with the alkali treatment, the effective surface available for contact with the matrix is increased, and the removal of the cementing hemicelluloses enables the cellulose chains to rearrange themselves to increase their crystallinity index [21,26,27]. It is also important to note that PP-A30-N composite has comparable tensile properties to those of PP-H30 material even though the hemp fibre is stiffer than the alfa fibre. In fact, as reported in the literature, the Young’s modulus and the tensile strength of the hemp fibre vary from 30 GPa to 60 GPa and 210 MPa to 1040 MPa [28], respectively, versus 18.42 GPa to 24.92 GPa and 187.5 MPa to 565 MPa for the alfa fibre [11,13-18]. These results indicate that alfa fibre constitute a potential reinforcement of polymer matrix in the North Africa countries, as there are other fibres in Europe such as hemp.

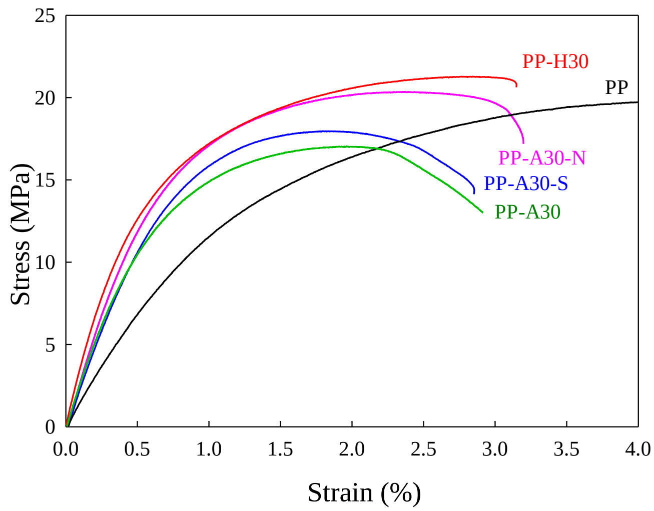


Figure 2: Stress-strain response of the non-recycled composites under monotonic tensile

Table 2: Tensile properties of the alfa and hemp fibres reinforced PP composites

Material	Young's modulus (GPa)	Tensile strength (MPa)	Strain at failure (%)
PP	1.705±0.05	20.34±0.34	15±0.24
PP-A30	2.66±0.15	17.23±0.33	3.01±0.21
PP-A30-S	3.02±0.28	17.71±0.35	2.93±0.31
PP-A30-N	3.45±0.13	20.35±0.66	2.86±0.34
PP-H30	3.59±0.12	21.03±0.43	3.24±0.26

In order to identify the effect of the recycling cycles number on the tensile properties of the studied materials, we illustrate in Fig. 3 the evolution of Young's modulus and tensile strength of PP-A30-S, PP-A30-N and PP-H30 composites in terms of injection cycles. These three composites were chosen among the studied composites because they showed the best mechanical proprieties. We remark that the Young's modulus and tensile strength are affected by the injection cycles (Figs. 3(a) and 3(b)). In fact, compared to non-recycled composites, after four recycling cycles the Young's modulus decreases by about 8% to 9.5%, 11% to 18% and 11% to 15% for the PP-H30, PP-A30-N and PP-A30-S composites, respectively. In the same order, this decrease is about 4% to 14%, 7% to 13% and 6% to 13% for the tensile strength. It was noticed that the tensile properties of PP-H30 composites were maintained with recycling approximately as those of composites reinforced with alfa fibres. Furthermore, many researchers found that Young's modulus and tensile strength of polypropylene composite reinforced with natural fibres such as sisal [5], flax [7] and wood flour [29] decrease with the reprocessing cycles. This is due to the inherent lower thermal stability of lignocellulosic materials which makes composite reinforced with lignocellulosic fibres more prone to undergo thermal degradation during processing than neat polymers [30].

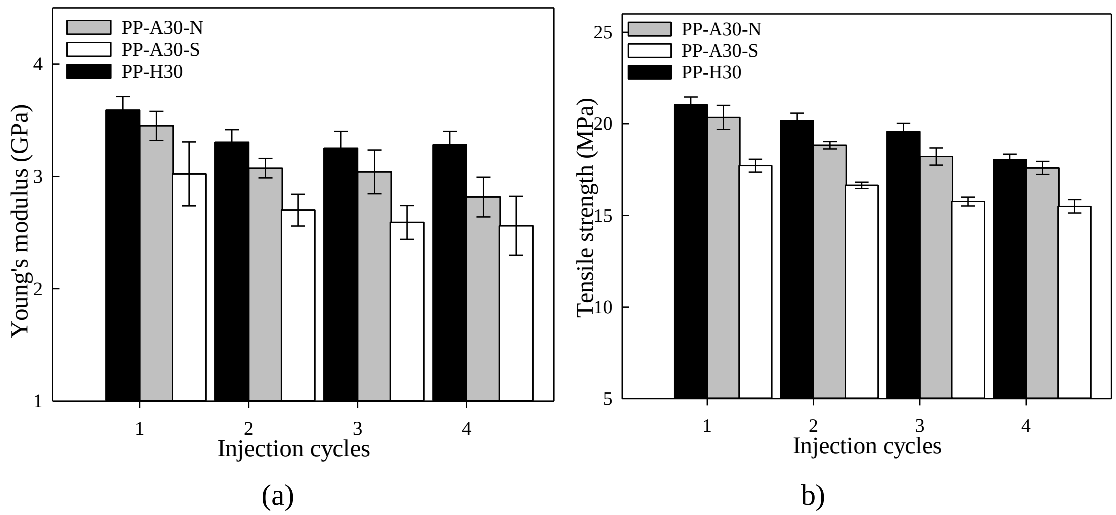


Figure 3: Evolution of the tensile properties according to the injection cycles: a) Young's modulus, b) tensile strength

3.2 Flexural Properties

Flexural tests were also carried out for at least five specimens of each studied composite. For all the composites, the addition of fibres increased the bending modulus and flexural strength of the composites but decreased their ductility compared to the pure polypropylene (Fig. 4). Moreover, as in the tensile test, the use of alkaline treatment allows a significant improvement in the flexural properties of polypropylene reinforced with alfa fibre composite compared to the treatment with salt water. In fact, the bending modulus and flexural strength of PP-A30-N composite are improved by 31 and 14% when compared to those of PP-A30-S composite (Tab. 2). However, the salt water treatment increased the flexural strength only by 7% compared to the untreated polypropylene reinforced with alfa fibre composite PP-A30. Moreover, the obtained results showed that even though, the PP-H30 exhibits a bending modulus and flexural strength higher by 20% and 8% than the PP-A30-N composite, it was observed that composites with alfa fibres have retained much more of the ductility of polypropylene.

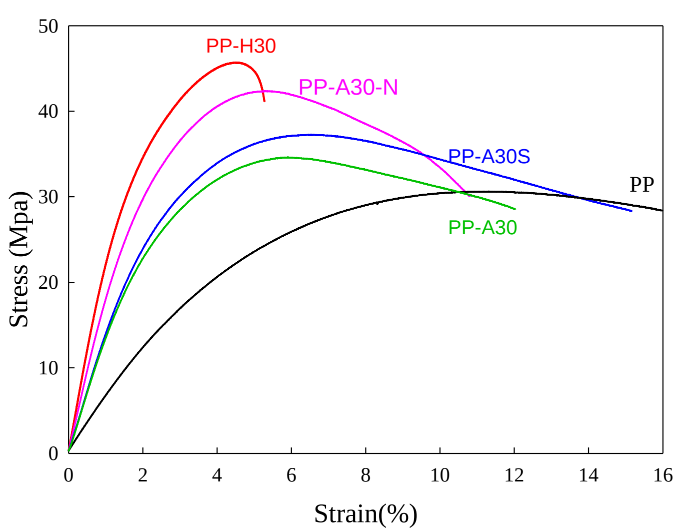
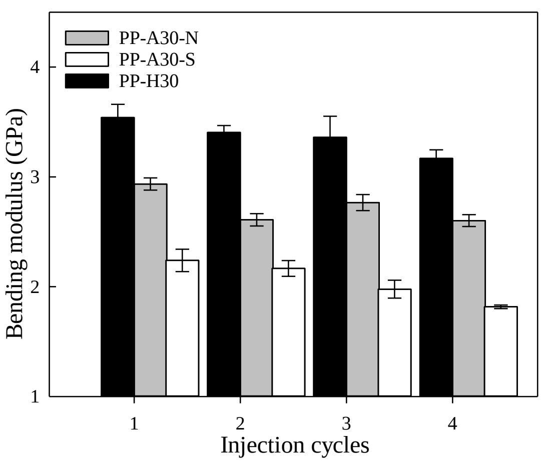


Figure 4: Stress-strain response of non-recycled composites under monotonic flexural tests

Table 3: Flexural properties of the alfa and hemp fibres reinforced PP composites

Material	Bending modulus (GPa)	Flexural strength (MPa)	Strain at failure (%)
PP	0.98±0.03	30.32±0.39	19.5±3
PP-A30	1.3±0.07	34.62±0.9	15.82±0.5
PP-A30-S	2.24±0.10	37.13±0.82	15.43±0.31
PP-A30-N	2.93±0.05	42.34±0.66	11.80±0.54
PP-H30	3.53±0.15	46.03±1.09	6.01±0.34

The evolution of the mean values of bending modulus and flexural strength as a function of injection cycles is presented in Fig. 5. The flexural properties of all studied composites decrease while increasing the injection cycles. Indeed, the bending modulus of PP-H30, PP-A30-N and PP-A30-S composites drop by ~10%, 11% and 18% after four recycling cycles, respectively. On the other hand, the flexural strength of PP-H30 and PP-A30-N composites show the same drop of ~7% after the injection cycles while it decreases by 15% for the PP-A30-S. A similar decrease of the bending modulus and flexural strength with recycling cycles was reported for wood reinforced plastic [31,29]. Moreover, Srebrenkoska et al. [6] had found that the flexural strength of polypropylene reinforced with rice hulls decreased by about 10% after two recycling cycles, although the flexural modulus remained practically unchanged. For the PP-A30-S composite, the important decrease in its flexural strength is likely to be attributed to the inefficiency of the salt water treatment used to improve the quality of the fibre-matrix interface.



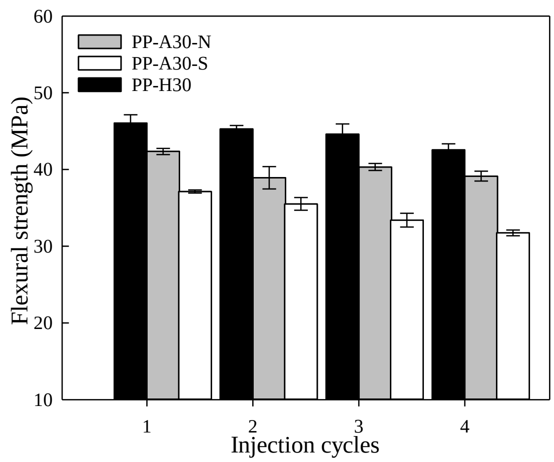


Figure 5: Evolution of the flexural properties in term of the injection cycles: a) bending modulus, b) flexural strength

3.3 Dynamic Mechanical Properties

The variations of the storage modulus and loss factor in terms of the temperature are depicted in Fig. 6. Two different behaviours of these properties are observed. Indeed, the storage modulus of the studied composites decreases while the loss factors are found to increase. This could be attributed to higher molecular mobility when increasing the temperature which makes the composites less stiff and more viscous [32,33]. For a given temperature, the increase of frequency leads to an increase in storage modulus and a decrease in the loss factor. In fact, at high frequencies, the molecules of the PP are not able to follow the applied periodical displacement due to their relaxation time [34,35]. Consequently, the materials behave stiffer and hence less energy is dissipated when increasing frequency. The addition of alfa fibres brings about an enhancement in the storage modulus and a decrease in the loss factor, which is consistent with the reinforcing effect of fibres and indicates more elastic behaviour of the composites as compared with the pure PP. A similar result was find with starch-based biopolymer reinforced with alfa fibre [36].

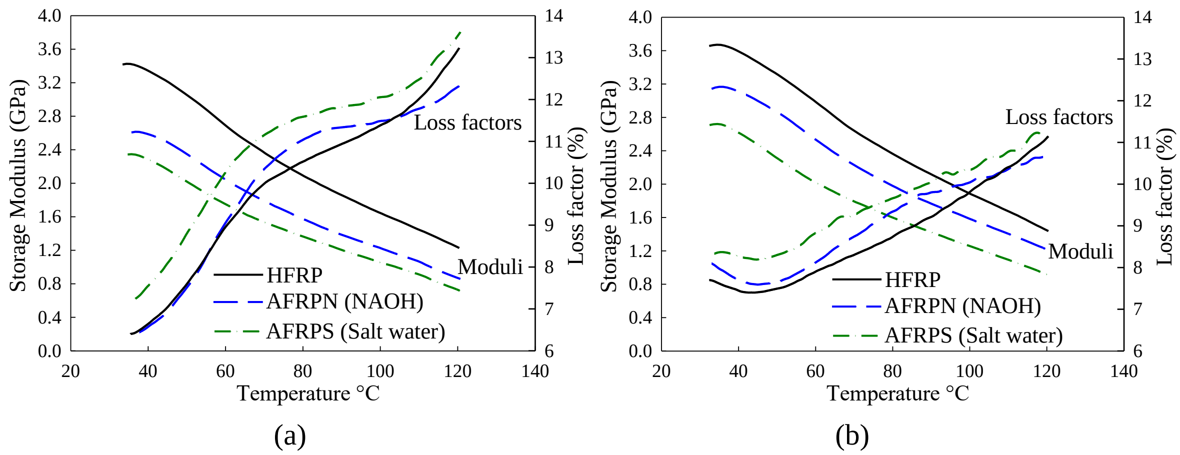


Figure 6: Variation of storage modulus and loss factor according to temperature for the studied composites: a) 1Hz and b) 50 Hz

Although the studied composites show practically the same evolution in terms of temperature and frequency, an important difference between their dynamic mechanical properties is clearly seen. In fact, the PP-A30-S and PP-A30-N composites show the lowest storage modules and the highest loss factor compared to PP-H30 material. The difference between the storage modulus of PP-H30 and alfa composites is due to the fact that the hemp fibre is stiffer compared to alfa fibre [28]. On the other hand, Bourmaud et al. [32] have reported that a poor fibre-matrix interface increases the molecular mobility in the interfacial zone which leads to higher damping. Thereby, the high loss factor values of the PP-A30-S composite confirmed that this composite has the weakest fibre-matrix interface.

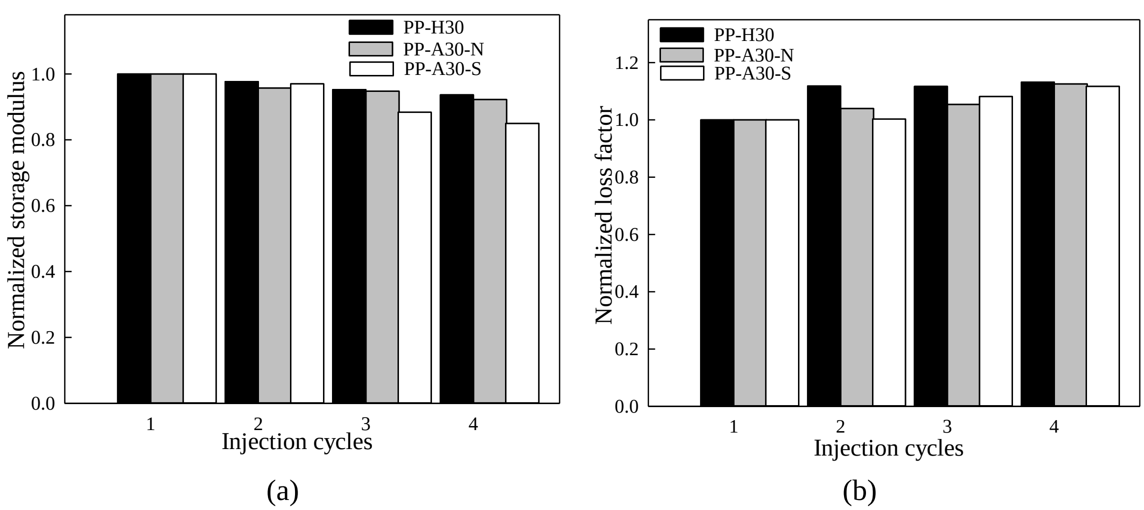


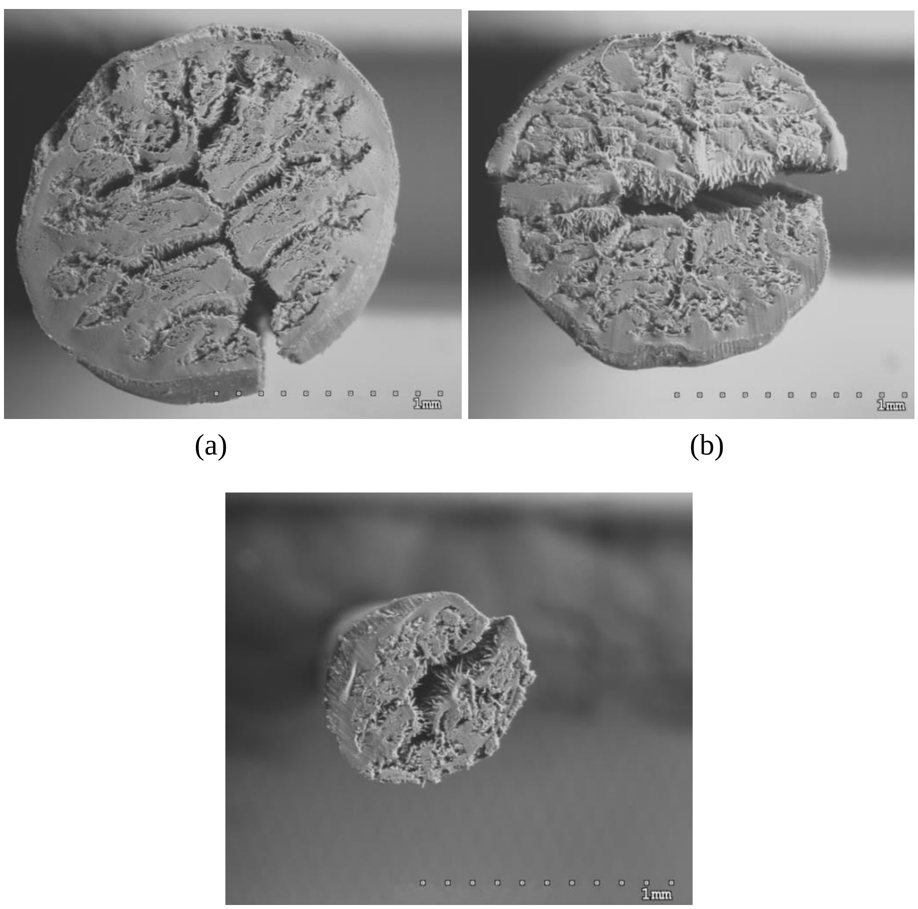
Figure 7: Dynamics properties of the studied composites according to the injection cycles at 30°C and 1 Hz stress frequency: a) normalized storage modulus and b) normalized loss factor

To better quantify the effect of recycling on the studied composites, the evolution of the normalized storage modulus and loss factor in terms of injection cycles at 30°C and 1 Hz stress frequency was presented in Fig. 7. For each composite, the storage modulus decreases while the loss factor increases when increasing the injection cycles. As a matter of fact, the storage modulus of PP-H30, PP-A30-N and PP-A30-S decrease, respectively, by about 6%, 7% and 15%, while their loss factor increase by 13%, 12% and 11% after the four injection cycles. These variations clearly indicate that the elastic behaviour of the composite decrease while his energy dissipation increase with the injection cycles.

The thermomechanical degradation of the materials by chain scission and the deterioration of fibre-matrix interface are the main reason for this behaviour [32,35,37]. It is worth noting that the PP-A30-N composite conserves its storage modulus and loss factor with the recycling cycles as the PP-H30 composites.

3.4 Fibre and Composites Morphology

The alfa stems have a circular shape with a variable diameter as shown in Fig. 8. Indeed, the diameter in the extreme lower part trend up to 1.75±0.14 mm, while in the extreme upper part the diameter is 0.67±0.16 mm. The cross section of the alfa stem indicate the presence of a hole inside the leaf. Thereby, the stem can be opened or closeed as function of the relative humidity [38]. As to alfa fibres; they are mainly located on the edge of the stem and have a diameter of 13.53±2.8 um (Fig. 9). Moreover, the surfaces of raw alfa were found to be smooth, which will result in a poor adhesion with the matrix (Fig. 9).



(a) (b)

(c)

Figure 8: Cross sections of alfa stem: a) lower extremity; b) middle; c) upper extremity

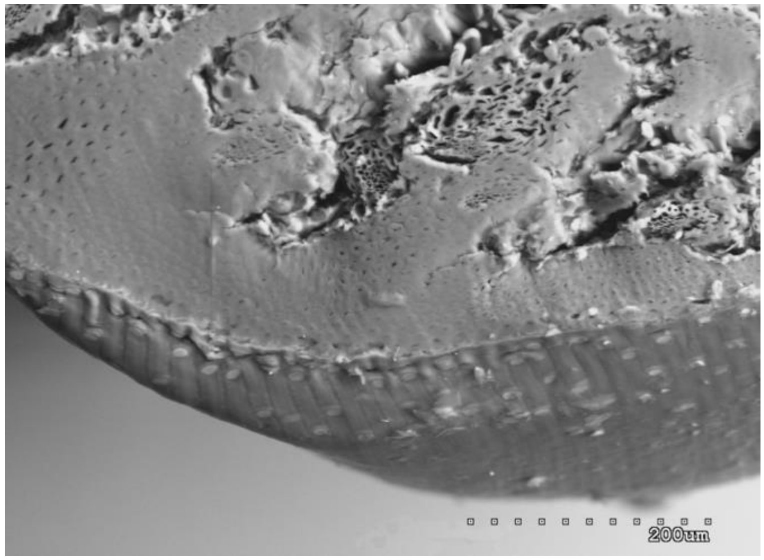
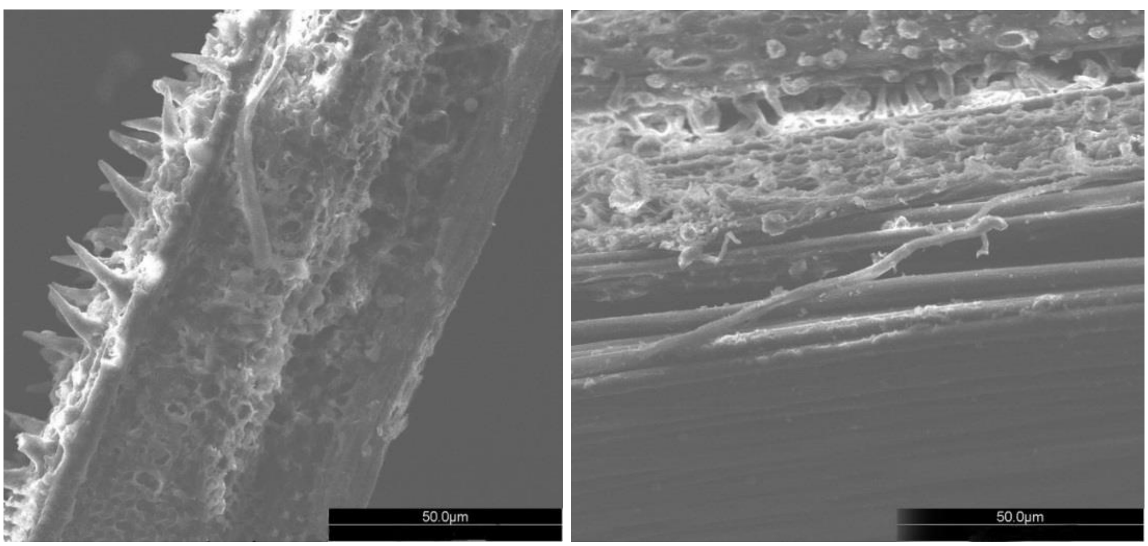


Figure 9: Alfa fibre

The effects of both treatments on the alfa fibre can be seen on Fig. 10. It is observed that salt water treatment produces a rough surface by only eliminating the wax, sand and dust that exist on the surface (Fig. 10(a)). On the other hand, the alkali treatment produces a rough surface and promotes the breakdown of the fibre bundle into smaller micro fibrils which enhance the effective surface area (Fig. 10(b)). In this way, the alkali treatment leads to a better fibre-matrix interface which increases the mechanical properties of the PP-A30-N composite compared to those of PP-A30-S.



(a) (b)

Figure 10: SEM images of treated alfa fibres: a) salt water and b) alkali solution

The fracture surfaces of non-recycled and recycled alfa and hemp composites are presented in Fig. 11. These observations show that the recycling induces a uniform dispersion of the hemp and alfa fibres within the composite (Figs. 11(b) and 11(d)). Moreover, it is also observed that the fibre diameter decreases after recycling especially for the alfa composites (Fig. 11b). In fact, fibres are aggregated into bundles and the recycling has induces their divisions, after a four injection cycle. This bundle division leads to a reduction in the fibre ratio and a proportional larger number of fibres with the injection cycles. As to the short fibre reinforced polymer, the aspect ratio is one of the most influential parameter on the mechanical properties. Mutje et al. [39] had found that there is a critical fibre aspect ratio, below which there is no possibility to reach a good strength transmission for any reinforcement. Accordingly, the reduction in the fibres aspect ratio can be the main reason behind the decrease in the mechanical properties of the studied composites with the recycling cycles. In fact, the diminution of the fibre dimensions with the recycling process makes some of them act like a filler instead of a reinforcement for the polypropylene matrix.

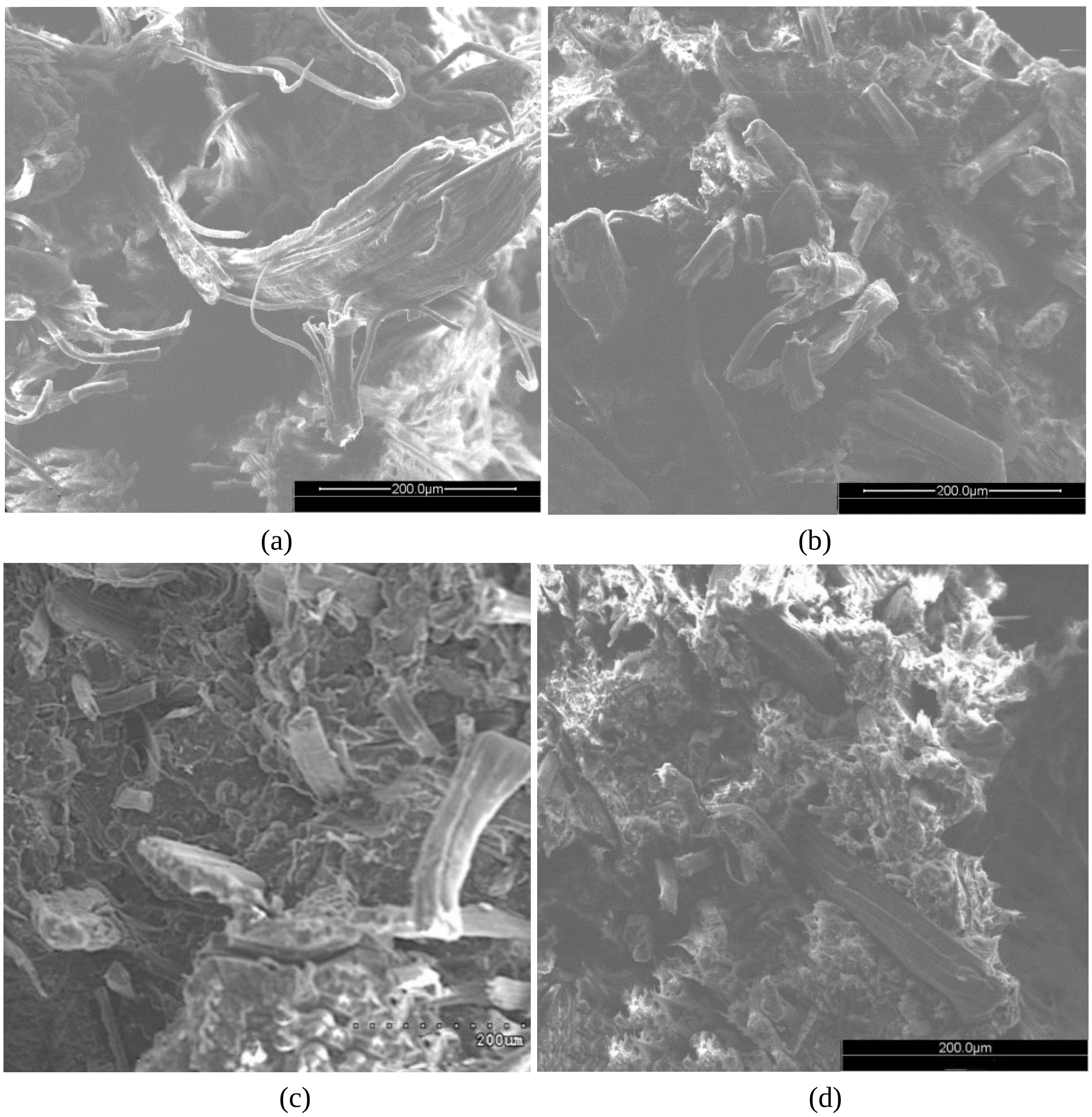


Figure 11: SEM images of the fracture surfaces of recycled and non-recycled composites: a) non-recycled PP-A30-N, b) PP-A30-N after four injection cycles, c) non-recycled PP-H30, d) PP-H30 after four injection cycles

4 Conclusion

This study aimed at investigating the recycling effect on mechanical and dynamical properties of short alfa and hemp fibres reinforced PP composite. For this purpose, alfa and hemp composites were elaborated by injection moulding process and recycled mechanically during four injection cycles. After that, the non-recycled and recycled composites were tested in static and dynamic tests in order to evaluate their mechanical properties and their evolution with respect to recycling cycles. Results of this study led to the following conclusions:

- The alkali treatment of the alfa fibre enhanced the properties of the PP-alfa composite when compared to the salt water treated materials. Besides, the alfa composite treated by alkali solution gave comparable tensile and flexural properties to those of hemp composite.
- Alfa-PP composites showed the lowest storage modulus and the highest loss factor compared to hemp composite.
- The injection cycles induced a deterioration in the alfa and hemp composites particularly at the fibre-matrix interface. Besides, the alfa fibre composites, especially those treated with alkali solution exhibited a mechanical response to recycling similar to that of hemp fibre. Thereby, mechanical recycling of PP/Alfa composites is one feasible option to re-use this type of material.
- The alfa fibre can constitute a potential reinforcement of polymer matrices in North African countries as there are other fibres in Europe such as hemp and flax fibres.

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