International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Effect of Sodium Hydroxide Concentration on the Surface and Mechanical Properties of Borassus Aethiopum Mart Fibre

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Abstract: ***The main objective of this study is to valorize the availability of the local material (borassus aethiopum mart fibers) of the West African sub region (Benin).This present study is focused on the determination of the mechanical properties of treated Borassus aethiopum mart fibres like tensile, elongation at break and the modulus of elasticity andthe characterization of the treatment effects on Borassus aethiopum mart fibre surface by means of Scanning Electronic Microscopy (SEM) analysis.Borassus aethiopum mart fibres undergone an alkaline treatmentat different concentrations of NaOH (3%, 5%and 10%) during different immersion periods of (1h and 3h). The results showed significant improvements in the tensile strength of the fibres treated with3%NaOH for 1hour and 3hours of the order of288.72and 233.54 respectively and 5% NaOH for 1hour and 3hours of the order of 252.5 $N/mm^2$and 216.14 N/mm^2NaOH compared to untreated fibres 210.45 N/mm^2. However, thetensile strengthof fibers treated with 10% NaOH for 1 hour, decreased considerably to 73.36 N/mm^2. This decrease in mechanical resistance is due to the high concentration of NaOH that weakened the fibres.***

Keywords: borassus aethiopum mart, mechanical properties, tensile strength, alkaline treatment, lignin, cellulose

1. Introduction

During the last decade, the use of natural fibres as reinforcement in composite materials has grown considerably (1). The latter compared to synthetic fibres offer several advantages such as: low cost, low density, improved tensile and flexural strength, thermal insulation and also the possibility of recycling(2). However, these natural fibres are not problem free. There are a certain number of difficulties associated with the integration of these fibres in the polymer matrices, in particular the fibre-matrix incompatibility (3).

Their structural compositions such as cellulose, hemicelluloses, lignin, pectin and waxy substances allow moisture absorption from the environment which leads to poor bonding with the matrix materials (4). Certain chemical treatment on natural fibres is needed to enhance the performance as reinforcement in polymer composite materials. The chemical modification directly influences the fibres structures and changes their compositions. As a result, moisture absorption tendency by the fibre is reduced facilitating better bonding with the matrix material (5). This provides better mechanical and thermal properties of fibre and composites (6).Several research activities have been conducted to improve fibre properties through different chemical treatments and their effects on the composites properties(5). The chemical treatment which is widely used is alkaline treatment(5). This treatment changes the orientation of highly packed crystalline cellulose order and forms amorphous region by swelling the fibre cell wall. This provides more access to penetration of chemical. Alkali sensitive hydrogen bonds existing among the fibres break down and new reactive hydrogen bonds form between the cellulose molecular chains. Due to this, hydrophilic hydroxyl groups are partially removed and moisture resistance property is improved(5). It also takes out certain portion of hemicelluloses, lignin, pectin, wax and oil covering materials (7). As a result, the fibre surface becomes cleaner and also mechanical properties of fibre are improved. However, when the alkaline concentration is higher than the optimum condition, excess delignification of the take place, which results in weakness or damage to the fibre(8; 7).

The objective of this present work is to evaluate the effect of sodium hydroxide concentration on the surface and mechanical properties (tensile, elongation at break and modulus of elasticity) of borassus aethiopum mart fibre. The main purpose of using alkaline treatment in borassusaethiopum mart fibre is to promote the fibre surface modification and improve the mechanical properties of the fibre.

2. Material and method

2.1 Material

Borassus aethiopum mart fibres come from borassus aethiopum mart plant which is a woody monocotyledon plant available in sub-Saharan Africa. It is very rich in fibre about 100 fibres percm^2. Its fibres brown in color are very long and can rich 10to15 cm. The fibres used for this study were taken from a piece of tree of about 1cm in the republic of Benin. Borassus aethiopum mart fibres are mainly composed of 62.57% cellulose, 19.52% lignin, 10.46% hemicellulose, and 7.45% extractives (9).

2.2 Pretreatment of Borassus Aethiopum fibres

The fibres were manually extracted from four pieces of borassus aethiopum mart tree which were divided using a wake machine. Then, they were soaked in water during 3 hours to facilitate the removal of contaminants and adherent dirt before being washed with distilled water. Thereafter, the fibres were dried in the open air for 24 hours at room temperature before being treated.

Figure 1*:* photography of untreated borassus aethiopum mart fibre

2.3 Alkaline treatment of borassus aethiopum mart fibres

Borassus aethiopum mart fibres were treated with sodium hydroxide at different concentration(3,5 and10%) and during immersion periods of 1and 3 hours. Sodium hydroxide was prepared by dissolving pellets in distilled water. The mass of sodium hydroxide(NaOH) varied depending on the concentration of the solution.

The quantity of NaOH used in terms of percentage was calculated based on the following notion. For 1Molarity of NaOH must be dissolved in 1000cm3 of water which is 1liter and as 1M(NaOH= Na=23g, O= 16g, H= 1g ⇒ 23g+16g+1g= 40g) which means 40g of NaOH to be dissolved in 1liter. In term of percentage: (40g/1000g)×100=4% NaOH. Meaning 3% of NaOH=30g, 5% NaOH= 50g and 10% NaOH =100g.

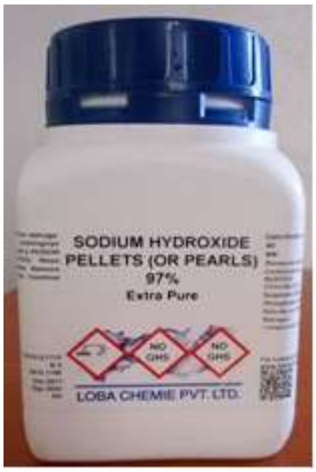


Figure 2: NaOH used for the treated fibres

Figure 3: Weight of NaOH pellets per percentage

To prepare 3% sodium hydroxide, 30 grams of NaOH pellets were weighed and then dissolved in 1 liter of distilled water in order to form 1 liter solution. Firstly, take the volumetric flask of 1liter capacity, and then add sodium hydroxide pellets slowly to distilled water in order to optimize the treatment. Similarly, the other concentrations were measured as 5% NaOH: 50 grams and 10% NaOH: 100 grams. This alkaline treatment was done during 1and 3hours for 3%and 5% NaOH and 1 hour for 10% NaOH only.

Table 1: weight of NaOH pellets in grams

Percentage of sodium hydroxide	Weight of sodium hydroxide in grams
3%	30
5%	50
10%	10

Figure 4: mixing of sodium hydroxide solution

After, the treatment the fibres were rinsed five times with distilled water to remove traces of NaOH on the fibres. Thereafter, the fibres were dried under the sun before scanning electron microscopy observation on the morphology of the fibres.

2.4Mechanical testing of untreated and treated fibres

Tensile tests of untreated and treated borassus aethiopum mart fibres (using 3%, 5%, and 10% of NaOH) were performed using Hounsfied Tensometer machine of 300N capacity based on the standard method for tensile properties of single textile fibre **(ASTM D3822-01)**at the University of Nairobi in mechanical engineering laboratory. For each treatment of fibre, 3 specimens were tested in order to take the average.

The stresses were calculated using the formula: $\boldsymbol{\sigma = F/S}$ where **F** is the tensile force in Newton (N) and **S** the cross section of the fibrein mm^2 which was calculated by determining first the size of a fibre by using a **Vernier Caliper.** The sections calculated are between 0.91 mm^2 and 1.07 mm^2 for the treated fibres and 1.1 mm^2 for the untreated fibres.

The deformations were calculated using the formula $\mathbf{A}(\%) = \mathbf{100}(\mathbf{L} - \mathbf{L_0})/\,\mathbf{L_0}$, where $\mathbf{L_0}$is the initial length and **L** the length after deformation. The modulus of elasticity was also calculated after the calculation of the two previous parameters.

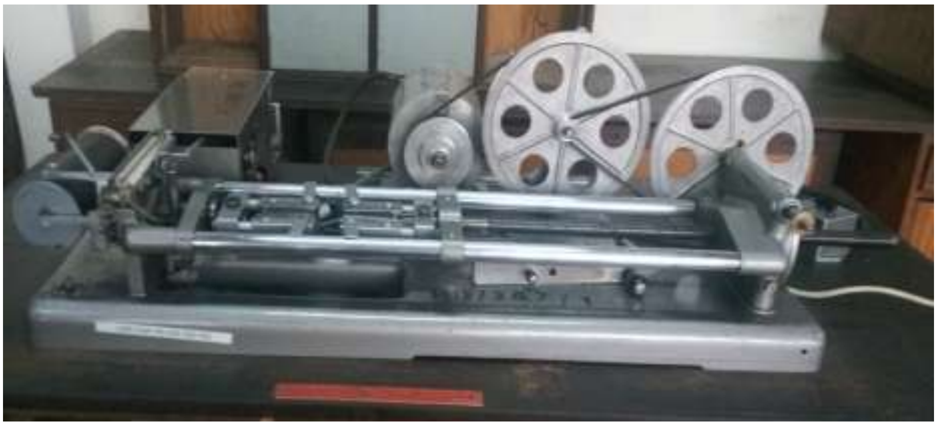


Figure 5: Tensile strength test machine for the determination of tensile force of fibre

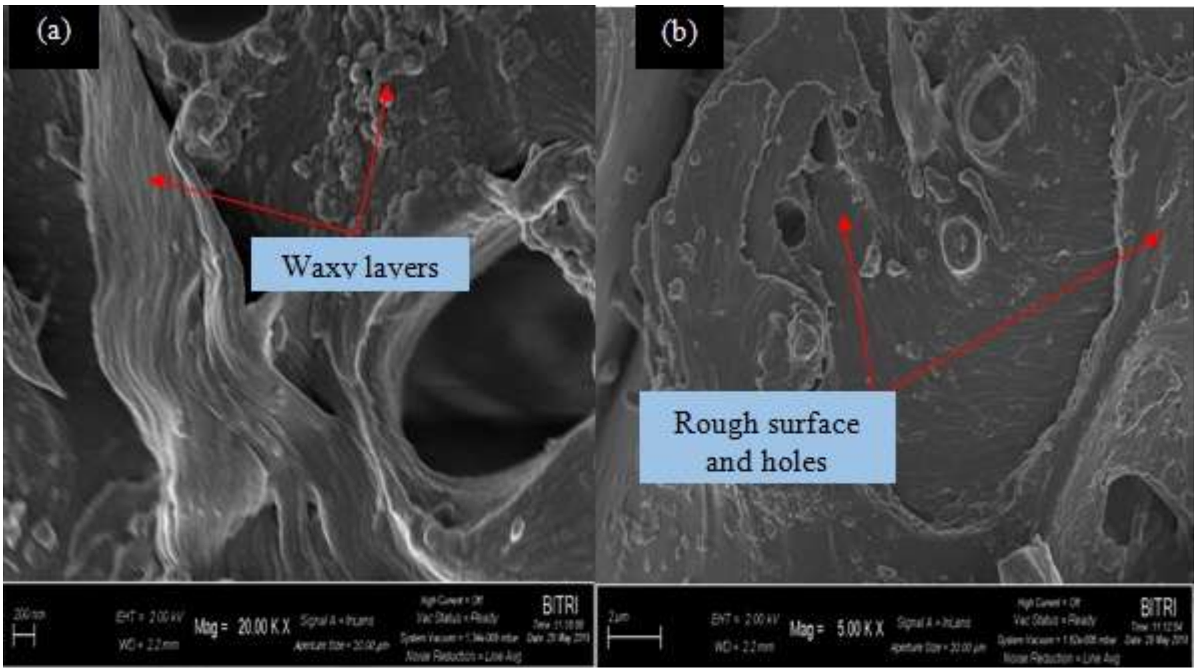
3. Results and Discussion

3.1 Effect of chemical treatment on the surface of borassus aethiopum fibres

The alkaline treatment on fibres by NaOH removes a certain amount of lignin, hemicellulose, waxes, oils, cuticles and impurities that cover the surface of external fibres. The treatment with NaOH of natural fibres allows the ionization of hydroxyl group of alcoholate(7).

$\text{Fibre} - \text{OH} + \text{NaOH} \rightarrow \text{Fibre} - \text{O} - \text{Na} + H_2O$

Thus, Scanning Electron Microscopy (SEM) provides a better technique for the examination of surface morphology of fibers. Changes in the morphology of fibres during treatment at different concentrations of NaOH are very remarkable.



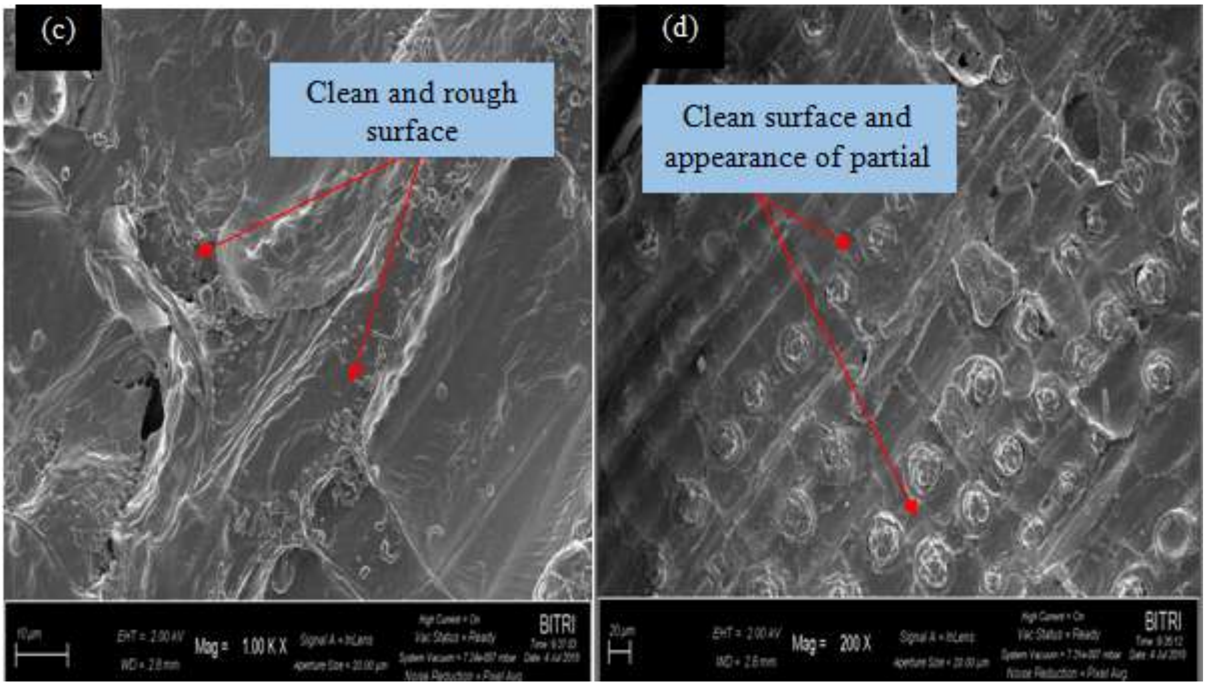


Figure 6: SEM micrographs of (a)untreated fibre, (b)3%NaOH-treated fibre,(c)5%NaOH-treated fibre and (d) 10%NaOH-treated borassus aethiopum mart fibre(at 1h treatment)

Figure 6 shows the SEM micrographs of the untreated and treated borassus aethiopum mart fibres surface. Fig 6 (a), shows the SEM micrograph of the untreated fibre surface that displays the presence of waxy layers which is a protective layer that lodge in the surface of natural fibre. These layers prevent a good adhesion between the fibre and matrix. Fig.6(b) shows the micrograph of treated fibre surface with 3%NaOH at 1h. it can be seen that the presence of waxy layers at this stage stars to be removed and the surface becomes rough with the presence of holes. From fig.6 (b), the effects of NaOH can been noticed. Fig.6(c) shows the fibre surface with 5%NaOH at 1h. at this stage the surface of the fibre becomes more clean compare to the previous figures. This is due to the increase in the concentration of NaOH which has enhanced the surface characteristics of the fibres. Researchers reported that increasing the concentration of alkaline treatment leads to the reduction of cementation components which allows good fibre-matrix bonds.

Fig.6(d) shows the SEM micrograph of the fibre surface treated with 10%NaOH at 1h. this micrograph displays a very clean surface compare to the two previous one. This is due, to the higher concentration of NaOH that has enhanced the surface characteristics of the fibre by removing the waxy layers from the surface of the fibre. This also increases the effective surface of adhesion with the matrix. Therefore, an improvement of the mechanical properties of the composite is increased(10; 1)

3.2 Tensile strength of untreated and treated borassus aethiopum mart fibres

The tensile strength of untreated and treated fibre were investigate and the results are given below

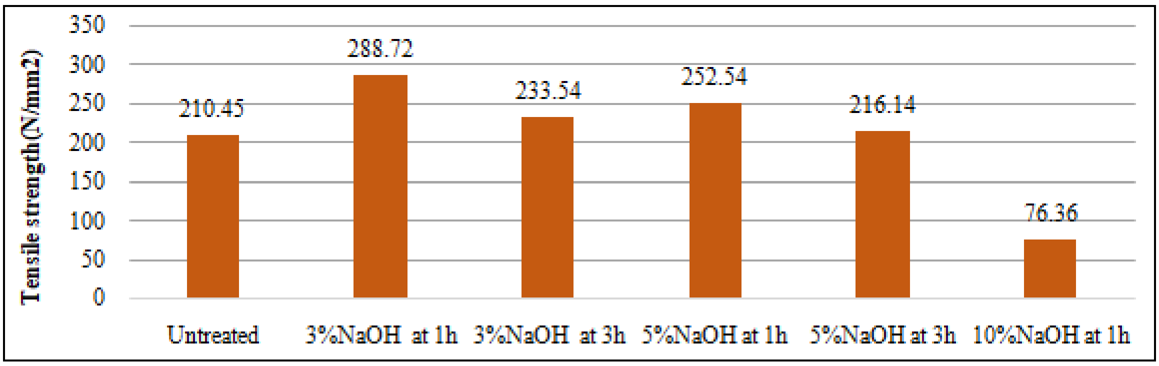


Figure 7: variation in tensile strength of untreated and treated fibres at 1-hour of immersion

The results of tensile test showed that alkaline treatment gives change on tensile strength of BAMF. A positive treatment effect was observed with the fibers treated with 3 and 5%NaOH solution when the fibers were treated at 1 and 3h immersion period as compared to the untreated fibers. When the fibers were treated with 10%NaOH solution at 1h, a decrease in tensile strength was observed.

Fig.7 shows the variation in tensile strength for untreated and treated fibers at different concentration of NaOH and at different immersion period of 1h and 3h. From the data presented in figure 7, it was first observed that, the tensile strength of treated BAMF increased with the lower concentration (3 and 5%) of NaOH and decreased with higher concentration (10%). This increase in tensile strength for 3 and 5%NaOH can beattributed to the fact, the alkaline treatment result in an improvement of fiber surface by making it uniform due to the elimination of micro voids in the fibers(11). Hence, the improvement in tensile strength of the fibers. On the other hand, the decrease in tensile strength of BAMF treated with 10%NaOH at 1h may be attributed to the high concentration of NaOH applied that yielded the main construction components of the fibers to be attacked(12). In addition, researchers reported that, the treatment of the fibers can increase or decrease the strength of the latter, that is to say, the alkali concentration must not be higher than the optimum condition (13).

Secondly, by referring to figure 7 it was observed that, BAMF treated with 3 and 5%NaOH at 1h offered better tensile strength than BAMF treated with 3 and 5%NaOH at 3h. This variation in tensile strength of the fibers treated with the same NaOH concentration but at different immersion period is clearly attributed to the long period of immersion. In fact, as the chemical treatment is to remove the weak boundary layers of natural fibers, the time of immersion could affect the properties of the latter(14). This means the time of immersion must also be optimized in order to come with better tensile strength.

3.3 Elongation at break (%) of untreated and treated borassus aethiopum mart fibres

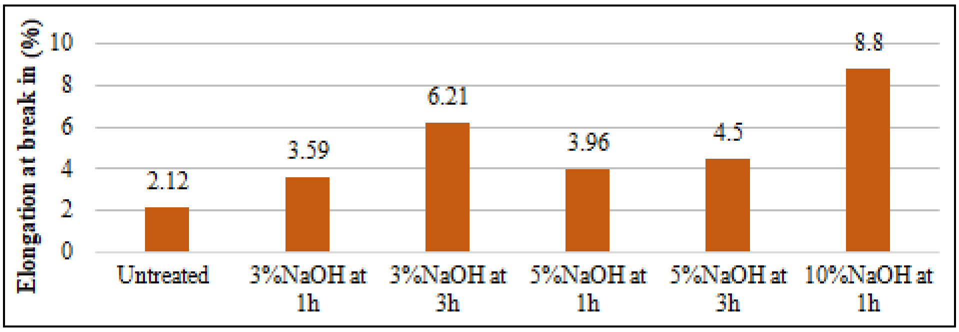


Figure 8: variation in elongation at break of untreated and treated fibresat: 1h and 3h immersion

Figures 9 show the variation in percentage of elongation at break of the untreated and treated fibres. It was observed that the elongation increased with the increase in the concentration of sodium hydroxide. The elongation at break for treated fibres with 5NaOH at 3h and 10%NaOH at 1h are 6.21and 8.8% respectively are higher than 5% that means at this level of the treatment borassus aethiopum fibres present characteristics of ductile material. This leads to good interfacial adhesion of the fibre and matrix and improve the mechanical properties of the composites. However, it was observed that the elongation at break for untreated and treated fibres with 3%NaOH at 1and 3h and 5%NaOH at 1h are 2.12; 3.59; 3.96 and 4.5% respectively are less than 5% that means the fibres presents characteristics of fragile material.

3.4 Modulus of elasticity(GPa) of borassus aethiopum mart fibres

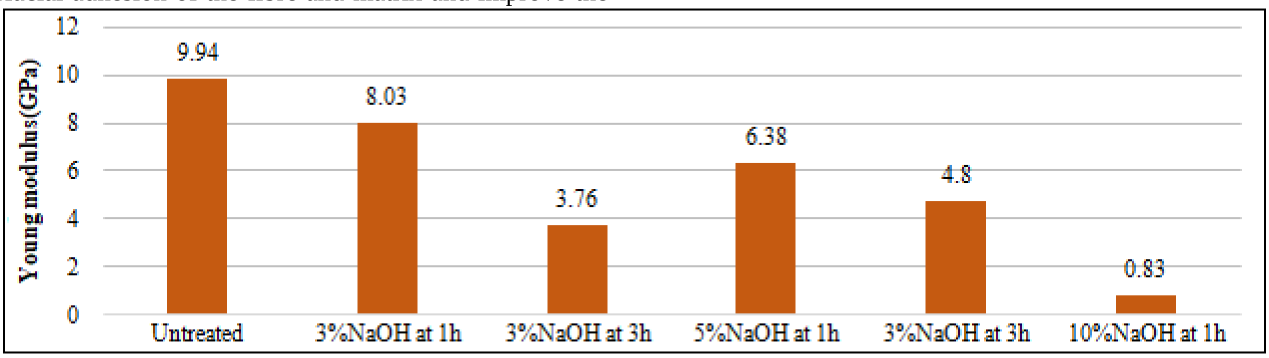


Figure 9: Variation in modulus of elasticity of untreated and treated fibresat 1h and 3h

The above figures indicate the modulus of elasticity of untreated and treated fibers. Firstly, it was observed that the modulus of elasticity was significantly reduced for the increased elongation and increased for decreased elongation. Secondly, it was observed that the modulus of elasticity started to decrease from the untreated to the treated fibers. This decreasing in modulus of elasticity is also due to each concentration of sodium hydroxide/ to the time of immersion used for each treatment. This decreasing in modulus of elasticity makes the fibers of borassus aethiopum mart to become more flexible, which is good for this kind of material vis-à-vis its utilization in the mortar blocks.

4. Conclusion

From the experimental results obtained, it can be concluded that:

The alkaline treatment of borassus aethiopum fibres with 3%, 5% and 10% of NaOH leads to the improvement of the borassus aethiopum fibre surface by the removal of waxy layers and impurities and allows a good interfacial adhesion if the fibre are used in the matrix.

The tensile strength increased with the fibre treated with 3%NaOH during 1hour. However, the alkaline treatment of borassus aethiopum fibres for a higher concentration of NaOH weakened the fibres and reduces their mechanical properties at 10%NaOH at 1h.

The results of this work, suggest that the treatment of borassus aethiopum fibres with NaOH like other natural fibres used as reinforcement in the matrix could lead to the increase of mechanical properties of composite material.

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