

Comparative Mechanical Analysis of Okra Fiber and Banana Fiber Composite Used in Manufacturing Automotive Car Bumpers

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Abstract

This work reports the effects of varying fiber length and percentage composition of tensile strength of okra and banana fiber reinforced composite. The fibers were mixed with 10%, 30%, and 50% okra and banana fiber content before chopping them to lengths of 10mm, 30mm and 50mm. The fibers were treated with 2% of NaOH, for an hour under constant stirring and allowed for 24hrs at room temperature and then dried in open air for 6-7days. The purpose of chemical treatment is to remove the moisture content on the fibers and to increase the tensile strength of the fibers. The fibers were subjected to tensile strength test and the result shows that the optimum combination of banana fiber length and its content is on 50mm length and 30% banana fiber content, while the okra fiber shows optimum value to be on 30% okra fiber content at 10mm length. Investigations, research and development study are still on going for the determination of the optimum combination to yield the desired properties.

Keywords

Fiber Length, Tensile Strength, Okra Fiber, Banana Fiber, Reinforced Fiber

1. Introduction

Development of more efficient material is very crucial for the improvement of new products nowadays. For this purpose, the interest in natural fiber reinforced polymer composites is swiftly increasing mutually in terms of their industrial applications and fundamental research especially in the automotive industries. It is used in fabrication of vehicle body; this reduces the weight of the vehicle and consequently reduces CO₂ emissions and fuel consumption to the required target in the transportation sector (Chidiebere et al 2015). Minimizing the use of fuel in order to reduce emissions is an important short-term and long-term goal. In order to reduce the amount of fuel consumption, more fuel efficient vehicle models should be produced as well as operating exiting ones

efficiently (Metu et al 2014).

This work presents the mechanical analysis of both okra and banana fiber composite. These engineered bio-composites are opening new markets in the field of commercial construction, automotive, aerospace and also reducing effects on the environment such as energy, air, water, and waste (Longanathan et al, 2014). Natural fibers have many distinctive advantages over other fillers with its limitless application areas (Chukwunye et al. 2015).

Composites are widely used but the mechanical properties of polymers are inadequate for many structural purposes (Santhosh, et al 2014). These problems are solved by reinforcing other materials with polymers. Reinforcement provides strength and rigidity to help and support the structural load. Composites are economical, renewable, completely or partially recyclable, and biodegradable. Many

lignocellulosic fibers like banana, sisal, bamboo, hemp etc. are more and more often applied as the reinforcement of composites. Sergio N. M. et al 2012 opined that the less common lignocellulosic fibers certainly possess an engineering potential, of both strength and stiffness, for polymer composite reinforcement. In addition to future specific works on the mechanical properties of these less common natural fiber composites, the thermal stability of such composites will also need to be investigated for practical use. Natural fibers such as banana and okra fibers have been studied as reinforcement and filler in composites.

Manish Kumar et al (2011) studied pulping of banana fiber for production of fiber, film and paper. Five pulping techniques have been explored. They include namely Kraft process, sulphite process, soda process, formic acid /acetic acid solvent and Urea/NaOH solvent system. These pulping methods are clarified under mechanical and chemical pulping fractions. Maleque, M.A. (2006) reported on mechanical properties of pseudo-stem banana fiber reinforced epoxy composite with a view to improving virgin epoxy material. It was observed that there were increase in tensile strength, flexural strength, impact strength and better ductility as shown in table 1.

Table 1. Mechanical properties of pseudo-stem banana fiber reinforced epoxy composite.

Material Properties	Level Reinforced Composite	Epoxy Material	Unit
Tensile strength			
Flexural strength	75	55	MPA
impact	7	5	KJ/m ²

Bernstad et al, (2012) presented on estimation of potential fiber recovery from banana pseudo-stem. The potential fiber extraction was gotten from the waste and also discovered that banana pseudo-stems have a high content of glucose and cellulose. Indira, K.N. et al (2013) studied mechanical properties and failure topography of banana fiber macro composites fabricated by RTM and CM Techniques. These were done with banana fiber reinforced phenol formaldehyde composites with different fiber lengths and fiber loadings prepared by compression molding (CM) and resin transfer molding (RTM) techniques have also been studied, putting into consideration the mechanical properties such as tensile, flexural, and impact behavior. RTM composites showed improved tensile and flexural properties as compared to CM composites. On the other hand, impact strength of RTM composites is slightly lower than that of CM composites. It was also discovered that mechanical properties increased with the increase in fiber loading, and then subsequently decreased with an increase in fiber loading in both techniques. At high fiber weight fractions, the strength decreased due to poor wetting and very poor stress transfer. The stress value increased up to 30mm fiber lengths and then decreased. In order to examine the fracture surface morphology of the composites, scanning electron microscopy (SEM) was performed on the composite samples. A good relationship between morphological and mechanical

properties has been observed. The mechanical properties of banana fiber/PF resin composites fabricated by RTM and CM techniques were analyzed as a function of fiber length and fiber loading. Tensile and flexural properties were found to be higher in RTM composites as compared to CM composites at all values of fiber loading. At higher fiber lengths, the stress value was lowered due the entanglements and fiber curling. The optimized fiber length was 30 mm. It was found that increasing the fiber content had a positive effect on the tensile and flexural strengths. The tensile and flexural properties increased with fiber loading. Andre L. P. et al (2014) studied on how banana pseudo stem fibers are composed of varying lignocellulosic composition throughout the diameter. The comparison of lignocellulosic content and physiochemical properties of different sheaths of pacovan banana pseudo stems were explored. The sheaths underwent series of experiment such as x-ray diffraction, Fourier transform infrared spectroscopy, thermo gravimetric analysis and differential scanning calorimetry measurements. From there work there were significant difference ($p < 0.05$) in the form analyzed lignocellulose fractions of pacovan banana also the outer sheaths were more suitable for α -cellulose extraction while the core was more suitable for extractives extraction and macro molecule increased radially from the core to the outer sheath. Marwan M. and Nasim U. (2015) studied the effect of Banana Fibers on the Compressive and Flexural Strength of Compressed Earth Blocks. The deflection at the mid-span of the blocks studied was calculated using the Linear Variable Differential Transformer (LVDT). From the study, samples reinforced with 50 mm fibers performed better, in both flexural and compressive strength, compared to the unreinforced samples and specimens reinforced with different variations of 25 mm fibers. The highest flexural and compressive strength values were recorded at reinforcement with 50 mm fibers and 0.35% fiber content by weight. The results made plain that the treated 50 mm fibers were the better performing fiber in this study. Santhosh J. et al (2014) studied the properties of banana fiber reinforced composites. They also showcase mechanical properties of untreated/alkali treated banana fiber/epoxy, untreated/alkali treated banana fiber/vinyl ester and treated banana/coconut shell powder/epoxy, treated banana/coconut shell powder/vinyl ester hybrid composites were investigated. The tensile, flexural and impact properties of the composites as a function of fiber content were analyzed. The surface modification by alkali treatment has improved the mechanical properties than untreated fiber composites. The alkali treatment of banana fiber has improved the mechanical properties like tensile, flexural and impact strength of both the epoxy/vinyl ester and hybrid composite. The authors concluded that the alkali treatment has provided better mechanical properties. In future various other natural reinforcing material could be used to mix with banana fiber to form a better hybrid composite which has a better mechanical properties and as well as cost effective. Ezema I. C. et al. (2014) studied the effect of surface treatment and fiber orientation on the tensile and

morphological properties of banana stem fiber reinforced natural rubber composite. A mixture of NaOH and Na₂SO₃ was used in modification of banana stem fibers (BSF). Unidirectional BSF reinforced natural rubber (NR) lamina composites were made using compression molding method. The results of the tensile loading in 0°, 45° and 90° to the fiber directions of the composite with fiber mass fraction of 30% were studied. Surface modification of the BSF with a mixture of 4% NaOH and 2% Na₂SO₃ increased the tensile strength and elastic modulus of the composite to 4.03 MPa and 147.34 MPa respectively from 3.12 MPa and 84.30 MPa of the untreated. Variation in properties due to fiber orientations was observed indicating a higher value of properties in the 0° fiber orientation than in 45° and 90° directions. The result of scanning electron microscope (SEM) micrographs of the surfaces of the fibers indicated an improvement in bonding of the fiber bundles prior to lamination with natural rubber as a result of surface treatment which resulted in its higher tensile strength. Paulo P. et al. (2013) studied characterization of HDPE reinforced with banana peel fibers. These samples of washed banana fibers and HDPE composites were characterized by tensile tests and thermal analysis.

Srinivasababu N. et al (2009) shows that chemically treated Okra fiber reinforced composites is better choice than other composites like sisal and banana fiber reinforced polyester composites because it shows highest tensile strength, tensile modulus and Specific tensile strength. They also stated that chemically treated okra fiber reinforced polyester composites at maximum volume fraction showed tensile strength, modulus of 154.17%, 114.13% and specific tensile strength and modulus of 12.26%, 129.82% higher than that of the pure polyester specimen, respectively. The effect of chemical treatment (i.e. bleaching, alkalization) was studied by Arifuzzaman Khan G. M. et al 2009, opined that chemically treated okra fiber has better surface properties while maintaining good inherent mechanical properties. According to them, the fiber is expected to act as a compatible reinforcing fiber with several hydrophobic resin systems both thermoplastic and thermosetting for the preparation of high performance composites. Igor Maria De Rosa et al (2009) studied the morphological, thermal and mechanical characterization of okra (*Abelmoschus esculentus*) fibers as potential reinforcement in polymer composites. Their results of the thermal and mechanical characterization, which are comparable to those of other common lignocellulose fibers, confirm that okra fibers show some potential as reinforcement in polymer matrix composites. Loganathan V.N. et al (2014) investigations indicated that, it is possible to enhance the properties of natural fiber reinforced composites through varying the fiber and matrix percentage. It was found that the natural fiber composites show maximum mechanical properties between 25% - 30% of the fiber reinforcements. These natural fibers offer a number of advantages over traditional synthetic fibers because of their superior corrosion resistance, excellent thermo-mechanical properties and high strength to weight

ratio. So, the natural fibers present many advantages as compared to synthetic fibers which make them attractive as reinforcement in composite materials, Shrikant M. Harle (2014). Srinivasababu N. et al (2009) also affirmed that okra fiber composites are useful for the preparation of doors for house hold purposes with light weight. Reem Sabah M. (2012) argued that several natural fiber composites possess similar mechanical properties with glass fiber composites, and they are applied in automobile and furniture industries. According to him Natural Fibers are renewable raw materials and they are recyclable. Further research work needs to be carried out in the development of natural fiber composites. This is important if new improved materials are to be developed for safe usage against crack growth and environmental pollution. Isa M. T. et al 2014 reported in his work that the composite (i.e. short okra and glass fiber hybridized) have properties which suggest their suitability for application in the building and construction industries as panels for partitioning and flooring or wall coverings, architectural landscaping to replace the hardwood currently used hence, preserving the environment.

The use of natural fibers is gaining popularity in many sectors especially in the automotive industries (Chukwunyelu et al 2015). Modern developments in automotive industry have seen emphasis towards addressing sustainability matter in operational requirements of components during the early stage of design. There are key problems facing the automotive industry, they include; global competition, need for efficient vehicles, cost reduction, greener environmental and safety requirements. These problems are largely influenced by the type of material used in automotive design processes. Consequently lighter materials mean lighter vehicles and low emission. Thus, composites are being used increasingly in automotive industry due to their strength, quality and light weight (Ahmed, 2013). These composites with good strength to weight ratio are good alternatives to conventional steels used in the manufacture of automobile body parts, bumpers etc. Prabhakaran et al (2012) reported that weight reduction with adequate improvement of mechanical properties has made composites as a viable replacement material for conventional steel and also absorb more collision energy than steel bumper

2. Experimental

2.1. Material

The selected raw material used for this study is okra fiber and banana fiber reinforced with Vinyl-ester resin.

2.2. Chemical Treatment of Okro and Banana Fibre

The fibers were chopped of length 10mm, 30mm and 50mm length and were treated with 2% of NaOH, for an hour under constant stirring and allowed for 24hrs at room temperature and then dried in open air for 6-7days. The purpose of chemical treatment is to remove the moisture

content on the fibers and to increase the tensile strength of the fibers.

Vinyl Ester is a resin produced by the esterification of an epoxy resin with an unsaturated monocarboxylic acid. The reaction product is then dissolved in a reactive solvent, such as styrene, to 35-45percent content by weight.

It can be used for an alternative to polyester and epoxy materials in matrix or composite materials, where its characteristics, strengths and bulk cost intermediate between polyester and epoxy. Vinyl ester has wide application in vinyl ester fiber glass-reinforced structures due to increased corrosion and resistance and ability to withstand water absorption. It is used to manufacture fiber reinforced polymer tanks and vessels. In this work, vinyl ester served as the matrix material for the production of okra and banana fiber reinforced polymer composite.

2.3. Mold Preparation

A mold of inner cavity of 163 x 12.5 x 6mm was used in the experiment. The mold cavity was cleaned to remove particles and then coated with layers of releasing agent (wax) for easy removal (De-molding) of the composite. Polyvinyl acetate (PVA) is applied which will form a water proof like surface on the composite and the mold is allowed to dry.

2.4. Composite Fabrication

The composite were produced using okra and banana fiber as a reinforcement and vinyl ester resin as a matrix material. Comprehensive literature review on mechanical behavior of polymer composites reveals that control parameters i.e. fiber length (fl) and fiber volume (vf) etc. largely influence the mechanical properties of polymer composites. Composite materials were fabricated using a simple hand layup technique. The control parameters used and their levels are given in table 2,

Table 2. Control parameters and their levels.

	Level 1	Level 2	Level 3
Fiber volume fraction (vf) in%	10	30	50
Fiber length (fl) in mm	10	30	50

The fibers were chopped of length 10mm, 30mm and 50mm before chemical treatment. The proportion of fiber (10%, 30% and 50% by weight of each 10mm, 30mm, and 50mm). The fibers were laid in the mold by a simple hand lay out technique and impregnated with the epoxy resin and allowed for curing.

2.5. Tensile Test

The tensile test is performed on specimens according to ASTM test standard D638-03 on a universal testing machine instron 3369. The cross head spread was maintained 2mm/min, at a temperature 22°C and humidity 50%.

In each case three samples are taken average value are recorded. In each case three samples were tested and average value was recorded. Specimen used for the test was cut to

size and required shape using a hand saw.

3. Results and Discussion

The analysis of the mechanical properties of composite materials containing banana and okro fiber is presented. Mechanical properties of composites such as tensile strength, strain, young modulus has been investigated and also discussed. These properties of the composite mainly depend on some factors such as fiber content and length.

Figure 1 shows the result for the tensile strength of composite containing banana fiber of 10mm length with content of 10%, 30% and 50%. The result shows that the tensile strength of the composite increases with increase in banana fiber. The three plots on the average have a constant stress value of 28.72N/mm² at the strain of 0.0047. 50% banana fiber content has the highest tensile strength value of 98.68N/mm² while the least is for 10% banana fiber content with a value of 78.95N/mm². Thus the increase in banana fiber content of the composite from 10% to 50% yields approximately 30% increases in the tensile strength of the composite.

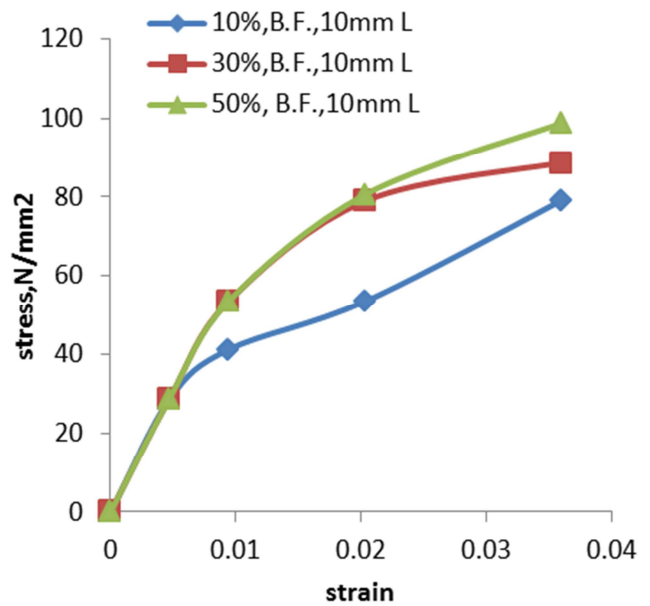


Figure 1. A graph of Stress vs. Strain for Banana Fiber of 10mm Length (Tensile Strength).

Figure 2 shows the result for the tensile strength of composite containing banana fiber of 30mm length with content of 10%, 30% and 50%. Generally; the result shows an increase in tensile strength of the composite as banana fiber content increases. However, the plots of 30% and 50% banana content are seen to have the same tensile strength. This shows that at the fiber length of 30mm and 30% banana fiber content, any further increase in the banana content does not increase the tensile strength of the material. 50% and 30% banana fiber content has the highest tensile strength value of 135.69N/mm² while the least is for 10% banana fiber content with a value of 45.23N/mm². Thus the increase

in banana fiber content of the composite from 10% to 30% or 50% yields about 200% increases in the tensile strength of the composite.

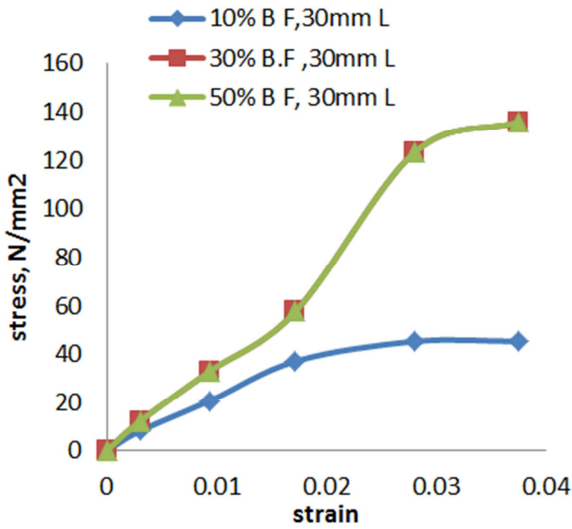


Figure 2. A graph of Stress vs. Strain for Banana Fiber of 30mm Length (Tensile Strength).

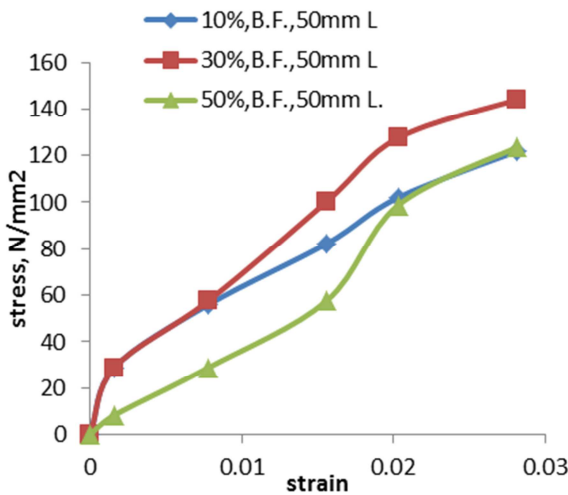


Figure 3. A graph of Stress vs. Strain for Banana Fiber of 50mm Length (Tensile Strength).

Figure 3 shows the result for the tensile strength of composite containing banana fiber of 50mm length with content of 10%, 30% and 50%. Contrast to figure 1 and 2, the result does not show an increase in tensile strength of the composite as banana fiber content increases. Rather, the optimum tensile strength for the three plots is on 30% banana fiber content with a tensile strength value of 143.91N/mm² while the minimum is on 10% banana content with a tensile strength value of 121.71N/mm². Thus the increase in banana fiber content of the composite from 10% to 30% yields approximately 18% increases in the tensile strength of the composite while the increase in banana content from 30% to 50% causes a significant decrease of about 14% in the tensile strength of the

material.

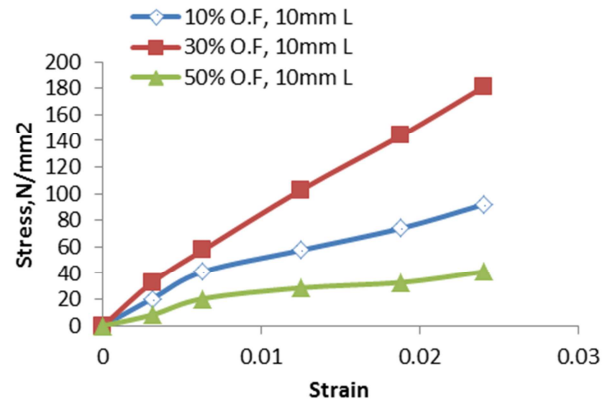


Figure 4. A graph of Stress vs. Strain for Okra fiber of 10mm Length (Tensile Strength).

Figure 4 shows the result for the tensile strength of composite containing okra fiber of 10mm length with content of 10%, 30% and 50%. Figure 1 and 4 have the same length of banana and okra fiber respectively, but with an unequal strength. Contrast to figure 1, the tensile strength does not increase with the increase in okra fiber as shown in figure 4. Rather, the optimum tensile strength for the three plots on figure 4 is on 30% okra fiber content with a tensile strength value of 180.92N/mm² while the minimum is on 50% okra fiber content with a tensile strength value of 41.11N/mm².

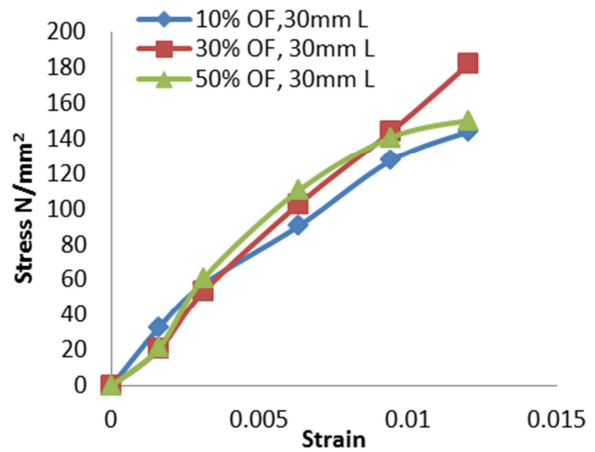


Figure 5. A graph of Stress vs. Strain for Okra fiber of 30mm Length (Tensile Strength).

Figure 5 shows the result for the tensile strength of composite containing okra fiber of 30mm length with content of 10%, 30% and 50%. Generally; the result shows an increase in tensile strength of the composite as okra fiber content increases. The optimum tensile strength for this plot is on 30% okra fiber content with a tensile strength value of 181.69N/mm² while the minimum is on 10% okra fiber content with a tensile strength value of 143.91N/mm².

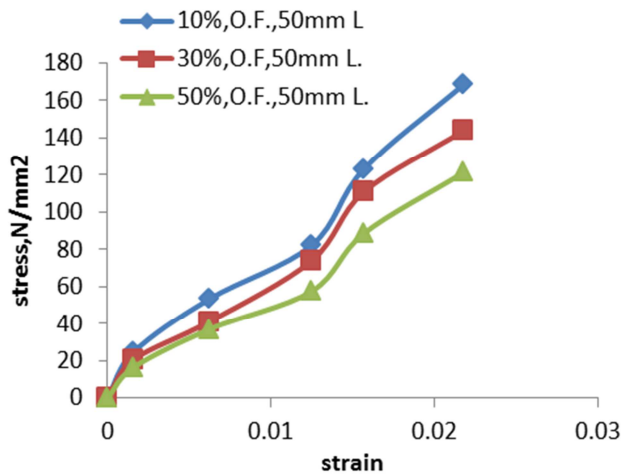


Figure 6. A graph of Stress vs. Strain for Okra fiber of 50mm Length (Tensile Strength).

Figure 6 shows the result for the tensile strength of composite containing okra fiber of 50mm length with content of 10%, 30% and 50%. The tensile strength decreases as the percentage of okra fiber increases. The optimum tensile strength for this plot is on 10% okra fiber content with a tensile strength value of 168.59N/mm² while the minimum is on 50% okra fiber content with a tensile strength value of 121.31N/mm².

4. Conclusion

This work reports the effects of varying fiber length and percentage composition of tensile strength of okra and banana fiber reinforced composite for automobile application. The fibers were mixed with 10%, 30%, and 50% okra and banana fiber content before chopping them to lengths of 10mm, 30mm and 50mm. The fibers were treated NaOH, The purpose of chemical treatment is to remove the moisture content on the fibers and to increase the tensile strength of the fibers. The samples were subjected to tensile strength test and the results as displayed in figures 1, 2 and 3 shows that the optimum combination of banana fiber length and its content is on 50mm length and 30% banana fiber content, while the analysis of figures 4, 5 and 6 shows optimum value to be on 30% okra fiber content at 10mm length.

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