Exploring Leaf Date Palm Fibers as Reinforcement for Geopolymer Composites made from Mining Waste

Hassan CHKALA[a,*], Said IGHIR[a], Mohamed CHIGR[a], Nour-Eddine EL MANSOURI[a]

a) Laboratory of Molecular Chemistry, Materials and Catalysis, Faculty of Science and Technology, Sultan Moulay Slimane University, Beni-Mellal, Morocco.

E-mail address of the corresponding author: hassan.chkala@usms.ma (H.CHKALA).

Introduction

The progress of global sustainable development and eco-friendly goals depends on the sustainability of materials. Geopolymer-based materials have emerged as an environmentally aware, efficient, and sustainable alternative for construction and building applications. However, these materials have some limitations, such as brittleness, limited deformation capacity, and low flexibility. To address these issues, a sustainable strategy involves incorporating natural fibers, like palm fibers, into geopolymer matrices. Therefore, this study examines the effect of adding leaf date palm fibers (LDPFs) in various concentrations (0.5%, 1%, 2%, 3%, and 4% by weight) into a geopolymer matrix derived from mining waste, with a focus on the mechanical, physical, and morphological properties of the resulting composites.

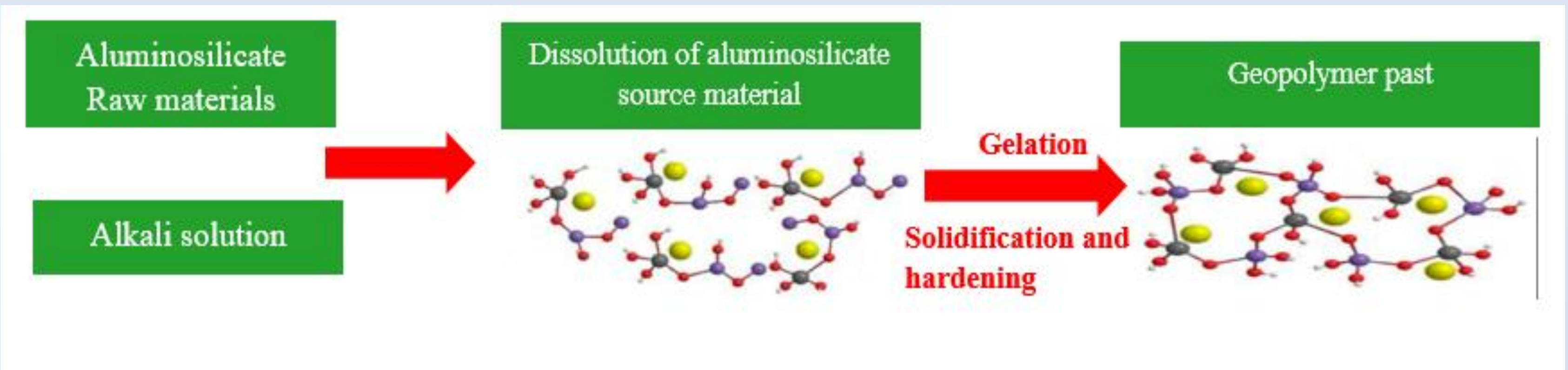
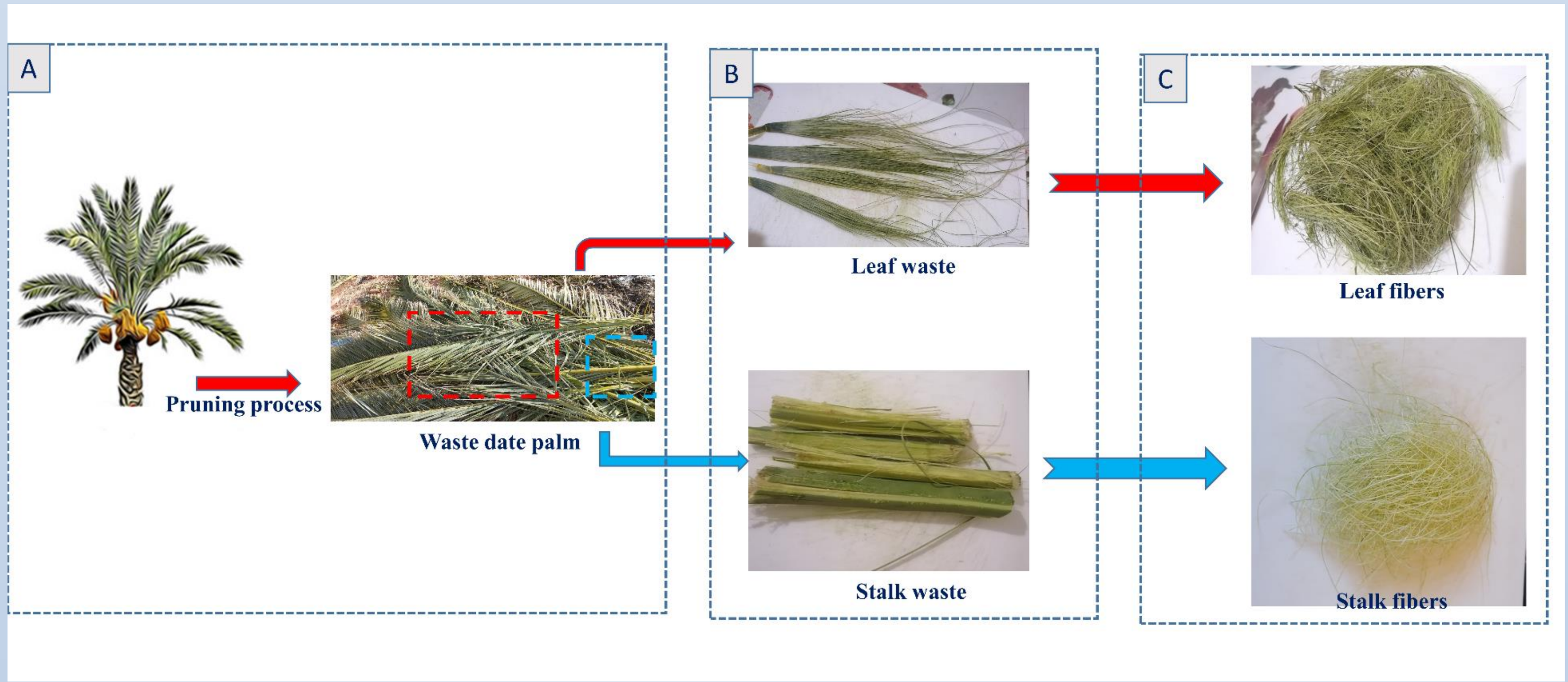


***Fig 1.** Workflow for obtaining geopolymer matrix.*

Materials & methodology

Fibers extraction



Geopolymer composites formulation

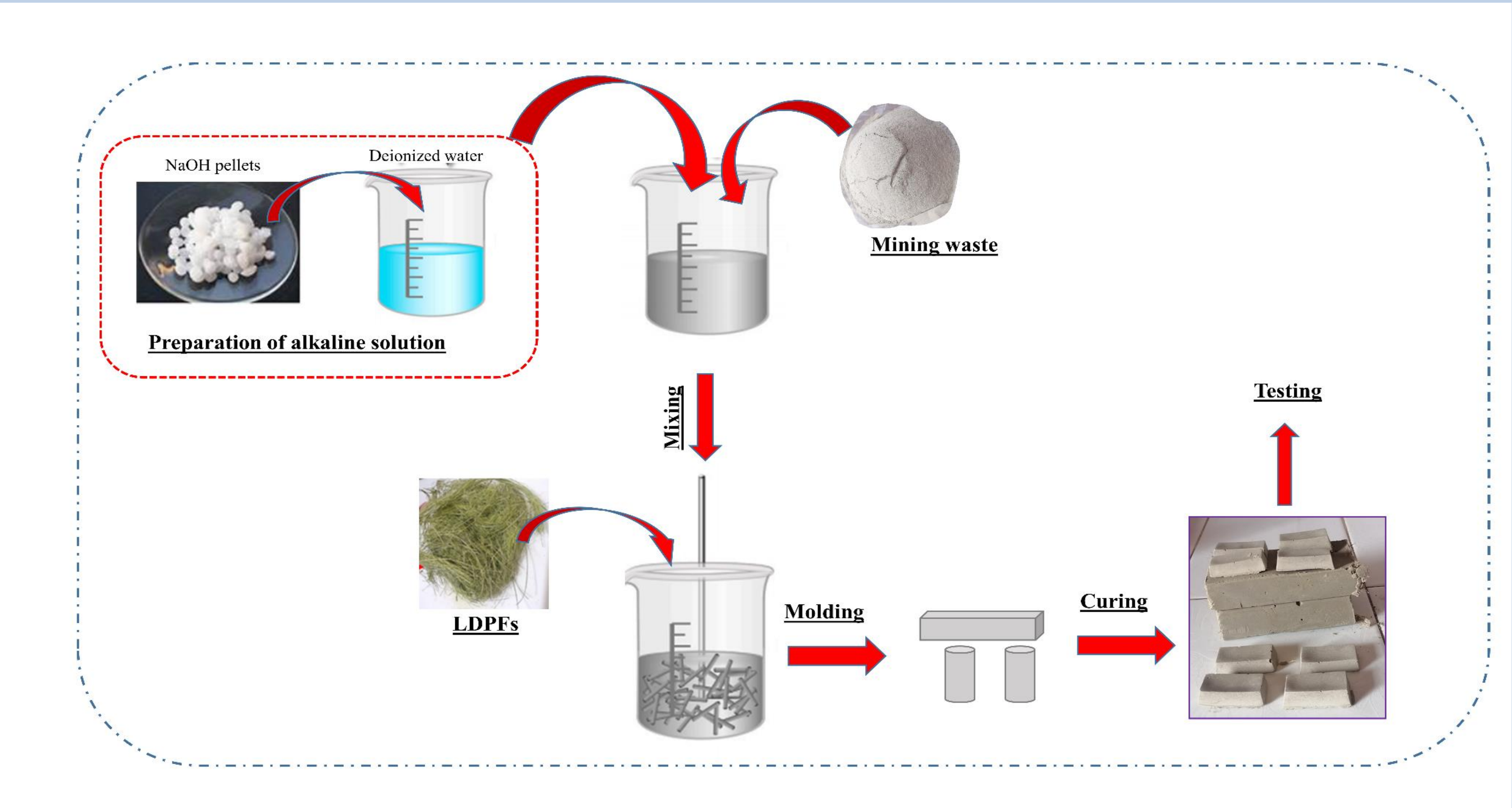


***Fig2.** Experimental procedure of fibers extraction and the formulation of geopolymer composites.*

Results and discussion

Chemical composition

The chemical composition of mining waste is presented in ***Table 1***. The primary components of this raw material are silica and alumina, classifying it as an aluminosilicate material suitable for formulating geopolymer composites.

***Table. 1**. Chemical Composition of mining residues*

Chem. Compo	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	MnO	others
Wt (%)	36,2	13,14	3,63	20,2	9,53	3,04	0,68	13,58

Structural and morphological characterization

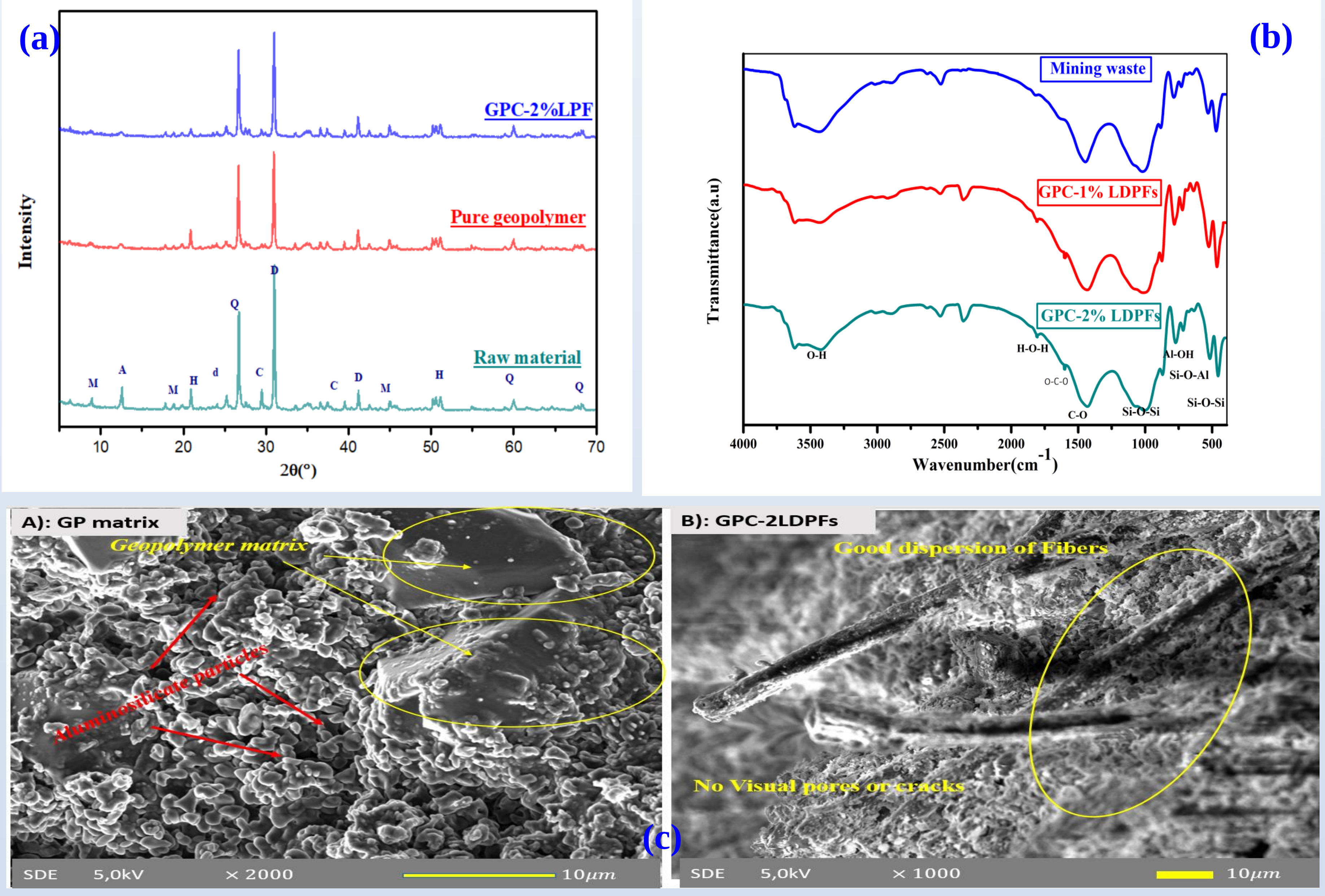


***Fig3.(a,b)** DRX patterns and FTIR spectra of mining waste and it's composite,**(c)** SEM morphology of GPC specimens.*

Figures ***3a, 3b***, and ***3c*** illustrate the main changes in structural properties, assessed by XRD and FTIR spectroscopy, along with morphological properties, observed through SEM, of the mining waste and their corresponding geopolymers composites. The analysis of the structural and morphological characteristics indicated a satisfactory level of geopolymerization, with the fibers showing strong interfacial bonding with the geopolymer matrix.

Mechanical and physical properties

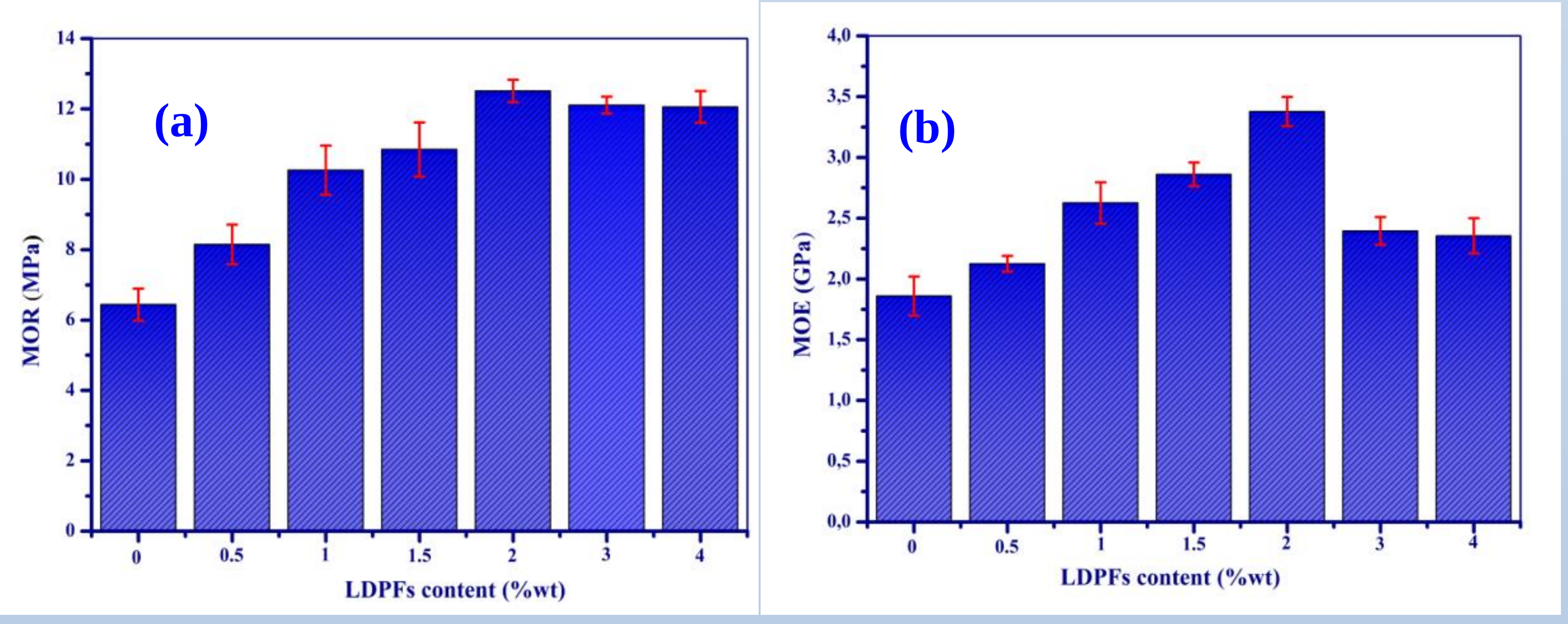


***Fig4. (a)** Modulus of rupture (MOR), and **(b)** Modulus of elasticity (MOE) versus fiber content.*

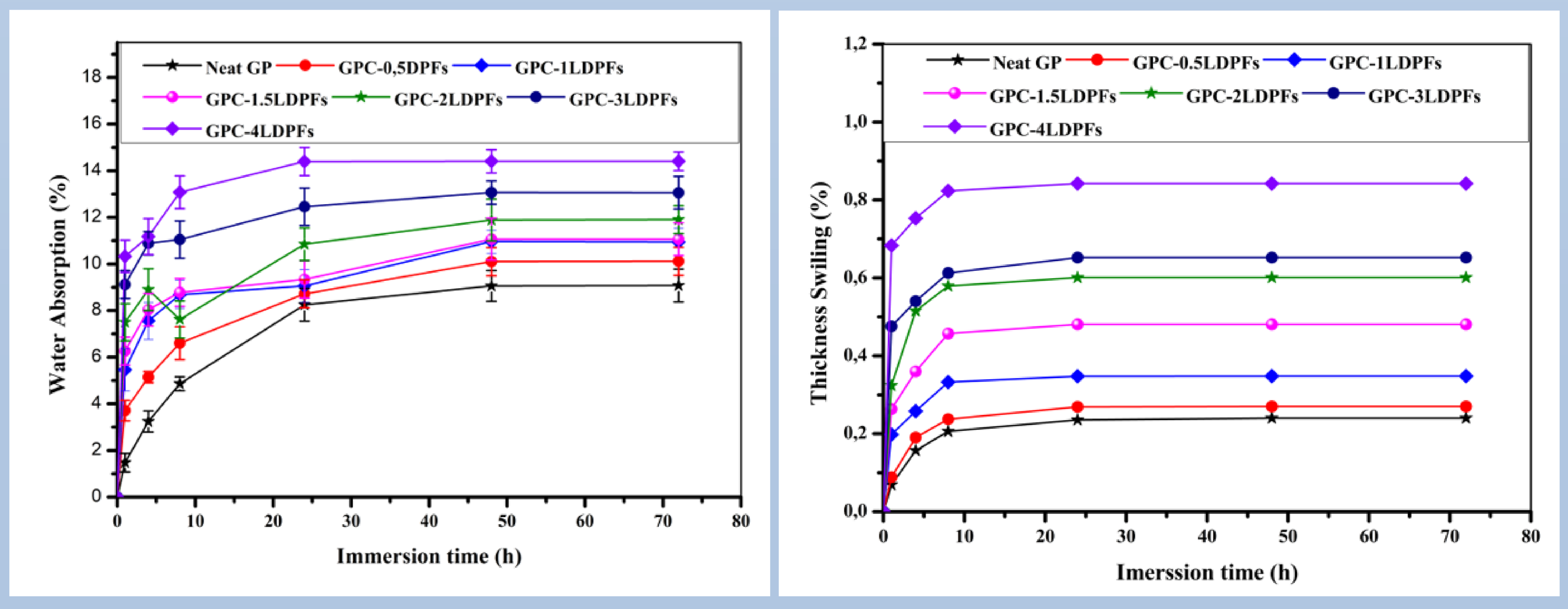


***Fig5. (a)** Water absorption (WA), and **(b)** Thickness swelling (TS) versus fiber content.*

Figures 4(a and b) illustrate the changes in the mechanical properties of the geopolymer composites versus fiber content. The findings suggest that incorporating LDPFs led to enhanced mechanical properties of the composites. The MOR achieved a maximum value of 12.51 MPa, while the MOE reached 3.4 GPa at 2% fiber content. These two mechanical properties nearly doubled compared to the pure geopolymer.

The physical properties of the composites versus the fiber content are illustrated in ***Figures 5(a and b)***. Both WA and TS swelling increased with higher fiber content and immersion time. This increase can be attributed to the increase in hemicelluloses, which possess a hydrophilic nature that facilitates the absorption of a significant amount of water within the fibers.

Conclusion

The findings suggest that Leaf Date Palm Fibers (LDPFs) are highly efficient in reinforcing the geopolymer matrix derived from mining waste, providing a cost-efficient alternative for improving construction materials.