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# Biodegradation of poly(ε-caprolactone)/poly(lactic acid) composites: The effect of fiber load and compatibilization

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# Introduction

The development of green composite materials has become necessary due to

- environmental concern
- over utilization and exploitation of resources that cannot be replaced or reintroduced into the environment.

This has prompted research interest in industries and the academic community.

# Introduction contd.

To solve the above mentioned problems materials scientist and engineers adopts the following.

- Developing biodegradable materials with properties that can be manipulated.
- Preparing  polymeric materials without using toxic or noxious components
- Developing materials that can naturally be broken down by the environment.

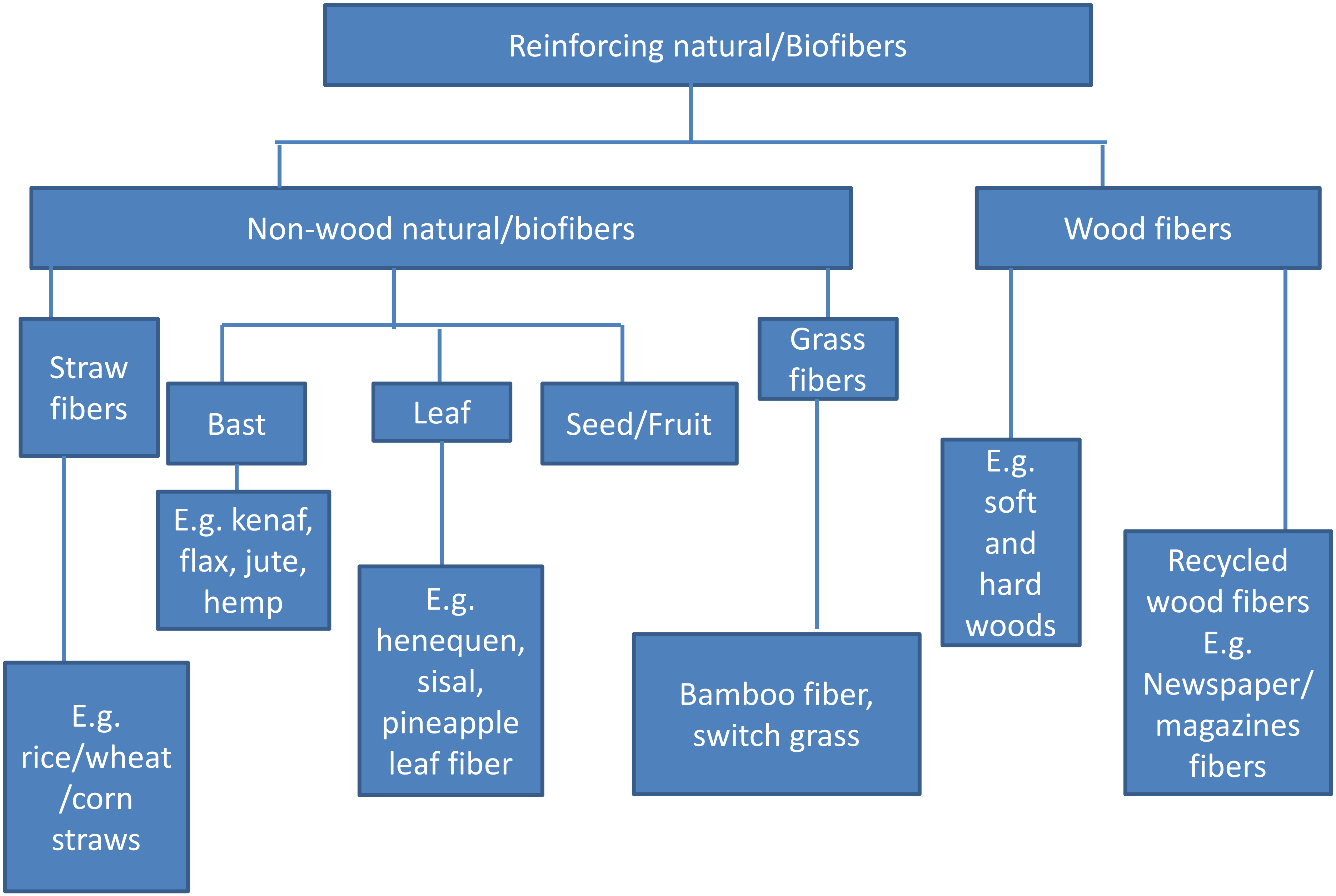
# Introduction contd.

To obtain eco-friendly composites, the following materials were used.

- Natural fibers as reinforcement in composites production.
- Biodegradable polymers (PCL and PLA) were used as matrix.

This in addition to environmental protection is to reduce cost and also create a new class of composite materials.

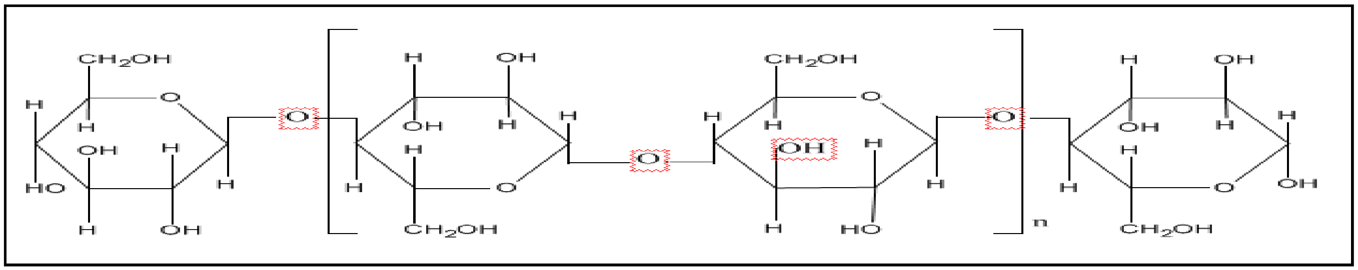
Figure1. Classification of Reinforcing Natural/Biofibers



# Composition of natural fibers

All natural fibers whether wood or non wood are

- Cellulosic in nature.
- Cellulose and lignin are the major components found in natural biofibers.
- Lignin is the material that gives support to the structure of plants.



# Table1. Chemical composition of some natural fibers

| Fiber | Cellulose (%) | Lignin (%) | Hemicellulose (or pentosan) (%) | Pectin (%) | Ash (%) |
|---|---|---|---|---|---|
| Abaca | 56-63 | 7-9 | 15-17 | - | 3 |
| Kenaf (bast) | 31-57 | 15-19 | 21.5-23 | - | 2-5 |
| Hemp | 57-77 | 3.7-13 | 14-22.4 | 0.9 | 0.8 |
| Ramie | 68.6-91 | 0.6-0.7 | 5-16.7 | 1.9 | - |
| Jute (bast) | 45-71.5 | 12-26 | 13.6-21 | 0.2 | 0.5-2 |
| Henequen | 77.6 | 13.1 | 4-8 | - | - |
| Flax fiber | 71 | 22 | 18.6-20.6 | 2.3 | - |

# Poly (lactic acid), PLA

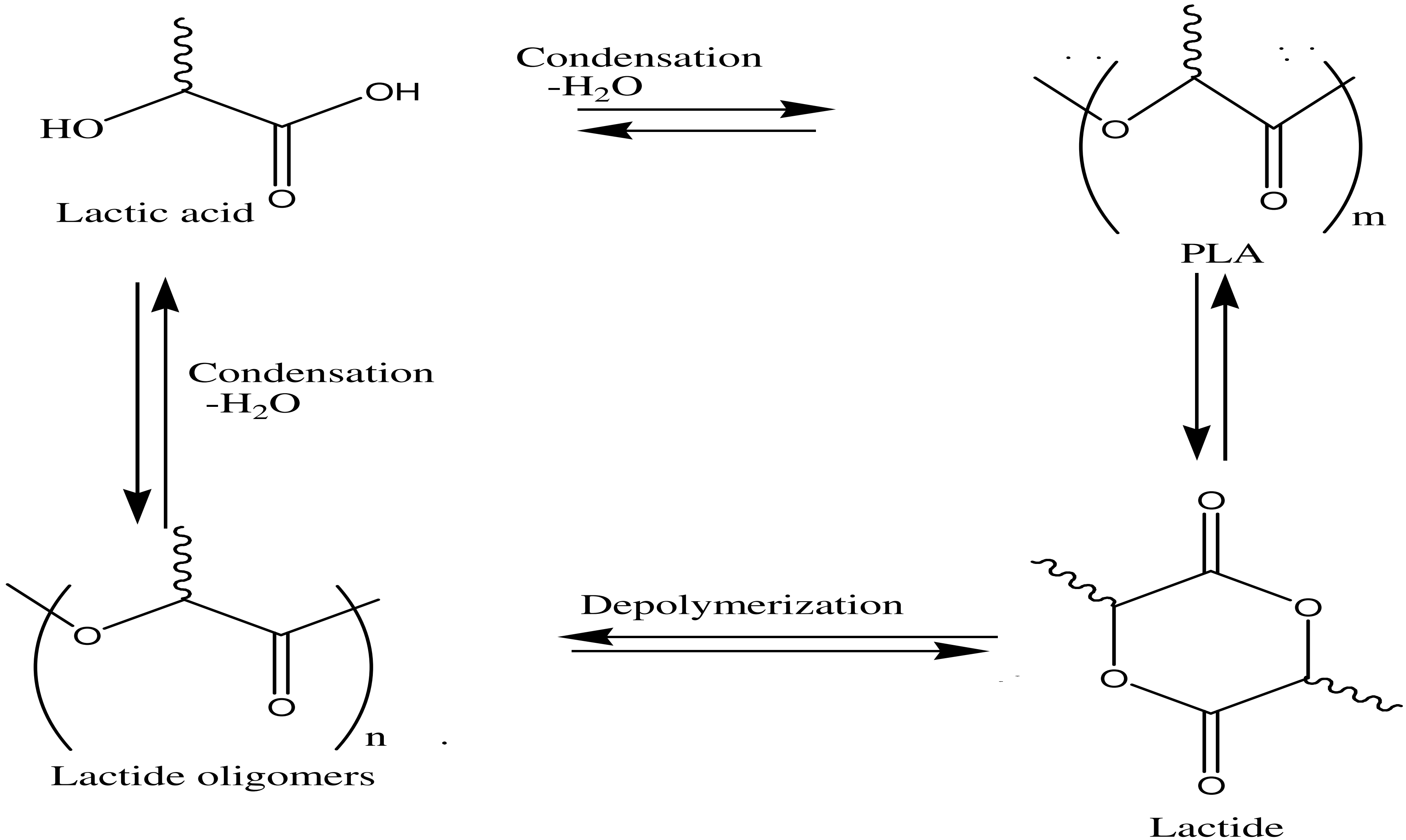
- PLA is a biodegradable thermoplastic that can be produced from sources that are considered renewable such as tapioca products, corn starch, and sugarcane.

- PLA can be synthesized through condensation polymerization of lactic acid and ring opening polymerization of lactide to produce polylactide.

## Properties

- It is highly crystalline
- Has Melting point of 150$^{o}$C
- Glass transition temperature between 60-65$^{o}$C

# Figure 3: Synthesis of PLA



# Advantages of PLA

- It is eco-friendly
- Has good biocompatibility especially in biomedical applications
- Has better thermal processibility than most biopolymers
- Its production save’s energy as such reduces cost

## Limitations of PLA

- Its toughness is poor
- It is hydrophobic
- It is chemically inactive as such difficult to modify

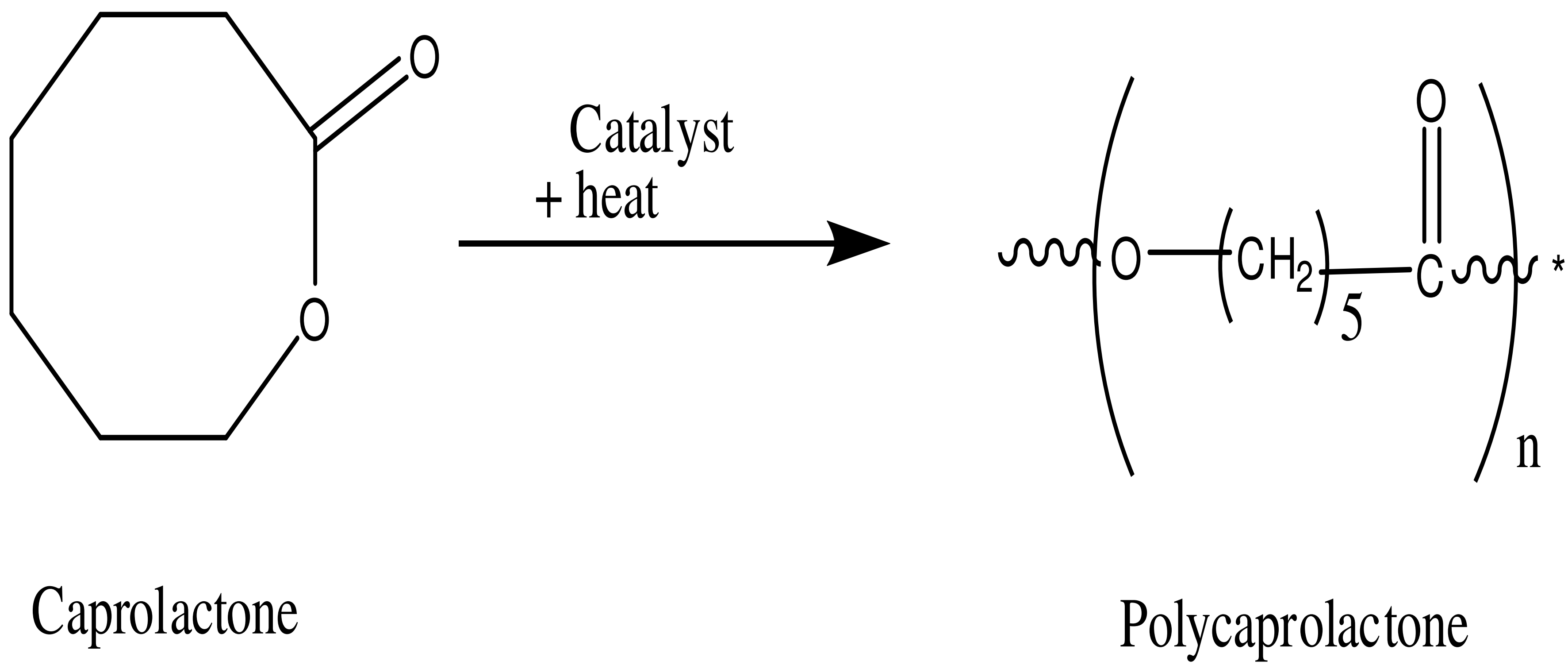
# Poly (ε-caprolactone), PCL

- PCL is petroleum derived synthetic biodegradable polymer.
- It is tough at ambient temperature and fairly rigid with an average modulus like that of polyethylene.
- PCL mixes a lot with other polymers and has some good mechanical properties.
-

## Properties

- It exhibits good solvent, oil, water, and chlorine resistance.
- Has low melting point (Mpt) between 58-62$^{o}$C.
- Low glass transition temperature, Tg; -60$^{o}$C.
- PCL is a highly degradable polymer and semi crystalline.

# Figure 4: Preparation of Poly (ε-caprolactone)



# Advantages of PCL

- It can be processed easily due to its low melting point
- PCL is highly degradable and also eco-friendly
- Has good biocompatibility especially in medical applications

## Limitations of PCL

- Its low Tg (-60℃) and melting point (58-62℃) reduces its chances of being used in some applications e. g. outdoor applications

# Research interest

In view of the above limitations, PCL and PLA were blended and reinforced with treated palm press fibers to achieve enhancement of the blends mechanical properties.

This is to expand the composites outdoor application areas.

To achieve the properties enhancement the following was employed to prepare the blends and composites.

# Methodology

The palm fibers were washed and treated with sodium hydroxide after which they were dried, pulverized and a maximum of 400μm particle size used as reinforcement.

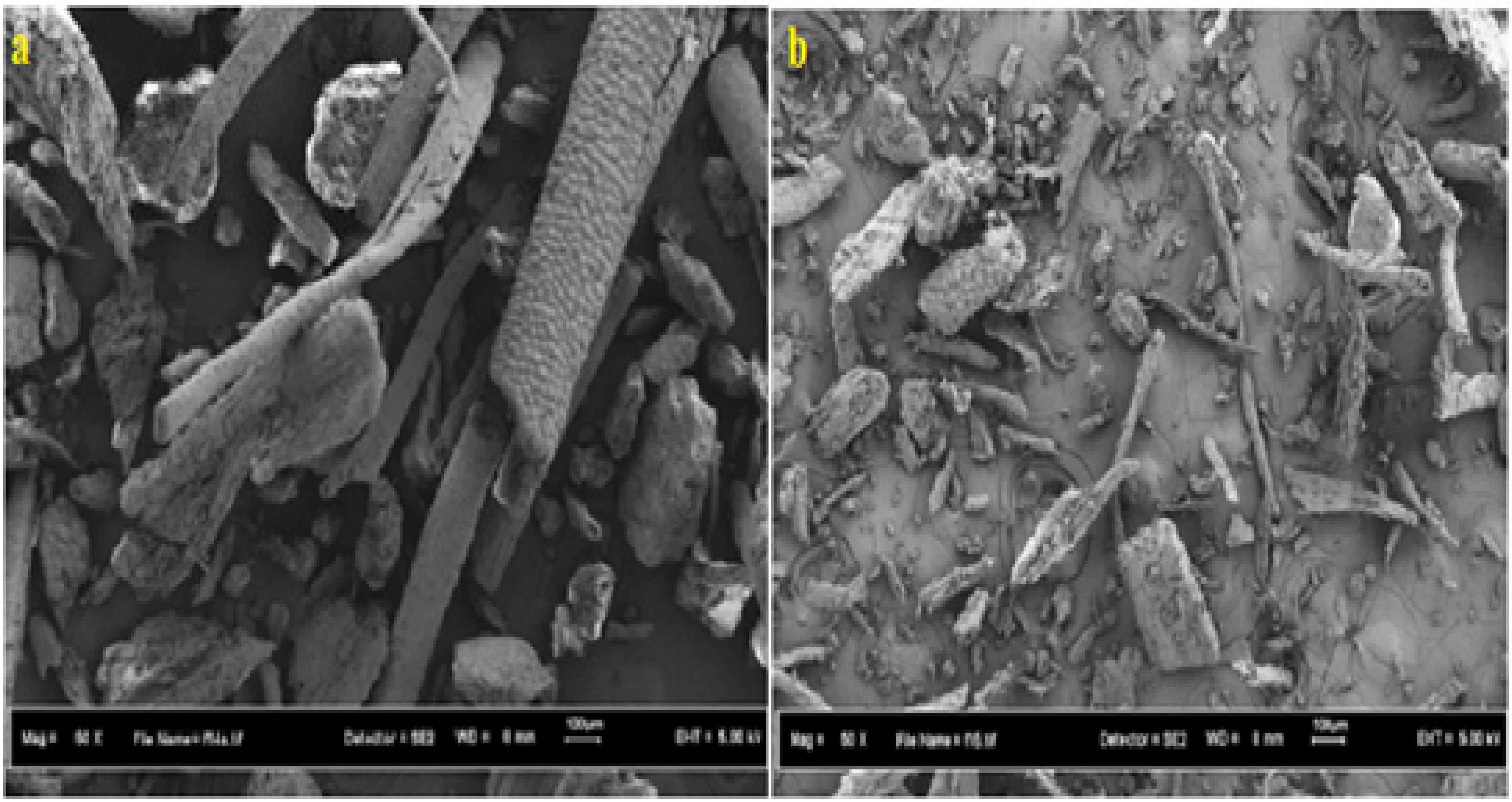
The blends and composite specimens used for determinations were prepared using twin screw extruder and injection molding machine.

# Characterization

- The Morphology and biodegradation of the fibers, blends and composites was studied using:
- Field Emission Scanning Electron Microscopy (FESEM)
- Fourier Transform Infrared Spectroscopy (FTIR)

# Results And Discussion

- **Fig. 1** FESEM micrographs of (a) untreated and (b) treated fibers



# **Fig. 2** FTIR of treated, untreated fibers, uncompatibilized and compatibilized blend

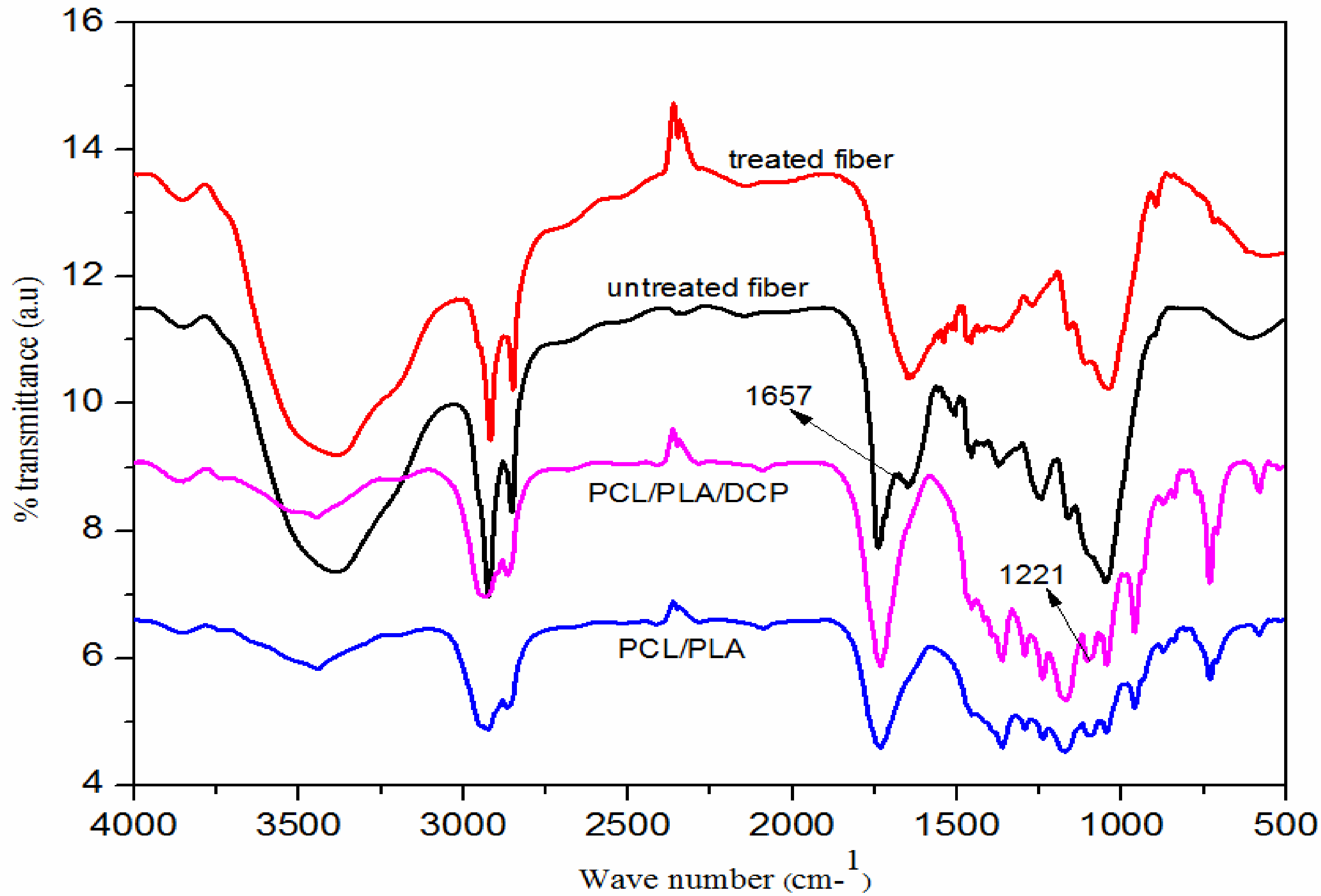
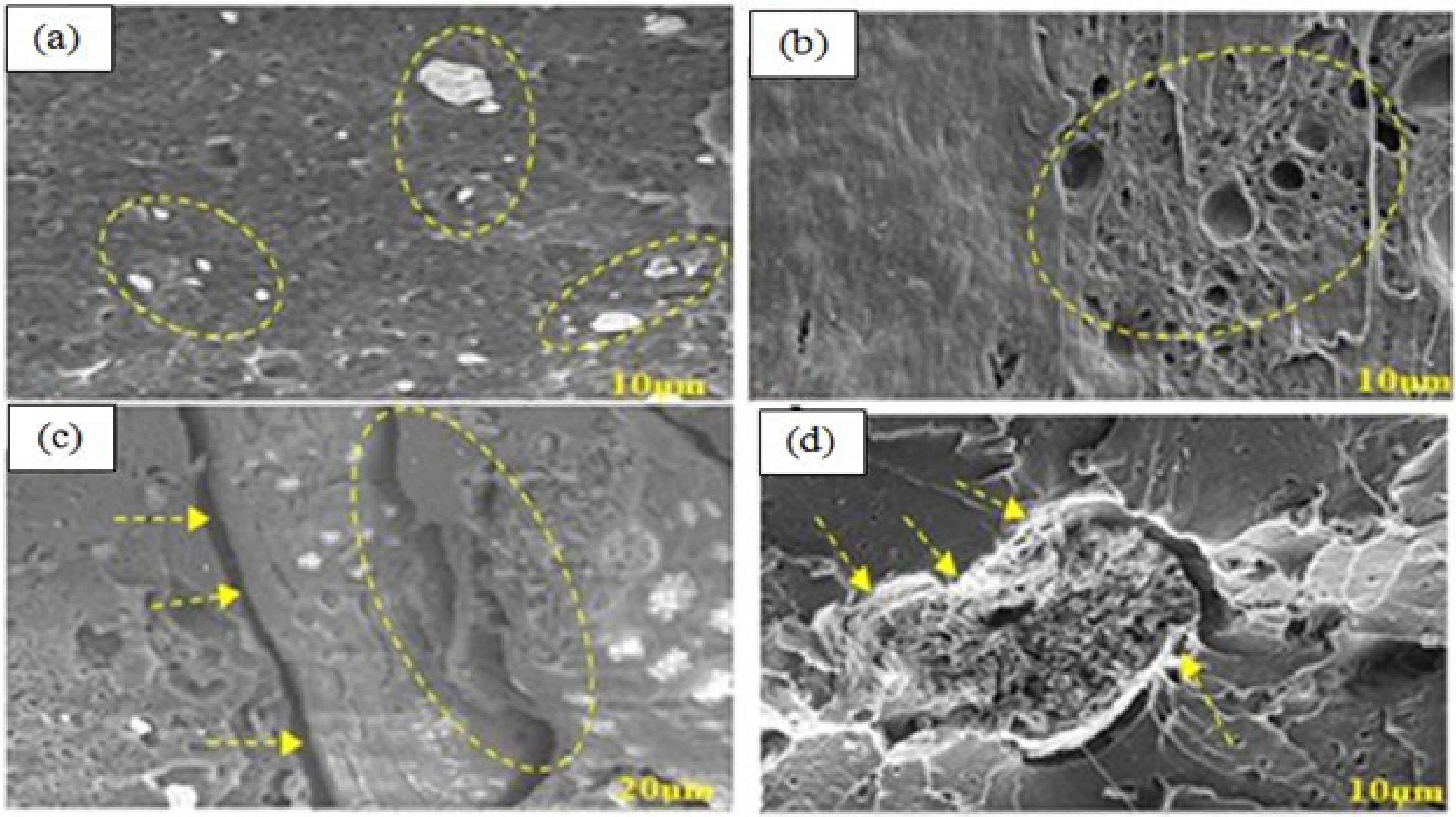


**Fig. 3** FESEM micrographs of (a) PCL/PLA (90/10), (b) PCL/PLA/DCP (90/10/0.01phr) (c) PCL/PLA/TF (90/10/25), (d) PCL/PLA/TF/DCP (90/10/10/0.01phr)



# Biodegradation

- **Fig. 4** Residual weights of neat polymers, compatibilized blend and composites

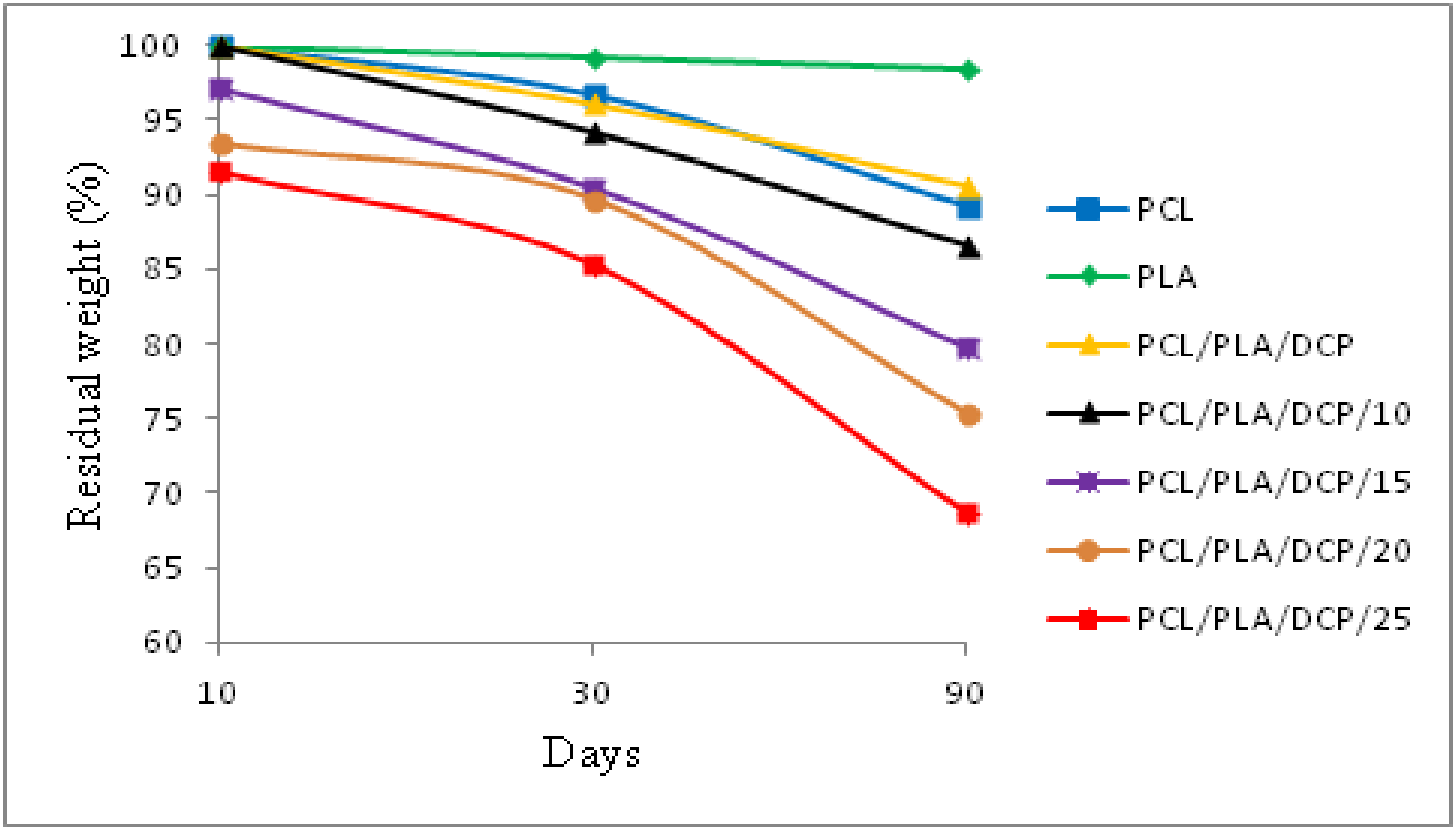


**Fig. 5** FESEM micrographs after 90 days soil burial (a90) PCL (b90) PLA (c90) PCL/PLA/DCP (d90) PCL/PLA Mag. x500

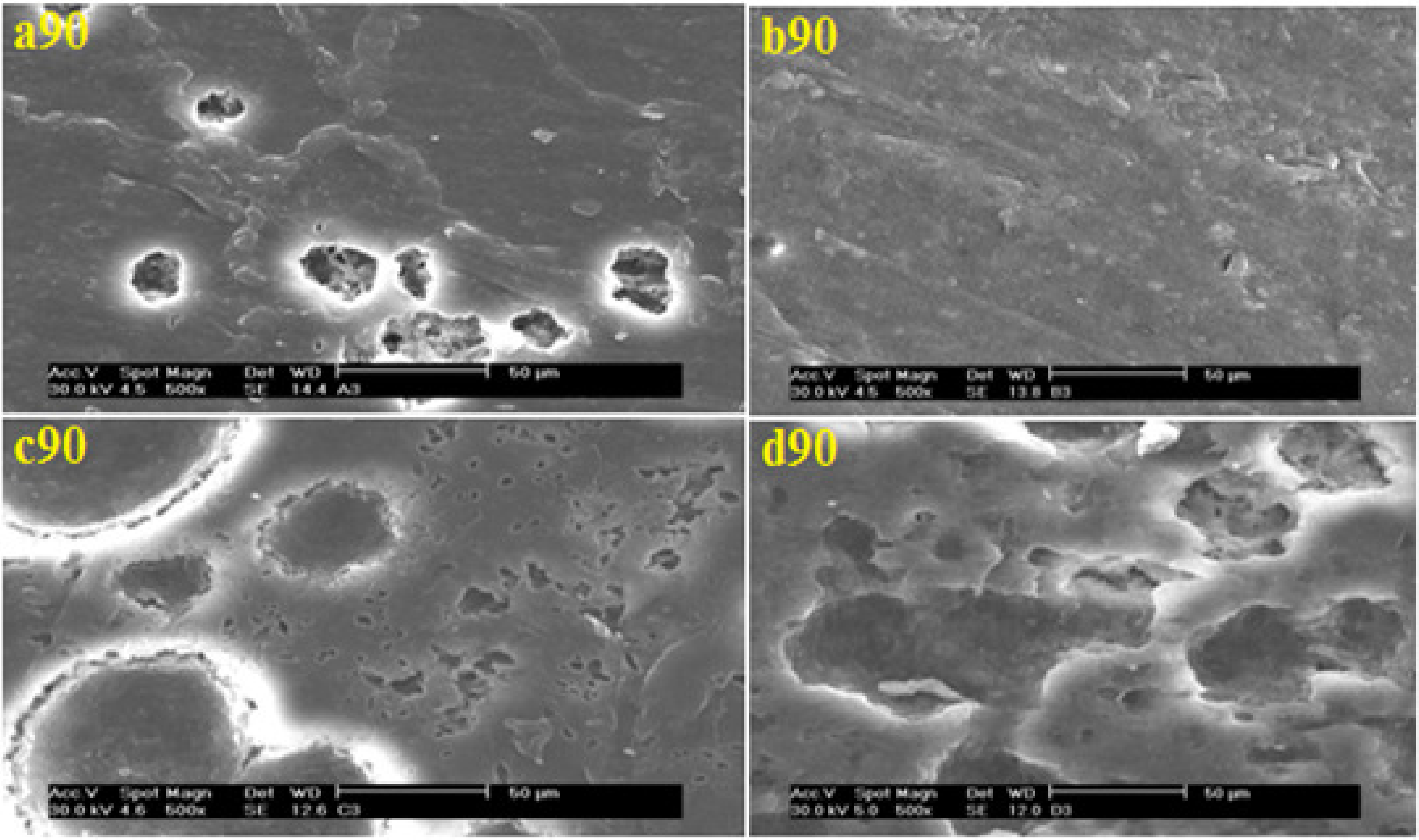
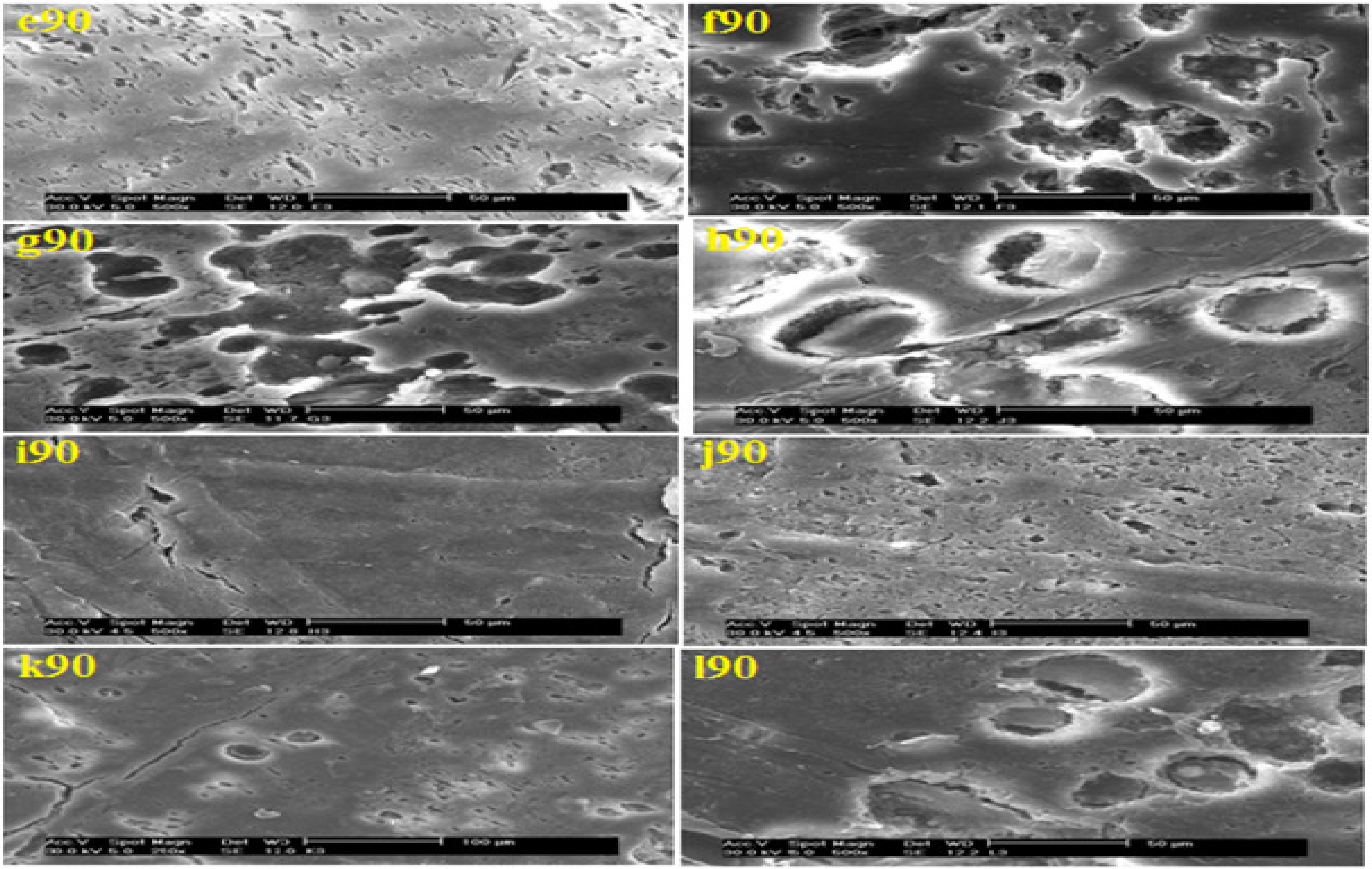


**Fig. 6** FESEM micrographs after 90 days soil burial (e90) PCL/PLA/DCP/10 (f90) PCL/PLA/DCP/15 (g90) PCL/PLA/DCP/20 (h90) PCL/PLA/DCP/25 (i90) PCL/PLA/10 (j90) PCL/PLA/15 (k90) PCL/PLA/20 (l90) PCL/PLA/25 Mag. x500



# Conclusions

The following conclusions were drawn:

- Optimized PCL/PLA composites were successfully prepared with treated palm press fibers.
- The incorporation of DCP improved the blend compatibility and biodegradation.
- The alkali treatment increased the interaction between the fibers and the matrix.
- The rate of biodegradation of the composites increased with fiber load (10 wt. % to 25 wt. %)

- Thank You For Your Attention

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