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Improving the Mechanical Properties of Epoxy by Adding Sub-micron Cantaloupe Peel Fibers

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Abstract

The use of bio-fruit waste has more attention in recent years because of the low cost of bio-fibers and the protection of the environment. In this study, the epoxy was reinforced with fruit residues (cantaloupe peel powder) in proportions (1%, 2%, 3%, 4%, 5%, 7.5%, and 10% by weight) as results of mechanical tests such as impact, hardness, flexural and compression.
Adding sub microns particle size cantaloupe peels particles with a weight ratio of 7.5% improves the epoxy mechanical properties, like impact strength, hardness, flexural strength, and compression strength by 59.43%, 5.8%, 45.7%, and 118.2%, respectively.

Using X-ray diffraction, the crystallite size (D) of cantaloupe peel the powder was about (3 nm). In this research, Scanning electron microscopy was used to examine the morphology of the (epoxy/7.5 % cantaloupe peel powder) composite and to interpret the improvement in epoxy mechanical properties.
Keywords: epoxy, impact strength, compression strength, cantaloupe peel fibers

1.Introduction

The use of agricultural waste as reinforcement in polymer instead of synthetic reinforcements has been increased. This is because natural fibers are environmentally friendly, non-toxicity, and have a low cost with lighter weight [1].

Cellulose is considered one of the best cheap materials due to its natural availability, so that it can be used as an alternative to the expensive materials of petroleum origin. Cellulose can be obtained either from a vegetarian or animal source and, generally, has excellent mechanical properties, such as tensile and bending strength. There are materials other than cellulose in plants, like pectin, Lignin, hemicellulose, and ash [2- 3].

In (2020), H K Hameed et al. reinforced the epoxy with orange peel fibers with percentages (5%,10%,15%, and 20 %). The results showed that adding (15 percent by weight) orange peel and carbonized orange peel particles to epoxy increased tensile strength. In comparison, the addition value (10 percent by weight) is sufficient for improving other mechanical properties [4].

In 2021, Tuan Anh Nguyen et al. utilized banana fibers that had been processed with 5% NaOH. Mechanical and thermal properties of banana fiber-reinforced epoxy resin with weight percent (10, 15, 20, and 25 %) were studied, and the improvement in both mechanical properties and thermal stability of epoxy was achieved using the weight ratio of 20% of banana fibers [5].

Melon fruit can be created in large amounts during industrial processing, posing a severe challenge in terms of environmental effects. On the other hand, these wastes are a rich source of bioactive chemicals and nutrients that have been shown to benefit human health, so (Fátima A. Miller et al.) 2021 used cantaloupe melon peel paste in packaging food additive as antibacterial material [6].

In this research, the sub-microns of cantaloupe peel fibers were used to improve the epoxy mechanical properties like (impact strength, flexural strength, hardness, and compressive strength) by adding these fibers in different weight fractions (1, 2, 3, 4, 5,7.5, and 10%).

2.Materials and Methods

2.1. Preparation of Composites

Cantaloupe peel wastes were dried in the sun for ten days and in the oven at 60 oCfor 7 hours; then, dried cantaloupe peels were milled using the device (NQM -0.4 ball mill), as shown in figures (1). Milling took about 60 minutes to get the sub microfibers with average particle size (~ 0.3 μm).

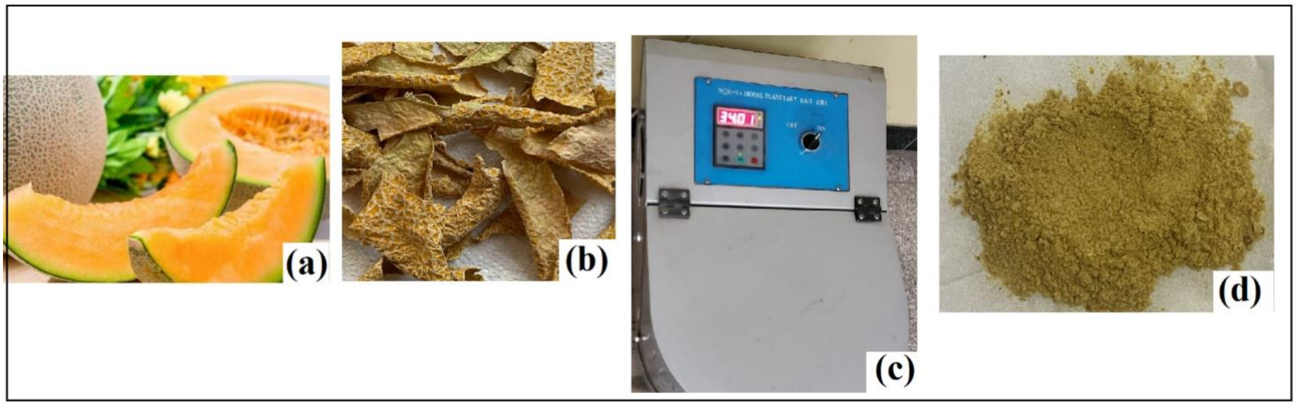


Figure 1: a) canteloupe fruits b) dried cantaloupe peels c) milling deviced) cantaloupe fibers

The fibers were mixed with epoxy (Sikadur-52) using the hand-Lay technique; hardener was added in a ratio of (1:2) to epoxy. The mixtures were poured into greased Silicone molds prepared to wear test.

Epoxy/ sub-microns cantaloupe fibers(EP / SMCaFs) composites were prepared with different weight ratios (1, 2, 3, 4, 5, 7.5, and 10 %).

The composites of (EP/ sMCaFs) with different weight percentages (1, 2, 3, 4, 5, 7.5, and 10 wt. %) of cantaloupe peels were prepared.

The (EP/ sMCaFs) mixtures are poured into silicone molds with (ASTM dimensions).

For easy removal of composite sheets, the mixture (EP/ sMCaFs) was allowed in molds to cure for (1-3) days at room temperature.

2.2.Mechanical Tests

2.2.1. Impact Test

For the Charpy impact test, the specimens are molded according to the international system (ISO-179) with dimensions (100×10× 8 mm).

2.2.2. Hardness Test

For the hardness test (Shore D), the specimens are molded according to (ASTM D 785-08).

2.2.3. Flexural Test

Flexural test performed using three-point bending factory-made by the instrument model H50 KT (Tinius Olsen/uk). The dimensions of the samples are (100×10×4mm) according to (ASTM-D790).

2.2.4.Compression Test

The compressibility qualities were tested using a hydraulic press. The test was done on composite resin specimens using a universal compression test machine. The compressive strain was found by dividing the change in the length of a specimen by the original length, and stress was calculated using equation (1) [7].

$$\text{Stress } (\boldsymbol{\sigma}) = \frac{F(N)}{A(mm^2)} \qquad (1)$$

Where

F: is the force applied on the specimen.

A: is the base area.

2.2.5 X-Ray Diffraction (XRD)

XRD was used to determine the crystallographic structure of a substance. This technique was developed using an X-ray diffraction device (SHIMADZU Japan) (XRD600). The X-Ray wavelength was 1.54 A° with a range of (10 - 80 degrees).

2-2-6 Microstructure Test

The microstructure of (EP/ sMCaFs) composite was checked by an electronic photography using the electronic scanning instrument (Tescan) manufactured in Britain.

3.Results

3.1 Mechanical Tests

3.1.1 Impact Results

Impact strength shows the extent of the ability of the material to absorb energy before it breaks after applying impact force [10]. **Figure (2)** shows the impact strength of (EP/ SMCaFs) composites, where the impact strength values increase from (9.12 kJ / m2) for pure epoxy to a maximum value (14.54 kJ / m2) with (7.5% SMCaFs) content and down to value (10.57 kJ / m2) with (10 % SMCaFs) content. This behavior of the impact strength curve is similar to that found by (Seenaa et al.) [8].

The addition of cantaloupe fibers with particle size 0.3 microns to epoxy with concentrations (5 and 7.5 wt %) improves the impact strength of the epoxy by 43.64 % and 59.43%, respectively. These proportions of fibers act as strength centers in the epoxy matrix [10].

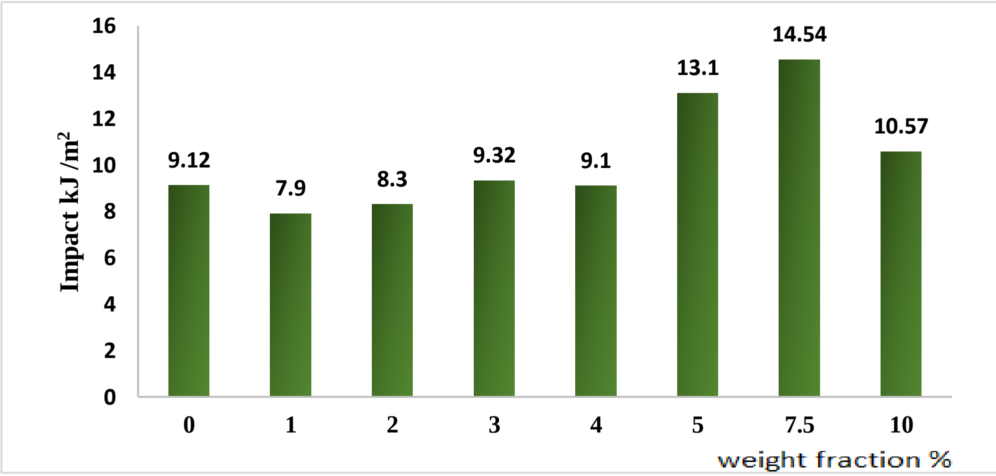


Figure 2. Impact strength of (EP/ SMCaFs) composites

3.1.2 Hardness Results

Figure (3) shows the increase in hardness by loading epoxy with SMCaFs at weight percentages ranging (from 2-7.5 %). (EP/ SMCaFs) composites at the Percentages of addition (5% and 7.5%) have higher values of hardness (81.2 and 82), respectively, compared to the hardness of neat epoxy (77.5). This is because of the excellent dispersion of SMCaFs between the chains of the epoxy matrix at these rates of additions, but at higher rates of additions (10%), the hardness values of (the EP/ SMCaFs) composite will be reduced. This may be due to the agglomeration of pumpkin particles in the epoxy matrix.

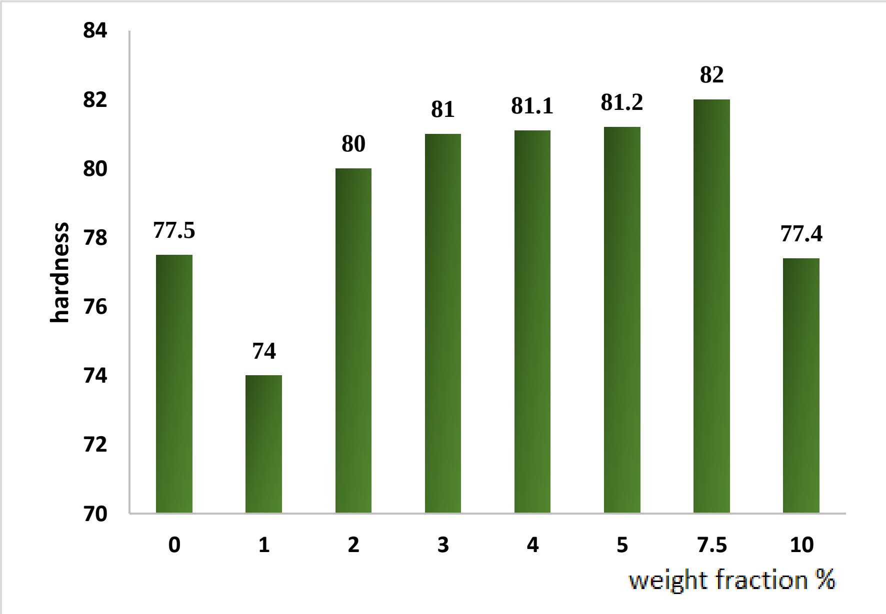


Figure 3. Hardness of (EP/ SMCaFs) composites

3.1.3 Flexural Results

Flexural strength indicates the material's resistance to bending when an external force is applied [10]. **Figure(4)** shows that the flexural strength increased from (40.1MPa) for neat epoxy, reaching higher values (51.57MPa) and (58.43 MPa) for (EP/5%SMCaFs) and (EP/7.5% SMCaFs) respectively. It reduced to value (42.85MPa) for (EP/ 10% 2.5MPF) composite, that means (5% and 7.5% SMCaFs) be a sufficient ratio to achieve good bonding between micro cantaloupe fibers and epoxy matrix. These results agreed with [9].

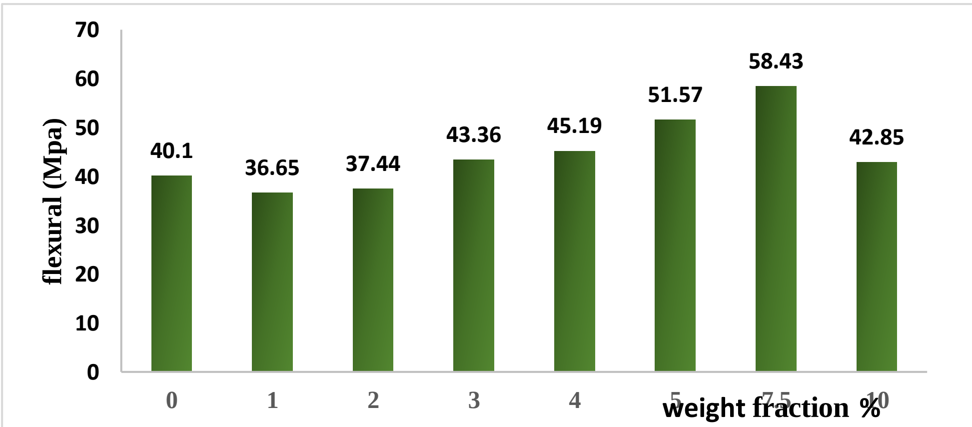


Figure 4. Flexural strength of (EP/ SMCaFs) composites

3.1.4 Compression Results

Table (1) illustrates the compression test results of (Epoxy/ SMCaFs) composites, where the stress and strain values of samples rise as the force applied increases; these results are consistent with [11-12].

Table 1. Compression stress and strain of (epoxy/ SMCaFs) composites

Epoxy				Epoxy\ 1% cantaloupe peels				Epoxy\ 2% cantaloupe peels				Epoxy\ 3% cantaloupe peels			
F (N)	Δ L (mm)	(σ) N/mm^2	ε	f (N)	Δ L (mm)	(σ) N/mm^2	ε	F(N)	Δ L (mm)	(σ) N/mm^2	ε	F(N)	Δ L (mm)	(σ) N/mm^2	ε
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
500	0.05	6.4358	0.002	500	0.05	6.384	0.002	500	0.04	6.32	0.001	500	0.09	6.078	0.003
1000	1.4	12.8716	0.057	1000	0.24	12.788	0.009	1000	0.28	12.64	0.011	1000	0.33	12.156	0.013
1500	2.1	19.5025	0.085	1500	0.48	19.152	0.019	1500	0.51	19.96	0.002	1500	0.65	18.234	0.025
1650	2.9	21.2382	0.117	2000	0.69	25.536	0.027	2000	0.71	25.281	0.008	2000	0.82	24.312	0.032
				2500	0.92	31.92	0.037	2500	0.91	31.601	0.035	2500	1	30.391	0.039
				3000	1.45	38.304	0.058	3000	1.5	37.921	0.045	3000	1.24	36.469	0.04
								3300	1.32	41.714	0.051				
Epoxy\ 4% cantaloupe peels				Epoxy\5% cantaloupe peels				Epoxy\7.5% cantaloupe peels				Epoxy\10% cantaloupe peels			
F(N)	Δ L (mm)	(σ) N/mm^2	ε	F(N)	Δ L (mm)	(σ) N/mm^2	E	F(N)	Δ L (mm	(σ) N/mm^2	ε	F(N)	Δ L (mm)	(σ) N/mm^2	ε
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
500	0.05	6.031	0.001	500	0.07	7.377	0.002	500	0.08	6.262	0.003	500	0.11	6.457	0.004
1000	0.17	12.063	0.006	1000	0.21	12.754	0.008	1000	0.21	12.525	0.008	1000	0.37	12.929	0.014
1500	0.42	18.095	0.016	1500	0.43	19.131	0.016	1500	0.5	18.788	0.019	1500	0.52	19.372	0.02
2000	0.58	24.127	0.022	2000	0.66	25.509	0.025	2000	0.84	25.051	0.033	2000	0.85	25.829	0.033
2500	0.75	30.159	0.029	2500	0.81	31.886	0.031	2500	1.05	31.314	0.041	2600	1.27	30.995	0.049
3000	0.98	36.191	0.038	2550	1.07	38.263	0.041	3000	1.35	37.577	0.053				
3200	1.19	38.604	0.046					3500	1.64	43.84	0.064				
								3700	1.85	46.346	0.072				

Figure (5) shows thatcompression strength increase from (21.23Mpa) for epoxy to higher value (46.34 Mpa)for (epoxy/7.5 % cantaloupe fibers) , which is due to the fact that (7.5 %) of cantaloupe peel is a good ratio for joining the epoxy chains and therefore improving the bearing capacity under the applied load.

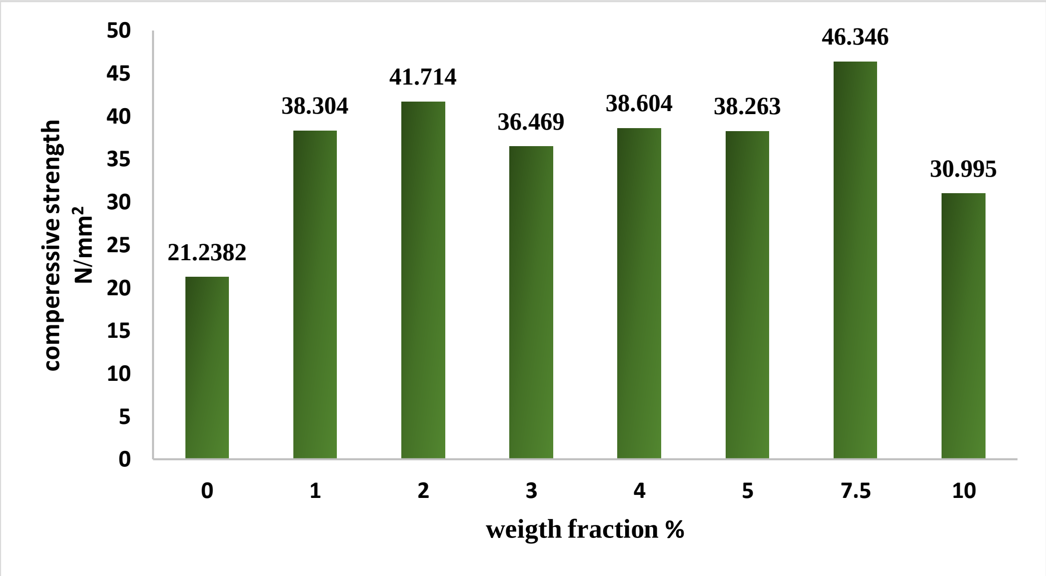


Figure 5. Compression strength of (EP/ SMCaFs) composites

Figure (6) shows that the maximum strain value decreases from a higher level (0.117) for neat epoxy to reach its minimum value (0.04) by adding 3% of cantaloupe fibers to epoxy and increasing up to (0.072) by adding 7.5% of cantaloupe peels waste fibers.

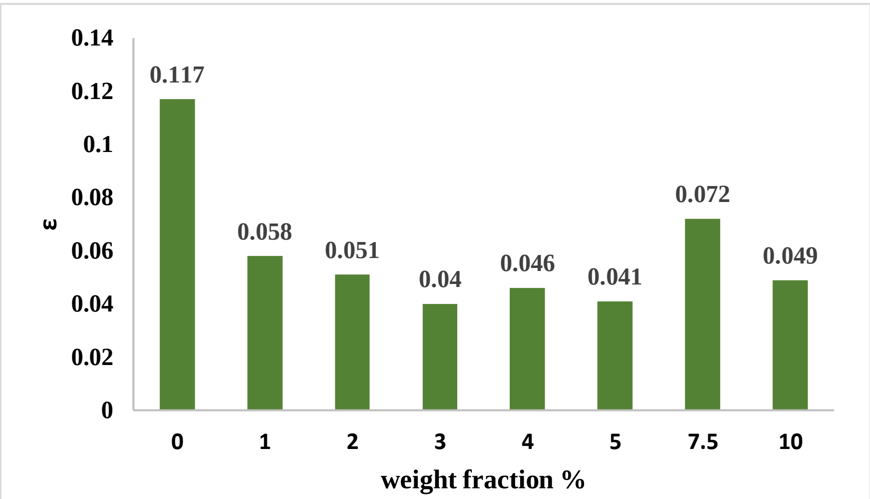


Figure 6. Compression strength of (EP/ SMCaFs) composites

3.2 X-Ray Diffraction (XRD)

Figure (7) shows the (XRD) pattern of cantaloupe peel powder, which can use to find the highest three peaks and there (θ) position and intensities are summarized in **Table (2)**.

Figure 7. XRD of cantaloupe peel fibers

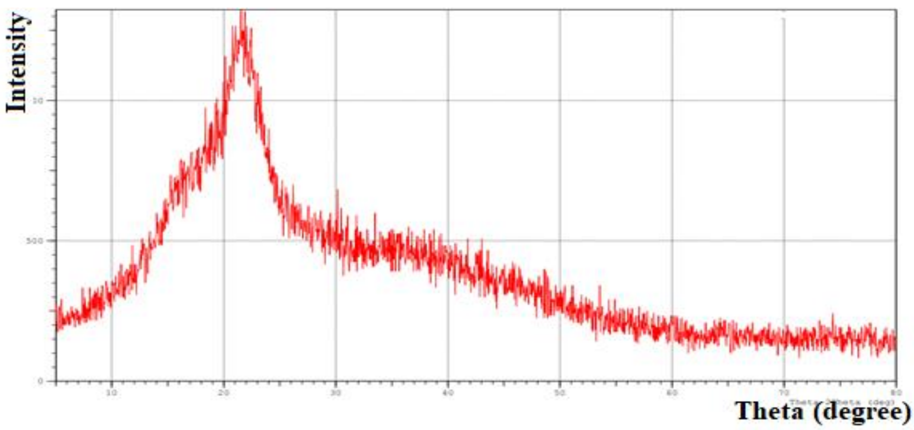


Table 2. The theta position, d – space, FWHM and intensity of the highest three peaks

No. peak	The Peak inX-ray spectrum	Theta position	d- space(A°)	FWHM (deg)	Intensities
1	6	21.37	4.15	4.8	124
2	5	18.826	4.709	0	71
3	4	16.91	5.238	0	56

To estimate the crystallite size (D), Scherer formula (2) is used [13].

$$D=\frac{K\ \lambda}{B\cos\theta} \ldots\ldots\ldots (2)$$

Where

λ: X ray wave length.

K : Scherer constant , which equals to 0.94

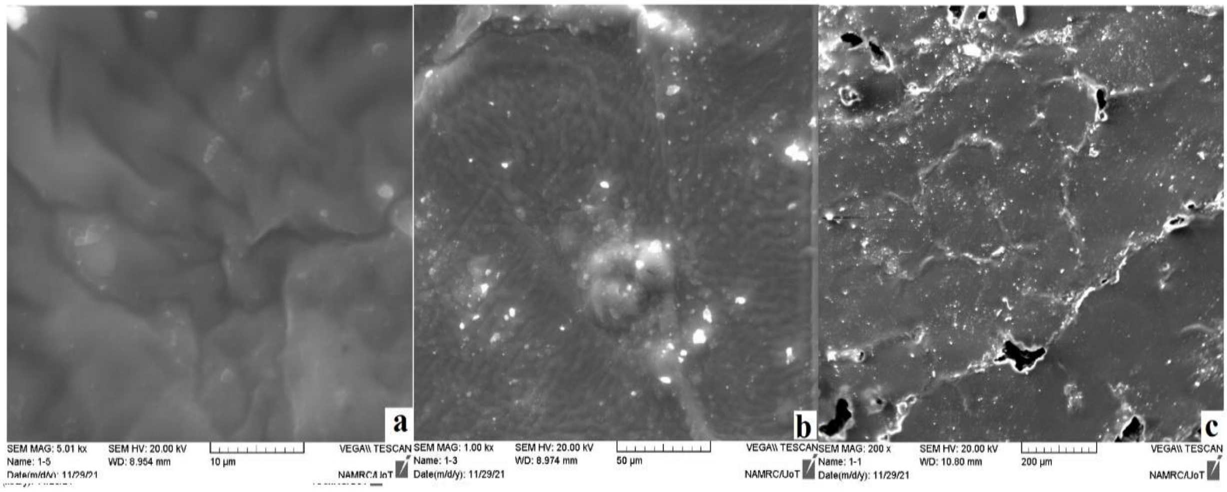
θ: is the diffraction angle

B: is full width at half maximum

crystallite size (D) of cantaloupe peel powder is about (3 nm) .

3.3 Saning Electron Microscope (SEM)

Figure (8) shows the morphology of the composite (epoxy/7.5 cantaloupe fibers) at various magnifications (5000 x,1000 x, and 200x), where the dispersion of cantaloupe particles in the epoxy is good, some agglomeration cavities can also be identified.



a) 5000x b) 1000x c) 200x

Figure 8. SEM images of epoxy/ sub microns cantaloupe peel fibers with magnification

4.Conclusion

1- Adding Cantaloupe peel fibers to epoxy greatly improves its mechanical properties.

2- The best value of cantaloupe peel fibers that make epoxy can be used as natural gelcoats 7.5%.

3-From the X-ray diffraction spectrum, cantaloupe peel fibers' crystallite size (D) can be determined.

4- SEM images of (epoxy/7.5% SMCaFs)) composite shows its morphology, which supports and explains the improvement in the mechanical properties.

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