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Recycling Carrot Powder as Mortar for Cement Replacement

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Abstract

This study was carried out to investigate the physical and mechanical properties of mortar cement produced from Carrot Powder (CP) . To do this, 4 mortar cement specimens were formed by changing the weight of CP and cement. Increasing ratio of CP weight ratio affected the compressive strength, impact, hardness. As for the bending ,water absorption and fracture toughness decreased and were affected positively. It was concluded that CP might be used in mortar cement production to replace the cement in certain ratio to make them profitable and lessen their adverse effects on the environment.

Keywords: Mechanical ;mortar cement ; recycling & reuse of materials

اعادة تدوير المواد الطبيعية كونها نفايات

الخلاصة

أجريت هذه الدراسة للتحقق من الخصائص الفيزيائية والميكانيكية لمونة الأسمنت المنتجة من مسحوق الجزر . ولأجراء هذه الدراسة استخُدمت أربع عينات من مونة الاسمنت عن طريق تغيير وزن مسحوق الجزر والاسمنت.وقد لوحظ ان زيادة النسبة الوزنية لمسحوق الجزر أدت الى زيادة مقاومة الانضغاط والصدمة والصلادة .وكان لها تأثير ايجابي على مقاومة الانحناء وامتصاصية الماء ومتانة الكسر حيث ادت الى نقصانها. وقد أستنتج أنها من الممكن استخدام مسحوق الجزر في إنتاج مونة الأسمنت باستبدال نسبة معينة من الأسمنت لجعلها اقتصادية وتقليل الآثار السلبية على البيئة.

INTRODUCTION

Carrot are rich in dietary fiber, antioxidants and minerals. Carrot fiber provides high strength, stiffness, toughness and a very smooth finish. The composite made from carrot fibers has a lower density than carbon fiber. It can also be molded which makes it valuable for many applications. The carrot fibers have stiffness of 130 GPa, strength of up to 5 GPa and density 1.5 g/cm^3 [1-2]. The percentage limit of fiber content is~ (25- 48)% fibers [3-5].Carrot fibers were used in: Sports equipment. [6] and automotive industry like the steering wheel in a race car is made from composite composed of carrot fibers [7].The aim of the research used in mortar cement production to replace the cement in certain ratio to make them profitable and lessen their adverse effects on the environment.

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Experimental Work

Table 1 summarizes the composition of the mortar investigated in this work, some of their properties and source.

Table (1). Composition, properties and source of mortar.

	Raw materials	Properties	Source
a.	Ordinary Portland Cement (OPC)	53μm fine powder as measured by particle analyzer (SALD-301V)	Portland
b.	Sand	Particle size less that 53 μm as specified by sieving method.	Al Ramadi Iraq
c.	Carrot seeds	**See sections 3.2, 3.3**	Iraq

Perpetration of Carrot Powder (CP)

Carrot seeds were purchased locally from iraqi vegetable supplier. They were cleaned to remove all foreign matter such as dust, dirt, and stones. The juice was removed from carrot seeds by using machine vegetables , the solid waste from carrot juice is rich in fiber. The percentage limit of fiber content is 30% fibers which is regarded as a functional fiber source. The carrot fiber was milled for 15 minutes. Figure1 shows the powder after milling. The carrot powder (CP) was only tested for particle size analysis and surface area to show the effect of milling time on the average particle size and specific surface area. The X-ray Diffraction (XRD) analysis was performed to determine the phases of the produced PC powder samples, the particle size used to measure the particle size distribution for powder used in this study. CP samples were also measured The chemical composition of the CP is determined using the Inductively coupled plasma optical emission spectroscopy (ICP-OES) chemical analysis machine.

Materials and Mortar Cement Mix

A mortar specimen of approximately 3cm×3cm for compression test and 1.5cm×1.5 cm for bending and impact test as shown in figure 2 was cast for each mix considering a control mix, four mixes corresponding to 5%, 10% and 15% carrot powder cement replacement .The specimens were left for setting for three different durations (7,14 and 28 days). Mixing proportions are given in table 2.

Table(2). Mortar Cement Mixture Proportioning

No.	CP (g)	Sand (g)	Cement (g)	Water (ml)	Replacement of Cement (%)
1	0	30	10	10	0%
2	2	28	10	10	5%
3	4	26	10	10	10%
4	6	24	10	10	15%

Results

Particle size analysis

The particle size distribution of the CP is shown in figure 3 exhibiting sizes in the range 20 – 400 μm. Figure 3 shows. The average size of the particles is found equal to 95.580μm. Therefore, the grinding has produced a CP. This powder is expected to mix homogeneously with the mortar cement providing reinforcement centers in the mortar cement at macro scale dimension.

FTIR- Fourier Transmission Infrared of CP

In order to understand the nature of carrot powder , The PC was investigated for their vibration spectra with infrared spectroscopy using Bruker ,TENSOR-27 model instrument from 500 cm^{-1} to 4000 cm^{-1} by using KBr tablet (see figure 4). FTIR spectra of the carrot powder were characterized by specific peaks at 607,929,1057,1158,1371,1636,2358 and 3352 cm^{-1}. From the FT-IR results of natural powder, we can conclude that, the powder can be characterized with specific bands of stretching C=O ester of aldehyde and ketone groups at 1636-1747 cm^{-1}, bands Stretching O-H at 3352 cm^{-1} and bands Stretching C-H asymmetrical at 2929 cm^{-1}

EDS- Energy Dispersive x-ray Spectroscopy of CP

To analyze the CP, energy-dispersive x-ray spectroscopy (EDS) was performed. EDS elemental analysis showed that the CP mainly consists of AL, C, O, and K as shown in figure 5 and table 3.

Table (3): Elemental composition of carrot powder as measured from EDS.

Element	C	O	Al	K
Weight Percentage (%)	58.379	6.525	31.425	3.309

Water absorption

For the water absorption test, the dried specimens are weighed. The material is then emerged in water at room temperature for 24 hours, specimens are removed, patted dry with a lint free cloth, and weighed by using equation 1 [9, 10].

$$\text{Water Absorption\%} = \left(\frac{(\text{Wet Weight} - \text{Dry Weight})}{\text{Dry Weight}}\right) * 100 \quad \ldots(1)$$

The water absorption values are calculated then the results are expressed in figure 6 which shows that increasing the CP-to-cement ratio in the cement mortar resulted into a decrease of water absorption by 26% compared with pure mortar. This behavior was found reproducible in all reinforced mortars regardless the time interval after which measurements were taken.

Hardness

Hardness results , as shown in figure7. reveal that an increase in the percentage of carrot particulates in mortar increases the material hardness. The increase in hardness is due to the presence of some mineral particles formed as a result of reaction between CP and mortar. being otherwise occupied with water.

Bending Results

Measurements of bending strength are shown in figure 8. It was found that addition of CP resulted into higher bending strength. In another word specimen containing CP were more resistant to the external bending forces than CP-free mortars. For each specimen the bending strength reduced with time due to hardening of cement mortars. In addition, increasing the CP-to-cement ratio was found to enhance the bending strength with regard as well as regardless time. To further elaborate this observation, the percentage enhancement of bending strength was calculated from the measurements and found equal to 12%, 52% and 62% for cement mortars after 7, 14 and 28 days respectively.

Compression Results

Compression test results are shown in figure 9. Results show that time has a great effect on compression which is obvious for all cement mortars (i.e. cement mortars get harder with time so more resistant to compression). Increasing the Cp-to-cement ratio in the mortar was found to enhance this property. Cement mortar with 6% CP-to-cement ratio showed compression value of 1.8 MPa which is higher than compression of the CP-free mortar (1.3 MPa). Furthermore, it was found that addition of 6% CP to the cement mortar enhances the compression property by about 200% (22 MPa) after 28 days compared with 38% (7.5 MPa) after 7 days. This means that addition of CP to the cement mortar improves the compression property by five times (i.e. 38% to 200%). This could be attributed to the fact that each CP particle creates a void of its material inside the specimen. This void is believed to act as a microstructure responsible of eliminating tensile stresses and resolving forces into compressive stresses at micro scale in a manner similar to arches spanning spaces and supporting weights in buildings [11].

Impact and Fracture Toughness

Impact strength, the energy required to break the sample, was found to increase with the increase of CP concentration. From the energy conservation point of view the energy due to the applied shock should transfer to the sample material upon the impact. This energy transfer may take different forms; i.e. from kinetic energy to heat or deformation. But since the force is applied for a short time the energy transfer has to occur in this time scale. The response of the material to this effect is to behave like it is brittle leading to occurrence of fracture at the point of impact according to the principle of time-temperature superposition[12-14] .

The energy absorbed in the present samples is found to increase with the increase of the CP ratio in the mortar . The reinforcing particles are believed to absorb part of the delivered energy and prevent formation of fractures in the mortar. The fracture toughness K_c , presented in figure 10, shows a decrease in value with the increase of CP concentration. The fracture toughness is calculated from equation 3 which shows a direct dependence on the impact strength and flexural modulus. The behavior of K_c in figure11 should therefore be attributed to the dominating effect of the flexural modulus E_b which appears as a second term in equation3. It is then justifying to reach at a conclusion that the addition of CP into the mortar had a more prominent effect on the flexural properties than on the impact resistance. The addition of CP made the mortar harder and less ductile product. Impact Strength Calculated From Equation 2.

$$Gc = Vc/A \quad \dots (2)$$

Where:

Gc: Impact strength.

Vc: The amount of absorbed energy to break the sample.

A: Cross Sectional area $K_c = \sqrt{(E_b X G_c)}$ ...(3)

E_b is the flexural modulus in Pa unit.
Kc :Fracture Toughness.
Gc: Impact strength

Scanning Electron Microscopy of CP

The microstructure of the carrot powder was examined using INSPECT S50 scanning electron microscope (SEM) from FEI instrumentation. In order to produce high contrast images and since carrot powder is not a conducting material the specimen were gold coated prior to measurements. SEM images of different magnification were obtained to have a better insight of the structure. The SEM images show that carrot powder is composed of folded sheets randomly oriented which is in its turn composed of the carrot fibers. See figure 12.

Conclusions

Increasing ratio of CP weight ratio affected the compressive strength, impact, hardness. The bending ,water absorption and fracture toughness decreased and were affected positively. It was concluded that CP might be used in mortar cement production replaced the cement in certain ratio to make them profitable and lessen their adverse effects on the environment**.**

Figure (1): (a) Carrot roots (b) Carrot fibers from processed roots (c) Carrot powder after being processed by ball milling.

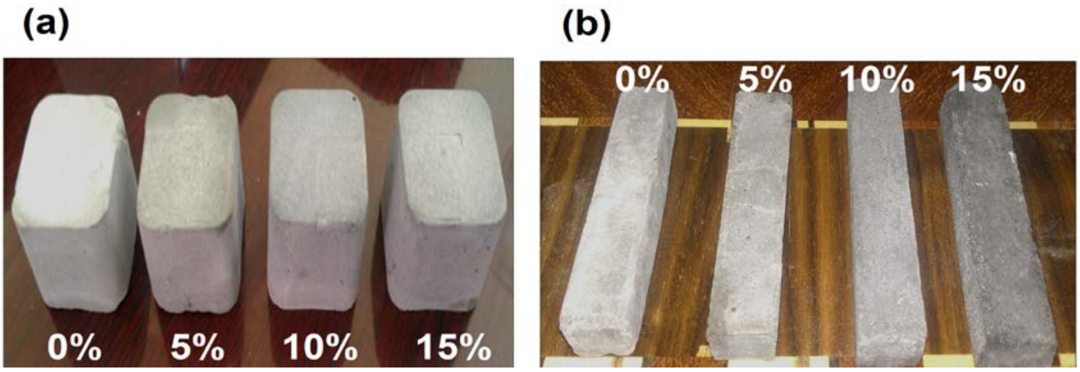


Figure (2): (a) Specimens for compression test (b) Specimens for bending and impact test

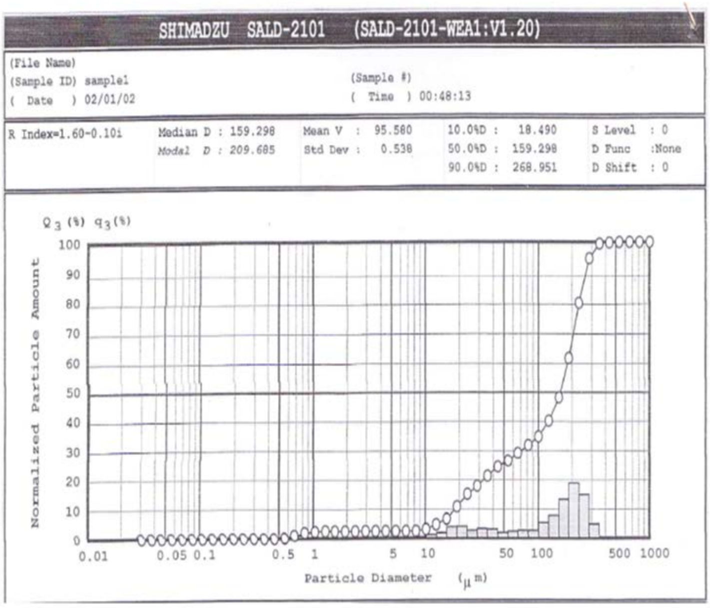


Figure (3): Particle size distribution of CP

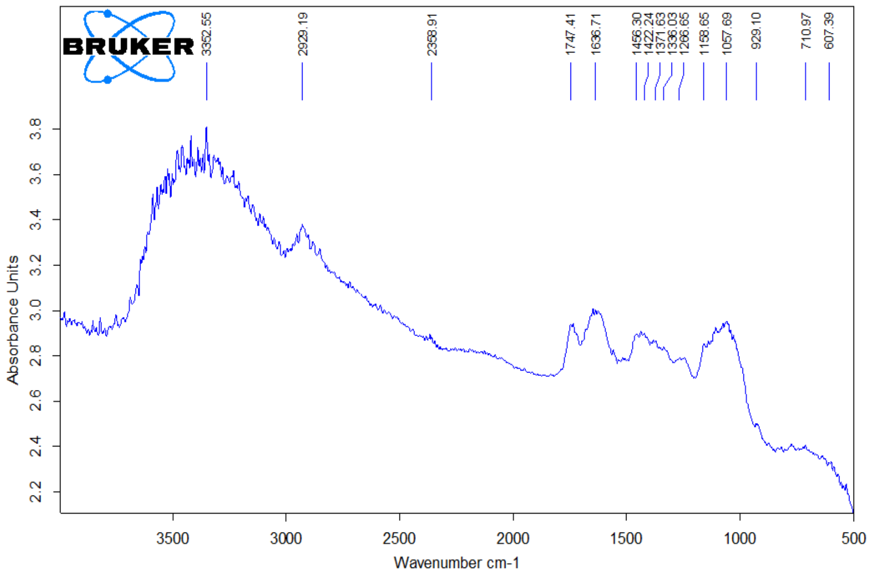


Figure (4):FTIR of PC

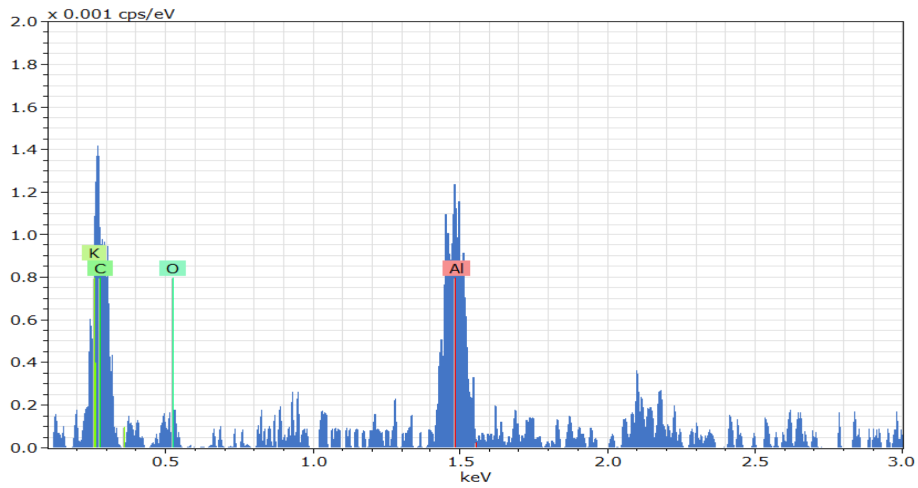


Figure (5): EDX of CP

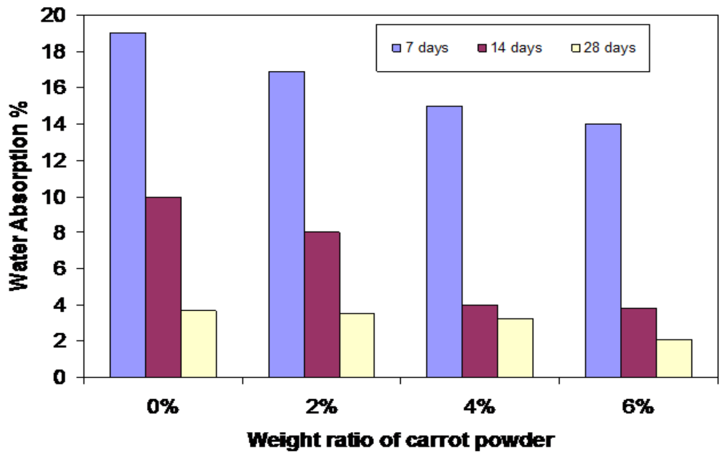


Figure (6): Water absorption of CP

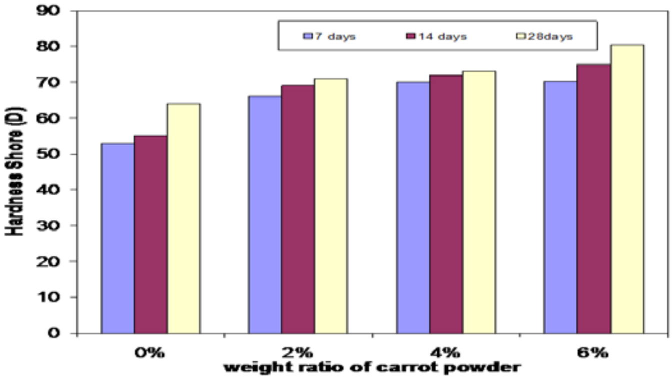


Figure (7): Hardness shore (D) of CP

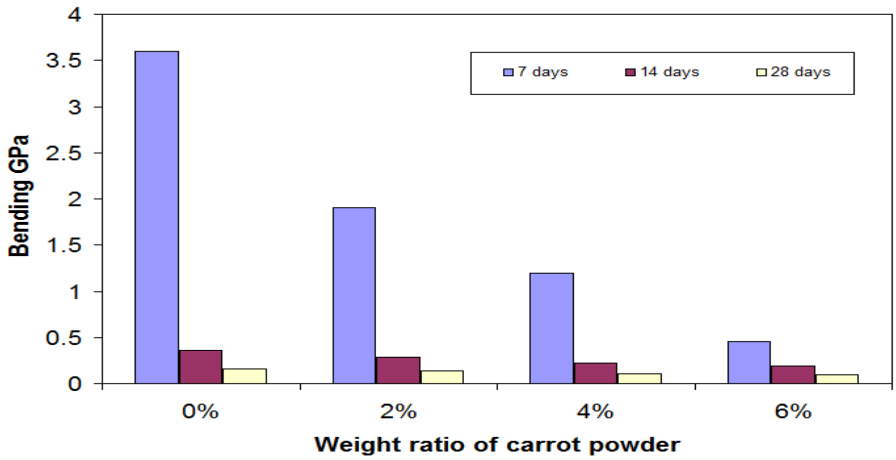


Figure (8): Bending of CP

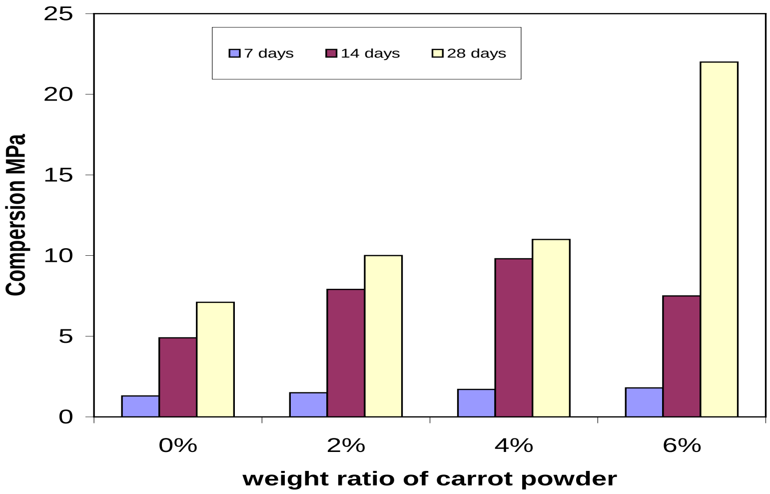


Figure (9) :Comprising of CP

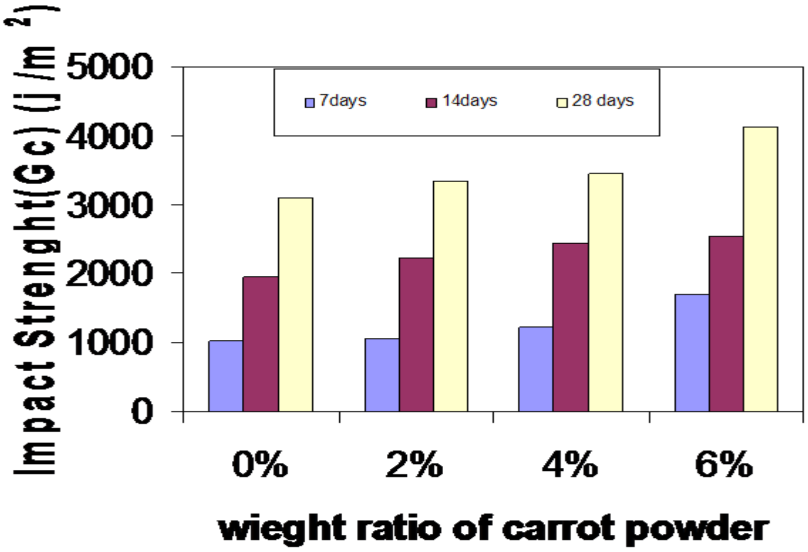
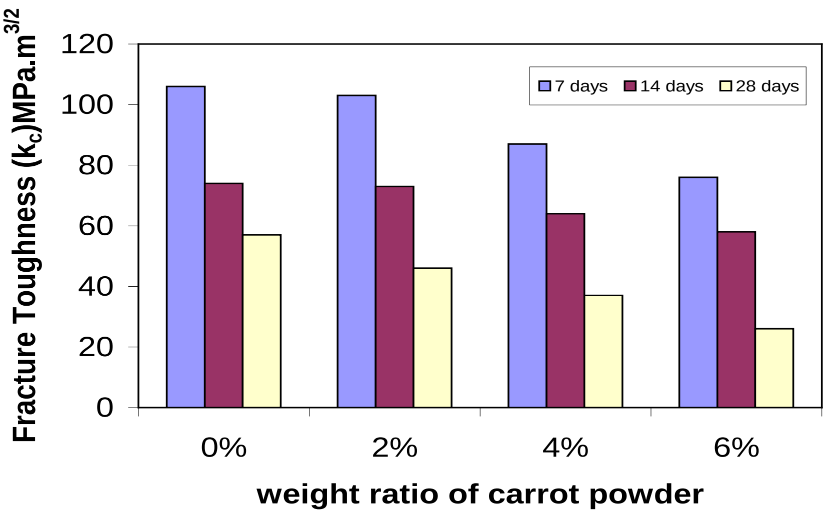


Figure (10): Impact strength of CP



Figure(11): Fracture Toughness of CP

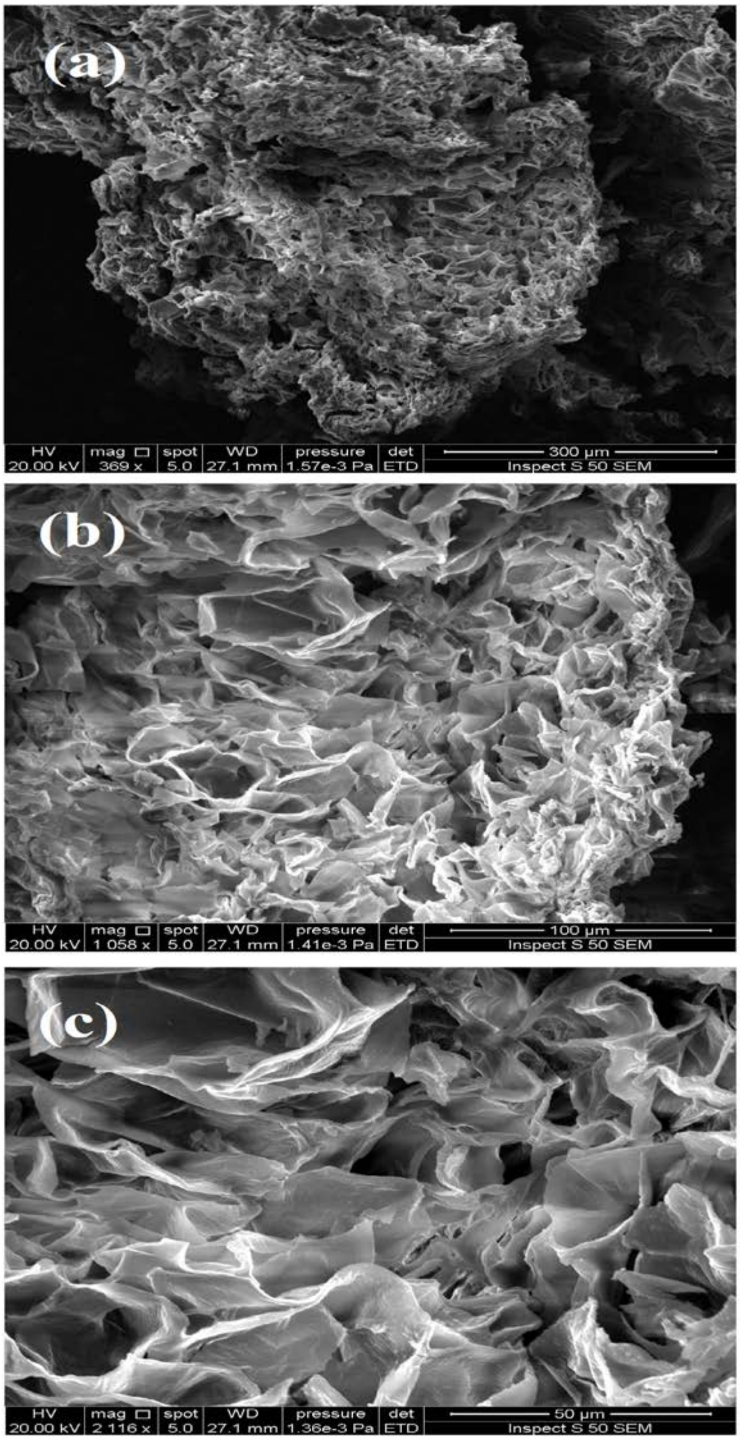

(a)
HV 20.00 kV | mag 369 x | spot 5.0 | WD 27.1 mm | pressure 1.57e-3 Pa | det ETD
300 µm
Inspect S 50 SEM
(b)
HV 20.00 kV | mag 1 058 x | spot 5.0 | WD 27.1 mm | pressure 1.41e-3 Pa | det ETD
100 µm
Inspect S 50 SEM
(c)
HV 20.00 kV | mag 2 116 x | spot 5.0 | WD 27.1 mm | pressure 1.36e-3 Pa | det ETD
50 µm
Inspect S 50 SEM

Figure (12) :SEM of CP

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