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Experimental Study to the Effect of Natural Particles Added to Unsaturated Polyester Resin of a Polymer Matrix Composite

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Abstract

Experimental investigations had been done in this study to demonstrate the effect of natural particles used as a reinforcement material to unsaturated polyester resin. The tensile test and water absorption were investigated according to (ASTM D638) and (ASTM D570), respectively. The influence of sunflower husk and pomegranate husk particles, used as a reinforcement material, on the tensile strength, Young's modulus and water absorption with different weight fraction (3%, 7% and 10%) and particle grain size (50µm, 100 µm and 150 µm), has been investigated. The water absorption of polymer composites was studied by measuring the specimen weight before and after immersion in water for one hundred days. In the experiments of tensile test, all specimens loading was performed with (50KN) operating at a crosshead speed of 10 mm/min. It is observed that the addition of sunflower husk up to 10% and pomegranate husk particles up to 7% as reinforcement materials to polyester resin, leads to increase the tensile strength and Young's modulus of the composite material prepared and the use of sunflower husk as a reinforcement material increased the tensile strength, Young's modulus and water absorption were better than pomegranate husk at the same percentage of addition. The decrease in reinforcement material grain size led to increase the tensile strength, Young's modulus and water absorption. Therefore, all the best result seen in composites containing reinforcement material with (50µm). Finally, the best result obtained in tensile strength, Young's modulus and water absorption were with the addition of 10% sunflower husk as a reinforcement material to polyester resin.

Keywords: *Polyester, Polymer composite; Pomegranate husk, Sunflower husk.*

1. Introduction

From thousands years, human has tried to improve the available materials in their surroundings to preferable the life of the people around him and the community in overall. These attempts had led to different research over the years to find alternatives materials. A lot of studies had done on composite material to investigate this new material specially polymer matrix composite which be capable substitute in the different industrial applications, when compared to old used materials. Also the studies show that the using of polymer composite gave a better performance than ceramics, polymeric materials or alloys [1].

There are two main type of polymer will used as matrix material, thermoplastic and thermoset. Thermoplastic is able to reformed after solidification like nylon and polyethylene, while thermoset is a material when solidification cannot be reformed like epoxy and polyester [2].

The composite material is a result of two phases, the first one called the matrix, while the second called the reinforcements phase. The characteristic of composite materials is dependent on the characteristic of the two phase's common in the preparation of the composite material [2].

In recent years, many studies have been done for natural fillers like coconut shell, pomegranate core, pineapple leaf, ginger, palm kernel, etc. as fillers in order to substitute the conventional fillers by using the natural fillers as a

reinforcement material in polymer matrix composites to decrease the cost, rise productivity beside the enhancement of the mechanical properties[3].

In order to obtain the tensile strength and the Young's modulus many researchers modified polymers using different natural fillers. N. W. A. Razak and A. Kalam [4] studied the effect of oil palm empty fruit bunch (OPEFB) on the mechanical properties and water absorption behaviour of OPEFB /PPnanoclay /PP hybrid composites. They observed that the increase of OPEFB fibre size has increased it flexural strength, modulus and water absorption at smaller OPEFB fibre size.

Moayad A. M. [5] study the effects of rice husk fillers on the mechanical properties of rubber composite and he discover that the increase in volume fraction of reinforcement materials leads to increase in young modulus and hardness.

Mohammed Almamory et.al[6] studied the effects of shells powder on mechanical and physical properties of nature rubber, and they observed that the tensile strength and the hardness of the composite material will improved after the addition of reinforcement material.

S. I. Durowaye [7] studied the mechanical behaviour of coconut shell and palm fruit particulate polyester composites in order to develop an engineering material for industrial application. The results show the maximum strength that the coconut shell and palm fruit particulate polyester composites can withstand while being stretched or pulled before breaking, their weight % (reinforcement) must be kept below 10%.

Aseel Basim et.al [8] Studied the mechanical properties for polymer matrix composite material reinforced by nature filler, they used both high density polyethylene (HDPE), and low density polyethylene (LDPE) as matrix to the composite material and used coconut shell particles and fish shell particles as reinforced fillers. They observed that the addition of nature fillers improve the mechanical properties.

Aseel Basim et.al[9] studied the effects of nature material (Rice Husk Ash, Carrot Powder, and Sawdust) as filler to fiber glass / epoxy composite on mechanical properties; they observed that the addition of fillers leads to incremental increase in water absorption, hardness, flexural strength and shear stress with increasing in volume fraction.

Jabbar H.[10] study the tensile and compressive properties of kaolin reinforced epoxy; he observed the tensile and yield strength of the composites decreases with rising kaolin content. It is also observed that mechanical properties increase with decrease in particle size in all cases.

Shaimaa H. Kamel [11] study the effect of grapes and dates particles reinforced polyester matrix composite on some of the mechanical properties, the results showed that the tensile strength and the Young's modulus of filled unsaturated polyester increase with the increment of the percentage of grapes and dates particles. Also that the percentage of (3.5 %) represents the greatest value for the modulus of elasticity for unsaturated polyester reinforced with dates particle and the percentage of (5 %) represents the greatest value for the modulus of elasticity for unsaturated polyester reinforced with grapes particle.

The aim of this research is to investigate the effect of adding pomegranate husk and sunflower husk in different grain size and weight fraction to polyester resin on tensile strength, young's modulus and water absorption.

2. Experimental details

2.1 Materials

2.1.1 Matrix Material

Unsaturated polyester used as a matrix material produced by (SIR). It is in liquid state at room temperature but after adding the hardener will change to solid state. The hardener used to this purpose Methyl Ethyl Keton Peroxide with mixing ratio 1:50 hardener to polyester resin at room temperature. After the adding of hardener to the resin the process of mixing will start and keep for 10 minutes till the homogenous will completed [2].

2.1.2 Reinforcement Material

The particle were collected and crashed by using an electrical mill. The particulates were received by vibratory sieve shaker to get a suitable size of (150, 100, 50 µm).

2.2 Specimens Preparation

Hand layup technique was used in this research to prepare the specimens. Glass mould used to casting the composite material specimens with dimension of (200, 150, and 5) mm as shown in Figure (1) The inner face of the mould was covered with a layer of Vaseline to ensure no-adhesion between the polymeric material and the

mould. The specimens were prepared by mixing the unsaturated polyester with pomegranate husk and sunflower husk powder by using different grain size and weight fraction of (3%, 7%, and 10%) according to roll of mix in term weight fraction as shown in equations (1), (2) and (3).

$$W_p = \frac{w_p}{w_c} \times 100\% \quad \ldots(1)$$

$$W_m = \frac{w_m}{w_c} \times 100\% \quad \ldots(2)$$

$$W_p + W_m = 1 \quad \ldots(3)$$

Where:

W_m, W_p: The weight fraction of matrix material and particles respectively.

w_c, w_m, w_p: Weight of composite material, matrix material and particles respectively.

The particles were supplementary to polyester and hardener and then they were homogeneously mixed at room temperature inside the molud and then left 24 hours for solidification completed.

3. Mechanical and physical Tests

3.1 Tensile Test

Tensile test was used to study the effect of axial load applied to the specimen by using tensile testing machine (Tensile test H50KT (TINIUS OLSEN)) England (UK) /mechanical engineering department /university of technology shown in figure (2). All the specimen have the same test conditions, the applied load was (50 KN), and the operating speed 10 mm/min. figure (3) shows some of the flat specimens was prepared to the purpose of tensile testing with different reinforcement particles grain size and weight fraction according to tensile test equations (4) & (5) and the American standard (ASTM D638) with thickness (5mm) as shown in figure (4).

$$\sigma = \frac{F}{A_0} \quad \ldots(4)$$

$$\epsilon = \frac{\Delta L}{L_0} = \frac{L_f - L_0}{L_0} \quad \ldots(5)$$

σ: Stress (Pa), F: Applied load (N), A_O: Original area (mm^2), ϵ: strain (unit less), ΔL: length change (mm), L_f: final length (mm), L_o: original length (mm).

3.2. Young's Modulus

The Young's modulus can be obtained by calculating the slope of the stress- strain curve for the tensile test in the proportional limit zone [12].

$$E = \frac{\sigma}{\epsilon} \quad \ldots(6)$$

Where:

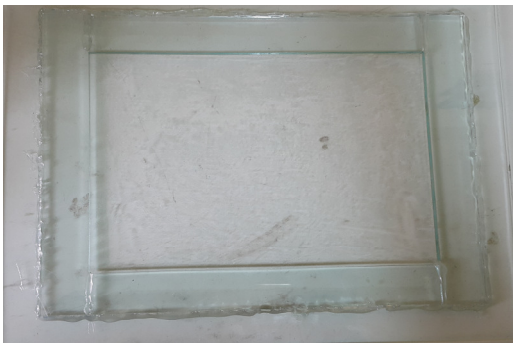
E: Young's modulus (Pa), σ: Stress (Pa), ϵ: strain (unit less).

3.3 Water Absorption

Disc specimens were prepared with diameter of 40 mm and thickness 5mm in order to obtain the water absorption of the composite material. The specimens weighted before and after immersion in water according to ASTM D 570 standard as shown in figure (5). The increase in the weight of the specimens was calculated by using equation (7).

$$\text{Water absorption} = \frac{\text{final weight} - \text{original weight}}{\text{original weight}} \quad ..(7)$$

The specimens were immersion for one hundred days in water and it was weighted every ten days.



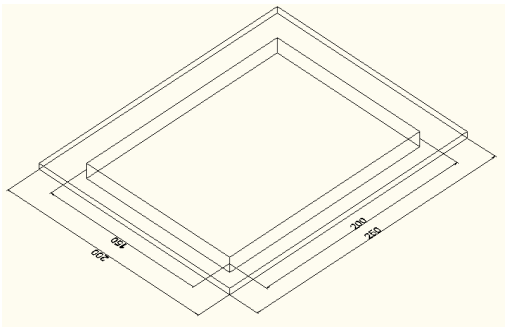


Fig. 1. The moulds shape.

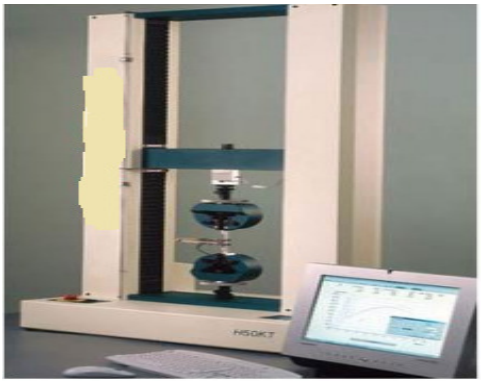


Fig . 2. Tensile test machine.

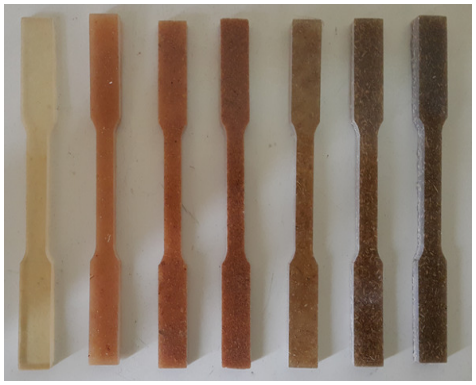


Fig . 3. Tensile test specimens.

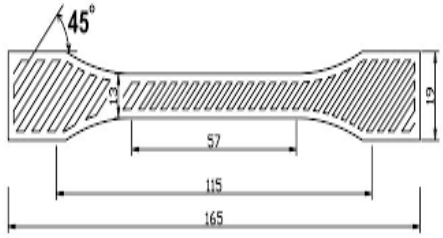


Fig. 4. Tensile test standard

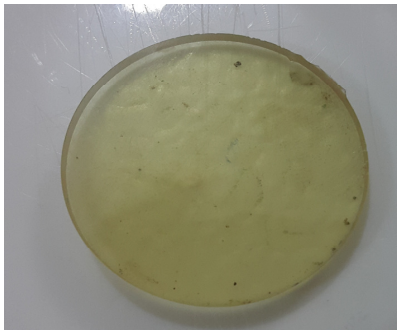


Fig. 5. Water absorption specimen.

4. Result and Discussion

4.1 Tensile Test

From Figure (6), it can observe that the addition of sunflower husk particles as a reinforcement materials leads to increase the tensile strength with the increasing in weight fraction of the reinforcement material by (11.6%, 31.5%, and 46.6%) respectively with particle grain size (50 µm) due to the high linkage between polyester and sunflower husk particles which leads to increase the resistance against the applied axial load. Also from the same figure it can recognize that the decrease in particles grain size leads to raising the tensile strength, because of that the decreasing in particles size leads to more contact between the matrix material and sunflower husk particles.

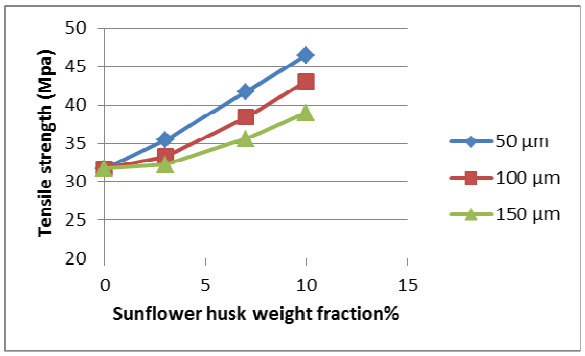


Fig. 6. Effect of sunflower husk particles on tensile strength.

Figure (7) shows the stress- strain curves of pure polyester and (3%,7% and 10%) sunflower husk (SH) weight fraction respectively with (50µm) grain size.

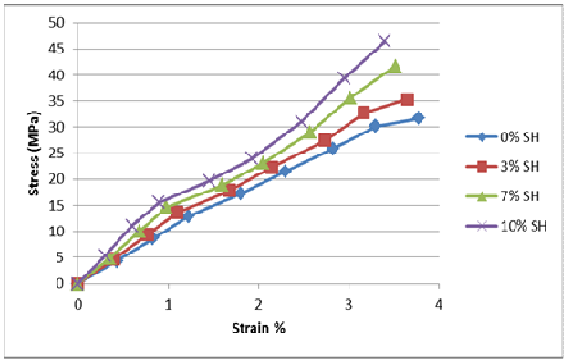


Fig. 7. Stress-Strain curves of different weight fraction of sunflower husk.

While Figure (8) show the effects of pomegranate husk particles on tensile strength with different particle grain size and weight fraction, from this figure it can see that the addition of particles leads to increasing in tensile strength due to increasing of pomegranate husk percentage till 7% after this percent the tensile strength will be decreases with all particle grain size, a similar behavior was seen by S. I. Durowaye et.al[7] we use coconut shell and palm fruit particles as a reinforcement material to polyester resin this may be due to increase in discontinuity between the particles surface and the matrix as the reinforcement concentration increases in the two composites**.**

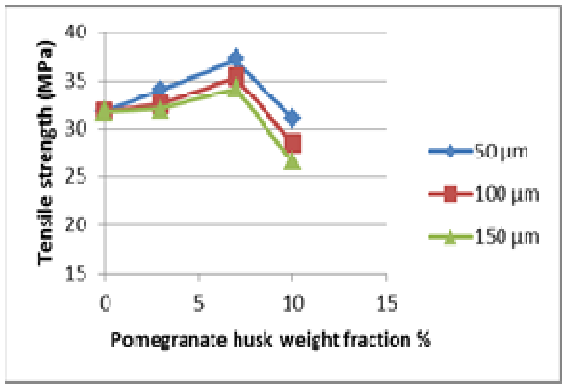


Fig. 8. Effect of pomegranate husk particles on tensile strength.

4.2 Young's Modulus

The relationship between the Young's modulus and sunflower husk particles percentage was shown in Figure (9). It can notice that the increasing in Young's modulus causing be the addition of reinforcement particles which added to unsaturated polyester resin. Sunflower husk particles work to prevent the polyester chains from slipping and this leads to increase the Young's modulus. The addition of 10 % sunflower husk particles with grain size (50 µm) gives the highest Young's modulus with increasing by 27.2% better than unsaturated polyester resin specimen. Analogous demeanor was seen by Shaimaa H. Kamel [11] with the addition of grapes particles to unsaturated polyester up to 5% these quantities of grapes particles strengthen the polyester specimen and increase the young's modulus.

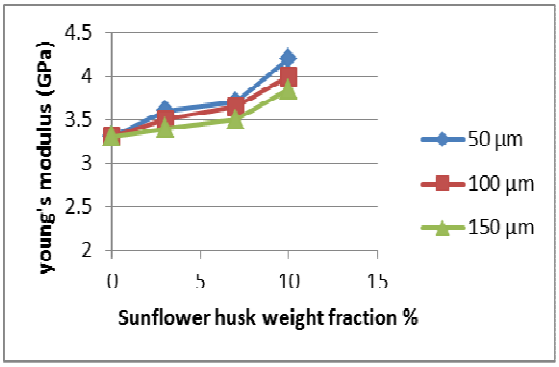


Fig. 9. Effect of sunflower husk particles on Young's modulus.

Figure (10) appears the behavior of Young's modulus after adding pomegranate husk particles with different weight fraction and particles grain size to unsaturated polyester resin. It can be observed that the addition of pomegranate husk particles with any particle size was used increase the Young's modulus up to 7% percent, while after this percent the Young's modulus values starting decrease.

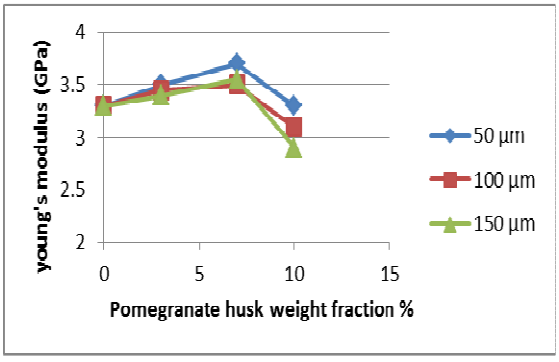


Fig. 10. Effect of pomegranate husk particles on young's modulus.

4.3. Water Absorption

Water absorption behaviors of the composite in water immersion against the time in (days) are shown in Figures (11) and (12). The addition of sunflower husk and pomegranate husk particles leads to increase the water absorption with the increasing in immersion time. A similar behavior was seen by and N. W. A. Razak and A. Kalam [4] Aseel Basim et.al [8] with the addition of natural fiber or particles the water absorption increase with the increasing in immersion time which leads to increase the humidity and decrease the adhesion between the matrix material and the reinforcement material made the composite material may be containing voids and porosity.

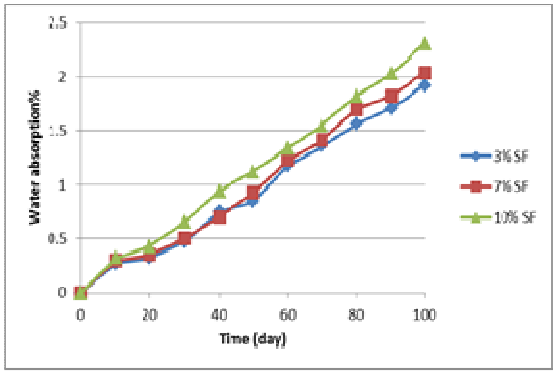


Fig. 11. Effect of sunflower husk particles on water absorption.

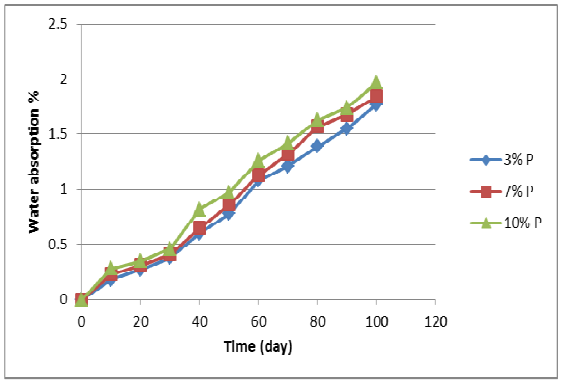


Fig. 12. Effect of pomegranate husk particles on water absorption.

Figure (13) show the difference in water absorption values at using varies particles grain size as a reinforcement material. The results show that the decrease in particle grain size leads to increase the water absorption and the use of sunflower husk have water absorption high than pomegranate husk. In the same filled Alaa A.Mohammed [13] and Hussein .A.Ali [14] have similar result where using different particles grain size the lowest particle size have the highest water absorption due to the decrease in contact area with the matrix.

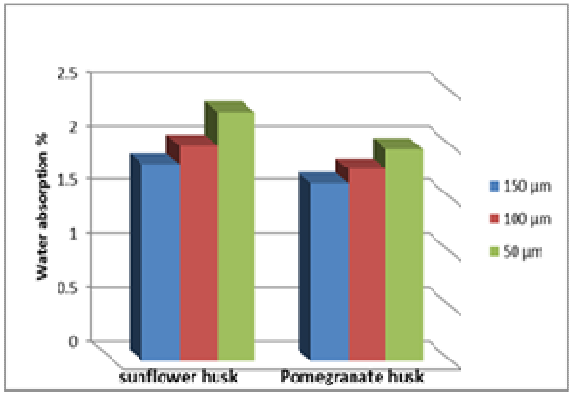


Fig. 13. Effect of sunflower husk and pomegranate husk grain size particles on water absorption.

*All abbreviations and symbols shown in Table (1)

5. Conclusions

From the up results it can conclude the following:

1- The addition of sunflower husk up to 10% and pomegranate husk particles up to 7% as reinforcement materials to polyester resin leads to increase the tensile strength and Young's modulus of the composite material prepared.
2- Using of sunflower husk as a reinforcement material increase the tensile strength and Young's modulus better than pomegranate husk at the same percentage of addition.
3- The water absorption of composite material prepared in this research increase with the increasing of reinforcement material weight fraction.
4- The addition of 10% sunflower husk as a reinforcement material to polyester resin give the best result in tensile strength and young's modulus, where the tensile strength and young's modulus increasing by (46.6%,27.2%) respectively.
5- The decreasing in reinforcement material grain size leads to increase the tensile strength, Young's modulus and water absorption. There for all the best result seen in composites containing reinforcement material with (50µm).

Table 1,
List of abbreviations and symbols

Abbreviations and Symbols	Meaning	Units
HDPE	High Density Polyethylene	-
LDPE	Low Density Polyethylene	-
OPEFB	Oil Palm Empty Fruit Bunch	-
ASTM	American Society of Testing and Materials	-
SH	Sunflower Husk	-
P	pomegranate	-
SIR	Saudi Industrial Resins	-

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دراسة عملية لتاثير اضافة دقائق طبيعية لراتنج البولي أستر غير المشبع لمادة متراكبة بوليمرية

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الخلاصة

في هذا البحث تمت دراسة تأثير اضافة دقائق تدعيم طبيعية لراتنج البولي أستر غير المشبع وعند كسر وزنية وحجوم حبيبية مختلفة. تم دراسة اختبار الشد وامتصاصية الماء للعينات المحضرة وفقا للمواصفات العالمية ASTM D638 و ASTM D570على التوالي. تم دراسة تاثير دقائق قشور حب عبادالشمس وقشور الرمان المستخدمة بوصفها مادة تدعيم على متانة الشد، معامل المرونة وامتصاصية الماء بكسور وزنية (3%, 7%, 10%) وحجوم حبيبية مختلفة (50µm, 100 µm, 150 µm) تم قياس قابلية امتصاص الماء للمادة المتراكبة عن طريق اخذ اوزان للعينات قبل وبعد الغمر في الماء لمدة مئة يوم. اما بالنسبة لاختبار الشد فقد تم تسليط حمل مقدارة (50KN) وبسرعة تشغيل 10mm/min. ومن خلال النتائج يمكن ملاحظة ان اضافة دقائق قشور حب عباد الشمس لغاية ١٠% ودقائق قشور الرمان لغاية ٧% ادى الى زيادة في متانة الشد ومعامل المرونة للمادة المتراكبة المحضرة. ومن خلال النتائج تبين أيضا ان إضافة دقائق قشور حب عباد الشمس اعطت نتائج افضل من دقائق قشور الرمان في جميع الاختبارات. ومن خلال المقارنة بين تاثير الحجم الحبيبي لمواد التدعيم يمكن ملاحظة ان استخدام حجم حبيبي (50µm) اعطى نتائج افضل من (100µm) و (150µm) في جميع الاختبارات. أن افضل نتائج سجلت لمتانة الشد، معامل المرونة وامتصاصية الماء كانت عند استخدام دقائق قشور حب عباد الشمس بنسبة (10%) كسر وزني وحجم حبيبي (50µm).