Mesopotamia Environmental Journal
Mesop. environ. j. 2016, Vol.2, No.4:1-8.

ISSN 2410-2598

Improvement of mechanical properties of polyvinyl alcohol by addition of biomaterial (Okra shell and peel peas) for production of environmentally friendly products

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To cite this article:
Abas, F. O . Improvement of mechanical properties of polyvinyl alcohol by addition of biomaterial (Okra shell and peel peas) for production of environmentally friendly products. *Mesop. environ. j*., 2016, Vol. 2, No.4, pp. 1-8.

Received Date: 20 / 3 /2016, **Accepted Date**:24 / 5 /2016, **Publishing Date**: 15/8/2016

Abstract

A bio-based automotive parts are currently astonishing applied such as, DaimlerChrysler of biggest proponent with up to 50 components in its European vehicles. The properties of natural fibers are closely related to the nature of cellulose and its crystallinity properties. Where, fibers with higher cellulose content possess impressive specific mechanical properties.

In making of natural fibers composites, the natural fibers are usually collected, dried, ground and sieved to obtain the desired size prior to processing between (125-250) µm. The processing method that used to prepare natural fiber based composites is moulding ,where the natural fiber for new composites are processing at low temperature limited to 100^{O}C with a shorter processing time reached 24hr in order to avoid the degradation of natural fibers.

PVA/natural fibers green composites processing methods and applications in various fields have been investigated. From results these green composite based on okra shell and peel Pease fibers reinforced PVA composites showed good fiber/matrix bonding and exhibited high tensile strength with the maximum fiber content in addition to other mechanical properties as (impact strength, compression strength, and bending distortion) with preference to the combined fibers composite that selected to be a best optimum one.

Keywords; Improvement, mechanical properties, polyvinyl alcohol, biomaterial, friendly automotive products.

Introduction

PVA is a common and well-known polymer that possesses salient features such as water solubility, ease-of-use, film-forming property, and biodegradability [1]. Also (PVA) has been widely used for the preparation of many blends and composites with several natural, renewable polymers such as chitosan, starch as fillers, and applied them in the development of green composite technology to achieve ecological sustainability. The composites materials should be able to recycled, reused, reprocessed or biodegradable, to minimize its impact to ecosystem. Then these polymers have good potential as biodegradable matrices in environmental friendly composites, in comparison to carbon fibers composites. Recently many innovative and environmentally conscious manufacturers, composite consists of PVA, a biopolymer, with natural fibers, are improve the biodegradability and physical properties of PVA, in order to choice it as eco-sustainable materials, according to the presence of –OH active groups and their hydrophilic nature to give high compatibility materials with PVA because of their good interaction between fibers and PVA resulting a good composite properties and satisfactory performance. many researchers are applied different application systems in this fields were found that compounding of PVA/corn fibers could be achieved at low temperatures (<170^{O}C) in the presence of a plasticizer[2].

Also the additive of high loading plasticizer reduced the melt viscosity during extrusion, this utilization of plasticizer yields uniform and flexible PVA/corn fibers composites. In other hand some investigators have added both urea and glycerol as plasticizers in PVA/lignocelluloses fiber based composites for mulch films applications. In addition Imam et al. [3] is observed the amount of CO2 released from the glycerol and urea where these additives could be the potential carbon and nitrogen sources for the microorganisms then enhanced the mineralization capacity of the soil [4], because of these applications are the use of biodegradable PVA/natural fibers composites as environmentally friendly products as applied in various areas, particularly for food packaging material and mulch films. Finally this type of green base PVA material is applied is an efficient binder for solid particles, including pigments, ceramic materials, cement based materials, plaster, cork, compressed waste products, nonwoven fabrics, and ribbons. Where is prepared PVA/pinewood saw dust composites by hot press moulding for particleboard applications[5], in order to gave high mechanical properties as tensile strength, shore hardness, and tensile modulus such as applied it in PVA/wood composites in particleboard to provide long term benefit in infrastructure from the economic and environmental point of view. In addition to high chemical resistance of these green material to grease, oils and solvents and this could led to the combination of cellulose packaging materials with PVA.

As the studied conducted which proved that the PVA/cellulose fiber composites meet the packaging requirements[6]. Additionally, the antimicrobial properties of essential oil prevent the occurrence of food-related diseases caused by pathogenic microorganisms. In this sector, PVA/natural fibers as mulch films[3] with few years later has been applied this material to the agricultural practice of mulching, due to the effectiveness of materials on the growth and yield of lettuce and corn[7]. The mechanical properties of fibers with higher hemicelluloses content tend to absorb more moisture and char formation is generally better with fibers that have higher lignin content as they experience degradation at relatively lower temperatures [8, 9, 10]. In conjunction with the completely green environmental policy, it is preferable to add the natural fibers in biodegradable polymers such as polyvinyl alcohol (PVA) to produce eco-sustainable composites [12-16].**Aims of this work are:**

1. Design and prepare a new green composite by use of bio- material wastes and eco- friendly material PVA.

2. Optimization and enhancement all mechanical properties as (tensile strength, impact strength, compression, hardness, bending distortion) respectively.

3. Check and optimization three systems as (Okra waste system, Pease peels wastes system, and Okra waste+ Pease peels system) respectively.

4. Finally study the suitability application of optimum system in the manufacturing of automotive parts.

Materials and Methods

Materials

Okra waste:were obtained from local municipal solid Iraqi wastes for canned food.
Pease peels:were also obtained from local municipal solid Iraqi wastes for canned food. Where figure (1) shows the base source material that will be used in preparing of green PVA composites.
Polyvinyl alcohol: obtained from BTU Company for chemical materials of highly pure compound of PVA (molecular weight 13–23 kDa, degree of hydrolysis 87–89%).

Fig. 1 estimate the biomaterial wastes okra shell and Pease peel

Methods

Preparation dietary fibre powders

Green waste pea peels fibre:
green pea peels were washed with water; then it was dried at 60 ºC for 12 hrs in an electric oven drier and ground by using the laboratory hammer mill, and let to pass through a 6 mesh sieve 125-250µm to sieving it into fine powder. Afterward packaged in polyethylene bags protected from light and moisture and stored in desiccators until use. Where table (1) shows the composition of wastes peas peel material.
Okra waste fibres:
The by-products obtained from Okra shell and the remaining pulp after cutting the fruits could be suitable sources of DF shell residue chopping, the material was washed under mild conditions to minimize losses of some soluble fibre components (such as pectins and pentosans) as well as bioactive components (such as flavonoids, poly-phenols and carotenes) [11], then dried at temperatures below 65 ºC avoids changes in the functional properties and in the content of poly-phenols, tannins, anthocyanidins and proteins for 12 hrs in an electric oven drier, and grinding to a particle size of 125-250 µm and stored in desiccators until use. And table (2) shows the compositions of wastes Okra material[11].

Preparation of composite green biomaterial:

The green composite applied in this work is made of PVA material as a matrix and Iraqi biomaterial wastes as fillers. Iraqi wastes have been collected and washed carefully and dried, the milling process was achieved by using electrical ball mall for 3 hr, and then the powder of wastes was passed through sieve with diameter of 125 micrometer and used as filler. A magnetic stirrer was used for 3 hr to make the solution highly homogeneous where PVA was dissolved in 40ml of distilled water with different additives (0/100, 30/70, 50/50, 70/30, 100/0 wt./wt. %) respectively. Each solution was placed in a Petri dish and then placed in a dust free chamber to evaporate the solvent slowly in air at room temperature for 48 hrs to make mould samples. Where table (3) shows the additives design for prepared samples.

Mechanical properties measurements:

Tensile mechanical property is made using the Instron Universal Testing Machine (Model 4401) equipped with: All testing was performed at room temperature (25±2°C). Other mechanical properties as Compression test, hardness test, impact strength test bending distortion are measured by use other measurement instruments as Rockwell hardness tester, The pendulum impact testing machine, three-point bending tester, and compression tester respectively at the condition of testing lab at (25±2°C) .

Table (1) shows the composition of Pease peel biomaterial wastes.

Contents	**Compositions %**
Dry matter	89.32
Crude protein	13.25
Crude fiber	9.62
Ether extract	-
N_2	51.57
Ash	10.32

Table (2) shows the composition of okra shell wastes

Contents	**Compositions %**
Potassium	8
Total carbohydrates	2
Dietary fiber	12
sugar	-
protein	3
Vitamin A	14
Calcium	8
Vitamin C	38
Vitamin B	10
Magnesium	14

Table (3) shows the design composition for prepared samples

No. Of sample content	PVOH wt.(gm)	Okra shell wt.(gm)	Pease peel wt.(gm)	Okra + Pease wt. (gm)
1	3	0	0	100/0
2	3	3	3	70/30
3	3	5	5	50/50
4	3	7	7	30/70
5	3	9	9	0/100

Results and Discussion

Mechanical behaviour of green PVA composites

PVA is compatible with natural fibers, owning to their ability to form biological groups between the hydroxyl groups in both PVA and the cellulose groups (flavonoids, poly-phenols and carotenes) in thefibers. Then we study their mechanical behaviour as (tensile strength, hardness, impact strength, compression, bending distortion). These measurements are achieved in composite material lab / material engineering department, where the impact strength is determined using the pendulum impact testing machine. While the bending distortion are determined using PHYWE, three point bending tester according to ASTM D790.

The hardness is determined using Rockwell hardness testerWlestorAmsler, Harkeprufer DIN 53505, Shore D. and tensile strength test is determined by use of INSTROIN tester and compression is determined by use COMPACT tester, Where figure (2) has been studied the effects of different and mixed biomaterial wastes (Okra shell, Pease Peel, and both Okra and Pease wastes), from these results you saw that all mechanical tensile property are enhanced with preference for mixed samples of optimum best ratio at (50/50, and 0/100) from Okra + Pease wastes in agreement with results that find all composites based on PVA and cellulose is likely to produce materials with excellent mechanical properties since both materials are polar polymer with high compatibility reactions[7][8], this is because most of the hydroxyl groups in cellulose molecules have already formed either intra- or inter-molecular hydrogen bonds within each other. Such composites have higher cost effectiveness than plastic mulches while at the same time are able to reduce the environmental concern.

And figure (3) shows the effect of separated and mixed biomaterial (Okra shell, Pease Peel , Okra + Pease) on the hardness property of these green composite samples , where (50/50, and 0/100) mixed design ratio are the optimum best one of professional mechanical behaviour according to their comptability reaction and hydroxyl active group found and optimum mechanical behaviour in prepared samples, and these results agreement with other authors [2] and [7, 8] that find all composites based on PVA and cellulose is likely to produce materials with excellent mechanical properties since both materials are polar polymer with high compatibility reactions, this is because most of the hydroxyl groups in cellulose molecules have already formed either intra- or inter-molecular hydrogen bonds within each other.

Also figure (4) indicated the effect of these wastes on the compression property of green composites, then from results it could see that both (50/50, and 0/ 100) mixed design ratio are the optimum best one that have professional mechanical behaviour according to their comptability reaction and hydroxyl active group found that gave optimum mechanical behaviour in prepared samples [2, 7, 8].

 ISSN 2410-2598

Figure (5) has been studied the effect of bio- wastes (Okra shell, Pease Peel, and both) on the impact strength of property of green PVOH composite from results it could see that (50/50, and 0/100) mixed design ratio are the optimum best one of professional mechanical behaviour according to their comptability reaction and hydroxyl active group found and optimum mechanical behaviour in prepared samples [2, 7,8].
Finally figure (6) estimate the effect of different and mixed biomaterial on bending strength property of green PVOH composite you could see that (50/50, and 0/ 100) mixed design ratio are the optimum best one of professional mechanical behaviour according to their comptability reaction and hydroxyl active group found and optimum mechanical behaviour in prepared samples [2,7,8].

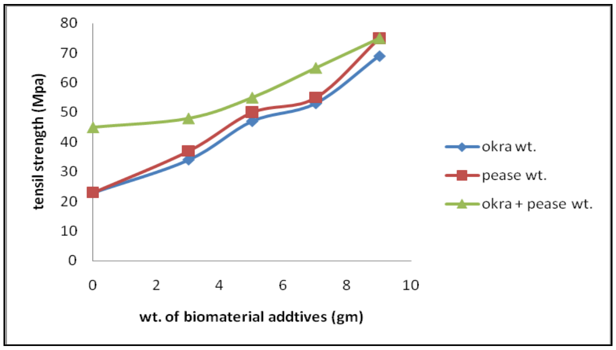

Fig. 2 estimate the effect of different and mixed biomaterial on tensile strength property of green PVA composite

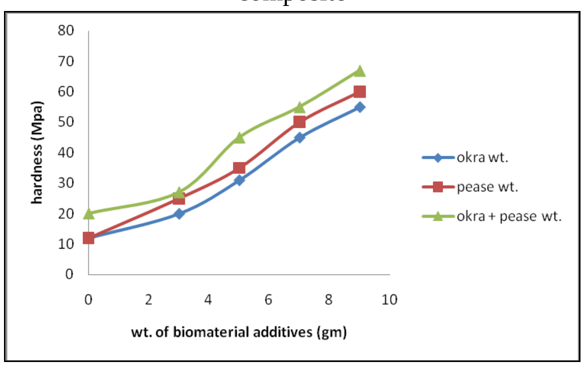

Fig. 3 estimate the effect of different and mixed biomaterial on hardness property of green PVA composite

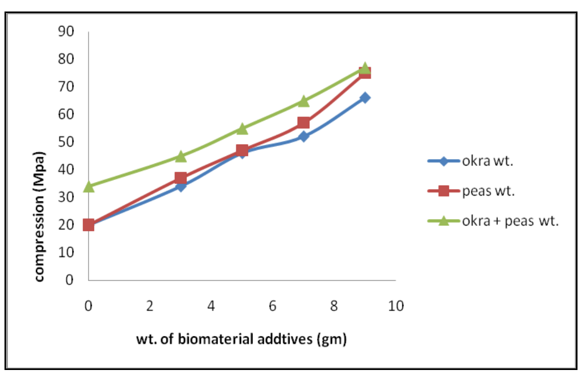

Fig. 4 estimate the effect of different and mixed biomaterial on compression property of green PVA composite

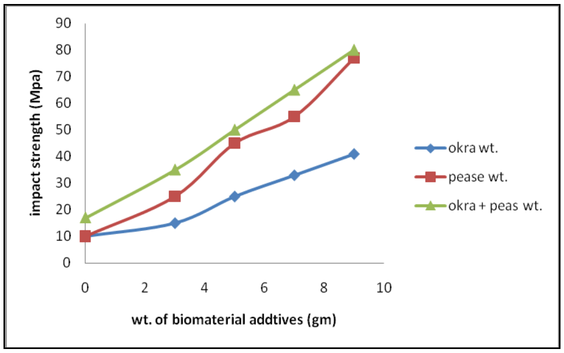

Fig. 5 estimate the effect of different and mixed biomaterial on impact strength property of green PVA composite

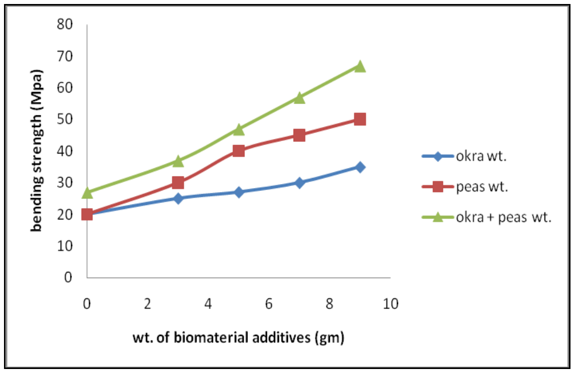

Fig. 6 estimate the effect of different and mixed biomaterial on bending strength property of green PVA composite

Conclusions

Natural fibers obtained from sustainable sources or derived from agro-wastes suffer a large variability ranging from the age and harvesting time of plant, climate and geographical conditions, variation in processing methods, and so on [9,10**]** then:

1. Hydrophilic natural fibers and PVA are combined; it is inevitable to consider their poor moisture resistance due to the presence of hydroxyl groups [11].
2. The long-term durability of these composites, particularly for load-bearing application (such as particleboards), is a major concern.
3. These green composites have demonstrated remarkable properties and thereby emerged as a new generation of composites, and advantageous characteristics, that suitable to for many fields including consumer, agriculture and biomedical.
4. This research is progress to overcome certain limitations in a more cost-effective and eco-friendly way without sacrificing their properties with wide applications of these materials in automotive industry.

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