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Development and Mechanical Assessment of Corn Flour and Olive Pomace Reinforced Bioplastics

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ABSTRACT

This study addresses the pressing need for renewable, biodegradable, and ecologically advantageous materials by harnessing olive-pomace fibers, an often-discarded byproduct of the olive oil extraction process. This investigation underscores the potential of repurposing these waste fibers as reinforcement agents in biocomposite materials. To unleash this potential, olive-pomace fibers were incorporated into a novel matrix composed of cornmeal. The research was spearheaded by the initial characterization of olive-pomace fibers, followed by the formulation and fabrication of biocomposite materials using the fibers in a cornmeal matrix. Subsequently, the mechanical integrity of the biocomposite was rigorously evaluated using Charpy impact tests on standard test specimens. A superior mechanical performance was observed in a specific formulation, labeled as MC40/OP5, which consisted of a 40% cornmeal and glycerol matrix reinforced with 5% olive-pomace fibers. Remarkably, the MC40/OP5 formulation demonstrated a Charpy impact strength of approximately 31.25 KJ/m². This value surpassed the impact strength of both the MC40 formulation, which consisted of 40% glycerol alone, and the MC40/OP10 formulation, which was reinforced with 10% olive-pomace fibers, by factors of 2.1 and 1.3 respectively. The implications of this research are considerable for the evolution of sustainable materials. The successful integration of olive-pomace fibers as reinforcement in biocomposites illuminates a prospective path for agricultural waste utilization to augment material properties. The enhanced mechanical performance of the MC40/OP5 formulation suggests promising avenues in areas requiring elevated impact resistance. In conclusion, this investigation contributes significantly to the ongoing endeavors in developing eco-friendly materials with enhanced mechanical characteristics, thereby bolstering environmental sustainability and resource efficiency.

1. INTRODUCTION

The escalating environmental implications of non-biodegradable plastics have necessitated a paradigm shift towards sustainable alternatives. Traditional plastics, primarily fossil fuel derivatives, have catalyzed revolutions in various industries, notwithstanding their grave ecological repercussions. Their persistence in natural ecosystems, compounded with their contribution to resource depletion and greenhouse gas emissions during their lifecycle, underscore the urgency for environmentally responsible alternatives. Bioplastics, derived from renewable sources, emerge as a compelling solution to these pressing concerns.

Bioplastics, sourced from renewable feedstock such as plant-based materials, present an eco-friendly alternative to conventional plastics. Their inherent biodegradability mitigates plastic waste accumulation and eases the strain on ecosystems. Furthermore, engineering advancements enable bioplastics to exhibit functional properties comparable to, or in certain instances, superior to their petroleum-based counterparts. This ensures that the transition to sustainable materials does not compromise performance.

A crucial strategy to enhance bioplastic properties involves the integration of natural fibers as reinforcement agents. Sourced from materials like flax, hemp, and jute, these fibers have demonstrated potential in significantly bolstering the mechanical characteristics of bioplastics. This reinforcement imparts strength, stiffness, and impact resistance, expanding the application scope of bioplastics beyond single-use disposables.

In the present study, the focus is placed on the exploitation of olive-pomace fibers, a byproduct of olive oil production, as a reinforcing component in bioplastics. Olive-pomace, hitherto an untapped resource, mitigates waste management challenges while contributing to the creation of novel materials. The choice of cornmeal as the matrix material, informed by its renewable and abundant nature, provides a conducive substrate for the integration of olive-pomace fibers. This selection aligns with the principles of resource efficiency and circular economy, further enhancing the environmental credentials of the resulting biocomposites.

The amalgamation of olive-pomace fibers and cornmeal matrix provides a unique platform for developing bioplastics with enhanced mechanical performance and reduced environmental impact. Harnessing the inherent properties of these natural materials, we aim to contribute to the advancement of sustainable materials engineering and advocate for an ecologically balanced approach to plastic consumption.

Through a comprehensive mechanical evaluation of the resulting biocomposites using Charpy impact tests, the benefits of this innovative approach are elucidated. By comparing different formulations and identifying optimal combinations of olive-pomace fiber content and matrix composition, valuable insights into the design and development of bioplastic materials for a range of applications are provided.

In essence, this study underscores the urgent need for sustainable alternatives to non-biodegradable plastics by exploring the potential of olive-pomace fiber-reinforced bioplastics. The incorporation of olive-pomace fibers within a cornmeal matrix reflects the multifaceted benefits of this approach, including waste reduction, resource efficiency, and enhanced material performance. As we navigate towards a greener future, the outcomes of our research hold promising potential in contributing to a more sustainable and harmonious coexistence with the natural world.

2. MATERIALS AND METHODS

2.1 Fiber extraction

During this research we use peat or what is known as olive pomace or olive residues as support fibers, as they are extracted from olive presses, and it is known as peat or olive pomace or al-Fitoura which is the remains of olives after extracting the oil from it. It can only be obtained in the fall or the beginning of winter after the season of olive picking and pressing, as the areas of its uses and benefit from it are still very few, as we have through this study to search for the extent of its use as an alternative to natural fibers and benefit from it in the field of manufacturing composite materials with natural composition.

Olive oil industry wastes such as olive stone ash, crushed olive stone and sludge from the extraction of pomace oil can also be used as effective secondary raw materials in the manufacture of clay bricks and cement paste.

Pomace oil extraction and oil refining process produce wastewater in the form of sludge. This is sometimes used as fertilizer in agriculture but is often dumped in landfills or water bodies or burned-creating a negative environmental impact.

(See the visual image of the olive droppings in Figure 1).

Figure 1. Olive pomace

See the visible image of the olive fecal matter in Figure 1 Olive pomace, to boot referred to as, olive cake or olive peel is that the stable residue received when the vegetable oil extraction method. It's one in all the most plentiful business by-merchandise withinside the Mediterranean region [1]. In keeping with the reviews of the International Olive Council, 2017, the arena producing of olives is expected to be offered in 2022 with or so 8,000,000 ton olive pomace.

Olive pomace or olive pressed leftovers consists of lignocellulosic cellulose, hemicellulose, lignin, phenolic compounds, uronic acids and oily residues.

In fact, there are two methods for extracting the oil: a conventional method and a centrifugal method (two-stage and three-stage system) [2].

For reference, the physical and chemical properties of olive pomace rely on the approach used to extract the oil, as proven in Table 1.

Table 1. Physicochemical traits of olive pomace from distinctive extraction systems

Parameters	Traditional System	Continuous System	
		3 Phases	2 Phases
Size (mm): Diameter (D), Languor (L)	D6.1, L22.5	D6.1, L22.5	D6.1, L21
Density (kg/m^3)	622.5	622.5	653-780
Conductivity (mS/cm)	0.5	0.5	2.6-3.42
Durability (%)	97.5	97.5	91.41-92.6
Heating Value (MJ/kg)	19.6	19.6	20.4
pH	5,29	6.6	5.1-5.32
Moisture (%)	27.9	44.1-51.2	78.7-64
Ashes (%)	3.55	2.4	4.3-6.74
Organic matter (g/kg)	-	-	932.6
Lignin (g/kg)	194.7	-	426.3
Hemicellulose (g/kg)	168.4	-	350.8
Cellulose (g/kg)	114.9	-	193.6
Fat (g/kg)	60–87.2	40-46	121
Protein (g/kg)	65.1	-	71.5
Organic Carbon (g/kg)	429	490±2	514-524.3
Soluble Phenols (g/kg)	11.46	4.5±0.4	31.7
Nitrogen (g/kg)	-	10.4±2.0	16.2-19.8
Phosphorus (g/kg)	-	1.2±0.2	0.7-1.2
Sulfur (g/kg)	-	0.013	0.011
Hydrogen (g/kg)	-	-	6.56
Arsenic (mg/kg)	-	<0.1	<0.1
Cadmium (mg/kg)	-	<0.05	<0.05
Mercury (mg/kg)	-	<0.05	<0.05
Nickel (mg/kg)	-	1.6	2.5
Lead (mg/kg)	-	0.2	2.2
Chromium (mg/kg)	-	1.2	0.7
Copper (mg/kg)	-	14.0-14.2	17-21.3
Zinc (mg/kg)	-	9.9-10	8-21
Sodium (mg/kg)	92.1	103.8	214.3-800
Calcium (mg/kg)	17148.4	3218.7	1693-4500
Magnesium (mg/kg)	1189.7	511.1	808-17 00
Potassium (mg/kg)	11366.2	16020.2	28433.9
Iron (mg/kg)	54.0	87.4	302.3-614

2.2 Morphological analysis of olive pomace

Examination with the aid of using an electron microscope (SEM) of the longitudinal topographic floor of the olive pomace proven in determined Figure 2 "a-b-c-d-e" famous a set of tightly person stable cells with extensive distribution in form and size, together with usual ironstone cells and lengthy shapes. Laminar-formed cells fashioned from a layered ring also can be seen. After grinding processing.

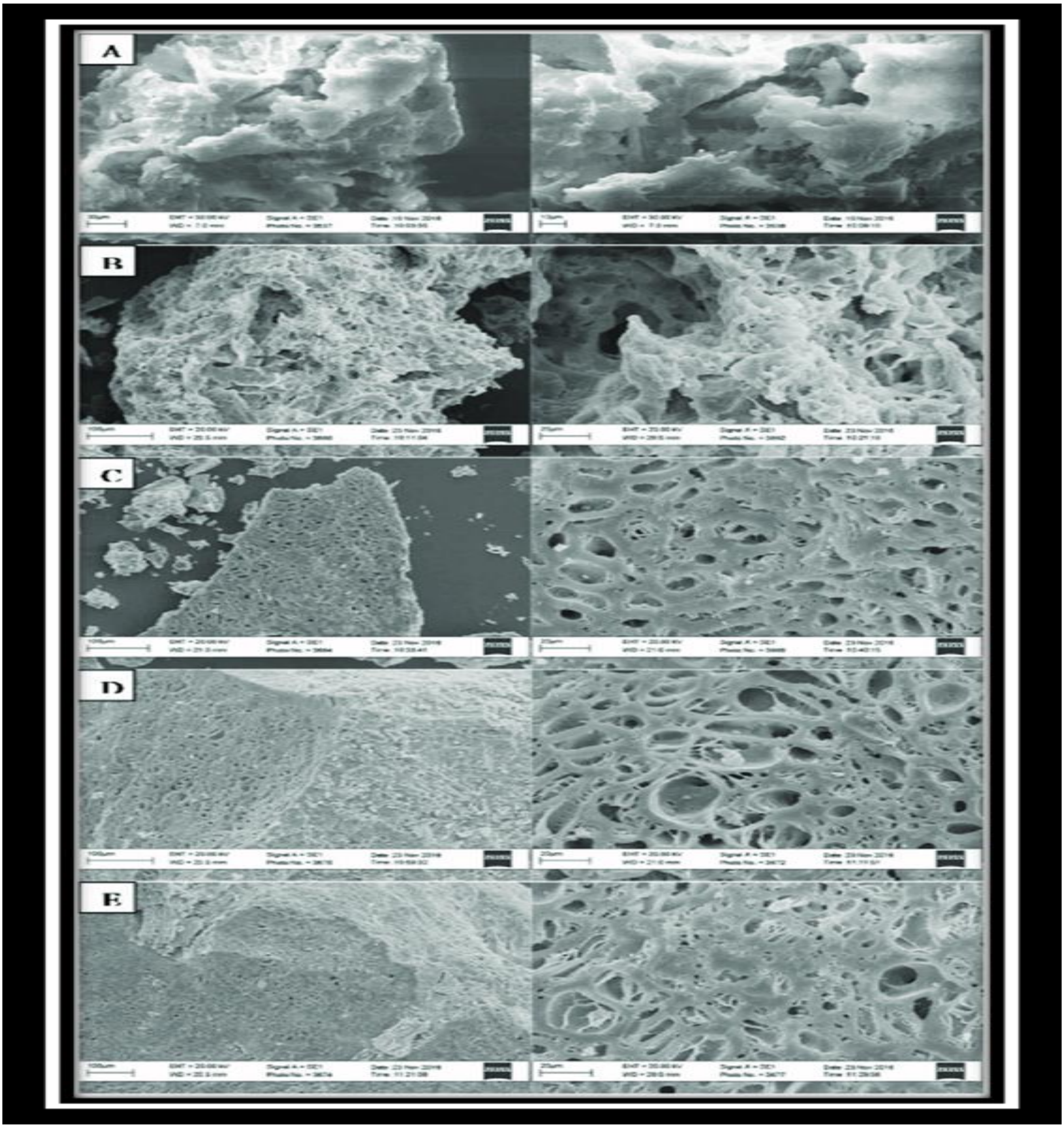

Figure 2. Scanning electron microscopy (SEM) of a, b, c, d, e of olive pomace

3. PREPARATION OF THE FIBERS

After amassing the leftovers of the olive urgent procedure or what is referred to as the olive pomace, they are reduced into portions, washed after which dried inside outdoors or inside the oven at the appropriate temperature, then they are overwhelmed and floor into slices. Small portions the use of an electric-powered grinder.

4. MATRIX

During this research we use corn flour as a matrix or base material.

4.1 Corn flour

Also known in English: Cornmeal. It is a flour produced from grinding dried yellow and white corn, and it is characterized by being a gluten-free product, and it is milled in several degrees, some of which are very soft and this results from grinding in machines with Steel rollers, some of which are coarse and result from grinding in the stone floor grinder according to Figure 3.

Corn flour is used in many uses, and it is worth noting that most types of corn flour sold in stores contain a high amount of starch [3]. Despite the many benefits of corn flour, it has some disadvantages, including the fact that corn contains a large amount of cellulose sugar, which is a type of insoluble fiber [3], which qualifies it to be a good alternative to industrial base material such as: polyester and epoxy.

Figure 3. Corn meal

Where the chemical analysis of corn flour showed the results of its compounds according to the following Table 2.

Table 2. Chemical properties of corn flour

Carbohydrate %	Fats %	Protein %	Fiber %	Ash %	Humidity %
67.63	4.4	11.0	2.22	1.25	13.5

4.2 Morphological evaluation of corn flour

Examination via way of means of the electron microscope (SEM) of the longitudinal topographic floor of cornmeal proven in Figure 4 reveals a set of flexible, unmarried, and dense cells of abnormal sizes.

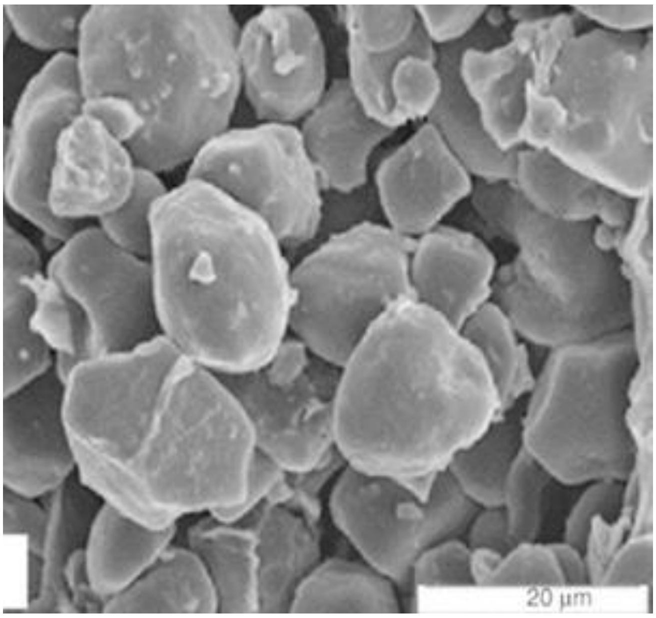

Figure 4. Scanning electron microscopy (SEM) of maize flour micrography

5. PREPARATION OF THE ORGANIC COMPOUND

The matrix includes the subsequent aggregate: MC corn flour, glycerol and water.

In this study, six matrices had been organized to be bolstered with fibers represented through olive pomace. These matrices encompass a aggregate of corn flour, glycerol and water, and this in one of a kind proportions as proven in Table 3.

Table 3. Component mass ratios for the numerous matrices used

Matrix	% Corn Flour	% Glycerol	% Water
MC10	10	90	100
MC20	20	80	100
MC30	30	70	100
MC40	40	60	100
MC50	50	50	100
MC60	60	40	100

In the second stage, the identical system is repeated, including the fiber-pomace-to every matrix at 5% of the load of the mixture, as proven in Table 4.

Table 4. Mass ratios of corn flour/olive pomace fortified with 5% of the development used

Matrix	% Corn Flour	% Glycerol	% Water	% Fiber
MC10/OP5	10	90	100	05
MC20/OP5	20	80	100	05
MC30/OP5	30	70	100	05
MC40/OP5	40	60	100	05
MC50/OP5	50	50	100	05
MC60/OP5	60	40	100	05

It the identical for the third stage, however this time the share of olive-pomace fibers is 10% of the burden of the mixture, as proven in Table 5.

Table 5. Mass ratios of corn flour/fiber-olive-pomace materials of 10% of the booster used

Matrix	% Corn Flour	% Glycerol	% Water	% Fiber
MC10/OP10	10	90	100	10
MC20/OP10	20	80	100	10
MC30/OP10	30	70	100	10
MC40/OP10	40	60	100	10
MC50/OP10	50	50	100	10
MC60/OP10	60	40	100	10

An organic compound is received via way of means of blending glycerin with distilled water in this research, then progressively including corn flour with stirring till a milky yellow liquid is received, then including olive pulp and heating the aggregate with non-stop stirring, till it turns into a gelatinous paste. Finally, its miles kneaded nicely and fashioned into molds, and left with inside the outdoors for 7 days at room temperature to dry. Figure 5 indicates samples with special reinforcements, where in subgraph (a) of Figure 5 represents the bioplastic without reinforcement, at the same time as Figure 5(b) represents the 5% olive-pomace fiber biocomposite reinforcement, and Figure 5(c) represents the reinforcement bio composite 10% fibers.

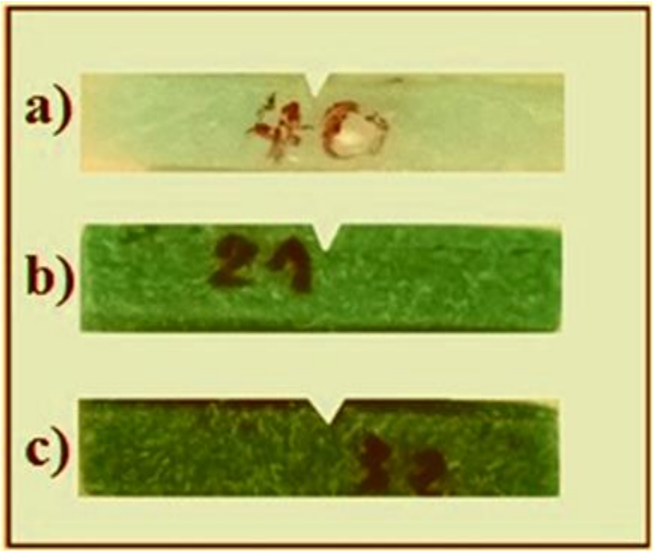

Figure 5. Samples (a. bioplastic maize flour;
b. bio-synthesized maize flour 5% olive pomace;
c. bio-synthesized maize flour/10% olive pomace)

6. CHARPY IMPACT TESTS

Fracture hardness checking out is an essential part of the protection evaluation process, to remedy troubles associated with fracture [4]. The Charpy effect energy (Toughness impact) of a fabric is the belongings of a fabric's resistance to fracturing while subjected to unexpected stresses. Samples had been organized in line with ASTM-A370 standard, inside the shape of a 4-dimensional prism with the subsequent measurements (10×10×55 mm), with a V-fashioned hollow and an intensity of two mm for every case. Samples had been examined with a Charpy hammer pendulum-Impact Tester 4J proven in Figure 6.

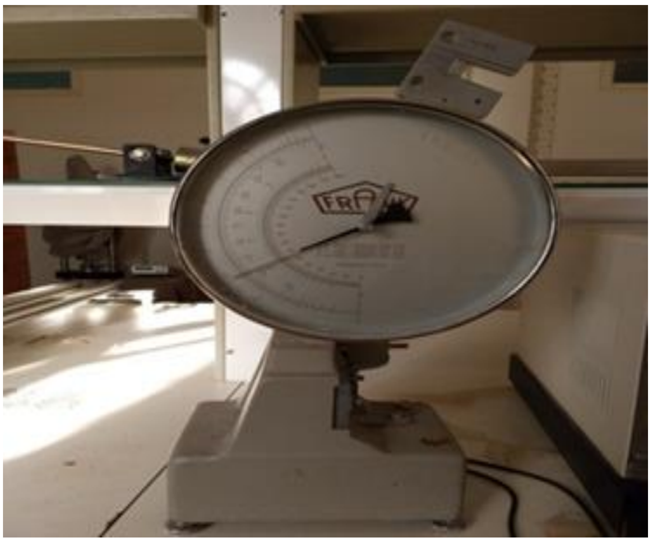

Figure 6. Pendulum impact tester-for 4J

7. RESULTS AND DISCUSSION

Suggests the variance of the common Sharpie surprise stiffness check with cornmeal/olive-pomace fiber-bolstered matrices in unique proportions Figure 7.

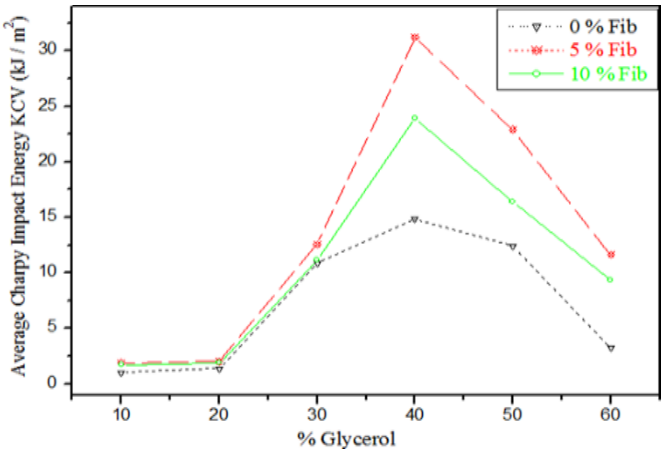

Figure 7. Variation of Sharpie effect with bioplastic reinforced with fibers-olive pomace-waste from the olive pressing process

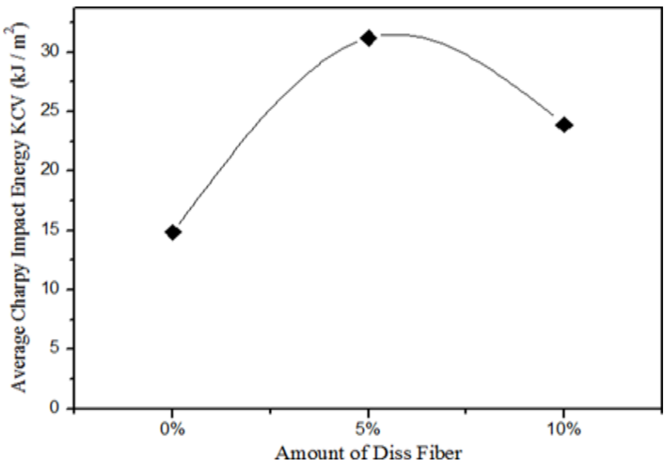

Figure 8. Mean charpy impact power of a matrix (40% glycerol) earlier than and after reinforcement

7.1 Detailed explanation of results

The evaluation of biocomposite samples fortified with various ratios of glycerol reveals interesting insights into the mechanical properties of the materials. Notably, the effect of fiber reinforcement on the mechanical performance is evident. Samples with 10%, 20%, and 30% glycerol ratios exhibited similar impact strength values before and after reinforcement due to the inherent brittle nature of the low glycerol content matrix. Conversely, samples with different matrices exhibited varying impact strength values based on their composition. The highest impact strength value, 14.75 kJ/m², was observed for the MC40 samples (40% glycerol without reinforcement). In contrast, 5% fiber reinforcement resulted in a significant improvement, with the highest impact strength value of 30.98 kJ/m² recorded for MC40/OP5 (40% glycerol reinforced with 5% olive-pomace fiber). Notably, the behavior observed aligns with previous findings on the influence of glycerol content on material brittleness and the potential for glycerol leaching phenomenon.

Figure 8 further illustrates the impact of olive-pomace fiber reinforcement on the hardness impact values of biocomposites. The enhancement of impact resistance is evident, particularly in the case of the MC40/OP5 biocomposites. The Charpy impact strength of MC40/OP5 reached approximately 30.98 kJ/m², marking a 2.1-fold increase compared to the MC40 matrix (40% glycerol) and a 1.3-fold increase compared to MC40/OP10 (40% glycerol fortified with 10% olive-pomace fiber). Comparable outcomes have been observed in other studies involving the influence of fiber content on impact strength and elongation.

7.2 Implications and application of results

The significant improvement in impact strength resulting from olive-pomace fiber reinforcement highlights the potential of utilizing this natural resource for enhancing biocomposite materials. These findings have profound implications for the development of bioplastics with improved mechanical properties, broadening their applicability in various industries. The utilization of olive-pomace fibers as a reinforcing element offers a sustainable solution to both waste management and material enhancement, aligning with the principles of circular economy and environmental stewardship.

7.3 Comparison with previous research

Our findings echo previous studies that have explored the relationship between fiber content and impact strength. Similar to research involving wood flour-reinforced matrices, the present study demonstrates that increasing fiber content can lead to a reduction in impact strength and elongation at break.

7.4 Anomalies and unexpected results

An interesting observation is the consistent impact strength values among samples with low glycerol content. This behavior underscores the influence of matrix composition on mechanical properties. Furthermore, the notable enhancement in impact strength resulting from olive-pomace fiber reinforcement suggests a synergistic strengthening effect that warrants further investigation.

Moving forward, our research opens avenues for optimizing biocomposite formulations, tailoring them to specific applications, and exploring innovative methods for enhancing the impact resistance of bioplastics. By unraveling the intricate interplay between matrix composition and fiber reinforcement, we can advance the realm of sustainable materials, driving us closer to a future where bioplastics play a pivotal role in sustainable development and environmental preservation.

Figure 9 suggests the conduct of every form of pattern inside the course of the surprising pressure carried out to it with a Charpy hammer, in which an unintentional rupture passed off that broken the MC40 pattern fracture into separate parts (Figure 9(a)) with a pressure of 14.75 (KJ/m^2), whilst this pressure is It became now no longer enough to interrupt the fiber-bolstered samples (Figure 9(b) and 9(c)) this reinforcement which earned it an enormously large fracture floor and better effect power required for rupture. The incorporation of the fibers reasons a tremendous distinction in comparison to the fashionable composite (0% fibers), ensuing in an unintentional rupture, completely in the reference [5].

We additionally distinguish the impact of the proportion of introduced fibers at the resistance of the pattern to the electricity of shocks, this means that an immoderate boom with inside the fibers-pomace-ends in a lower with inside the capacity of the samples to face up to the surprise electricity, so the best ratio of fiber reinforcement, that's 5%, need to be taken into account, as we notice That those MC40/OP5 samples do now no longer absolutely break (Figure 9(c)), however, bend barely because of the rupture of a part of the fibers and the withdrawal of the alternative element on the slit, will lessen the effect electricity. In different words, if all the fibers are broken, and the pattern is reduced into parts, the absorbed surprise strength might be better than 30.98 KJ/m^2) recorded, Previous experiments have proven this with different fibers. The ductility of the biocomposites decreases fairly because the alpha fiber loading will increase with the aid of using extra than 15% with the aid of using weight [6]. Also, biocomposites are fortified with the aid of using the fiber content material in wooden flour [7].

Figure 9. Appearance of the overall shape of the effect samples 40% glycerol earlier than and after reinforcement (a. MC40 bioplastic; b. MC40/OP5 bio composite; c. MC40/OP10 bio composite)

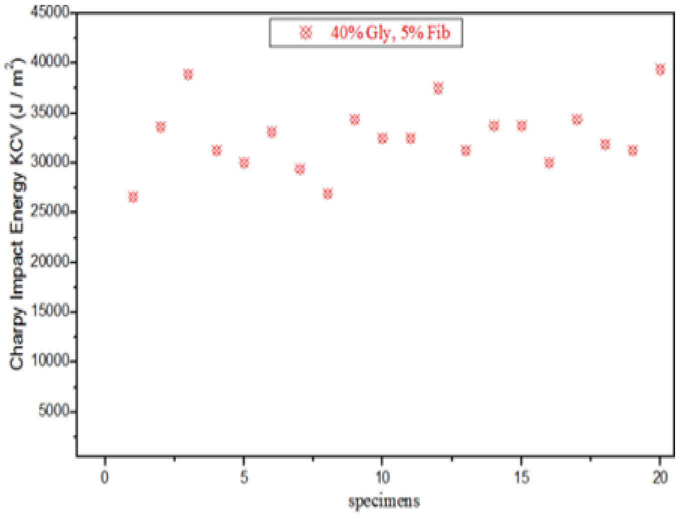

Figure 10. Variation of hardness values for charpy test for biocomplexes (MC40/OP5) maize flour/olive pomace

Figure 10 gives the variance in hardness values for Charpy's take a look at of twenty (20) samples of the MC40/OP5 cornmeal/olive-pomace biocomposites. This distinction in values may be especially associated with elements that have been modified throughout trying out or with defects in manufacturing facility characteristics. Such as its age or fiber extraction process [8].

8. CONCLUSION AND FUTURE WORKS

In this research, we embarked on the formulation of bioplastics through the integration of corn flour, glycerin, and other constituents, fortified with naturally derived fibers sourced from olive pomace. The incorporation of olive pomace fibers yielded significant enhancements in the mechanical properties of the resulting biocomposites. Notably, olive pomace played a pivotal role in impeding crack propagation and resisting impact forces, as evidenced by Charpy impact testing. Our results demonstrate that the hardness impact coefficient of the MC40/OP5 biocomposite, comprising 40% glycerol and fortified with 5% olive pomace, exhibited remarkable uniformity and dispersion, registering at approximately 30982.42 Joules/m² with a standard deviation of 3198.72 Joules/m². This achievement surpassed the impact strength of the MC40 matrix (40% glycerol) by a factor of 2.1 and outperformed the MC40/OP10 biocomposite (fortified with 10% olive pomace) by a factor of 1.3.

Microscopic observations unveiled the robust surface of olive pomace as a potent source of crack resistance, imparting significant reinforcement to the composite material. This heightened strengthening attribute is believed to stem from the well-distributed fine pores spanning the entire surface of the material. The utilization of olive pomace fibers in both fiber and bioplastic contexts showcased numerous advantages, underscoring the promising potential of this waste-derived resource.

Olive-pomace fibers as reinforcements offer an intriguing avenue for repurposing abundant natural residues into cost-effective, environmentally friendly biocomposites, which can serve as sustainable alternatives to conventional plastics across various domains.

Natural fiber reinforcements contribute to reduced costs, lower material weight, diminished environmental degradation, and renewed ecological balance [9].

The exceptional properties of olive pomace fibers parallel those of other commonly used natural fibers, thus opening avenues for diverse applications.

Our experimental outcomes underscore the comparable reinforcing potential of olive pomace fibers, placing them in line with other widely recognized natural fiber options.

By achieving these compelling results, our study extends the horizons of bioplastic development and reinforces the case for leveraging olive pomace as a sustainable reinforcement material. Going forward, future research could delve deeper into optimizing the blend ratios of biocomposites to extract maximal mechanical benefits [10]. Moreover, further investigations could explore the influence of processing techniques and fiber treatments on the overall performance of bioplastics. By building upon these insights, we aspire to pave the way for more resilient and environmentally friendly bioplastics [8]. Contributing to a more sustainable and harmonious coexistence with our environment.

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NOMENCLATURE

MC	Maize Flou
OP	Olive Pomace