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MECHANICAL PROPERTIES OF *FICUS POLITA* SEEDS POWDER AND CALCIUM CARBONATE FILLED POLYPROPYLENE, POLYSTYRENE AND POLYVINYLACETATE BLENDS

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ABSTRACT

Mechanical properties of pure polypropylene (PP), PP/PS/PVAc, PP/PS/PVAc/calcium carbonate (B/$CaCO_3$) and PP/PS/PVAc/*Ficus polita* seed powder (B/FPSP) were reported in this work. The blends with and without filler were prepared by compression molding technique. The compressed molded samples with and without filler of different compositions (100/0, 80/15/5, 60/30/10 and 40/40/20 and B_1/$CaCO_3$, B_2/$CaCO_3$, B_1/FPSP and B_2/FPSP) were characterized for the mechanical properties. Comparative studies were made on the mechanical properties of the pristine polypropylene and the blend with and without filler. Mechanical properties such as tensile strength, Young's modulus and percentage elongation at break, Hardness behavior and Impact strength of both PP, PP/PS/PVAc, B/$CaCO_3$ and B/FPSP blends. These parameters increased with increasing of filler loading (10-20g). B_2/$CaCO_3$ and B_2/FPSP blends filled with 20 g of both fillers had the highest tensile strength, compared with the other blends of different composition. Thus, they can with stand maximum load at a particular applied load as compared to blends of other filler compositions. These blends could withstand loads of 632.76 N and 457.64 N with extensions of 7 mm and 3.3 mm respectively. The blends prepared most especially the composition filled with 10-20 g of both fillers can be used for engineering applications

Keywords: Blend, Calcium carbonate, *Ficus polita* seed powder, Mechanical properties and Polypropylene

INTRODUCTION

Petroleum-based synthetic polymers are widely used in modern society. Many of the mechanical, physical and chemical properties of plastics make them ideal materials for a variety of products and applications.

It is well known that mechanical properties might be used to assess the miscibility in polymer blends through a comparison of experimental results and predictions base on the different methods used during the experimental exercises. Indeed, the mechanical properties of polymer blends depend on the intermolecular forces, chain stiffness, and molecular symmetry of the individual polymers used to prepare the blend [1, 2]. The development of polymer science and technology adds to traditional disciplines a new knowledge and its application for practical purposes of increasing importance. In previous works, conducted usingScanning electron microscopy (SEM) and differential scanning calorimetry (DSC**)** poly (vinylacetate) (PVAc), (10 wt%) has enhanced both mechanical and compatibility of PPC and PLA blends [3-5]. They found that these specimens displayed good interfacial adhesion between the fiber and the resin resulting in better mechanical properties.

However, some other authors [6] have suggested better approach of improving the morphological properties of polymer composite through fiber surface modifications and the formation of functionalities by plasma treatment. Liu and Wang [2,7] investigated the tensile behavior of PP/10–25 vol% HA (24.5 µm) composites. They found that the Young's modulus of PP (1.30 GPa) increases with HA content up to 25 vol%. The modulus and tensile strength of PP/20 wt% HANR nanocomposite are 6.67 and 2.28 GPa respectively with the CNF and HANR filler yielding an ameliorated tensile strength, Young's modulus, impact strength, thermal stability, and biocompatibility of PP. The PP/20% CNF–20% HANR hybrid composite was found to exhibit the highest tensile strength, elastic modulus, thermal stability, and biocompatibility. Wang *et al.*, and Imre *et al.* [7, 8] suggested a novel method by incorporating methyl groups into the surface of fiber thereby exposing them to plasmas treatment. This approach was later flawed following the formation of strong covalent bonds at the composite interface [9]. Interfacial adhesion between reinforcing fibers and matrices can be enhanced by various methods. As recommended in recent published work by Adeosun *et al.*, and Ragosta *et* *al.*, [9,10] the most effective strategy is tailoring the fiber in hierarchical method by means of sizing the fiber along a specific orientation.

Ficus polita is a tropical African evergreen shrub or small tree belonging to the family Moraceae, and usually growing up to 15 metres tall, and sometimes to 40 meters tall. The leaves are occasionally harvested from the wild for food. Traditionally the fruit and young leaf are chewed for dyspepsia [6]. The young leaves are also edible and the bark and roots infusions are used in treatment of infectious diseases, abdominal pain, dyspepsia and diarrhoea like many of the species of the Moraceae family (Usuki, Satoh, Kamigaito). The plant is commonly known as Hartblaarvy, Heart-leaved fig, polish fig, rubber plant, wild rubber fig, wild rubber tree [8]. Locally, it is called Durumi in Hausa [9]. This research will focus to investigate the effect of *Ficus polita* seeds powder and calcium carbonate on the mechanical properties of PP/PS/PVAc blend with and without filler in order to assess its applicability in industrial and domestic use.

MATERIALS AND METHODS

Polypropylene was supplied by Dushanzi Chemical Company, China, as the major polymer with the trade name PP, T30s with density 0.91 g/cm^3 , melt flow index 2.8 g/ 10 min and 230 °C, 2.16 kg accordingly. The Polystyrene, PS, molecular weight of approximately 100, 000, (Trade name 5250) was purchased from BDH Chemical limited, England. The melt flow rate is 7 g/10 min (200 ^{o}C/5 kg). The Polyvinylacetate (PVAc), with chemical formula $(C_4H_6O_2)_n$ with molecular weight 1900, viscosity of 8.8 w/w % solution in toluene at 20 °C 5-7cS and its softening point is 105 °C, was supplied by Sigma Aldrich. The Calcium carbonate $CaCO_3$, with molecular weight of 100.09 g was purchased from Scientific Equipment Division Fisons Plc, Middlesex, England. The *Ficus polita* seeds were obtained locally from Samaru in Sabon Gari Local Government, Kaduna State, Nigeria.

Sample Preparation

Preparation of Ternary blends

Mixing, compounding and pressing of PP/PS/PVAc with and without filler

A roller was used. The PP, PS and PVAc processing temperatures were set with that of PP at 170 °C, PS at 170 -180 °C and PVAc at 150 ^{o}C respectively. The nip of the rollers was adjusted and the polymers were subsequently poured on the nip, after total melting had been attained.

When a homogeneous mixture was achieved, the compounded sample was sheeted out for further processing. The compounding was done base on the formulation proposed by Mamza [21], according to Tables 1 and 2. Pressing was done by compression moulding technique at the rate of 190 ^{o}C/4 Pa/hour.

Table of Formulation (1)

The composition of poly (propylene)/poly (styrene)/poly (vinyl acetate) blend without filler

S/NO	Blend ratios PP/PS/PVAc	Wt of PP	Wt of PS	Wt of PVAc
1	100/0/0	100	0	0
2	50/20/30	50	20	30
3	50/25/25	50	25	25
4	50/30/20	50	30	20
5	50/35/15	50	35	15
6	50/40/10	50	40	10
7	60/20/20	60	20	20

Table of Formulation (2)

The composition of poly (propylene)/poly (styrene)/poly (vinyl acetate) blend with filler

S/N	Filler loading (g)	PP/PS/PVAc (g/g/g/)	B/$CaCO_{3(g)}$	B/FPSP
1	0	100/0/0	100/0/0/0	100/0/0/0
2	10	85/15/5	85/15/5/10	85/15/5/10
3	20	70/20/10	70/20/10/10	70/20/10/10
4	30	60/20/20	60/20/20/30	60/20/20/30
5	40	50/30/20	50/30/20/40	50/30/20/40

Mechanical tests

The tensile test was conducted according to ASTM 638-2007-2018 standards using Instron testing machine (model W 9875). The load applied was (0-50000) N. Hardness test was carried out according to ASTM D2240-082018, Impact test of this research was carried out in accordance with the American Society for Testing Materials ASTMD 256, 2019 as described by Gao *et al.*, and Liu *et al.*, [2, 5] and flexural test was performed according to ASTM D7264-2007-2018.

RESULTS AND DISCUSSION

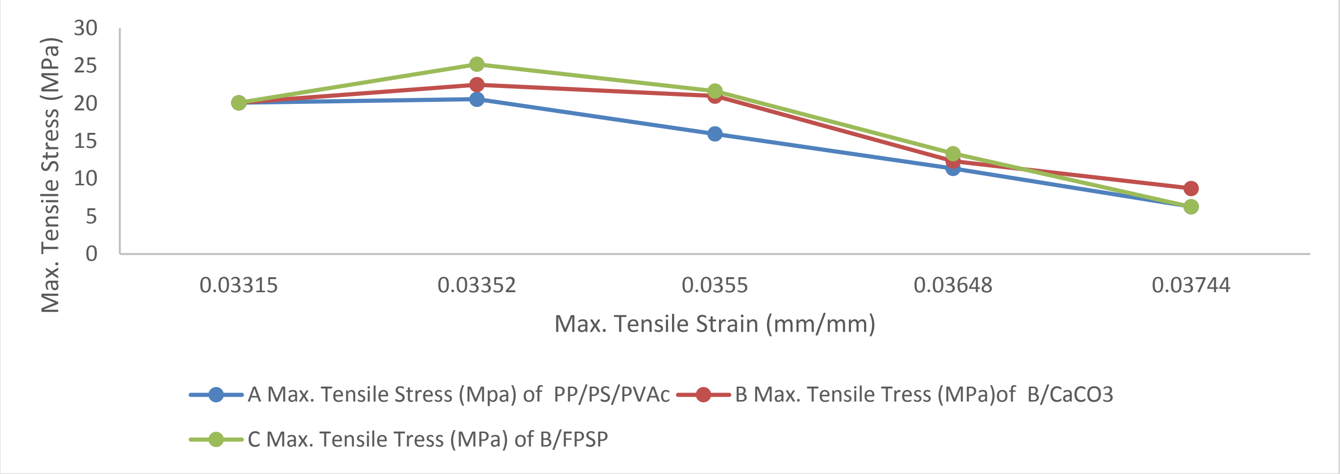

Figure 1a: Plot of Stress- Strain Curve of ternary the blends with and without filler

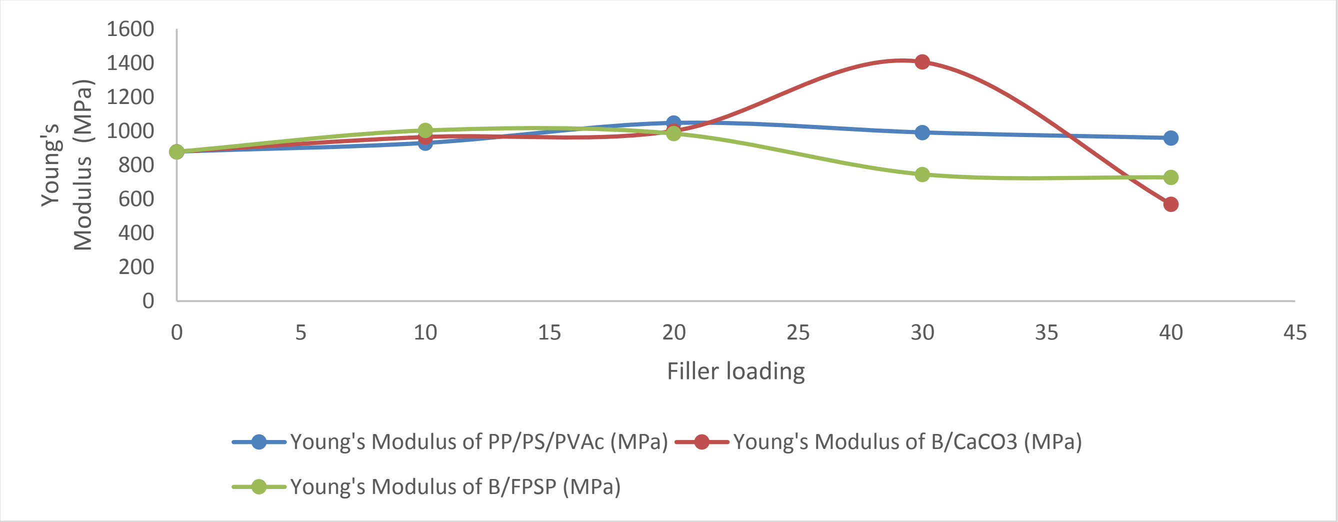

Figure 1b: Plot of Young’s Modulus of the ternary Blends with and without filler

The results of tensile tests (stress-strain curve) for the blends of PP/PS/PVAc, PP/PS/PVAc/$CaCO_3$ and PP/PS/PVAc/FPSP were presented in Figure 1a and 1b. The results showed that the blends without filler have lower tensile strengths than both PP/PS/PVAc/$CaCO_3$ and PP/PS/PVAc/FPSP so, they have higher tensile strength and higher elongations as compared to pristine polypropylene, and the blends without filler. These figures also displayed the behavior of both types of blends which were intermediate between the pure polypropylene and the unfilled blends. By increasing the weight of the two fillers, that is, the calcium carbonate and the *Ficus polita* seeds powder from 10 g up to 20 g to the PP/PS/PVAc blends, there was increase in the tensile strength which was accompanied with change from soft and brittle to hard, rigid and tough with increase in weight of PS and PVAc in the blends without filler in the blend.

It was also noted that the blends filled with 20 g $CaCO_3$ and 20 g FPSP had the highest tensile compared to the blends of other filler compositions. These blends could bear loads of 632.76 N and 457.64 N with extensions of 7 mm and 3.3 mm respectively. Ibrahim and Kadum [14], reported similar results and they stated that the presence of PS in PP has greatly increased both the Young's Modulus and the tensile strength as also reported by Wang *et al.,* [15]. The Polypropylene blended materials are known to provide flexible design application with high durability, coupled with their weight reduction properties. However, their inherent brittleness in many experimental works restrains many of its applications [16]. Researchers [17], have reported on toughening of epoxy reinforced composite with much emphasis on its salient properties.

Thus, the incorporation of additional Polypropylene-rubbery phase into the composite tend to homogenize matrix during curing, leading to uniform morphologies [18]. Findings from Narayanan *et al.*, [19] and Du *et al.*, [20] depicted corresponding results.

There was sharp decrease of the tensile properties on further addition of the two fillers into the blends, with the polypropylene blend of (60/40) of both the calcium carbonate and *Ficus polita* seeds powder having the least mechanical properties. It has been established by Mamza *et al.*, [21] that PP/$CaCO_3$ and PP/CNSP composites helped to raise the fracture toughness of polypropylene even at temperature above 80 ℃. Another author [22] revealed that increase in modulus can be explained by the filler's presence in PP that limits mobility and deformability of the matrix through the introduction of mechanical restraint in the composites system. This agreed with observation by Chang *et al.*, [22] whose report depicted that the Young's modulus of polypropylene filled with silicate increased also in the presence of the filler.

Polypropylene is slightly hard, while polystyrene is a hard and strong material, polvinylacetate is elastic and shows dipole-dipole type of attraction as a result of the electrostatic interactions between oxygen atom of one chain and hydrogen of another chain. This increases their ductility, toughness and flexibility, and results in harder and tougher blends [23-25].

The decrease in tensile strength is due to almost lack of interfacial interaction among the blend components of PP/PS/PVAc at compositions beyond the 20 g fillers' loading. Similar results were reported by Yang *et al.*, [24] and Jun [26]. According to the results reported by Famri *et al.*, [27], a combined stiffening effect of nanofiller and compatibilizer can enhance the mechanical properties.

It was revealed by Abioye *et al.*, [29] that, there was decreased in both tensile strength and modulus of elasticity of PP/PS/Al blend at relatively high amount of the Al. It was also observed that at higher filler loading, it is more difficult for the pristine polypropylene to fully impregnate the filler, thus leading to poor interfacial bonding and consequently lower the mechanical properties. This result is in assent with earlier reported results [16, 30-32].

There was further enhancement of the tensile and flexural strength when the PP was blended with microcrystalline wax at 3/97 composition respectively, which were 25 % and 6 % higher than the pristine PP, PP/POE and PP/HDPE respectively [33].

Hardness Test

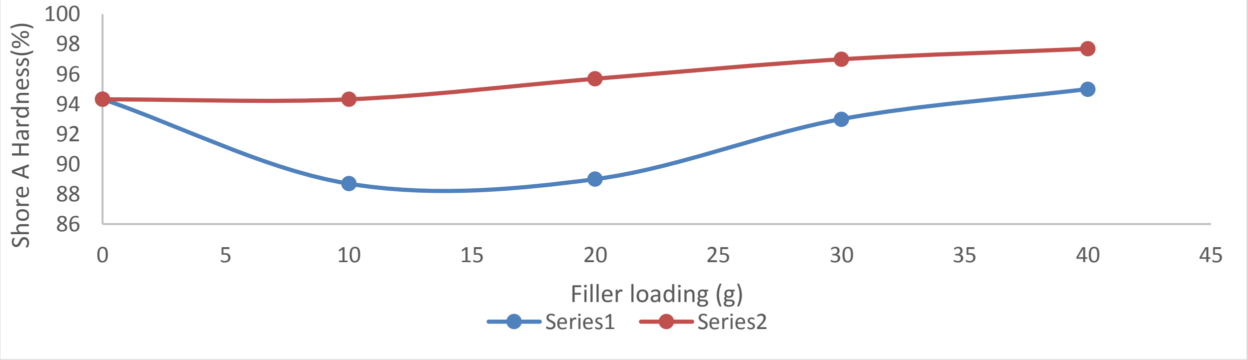

Figure 2: Plot of Shore A Hardness of B/$CaCO_3$ and B/FPSP versus filler loading

The Hardness test results of PP, PP/PS/PVAc, PP/PS/PVAc/$CaCO_3$ and PP/PS/PVAc/FPSP respectively were represented in figure 2. The result confirmed that neat PP has the lowest hardness value than both PP/PS/PVAc/$CaCO_3$ and PP/PS/PVAc/FPSP composites, where PP/PS/PVAc/FPSP having optimum hardness value for all compositions of (PP/PS/PVAc/$CaCO_3$) and (PP/PS/PVAc/FPSP). Furthermore, it was also noticed that the hardness values generally of both PP/PS/PVAc/$CaCO_3$ and PP/PS/PVAc/FPSP composites increased as the weight of both fillers increased from 10g to 40g for (PP/PS/PVAc/FPSP) and 10 g to 20 g for PP/PS/PVAc/$CaCO_3$ loading slightly decreased and increase from 30g to 40g for PP/PS/PVAc/$CaCO_3$ loading. The highest hardness value was recorded at 40 g FPSP of (PP/PS/PVAc/FPSP) composite which was 97.7 %. Hardness properties of any given composite depends on the type and the distribution of the filler used in the matrix [34]. Farbodi suggested that, PVAc improved the hardness of PP [35].

The Impact Strength

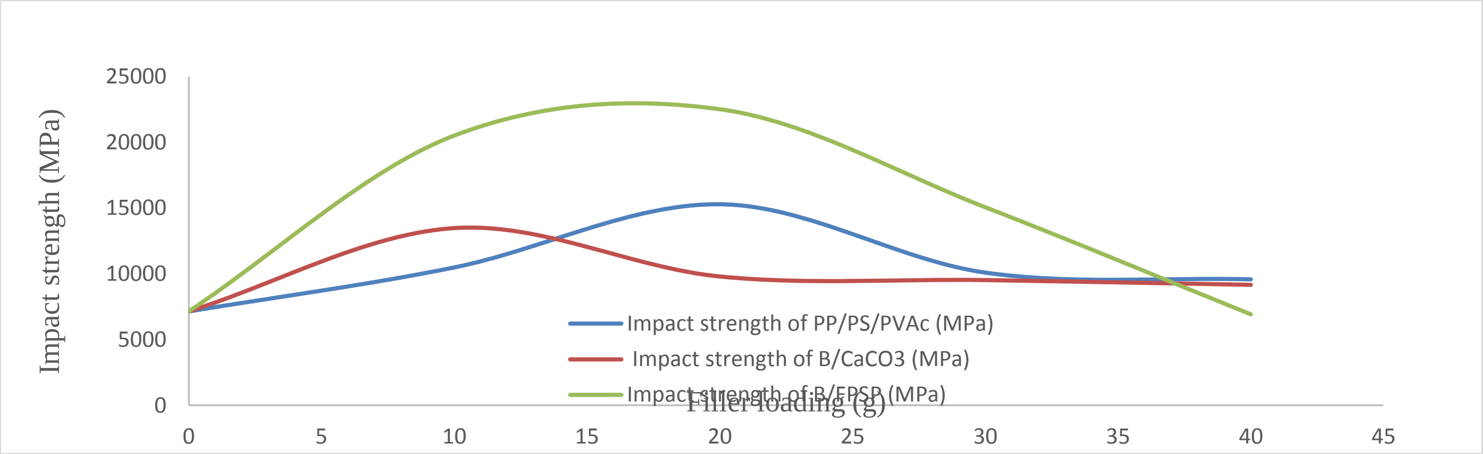

Figure 3: Plot of Impact strength (MPa) versus filler loading (g) of the ternary blend with and without filler

Figure 3 shows the effect of filler ratio on impact strength for PP, PP/PS/PVAc, PP/PS/PVAc/$CaCO_3$ and PP/PS/PVAc/FPSP respectively. There was general increase of the impact strength at 10-30 g of $CaCO_3$ and FPSP loading. This result of the impact strength of this research corresponds with the results reported by Kumar *et al.*, [16].

A depression in impact strength was recorded only at 40 g FPSP load in the blend. Hameed [36] reported that impact strength increased in the ternary blend prepared by mixing EP with (UP/PSR) and (PVC/PSR) respectively. Similar results had been reported [37-39] in which the impact strength of PP was significantly improved by 85 % by the addition of HDPE in to the PP compared to the PP/POE and the pure PP composite. After the maximum impact strength was obtained, a depression in the impact strength was recorded with increase in filler content. The optimum impact strength was obtained at 30 g filler loading for both calcium carbonate and *Ficus polita* seeds powder and the minimum impact strength at 40 g filler loading of the two fillers used.

Calcium carbonate is one of the most commonly used inorganic filler in PP. So many groups have studied the mechanical properties of PP/$CaCO_3$ nanocomposites. Akinci, [40] found that impact strength of PP could be increased from 55 J/m to 133 J/m by adding 9.2 vol. % surfactant treated 44 nm $CaCO_3$. Yang *et al.*, [41], studied the morphology and mechanical properties of polypropylene/calcium carbonate nanocomposites and revealed that the intrinsic toughness of PP matrix was influenced by the addition of 10 g of nano $CaCO_3$4.5 times that of the matrix. Other authors reported similar result [15].

Flexural Strength

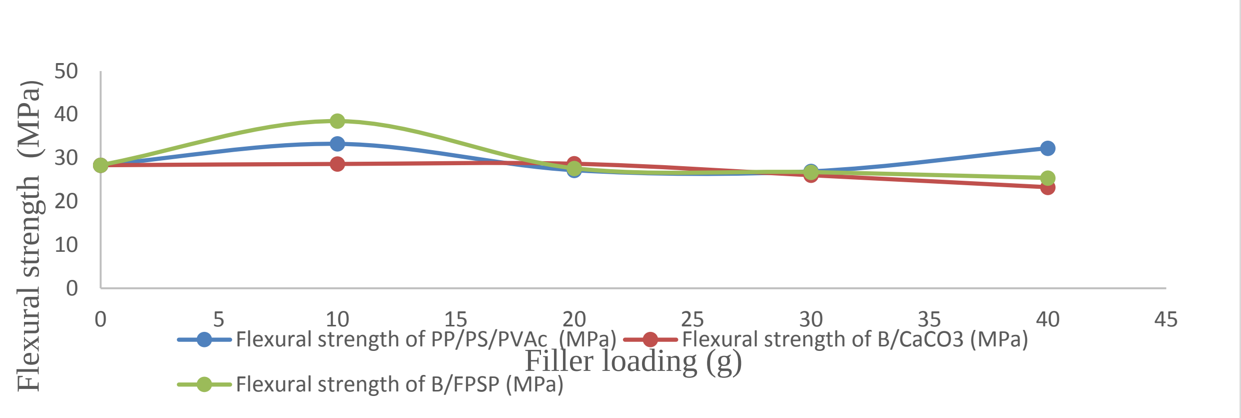

Figure 4: Plot of Flexural strength (MPa) versus filler loading (g) of the ternary blend with and without filler

Flexural strength is the ability of material to withstand bending forces applied perpendicular to longitudinal axis Kumar *et al.*, [14]. It is expressed in N/mm^2 or MPa. Figure 4 illustrates the

Flexural Strength at different blend composition and different PP/PS/PVAc/$CaCO_3$ or PP/PS/PVAc/FPSP compositions. The effect of addition of the two polymers (PS and PVAc) in to the PP, on the flexural strength is shown for different blend ratios in figure 4. It can be seen that the flexural strength has generally increased in both blends with and without filler that, the PP that is rigid and hard becomes flexible since its bending property increased. However, its hardness property increases due to the presence of the PS in the blends at all composition these results complements the results obtained by Kumar *et al.,* [14]. Polypropylene contributes toughness and impact strength, and Polystyrene provides surface gloss and rigidity while Polyvinylacetate provides flexural strength and modulus of elasticity. This result corresponds with the result reported by Guo *et al.,* [23]. There was evidence of enhancements in both the flexural strength and the ductility upon adding 10 g PVAc, Gao *et al.*,[5]. Kumar *et al.*, [14] also established that 20 wt % of HDPE increased the flexural strength of PP/HDPE polyblends by 47%. Odusami *et al.* [15] observed an increase in the flexural strength and the compatibility in Polypropylene/Polyamide-12 blend. Similar results were reported by other authors' that, the changes in the mechanical properties of polypropylene as it is blended with low density polyethylene in which the flexural strength and tensile strength of 75PP/25LDPE inclined slightly [15]. This behavior was attributed to two reasons: one reason is the phase separation of PE where its particles serve as the nucleating agent for PP and the spherulite size of PP is decreased, which is adverse to the crystallinity of PP (PP has low crystallinity). The second reason is that LDPE has a higher flexural strength and low tensile strength and in comparison to the pristine PP. Thus the higher content of the LDPE, the lower crystallinity of PP which improves its flexural strength. This implies that there was partial transfer of both flexibility and tensile stress. Consequently flexural strength and tensile strength were affected at higher LDPE content [16, 45]

CONCLUSION

In this research, the compression molding technique of PP, PP/PS/PS/PVAc ter-blends with and without filler were studied and the effect of the inclusion of the different fractional weights of *Ficus polita* seeds powder and calcium carbonate as fillers on the mechanical properties of the articles prepared were significantly scrutinized. The mechanical properties, such as tensile properties, hardness, impact strength and flexural properties were significantly improved as a result of the addition of $CaCO_3$ and FPSP. The tensile strength was significantly increased with the addition of 10 g of both $CaCO_3$ and FPSP by 78.80% and 94.64% respectively.

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