Synthesis and Physico-Mechanical characterization of Polystyrene Blended with *Uvaria Chamae* Seed Oil (UCSO) used as a Plasticizers

Abstract

Polystyrene has long been recognized as a versatile and cost-effective solution for rigid packaging and food service disposables. The current research focuses on the synthesis and physico-mechanical characterization polystyrene blended with *Uvaria chamae* seed oil (UCSO), used as a plasticizer. UCSO was extracted with hexane and used as a plasticizer in the suspension polymerization of styrene. The findings on the quality of the oil are as follows: oil content (12.54%), specific gravity at 25 ^{o}C (0.94 ± 0.00), acid value (8.029 ± 0.12 mg KOH), iodine value (18.987 ± 0.40), peroxide value (7.0), free fatty acid (4.015%), and saponification values (173.392). The mechanical properties of the polystyrene blend with *Uvaria chamae* seed oil (PS-UCSO) at 100g were reported as: ultimate tensile strength (48.6 MPa), Young modulus **(**1985.3 MPa**),** % elongation **(**12.6%), break load (390.6 N), peak load (386.5 N), Shore D hardness (80.0), and water absorption (1.31%). Other properties like thermal conductivity and thermal resistance were reported as 0.2614 (W/m.K.) and 3.8256 (1/k). The findings revealed that the mechanical properties of PS-UCSO were highly competitive with the conventional white petroleum oil used as a plasticizer. As a recommendation, *Uvaria chamae* seed oil should be used as a plasticizer since it is available, cheap, and environmentally friendly.

Keywords: Mechanical properties, Plasticizers, Polystyrene, Seed oil

1.0 Introduction

Polystyrene (PS) is a versatile thermoplastic material that is commonly used in several industries, such as packaging, appliances, consumer electronics, building, medical, and others. In the previous two decades, the packaging industry has experienced significant growth in its use of plastics. The widespread use of plastics can be attributed to their convenience, safety, affordability, and attractive aesthetic characteristics. Polystyrene has the ability to be shaped into various objects, including single-use cups, music compact discs, water pumps for showers, and packaging made of plastic [1,2]. According to Somarathna et al. [3], this material is easy to handle, moisture-resistant, inexpensive, visually appealing, and easily recyclable. Polystyrene is unique among polymers because of its particular chemical and physical properties. It exhibits chemical inertness and exceptional resistance to alkalis and halide acids, as well as oxidizing and reducing agents. Polystyrene (PS) possesses a multitude of remarkable qualities, such as excellent electrical insulation, strong transparency, incredible water resistance, and outstanding chemical stability [4, 5].

In recent times, there has been a growing fascination with substituting petroleum-derived plastics with sustainable, bio-based, and easily decomposable substances. However, there is a connection between this and declining mechanical properties and the chaos brought on by petroleum products. Vegetable oil has gained increasing attention as a new environmentally friendly substance because of its positive physical features and favourable degrading traits [2, 6]. Ongoing research endeavours have been focused on the advancement of plasticizers and composites that can be used to enhance the physical and mechanical properties of plastic materials. Diverse techniques, such as mechanical mixing, bulk polymerization, solution polymerization, and emulsion polymerization, have been utilized. Bio-based polymerization stands out among the materials methods due to its ease of manipulation, low cost, and environmental friendliness [1, 7].

Uvaria chamae, an indigenous plant found in West and Central Africa, is used for its therapeutic properties in treating fevers. Additionally, it exhibits antibacterial and anti-diabetic characteristics. The root possesses a widely acknowledged standing in the realm of African traditional medicine. The plant is highly valued for its hypoglycemic properties [8], which make it a promising choice for diabetes treatment. It is commonly referred to as a bush banana or finger root due to the fruit that grows on its short branches, which resembles finger-like clusters of fruit carpel [9, 10]. This unique shape has led to the use of native names such as bush banana, which conveys a sense of wildness [11]. Foroutan et al. [12] found that both edible and non-edible oils have been effectively employed in the manufacturing of biodiesel. Nevertheless, developing countries such as Nigeria rely on conventional diesel, which is derived from their crude oil, instead of an alternative oil-producing crops, such as soybeans, groundnuts, cottonseeds, sunflowers, rapeseeds, oil palm, and coconut oil, as a source of fuel [8, 13, 14].

Plasticization can be seen as the alteration of the thermal and mechanical characteristics of a specific polymer. This alteration involves reducing the stiffness of the polymer at room temperature, lowering the temperature at which significant deformations can occur with relatively small forces, increasing the elongation to break at room temperature, and enhancing the toughness (impact strength) even at very low temperatures [2, 15, 16]. Polymer restructuring is the act of modifying the polymer's arrangement to enhance its flexibility. Plasticization causes the membrane's fractional free volume to rise, resulting in enhanced diffusion of all gas species through the membrane. This leads to improved impermeability but a decrease in selectivity [15]. The membrane structure expands as a result of a penetrant's absorption into the polymer matrix [17]. Researchers have looked into using rubber seed oil (RSO), cellulose, organic metabolite and epoxidized oil with different levels of epoxidation as a plasticizer in the production of polystyrene[14,17. Plasticizers are found to increase the tensile strength, tear strength, abrasion resistance, and thermal conductivity of plastic materials [18]. Similarly, Esmaeili et al. [19] and Nsude et al. [20] argue that the addition of plasticizers to polymers improves their mechanical characteristics, such as elongation at break, tear strength, abrasion resistance, and compression set.

The inclusion of vegetable oil can enhance the qualities of PS, which is a brittle, non-crystalline, and aromatic polymer with low mechanical and thermal stability, as well as have a detrimental impact on the environment [16, 21]. However, further research is required to examine the impact of seed oil on the mechanical properties of polystyrene blends. This study focused on the synthesis and characteristics of the physico-mechanical properties of polystyrene blended with white petroleum oil and *Uvaria chamae* seed oil plasticizers.

2.0 Materials and methods

2.1 Materials

Potassium disulphate, n-hexane, styrene, *uvaria chamae* seed oil, sethanol, toluene and aluminum sulphate 18-hydrate were from Scharlau Chemie, Hot plate wooden mould (102 cm x 51cm x 63cm), camry emperors weighing balance, S-metlar balance (electronic),

2.2 Sample collection and preparation

The sample was collected from dried seeds of *Uvaria chamae* in Awgu L.G.A of Enugu state, Nigeria. The research was carried out at Department of Industrial Chemistry, Enugu State University of Science and Technology, Enugu State, Nigeria. The seeds were peeled to obtain the kernels, which were air-dried and pulverized to a fine powdered form and stored in an airtight plastic container.

2.3 Extraction procedure

The plant seeds of *Uvaria chamae* were ground and air-dried to a particle size of approximately 200 g. After weighing and packing them into a thimble, they were placed into a Soxhlet extractor. The 500 cm^3 of standard hexane and the anti-bumping chips were heated on a heating mantle at 70 ◦C in a 1000 cm^3 round bottom flask to remove impurities. The solvent was left to clear before the extraction was stopped. At 40 ◦C, a rotary evaporator was used to collect and dry the solvent in the flask with a round bottom. To get an average percentage of extraction and adequate oil for additional testing, the procedure was repeated [22].

$$\text{Oil content} = \frac{Weight\ of\ the\ oil}{Weight\ of\ sample} \times 100$$

2.4 Specific gravity of seed oil

After recording the mass of an empty, clean, and dry 50 cm^3 density bottle, the mass of the bottle and its contents were measured by filling it with distilled water and then weighing it again. After measuring the weight of each seed oil in its own density bottle, the specific gravity was calculated by adding the combined weight of the bottle and oil at 25 ^oC [23]:

$$\text{Specific gravity} = \frac{Weight\ of\ oil}{Weight\ of\ Water}$$

2.5 Saponification value

For each oil sample, 5 cm3 was measured and added to a volumetric flask along with 50 ml of alcoholic KOH. The mixture was then allowed to drain for 30 minutes. A blank was also made by removing 50 cm3 of alcoholic KOH and letting it drain for 30 minutes. Boiling the flask gradually for around an hour is the plan after connecting it to the air condenser. Once cooled, the condenser was cleaned with a small amount of distilled water and subsequently removed from the flask. Lastly, 1 ml of phenolphthalein was added and the colour would be removed by titrating it against 0.5 millimolar of hydrochloric acid [23].

$$\text{Saponification value} = \frac{(56 \times N(V0 - V1)}{W}$$

Where; V0 = the volume of the solution used for the blank test; V1 = the volume of the solution used for determination; N = actual normality of the HCl used; W = Mass of the sample.

2.6 Acid value

Exactly 2 cm^3 of oil sample was weighed into a 250 cm^3 conical flask and dissolved in 25 cm^3 of alcohol each. Then, two drops of phenolphthalein indicator were introduced. The contents were titrated with alcoholic potassium hydroxide. Blank titration was carried out with 100 cm^3 of the titration solvent and 0.5 cm^3 of indicator solution. The KOH solution was standardized on a regular basis to detect the 0.0005 molarity change. The volume of 0.1cm^3 KOH (VA) for the sample titration, and volume for the blank (VB), were noted [24].

$$\text{Acid value} = \frac{M \times 56.1}{W}$$

Where; A = Amount (mL) of 0.1M KOH consumed by sample, M= Molarity of KOH, W= weight (g) of oil sample.

2.7 Iodine value

Exactly 0.4 cm^3 of the oil sample was measured and placed into a conical flask. Subsequently, 20 cm_3 of CCl_4 was introduced to dissolve the oil. After the specified time elapsed, a total of 20 cm^3 of a solution containing 10% KI (10 g dissolved in 100 cm^3 of water) and 125 cm^3 of distilled water were introduced into the mixture using a measuring cylinder. The substance was subjected to titration using 0.1M sodium-thiosulphate solutions until the yellow colour was hardly imperceptible. A small amount of 1% starch indicator was introduced, and the titration will proceed by gradually adding thiosulfate until the blue coloration vanishes upon vigorous agitation. The identical methodology was employed for the blank examination [24].

$$\text{Iodine value} = \frac{(12.69 \times C \times (V0 - V1)}{W}$$

C = Concentration of sodium thiosulphate used, V1 = Volume of sodium thiosulphate used for blank, V2 = Volume of sodium thiosulphate used for determination, W =Mass of the sample.

2.8 Peroxide value

Exactly, 1.0 cm^3 of the seed oils were weighed into a clean dry boiling tube and 1g of powdered KI and 30 cm^3 of solvent (2 cm^3 of chloroform and 3 cm of glacial acetic acid) mixture was added. Hence, the tube was placed in boiling water so that the liquid boils within 30 seconds and allowed to boil vigorously for not more than 30 seconds. The contents were transferred quickly to a conical flask containing 20 cm3 of 5% KI (5 g dissolved in 100cm^3 of H_2O) solution and the tube was washed twice with 25 cm^3 water each time and collected into the conical flask. Then, the solution was titrated against 0.001 M $Na_2S_2O_3$ solution until the yellow color disappear and 0.5 cm^3 of starch will be added with vigorous shaking and titrated carefully till the blue color disappear [22].

$$\text{Peroxide value} = \frac{(V \times M \times 1000}{W}$$

V= Volume of sodium thiosulphate solution used, M= Molarity of thiosulphate, W=Weight of the oil sample

2.9 Polymerization and Plasticization of Polystyrene

Koralege and Jayasuriya [22] described a method for in situ suspension polymerization of styrene that was adopted for this study. Potassium disulphate (1.5g) was dissolved in 2 ml of water in a 200-ml-capacity beaker and stirred for 6 minutes. A solution of styrene (90 ml) was added to the solution and stirred under heat until there was an observable colour change from transparent to milky at 87 °C. Plasticizer (WPO) was added and continuously stirred until the mixture started becoming viscous at temperatures of 120 ^{o}C; the viscosity changed colour from milky to brown at 130 ^{o}C; the solution became more viscous; and plasticity was achieved at 140 ^{o}C. The formation of polystyrene sheets with UCSO plasticizers is illustrated in Table 1.

Table 1: Formation of Polystyrene Sheet with Plasticizer

SAMPLE NAME	UCSO/WPO(g)	Styrene(ml)	Initiator(g)
PS-UCSO$_1$	100.00	90	1.5
PS-UCSO$_2$	80.20	90	1.5
PS-UCSO$_3$	60.40	90	1.5
PS-UCSO$_4$	40.60	90	1.5

2.10 Mechanical Properties

Mechanical properties were examined with a Hounsfield T series universal testing machine, model-H10KT, using ASTM D638 Tensile Test. Stress/strain curves were obtained at an extension speed of 1 mm min-1 and 100 N Load range.

Tensile properties: The tensile test was conducted on the analysed samples using a Zwick Roell testing equipment in accordance with the ASTM D 638 standard. The observations were performed at a consistent velocity of 5 ml/minute under normal atmospheric conditions at a temperature of 23–25°C.The examination involved analysing five specimens from each polystyrene blend. The test findings were averaged and subsequently published.

Shore D hardness: The Shore D hardness of the samples under investigation was determined using a commercially available durometer in accordance with the ASTM D 2240 standard. Each formulation underwent three measurements, and the average hardness value was recorded.

Thermal Resistance Test: The sample's area (A) was measured using a Vanier calliper. Prior to heating at room temperature (T1), measurements were made for the thickness (x) and the beginning temperature. The oven was preheated for 5 minutes before placing the samples inside. After 30 minutes, the sample was removed and the final temperature was measured. The thermal conductivity was determined using the given equation.

$$Q = \frac{KA(T2-T1)}{x}$$

Where Q = thermal flux, K = thermal conductivity, T_2 = final temperature of the sample, T_1 = initial temperature of the sample, A = area of the sample, x = thickness of the sample.

2.11 Water Absorption

Specimens were tested for water absorption. The water absorption of the specimens was calculated by using

$$\text{Water absorption (\%)} = \frac{(W2- W1)}{W1} \times 100$$

Where W1 is the weight of the specimen before immersing in water and W2 is the weight of the specimen after 144-hours water immersion

3.0 Results and discussion

3.1 Physicochemical properties *Uvaria chamae* seed oil

The physicochemical properties *Uvaria chamae* seed oil is shown in Table 2. The properties considered were oil content, specific gravity, acid value, iodine value, peroxide, free fatty acid, and saponification values.

Table. 2: Result of physicochemical properties of the Uvaria chamae seed oil

	Properties	Values
1	Oil content	12.54
2	Specific gravity	0.94 ± 0.00
3	Acid value(mg KOH)	8.029 ± 0.12
4	Iodine value	18.987 ± 0.40
5	Peroxide value	7.0
6	Free fatty acid %	4.015
7	Saponification values	173.392

The oil content of the Uvaria chamae seed extracted using hexane was recorded at 12.54%. In a comparable study, Amos-Tautua and Onigbinde [25] found that groundnut and maize had a low oil content of 10.54% and 6.63% respectively, but soybean had a relatively high oil content of 14.51%. Chatepa et al. [26], reported the comparatively high oil content of 34.91±0.93, 46.05±0.19, and 31.65±0.44 for *M. oleifera*, *P. curatellifolia*, and A. digitata seeds. The limited oil content of vegetables can impact the accessibility and cost-effectiveness of oils and other food products generated from these plants. Seeds with a high proportion of free fatty acids (FFA) (> 1%w/w) are responsible for both poor oil yield and the production of soap [27]. The specific gravity of *Uvaria chamae* seed oil is 0.94. This indicates that the oils have a lower viscosity than water and do not contain any dense components. The analysis of specific gravity is crucial as it directly impacts the energy density, also known as specific energy, of petrol [13].

The acid value is a significant characteristic in multiple industries, such as food processing, biodiesel manufacture, and cosmetics. The acid value of the extracted *Uvaria chamae* seed oil was reported as 8.029 ± 0.12. Amos-Tautua and Onigbinde [25] found that the acid values for soybean and groundnut were 19.21 and 4.63, respectively, in a related study. Chatepa et al. [26] documented an acid value of 2.68±0.01 for groundnut and 9.46±0.02 for pigeon pea. The oil's low acid levels indicate a reduced susceptibility to rancidity, a chemical deterioration process in which free fatty acids and other degradation products can adversely affect the oil's flavour and aroma [28]. Another consequence of low acid values is enhanced stability during the processing phase and decreased equipment corrosion.

The iodine value of *Uvaria chamae* seed oil was 18.987 ± 0.40, which was lower than the iodine value of castor oil (84.8 gI2/100g) reported by Aremu et al. [29], as well as the iodine values of soybean (73.02 gI2/100g) and pigeon pea (69.64± 5.19) reported by Chatepa et al. [26]. The oil's iodine value exceeded the value of 1.85 published by Konuskan et al. [30] for rubber seed. According to Onoji et al. [31], this suggests that the oil will become unstable and susceptible to rancidity or peroxidation over time. The iodine value is used to determine the quantity of unsaturated fats and oils present in the sample. The low iodine value of UCSO suggests a reduced level of unsaturation, indicating that the oil has a larger concentration of saturated fatty acids [13, 15]. Oils possessing low iodine concentrations typically exhibit enhanced stability and reduced susceptibility to oxidation. These properties make them well-suited for applications that need stability and resistance to rancidity, such as in the production of cooking oils and food processing [32, 33]. The inherent stability of oils with low iodine values enhances the longevity of items derived from such oils. This is especially advantageous in the food industry, where there is a preference for items that have extended periods of time in which they may be stored without spoiling [34].

The peroxide value of *Uvaria chamae* seed oil was measured to be 7.09± 0.00 Meq/kg, which was found to be below the standard set by NIS [35]. Elevated peroxide values suggest a significant presence of oxidative rancidity in the oils, accompanied by a deficiency or insufficient quantities of antioxidants. However, certain antioxidants like propyl gallate and butyl hydroxyl anisole can be employed to mitigate rancidity [36]. The fatty acid content of UCSO was determined recorded at 4.015%, which aligns with the findings of Tavakoli et al. [33]. Their study showed a relatively low concentration of α-linolenic acid (0.63 to 1.36%) in comparison to the "Dezful" oil (4.60%) derived from pomegranate seed oils. The presence of minimal amounts of free fatty acids in seed oil is linked to superior quality, enhanced durability, and enhanced adaptability for many uses in the food, industrial, and pharmaceutical industries [26, 37]. According to the study by Sani et al. [32], the saponification value of Uvaria chamae seed oil (173.39 mgKOH/g) was lower than that of Cocos nucifera oil (246 mgKOH/g). The saponification value plays a vital role in the shampoo and soap industries as it determines the presence of oil as conventional triglycerides [34].

3.2 Mechanical Properties of Polystyrene Blend with petroleum and vegetable oil

The mechanical properties of *Uvaria chamae* seed oil are shown in Table 3. It shows the polystyrene blend with white petroleum oil (WPO) and *Uvaria chamae* seed oil (UCSO) at different concentrations of plasticizer and constant volumes of polystyrene.

Table 3: Mechanical Properties of Polystyrene Blended with petroleum and *Uvaria chamae* seed oil

Blends	UTS (Mpa)	Young modulus (Mpa)	%elongation	Break load (N)	Peak load (N)	Shore D hardness
PS	55.7	1844.8	12.3	431.61	605.4	84.2
PS- WPO$_1$	50.6	1996.1	12.4	400.4	603.7	83.0
PS-UCSO$_1$	48.6	1985.3	12.6(1.6)	390.6	386.5	80.0
PS-WPO$_2$	46.4	1980.8	18.1(69.8)	398.8	552.5	78.2
PS-UCSO$_2$	45.3	1954.0(52)	20.1(69.8)	319.8	352.5	77.2
PS-WPO$_3$	50.4	1986.4	22.1(286.1)	356.9	500.3	74.4
PS-UCSO$_3$	44.2	1878	30.7	200.1	344.2	74.4
PS-WPO$_4$	40.0	1954.0	30.4	317.9	440.7	73.7
PS-UCSO$_4$	37.5	1797.9	49.5	301.9	311.24	72.4

UTS= ultimate tensile strength; PS=polysterine; WPO= white petroleum oil; UCSO= Uvaria chamae seed oil

The polystyrene polymers that contain the most UCSO have the highest UTS values. The UTS of PS-UCSO$_1$ was estimated at 48.6 Mpa, while that of PS-WPO$_1$ was 50.6 Mpa. The polystyrene polymer without plasticizer was found to have a pressure of 55.7 Mpa, slightly higher than PS-UCSO$_1$ and PS-WPO$_1$. The polystyrene polymer with WPO has a slightly higher stress tolerance than the one with UCSO 1. The data also revealed an increase in the UTS as the concentration of the plasticizer was increased. The increased UTS suggests that PS-UCSO$_1$ can be used to design structural elements in civil engineering, mechanical engineering components, and even medical applications such as orthopaedic implants [38]. Reza-Barzegari [39] discovered a high ultimate tensile strength behaviour in heavily packed polystyrene with lignin. In a comparable study, Das et al. [38] observed impact strengths and improved mechanical properties of an unsaturated polyester resin/styrene/tung oil blends.

The Young modulus of PS-WPO with the highest plasticizer was recorded at 1996.1 Mpa, and PS-UCSO1 recorded 1986.4 Mpa, whereas polystyrene polymer without plasticizer recorded 1844.8 Mpa. The PS-WPO has the highest Young modulus, which is an indication of high stiffness and slight changes under elastic loads. The increase in plasticizer improved the stiffness of the polystyrene polymer blend [40, 41, 42]. The percentage elongation of the polystyrene with UCSO was above that of WPO in each of the different concentrations used in the polymeration reaction. This is attributed to the relatively low Young modulus of the PS-UCSO, and the percentage elongation of both PS-WPO and PS-UCSO increases as the Young modulus decreases. From Table 2, the PS-WPO and PS-UCSO with lower concentrations of plasticizer have the highest percentage elongation of 30.4% and 49.5%, respectively. The findings align with the observations made by Garcia-Garcia et al. [43], who documented a significant increase in % elongation and improved mechanical characteristics of poly (3-hydroxybutyrate). In a similar study, Mishra & Naik [40] documented Young's modulus values of 12264 Mpa and 446 Mpa for banana-fibre polystyrene composites.

The break load is the maximum force or stress that a material can withstand before it fails or breaks. The break load of polystyrene at different amounts of plasticizer (WPO and UCSO) is reported in Table 2. The highest break load was reported for PS-WPO_1 (400.4 N) and PS-$USCO_1$ (390.6 N), and the break load of the polystyrene blend decreased as the amount of plasticizer decreased. The highest peak loads for PS-WPO_1 and PS-$UCSO_1$ were recorded as 603.7 N and 386.5 N, respectively. These records implied that PS-WPO_1 would slightly withstand more loads than PS-$UCSO_1$. Polystyrene polymers with a low peak load might be more brittle and less able to withstand heavy loads [44]. They may be suitable for applications requiring low strength and may not be ideal for situations where durability and resistance to mechanical stress are crucial [45, 45].

The findings also reported the highest shore D hardness of 83.0 and 80.0 for PS-WPO_1 and PS-$UCSO_1$. The high Shore D hardness for polystyrene indicates that the material is relatively rigid and resistant to indentation [41, 44]. PS-WPO_1 and PS-$UCSO_1$ polymers are harder and less flexible. This characteristic is beneficial in applications where the material needs to maintain its shape and resist deformation under load. PS-WPO_1 and PS-$UCSO_1$ might be used in rigid packaging, durable containers, or structural components that require a high level of stiffness [47]. Figure 1-6 illustrates the relationship between the amount of plasticizers (UCSO and PS-WPO) and the mechanical properties of polystyrene when blended with UCSO and PS-WPO. There was a general improvement in the mechanical properties of polystyrene blends as the amount of plasticizer increased, except for the percentage elongation (Figure 3), which decreased with increasing plasticizer mass.

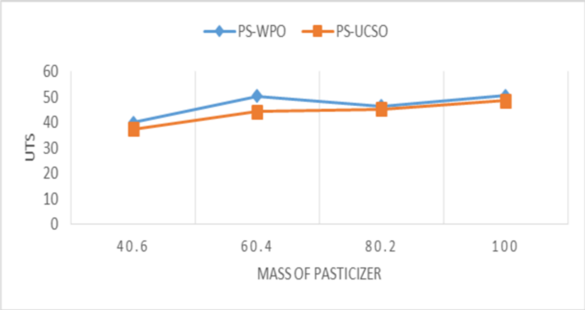

Figure 1: Ultimate Tensile Stress of UCSO and PS-WPO

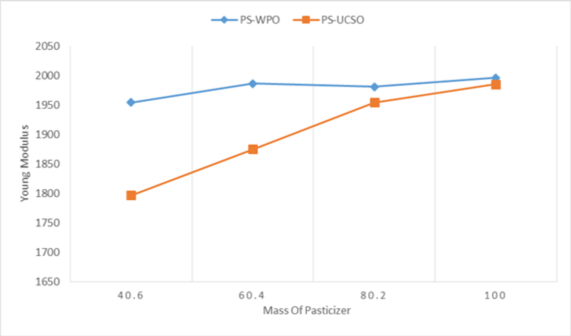

Figure 2: Young modulus of UCSO and PS-WPO

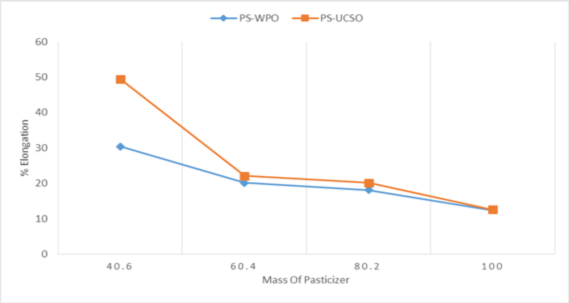

Figure 3: % Elongation of UCSO and PS-WPO

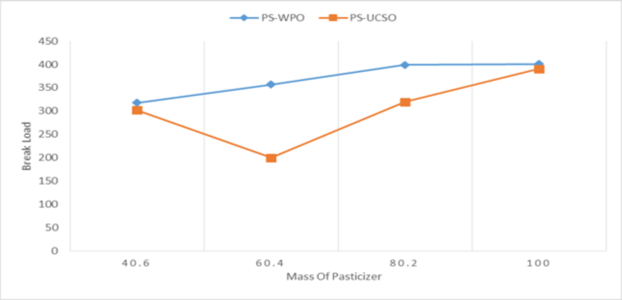

Figure 4: Break Load of UCSO and PS-WPO

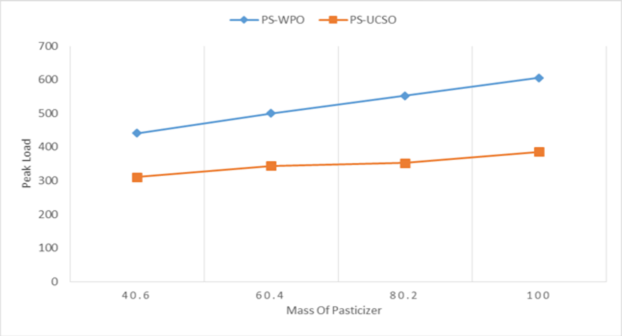

Figure 5: Peak Load of UCSO and PS-WPO

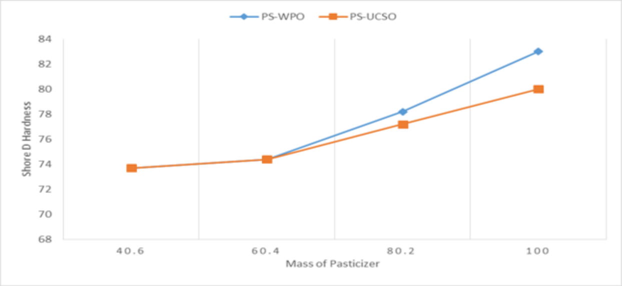

Figure 6: Shore D Hardness of UCSO and PS-WPO

3.3 Thermal Resistance Studies of Polystyrene Blend with petroleum and vegetable oil

The thermal studies of polystyrene blend with white petroleum (WPO) and vegetable oil (UCSO) is shown in Table 4.

Table 4: **Thermal Studies of polystyrene blend with petroleum and vegetable oil**

Sample I.D	**Area (m^2)**	**Thickness (m)**	**Thermal flux (Q)**	**Temp. Change (C)**	**Thermal Conductivity (W/m.K)**	**Thermal Resistance (1/k)**	**Water Absorption**
PS - WPO	3.800	0.0015	2000	22	0.2558	3.9093	3.61
PS-UCSO	3.800	0.0015	2000	22	0.2614	3.8256	1.31

The study recorded a temperature change of 22 ^{O}C, Thermal flux (2000 Q), Thickness (0.0015 m) and Area (3.800 m^2) for both polystyrene blend with WPO and UCSO. Polystyrene is noted for its poor thermal conductivity, which makes it an excellent insulator. Polystyrene typically has a thermal conductivity of 0.03 to 0.04 W/m•K [48, 49]. Polystyrene's low thermal conductivity indicates that it may effectively withstand heat transfer. However, the thermal conductivity of PS-UCSO and PS-WPO was determined to be 0.2614 and 0.2558 W/m.K, respectively. PS-UCSO's thermal conductivity was slightly higher than PS-WPO. This indicates that the heat transfer capacity of PS-UCSO and PS-WPO has enhanced. The thermal conductivity (K) of PS-WPO and PS-UCSO exceeded the stated value of 0.1629 (W/m.K) for polystyrene at 71 ^{o}C by Doğan and Tan [21]. In a comparable work, Cao et al. [48] found that polystyrene/poly (vinylidene fluoride) blends had a high thermal conductivity, as did surface modification of SiC nanoparticles.

The thermal resistance of PS-UCSO and PS-WPO was estimated as 3.8256m^2•K/W and 3.9093m^2•K/W, respectively. These results were lower than the thermal resistance of polystyrene polymers, which was reported at 7.2727 m^2•K/W by Reza Barzegari et al. [39], making it a better insulator than the modified. The water absorption capacity of PS-UCSO and PS-WPO was 1.31% and 3.61%, respectively. According toArman et al. [36] and Vėjelis and Vaitkus [50], the PS-UCSO with lower water absorption has a closer cell, making it more water resistant.

4.0 Conclusion

The study on the synthesis and physico-mechanical characterization of polystyrene derived from *Uvaria chamae* seed oil (UCSO) employed as a plasticizer reveals the significance of Uvaria chamae seed oil in polystyrene production. The oil quality examination showed a high saponification value, indicating that UCSO is acceptable for soap manufacture. Additionally, the iodine level of 18.987 ± 0.40 indicated the oil's unsaturation.

Polystyrene reinforced with UCSO showed enhanced mechanical properties in comparison to polystyrene containing white petroleum oil, specifically in the areas of ultimate tensile strength, Young modulus, break load peak load, and shore D hardness. Nevertheless, the percentage of elongation was greater with PS-UCSO.

The thermal conductivity of PS-UCSO suggests that the heat transfer potency and thermal resistance are consistent with PS-WPO, and it may function as a poor insulator. According to the results, the polystyrene with UCSO as a plasticizer exhibits favourable mechanical qualities suitable for packing, characterized by durability and a high level of suitability. The discoveries will enable engineers, researchers, and manufacturers to make informed decisions that improve the overall performance, reliability, and safety of products built from polystyrene.

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