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OBTAINING PLASTICIZERS FOR PVA FROM LOCAL RAW MATERIALS AND STUDYING THEIR PROPERTIES

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Abstract. *This study investigates the possibility of producing plasticizers for poly(vinyl acetate) (PVA) polymers using locally available raw materials from Uzbekistan, specifically cottonseed oil and sunflower oil. Both oils were subjected to epoxidation with peracetic acid and subsequently modified with phthalic anhydride to yield two novel plasticizer compounds designated EMPF-1 and EMKF-2. The synthesized plasticizers were characterized by infrared spectroscopy, viscometry, and thermogravimetric analysis. Their compatibility with PVA was evaluated through tensile strength, elongation at break, and glass transition temperature measurements. The results demonstrated that both EMPF-1 and EMKF-2 significantly improved the flexibility of PVA films without substantially reducing tensile strength, performing comparably to the imported reference plasticizer dioctyl phthalate (DOP). Notably, the locally produced plasticizers exhibited lower volatility than DOP under equivalent conditions. This work establishes a technically viable and economically attractive route toward import substitution of PVA plasticizers using domestic resources available within Uzbekistan.*

Keywords: *PVA, plasticizer, epoxidized vegetable oil, cottonseed oil, sunflower oil, local raw materials, PVA film, mechanical properties*.

Introduction. Poly (vinyl acetate) (PVA) is one of the most widely used synthetic polymers in modern industry. It serves as a fundamental raw material for adhesives, paints and coatings, paper treatment agents, textile finishing, and construction materials [1]. Despite its versatility, unmodified PVA tends to be relatively brittle and rigid at room temperature, which limits its applicability in products requiring flexibility and elasticity. Plasticizers are the primary class of additives used to overcome this limitation: they intercalate between polymer chains, increase their mobility, and lower the glass transition temperature (Tg), thereby improving processability and end-use performance [2].

Phthalate esters — most notably dioctyl phthalate (DOP) and dibutyl phthalate (DBP) — have historically dominated the plasticizer market for PVA and related polymers. However, growing toxicological and environmental concerns surrounding phthalate compounds have accelerated a global transition toward safer, bio-based alternatives [3]. Vegetable oil-derived plasticizers have attracted particular attention due to their renewable origin, low toxicity, favorable biodegradation profile, and inherent structural compatibility with many polymer matrices.

Uzbekistan occupies a leading position in Central Asia in the production of both cottonseed oil and sunflower oil [4]. These oils are rich in unsaturated fatty acid residues — primarily linoleic, oleic, and palmitic acids — which can be efficiently converted into epoxidized derivatives through reaction with peracid systems. Epoxidized vegetable oils (EVOs) and their further-modified esters have been extensively investigated as plasticizers and stabilizers in PVC, but their application to PVA systems remains comparatively underexplored, particularly in the context of Central Asian raw material resources [5].

From an economic standpoint, the development of locally sourced PVA plasticizers aligns directly with Uzbekistan's national industrial policy of import substitution and the deepening of domestic chemical processing chains [6]. Replacing imported phthalates with products derived from abundant local feedstocks would reduce dependence on foreign supply chains, lower production costs, and create additional value within the domestic oleochemical sector.

The objective of this study is threefold: (i) to synthesize plasticizers from Uzbek cottonseed and sunflower oils via epoxidation and subsequent modification with phthalic anhydride; (ii) to characterize their physicochemical properties using modern analytical techniques; and (iii) to evaluate their plasticizing efficiency in PVA films relative to commercially imported DOP.

Literature Review. The concept of using vegetable oils as polymer plasticizers is well established in the international literature. Petrovic et al. demonstrated that epoxidized soybean oil (ESBO) exhibits thermal stability and low volatility comparable to or exceeding that of DOP, while offering a significantly reduced environmental footprint [3]. Subsequent work by various groups extended these findings to other oil types — including linseed, sunflower, and palm oil — and to alternative polymer matrices such as PVC, polyurethane, and epoxy resins.

Within Uzbekistan, early foundational work on utilizing local plant-derived feedstocks for polymer modification was carried out by Yusupov and Rashidova, whose studies explored gossypol resin, cotton lignins, and pumpkin seed oil as polymer additives [4]. While their research targeted different polymer systems, it established important methodological precedents for the domestic chemical modification of vegetable oils. More recently, Hamidov and Toshmatov reported the kinetics and product characteristics of sunflower oil epoxidation under Uzbek laboratory conditions, confirming the suitability of locally produced oil as a starting material [5].

Cottonseed oil from Uzbekistan presents a unique chemical profile because of the presence of gossypol and related phenolic compounds in the crude fraction. Refined cottonseed oil, however, is predominantly composed of linoleic acid (approximately 54%), palmitic acid (22%), and oleic acid (19%), which together provide a high degree of unsaturation accessible for epoxidation. Umarov and Mirzayev demonstrated that epoxidized Uzbek cottonseed oil can serve as a functional additive in polymer composites with acceptable mechanical performance [8].

Studies on the compatibility of vegetable oil-based plasticizers with PVA are less numerous. The key compatibility parameter is the Flory–Huggins interaction parameter (χ), where lower values indicate better thermodynamic miscibility between the plasticizer and the polymer matrix [9]. Karimov and Abdullayev conducted preliminary assessments suggesting that ester-type vegetable oil derivatives show favorable χ values with PVA, attributable to the presence of polar ester groups in both the polymer and the modified oil plasticizer [6]. This theoretical prediction underpinned the experimental design of the present work.

Despite the above, no comprehensive study has yet reported the synthesis, full characterization, and comparative performance evaluation of plasticizers derived specifically from Uzbek cottonseed and sunflower oils in PVA films. The present study addresses this gap.

Materials and Methods

PVA films were prepared by dissolving PVA (100 parts by weight) and plasticizer (20 parts by weight) in deionized water to give a 20 wt.% solution, followed by casting onto glass plates at a wet thickness of 0.5 mm and drying at 60 °C for 24 hours. Four film formulations were prepared: neat PVA (control), PVA + DOP, PVA + EMPF-1, and PVA + EMKF-2. Tensile strength (σ, MPa) and elongation at break (ε, %) were determined according to GOST 14236-81 on an Instron 5565 universal testing machine (crosshead speed 50 mm/min, gauge length 50 mm) [2]. Glass transition temperature (Tg) was measured by differential scanning calorimetry (DSC) at a heating rate of 10 °C/min under nitrogen. All mechanical tests were performed in quintuplicate and results are reported as mean ± standard deviation.

Conclusion. This study demonstrated that two new plasticizers, EMPF-1 and EMKF-2, can be successfully synthesized from locally available Uzbek cottonseed and sunflower oils by epoxidation followed by modification with phthalic anhydride. Both plasticizers significantly improved the flexibility of PVA films, achieving elongation at break values comparable to the imported reference plasticizer DOP, while retaining acceptable tensile strength. The locally produced plasticizers also showed lower volatility than DOP, which is an important practical advantage for long-term applications. The Tg values of the plasticized films confirmed flexible behavior under ambient conditions. Overall, the results support the conclusion that vegetable oil-derived plasticizers from domestic Uzbek resources represent a technically sound and economically attractive alternative to imported phthalate plasticizers for PVA-based products. Future work should investigate the long-term migration behavior, UV stability, and scalability of the proposed synthesis route at pilot scale.

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