**Assessment of Physical and Chemical Features of Unsaturated Polyester**

**Resin Enhanced with Eggshell Components**

***Ercan AYDOĞMUŞ1,[[1]](#footnote-1)\*[C:\Users\Abdullah\AppData\Local\Microsoft\Windows\INetCache\Content.Word\ORCID-iD_icon-16x16.gif](https://orcid.org/0000-0002-1643-2487), Mustafa DAĞ2[C:\Users\Abdullah\AppData\Local\Microsoft\Windows\INetCache\Content.Word\ORCID-iD_icon-16x16.gif](https://orcid.org/0000-0001-9540-3475), Zehra Gülten YALÇIN2[C:\Users\Abdullah\AppData\Local\Microsoft\Windows\INetCache\Content.Word\ORCID-iD_icon-16x16.gif](https://orcid.org/0000-0001-5460-289X)***

*1Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ, Türkiye*

*2Karatekin University, Faculty of Engineering, Department of Chemical Engineering, Çankırı, Türkiye*

|  |
| --- |
| **Abstract**  This study aims to investigate the physical and chemical properties of unsaturated polyester resin with the addition of eggshells. Eggshells were first crushed, dried, and then ground to particle sizes ranging from 50 to 100 mesh. The experiment was conducted by adding eggshell additives at proportions of 0 wt.%, 1 wt.%, 2 wt.%, 3 wt.%, and 4 wt.% to the unsaturated polyester resin. The properties examined include density, Shore D hardness, thermal conductivity coefficient, and activation energy values. According to the results obtained in this research, eggshell reinforcement increases the density of the polyester composite. As the filler ratio increases, Shore D hardness of the composite rises. The thermal conductivity coefficient of the polyester composite is also directly proportional to the filler ratio. Additionally, when thermal decomposition experiments of the samples are examined, eggshell reinforcement raises the activation energy of the composite. Accordingly, it can be said that the thermal stability of the composite is improved with the organic filler. The results indicate how the addition of eggshells affects the physical and chemical properties of unsaturated polyester resin. The study highlights the potential advantages of using materials in a more sustainable and environmentally friendly manner. This research offers a fresh perspective in the fields of materials science and chemistry, presenting innovative solutions for industrial applications. |
| Keywords: Unsaturated Polyester Resin, Eggshell Additives, Chemical Properties, Natural Additives |

1. **Introduction**

Unsaturated polyester resins have gained significant attention in various industries due to their versatile applications and favorable mechanical properties. These resins are widely used in composite materials, coatings, and adhesives, among other fields. However, enhancing their properties and sustainability is a constant pursuit in material science and engineering [1-4].

One promising avenue in this quest is the incorporation of natural additives into the resin matrix. In this study, we focus on eggshells as a potential natural additive for unsaturated polyester resins. Eggshells are readily available and often discarded as waste, making them an environmentally attractive choice [5-8].

The objective of this research is to examine the impact of eggshell additives on the physical and chemical properties of unsaturated polyester resins. Specifically, we investigate the effects on hardness, thermal conductivity, and activation energy. Understanding how eggshell additions influence these characteristics is crucial for both enhancing the performance of the resin and contributing to sustainable material development [9-11].

This study contributes to the broader understanding of using natural additives in composite materials, offering a novel perspective on how waste materials can be repurposed for industrial use. The findings have the potential to open new avenues for sustainable material development and contribute to reducing environmental waste [12-14].

The polyester composite material has been obtained by reinforcing a synthesized eggshell with unsaturated polyester. Some thermophysical properties of the obtained product have been characterized according to the intended use. In this study, waste organic reinforcement filler is reinforced into the polyester composite.

1. **Materials and Methods**

Unsaturated polyester (UP), methyl ethyl ketone peroxide (MEKP), and cobalt octoate (Co Oc) used in experimental studies have been supplied from Turkuaz Polyester company. In this study, waste eggshells are prepared for composite production after being dried and ground. The filler, whose particle size range is between 297 μm and 149 μm, is added to the unsaturated polyester. After the mixture is homogenized, MEKP and Co Oc are added in certain proportions. After mixing for a short time, the sample is poured into standard molds. After waiting 24 hours for curing, physical and chemical tests are performed [15-17]. Figure 1 shows waste chicken egg shells and their ground form.

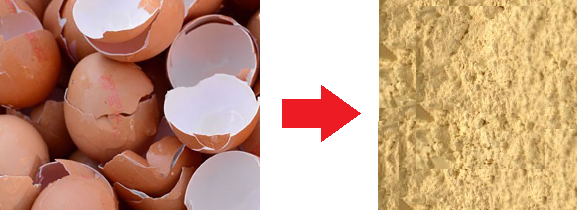
****

Figure 1. Eggshell and its ground powder.

Table 1 shows the experimental work plan and the proportions of each component in polyester composite production. Here, the ratios of MEKP and Co Oc in the mixture are constant, but the ratio of UP and filler varies. Additionally, the stages in polyester composite production are briefly schematized in Figure 2. The order of each component in composite production is easily understood.

**Table 1.** Experimental study plan

|  |  |  |  |
| --- | --- | --- | --- |
| **UP**  **(wt%)** | **Filler**  **(wt%)** | **MEKP**  **(wt%)** | **Co Oc (wt%)** |
| 98 | 0 | 1.5 | 0.5 |
| 97 | 1 | 1.5 | 0.5 |
| 96 | 2 | 1.5 | 0.5 |
| 95 | 3 | 1.5 | 0.5 |
| 94 | 4 | 1.5 | 0.5 |

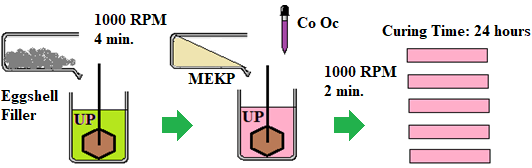


Figure 2. Polyester composite production scheme.

1. **Results and Discussion** 
   1. **Density of polyester composite**

After the resulting polyester composite is cured, physical and chemical tests are performed. Figure 3 expresses the relationship between the density of the composite and the proportion of eggshells. As the filler ratio increases, the density of the polyester composite also rises.



**Figure 3**. Change in the density of the eggshell reinforced the polyester composite.

* 1. **Hardness of polyester composite**

Shore D hardness tests are repeated five times for each sample and their average values are taken. The smooth surfaces of the composites removed from the molds are prepared according to standards. It has been determined that as the filling ratio in the polyester composite increases, Shore D hardness also goes up (Figure 4).



**Figure 4.** Variation of Shore D hardness of eggshell reinforced the polyester composite.

* 1. **Thermal conductivity of polyester composite**

When the thermal conductivity tests of the composites are examined, polyester without added filler has a thermal conductivity coefficient value of 0.056 W/m·K. As seen in Figure 5, as the filler ratio rises, the thermal conductivity coefficient also increases.



**Figure 5.** Change in the thermal conductivity of filler (eggshell) reinforced the composite.

* 1. **Thermal decomposition of polyester composite**

Activation energies of eggshell-reinforced polyester composites have been found in the range of 0.15 to 0.85 conversion ratio. Thermal decomposition experiments have been carried out at a heating rate of 10 K/min in the temperature range of 295 K to 875 K. The activation energies calculated in the thermal decomposition curves of polyester composites are given in Table 2. The activation energy values of the composites are found according to Coats-Redfern.

**Table 2.** Activation energy of the polyester composite

|  |  |
| --- | --- |
| Eggshell (wt%) | Activation Energy  (kJ/mol) |
| 0 | 121.640 |
| 1 | 122.367 |
| 2 | 123.045 |
| 3 | 123.928 |
| 4 | 124.706 |

1. **Conclusion**

In this study, waste eggshells are used in polyester composite production. Environmentally friendly composite materials with low carbon footprint are produced. The thermal stability of the resulting composite is improved. Economical and high-density polyester composite production is achieved. In addition, composites with increased thermal conductivity coefficients can be preferred today. This research is important in terms of both thermal stability and waste evaluation. Eggshells used as fillers are not added to this study because they negatively affect the surface morphology of the composite when used in high amounts.

**References**

1. Aydoğmuş, E., Arslanoğlu, H., & Dağ, M. (2021). Production of waste polyethylene terephthalate reinforced biocomposite with RSM design and evaluation of thermophysical properties by ANN. *Journal of Building Engineering*, 44, 103337.
2. Orhan, R., Aydoğmuş, E., Topuz, S., & Arslanoğlu, H. (2021). Investigation of thermo-mechanical characteristics of borax reinforced polyester composites. *Journal of Building Engineering*, 42, 103051.
3. Orhan, R., and Aydoğmuş, E. (2022). Investigation of some thermophysical properties of *Asphodelus aestivus* reinforced polyester composite, *Firat University Journal of Experimental and Computational Engineerin*g 1(3), 103-109.
4. Orhan, R., and Aydoğmuş, E. (2022). Production and Characterization of Waste Corncob Reinforced Polyester Composite, *European Journal of Science and Technology*, 42, 176-179.
5. Yanen, C., Dağ, M., and Aydoğmuş, E. (2022). Investigation of Thermophysical Properties of Colemanite, Ulexite, and Tincal Reinforced Polyester Composites, *European Journal of Science and Technology*, 36, 155–159, 2022.
6. Aydoğmuş, E., and Arslanoğlu, H. (2021). Kinetics of thermal decomposition of the polyester nanocomposites, *Petroleum Science and Technology*, 39(13–14), 484–500.
7. Şahal, H., and Aydoğmuş, E. (2022). Investigation of Thermophysical Properties of Polyester Composites Produced with Synthesized MSG and Nano-Alumina, *European Journal of Science and Technology*, 34, 95-99.
8. Şahal, H., Aydoğmuş, E., and Arslanoğlu, H. (2022). Investigation of thermophysical properties of synthesized SA and nano-alumina reinforced polyester composites, *Petroleum Science and Tec*hnology, 1–17.
9. Yanen, C., and Aydoğmuş, E. (2021). Characterization of Thermo-Physical Properties of Nanoparticle Reinforced the Polyester Nanocomposite, *Dicle University Journal of the Institute of Natural and Applied Science*, 10(2), 121–132.
10. Aydoğmuş, E., Arslanoğlu, H., and Dağ, M. (2021). Production of waste polyethylene terephthalate reinforced biocomposite with RSM design and evaluation of thermophysical properties by ANN, *Journal of Building Engineering*, 44, 103337.
11. Aydoğmuş, E. (2022). Biohybrid nanocomposite production and characterization by RSM investigation of thermal decomposition kinetics with ANN, *Biomass Conversion and Biorefinery*, 12, 4799-4816.
12. Aydoğmuş, E., Dağ, M., Yalçın, Z.G., and Arslanoğlu, H. (2022). Synthesis and characterization of waste polyethylene reinforced modified castor oil‐based polyester biocomposite, *Journal of Applied Polymer Science*, 139, e525256.
13. Demirel, M.H., and Aydoğmuş, E. (2022). Production and Characterization of Waste Mask Reinforced Polyester Composite, *Journal of Inonu University Health Services Vocational School*. 10(1), 41-49.
14. Demirel, M.H., and Aydoğmuş, E. (2022). Waste Polyurethane Reinforced Polyester Composite, Production and Characterization, *Journal of the Turkish Chemical Society Section A: Chemistry*, 9(1), 443–452.
15. Buran, A., Durğun, M.E., and Aydoğmuş, E. (2022). *Cornus alba* Reinforced Polyester-Epoxy Hybrid Composite Production and Characterization, *European Journal of Science and Technology*, 43, 99-103.
16. Buran, A., Durğun, M.E., Aydoğmuş, E., and Arslanoğlu, H. (2023). Determination of thermophysical properties of *Ficus elastica* leaves reinforced epoxy composite. *Firat University Journal of Experimental and Computational Engineering*, 2(1), 12-22.

1. \* Corresponding author. *e-mail address: ercanaydogmus@firat.edu.tr* [↑](#footnote-ref-1)