

**Research Article**

# Effect of Arenga pinnata Palm Wine on Surface Roughness of Acrylic and Thermoplastic Nylon: SEM Study

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Acrylic resin, Arenga pinnata, SEM, tuak aren, thermoplastic nylon.



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## ABSTRACT

**Introduction:** Surface roughness is an important property of denture base materials because it affects hygiene, comfort, and durability. Rough surfaces can retain debris and microorganisms, increasing the risk of halitosis and mucosal irritation. Tuak aren (Arenga pinnata palm wine), a traditional fermented beverage, contains alcohol and has an acidic pH that may alter denture base materials. This study evaluated the effect of tuak aren on the roughness of acrylic and thermoplastic nylon denture bases.

**Materials and Methods:** Four groups were studied: acrylic plates (A1) and thermoplastic nylon plates (A2) immersed in distilled water as controls, and acrylic plates (B1) and thermoplastic nylon plates (B2) immersed in tuak aren as treatments. After 11 days of immersion, surface morphology was examined using scanning electron microscopy (SEM), and surface roughness was measured using a profilometer.

**Results and Discussion:** Descriptive analysis showed that A1 had the lowest surface roughness, while B2 had the highest. One-way ANOVA demonstrated significant differences among groups. LSD post hoc analysis revealed significant differences between B2 and groups A1, A2, and B1. SEM observations at 500× magnification showed microscopic surface changes after immersion in tuak aren. Profilometer measurements were consistent with SEM findings.

**Conclusion:** Exposure to tuak aren increased the surface roughness of denture base materials, with the greatest effect observed in thermoplastic nylon plates.

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## INTRODUCTION

Oral health problems remain highly prevalent in Indonesia and may lead to tooth loss that requires prosthodontic rehabilitation. According to the Indonesian Basic Health Research (Riskesdas), approximately 57.6% of the population experienced oral health problems, yet only a small proportion sought treatment from dental professionals.<sup>1</sup> Tooth loss can negatively affect mastication, speech, and facial aesthetics, thereby reducing quality of life. Denture therapy is therefore commonly used to restore oral function and appearance. Epidemiological studies have also reported that the prevalence of edentulism among adults aged 50 years and older in Indonesia is around 7.2%, indicating a continuing need for prosthodontic treatment.<sup>2</sup> The increasing use of denture prostheses highlights the importance of understanding the physical properties of denture base materials, as these characteristics influence the longevity, hygiene, and clinical performance of the prosthesis.

Oral health problems remain highly prevalent in many populations and often lead to tooth loss requiring prosthodontic rehabilitation. The use of dentures is therefore essential to restore mastication, speech, and facial aesthetics, thereby improving patients' quality of life. As the number of denture users increases, understanding the properties of denture base materials becomes increasingly important to ensure optimal clinical performance and longevity.

One critical property of denture base materials is roughness surface. A rough surface may facilitate the retention of plaque, food debris, and microorganisms, which can lead to halitosis, mucosal irritation, and reduce patient comfort. Previous studies have indicated that denture surfaces

with roughness values exceedingly approximately 0.2  $\mu\text{m}$  may promote microbial adhesion and plaque accumulation.<sup>3,4,5</sup> Heat-polymerized acrylic resin remains the most widely used denture base material due to its favorable aesthetics and ease of processing, while thermoplastic nylon has gained attention because of its flexibility and improved esthetic properties. However, these materials exhibit different surface characteristics and may respond differently to environmental exposure.<sup>6</sup> In addition to mechanical factors, the physical properties of denture base materials can also be influenced by dietary habits, particularly exposure to acidic or alcoholic beverages. Such substances may alter the surface morphology and roughness of polymer-based materials over time.

Nationally, the prevalence of alcohol consumption in Indonesia is relatively low compared with many other countries. Analysis of the 2018 Indonesian Basic Health Research (Riskesdas) indicates that approximately 3.7% of individuals aged 15 years and older report consuming alcoholic beverages, with variations across regions and population characteristics.<sup>7</sup> In addition to commercially produced alcoholic drinks, the consumption of traditional fermented beverages is also common in several regions. Studies examining alcohol consumption patterns in Indonesia have reported that about 55.4% of alcohol consumption in rural areas originates from traditional beverages, including tuak and arak.<sup>8</sup> In certain regions, particularly in Bali, traditional fermented drinks such as tuak remain widely consumed within local communities.<sup>9</sup> Fermented beverages typically contain alcohol and exhibit an acidic pH, both of which may interact with polymer-based dental materials. Continuous exposure to such substances may contribute to changes in

surface morphology and increased surface roughness of denture base materials. Understanding these interactions is important because surface alterations may influence plaque retention, hygiene, and the long-term clinical performance of denture prostheses.

Nevertheless, studies investigating the influence of traditional fermented beverages, such as tuak aren, on denture base materials remain limited. Therefore, investigating the interaction between traditional fermented beverages and denture base materials is important to better understand possible changes in surface characteristics, particularly surface roughness, which may affect the clinical performance and hygiene of denture prostheses. This study aimed to evaluate the effect of tuak aren immersion on the surface roughness of acrylic resin and thermoplastic nylon denture bases.

## MATERIAL AND METHODS

This study was conducted through several sequential stages. First, specimens made of heat-polymerized acrylic resin and thermoplastic nylon plates measuring 60 × 10 × 2.5 mm, prepared following the general specimen preparation guidelines described in ISO 1567: Dentistry-Denture Base Polymers, provided sufficient flat surface area for profilometer tracing and subsequent microscopic observation. Each specimen was polished using sequential silicon carbide abrasive papers with 400, 800, and 1200 grit with the aid of a rotary grinder to obtain a smooth surface that simulated the clinical characteristics of denture base materials.

Second, the specimens were randomly divided into four groups (n = 6 per group). Groups A1 (acrylic) and A2 (thermoplastic nylon) were

immersed in 300 mL of distilled water and served as the control groups. Groups B1 (acrylic) and B2 (thermoplastic nylon) were immersed in 300 mL of tuak aren as the treatment groups. All samples were stored at 37 °C to simulate intra-oral conditions. The immersion period of 11 days was selected to represent short-term aging, consistent with immersion protocols commonly reported in the literature (7–14 days) for detecting early changes in denture base surface properties.<sup>9-13</sup>

The tuak aren used in this study was obtained from traditional palm sap tapping of *Arenga pinnata* in Karangasem, Bali, Indonesia. The tuak aren was a locally produced, non-commercial traditional beverage obtained from *Arenga pinnata* sap tapping in Karangasem, Bali, Indonesia. It was not a branded product but was collected directly from local producers who follow traditional fermentation practices without industrial processing or standardization. This approach was chosen to reflect real-life community consumption and to better represent the typical chemical characteristics of traditionally fermented palm wine. Fresh sap was collected from the palm inflorescence using bamboo containers and allowed to ferment naturally at ambient temperature following the common local palm wine production process.

The fermented liquid was filtered to remove impurities and subsequently used as the immersion medium for the experimental groups. Preliminary phytochemical screening of the tuak aren sample was performed using standard qualitative methods to identify the presence of major bioactive compounds, including saponins, phenolics, terpenoids, alkaloids, and flavonoids. The acidity of the palm wine was measured prior to the experiment using a digital pH meter, and the solution exhibited an average pH of approximately 3.5–4.0 (Figure 1).

After immersion, the specimens were rinsed with distilled water and dried with tissue paper. Surface roughness (Ra) was measured using a profilometer, in which a stylus tip traverses the specimen surface to detect surface irregularities. Three reference points were marked on each specimen, and measurements were taken with a 17.5 mm stylus path across the flat surface. Each point was measured three times and averaged. Finally, for SEM analysis, specimens were sectioned into 10 × 10 × 2.5 mm pieces to fit the specimen holder and facilitate microscopic observation, mounted on specimen stubs, and coated with a conductive layer. The surface morphology was then examined using Scanning Electron Microscopy at 500× magnification to evaluate microscopic topographical changes. The study was conducted at the Faculty of Mechanical Engineering, Pendidikan Ganesha University, and the Faculty of Mechanical Engineering, Udayana University.

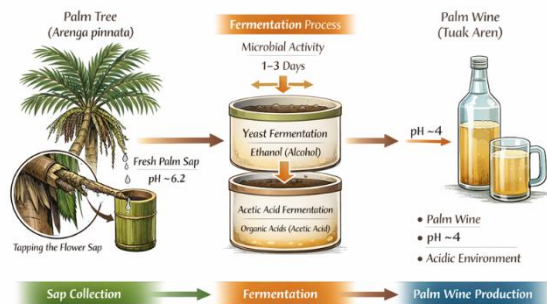


Figure 1. Traditional collection of *Arenga pinnata* palm sap, where the inflorescence stalk is tapped, and the sap is collected in a bamboo container. The collected sap subsequently undergoes natural fermentation to produce palm wine (tuak aren).

## RESULTS AND DISCUSSIONS

SEM observations of the heat-polymerized acrylic surface (Figures 2A and 2C) revealed noticeable morphological changes following immersion in tuak aren. In the control group (A1), the acrylic surface appeared relatively smooth with minimal variation in surface elevation. However, after

immersion in tuak aren (B1), more pronounced morphological alterations were observed, characterized by the presence of micropits and microcracks distributed across the examined surface area.

SEM observations of the thermoplastic nylon denture base material (Figures 2B and 2D) revealed surface morphological characteristics that differed from those of heat-polymerized acrylic resin. In the control group (A2), the nylon surface exhibited a relatively organized morphology with features typical of crystalline polymer structures. Variations in contrast observed in the SEM micrographs may indicate the presence of both crystalline and amorphous domains within the polymer matrix. These structural domains are commonly found in polyamide-based thermoplastic materials and influence their mechanical and surface properties. Such structural characteristics contribute to the flexibility and viscoelastic behavior that make thermoplastic nylon widely used as a denture base material.<sup>14,15</sup>

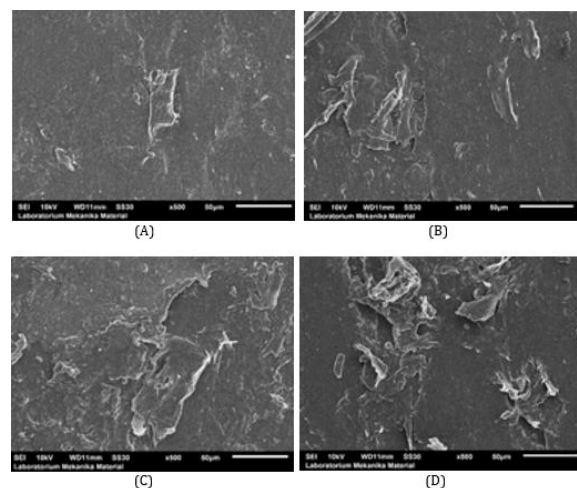


Figure 2. SEM observation results: (A) Smooth, homogeneous surface of control acrylic (A1); (B) Organized surface of control nylon with slight variations (A2); (C) Micropits and microcracks present on acrylic after tuak aren immersion (B1); (D) Cracks and delamination on nylon indicating severe degradation after tuak aren immersion (B2).

After immersion in tuak aren (B2), more pronounced morphological changes were observed on the thermoplastic nylon surface. SEM images demonstrated the presence of larger surface defects, including elongated cracks, irregular depressions, and areas suggestive of surface delamination. These alterations may occur as a result of environmental exposure to liquids containing chemical components capable of interacting with polymer structures. Acidic or alcoholic solutions may diffuse into the polymer matrix through microscopic pores, leading to gradual weakening of intermolecular interactions and subsequent structural degradation. Previous investigations have shown that exposure of denture base polymers to chemically active environments can accelerate hydrolytic processes and contribute to surface deterioration.<sup>3,5</sup>

The relatively higher occurrence of cracks observed in the thermoplastic nylon group may also be associated with the material's semi-crystalline nature. Although crystalline regions enhance the mechanical strength of the polymer, they may also act as points of stress concentration when the material experiences mechanical or environmental stress beyond its elastic limit. Under such conditions, crack initiation and propagation may occur within the polymer structure, eventually altering the surface morphology. Similar fracture patterns have been described in studies evaluating aging and environmental exposure of thermoplastic denture base materials, where changes in microstructure became evident through SEM analysis.<sup>6,15</sup>

These morphological findings correspond with the quantitative surface roughness (Ra) values obtained from profilometer measurements. The formation of cracks, pits, and delamination

features increases the irregularity of the material surface, thereby contributing to higher roughness values. Descriptive statistical analysis supported these observations by demonstrating variation in roughness among the experimental groups. As presented in Table 1, the thermoplastic nylon specimens immersed in palm wine (B2) exhibited the highest mean roughness value, whereas the acrylic control group (A1) showed the lowest. This pattern suggests that exposure to tuak aren may promote greater surface degradation in thermoplastic nylon compared with heat-polymerized acrylic resin. Similar trends have been reported in previous studies evaluating the influence of chemical environments on denture base materials, where polymer degradation was associated with increased surface roughness and altered surface topography.<sup>3,4</sup>

Table 1. Descriptive statistical analysis of surface roughness (Ra)

Group	N	Mean (Ra)	Standard Deviation (SD)
A1	6	0.619	0.191
A2	6	0.626	0.173
B1	6	0.681	0.075
B2	6	0.986	0.274

Surface roughness (Ra) was measured using a profilometer. A1: Acrylic immersed in distilled water; B1: Acrylic immersed in tuak aren; A2: Thermoplastic nylon immersed in distilled water; B2: Thermoplastic nylon immersed in tuak aren

The Shapiro–Wilk test confirmed that the data were normally distributed. Homogeneity of variance was evaluated using Levene's test, yielding a significance value (Sig.) of 0.073. The results of the One-Way ANOVA test (Table 2) confirmed the presence of statistically significant differences among the immersion groups for both denture base materials. Further analysis using the Least Significant Difference (LSD) post hoc test provided additional evidence supporting these findings. As

shown in Table 3, the B2 group demonstrated a significant difference compared with the other experimental groups. Overall, these results indicate that immersion in tuak aren had the greatest effect on increasing surface roughness, particularly in the thermoplastic nylon material. This finding suggests that the chemical characteristics of palm wine may contribute more strongly to surface degradation in thermoplastic nylon compared with heat-polymerized acrylic resin.

Table 2. Results of One-Way ANOVA Analysis

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.548	3	0.183	4.940	0.010*
Within Groups	0.739	20	0.037		
Total	1.287	23			

\*. The mean difference is significant at the 0.05 level.

Table 3. Results of the LSD Test

Group I	Group J	Mean Difference (I-J)	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
A1	A2	0.007	0.952	0.2384	0.2247
A1	B1	0.062	0.584	0.2934	0.1697
A1	B2	0.367	0.003*	0.5989	0.1358
A2	B1	0.055	0.626	0.2865	0.1765
A2	B2	0.360	0.004*	0.5920	0.1290
B1	B2	0.305	0.012*	0.5370	0.0740

\*. The mean difference is significant at the 0.05 level. A1: Acrylic immersed in distilled water; B1: Acrylic immersed in tuak aren; A2: Thermoplastic nylon immersed in distilled water; B2: Thermoplastic nylon immersed in tuak aren

The findings of this study demonstrate that immersion in tuak aren significantly increases the surface roughness of denture base materials, particularly in thermoplastic nylon. Among the experimental groups, B2 exhibited the highest roughness value, whereas A1 showed the lowest. This pattern suggests that exposure to fermented palm wine may accelerate surface degradation, especially in materials with higher susceptibility to environmental interaction. Previous studies have reported that immersion of heat-cured acrylic

resin in acidic solutions, such as vinegar and Averrhoa bilimbi extract, can significantly increase surface roughness due to polymer degradation and surface erosion.<sup>13</sup> These findings are consistent with the present study, as *Arenga pinnata* palm wine (tuak aren) also exhibits an acidic pH and contains alcohol as a result of natural fermentation. The combined effect of acidity and ethanol may enhance liquid diffusion into the polymer matrix, leading to plasticization, microstructural degradation, and increased surface irregularities. This mechanism may explain the higher surface roughness observed, particularly in thermoplastic nylon, which is more susceptible to liquid absorption and chemical exposure. Similar observations have been reported in previous studies, indicating that exposure to acidic or alcoholic solutions can induce microstructural degradation in denture base polymers through mechanisms such as plasticization and weakening of polymer bonds.<sup>16,17</sup> These processes may lead to surface softening and increased susceptibility to microstructural damage.

Low-pH beverages are known to facilitate the penetration of liquid molecules into polymer matrices.<sup>16</sup> When acidic or alcoholic components penetrate the polymer network, they may disrupt intermolecular interactions and accelerate hydrolytic or chemical degradation processes. Based on previous reports on naturally fermented palm sap beverages, the alcohol content of palm wine generally ranges from approximately 4-7%, depending on the duration of fermentation. Tuak aren is produced through the natural fermentation of *Arenga pinnata* sap. During fermentation, microbial metabolism converts sugars into ethanol while producing organic acids that gradually lower the pH of the liquid.<sup>19,20</sup> Consequently, such interactions may contribute to the development of

surface irregularities and an increase in roughness values observed in denture base materials exposed to chemically active environments.

The different responses observed between acrylic resin and thermoplastic nylon can be explained by the distinct physicochemical characteristics of these materials. Heat-polymerized acrylic resin (PMMA) possesses a relatively stable cross-linked polymer network that contributes to its dimensional stability and resistance to mild chemical exposure. This cross-linked structure restricts the penetration of external molecules into the polymer matrix, thereby improving its resistance to degradation when exposed to weak acidic environments. In contrast, thermoplastic nylon (polyamide) exhibits a more flexible polymer chain structure and demonstrates hygroscopic behavior, allowing water and other liquid molecules to diffuse more readily into the material. The presence of amide functional groups within the polyamide chain facilitates hydrogen bonding with water molecules, which may promote liquid absorption and structural changes within the polymer matrix.<sup>5,21</sup>

As a consequence of this higher affinity for liquid absorption, thermoplastic nylon may undergo more pronounced structural alterations when exposed to chemically active solutions. Penetration of acidic or alcohol-containing liquids into the polymer matrix may weaken intermolecular interactions, induce plasticization, and contribute to microstructural degradation of the material. Previous investigations evaluating denture base polymers have also reported that thermoplastic polyamide materials tend to demonstrate lower surface stability compared with conventional heat-polymerized acrylic resin when exposed to acidic beverages or alcohol-containing solutions.

Thermoplastic polyamide materials have been reported to exhibit different surface stability compared with conventional heat-polymerized acrylic resin under simulated aging conditions.<sup>4,14</sup> In addition, exposure to acidic or alcohol-containing solutions has been shown to promote surface degradation and increase roughness in denture base materials.<sup>11,13,18</sup> These interactions may result in increased surface irregularities and roughness, ultimately affecting the long-term performance of denture base materials. The present findings highlight that fermented beverages such as tuak aren may influence the surface integrity of denture base materials, with thermoplastic nylon demonstrating greater vulnerability to chemical exposure than heat-polymerized acrylic resin.

## CONCLUSION

In conclusion, immersion in tuak aren appears to increase the roughness of denture base materials, especially thermoplastic nylon, which may have clinical implications for the long-term durability of dentures and the potential for microbial adhesion.

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