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ORIGINAL RESEARCH

THE EFFECT OF ROBUSTA COFFEE ON THE COLOR STABILITY OF THERMOPLASTIC NYLON DENTURE BASE

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ABSTRACT

***Introduction**: Thermoplastic nylon is a flexible denture base material known for its excellent esthetics, making it a viable alternative for patients allergic to residual monomers or metals. However, its high water absorption rate may compromise color stability, a critical property for clinical longevity. Robusta coffee, a widely consumed beverage in South Sumatra, contains high concentrations of chromogenic agents that potentiallly induce significant staining.* **Aim:** *This study aimed to evaluate the effect of robusta coffee immersion and duration on the color stability of thermoplastic nylon denture base.* **Methods:** *This laboratory experimental study employed a pretest–posttest control group design. Thirty-two thermoplastic nylon specimens (20 × 3 mm) were divided into eight groups (n=4) and immersed in either robusta coffee or distilled water for 1, 3, 5, and 7 days. Color changes were quantified using a colorimeter. Data were analyzed using paired t-test, one-way ANOVA, and post hoc LSD tests).* **Result:** *The paired t-test revealed significant changes in lightness (ΔL) accross all groups($p<0.05$. The highest mean color change (ΔE) occurred in the 7-day robusta coffee immersion group (mean = 14.25), while the lowest was observed in the the 1-day distilled water group (mean = 9.68).* **Conclusion:** *Immersion in robusta coffee significantly affects the color stability of thermoplastic nylon. Furthermore, increased immersion duration correlates with a higher degree of discoloration.*

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INTRODUCTION

The denture base is a critical component that rests on the oral soft tissues, serving as the foundation for the artificial teeth attachment.[1] Its durability and mechanical performance are heavily dictated by the material properties used in fabrication.[2] Denture bases are commonly fabricated from acrylic-based or metal-based materials. Conventional acrylic resin is known to be prone to fracture, while metal-based dentures are rigid and relatively heavy. Due to these limitations, thermoplastic nylon has been introduced as an alternative denture base material.[3,4]

Thermoplastic nylon offers distinct advantages, including high elasticity suitable for

flexible dentures, good esthetics, and biocompatibility for patients sensitive to residual acrylic monomers or metallic components. However, its hydrophilic nature remains a concern, as water sorption significantly affects the color stability of the denture base.[5] In dentistry, color stability is a paramount factor in determining the long-term success of dental materials.[6] Discoloration of denture bases often results from the interaction between the material and pigments from dietary beverages, which permeate the polymer matrix.[7]

In Indonesia, coffee consumption is a deeply rooted social and functional habit, with per capita consumption increasing by 1.52% annually.[8,9] The increase in coffee consumption is influenced by various factors, including functional effects such as improved alertness and energy, as well as social factors such as comfort and social interaction.[9]

South Sumatra is one of the provinces with the highest coffee bean production in Indonesia.[8] Robusta coffee dominates the regional production and is characterized by a high concentration of polyphenols and an acidic pH (approximately 5.61–5.69).[10,11] The acidic environment can induce the degradation of nylon polymer chains, thereby facilitating the diffusion and deposition of chromogenic pigments into the material.[10,11]

While Kasuma et al. (2015) demonstrated that the color stability of heat-cured acrylic resin is affected by Robusta coffee,[10] there is limited data regarding its impact on thermoplastic nylon, which possesses higher water sorption properties. Therefore, this study aims toevaluate the effect of robusta coffee on the color stability of thermoplastic nylon denture bases.

METHODS

This was an in vitro laboratory study using a pretest–posttest control group design. The study was conducted at the Agricultural Engineering Chemistry Laboratory, Faculty of Agriculture, Sriwijaya University, Palembang. A total of 32 thermoplastic nylon (Valplast®, USA) specimens were fabricated at the Musi Dental Laboratory, Palembang, with dimensions of 20 × 3 mm according to ISO 1567 standards. Each sample was coded and randomly divided into eight groups (n=4). Four treatment groups were immersed in Robusta coffee solution for 1, 3, 5, and 7 days, while four control groups were immersed in distilled water for the same durations.

The Robusta coffee solution (Piko®, Indonesia) was prepared daily by dissolving 20 g of coffee powder in 200 mL of boiling distilled water. The mixture was stirred and subsequently filtered using filter paper to ensure a sediment-free solution. The filtrate was allowed to cool for 20 minutes to reach a stable temperature before the specimens were immersed. The pH of the solution was monitored using a digital pH meter to ensure consistency across batches.

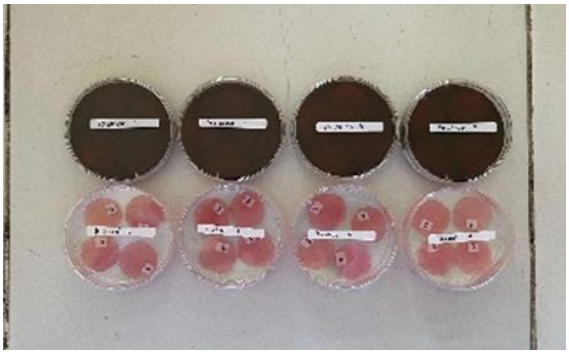

Figure 1. Immersion of samples in a soaking solutions

All specimens were incubated at 37°C during the immersion period (Figure 1). Following immersion, the specimens were removed, rinsed and gently dried, and evaluated for color change using a colorimeter. Color changes of the thermoplastic nylon samples were quantified before and after immersion using a colorimeter (NH310, China). Each specimen was measured three times at different points to obtain an average value. Color coordinates were recorded based on the CIE L*a*b* color system, where L* represents lightness, a* represents the green–red axis, and b* represents the yellow–blue axis and color changes were calculated using the following formula.

$$\Delta E^* = \{(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2\}^{1/2}$$

The values of ΔL*, Δa*, and Δb* were obtained by subtracting the L*, a*, and b* values after immersion from the corresponding values measured before immersion.

Figure 2. Measurement of thermoplastic nylon color using a colorimeter

Data were analyzed using the paired t-test to compare pretest and posttest measurements within each group. One-way analysis of variance (ANOVA) was subsequently performed to assess differences across groups, followed by the Least Significant Difference (LSD) post-hoc test for multiple comparisons ($p<0.05$).

RESULTS

The pH of each soaking solution was measured using a pH meter (Table 1).

Table 1. pH values of soaking Solutions

Solutions	pH
Distilled water	7,4
Robusta coffee	5,7

Normality and homogeneity tests (Shapiro–Wilk and Levene's tests) yielded $p > 0.05$, confirming that the data were normally distributed and homogeneous. The paired t-test showed significant color differences before and after immersion in all groups ($p < 0.05$). The most substantial color change was observed after 7 days of immersion in Robusta coffee (14.25 ± 0.42), whereas the 1-day distilled water group showed the least change (9.68 ± 2.06) (Table 2).

Table 2. Paired t-test results

Group	Mean±SD	p-value
DW-1 day	9.68±2.06	0.003
DW-3 day	10.26±0.58	<0.001
DW-5 day	11.31±1.51	<0.001
DW-7 day	11.47±0.95	<0.001
RC-1 day	11.13±1.34	<0.001
RC-3 day	11.74±2.15	0.002
RC-5 day	12.13±1.25	<0.001
RC-7 day	14.25±0.42	<0.001

*DW= distilled water
RC= Robusta coffee

Furthermore, one-way ANOVA revealed significant differences in total color change (ΔE) acrossm all groups (Table 3).

Table 3. One-way ANOVA results

Value	Sig.
ΔE	0.007

Post hoc Least Significant Difference (LSD) analysis of ΔE values revealed significant differences between the 1-day control group and the 5-day Robusta coffee group ($p < 0.05$), as well as between the 7-day Robusta coffee group and all other groups ($p < 0.05$).

Table 4. LSD post-hoc test results

Group	Result
DW 1 day-RC 5 day	0.025*
DW 1 day-RC 7 day	<0.001*
DW 3 day-RC 7 day	<0.001*
DW 5 day-RC 7 day	0.006*
DW 7 day-RC 7 day	0.007*
RC 1 day - 7 day	0.004*
RC 3 day - 7 day	0.016*
RC 5 day - 7 day	0.043*

*DW = distilled water
RC = Robusta coffee

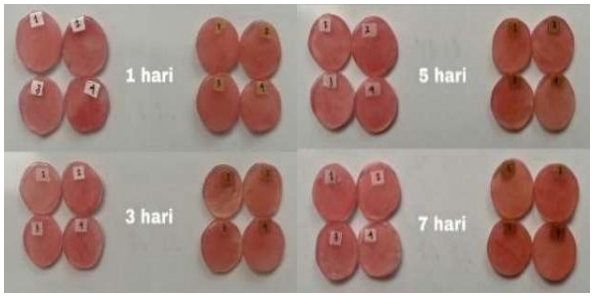

Figure 3. Thermoplastic nylon samples

DISCUSSION

All sample groups exhibited color changes after immersion, which may be associated with the hydrophilic characteristics of thermoplastic nylon. The presence of amide groups (–NH) promotes solution absorption and diffusion into the polymer chains, potentially leading to structural weakening and reduced color stability.[12,13] According to Song et al. (2019), the water absorption value of thermoplastic nylon (Valplast®) is 12.67 μg/mm³, which is within the ISO 1567 standard limit of ≤ 32 μg/mm³. Nevertheless, its color stability remains relatively low, as prolonged immersion promotes the absorption of water and coffee pigments into the polymer matrix, leading to pigment accumulation and increased color change.[14]

The group immersed in Robusta coffee for 7 days showed significant differences compared to all other groups, indicating that the greatest color change occurred after prolonged immersion. The higher ΔE value observed in this group may be attributed to the acidic nature of the Robusta coffee solution used in this study, which had a pH of approximately 5.7. In addition, the discoloration potential of coffee is associated with its chlorogenic acid and tannin content. These compounds are phenolic derivatives with acidic properties due to the presence of hydroxyl (–OH) groups bound to phenyl rings. The relatively weak bond between oxygen (O) and hydrogen (H) facilitates the release of hydrogen ions (H^+), contributing to an acidic environment. Oxidation of phenolic compounds may further increase H^+ release, which can promote degradation of nylon polymer chains, leading to reduced physical properties. Consequently, this process may facilitate pigment adhesion and diffusion into the nylon material, resulting in increased discoloration.[12,15]

In the control group, distilled water exhibited a neutral pH (approximately 7.4) and consisted primarily of H_2O molecules with relatively stable ions. Distilled water is a colorless, odorless, and tasteless liquid and is classified as a weak electrolyte.[12] These conditions resulted in minimal color change in the control groups. This finding is consistent with

the post hoc LSD analysis of ΔE values shown in Table 4, which demonstrated no significant differences among the control groups. Arifin et al. (2024) reported that a ΔE value greater than 3.7 indicates a visible and clinically unacceptable color change.[16] In the present study, all ΔE values exceeded 3.7, indicating that the color change sobserved in thermoplastic nylon denture bases were visually perceptible and clinically unacceptable.

The group immersed in Robusta coffee for 7 days showed the most significant discoloration. This finding aligns with the theory that coffee contains potent chromogens such as tannins and chlorogenic acid, which cause staining through both adsorption and absorption mechanisms. Unlike other beverages, the brown pigmentation in coffee has a lower polarity, which facilitates its affinity and penetration into the polymer matrix. Furthermore, the acidic pH of the Robusta solution (approx. 5.7) may further compromise the surface integrity of the thermoplastic nylon, creating microscopic irregularities that trap these pigments.[17] One limitation of this study is the potential formation of microporosity due to inaccuracies during sample preparation. During fabrication, air entrapment may occur, leading to microporosity that facilitates pigment adhesion in porous areas.[12]

This study is expected to provide useful information for denture wearers in Palembang regarding the potential effects of coffee consumption on denture discoloration. Limiting coffee intake, choosing coffee with lower concentration, or adding milk may help reduce the risk of discoloration, as these measures can decrease pigment intensity and absorption.[9,18] Proper denture care practices, such as rinsing the mouth after consuming coffee, cleaning dentures with a brush after meals and beverages, and using denture cleansing solutions are recommended. For optimal results, these daily mechanical habits should be complemented by effective overnight chemical soaking. Clinical evidence indicates that immersing dentures overnight in a low-concentration 0.5% sodium hypochlorite solution is highly efficacious for removing biofilm. In contrast, commonly used alkaline peroxide effervescent tablets may not provide any additional biofilm removal benefits over plain water for individuals who already maintain adequate brushing routines. compared to brushing alone.[19] In addition, patient education provided by dentists regarding the effects of colored beverages and the importance of regular denture cleaning is essential to prevent discoloration and prolong denture longevity.[20]

CONCLUSION

In conclusion, immersion in Robusta coffee solution significantly compromises the color stability of thermoplastic nylon denture bases. This effect is time-dependent, where longer immersion leads to greater discoloration due to the synergistic action of the solution's acidity and its chromogenic agents (chlorogenic acid and tannins). Patients using thermoplastic nylon dentures should be advised on strict hygiene protocols after consuming Robusta coffee to maintain the esthetic longevity of their prosthesis.

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