

Corn Husk Powder Improves Flexural, Compressive, and Impact Strength of Heat-Cured Acrylic Resin

Dyah Noviana Primasari*, Cindy Ayu Fitriyanti**, Nabilah Febriyanti Denta Gunawan**, Mohammad Dhiya Fayiz**, Rudy S***, Ige Frameski Radila Muga*, Catur Septommy*

*Department of Biomaterials and Dental Technology, Faculty of Dentistry, Institut Ilmu Kesehatan Bhakti Wiyata, Kediri, Indonesia

**Undergraduate Dental Medicine Study Program, Faculty of Dentistry, Institut Ilmu Kesehatan Bhakti Wiyata, Kediri, Indonesia

***Department of Prosthodontics, Faculty of Dentistry, Institut Ilmu Kesehatan Bhakti Wiyata, Kediri, Indonesia

Correspondence: dyah.noviana@iik.ac.id

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ABSTRACT

Background: Heat-cured acrylic resin is widely used for denture bases due to its affordability and acceptable aesthetics, but its poor resistance to flexural, compressive, and impact forces remains a significant limitation.

Method: This laboratory study integrated findings from three experiments using a post-test-only control design to evaluate the effects of corn husk powder (*Zea mays L.*) on acrylic resin properties. The powder was blended at 0%, 1%, 2%, 3%, 4%, and 5% weight concentrations. Testing included three-point bending, uniaxial loading (ISO 604), and the Charpy method. Data were analyzed via ANOVA and post-hoc LSD tests ($\alpha=0.05$).

Result: Adding corn husk powder significantly improved all three mechanical properties compared to the control ($p<0.05$). Flexural strength peaked at 103.12 MPa with 3% loading (control: 63.33 MPa). Compressive strength similarly rose from 82.28 MPa to 107.35 MPa at 3% concentration. Impact strength markedly increased from 23.64 kJ/m² to 160.44 kJ/m² at 2% loading, though values declined at higher concentrations.

Conclusion: Incorporating corn husk powder effectively reinforces heat-cured acrylic resin. While the optimum concentration varied, a range of 2% to 3% provided the best overall mechanical enhancement, beyond which properties decreased.

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INTRODUCTION

Losing teeth is a common dental problem that may require prosthetic treatment to restore mastication, speech, and facial appearance. For decades, heat-cured acrylic resin has been widely used for denture bases, because it is relatively inexpensive, has acceptable esthetic properties, and can be processed and repaired easily.¹⁻⁵ Despite these practical benefits, the material has limited mechanical strength. Under continuous chewing forces or from accidental drops, this limited mechanical strength may lead to cracks and denture base fracture during use.

To improve these mechanical properties, the addition of reinforcing powders has been investigated. Reinforcing powders may improve stress distribution within the acrylic matrix. Recently, natural cellulosic powders have received attention as reinforcement materials for this purpose, because they are renewable, low-cost, and available as agricultural byproducts.⁶⁻⁸ However, their reinforcing effect depends on several factors, including cellulose content, powder dimensions, powder distribution, and powder-matrix interaction.

Corn husks (*Zea mays L.*) contain cellulose, making them a potential natural reinforcing material.^{9,10} However, an important consideration is the difference in surface properties between hydrophilic powders and hydrophobic acrylic resin.^{9,11} To improve powder-matrix interaction, alkaline treatment is used to remove surface lignin and hemicellulose, while silane coupling agents improve the interaction between the modified powders and the resin.^{9,11}

Prior research on natural powders, including sisal, coir, ramie, banana stem, and pineapple leaf, has reported improvements in the mechanical properties of acrylic resin after appropriate surface treatment.¹²⁻¹⁵ However, information on corn husk powder remains limited, with most available literature focusing only on individual mechanical properties in separate studies. Therefore, this study compares the findings of three independent experiments to evaluate the flexural, compressive, and impact properties, while identifying the powder concentration that produced the highest value for each mechanical test.

RESEARCH METHOD

This study combines findings from three independent laboratory experiments using a post-test-only control group design. Flexural strength was evaluated using three-point bending, impact strength was tested via the Charpy method, and compressive strength was measured through vertical loading in accordance with ISO 604. Because the experiments were conducted separately, the findings are presented as a descriptive comparison rather than a pooled analysis.

The laboratory testing protocols for this dental material investigation strictly operated under the ethical supervision of the Health Research Ethics Committee at Institut Ilmu Kesehatan Bhakti Wiyata Kediri under registry codes 335/FKG/EP/II/2025, 473/FKG/EP/II/2026 and 345/FKG/EP/II/2025.

Each of the three experiments comprised six distinct group: a powder-free control (0%) and five experimental groups with corn husk powder at concentrations of 1%, 2%, 3%, 4%, and 5%. These concentrations (V_p) were calculated based on the weight of the acrylic resin powder (W_s) using the following formula:

$$V_p = (W_p / W_s) \times 100\%$$

Where V_p represents the filler concentration (%), W_p is the actual mass of the corn husk powder (g), and W_s is the actual mass of the acrylic resin powder (g). The baseline weight of the acrylic resin powder (W_s) differed between the component studies (4.00 g for flexural and impact tests versus 3.00 g for compressive tests)

because the specific requirements for each mechanical test dictated distinct specimen dimensions and mold volumes. The detailed formulation, specimen dimensions, and precise actual mass for each experimental group are presented in Tabel 1.

Table 1. Formulation, Specimen Dimensions, and and Actual Mass of Acrylic Resin Powder (Ws) and Corn Husk Powder (Wp)

Group (Vp)	Powder (Wp)			
	Ws (g) [Flexural & Impact] (65 x 10 x 2.5 mm)	Ws (g) [Compressive] (10 x 10 x 4 mm)	Wp (g) [Flexural & Impact]	Wp (g) [Compressive]
Control (0%)	4.00	3.00	0.00	0.00
1%	4.00	3.00	0.04	0.03
2%	4.00	3.00	0.08	0.06
3%	4.00	3.00	0.12	0.09
4%	4.00	3.00	0.16	0.12
5%	4.00	3.00	0.20	0.15

Materials and powder preparation

The experimental setup utilized heat-cured acrylic resin (Hirodent) as the matrix and corn husk as the reinforcing material. Fresh, undamaged husk material from the outermost four layers was selected and ethically harvested from an agricultural center in Ngadiluwih Village, Kediri Regency, East Java, Indonesia. The husks were cut into small pieces, washed with distilled water, and immersed in ethanol for 30 minutes. After drying, the material was ground and passed through a 100-mesh sieve. The resulting powder was treated with 6% NaOH for 1 hour at 100°C to remove lignin and hemicellulose, neutralized with 6% CH₃COOH for 1 hour at 100°C, and bleached with 2% H₂O₂ for 2 hours at 60°C. The treated material was rinsed until neutral pH, dried again in a laboratory oven for 1 hour at 100°C, and mixed with a silane coupling agent (Ultradent Products, Inc.) where the silane grafting activation was completed at 110°C for 5 minutes before the required powder concentrations were prepared.



Figure 1. Treated corn husk powder (alkali and silane treated) ready for mixing with acrylic powder

Specimen groups and fabrication

For the flexural and impact tests, rectangular specimens were fabricated with dimensions of $65 \times 10 \times 2.5$ mm in accordance with ISO 20795-1 or ADA Specification No. 12 guidelines for denture base polymers.^{16,17} Meanwhile, the compressive test utilized smaller blocks measuring $10 \times 10 \times 4$ mm to evaluate compressive properties without buckling, as standardized by ISO 604.

The fabrication process involved mixing the acrylic powder and liquid monomer following the exact laboratory protocols of the respective source studies. The pre-treated corn husk powders were then blended into the mixture before it was packed into molds, heat-cured, deflashed, and finished through standard polishing techniques.

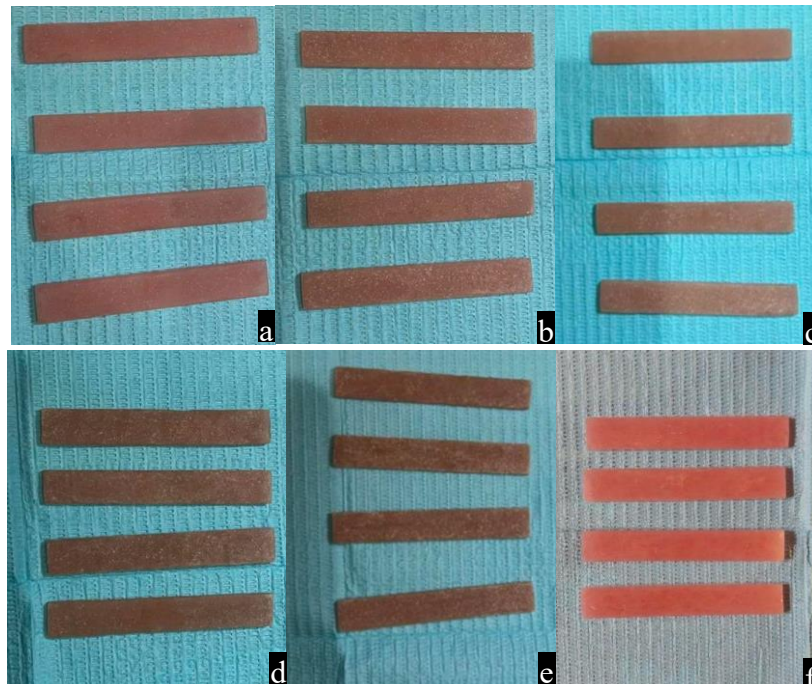


Figure 2. Acrylic resin specimens reinforced with corn husk powder at various concentrations for flexural and impact testing:

(a) 1%, (b) 2%, (c) 3%, (d) 4%, (e) 5%, and (f) 0% (control)

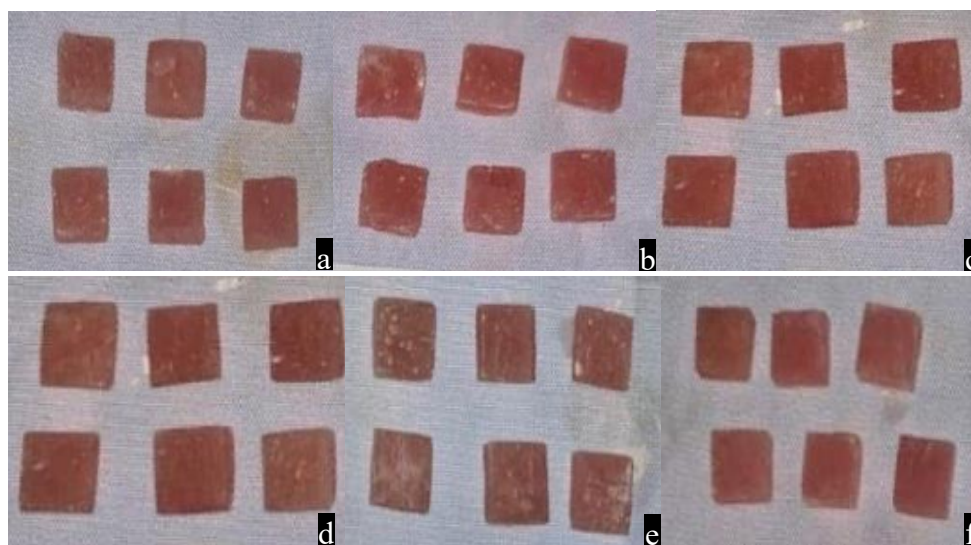


Figure 3. Acrylic resin specimens reinforced with corn husk powder at various concentrations for compressive testing:

(a) 1%, (b) 2%, (c) 3%, (d) 4%, (e) 5%, and (f) 0% (control)

Mechanical testing

Prior to testing, the dimensions of all cured specimens were precisely measured and verified using a digital caliper. Flexural strength was evaluated using a three-point bending configuration on a Universal Testing Machine with a 20 mm support span and a centralized load, in accordance with ISO 20795-1 and ADA Specification No. 12 guidelines. For compressive strength, a vertical load was applied continuously to each specimen until structural deformation or complete failure occurred, in accordance with ISO 604.

Impact strength was determined using the Charpy method on a universal impact testing machine. Following deflasking and final polishing, all specimens were stored in dry, airtight containers at a controlled room temperature (25°C) until the moment of testing to prevent any environmental moisture degradation. Each unnotched specimen was positioned with a horizontal support over a 20 mm support span and struck flatly on the reverse side, perpendicular to the specimen's primary plane, by a calibrated pendulum. The apparatus operated with a total capacity of 100 Joules (J), a 0.6-meter arm length, and a pendulum mass of 8.3 kg, delivering an impact velocity of ± 5 m/s. The total absorbed energy was recorded, and to ensure scientific accuracy, these raw Joule values were subsequently converted into true impact strength expressed in kilojoules per square meter (kJ/m²) based on the specimen's actual cross-sectional area.

Statistical analysis

The three independent datasets were statistically processed and analyzed separately using SPSS software. To verify the underlying assumptions for parametric analysis, Shapiro-Wilk testing was used to assess data normality, while Levene's test was used to assess the homogeneity of variance across groups. Mean differences among the various concentration groups were subsequently evaluated through One-Way ANOVA. Whenever the ANOVA yielded a statistically significant result, a post-hoc Least Significant Difference (LSD) test was performed to identify specific group differences, with the threshold for statistical significance established at $p < 0.05$.

Table 2. Specimen configuration and mechanical test standard for the integrated studies.

PROPERTY TESTED	SPECIMEN SIZE (MM)	STANDARD / METHOD	N PER GROUP	TOTAL N
FLEXURAL STRENGTH	65 × 10 × 2.5	Three-point bending, UTM	4	24
IMPACT STRENGTH	65 × 10 × 2.5	Charpy	5	30
COMPRESSIVE STRENGTH	10 × 10 × 4	ISO 604, UTM	5	30

RESULTS

Flexural strength

Incorporating the natural powders increased mean flexural strength, with the highest value observed at 3% powder concentration. Specifically, the control group recorded a mean strength of 63.33 ± 4.38 MPa, whereas the values for the 1%, 2%, 3%, 4%, and 5% powder groups were 85.46 ± 13.66 , 86.64 ± 3.69 , 103.12 ± 5.13 , 85.94 ± 17.34 , and 84.29 ± 4.18 MPa, respectively. One-Way ANOVA showed a significant effect of powder concentration on flexural strength ($F = 6.83$, $p = 0.001$; $\eta^2 = 0.655$). Post-hoc testing also revealed

statistically significant differences between the powder-free control and all powder-treated groups. A similar concentration-dependent pattern has been reported for powder-reinforced acrylic resin matrices.^{6,12,13}

Table 3. Mean flexural strength (MPa) according to corn husk powder concentration.

GROUP	CONTROL L (0%)	1%	2%	3%	4%	5%
MEAN $\pm$ SD (MPa)	63.33 $\pm$ 4.38	85.46 $\pm$ 13.66	86.64 $\pm$ 3.69	103.12 $\pm$ 5.13	85.94 $\pm$ 17.34	84.29 $\pm$ 4.18

The 3% formulation showed the highest flexural strength, corresponding to a 62.8% increase over the control value.

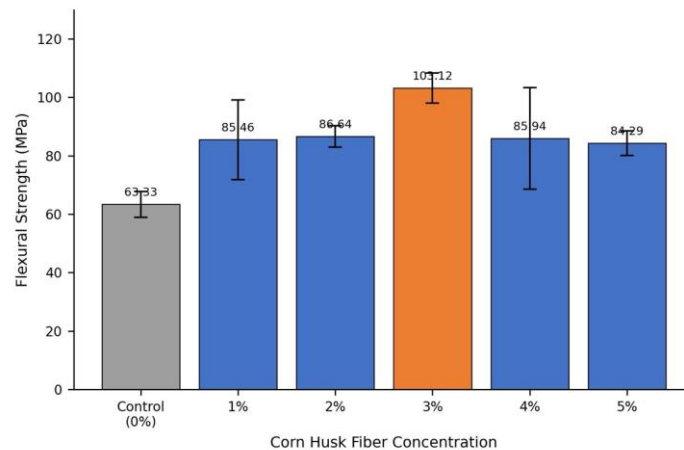


Figure 4. Mean flexural strength (MPa $\pm$ SD) of heat-cured acrylic resin by corn husk powder concentration.

Compressive strength

A similar pattern was observed for compressive strength. The control group demonstrated a mean compressive value of 82.28 ± 2.03 MPa, increased to 101.65 ± 2.35 MPa at 1% powder content, 104.40 ± 3.10 MPa at 2%, and reached the highest value of 107.35 ± 3.32 MPa at the 3% powder concentration. The values then decreased, dropping to 101.19 ± 2.73 MPa at 4% and 100.30 ± 1.79 MPa at 5% powder loading. One-Way ANOVA confirmed statistically significant differences among the six groups ($F = 50.35$, $p < 0.001$; $\eta^2 = 0.913$), highlighting a significant effect of powder concentration on compressive strength. Furthermore, post-hoc analysis established that the powder-free control differed significantly from every experimental treatment group.

Table 4. Mean compressive strength (MPa) according to corn husk powder concentration.

GROUP	CONTROL (0%)	1%	2%	3%	4%	5%
MEAN $\pm$ SD (MPa)	82.28 $\pm$ 2.03	101.65 $\pm$ 2.35	104.40 $\pm$ 3.10	107.35 $\pm$ 3.32	101.19 $\pm$ 2.73	100.30 $\pm$ 1.79

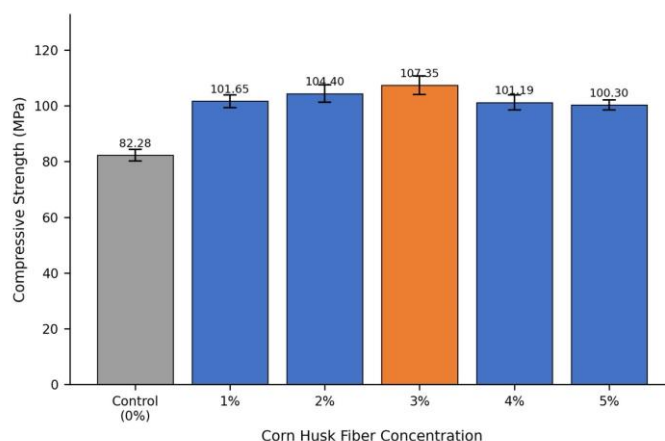


Figure 5. Mean compressive strength (MPa $\pm$ SD) of heat-cured acrylic resin by corn husk powder concentration.

Impact strength

Impact strength showed the largest relative increase among the three mechanical properties. The baseline control group yielded a mean impact strength of 23.64 ± 8.28 kJ/m², which increased to 82.72 ± 11.84 kJ/m² with 1% powder incorporation and reached 160.44 ± 14.96 kJ/m² at the 2% loading. At higher powder concentrations, the values decreased, with mean values diminishing to 93.80 ± 8.84 kJ/m², 75.04 ± 5.24 kJ/m², and 60.48 ± 9.36 kJ/m² for the 3%, 4%, and 5% groups, respectively. One-Way ANOVA showed a significant difference among the groups ($F = 97.50$, $p < 0.001$; $\eta^2 = 0.953$), indicating that powder concentration had a significant effect on impact strength. Additionally, post-hoc comparisons confirmed a statistically significant difference between the unreinforced control and all powder-modified treatment groups. This finding is consistent with previous studies of powder-reinforced acrylic denture base matrices.^{12,14,15}

Table 5. Mean impact strength (Joule) according to corn husk powder concentration.

GROUP	CONTROL (0%)	1%	2%	3%	4%	5%
MEAN $\pm$ SD (kJ/m ²)	23.64 $\pm$ 8.29	82.72 $\pm$ 11.84	160.44 $\pm$ 14.96	93.80 $\pm$ 8.84	75.04 $\pm$ 5.24	60.48 $\pm$ 9.36

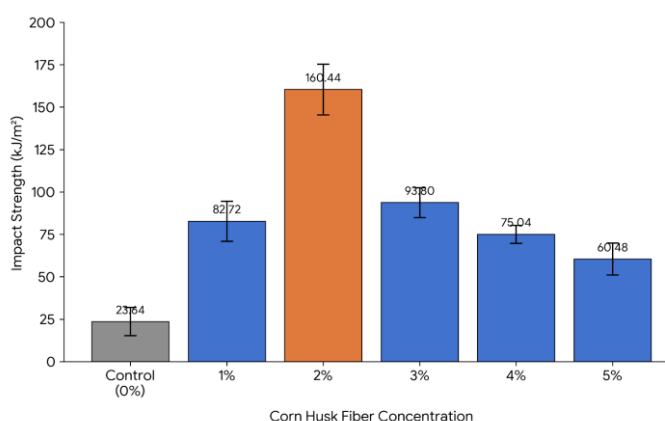


Figure 6. Mean impact strength (Joule $\pm$ SD) of heat-cured acrylic resin by corn husk powder concentration.

Cross-property summary

The highest flexural and compressive strengths were obtained at 3% powder concentration, whereas impact strength reached its highest value at 2%. Compared with the control groups, these optimal configurations

yielded a 62.8% improvement in flexural strength, a 30.5% gain in compressive strength, and a 578.7% increase in impact strength.

Table 6 Percentage increase over control at the optimal corn husk powder concentration for each property.

PROPERTY	CONTROL MEAN	OPTIMAL CONCENTRATION	OPTIMAL MEAN	INCREASE OVER CONTROL
FLEXURAL STRENGTH	63.33 MPa	3%	103.12 MPa	+62.8%
COMPRESSIVE STRENGTH	82.28 MPa	3%	107.35 MPa	+30.5%
IMPACT STRENGTH	23.64 kJ/m ²	2%	160.44 kJ/m ²	+578.7%

DISCUSSION

The addition of corn husk powder improved the three mechanical properties evaluated in this study compared with the unreinforced acrylic matrix. However, the optimum concentration differed among the mechanical tests. A 3% powder loading produced the highest flexural and compressive strengths, whereas a 2% concentration produced the highest impact strength.

The improvement in mechanical strength may be related to the cellulose content of the corn husk material. When the treated powders are well distributed within the acrylic matrix, they may contribute to stress transfer within the matrix. This finding is consistent with previous studies of natural powder-reinforced acrylic denture resins.⁹⁻¹⁵

Surface treatment may have contributed to the improvement in mechanical properties. Alkali treatment removes part of the non-cellulosic components from the powder surface, which may improve powder-matrix interaction, while the silane treatment may further improve the interaction between the powder and resin. Good powder-matrix adhesion is important because effective stress transfer is needed between the resin matrix and the powder.

The drop in strength observed at the 4% and 5% levels suggests that increasing powder concentration does not always improve mechanical strength. At higher concentrations, non-uniform powder distribution or powder agglomeration may contribute to the decrease in strength.¹⁹ However, these factors were not directly evaluated in this study. Similar concentration-dependent trends have been documented across various reinforced polymer systems.^{6,20}

These findings indicate that increasing powder concentration beyond the optimal level does not necessarily improve mechanical strength.

The lower optimum concentration for impact strength may be related to the different loading characteristics of the Charpy test and may explain why the highest impact strength was observed at 2%.⁴ This finding may be relevant when selecting denture base formulations for routine mastication and resistance to accidental impact.⁴

The appearance of the denture base is also an important consideration, as higher powder concentrations may affect the color of the material.³ However, color stability was not quantitatively evaluated in this study. Therefore, the 2%–3% concentration range may provide a favorable balance between mechanical improvement and material appearance.

This study has several limitations. Manual blending may not have produced completely uniform powder distribution. Furthermore, while mechanical reinforcement implies effective interfacial stress transfer and mechanical interlocking, these mechanisms were not qualitatively or quantitatively verified through advanced characterization techniques such as Scanning Electron Microscopy (SEM), Fourier-Transform Infrared Spectroscopy (FTIR), or surface topography analysis. Additionally, the analysis was limited by the relatively small sample sizes, independent testing batches, and lack of long-term testing under simulated oral conditions such as moisture degradation and cyclic fatigue.

The three datasets indicated that corn husk powder may be a potential natural reinforcement for heat-cured acrylic resin. The 2% to 3% concentration range included the highest-performing concentrations across the three mechanical tests, although the appropriate concentration may depend on the mechanical property required for a particular application, such as flexural strength, compressive strength, or impact tolerance.^{20,21,22}

The magnitude of the increase in impact strength should be interpreted within the conditions of this laboratory study. A nearly six-fold increase in Charpy energy absorption does not mean that a denture would have six times greater fracture resistance under clinical conditions. To validate such an extrapolation, further investigations focusing on dynamic fatigue, material aging, and clinically simulated testing would be needed.

From a materials-development perspective, corn husk may be useful as a reinforcing material and could provide an application for an agricultural byproduct. However, before clinical application can be considered, further studies should evaluate the reproducibility of powder processing techniques, along with its color stability, surface topography, water sorption, thermal degradation, and biocompatibility.^{20,21,22}

The integrated research design employed in this study has advantages and limitations, allowing comparison of several mechanical properties, although the analysis is descriptive. Because the datasets were compiled at separate intervals rather than from a single, uniform batch, this cross-property comparison should not be interpreted as a pooled effect estimate.

Future studies should fabricate all test specimens within a single, standardized experimental run, increase the sample size, and use microscopic analysis to evaluate powder distribution. Future studies should also evaluate these formulations under cyclic fatigue loading and simulated oral aging environments.

CONCLUSION

The addition of treated corn husk powder to heat-cured acrylic resin improved the flexural, compressive, and impact strengths relative to the unreinforced control group. The highest mean values for flexural and compressive strengths were obtained at 3% powder concentration, whereas the highest impact strength was obtained at 2% powder concentration. The decrease in mechanical properties at 4% and 5% concentrations indicates that increasing the powder content beyond these specific limits does not necessarily improve mechanical strength. Under the conditions of this laboratory study, a concentration range of 2% to 3% provided the most favorable overall mechanical performance.

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