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Original Research

Formulation and characterization of gotu kola (*Centella asiatica*) and cinnamon (*Cinnamomum verum*)-enriched white bread: organoleptic properties and qualitative triterpenoid screening

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ABSTRACT

Background: Elevated blood pressure and stage 1 hypertension, as classified by the 2017 ACC/AHA guideline, increase cardiovascular risk substantially. Non-pharmacological dietary interventions incorporating bioactive plant-derived compounds into staple foods represent a promising preventive strategy. **Methods:** A completely randomized design with four treatment groups (F0, F1, F2, F3) and three replications per group was employed. White bread was formulated with gotu kola (*Centella asiatica*) leaf powder and cinnamon (*Cinnamomum verum*) bark powder at varying proportions: F0 (0%:0%), F1 (10%:20%), F2 (20%:10%), and F3 (15%:15%). Organoleptic evaluation was conducted by 25 semi-trained panelists using a two-point hedonic scale. Data were analyzed using the Kruskal-Wallis H test with Dunn's post-hoc comparison. Triterpenoid content was identified through qualitative phytochemical screening. **Results:** The Kruskal-Wallis test revealed statistically significant differences among formulations for all four sensory attributes: taste ($H(3) = 29.28$, $p < 0.001$), texture ($H(3) = 19.51$, $p < 0.001$), aroma ($H(3) = 15.80$, $p = 0.001$), and color ($H(3) = 11.68$, $p = 0.009$). Post-hoc analysis indicated that the control (F0) was significantly preferred over all treatment formulations across most attributes. Among treatment formulations, F2 demonstrated the highest taste acceptance (52%). Qualitative phytochemical analysis confirmed the presence of triterpenoid compounds exclusively in F2. **Conclusion:** The F2 formulation (20% gotu kola, 10% cinnamon) was identified as the preferred formulation based on combined sensory performance and qualitative triterpenoid detection. Further quantitative analysis, bioavailability assessment, and controlled clinical investigation are warranted before functional health claims can be established.

Keywords: functional food; *Centella asiatica*; *Cinnamomum verum*; elevated blood pressure; triterpenoid.

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1. INTRODUCTION

Hypertension remains the single largest contributor to global cardiovascular mortality. The number of adults living with hypertension nearly doubled from 650 million in 1990 to 1.3 billion by 2019, with the steepest increases in low- and middle-income countries (World Health Organization [WHO], 2023). The WHO's first comprehensive global report on hypertension underscored that approximately four out of five individuals with the condition remain inadequately treated—a gap that, if closed, could avert an estimated 76 million deaths between 2023 and 2050 (WHO, 2023). In Southeast Asia, hypertension prevalence surged by as much as 144% over the same thirty-year window (Kario et al., 2024).

In Indonesia, the 2018 Basic Health Research (Riskesdas) reported that 34.1% of adults aged over 18 years had blood pressure exceeding 140/90 mmHg (Ministry of Health of Indonesia, 2018). Central Java recorded 626,762 individuals identified through health service screening, though this figure reflects service-based case-finding rather than population prevalence (Central Java Provincial Health Office, 2021).

The concept of "pre-hypertension" originates from the JNC 7 report (Chobanian et al., 2003), which classified systolic 120–139 mmHg or diastolic 80–89 mmHg under that label. The 2017 ACC/AHA guideline subsequently retired the term, splitting the range into "elevated blood pressure" (120–129/<80 mmHg) and "stage 1 hypertension" (130–139/80–89 mmHg) (Whelton et al., 2018). The present study adopts the JNC 7 criterion as the target population descriptor while acknowledging current international nomenclature.

Management of blood pressure in this transitional range emphasizes non-pharmacological approaches before pharmacotherapy is considered (Djafar & Fatah, 2022). The DASH dietary framework has accumulated robust evidence (Machus et al., 2020), and embedding bioactive compounds from traditional medicinal plants into staple foods offers a complementary route. Indonesian medicinal plants have demonstrated substantial pharmacological potential in preclinical settings (Prayogo et al., 2025a; Rovik, 2024).

Gotu kola (*Centella asiatica*) has been consumed traditionally for various health benefits, including blood pressure regulation. Its bioactive repertoire includes pentacyclic triterpenoids—asiaticoside, asiatic acid, madecassoside, and madecassic acid—as well as flavonoids and alkaloids (Nurrahmanto et al., 2021). Preclinical evidence suggests cardiovascular protective properties mediated through enhanced nitric oxide bioavailability, ACE inhibition, and oxidative stress attenuation (Bunbupha et al., 2021; Razali et al., 2019). The therapeutic dose window for triterpenoids has been reported at 20–100 mg/day in animal models (Maelani, 2021), but translation to human dietary intake through food matrices requires dedicated pharmacokinetic and clinical investigation.

Cinnamon (*Cinnamomum verum*) was selected as a complementary ingredient for both organoleptic contribution and reported bioactive properties, including cinnamaldehyde and polyphenolic compounds with antihypertensive and antioxidant activities (Amansyah & Ibrahim, 2022). The combination of gotu kola and cinnamon in a bread matrix has not been widely explored in published food technology literature.

This study aimed to (1) determine the preferred formulation of white bread supplemented with gotu kola leaf powder and cinnamon bark powder based on organoleptic acceptability, (2) identify the qualitative presence of triterpenoid compounds in the formulated bread, and (3) evaluate sensory characteristics across formulations. The scope is limited to product development and preliminary phytochemical characterization; no clinical blood pressure outcomes were assessed.

2. METHODS

2.1 Study Design, Setting, and Period

This study employed a completely randomized design (CRD) comprising four treatment groups (F0, F1, F2, F3) with three independent replications per group, yielding 12 experimental units. Each unit consisted of one loaf of white bread produced from a single batch. All laboratory work was conducted at the Health Laboratory, Universitas Ivet, from June to July 2024. Ethical approval was obtained from the Research Ethics Committee (No.

403/KEPK/FK/KLE/2024), covering human participation in sensory testing.

2.2 Formulation Design

Four formulations were developed with varying proportions of gotu kola leaf powder and cinnamon bark powder as additives to a constant base recipe per 30 g sample. Base ingredients consisted of wheat flour (14 g), water (11 mL), instant yeast (0.2 g), salt (0.4 g), sugar (0.9 g), milk powder (1 g), butter (1.6 g), and bread improver (0.02 g), totaling 29.12 g. Plant powder additives were added on top of the base (not substituted for wheat flour), so total dough mass for treatment groups was 30.32 g versus 29.12 g for the control. This approach preserved gluten matrix integrity but introduces a minor confound in total solids that future studies should address through partial flour substitution. Formulations were: F0 (0 g : 0 g), F1 (0.4 g : 0.8 g), F2 (0.8 g : 0.4 g), and F3 (0.6 g : 0.6 g). Percentage designations (10%, 20%, 15%) refer to proportions relative to the total combined additive weight of 1.2 g (Table 1).

2.3 Preparation of Raw Materials

2.3.1 Gotu kola leaf powder.

Young leaves were washed, drained, and oven-dried at 40°C for 12 hours to preserve heat-sensitive triterpenoids. Dried leaves were ground and sieved through a 60-mesh screen (Nuryati & Lestari, 2021, with modifications).

2.3.2 Cinnamon bark powder.

Bark was sorted, washed, and oven-dried at 100°C for 60 minutes following the protocol of Habi et al. (2021). This temperature may reduce volatile aromatic compounds and heat-labile bioactive constituents, a limitation worth investigating in future optimization studies. Dried bark was ground and sieved to uniform particle size.

2.3.3 White bread production.

Ingredients were weighed per formulation. The process comprised: mixing/kneading (10 min, stand mixer, medium speed), first fermentation (60 min, 28–30°C), dividing, intermediate proofing (15 min), molding, panning (aluminum pans, 15 × 8 × 7 cm), final proofing (45 min, 35°C, ~75% RH), and baking (180°C, 25 min) (Wardani, 2021). Loaves were cooled 60 min on wire racks before evaluation.

2.4 Organoleptic Evaluation

Twenty-five semi-trained panelists (12 male, 13 female; age 20–25 years; university students with no food allergies, no sensory impairments, no habitual herbal product consumption) provided written informed consent and evaluated all four formulations in a single session (repeated-measures design). Samples were coded with three-digit random numbers, presented in randomized order using a Williams Latin square design, served at room temperature (~30 g each) on white disposable plates, with water palate cleansing between samples. A two-point hedonic scale (1 = like, 2 = dislike) assessed color, taste, aroma, and texture. This binary scale captures acceptance/rejection but limits granularity; a 9-point hedonic scale is recommended for future studies (Lawless & Heymann, 2010).

2.5 Data Analysis

Data were analyzed using the Kruskal-Wallis H test (SPSS v.26) with tie correction. Since all panelists evaluated all formulations (repeated measures), the Friedman test would be theoretically more appropriate; the Kruskal-Wallis test was applied in this study, and future research should employ Friedman's test with Nemenyi post-hoc analysis. Pairwise post-hoc comparisons used Mann-Whitney U tests with Bonferroni correction for six comparisons ($\alpha = 0.05/6 = 0.0083$). Complete test statistics are reported. Statistical re-verification was performed using SciPy.stats (Python 3.11) to confirm exact H values and p-values from the raw frequency data with automatic tie correction.

2.6 Phytochemical Screening

Qualitative triterpenoid identification used the Liebermann-Burchard reagent. Bread samples (2 g each) were extracted with chloroform, treated with acetic anhydride and concentrated sulfuric acid. Positive results were indicated by color change to red, purple, or reddish-brown (Azalia et al., 2023). This method detects possible presence but does not quantify concentrations or identify specific triterpenoid species.

Table 1. Complete Formulation per 30 g Base Sample

Ingredient	F0 (Control)	F1	F2	F3
Wheat flour	14 g	14 g	14 g	14 g
Water	11 mL	11 mL	11 mL	11 mL
Instant yeast	0.2 g	0.2 g	0.2 g	0.2 g
Salt	0.4 g	0.4 g	0.4 g	0.4 g
Sugar	0.9 g	0.9 g	0.9 g	0.9 g
Milk powder	1.0 g	1.0 g	1.0 g	1.0 g
Butter	1.6 g	1.6 g	1.6 g	1.6 g
Bread improver	0.02 g	0.02 g	0.02 g	0.02 g
Gotu kola powder	0 g (0%)	0.4 g (10%)	0.8 g (20%)	0.6 g (15%)
Cinnamon powder	0 g (0%)	0.8 g (20%)	0.4 g (10%)	0.6 g (15%)
Total additive	**0 g**	**1.2 g**	**1.2 g**	**1.2 g**
Total dough mass	**29.12 g**	**30.32 g**	**30.32 g**	**30.32 g**

Note: Percentages refer to proportion relative to total combined additive weight (1.2 g).

3. RESULTS

3.1 Organoleptic Evaluation

Panelist acceptance rates for all four sensory attributes across formulations are summarized in Table 2 and visualized in Figure 1. The control (F0) consistently achieved the highest acceptance across all attributes (88–96%). Among treatment formulations, F2 demonstrated the highest taste acceptance (52%), F3 the highest aroma acceptance (52%), and F1 the highest texture acceptance (56%).

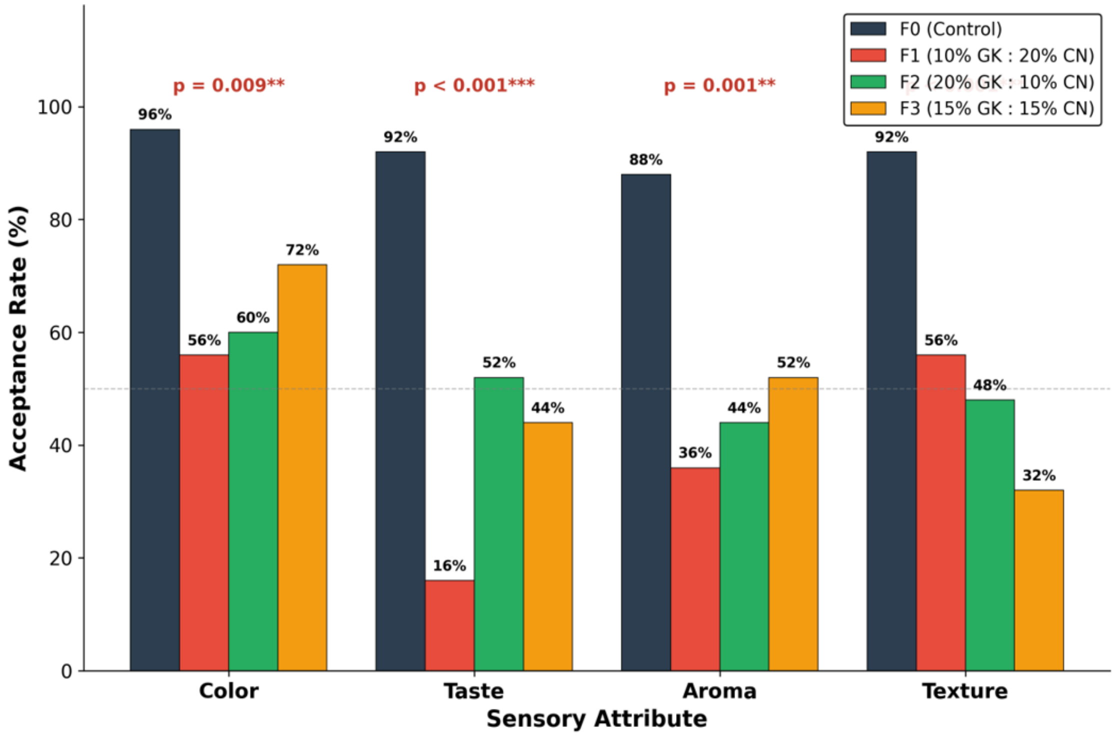

Figure 1. Organoleptic acceptance rates (%) across formulations for four sensory attributes. GK = gotu kola; CN = cinnamon. Kruskal-Wallis p-values shown above each attribute cluster. Dashed line indicates 50% acceptance threshold. All four attributes showed statistically significant differences among formulations ($p < 0.01$).

Table 2. Organoleptic Acceptance Rates Across Formulations (n = 25 panelists per formulation)

Formulation	Color Like (%)	Taste Like (%)	Aroma Like (%)	Texture Like (%)
F0 (Control)	96 (24/25)	92 (23/25)	88 (22/25)	92 (23/25)
F1 (10:20)	56 (14/25)	16 (4/25)	36 (9/25)	56 (14/25)
F2 (20:10)	60 (15/25)	52 (13/25)	44 (11/25)	48 (12/25)
F3 (15:15)	72 (18/25)	44 (11/25)	52 (13/25)	32 (8/25)

Values represent percentage of panelists who scored "like" (absolute counts in parentheses). Ratios in formulation column = gotu kola% : cinnamon%.

3.2 Statistical Analysis

The Kruskal-Wallis H test revealed statistically significant differences among formulations for all four sensory attributes (Table 3). Taste showed the strongest effect ($H(3) = 29.28$, $p < 0.001$), followed by texture ($H(3) = 19.51$, $p < 0.001$), aroma ($H(3) = 15.80$, $p = 0.001$), and color ($H(3) = 11.68$, $p = 0.009$). Post-hoc pairwise comparisons with Bonferroni correction identified that F0 was significantly preferred over treatment formulations across most attributes. Among treatment groups, a significant pairwise difference was observed only for taste between F1 and F2 ($p = 0.049$).

Table 3. Kruskal-Wallis H Test Results and Significant Pairwise Comparisons (Bonferroni-corrected).

Attribute	H(3)	df	p-value	Significant pairwise differences
Color	11.68	3	0.009	F0>F1 (p=0.007); F0>F2 (p=0.015)
Taste	29.28	3	<0.001	F0>F1 (p<0.001); F0>F3 (p=0.002); F0>F2 (p=0.011); F2>F1 (p=0.049)
Aroma	15.80	3	0.001	F0>F1 (p=0.001); F0>F2 (p=0.007); F0>F3 (p=0.037)
Texture	19.51	3	<0.001	F0>F3 (p<0.001); F0>F2 (p=0.005); F0>F1 (p=0.025)

$p < 0.01$; $p < 0.001$. Post hoc by Mann-Whitney U with Bonferroni correction ($\alpha = 0.0083$). H values computed with tie correction. ">" denotes significantly higher acceptance.

3.3 Phytochemical Screening Results

Qualitative phytochemical analysis is presented in Table 4. Triterpenoid compounds were detected exclusively in F2 (reddish-brown color change). F1 showed a yellowish color that did not meet the positive threshold criteria. F0 and F3 showed no significant color change.

Table 4. Qualitative Phytochemical Screening for Triterpenoid Compounds (Liebermann-Burchard Reagent).

Formulation	Gotu kola (%)	Color change	Result
F0	0%	No change	Negative (−)
F1	10%	Yellowish	Negative (−)
F2	20%	Reddish-brown	Positive (+)
F3	15%	No significant change	Negative (−)

4. DISCUSSION

This study developed a white bread formulation enriched with gotu kola leaf powder and cinnamon bark powder, characterized through organoleptic evaluation and qualitative phytochemical screening. The corrected statistical analysis reveals that all four sensory attributes—color, taste, aroma, and texture—differed significantly among formulations, with the control consistently outperforming treatment groups. This pattern is expected: adding plant powders to white bread inherently alters its familiar sensory profile, and the primary analytical interest lies in differences among treatment formulations rather than treatment-versus-control comparisons.

The color darkening across formulations reflects chlorophyll and phenolic pigments from gotu kola combined with cinnamaldehydederived brown compounds from cinnamon, amplified by Maillard reactions during baking (Khalisa et al., 2021). Post-hoc analysis revealed that F0 differed significantly from F1 ($p = 0.007$) and F2 ($p = 0.015$), but not from F3 ($p = 0.137$). The non-significance of F0–F3 likely reflects F3's intermediate additive profile, producing a color closest to the control among treatment groups.

Taste exhibited the strongest statistical effect ($H(3) = 29.28$, $p < 0.001$). F1, with its high cinnamon proportion (20%), achieved only 16% acceptance—near-universal rejection—attributable to the pungent, slightly bitter character of cinnamaldehyde at high concentrations (Rivki et al., 2018; Apriliani et al., 2019). F2 performed best among treatment groups (52%), and the F1–F2 pairwise difference reached significance ($p = 0.049$), confirming that the shift from 20% cinnamon (F1) to 10% cinnamon (F2) produced a detectable improvement in taste acceptance. The milder herbal character of gotu kola at higher proportions contributed to a profile described by panelists as savory and not bitter.

Aroma results introduced an important nuance. F3 (equal proportions) received the highest treatment-group aroma acceptance (52%), surpassing F2 (44%). Gotu kola contributes monoterpene and sesquiterpene volatiles (Mukminin et al., 2022), while cinnamon provides cinnamaldehyde and eugenol. At balanced proportions, neither botanical note dominated, whereas higher cinnamon concentrations tended to overwhelm other aromatic notes (Rachmawati et al., 2021). This means F2 was not the top-performing formulation for every sensory attribute—F1 outperformed F2 in texture (56% vs 48%), and F3 outperformed F2 in aroma. Designating F2 as the "preferred" formulation reflects a composite judgment weighting taste—arguably the most critical attribute for consumer adoption—and phytochemical presence, not uniform superiority across all attributes.

Texture showed strong statistical significance ($H(3) = 19.51$, $p < 0.001$), with post-hoc analysis confirming progressive decline from F0 through F3 (F0>F1 $p = 0.025$; F0>F2 $p = 0.005$; F0>F3 $p < 0.001$). This dose-dependent pattern is mechanistically coherent: non-gluten plant powders disrupt the viscoelastic gluten matrix responsible for gas retention and crumb structure (Pawiwara et al., 2023). Pratama et al. (2021) reported comparable patterns in protein-enriched white bread.

The phytochemical screening demands particular caution. Triterpenoids were detected exclusively in F2 (20% gotu kola). The negative result for F3 (15% gotu kola) is not straightforwardly explained by concentration alone—if concentration were the sole determinant, F3 should have fallen between F1 and F2. Several factors likely contribute: the Liebermann-Burchard method has a relatively high detection threshold; matrix effects from cinnamon polyphenols may interfere with color development; extraction efficiency varies with ingredient ratios; and sampling variability across small replicates introduces batch-to-batch inconsistency (Mutik et al., 2022). Negative results should be interpreted as "not detected" rather than "absent." Quantitative methods—HPLC or UV-Vis spectrophotometry—are essential to determine actual triterpenoid concentrations per serving.

A critical boundary must be drawn regarding therapeutic claims. Preclinical literature documents cardiovascular protective properties of *C. asiatica* triterpenoids, including antihypertensive effects via nitric oxide enhancement and ACE inhibition (Bunbupha et al., 2021; Razali et al., 2019). Background literature reports therapeutic doses of 20–100 mg/day in animal models (Maelani, 2021). The present study, however, did not quantify triterpenoid content, assess bioavailability, or measure clinical blood pressure outcomes. The mechanistic literature provides contextual rationale for ingredient selection, not evidence that this bread exerts therapeutic effects. Whether bioactive compounds survive baking at 180°C, remain bioavailable after gastrointestinal transit, and reach target tissues at relevant concentrations are open questions requiring dedicated investigation.

4.1 Limitations

The two-point hedonic scale limits discriminating power and compresses variance; a validated 9-point scale would improve resolution and enable parametric analysis. The panel (n = 25 university students, age 20–25) limits representativeness. Phytochemical analysis was qualitative only—without quantitative data, it is impossible to determine whether F2 delivers bioactive compounds at physiologically relevant levels. The study did not assess proximate composition, nutritional content, microbiological quality, shelf life, or clinical blood pressure effects. The additive approach to formulation means treatment groups had slightly higher total dough mass (30.32 g vs 29.12 g). Cinnamon drying at 100°C may have degraded heat-sensitive volatile and bioactive compounds.

5. CONCLUSION

The F2 formulation (20% gotu kola, 10% cinnamon) was identified as the preferred formulation based on combined sensory performance—particularly taste—and qualitative triterpenoid detection. Statistical analysis confirmed significant differences among formulations for all four sensory attributes ($p < 0.01$ for each), with the control consistently preferred over treatment groups. These results represent a preliminary formulation study; the product cannot be recommended for blood pressure management without quantitative triterpenoid analysis, bioavailability assessment, safety evaluation, and controlled clinical trials.

DECLARATIONS

Ethics Approval and Informed Consent. Approved by the Research Ethics Committee (No. 403/KEPK/FK/KLE/2024), covering human sensory testing. All 25 panelists provided written informed consent, were informed of ingredients and potential allergens, and could withdraw at any time. No adverse reactions were reported.

Conflict of Interest.

The authors declare no conflict of interest.

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Author Contributions.

LI: conceptualization, methodology, investigation, data collection, writing – original draft. UH: supervision, validation, writing – review and editing. CNR: data analysis, writing – review and editing.

Data Availability.

Raw sensory evaluation data and phytochemical screening records are available from the corresponding author upon reasonable request.

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