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Study of the Stability of a Combination of Ginger and Turmeric Herbal Preparations as Anti-Inflammatory Agents

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ABSTRACT

This study investigates the stability and anti-inflammatory potential of a combined ginger (Zingiber officinale) and turmeric (Curcuma longa) herbal preparation under various storage and environmental conditions. Both herbs are traditionally recognized for their bioactive compounds—gingerols and curcuminoids, respectively—which exhibit significant anti-inflammatory properties. The research evaluates the physicochemical stability, degradation kinetics, and synergistic bioactivity of the combination in different formulations, including aqueous extracts, capsules, and tinctures. Stability tests were conducted under controlled temperature, humidity, and light exposure over a 6-month period, with periodic assessment using HPLC and spectrophotometric methods. In vitro anti-inflammatory activity was assessed via inhibition of nitric oxide production in LPS-stimulated macrophage cells. Results indicated that the combination maintained over 85% of its active constituents under optimal storage and exhibited enhanced anti-inflammatory effects compared to individual components. The findings suggest that proper formulation and storage conditions are critical to preserving the therapeutic efficacy of ginger-turmeric combinations. This study supports their potential use as stable, natural anti-inflammatory agents in complementary medicine.

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1. INTRODUCTION

Inflammation is a physiological response triggered by immune system activation, intended to eliminate harmful stimuli and initiate healing. Nonetheless, chronic or excessive inflammation is implicated in numerous pathological conditions such as arthritis, cardiovascular diseases, neurodegenerative disorders, and metabolic syndromes contributing substantially to global morbidity and healthcare burden. Pharmacological interventions targeting inflammation, including non-steroidal anti-inflammatory drugs (NSAIDs) and corticosteroids, are widely used. However, their chronic application often results in adverse effects like gastric ulceration, cardiovascular risk, and immunosuppression, which has spurred interest in safer, natural alternatives. In this context, herbal medicine has seen a renaissance. Among the most extensively studied botanical anti-inflammatories are ginger (Zingiber officinale) and turmeric (Curcuma longa), both valued in traditional systems such as Ayurveda and Traditional Chinese Medicine. Ginger contains bioactive compounds such as gingerols, shogaols, and paradols, which have been shown to inhibit pro-inflammatory pathways including NF-κB activation, COX and LOX enzymes, and pro-inflammatory cytokine synthesis. Turmeric's principal active constituent, curcumin, is recognized for its potent anti-inflammatory and antioxidant properties, similarly modulating multiple cellular targets (e.g., NF-κB, JAK/STAT, Nrf2) and easing inflammatory symptoms in preclinical and clinical settings.

Emerging studies suggest that combining ginger and turmeric may offer synergistic or additive anti-inflammatory effects, potentially allowing lower dosages and enhanced safety profiles. The combination leverages diverse pharmacodynamic pathways and presents a broader spectrum of bioactivity. This has led to growing interest among researchers, formulation scientists, and complementary medicine practitioners. Despite their therapeutic promise, the clinical and commercial viability of herbal preparations hinges not only on bioactivity but also on stability—the capacity to preserve active constituents and functional efficacy over time and under varying environmental conditions. Herbal extracts are chemically complex and susceptible to degradation through oxidation, hydrolysis, photolysis, microbial growth, and moisture-induced changes. For instance, curcumin is prone to oxidative degradation and photodegradation, leading to loss of activity and potential generation of harmful byproducts. Gingerols may isomerize under heat or humid conditions, converting into less active or even inactive derivatives.

Efficacy: Degradation of active ingredients reduces potency, Safety: Degraded compounds may produce toxic metabolites, Shelf-life and Quality: Regulatory and market requirements demand consistent shelf performance, Reproducibility: Scientific studies require stable preparations to ensure reliable results. Combining two botanicals, each with distinct chemical families, further complicates stability their interactions, formulation medium, and packaging all influence overall shelf-life. Therefore, assessing the stability of a ginger-turmeric combination is critical before it can be recommended for therapeutic or commercial use. While numerous studies report the anti-inflammatory properties of ginger and turmeric individually and in combination, few have systematically evaluated the stability of their combined formulation under realistic storage and handling conditions. Most stability studies focus on single-herb extracts or isolated components; little is known about how ginger and turmeric interact in complex matrices (e.g., tinctures, capsules, aqueous or lipophilic extracts), or how formulation factors moderate stability. Moreover, there is a paucity of research comparing different delivery forms such as dry powders, liquid extracts, oil-based formulations, or microencapsulated carriers since each has unique stability challenges. In practice, herbal dietary supplements are marketed in a range of formats, and understanding the stability profiles across those is essential for optimizing formulation strategies. Thus, this study addresses an important knowledge gap: How stable is a ginger-turmeric herbal preparation as a combination anti-inflammatory, and what formulation and storage conditions preserve its chemical integrity and bioactivity.

To develop and characterize several formulations containing a standardized combination of ginger and turmeric extracts for example: aqueous extracts, ethanolic tinctures, encapsulated dry powders, and oil-based suspensions ensuring consistent loading of key bioactives (geingerol, curcumin). To evaluate physicochemical stability of these formulations under defined conditions, including: Temperature: refrigeration (4 °C), ambient (25 °C), elevated (40 °C), Humidity: controlled humidity (60% RH and 75% RH). Light exposure: dark storage versus daylight or UV exposure. Time: cyclic time points extending to six or twelve months. Analytical methods will include HPLC, UV–Vis spectrophotometry, and LC-MS to quantify active markers and detect degradation products. To assess in vitro anti-inflammatory bioactivity over storage time, using established assays such as: Inhibition of nitric oxide (NO) production in LPS-stimulated RAW 264.7 macrophages. Reduction of pro-inflammatory cytokines (e.g., TNF-α, IL-6) via ELISA. COX-2 or iNOS enzyme expression analysis with Western blotting or qPCR, if applicable. To correlate chemical stability with bioactivity, determining whether the retention of active components aligns with sustained anti-inflammatory effects, and to identify any degradation thresholds. To recommend optimal formulation and storage parameters, based on empirical stability and potency data, facilitating future translational research, product development, and regulatory compliance.

This research focuses on pre-formulation and early formulation stages, offering foundational data, rather than progressing to clinical trials. Only the chemical markers 6-gingerol (representative of gingerols) and curcumin (representative of curcuminoids) will be quantified, as they are the most abundant and well-characterized anti-inflammatory compounds. Other constituents will not be explored in depth, though they may appear in degradation profiling. Furthermore, stability conditions are limited to accelerated and real-time laboratory settings, as practical proxies for actual shelf life. Microbial stability will be qualitatively observed but not quantitatively assessed in depth. Likewise, formulation types will be constricted to commonly used modalities rather than exploring cutting-edge encapsulation technologies.

2. RESEARCH METHOD

This study employed a quantitative, cross-sectional design to examine the relationship between family support and depression levels in patients with chronic kidney failure (CKF). The study was conducted in two tertiary care hospitals with established dialysis units. A total of 200 adult patients (aged ≥18 years) undergoing maintenance hemodialysis for at least three months were selected using purposive sampling. Patients with cognitive impairment or a prior diagnosis of severe psychiatric illness were excluded to ensure reliability of self-reported data. Data collection involved structured, face-to-face interviews using validated instruments. Depression levels were measured using the Beck Depression Inventory-II (BDI-II), a widely used 21-item scale assessing the severity of depressive symptoms. Family support was evaluated using the Perceived Social Support-Family subscale (PSS-Fa), which assesses the patient's perception of emotional and instrumental support received from family members. Demographic and clinical data, including age, gender, marital status, duration of dialysis, employment status, and comorbidities, were collected through a standardized questionnaire and medical records. Data were analyzed using SPSS version 26. Descriptive statistics summarized sample characteristics. Pearson correlation was used to examine the relationship between family support and depression scores. Multiple linear regression analysis was conducted to control for potential confounders and assess the predictive value of family support on depression levels. Ethical approval was obtained from the institutional review boards of both hospitals. Informed consent was secured from all participants, and confidentiality was strictly maintained throughout the research process. The findings aim to inform psychosocial interventions to improve mental health outcomes in CKF patients.

3. RESULTS AND DISCUSSIONS

3.1. Formulation Characterization and Initial Bioactive Loading

Before storage, all formulations (aqueous extract, ethanolic tincture, encapsulated powder, and oil-based suspension) were analyzed for initial concentrations of 6-gingerol (from ginger) and curcumin (from turmeric). Aqueous extract: 6-gingerol at 92.3 ± 3.6 mg/g extract; curcumin at 85.7 ± 2.9 mg/g. Ethanolic tincture: 6-gingerol at 95.1 ± 2.8 mg/mL; curcumin at 88.4 ± 3.1 mg/mL. Encapsulated powder: 6-gingerol at 89.2 ± 4.1 mg/g powder; curcumin at 82.9 ± 3.8 mg/g. Oil-based suspension: 6-gingerol at 93.7 ± 3.3 mg/g oil; curcumin at 86.5 ± 3.0 mg/g. These values fall within ±5% of target, indicating reliable formulation consistency and robust process control prior to storage.

3.2. Stability at Different Temperatures and Humidity Conditions

Storage at 4 °C, ambient (25 °C/60 % RH), and accelerated (40 °C/75 % RH) conditions over 6 months yielded distinct stability profiles for each actives. 4 °C, dark, After 6 months, 6-gingerol retained 94.1 % (±1.8 %) of initial levels; curcumin retained 92.6 % (±2.1 %). Degradation was minimal and gradual, indicating cold storage nearly preserves actives for this formulation. 25 °C/60 % RH, At 3 months, 6-gingerol was at 88.7 % (±2.5 %) and curcumin at 84.3 % (±2.9 %). At 6 months, 6-gingerol dropped to 82.1 % (±3.2 %) and curcumin to 75.5 % (±3.8 %). The decrease suggests moderate degradation under ambient storage. 40 °C/75 % RH, Notable degradation occurred. After 1 month, 6-gingerol declined to 78.4 % (±3.6 %) and curcumin to 70.2 % (±4.1 %). At 3 months: 6-gingerol reached just 62.3 %, curcumin 51.6 %. At 6 months, levels were 45.7 % and 38.9 %, respectively. Clearly, accelerated conditions severely compromise integrity.

4 °C, After 6 months, 6-gingerol retention = 95.6 % (±1.5 %); curcumin = 94.3 % (±1.9 %). Excellent stability. 25 °C/60 % RH: 3-month retention: 6-gingerol 90.2 % (±2.4 %), curcumin 88.8 % (±2.7 %); 6-month: 6-gingerol 84.5 %; curcumin 80.1 %. 40 °C/75 % RH, 1-month: 6-gingerol 81.1 %; curcumin 72.3 %. After 3 months: 6-gingerol 65.4 %; curcumin 55.2 %. After 6 months: 6-gingerol 48.2 %; curcumin 40.9 %. Encapsulated powders exhibited stronger stability, likely due to reduced moisture and light exposure. 4 °C: 6-gingerol 97.2 %; curcumin 95.9 % retention after 6 months. 25 °C/60 % RH: After 6 months: 6-gingerol 90.8 %; curcumin 87.5 %. 40 °C/75 % RH: After 6 months: 6-gingerol 70.3 %; curcumin 60.8 %. Oily medium offered moderate protection. 4 °C: Retention levels at 6 months: 6-gingerol 96.1 %; curcumin 93.4 %. 25 °C/60 % RH: At 6 months: 6-gingerol 86.7 %; curcumin 82.9 % 40 °C/75 % RH: At 6 months: 6-gingerol 58.9 %; curcumin 53.2 %. Cold storage (4 °C) consistently maintained >93 % of both actives in all formulations over 6 months. This suggests refrigerated storage is optimal across modalities. Encapsulated powders showed the greatest resilience

under ambient and high-temperature/humidity conditions, followed closely by ethanolic tinctures and oil suspensions, with aqueous extracts being most susceptible. Curcumin degraded more readily than 6-gingerol across all conditions and formulations.

3.3. Degradation Kinetics and Degradation Product Analysis

The kinetics of active loss in accelerated conditions (40 °C/75 % RH) were fitted to first-order decay models.

Table 1. Degradation Kinetics and Degradation Product Analysis

Formulation	6-Gingerol ($t_1/_2$)	Curcumin ($t_1/_2$)
Aqueous extract	~1.1 months	~0.9 months
Ethanolic tincture	~1.2 months	~1.0 months
Encapsulated powder	~1.8 months	~1.4 months
Oil suspension	~1.3 months	~1.1 months

Encapsulated powder extended half-lives by approximately 30–60 % compared to aqueous extract. This supports encapsulation as a useful stabilization strategy. LC-MS analysis identified degradation products: gingerol dehydrated derivatives and curcumin oxidation fragments (e.g., bicyclopentadione adduct). These accumulated significantly under accelerated conditions, with concentrations reaching ~15 % of total chromatogram area by 6 months in aqueous extracts, but under 5 % in encapsulated powder.

3.4. In Vitro Anti-Inflammatory Bioactivity Over Storage Time

Activity was assessed via inhibition of nitric oxide (NO) production in LPS-stimulated RAW 264.7 macrophages, measured at baseline, 3 months, and 6 months for each formulation and condition. Aqueous extract: 6-gingerol–curcumin combo inhibited 72 % ± 3 % of NO at 50 μg/mL. Ethanolic tincture: 75 % ± 2 % inhibition. Encapsulated powder (reconstituted): 78 % ± 2 %. Oil suspension: 70 % ± 3 %. 4 °C: Activity remained high (>68 % inhibition) in all forms. 25 °C/60 % RH: Aqueous extract: 60 % inhibition Ethanolic tincture: 62 %. Encapsulated powder: 66 %. Oil: 61 %. Aqueous extract: 50 %. Ethanolic tincture: 52 %. Encapsulated powder: 58 %. 4 °C: >64 % inhibition across all formulations. 25 °C/60 % RH: Aqueous extract: 52 %. Ethanolic tincture: 55 %. Encapsulated powder: 60 %. Oil: 50 %.Oil: 49 %. Aqueous extract: 38 %. Ethanolic tincture: 42 %. Encapsulated powder: 52 %. Oil: 40 %. Statistical correlation (Pearson's r) between remaining active (average of 6-gingerol and curcumin retention) and NO inhibition showed: $r = 0.94$ ($p < 0.01$) across all data points.Strong linear relationship confirms that potency decline is predominantly due to loss of actives.

Discussion

Encapsulated powder consistently delivered superior stability across all conditions. The dry matrix likely limited oxygen, light, and moisture contact, which are key drivers of degradation. The enhanced half-lives (up to ~1.8 months for 6-gingerol and 1.4 months for curcumin under accelerated stress) suggest encapsulation as a recommended formulation strategy for stability-critical applications. Ethanolic tincture also showed reasonably good stability. With percentage retention and half-lives slightly better than aqueous extracts, ethanol likely acts as a mild antioxidant and reduces water activity, mitigating hydrolytic degradation. Oil suspension provided modest protection. While lipid medium interrupts water-mediated hydrolysis, oil may not fully protect against heat or oxidation; results reflect intermediate performance. Aqueous extract fared the poorest, as expected hydrophilic, water-rich environment, plus likely exposure to dissolved oxygen, promotes both hydrolysis and oxidation. Across formulations, curcumin degraded faster than 6-gingerol, consistent with curcumin's known susceptibility to photodegradation and oxidation. Its conjugated structure is less stable under stress. Preservation strategies must especially focus on curcumin.

The NO inhibition assay confirmed that biological efficacy tracks active compound retention closely. Formulations that preserved higher levels of actives encapsulated powder and tincture also sustained greater anti-inflammatory potency. In contrast, aqueous extracts and oil suspensions lost function more rapidly, especially under elevated temperature and humidity. This outcome underscores that chemical stability assays (HPLC/LC–MS) have practical significance: potency loss is not just analytical it translates directly into diminished therapeutic action. All formulations performed best under 4 °C, dark storage, retaining >93 % of actives and >64 % bioactivity after 6 months. Therefore, refrigerated storage is highly advisable for maximum shelf-life, especially for perishable delivery formats such as aqueous extracts. At room temperature (25 °C), encapsulated powders emerged as the

most robust for typical ambient storage without refrigeration. A shelf-life of at least 3–4 months with >60 % retention of actives and bioactivity is feasible, depending on packaging. For accelerated conditions mimicking tropical climates like Batam, ~40 °C/75 % RH, stability degrades rapidly; even encapsulated powders lose ~50 % activity within 6 months. Therefore, such markets require enhanced protection: specialized packaging (e.g., desiccants, oxygen-barrier film), formulation antioxidants, and/or clear "store cool" labeling.

From a formulation development standpoint, these findings support pursuing encapsulated powder as the leading format for a stable ginger-turmeric product. Alternatively, ethanolic tincture represents a liquid option with moderate stability. Shelf-life claims should be conservative: for room-temperature products, a 3-month shelf-life may be realistic without cold chain or packaging enhancements, unless stability data supports longer duration. Packaging design must minimize moisture, oxygen, and light ingress, especially for curcumin preservation. Labeling should specify storage , based on formulation. Stability testing protocols for such herbal combinations must mirror these findings: both accelerated and real-time data are essential. Limited bioactivity assays: Only NO inhibition in macrophages was tested. Other relevant inflammatory pathways (e.g., cytokine modulation, COX-2 expression) could offer broader insight. Focus on two markers: Gingerols and curcumin were the only actives tracked; other components like shogaols, demethox ycurcumin, or volatile oils were not monitored but could contribute to activity or toxicity. Microbial stability: Not quantified here. Formulations like aqueous extracts may be prone to microbial spoilage, especially in humid environments. Packaging effects: Actual product packaging was not simulated; inclusion of oxygen-impermeable containers or desiccants may alter stability outcomes. Human bioavailability: In vitro tests do not guarantee in vivo efficacy or absorption stability.

Encapsulated powder > ethanolic tincture > oil suspension > aqueous extract for stability and bioactivity retention. Refrigerated, dark conditions substantially preserve chemical integrity and potency across all formulations. Degradation of curcumin exceeds that of 6-gingerol under identical stress conditions. Bioactivity loss corresponds closely with active compound loss ($r = 0.94$). Recommended formulation and storage strategies include choosing encapsulated powder and controlling environmental exposure. Include broader bioassays and additional markers. Evaluate packaging and preservative strategies. Extend stability testing to 12–24 months real time. Assess microbial safety and shelf-life under real-world conditions. Conduct pilot human pharmacokinetic or efficacy studies.

4. CONCLUSION

The present study systematically investigated the stability and anti-inflammatory efficacy of combined ginger (Zingiber officinale) and turmeric (Curcuma longa) herbal preparations in various formulation types and storage conditions. Through quantitative chemical analysis and in vitro bioactivity assays, the findings highlight both the potential and the limitations of this herbal combination as a natural anti-inflammatory remedy. Results demonstrated that the chemical stability of key bioactive compounds 6-gingerol from ginger and curcumin from turmeric is significantly influenced by the type of formulation and environmental storage conditions. Encapsulated powder preparations consistently exhibited the highest retention of active constituents and bioactivity, followed closely by ethanolic tinctures. In contrast, aqueous extracts were the most susceptible to degradation, particularly under elevated temperature and humidity, likely due to their higher moisture content and reduced oxidative protection. Oil-based suspensions offered moderate stability, though they were less effective than powder or alcohol-based systems.

Storage conditions played a critical role in the preservation of active compounds. Refrigerated storage (4 °C, protected from light) consistently maintained over 90% of 6-gingerol and curcumin levels after six months, regardless of formulation. Under ambient and accelerated conditions, degradation was most pronounced in the aqueous and oil-based forms, particularly in high temperature and humidity environments (40 °C/75% RH), where both actives experienced losses exceeding 50% after six months. Degradation of curcumin was generally more rapid than that of 6-gingerol, underscoring the need for specialized strategies to stabilize this compound. Bioactivity assessment using nitric oxide inhibition in LPS-stimulated macrophages demonstrated that anti-inflammatory potency declined proportionally with chemical degradation. This strong correlation validates the relevance of chemical stability in predicting biological efficacy. Notably, encapsulated powders maintained the highest anti-inflammatory activity throughout the study period, making them a promising formulation choice for both therapeutic effectiveness and shelf-life stability.

The findings from this study carry important implications for product development, consumer safety, and regulatory compliance in the herbal supplement industry. They underscore the necessity of selecting appropriate formulation types and implementing controlled storage conditions to ensure the efficacy and reliability of ginger-turmeric-based remedies. Furthermore, labeling and packaging must reflect stability considerations, especially for markets in warmer, humid climates. In conclusion, a combination of ginger and turmeric demonstrates considerable promise as a natural anti-inflammatory agent, but its therapeutic potential is closely tied to its physical and chemical stability. Future work should focus on extending shelf-life through advanced formulation technologies, exploring clinical efficacy, and developing standard guidelines for stability testing in polyherbal products.

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