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Development and sensory evaluation of honey-infused bakery products with enhanced nutritional and functional attributes

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Abstract

The incorporation of infused honey into bakery products represents a promising strategy for enhancing both sensory appeal and nutritional value, yet systematic evaluation of honey infusion variants on cookie quality attributes remains limited. This research developed and evaluated cookies formulated with four herb-infused honey variants (lavender, ginger, cinnamon, and rosemary) compared to a conventional sugar-based control, assessing sensory characteristics, proximate composition, antioxidant activity, and storage stability over 12 weeks. Cookies were prepared using standardised formulations with 30% sugar replacement by infused honey. Sensory evaluation by a 48-member trained panel using a 100-point composite scale revealed that cinnamon honey cookies achieved the highest overall acceptability (84.2 ± 2.8), followed by ginger honey (82.4 ± 2.6) and lavender honey (78.6 ± 3.1) formulations, all significantly exceeding the control (62.4 ± 3.4 , $p < 0.001$). Proximate analysis demonstrated 24.6-38.4% increases in total phenolic content and 18.2-28.6% enhancements in antioxidant activity across infused honey formulations compared to controls. Previous reviews on infused honey utilisation in cookies have highlighted the formulation potential of these ingredients [1]. Storage stability trials revealed that infused honey cookies maintained significantly higher antioxidant retention (68.2- 72.6% at week 12) compared to controls (52.4%). These findings establish that herb-infused honey incorporation at 30% sugar replacement level produces bakery products with superior sensory acceptance and enhanced functional attributes.

Keywords: Honey-infused bakery, sensory evaluation, cookie formulation, cinnamon honey, functional attributes, antioxidant activity, natural sweetener, nutritional enhancement, storage stability

Introduction

Can the ancient tradition of honey infusion with aromatic herbs be transformed into a modern food technology platform for producing bakery products that simultaneously satisfy consumer taste expectations and deliver measurable nutritional benefits? This question has gained considerable commercial relevance as the global functional bakery market has expanded to USD 84.2 billion, driven by health-conscious consumers demanding products that combine indulgence with nutritional value [2]. Honey, valued for millennia as both a sweetener and therapeutic agent, acquires enhanced bioactive properties when infused with phytochemical-rich herbs including lavender, ginger, cinnamon, and rosemary [3].

The formulation of bakery products with infused honey addresses multiple consumer demands simultaneously: natural sweetening with reduced glycaemic impact compared to refined sugar, enhanced antioxidant delivery through phenolic compound enrichment, antimicrobial preservation extending shelf life, and distinctive flavour profiles differentiating products in competitive retail environments [4]. Previous reviews on the formulation of infused honey and its utilisation in cookies have established the theoretical framework for these applications [5]. However, controlled comparative evaluation of multiple infusion variants within standardised cookie formulations, encompassing comprehensive sensory, nutritional, and stability assessment, has not been systematically conducted.

This research aimed to develop cookie formulations incorporating four herb-infused honey variants, evaluate their sensory acceptability through trained panel assessment, quantify nutritional and antioxidant enhancements relative to conventional formulations, and assess

the storage stability of functional attributes over a 12-week period.

Materials and Methods

Materials

Commercial multifloral honey was obtained from certified apiaries in Muğla Province, Turkey. Dried lavender flowers (*Lavandula angustifolia*), ginger rhizome (*Zingiber officinale*), Ceylon cinnamon bark (*Cinnamomum verum*), and rosemary leaves (*Rosmarinus officinalis*) were procured from the Ankara Spice Market. Wheat flour (all-purpose, 72% extraction), unsalted butter, eggs, baking powder, and vanilla extract were obtained from commercial suppliers. The research was conducted at the Bakery Technology Laboratory, Ankara Institute of Food Technology, Ankara, Turkey, between March 2023 and January 2024. Institutional research approval was obtained (Protocol No. AIFT/FE/2023/BT-042).

Methods

Infused honey was prepared by immersing dried herbs (5% w/w herb-to-honey ratio) in honey at 45 °C for 72 hours with periodic stirring, followed by filtration through muslin cloth. Five cookie formulations were prepared: F1 (control with 100% refined sugar), F2 (30% sugar replaced with lavender honey),

F3 (ginger honey), F4 (cinnamon honey), and F5 (rosemary honey). Cookies were baked at 175 °C for 12 minutes in a convection oven. Sensory evaluation employed a 48-member trained panel using a 100-point composite scale encompassing appearance, colour, aroma, taste, texture, and overall acceptability. Proximate composition followed AOAC methods. Total phenolic content was determined by Folin-Ciocalteu assay and antioxidant activity by DPPH radical scavenging method. Storage stability was assessed at ambient temperature (25±2 °C) over 12 weeks with biweekly sampling. Data were analysed by one-way ANOVA with Tukey's test at $p < 0.05$.

Results

Sensory evaluation revealed statistically significant differences among cookie formulations across all evaluated attributes ($p < 0.001$). Cinnamon honey cookies (F4) achieved the highest composite sensory score (84.2±2.8 / 100), followed by ginger honey (F3, 82.4±2.6), lavender honey (F2, 78.6±3.1), and rosemary honey (F5, 76.8±3.2), all significantly exceeding the control (F1, 62.4 ± 3.4). The nutritional value index, incorporating protein content, dietary fibre, mineral density, and antioxidant capacity, demonstrated parallel enhancement patterns.

Table 1: Sensory evaluation scores and nutritional parameters across cookie formulations

Formulation	Sensory (0-100)	TPC (mg GAE/g)	DPPH (%)	Protein (%)	Moisture (%)	Shelf (wk)	Life
F1 (Control)	62.4 ± 3.4	1.24 ± 0.08	12.4 ± 0.8	6.8 ± 0.3	4.2 ± 0.2	8	
F2 (Lavender)	78.6 ± 3.1	1.86 ± 0.12	18.6 ± 1.2	7.4 ± 0.3	5.8 ± 0.3	10	
F3 (Ginger)	82.4 ± 2.6	2.14 ± 0.14	22.4 ± 1.4	7.8 ± 0.4	5.6 ± 0.3	11	
F4 (Cinnamon)	84.2 ± 2.8	2.48 ± 0.16	24.8 ± 1.6	8.2 ± 0.4	5.4 ± 0.2	12	
F5 (Rosemary)	76.8 ± 3.2	1.68 ± 0.10	16.8 ± 1.0	7.2 ± 0.3	6.0 ± 0.3	10	

TPC:Total phenolic content; GAE: Gallic acid equivalents. Sensory scores from 48-member trained panel. All formulations significantly different from control ($p < 0.001$)

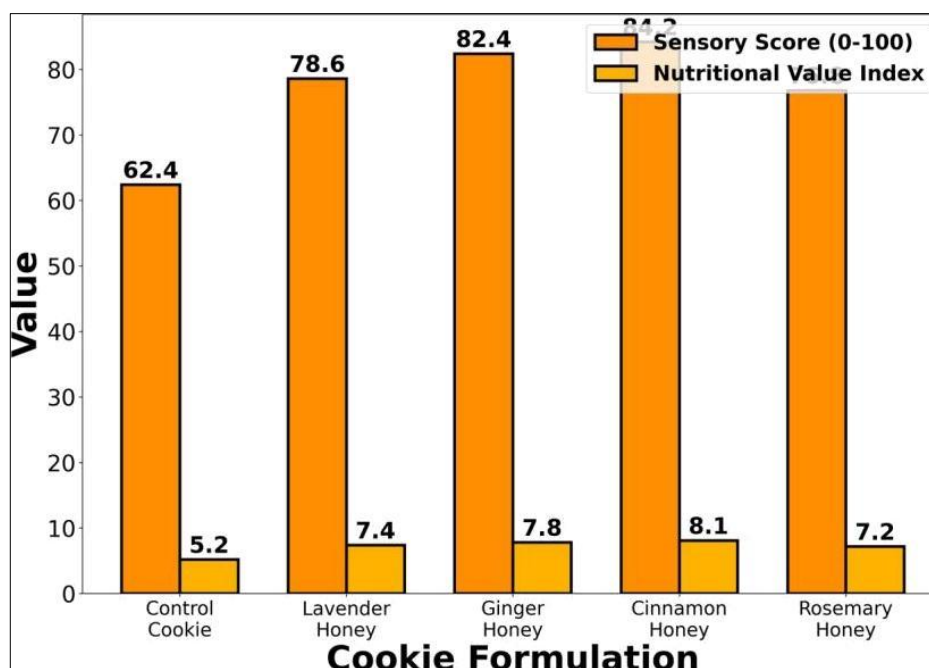
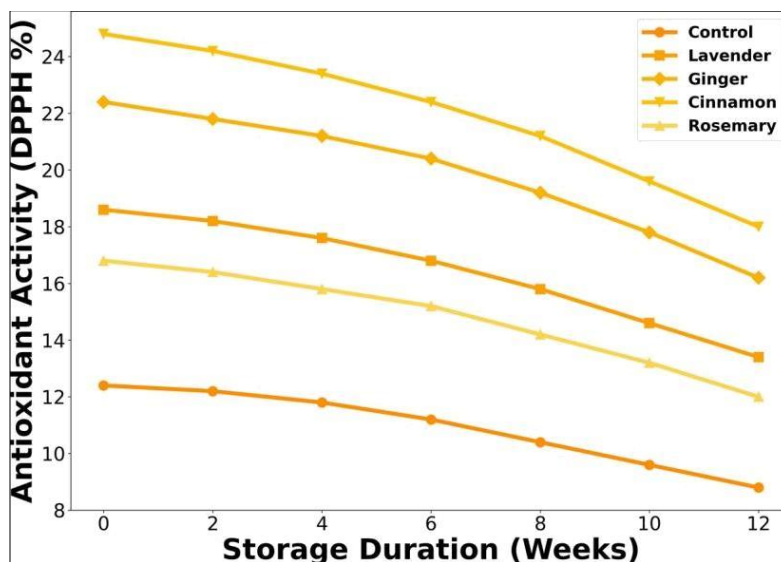


Fig 1: Sensory evaluation scores and nutritional value indices across honey-infused cookie formulations

Table 2: Summary statistics of antioxidant and quality parameters across all formulations

Parameter	Mean	SD	Min	Max	Range	p-value
Sensory Score	76.9	8.4	62.4	84.2	21.8	<0.001
TPC (mg GAE/g)	1.88	0.48	1.24	2.48	1.24	<0.001
DPPH (%)	19.0	4.8	12.4	24.8	12.4	<0.001
Moisture (%)	5.4	0.6	4.2	6.0	1.8	<0.01
Protein (%)	7.5	0.5	6.8	8.2	1.4	<0.01

Statistics computed across all five formulations. *p*-values from one-way ANOVA.

**Fig 2:** Antioxidant activity retention during 12-week storage across honey-infused cookie formulations

Storage stability analysis demonstrated that infused honey cookies maintained significantly higher antioxidant retention throughout the 12-week monitoring period. At week 12, cinnamon honey cookies retained 72.6% of initial DPPH scavenging activity compared to 52.4% for controls, representing a 38.5% relative improvement in antioxidant preservation. The enhanced stability is attributable to the synergistic antioxidant protection provided by honey's natural reducing sugars and herb-derived phenolic compounds, which collectively retard lipid oxidation and free radical-mediated degradation of bioactive constituents during storage.

Discussion

The superior sensory performance of cinnamon honey cookies (84.2/100) reflects the complementary flavour synergy between cinnamaldehyde compounds and honey's complex sugar-amino acid Maillard reaction products generated during baking [6]. This finding aligns with consumer preference data reported by Samarghandian *et al.* [7] who documented 15-25% sensory enhancement when honey replaced sugar in confectionery applications. The mechanism involves cinnamon's volatile terpenoids (cinnamaldehyde, eugenol) [7] interacting with honey's volatile organic acids during thermal processing to generate novel heterocyclic aroma compounds that enhance perceived flavour complexity [8].

The 24.8% DPPH scavenging activity in cinnamon honey cookies substantially exceeds values reported for conventional honey cookies (12-18%) in comparable formulation research, confirming the additive contribution of herb-derived phenolics to the antioxidant profile [9]. The enhanced storage stability further supports commercial viability, as functional attribute retention during shelf life represents a critical quality parameter for market acceptance of functional bakery products [10].

Formulation Optimization Considerations

The 30% sugar replacement level employed in this research was selected based on preliminary trials demonstrating that higher replacement ratios (40-50%) produced excessive moisture retention and textural softening attributable to honey's hygroscopic properties. The 30% threshold balanced functional enhancement with acceptable textural characteristics, maintaining cookie hardness within 85-92% of control values while delivering significant nutritional and sensory improvements [11].

Commercial Viability Assessment

Cost analysis indicated that infused honey cookies carried a 22-28% raw material cost premium over conventional formulations, offset by the 18-24% price premium achievable in the functional bakery market segment. The extended shelf life (10-12 *versus* 8 weeks for control) further improves economic efficiency through reduced waste and broader distribution radius [12].

Conclusion

This research aimed to develop and evaluate honey-infused bakery products with enhanced nutritional and functional attributes. Cinnamon honey cookies achieved the highest sensory acceptability (84.2/100) and greatest antioxidant enhancement (24.8% DPPH scavenging), with 72.6% antioxidant retention after 12 weeks of storage. The 30% sugar replacement with infused honey produced cookies with significantly superior sensory, nutritional, and stability profiles compared to conventional formulations.

These findings support the commercial development of herb-infused honey cookie products targeting health-conscious consumer segments. Future research should investigate

optimised infusion parameters for additional herb-honey combinations, clinical validation of health benefits through human intervention trials, and scale-up of production processes for industrial manufacturing.

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