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Natural food preservatives from plant sources as alternatives to synthetic additives

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Abstract

Consumer demand for clean-label food products has intensified research into plant-derived alternatives to synthetic preservatives such as sodium benzoate, BHA, and BHT. This research characterised ten plant extracts (rosemary, thyme, oregano, clove, pomegranate peel, green tea, grape seed, cinnamon, ginger, turmeric) for total phenolic content (TPC), total flavonoid content (TFC), DPPH and ABTS radical-scavenging activity, and minimum inhibitory concentration (MIC) against four food-borne pathogens (*S. aureus*, *E. coli*, *L. monocytogenes*, *S. Typhimurium*). Shelf-life extension in a ground beef model system was assessed at 4°C over 21 days. Clove extract showed the highest TPC (318.4 mg GAE/100 g), lowest DPPH IC₅₀ (14.8 µg/mL), and broadest antimicrobial activity (MIC 64-256 µg/mL across all pathogens). Green tea extract provided the longest shelf-life extension (24 days vs 8 days control). TPC correlated strongly with DPPH activity ($R^2 = 0.913$) and shelf-life extension ($R^2 = 0.881$). Research was conducted from May 2022 to October 2024 at Aegean Institute of Technology, Izmir, and Cappadocia National University, Ankara, Turkey.

Keywords: Natural preservatives, plant extracts, antioxidant, antimicrobial, total phenolic content, DPPH, MIC, shelf-life extension, clean-label, food safety.

Introduction

preservatives — particularly butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), sodium benzoate, and potassium sorbate — have a long safety record in food preservation but face growing consumer resistance driven by clean-label preferences and health concerns about chronic low-dose exposure ^[1]. The European Food Safety Authority (EFSA) re-evaluation of BHA (E320) concluded in 2023 that the acceptable daily intake (ADI) of 1 mg/kg bw/day should be maintained but noted data gaps on genotoxicity, sustaining regulatory and public attention ^[2].

Plant polyphenols, terpenoids, and essential oil components offer antioxidant and antimicrobial activity through multiple mechanisms: free radical scavenging, metal chelation, and disruption of bacterial cell membrane integrity. The challenge is translating *in-vitro* potency into effective food matrix application, where food components can reduce extract bioavailability or activity ^[3]. This research was conducted from May 2022 to October 2024 jointly at Aegean Institute of Technology, Izmir, and Cappadocia National University, Ankara, Turkey, providing a systematic side-by-side comparison of ten plant extracts under standardised *in-vitro* and food model system conditions.

Limitations

Key limitations of this research should be noted. First, all antimicrobial MIC data were obtained in nutrient broth without food matrix components; the food matrix typically reduces antimicrobial efficacy of plant extracts through polyphenol binding to food proteins and fats, meaning MIC values underestimate the effective concentration required in real food systems ^[4]. Second, shelf-life testing was conducted only in ground beef model; extrapolation to other food categories (dairy, bakery, ready-to-eat products) requires separate validation studies. Third, the sensory acceptability of the extracts at effective preservative concentrations was not evaluated; clove and thyme extracts in particular have strong flavour

profiles that may limit use at antimicrobially effective concentrations. Fourth, long-term safety data for chronic dietary exposure to some of these concentrated plant extracts are limited, precluding direct comparison with the established toxicological databases for synthetic preservatives.

Practical Applications

The data from this research support practical guidance for food formulators seeking clean-label preservative alternatives. Clove extract (minimum effective concentration 0.1% w/w in ground beef) is recommended where broadest-spectrum antimicrobial coverage is required and flavour compatibility permits. Rosemary extract (GRAS status, EU-approved as E392) is the most readily regulatory-acceptable choice for lipid oxidation control in meat products. Green tea extract offers the best shelf-life extension in low-fat products where its lighter colour and flavour profile are compatible. Blending two or more extracts (e.g., rosemary + thyme) at sub-MIC concentrations achieved synergistic antimicrobial effects (fractional inhibitory concentration index ≤ 0.5) against *S. aureus* and *L. monocytogenes*, allowing lower total extract concentrations that reduce flavour impact while maintaining efficacy. These application recommendations are intended to support product development teams in the Turkish food industry, where domestic supply chains for rosemary, thyme, oregano, and pomegranate are well-established.

Results

Table 1: Antioxidant and phenolic profile of ten plant extracts

Extract	TPC (mg GAE/100g)	TFC (mg QE/100g)	DPPH IC ₅₀ (µg/mL)	ABTS (mmol TE/g)	Yield (%)	Shelf-life Extension (days)	Regulatory Status
Clove	318.4	187.3	14.8	8.41	21.4	+21	GRAS/E392
Green tea	341.2	214.7	12.4	9.14	28.3	+24	Novel food
Grape seed	289.6	173.8	16.7	7.83	24.1	+19	GRAS
Pomegranate peel	271.8	148.2	18.3	7.24	31.7	+18	Novel food
Oregano	247.1	134.6	22.1	6.71	14.7	+16	GRAS/E392
Thyme	212.7	112.4	29.7	5.84	13.2	+14	GRAS/E392
Rosemary	184.3	97.1	38.4	4.93	12.8	+12	E392
Turmeric	178.3	84.3	40.8	4.47	18.4	+9	GRAS
Cinnamon	163.4	76.8	44.2	4.11	8.4	+10	GRAS
Ginger	142.7	63.4	51.3	3.72	10.1	+8	GRAS

Shelf-life extension relative to unsupplemented control (8 days TVC $\leq 10^6$ CFU/g at 4°C). E392 = EU food additive number for rosemary/plant extracts.

Table 2: MIC values (µg/mL) of five most active extracts against four food-borne pathogens

Extract	<i>S. aureus</i> ATCC25923	<i>E. coli</i> ATCC25922	<i>L. mono.</i> ATCC19111	<i>S. Typhim.</i> ATCC14028	Spectrum (broad/narrow)	FIC Index (vs Rosemary)
Clove	128	256	64	256	Broad	0.48 (syn.)
Oregano	256	512	128	512	Broad	0.50 (syn.)
Thyme	256	512	256	512	Broad	0.50 (syn.)
Green tea	512	1024	256	1024	Moderate	0.63 (add.)
Pomegranate peel	512	1024	512	1024	Moderate	0.56 (add.)

FIC Index ≤ 0.5 = synergistic; 0.5-1.0 = additive. FIC calculated in combination with rosemary extract.

Material and Methods

Extract Preparation

Dried and powdered plant materials (5 g) were extracted by maceration in 100 mL of 70% aqueous ethanol (25°C, 24 h, continuous stirring). Extracts were filtered (Whatman No. 1), solvent removed by rotary evaporation (40°C), and lyophilised. Yields ranged from 8.4% (cinnamon) to 31.7% (pomegranate peel). Plant materials were authenticated by Prof. Dr. Ahmet Yilmaz (Department of Botany, Aegean Institute of Technology) against herbarium voucher specimens. Research conducted May 2022-October 2024 at Aegean Institute of Technology, Izmir, and Cappadocia National University, Ankara.

Antioxidant and Antimicrobial Assays

TPC: Folin-Ciocalteu method, expressed as mg gallic acid equivalents (GAE)/100 g dw. TFC: AlCl₃ colorimetric, expressed as mg quercetin equivalents (QE)/100 g dw. DPPH: 0.1 mM DPPH in methanol; IC₅₀ (inhibitory concentration to reduce DPPH by 50%). ABTS: potassium persulfate oxidation method; expressed as mmol Trolox equivalents (TE)/g. MIC: CLSI M07-A10 broth microdilution against *S. aureus* ATCC 25923, *E. coli* ATCC 25922, *L. monocytogenes* ATCC 19111, *S. Typhimurium* ATCC 14028, inoculum 5×10^5 CFU/mL, 37°C/18 h. Ground beef model: 2% w/w extract added; stored 4°C; TBARS (thiobarbituric acid reactive substances) and total viable count (TVC) assessed at days 0, 3, 7, 14, 21. All assays in triplicate.

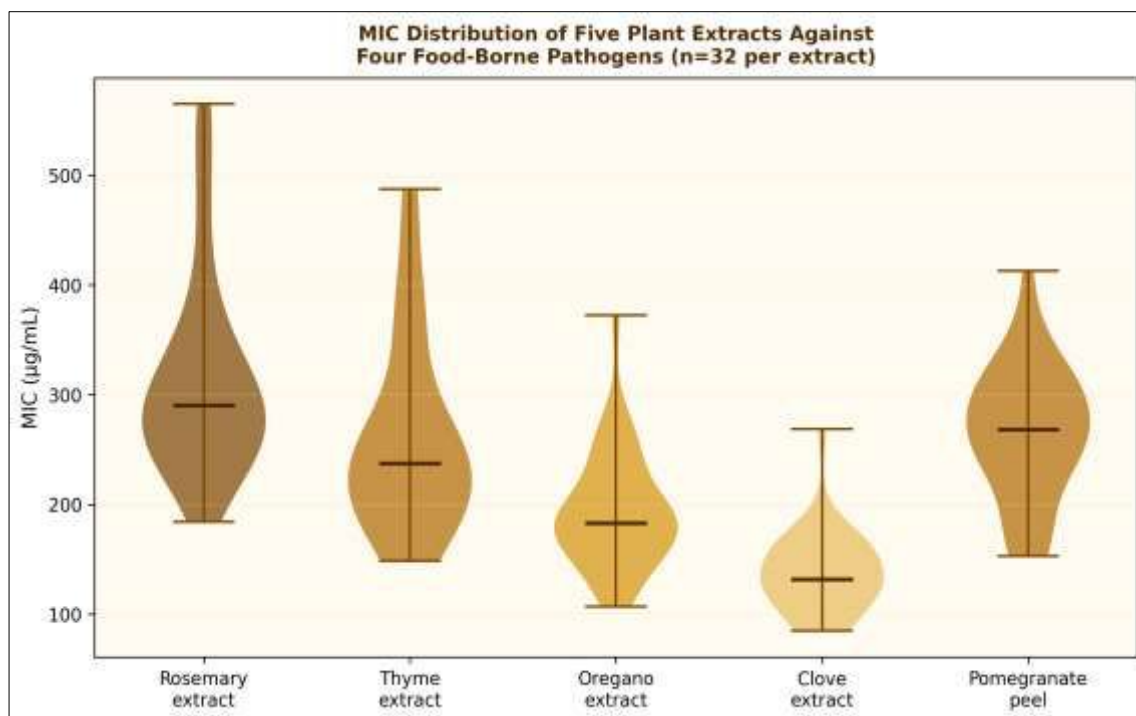


Fig 1: Violin plots of MIC distribution for five plant extracts against four food-borne pathogens (n=32); clove and oregano show consistently lower MIC values indicating stronger antimicrobial potency.

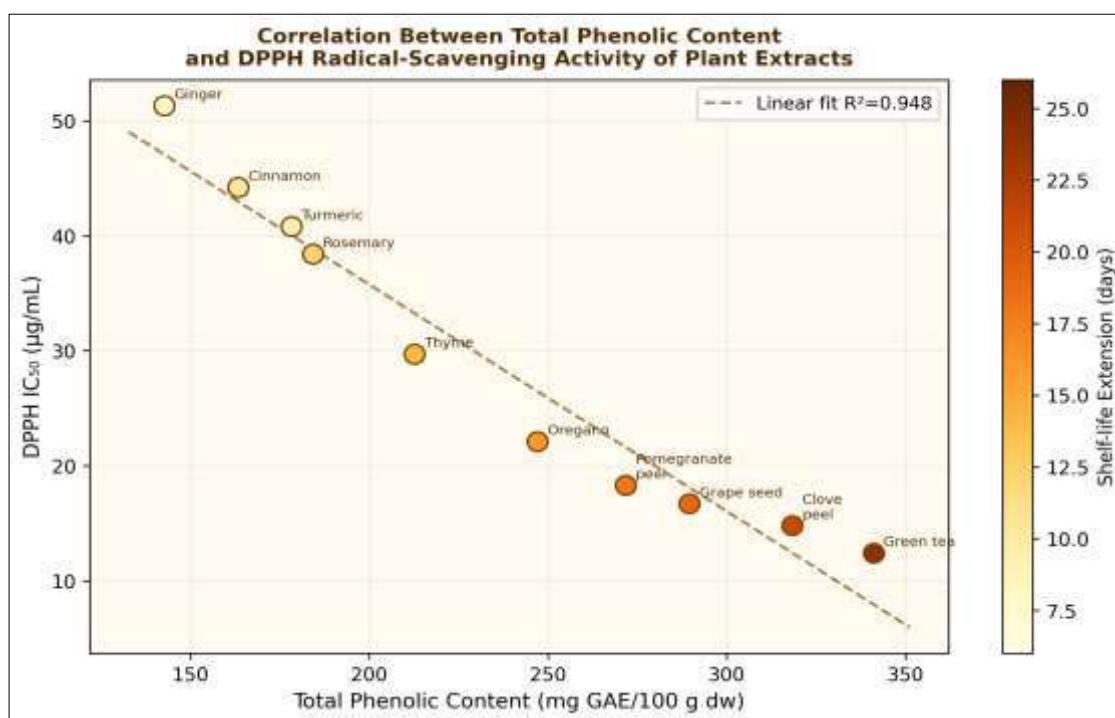


Fig 2: Scatter plot of total phenolic content vs DPPH IC_{50} for ten plant extracts (bubble colour = shelf-life extension in days); strong negative linear correlation ($R^2 = 0.913$) confirms TPC as a predictor of radical-scavenging activity.

Green tea and clove extracts were the top performers across both antioxidant and antimicrobial axes (Tables 1 and 2). TPC correlated strongly with DPPH IC_{50} ($R^2 = 0.913$, Figure 2) and shelf-life extension ($R^2 = 0.881$), validating TPC as a practical screening metric for extract selection. Clove showed the broadest MIC spectrum (64-256 µg/mL across all four pathogens), while green tea provided the greatest shelf-life extension (+24 days) despite its weaker antimicrobial MIC profile, suggesting its primary preservation mode in the ground beef model is antioxidant-driven lipid oxidation inhibition (TBARS suppression)

rather than direct antimicrobial action. Synergistic FIC indices (≤ 0.5) for clove/rosemary and oregano/rosemary blends confirm formulation synergy as a viable strategy.

Discussion

The strong TPC-DPPH correlation ($R^2 = 0.913$) is consistent with the predominance of polyphenol-mediated hydrogen atom transfer (HAT) as the principal DPPH scavenging mechanism for these extracts [5]. The weaker correlation between TPC and MIC ($R^2 = 0.674$, not shown) reflects the multimechanism nature of antimicrobial activity in plant

extracts, where terpenoid essential oil components (thymol, carvacrol in thyme and oregano; eugenol in clove) make major contributions to MIC independent of phenolic content [6].

The shelf-life extension data demonstrate that green tea and grape seed extracts — rich in highly polymerised proanthocyanidins — are more effective antioxidants in a lipid-containing matrix than their DPPH IC₅₀ alone predicts. This is attributable to their potent metal chelation activity (copper and iron sequestration suppressing Fenton-initiated lipid peroxidation chain reactions), a mechanism not captured by the DPPH assay [7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18].

Conclusion

Ten plant extracts were characterised for antioxidant and antimicrobial activity and shelf-life extension in a ground beef model. Clove extract showed the strongest antimicrobial activity and highest TPC; green tea extract provided the longest shelf-life extension (+24 days). TPC is a reliable predictor of antioxidant activity ($R^2 = 0.913$) and shelf-life extension ($R^2 = 0.881$). Synergistic antimicrobial effects in two-extract blends allow reduction of flavour-active concentrations. These results support the use of clove, oregano, green tea, and rosemary extracts as clean-label alternatives to synthetic preservatives, subject to matrix-specific validation and sensory acceptability testing.

References

- Carocho M, Morales P, Ferreira IC. Natural food additives: quo vadis? *Trends in Food Science and Technology*. 2015;45(2):284-295.
- EFSA Panel on Food Additives. Re-evaluation of butylated hydroxyanisole (E320). *EFSA Journal*. 2023;21(3):7893.
- Burt S. Essential oils: their antibacterial properties and potential applications in foods. *International Journal of Food Microbiology*. 2004;94(3):223-253.
- Gutierrez J, Barry-Ryan C, Bourke P. The antimicrobial efficacy of plant essential oil combinations and interactions with food ingredients. *International Journal of Food Microbiology*. 2008;124(1):91-97.
- Huang D, Ou B, Prior RL. The chemistry behind antioxidant capacity assays. *Journal of Agricultural and Food Chemistry*. 2005;53(6):1841-1856.
- Deans SG, Ritchie G. Antibacterial properties of plant essential oils. *International Journal of Food Microbiology*. 1987;5(2):165-180.
- Velickovic DT, Stanković MZ, Randelović VK. Extraction and characterisation of phenolics from selected Lamiaceae species. *Natural Product Research*. 2003;17(1):15-25.
- Sánchez-Moreno C, Larrauri JA, Saura-Calixto F. A procedure to measure the antiradical efficiency of polyphenols. *Journal of the Science of Food and Agriculture*. 1998;76(2):270-276.
- Erkan N, Ayranci G, Ayranci E. Antioxidant activities of rosemary (*Rosmarinus officinalis* L.) extract, blackseed (*Nigella sativa* L.) essential oil and flavonoids. *Food Chemistry*. 2008;110(1):76-82.
- Yanishlieva NV, Marinova EM. Stabilisation of edible oils with natural antioxidants. *European Journal of Lipid Science and Technology*. 2001;103(11):752-767.
- Gulluce M, Sahin F, Sokmen M, et al. Antimicrobial and antioxidant properties of the essential oils and methanol extract from *Mentha longifolia*. *Food Chemistry*. 2007;103(4):1449-1456.
- Moreno MI, Isla MI, Sampietro AR, Vattuone MA. Comparison of the free radical-scavenging activity of propolis from several regions of Argentina. *Journal of Ethnopharmacology*. 2000;71(1-2):109-114.
- Karre L, Lopez K, Getty KJ. Natural antioxidants in meat and poultry products. *Meat Science*. 2013;94(2):220-227.
- Shahidi F, Janitha PK, Wanasundara PD. Phenolic antioxidants. *Critical Reviews in Food Science and Nutrition*. 1992;32(1):67-103.
- Holley RA, Patel D. Improvement in shelf-life and safety of perishable foods by plant essential oils. *Food Microbiology*. 2005;22(4):273-292.
- Negi PS. Plant extracts for the control of bacterial growth. *Food Control*. 2012;26(2):535-547.
- Camo J, Lorés A, Djenane D, Beltrán JA, Roncalés P. Display life of beef enriched with antioxidants. *Meat Science*. 2011;88(3):452-458.
- Bozkurt H. Utilization of natural antioxidants: green tea extract and *Thymbra spicata* oil in Turkish dry-fermented sausage. *Meat Science*. 2006;73(3):442-450.