



In vitro antioxidant evaluation of a herbal formulation containing sesame root (*Sesamum indicum* L.) and raspberry (*Rubus idaeus* L.)

R Gomathi^{1,2}, T N Uma Maheswari^{2*} & S Rajesh Kumar³

¹Department of Oral Medicine and Radiology, KSR Institute of Dental Science and Research, KSR Kalvi Nagar, Thokkavadi, Tiruchengode 637 215, Tamil Nadu, India

²Department of Oral Medicine and Radiology, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai 600 077, Tamil Nadu, India

³Nanomedicine Laboratory, Product Development and Zebrafish Unit, Saveetha Medical College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai 602 105, Tamil Nadu, India

*Correspondence: T N Uma Maheswari, umamaheswaritn@saveetha.com

Abstract

Oxidative stress causes tissue damage, persistent inflammation and slowed wound healing. There is growing interest in plant-based antioxidants as safer substitutes for synthetic ones. Rich in lignans and polyphenols, sesame (*Sesamum indicum* L.) and raspberry (*Rubus idaeus* L.) have been shown to possess cytoprotective and free-radical-scavenging properties important for tissue protection. This study aimed to develop an aqueous sesame–raspberry herbal formulation and evaluate its *in vitro* antioxidant potential using 2,2-diphenyl-1-picrylhydrazyl (DPPH), hydrogen peroxide (H₂O₂) scavenging and ferric reducing antioxidant power (FRAP) assays. The roots of *S. indicum* and *R. idaeus* fruits were cleaned, dried in the shade, ground into a powder and extracted separately with distilled water under controlled heating conditions. The extracts were oven-dried and combined in equal amounts to prepare the herbal formulation. The final dry extract yield was 10.46 %. Preliminary phytochemical screening was performed and the antioxidant activity of the formulation was evaluated using DPPH, H₂O₂ scavenging and FRAP assays at concentrations of 10–50 µg/mL, with ascorbic acid as the reference standard. Preliminary phytochemical screening revealed abundant flavonoids and phenols, moderate levels of alkaloids, tannins, glycosides, terpenoids and anthocyanins and the presence of saponins and steroids. The herbal formulation demonstrated concentration-dependent antioxidant activity, with responses ranging from 62.25–89.99 % in the DPPH assay, 47.30–84.45 % in the H₂O₂ assay and 67.41–87.62 % in the FRAP assay across 10–50 µg/mL. The formulation showed lower antioxidant responses than the ascorbic acid standard across the tested concentrations. The aqueous sesame–raspberry herbal formulation demonstrated measurable *in vitro* antioxidant activity across the tested concentration range. Further studies involving quantitative phytochemical characterisation, additional concentration ranges and biological models are required to further establish its antioxidant potential.

Keywords: antioxidants; free radical scavengers; *in vitro* techniques; oxidative stress; *Rubus idaeus*; *Sesamum indicum*

Received: 13 May 2026. **Accepted:** 09 August 2026. **Published:** Version 1.0: 03 October 2026; Version 2.0: 13 October 2026.

Cite this article: Gomathi R, Uma MTN, Rajesh KS. *In vitro* antioxidant evaluation of a herbal formulation containing sesame root (*Sesamum indicum* L.) and raspberry (*Rubus idaeus* L.). Plant Science Today. 2026; 13(4): 1-11. <https://doi.org/10.14719/pst.15525>

1. Introduction

Sesame and raspberry are emerging as a effective combination of phytochemicals for antioxidant-based formulations used against tissue damage and oxidative stress. Sesamin, sesamol and sesamol bioactive lignans present in seeds and roots of *Sesamum indicum* L. (sesame) effectively reduce lipid peroxidation, stabilise membranes and scavenge free radicals (1, 2). Sesame has been common in functional and medicinal

foods because its components possess antihypertensive, anticancer and cytoprotective activities (3). Sesame (known as the “Queen of oilseeds”) is an abundant and extremely bioactive crop worldwide. Although the leaves and stems also have antioxidant and antibacterial properties, the oil obtained from the seeds has been studied more extensively (4). Sesame root, in contrast, remains comparatively under-investigated despite reports of antioxidant activity



comparable to that of the leaf and seed, driven by lignans and phenolics. Being a non-edible, currently under-utilised part of the plant, using sesame root here also serves a valorisation purpose distinct from the seed-oil literature.

Raspberries, especially *Rubus idaeus* L. (raspberry), are among the most phytochemical-rich fruits and polyphenols have been recognised as key bioactive compounds (5). These compounds include ellagitannins, phenolic acids, anthocyanins, catechins and proanthocyanidins that contribute to antioxidant, anti-inflammatory and chemopreventive effects. Berry fruits consistently rank among the highest sources of total phenolics and antioxidant capacity (AOC), with levels up to four times greater than those of many other fruits. Raspberry fruit is a widely consumed dietary food with a long history of traditional use and the cited literature reports a generally favourable safety profile in food-level intake (6–8); however, this should not be over-generalised as a blanket claim of “no drug interactions” or of unrestricted safety in pregnant women and children, as dedicated interaction/safety studies in these specific populations are limited and this caveat is noted accordingly.

The combination of sesame lignans and raspberry polyphenols offers a complementary approach to restoring redox balance, regulating inflammation and potentially supporting tissue regeneration (9). The specific combination of sesame root and raspberry has not been previously reported, which represents the research gap addressed by this study. The two ingredients were selected based on their distinct and potentially complementary phytochemical profiles. Sesame contains lipophilic lignans, including sesamin, sesamol and sesamol, whereas raspberry is rich in hydrophilic polyphenols and anthocyanins. These compounds may contribute to antioxidant activity through complementary mechanisms, including electron or hydrogen donation and metal chelation, potentially resulting in additive effects. However, the presence of synergistic interactions was not assessed in the present study. In addition, considering that oral candidiasis may occur as a complication or coexisting condition in patients with oral mucositis, the formulation was developed to provide both antioxidant and antifungal properties. Therefore, the sesame root–raspberry combination was hypothesised to provide complementary antioxidant activity along with antifungal potential, supporting its further investigation for possible application in the management of oral mucosal conditions. Mechanistically, this dual-herbal formulation may act through electron or hydrogen donation, reactive oxygen species (ROS) scavenging and stabilisation of cellular biomolecules.

2. Materials and Methods

This study was approved by the Institutional Ethics Committee (IEC; Proposal Nos. IHEC/SDC/PhD/OMED-1628/21/237 and IEC-FAC/MAR/2025/270). The study adhered to the Declaration of Helsinki's ethical guidelines. The IEC approval was obtained as a

departmental/institutional requirement for all dissertation-linked research protocols at the authors' institution, even though the present work involved only chemical, plant-extract-based *in vitro* antioxidant assays and did not use human participants, human/animal biological samples, or animal experimentation.

Sample size estimation

The antioxidant assays in the present study were performed using 3 technical replicates at each concentration rather than independent biological replicates. The triplicate measurements were used to assess assay repeatability and are reported as $n = 3$ technical replicates. As the present study involved chemical *in vitro* antioxidant assays, no biological sample-size calculation was applied.

Methodology

Preparation of herbal formulation using raspberry and sesame extract

To ensure purity and quality, fresh samples of *S. indicum* and *R. idaeus* were gathered from reputable herbal shops in Chennai, India, for the creation of a standardised herbal formulation. To eliminate debris and deteriorated areas, each sample was visually examined. To remove dust, pesticides and surface impurities, the materials were thoroughly cleaned with distilled water. Following washing, samples of sesame and raspberry roots were shade-dried in a controlled environment to prevent heat-sensitive phytoconstituents from degrading, using a technique modified from previous study (10). The botanical identity of both raw materials was confirmed macroscopically and organoleptically based on the available vendor documentation prior to processing. The available authentication details were Certificate No. QCC0E35/0524 and Order No. 403-6692592-5929145. No separate herbarium voucher specimen number or deposition location was available. Aqueous extraction was deliberately selected over hydroalcoholic or organic-solvent extraction to minimise solvent residues and ensure biocompatibility for the intended topical/oral biomedical application.

A sterile mortar and pestle were used to finely powder the materials after they had fully dried. A digital laboratory balance was used to weigh precisely 1 g of raspberry powder and 1 g of sesame root powder separately for the formulation. Using a heating mantle kept at 50–60 °C for 15 min, each powder sample was combined separately with 100 mL of distilled water and subjected to heat extraction. This regulated heating process improved the release of water-soluble bioactive compounds and aided in the breakdown of plant cell walls. Clear aqueous extracts were obtained by filtering the mixtures through sterile muslin cloth after they had been heated. The density of phytochemicals was then increased by concentrating the filtrates using a heating mantle until the final volume was reduced to 3–5 mL. To create fine herbal powders, the concentrated extracts were then moved to sterile petri dishes and dried at 50 °C in a hot air oven. One gram of the dried and powdered plant material was extracted with 100 mL of distilled water. The aqueous extract was subjected to

boiling and subsequently concentrated to obtain 5 mL of a thick, concentrated herbal extract. The final dry extract obtained was 104.6 mg (0.1046 g), corresponding to an extraction yield of 10.46 %. The concentrated extract was used as the stock solution and appropriate dilutions in the concentration range of 10–50 µg/mL were prepared for subsequent biomedical applications. Under aseptic conditions, the powdered sesame and dried raspberries were meticulously scraped and gathered. Equal amounts of the two powders were mixed with sterile distilled water to create a homogeneous mixture to create a combined herbal preparation. To maintain its bioactivity and prevent microbial deterioration, the finished preparation was kept in airtight containers at 4 °C. Additionally, this formulation was employed in biomedical applications, specifically to evaluate its possible antioxidant and therapeutic qualities.

Preliminary phytochemical screening of the herbal formulation

Preliminary phytochemical screening of the sesame–raspberry herbal formulation was performed to identify the major classes of phytochemical constituents present in the combined extract. The extract was qualitatively screened for alkaloids, flavonoids, phenols, tannins, saponins, glycosides, terpenoids, steroids and anthocyanins using standard phytochemical screening procedures. The intensity of the reactions was recorded semi-quantitatively as present (+), moderate (++), or abundant (+++). The results of the preliminary phytochemical screening are presented in Table 1.

Table 1. Preliminary phytochemical screening of the sesame–raspberry herbal formulation

Sl. No	Phytochemical constituents	Sesame and raspberry extract
1	Alkaloids	++
2	Flavonoids	+++
3	Phenol	+++
4	Tannins	++
5	Saponins	+
6	Glycosides	++
7	Terpenoids	++
8	Steroids	+
9	Anthocyanins	++

+++ : abundant; ++ : moderate; + : present.

Assessment of antioxidant potential of the herbal formulation

Several *in vitro* tests, such as the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging test, the hydrogen peroxide (H₂O₂) inhibition test, a deoxyribose-degradation hydroxyl-radical scavenging assay (H₂O₂/Fe³⁺-ethylenediaminetetraacetic acid (EDTA) system) and the ferric reducing antioxidant power (FRAP) test, were used to evaluate the antioxidant effectiveness of the raspberry-sesamum herbal formulation. Ascorbic acid was used as the standard reference compound for comparison in every evaluation.

DPPH assay: The DPPH assay was performed using the previous study methodology to evaluate the antioxidant potential of the herbal formulation (11). A working

concentration of 20 µM was obtained by diluting a 0.1 mM DPPH stock solution with methanol. In a 96-well plate, 200 µL of the DPPH working solution was mixed with varying concentrations of the formulation (10–50 µg/mL). To guarantee a full reaction, the samples were incubated for 30 min at room temperature in the dark.

A microplate reader was used to measure absorbance at 517 nm after incubation, using methanol as the blank. The following formula was used to determine the percentage of DPPH radical scavenging activity:

DPPH scavenging activity (%) =

$$[(A_{\text{control}} - A_{\text{sample}})/A_{\text{control}}] \times 100$$

Where A_{control} denotes the absorbance of the DPPH solution without the sample and A_{sample} represents the absorbance in the presence of the extract. Ascorbic acid was employed as the standard reference (positive control) for comparison.

H₂O₂ scavenging assay: The hydroxyl radical scavenging activity of the sesame-raspberry herbal formulation was evaluated using the deoxyribose degradation method. Briefly, 100 µL of 28 mM 2-deoxy-2-ribose was added to the herbal formulation at different concentrations (10–50 µg/mL) to prepare the reaction mixture. Subsequently, 200 µL of EDTA, 200 µL of ferric chloride (200 µM) and 100 µL of ascorbic acid were added to the reaction mixture. The reaction mixture was incubated at 37 °C for 1 hr. Following incubation, the absorbance was measured at 532 nm using a spectrophotometer. The reaction D mixture without the test formulation was used as the control (blank). Ascorbic acid was used as the positive standard for comparison.

The percentage of hydroxyl radical scavenging activity was calculated using the following formula:

Hydroxyl radical scavenging activity (%) =

$$[(A_{\text{blank}} - A_{\text{sample}})/A_{\text{blank}}] \times 100$$

Where A_{sample} represents the absorbance of the reaction mixture containing the herbal formulation and A_{blank} represents the absorbance of the control reaction without the test formulation (11).

Ferric reducing antioxidant power: The FRAP assay was performed to evaluate the reducing capacity of the sesame–raspberry herbal formulation. The FRAP reagent was freshly prepared by mixing acetate buffer (300 mM, pH 3.6), 2,4,6-tripyridyl-s-triazine (TPTZ) solution [10 mM in 40 mM hydrochloric acid (HCl)] and ferric chloride (20 mM) in a ratio of 10 : 1 : 1. Different concentrations of the herbal formulation (10–50 µg/mL) were added to the freshly prepared FRAP reagent and the reaction mixture was incubated at 37 °C for 30 min. The reduction of Fe³⁺ to Fe²⁺ was measured using an ultraviolet-visible (UV-Vis) spectrophotometer at 593 nm. ferrous sulphate (FeSO₄) was used as the calibration standard and a calibration curve was prepared using different concentrations of FeSO₄. The antioxidant activity of the test samples was determined based on the calibration curve and expressed as µg/mL



Fe²⁺ equivalents. Higher absorbance values indicated greater reducing antioxidant capacity.

Statistical analysis

SPSS software (version 23.0, Chicago, IL, USA) was used for statistical analysis. The results were expressed as mean $\pm$ standard deviation (SD), based on 3 technical replicates ($n = 3$) per group. An independent samples t -test was used to compare the percentage inhibition/FRAP values between the herbal formulation and the standard at each concentration, with $p < 0.05$ considered statistically significant. As the measurements were based on technical replicates rather than independent biological replicates, the statistical findings were interpreted with caution and were considered indicative of assay-level differences rather than biological effect size. The 95 % confidence intervals (CI) were additionally calculated for the mean values to aid interpretation.

3. Results

Preliminary phytochemical screening

Preliminary phytochemical screening of the sesame–raspberry herbal formulation revealed the presence of several classes of phytochemical constituents. Flavonoids and phenols were detected abundantly (+++), while alkaloids, tannins, glycosides, terpenoids and anthocyanins were present at moderate levels (++).

Saponins and steroids were detected as present (+). These findings indicate the presence of diverse phytochemical constituents that may contribute to the antioxidant activity observed in the DPPH, H₂O₂ and FRAP assays.

Analysis of the antioxidant potential of the herbal formulation using the DPPH assay

Five DPPH concentrations (10–50 μ g/mL) were used to compare the antioxidant activity of the sesame + raspberry herbal formulation with the standard. The mean percentage inhibition (scavenging activity), expressed as mean $\pm$ SD, was used to assess antioxidant efficiency. The standard continuously demonstrated greater antioxidant activity than the formulation at every tested concentration. The mean differences showed a discernible variation in effectiveness, ranging from 2.10–7.05 % inhibition. At 30 μ g/mL, the greatest difference was noted, indicating that the standard's antioxidant response peaked at this concentration. High reproducibility across triplicate measurements was indicated by low standard error values. The superior antioxidant potential of the standard over the sesame + raspberry extract was confirmed by independent t -test analysis, which showed statistically significant differences at all concentrations ($p < 0.05$). Overall, the herbal formulation showed noticeable antioxidant activity, but it was consistently lower than the standard, suggesting that the reference compound is more effective at scavenging free radicals (Table 2, Fig. 1).

Table 2. Comparison of the percentage inhibition of sesame + raspberry herbal formulation extract and the standard at various DPPH concentrations

Concentration (μ g/mL)	Sesame + raspberry herbal formulation extract (mean $\pm$ SD)	Standard mean $\pm$ SD	Mean difference (%)	N	Standard error	Confidence interval	Independent t -test	p -value
10	62.25 $\pm$ 0.42	66.47 $\pm$ 0.28	−4.22	3	0.29	95 %	−14.48	0.000
20	72.74 $\pm$ 1.12	78.80 $\pm$ 0.80	−6.33	3	0.80	95 %	−7.96	0.001
30	79.12 $\pm$ 0.63	86.17 $\pm$ 0.88	−7.05	3	0.63	95 %	−11.28	0.000
40	83.69 $\pm$ 0.53	88.57 $\pm$ 0.52	−5.15	3	0.63	95 %	−8.17	0.001
50	89.99 $\pm$ 0.45	92.10 $\pm$ 1.11	−2.11	3	0.69	95 %	−3.05	0.038

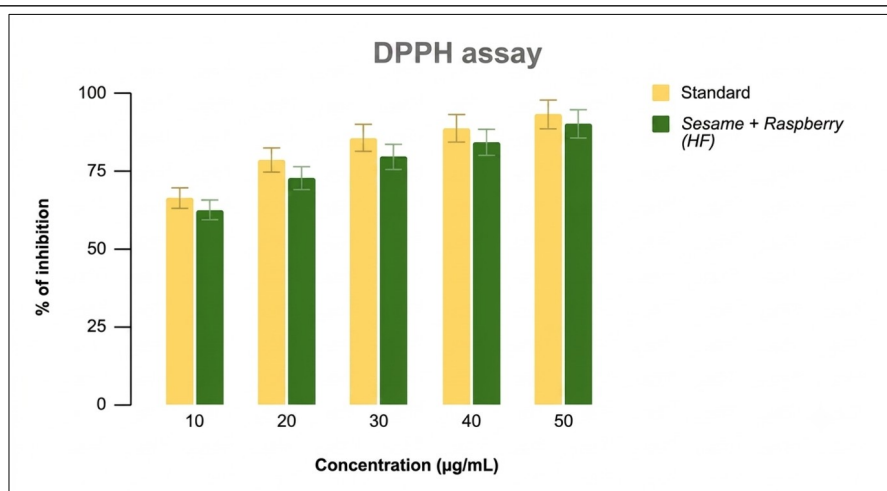


Fig. 1. Analysis of the antioxidant potential of the herbal formulation using DPPH assay.

Analysis of the antioxidant potential of the herbal formulation using H₂O₂ assay

The hydrogen peroxide (H₂O₂) scavenging assay was used to compare the antioxidant activity of the sesame + raspberry herbal formulation with the standard at concentrations ranging 10–50 µg/mL. Three measurements of the percentage inhibition were made and the results were reported as mean ± SD. The standard showed better antioxidant activity than the herbal formulation at all tested concentrations. The highest difference was found at 30 µg/mL, indicating peak scavenging efficiency. The mean difference varied from 3.97–4.74 % inhibition. Strong reliability and repeatability of the results were validated by low standard error values. Across all concentrations, independent *t*-test analysis showed statistically significant differences between the herbal extract and the standard (*p* < 0.05). The sesame + raspberry formulation exhibited significant antioxidant activity, but it was consistently below the standard. These findings imply that the formulation has promising antioxidant potential, which could be enhanced by concentration optimisation or formulation refinement (Table 3, Fig. 2).

Analysis of the antioxidant potential of the herbal formulation using the FRAP assay

The FRAP assay was used to further investigate the antioxidant potential of the herbal formulation at various concentrations (10–50 µg/mL) and the outcomes were compared with the standard compound. Stronger ferric-reducing ability at a lower concentration was demonstrated by the standard's higher percentage inhibition at 10 µg/mL compared to the sesame + raspberry herbal formulation. At 30 µg/mL, the standard demonstrated superior antioxidant activity with a discernible difference in response, exhibiting a similar trend (12). The standard consistently outperformed the herbal extract at 40–50 µg/mL, indicating a higher capacity to scavenge free radicals. Although the herbal formulation has noticeable FRAP activity, it is still relatively less potent than the standard, according to independent *t*-test analysis, which confirmed significant differences between the groups at all concentrations (*p* < 0.001). These results highlight the formulation's potential as a natural source of antioxidants, though additional optimisation might improve its effectiveness (Table 4, Fig. 3).

Table 3. Comparison of the percentage inhibition of the sesame + raspberry herbal formulation extract and the standard across different H₂O₂ concentrations

Concentration (µg/mL)	Sesame + raspberry herbal formulation extract (mean ± SD)	Standard mean ± SD	Mean difference	N	Standard error	Confidence interval	Independent <i>t</i> -test	<i>p</i> -value
10	47.30 ± 0.32	51.27 ± 0.21	-3.97	3	0.22	95 %	-17.96	0.000
20	52.95 ± 0.82	57.10 ± 0.58	-4.15	3	0.58	95 %	-7.15	0.002
30	61.77 ± 0.49	66.51 ± 0.68	-4.74	3	0.48	95 %	-9.79	0.001
40	74.11 ± 0.47	78.70 ± 0.46	-4.59	3	0.38	95 %	-12.08	0.000
50	84.45 ± 0.42	88.88 ± 1.07	-4.43	3	0.66	95 %	-6.67	0.030

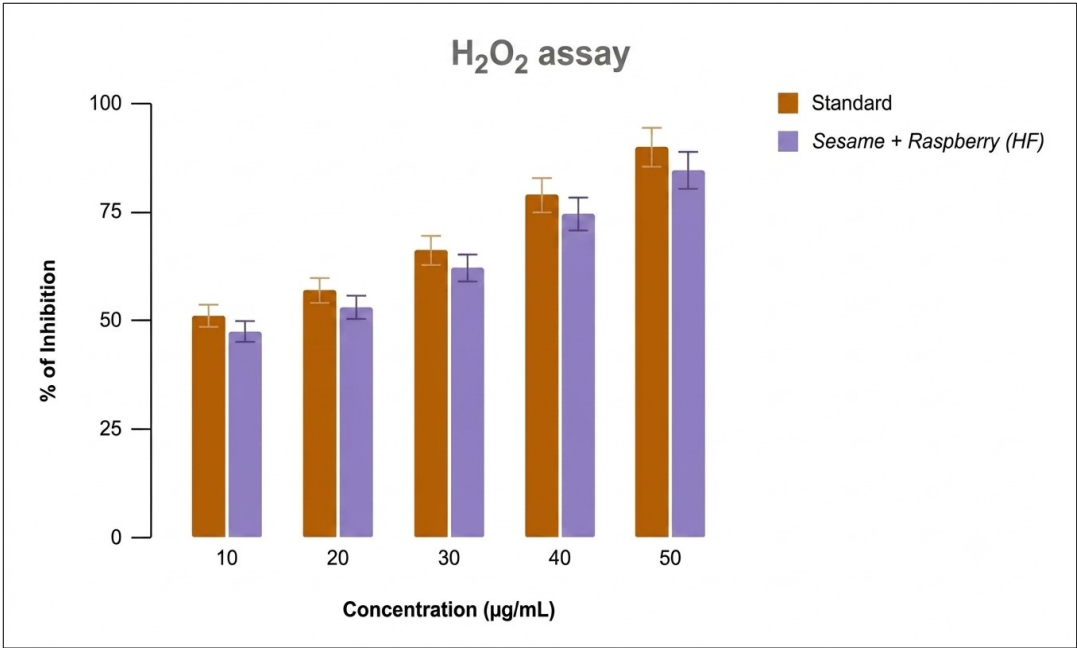
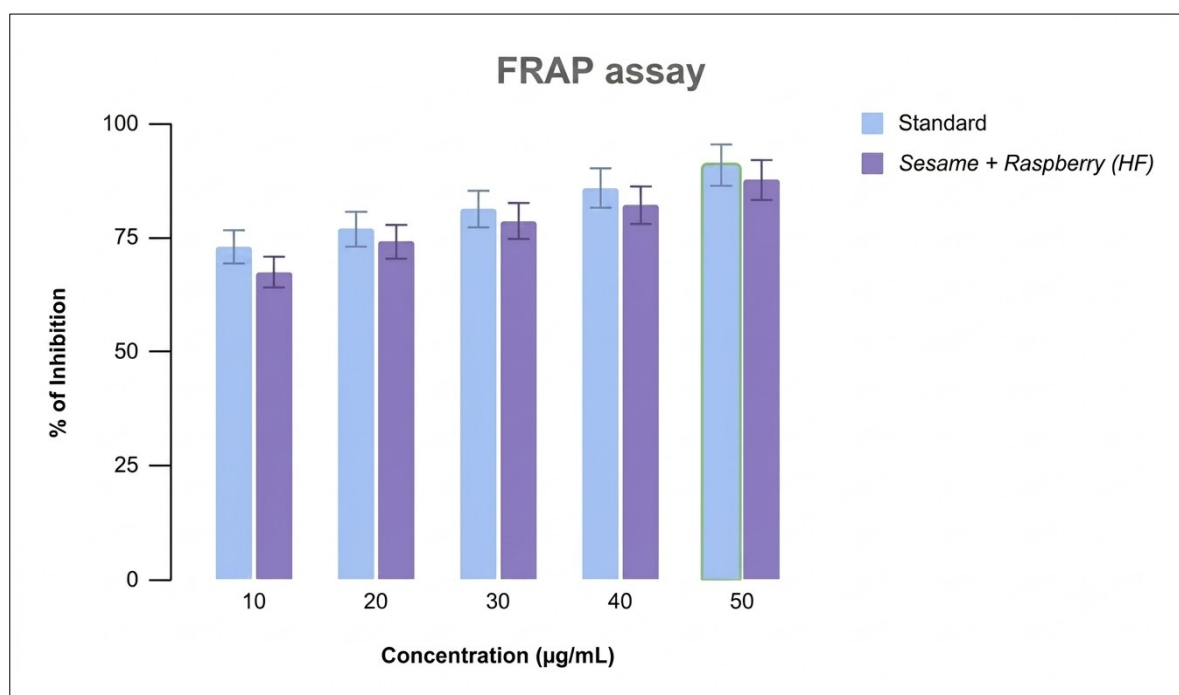


Fig. 2. Analysis of the antioxidant potential of the herbal formulation using H₂O₂ assay.



Table 4. Comparison of ferric reducing antioxidant power (FRAP) values between the sesame + raspberry herbal formulation extract and the standard at various FRAP concentrations

Concentration (µg/mL)	Sesame + raspberry herbal formulation extract (mean ± SD)	Standard mean ± SD (% reduction activity)	Mean difference	N	Standard error	Independent <i>t</i> -test	Confidence interval	<i>p</i> -value
10	67.41 ± 0.12	72.98 ± 0.12	-5.57	3	0.10	-56.84	95 %	0.000
20	74.06 ± 0.10	76.84 ± 0.10	-2.78	3	0.08	-34.04	95 %	0.000
30	78.68 ± 0.15	81.31 ± 0.15	-2.63	3	0.12	-21.47	95 %	0.000
40	82.08 ± 0.17	85.84 ± 0.17	-3.76	3	0.14	-27.08	95 %	0.000
50	87.62 ± 0.11	90.89 ± 0.11	-3.27	3	0.09	-36.40	95 %	0.000

**Fig. 3.** Analysis of the antioxidant potential of the herbal formulation using FRAP assay.

Comparative evaluation of antioxidant assays

The sesame + raspberry herbal formulation demonstrated significant antioxidant activity in all three assays (DPPH, H_2O_2 and FRAP), albeit consistently below the standard. In both the DPPH and H_2O_2 assays, the maximum activity was found at 30 µg/mL, whereas FRAP produced better results at higher concentrations (40–50 µg/mL). The herbal formulation showed consistent antioxidant potential, supported by statistically significant results, even though the standard showed superior scavenging and reducing ability across all tests. All things considered, the extract shows promise as a natural source of antioxidants and could be further enhanced by formulation or concentration optimisation.

For the DPPH radical scavenging assay, inhibition exceeded 50 % at the lowest tested concentration (10 µg/mL) for both the formulation (62.25 ± 0.42 % inhibition) and the ascorbic acid standard (66.47 ± 0.28 % inhibition). Across all concentrations

and all three assays, independent *t*-test analysis confirmed statistically significant differences between the formulation and the standard ($p < 0.05$), with the standard consistently showing marginally higher percentage inhibition. These findings indicate that the sesame + raspberry herbal formulation possesses strong, concentration-dependent antioxidant activity that approaches, but does not fully match, the potency of ascorbic acid.

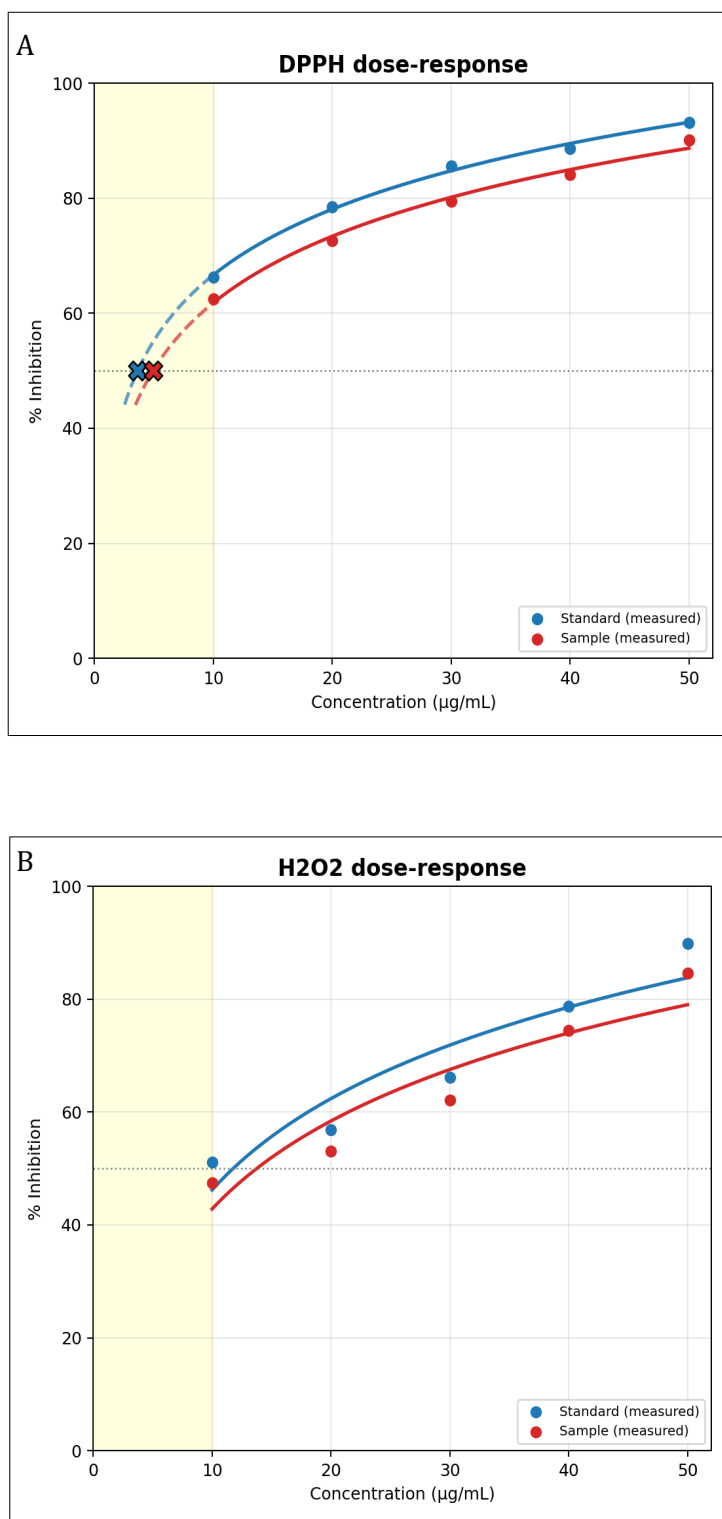
Dose-response analysis and estimation of IC_{50} values

Dose-response regression analysis was performed to estimate the IC_{50} values of the sesame-raspberry herbal formulation and the standard for the DPPH, FRAP and H_2O_2 assays. The antioxidant activity of the sesame-raspberry herbal formulation increased with increasing concentration across the tested range (10–50 µg/mL) in the DPPH, H_2O_2 and FRAP assays. Based on the available concentration-response data, the estimated IC_{50} values for the herbal formulation were

8.0 $\mu\text{g/mL}$ for DPPH and 14.46 $\mu\text{g/mL}$ for H_2O_2 . The IC_{50} value obtained for DPPH was below the lowest experimentally tested concentration and therefore represents an extrapolated estimate rather than an experimentally validated IC_{50} . For the FRAP assay, the estimated value of 7.4 $\mu\text{g/mL}$ was similarly below the lowest tested concentration and should be interpreted as an extrapolated estimate.

The dose–response curves are presented in Fig. 4(A–C). In the DPPH and FRAP assays, the

response exceeded 50 % at the lowest experimentally tested concentration (10 $\mu\text{g/mL}$); therefore, the corresponding values of 8.0 and 7.4 $\mu\text{g/mL}$, respectively, were obtained by extrapolation of the regression model below the experimentally tested concentration range and should be interpreted as regression-based estimates rather than experimentally validated IC_{50} values. In contrast, the H_2O_2 IC_{50} values fell within the experimentally tested concentration range and were estimated from the corresponding dose–response relationship.



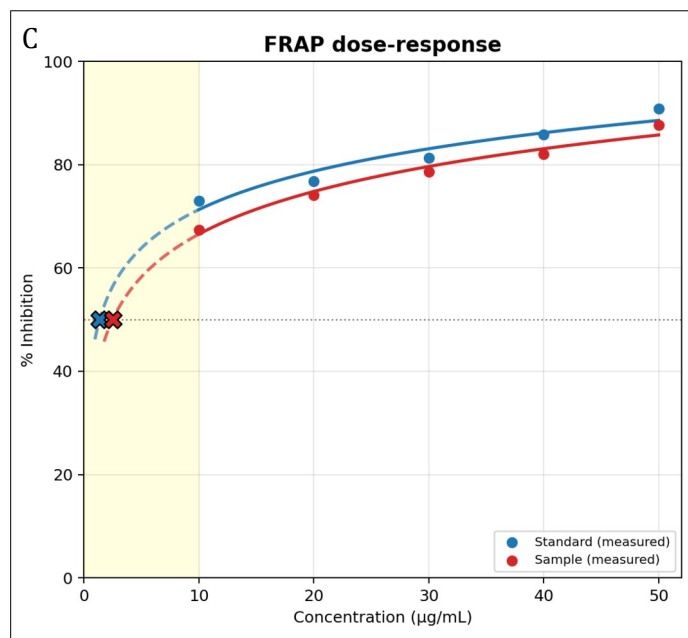


Fig. 4. (A–C) Dose–response curves of the standard and sesame–raspberry herbal formulation for DPPH, H₂O₂ assays and FRAP.

4. Discussion

The present study used the FRAP, DPPH and H₂O₂ scavenging assay to assess an herbal formulation of *S. indicum* and *R. idaeus*. The formulation demonstrated significant, dose-dependent antioxidant activity ($p < 0.05$), despite being less effective than ascorbic acid. The FRAP activity increased at higher concentrations (40–50 µg/mL), whereas DPPH and H₂O₂ scavenging activity peaked at 30 µg/mL. These findings support further translational and biological research and validate the formulation's consistent antioxidant potential. Rather than exhibiting the high potency of a purified small-molecule antioxidant, the results are consistent with the expected behaviour of crude plant extracts, which contain complex mixtures of phytochemicals with moderate but broad-spectrum antioxidant effects. The sesame–raspberry formulation possesses genuine free-radical scavenging and ferric-reducing capabilities, as evidenced by the consistent statistical significance observed across all assays.

Mechanistically, the polyphenol-rich composition of raspberry and the well-established lignan profile of sesame may explain the antioxidant behaviour of this formulation. Sesame lignans, particularly sesamin, sesamol and sesamol, have been shown to strongly inhibit lipid peroxidation, enhance reducing power and scavenge DPPH radicals (13). Sesamol frequently outperforms traditional phenolic antioxidants *in vitro*. Sesamin and sesamol also exhibit clinically significant antioxidant, antihypertensive and anticancer properties, supporting their potential for systemic cytoprotection (14). The antioxidant activity observed in the present formulation is further supported by previous findings (15).

Raspberry's diverse range of polyphenols further enhances this lignan-based antioxidant activity.

Phenolic and anthocyanin-rich raspberry fractions have demonstrated strong DPPH scavenging activity, ferric-reducing power and Fe²⁺-chelating capacity (16). Similarly, red raspberry leaf extracts with high phenolic content have exhibited potent antioxidant responses (17). However, the possibility of pro-oxidant effects at higher concentrations highlights the importance of dose selection, which is consistent with the present finding that maximum antioxidant activity occurred at the intermediate concentration of 30 µg/mL.

The antioxidant patterns observed in this investigation are also consistent with the kinetics of conventional antioxidant assays. The peak scavenging activity at 30 µg/mL and the subsequent saturation observed in DPPH and H₂O₂ assays are consistent with the established concentration-dependent but saturable behaviour of the DPPH assay (18). Likewise, the increasing FRAP values at 40–50 µg/mL reflect the dose-dependent reducing power measured by the FRAP assay (19). These similarities demonstrate that the observed antioxidant activity is supported by multiple assay systems, thereby strengthening the scientific validity of the findings.

The superior antioxidant efficacy of ascorbic acid was consistently demonstrated; however, this should not be considered a limitation of the present formulation. Sesame lignans and raspberry polyphenols have been associated with broader biological effects, including modulation of endogenous antioxidant enzymes, improvement of lipid profiles and reduction of inflammatory mediators, whereas isolated compounds such as ascorbate exhibit strong redox activity but often lack sustained *in vivo* effects (20). Therefore, the formulation's moderate but consistent antioxidant activity may be particularly relevant in biological systems where multi-target antioxidant mechanisms are advantageous.

The AOC of plant extracts is strongly influenced by the extraction strategy. To ensure safety and biocompatibility for biomedical applications, aqueous extraction at controlled temperatures was employed in the present study. However, previous studies have demonstrated that processing methods and solvent type influence lignan yield, particularly sesamol, with roasted oils and organic extracts producing higher antioxidant activity (13). Similarly, phenolic- and anthocyanin-enriched raspberry fractions have been reported to exhibit greater antioxidant activity than crude extracts (21), underscoring the need for optimised extraction techniques, such as hydroalcoholic extraction or selective enrichment of bioactive compounds.

The overall antioxidant profile of the formulation is consistent with therapeutic and nutraceutical applications. Sesame has long been recognised in traditional medicine for its beneficial effects on cardiovascular, hepatic and metabolic health, whereas raspberry polyphenols are associated with anti-inflammatory and cytoprotective properties. Their collective role in mitigating oxidative stress has also been reported (22). Therefore, the sesame–raspberry formulation may serve as a multifunctional plant-based oral care supplement rather than a replacement for synthetic antioxidants.

The formulation can also be meaningfully contextualised with previously published studies on dual and poly-herbal plant extract combinations. Polyherbal antioxidant formulations have demonstrated that combinations, such as *Mentha piperita* with *Thymus vulgaris* ($\Sigma\text{FIC} = 0.32$ in DPPH; $\Sigma\text{FIC} = 0.15$ in FRAP) and *Rosmarinus officinalis* with *Syzygium aromaticum* ($\Sigma\text{FIC} = 0.47$ in FRAP) exhibit genuine synergistic antioxidant activity when extracts are combined in a 1 : 1 ratio and evaluated using DPPH, ABTS and FRAP assays. These results confirm that dual-herb formulas can elicit a wider range of redox protection than either component alone, a principle that underpins the rationale of our sesame-raspberry pairing. We note that the present design did not include sesame-alone or raspberry-alone treatment arms, so true synergism (e.g., via combination index or ΣFIC analysis) could not be directly assessed for our formulation; the literature comparisons above are offered as contextual precedent for dual-herb antioxidant combinations rather than as evidence of synergy in this specific formulation and formal synergy testing with single-component controls is proposed as a priority for future work.

A more directly comparable study investigated the combination of green tea (*Camellia sinensis* (L.) Kuntze) and peppermint (*Mentha × piperita*) (23). Co-macerated and lyophilised extracts produced nearly additive antioxidant interactions (combination index, $\text{CI} \approx 1.0$) in DPPH and ABTS assays, with dose reduction indices of up to 4.44. Furthermore, ternary mixtures of epigallocatechin gallate (EGCG), quercetin and rosmarinic acid exhibited the strongest synergistic interactions ($\text{CI} = 0.67\text{--}0.86$). Importantly, extract preparation methods substantially influenced the degree of interaction, with post-mixed extracts showing assay-

dependent antagonism ($\text{CI} = 1.83$) during intracellular ROS inhibition. This observation is particularly relevant because the aqueous co-extraction and equal-ratio blending strategy used in the present study parallels the co-maceration approach that produced near-additive interactions.

Comparable antioxidant activity has also been reported for pomegranate peel extracts, in which methanolic fractions produced antioxidant inhibition of up to 83 % at 50 ppm in β -carotene–linoleate and DPPH model systems. Remarkably, the aqueous sesame–raspberry formulation achieved 84.45–89.99 % scavenging activity at 50 $\mu\text{g/mL}$ in H_2O_2 and DPPH assays, despite aqueous extraction has inherently lower phenolic concentrations than organic solvents (24). Overall, the antioxidant profile of the present sesame–raspberry formulation aligns with the additive-to-near-synergistic effects reported for other complementary dual-herb combinations. The phytochemical complementarity of raspberry polyphenols and sesame lignans provides a scientifically plausible mechanistic basis for further optimisation through hydroalcoholic extraction, bioactive enrichment or nanoencapsulation to improve bioavailability and antioxidant potency.

5. Limitations of the Study

The study was limited to aqueous extracts and *in vitro* antioxidant assays; therefore, the findings may not directly reflect biological or clinical efficacy. Preliminary qualitative/semi-quantitative phytochemical screening was performed, but quantitative estimation of total phenolics, flavonoids and lignans not conducted. Stability, formulation optimisation and *in vivo* evaluation were also not performed.

The DPPH (8.0 $\mu\text{g/mL}$) and FRAP (7.4 $\mu\text{g/mL}$) IC_{50} values were extrapolated below the lowest tested concentration (10 $\mu\text{g/mL}$) and should therefore be interpreted as approximate estimates. Further studies using lower concentrations and appropriate nonlinear dose–response analysis are required for validation. Because technical replicates rather than biological replicates were used, the statistical findings should also be interpreted with caution.

Individual sesame and raspberry extracts were not evaluated separately; therefore, additive or synergistic interactions could not be determined. Future studies should include individual extract controls, quantitative phytochemical analysis and appropriate synergy assessment.

6. Future Prospects of the Study

To improve antioxidant potency, future research should incorporate solvent-based extraction, dose optimisation and comprehensive phytochemical profiling. Stability testing, wound-healing models, cell-line assays and *in vivo* experiments are essential to establish biological efficacy. The development of a standardised

nutraceutical or therapeutic product for clinical evaluation may be aided by formulation improvement, encapsulation methods and bioavailability evaluations. Future studies should also compare sesame and raspberry individually with their combined formulation under identical experimental conditions and apply appropriate synergy models to determine whether the observed antioxidant activity is additive, complementary or synergistic.

7. Conclusion

The sesame–raspberry formulation demonstrated strong, dose-dependent antioxidant activity in DPPH, H₂O₂ scavenging and FRAP assays, indicating promising free-radical scavenging and ferric-reducing potential. Its consistent activity indicates promising therapeutic utility, despite being less potent than standard ascorbic acid. This dual-herbal blend has the potential to be used as a natural antioxidant in biomedical applications with additional optimisation.

Authors' contributions

RG was responsible for the conceptualisation of the study, conducting the study, data collection and manuscript preparation. TNUM contributed to the conceptualisation of the study, statistical analysis and interpretation and manuscript editing. SRK contributed to the conceptualisation of the study and manuscript editing. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest

Authors do not have any conflict of interests to declare.

Ethical issues

None

References

- Pathak N, Bhaduri A, Rai AK. Sesame: bioactive compounds and health benefits. In: Bioactive molecules in food. Cham: Springer; 2019. p. 181–200. https://doi.org/10.1007/978-3-319-78030-6_59
- Kamal-Eldin A, Moazzami A, Washi S. Sesame seed lignans: potent physiological modulators and possible ingredients in functional foods & nutraceuticals. Recent Pat Food Nutr Agric. 2011;3(1):17–29. <https://doi.org/10.2174/2212798411103010017>
- Konsoula Z, Liakopoulou-Kyriakides M. Effect of endogenous antioxidants of sesame seeds and sesame oil on the thermal stability of edible vegetable oils. LWT Food Sci Technol. 2010;43(9):1379–86. <https://doi.org/10.1016/j.lwt.2010.04.016>
- Gomathi R, Uma Maheswari TN, Rajesh Kumar S. Sesame a boon to dentistry – a systematic review. Innovations. 2022; (70):1517.
- Ramalingam G, Uma Maheswari TN, Rajesh Kumar S. Raspberries: an aggregation of its bioactive constituents – a narrative review. J Clin Diagn Res. 2024;18(2):ZE11–5. <https://doi.org/10.7860/JCDR/2024/64699.19083>
- Szymanowska U, Baraniak B. Antioxidant and potentially anti-inflammatory activity of anthocyanin fractions from pomace obtained from enzymatically treated raspberries. Antioxidants (Basel). 2019;8(8):299. <https://doi.org/10.3390/antiox8080299>
- Nile SH, Park SW. Edible berries: bioactive components and their effect on human health. Nutrition. 2014;30(2):134–44. <https://doi.org/10.1016/j.nut.2013.04.007>
- Lopez-Corona AV, Valencia-Espinosa I, González-Sánchez FA, Sánchez-López AL, García-Amezquita LE, García-Varela R. Antioxidant, anti-inflammatory and cytotoxic activity of phenolic compound family extracted from raspberries (*Rubus idaeus*): a general review. Antioxidants (Basel). 2022;11(6):1192. <https://doi.org/10.3390/antiox11061192>
- Scott MB, Styring AK, McCullagh JSO. Polyphenols: bioavailability, microbiome interactions and cellular effects on health in humans and animals. Pathogens. 2022;11(7):770. <https://doi.org/10.3390/pathogens11070770>
- Gomathi R, Umamaheswari TN, Prethipa R. Evaluation of antioxidant, anti-inflammatory, and antimicrobial activities of raspberry fruit extract: an *in vitro* study. Cureus. 2024;16(2):e54045. <https://doi.org/10.7759/cureus.54045>
- Gomathi R, Uma Maheswari TN, Rajesh Kumar S. Comparative antioxidant activity of sesame root and leaf extract: an *in vitro* study. Int J Ayurvedic Med. 2024;15(1):143–7. <https://doi.org/10.47552/ijam.v15i1.4310>
- Noreen H, Semmar N, Farman M, McCullagh JSO. Measurement of total phenolic content and antioxidant activity of aerial parts of medicinal plant *Coronopus didymus*. Asian Pac J Trop Med. 2017;10(8):792–801. <https://doi.org/10.1016/j.apjtm.2017.07.024>
- Mahendra Kumar C, Singh SA. Bioactive lignans from sesame (*Sesamum indicum* L.): evaluation of their antioxidant and antibacterial effects for food applications. J Food Sci Technol. 2015;52(5):2934–41. <https://doi.org/10.1007/s13197-014-1334-6>
- Dar AA, Verma NK, Arumugam N. An updated method for isolation, purification and characterization of clinically important antioxidant lignans – sesamin and sesamol, from sesame oil. Ind Crops Prod. 2015;64:201–8. <https://doi.org/10.1016/j.indcrop.2014.10.026>
- Kim Y, Kim J, Kim S, Kim MY, Kim Y. Lignan content and antioxidant capacity of eight sesame varieties cultivated in Korea. Prev Nutr Food Sci. 2024;29(4):563–71. <https://doi.org/10.3746/pnf.2024.29.4.563>
- Szymanowska U, Baraniak B, Bogucka-Kocka A. Antioxidant, anti-inflammatory, and postulated cytotoxic activity of phenolic and anthocyanin-rich fractions from Polana raspberry (*Rubus idaeus* L.) fruit and juice-*in vitro* study. Molecules. 2018;23(7):1812. <https://doi.org/10.3390/molecules23071812>
- Garjonyte R, Budiene J, Labanauskas L, Judzentiene A. *In vitro* antioxidant and prooxidant activities of red raspberry (*Rubus idaeus* L.) stem extracts. Molecules. 2022;27(13):4073. <https://doi.org/10.3390/molecules27134073>

18. Baliyan S, Mukherjee R, Priyadarshini A, Vibhuti A, Gupta A, Pandey RP, et al. Determination of antioxidants by DPPH radical scavenging activity and quantitative phytochemical analysis of *Ficus religiosa*. *Molecules*. 2022;27(4):1326. <https://doi.org/10.3390/molecules27041326>
19. Benzie IF, Strain JJ. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. *Anal Biochem*. 1996;239(1):70–6. <https://doi.org/10.1006/abio.1996.0292>
20. Hadipour E, Emami SA, Tayarani-Najaran N, Tayarani-Najaran Z. Effects of sesame (*Sesamum indicum* L.) and bioactive compounds (sesamin and sesamol) on inflammation and atherosclerosis: a review. *Food Sci Nutr*. 2023;11(7):3729–57. <https://doi.org/10.1002/fsn3.3407>
21. Čanadanović-Brunet J, et al. Phenolic profile, antiradical and antitumour evaluation of raspberry pomace extract from Serbia. *Iran J Pharm Res*. 2017;16(Suppl):142–52.
22. Sariburun E, Şahin S, Demir C, Turkben C. Phenolic content and antioxidant activity of raspberry and blackberry cultivars. *J Food Sci*. 2010;75(4):C328–35. <https://doi.org/10.1111/j.1750-3841.2010.01571.x>
23. Kurin E, Hajská M, Kostovčíková E, Dokupilová K, Mučaji P, Nagy M, et al. Unveiling synergistic antioxidant effects of green tea and peppermint: role of polyphenol interactions and blend preparation. *Int J Mol Sci*. 2025;26(13):6257. <https://doi.org/10.3390/ijms26136257>
24. Negi PS, Jayaprakasha GK, Jena BS. Antioxidant and antimutagenic activities of pomegranate peel extracts. *Food Chem*. 2003;80(3):393–7. [https://doi.org/10.1016/S0308-8146\(02\)00279-0](https://doi.org/10.1016/S0308-8146(02)00279-0)

Additional information

Peer review: Publisher thanks the Sectional Editor and anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information: Available at https://horizonpublishing.com/journals/index.php/PST/open_access_policy.

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: See https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting.

Copyright: © The Author(s). This is an open-access article distributed under the Creative Commons Attribution License CC BY 4.0.

Publisher information: Plant Science Today is published by Horizon e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.