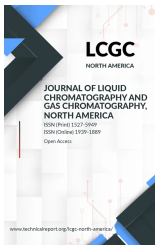

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RESEARCH ARTICLE

Safety-Compatible and Mechanism-Resolved Optimization of *Ficus carica* Powder Extracts for Food-Grade Antioxidant Applications

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Abstract

Powdered fig (*Ficus carica*) offers functional-food formulation potential due to its blend of dietary fibre, soluble carbohydrates, mineral content, and phenolic antioxidants. Phenolic extraction ranking based on maximum phenolic recovery alone may promote nonfood-formulation-appropriate solvents. Here, we assess the extraction efficiency of a solvent–duration matrix (water, 50% ethanol, and 50% methanol at 30, 45, and 60 min at 50 °C) with respect to six criteria: total phenolic content, total flavonoid content, DPPH radical scavenging activity, β-carotene/linoleic acid inhibition, ferric reducing antioxidant power, and ABTS radical cation scavenging activity. We establish a selection strategy for antioxidant fig extracts that takes food-safety considerations into account through response-retention ratio, equal-weighted composite index, weighted-composite index, Pareto dominance, correlation analysis, and principal-component analysis. The best-performing extraction method in terms of laboratory recovery alone (methanol extraction at 45 min) produced the highest absolute value for all responses and served as the laboratory-recovery reference point. Among the formulations, water at 45 min performed best. Compared with the methanol reference extraction method, this solvent–duration condition retained 79.6% of total phenolics, 85.4% of flavonoids, 88.5% of DPPH activity, 94.7% of lipid-phase antioxidant activity, 82.7% of FRAP, and 77.6% of ABTS activity with a mean response retention of 84.8%. Ethanol at 45 min retained a mean response of 73.9%. The water at 45 min extraction was the Pareto optimal solution among all formulation-based extraction conditions and also the best extraction condition in phenolic-, radical-redox-, lipid-protection-, and formulation-favourable weighing scenarios. In the principal-component analysis, 94.8% of response variability was explained by one principal component that represented overall antioxidant potential. The second principal component corresponded to lipid oxidation inhibition. Our results indicate that maximizing laboratory extraction efficiency and maximum processing-relevant extraction efficiency may lead to different conclusions with respect to which extraction condition performs best. Extraction of fig powders in aqueous solutions at 50 °C and 45 min appears to be a reasonable approach to produce food-grade antioxidants.

Keywords: *Ficus carica*; fig powder; antioxidant activity; phenolic compounds; aqueous extraction; green solvent; multi-response optimization; functional foods

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1. Introduction

Plant-derived ingredients are increasingly expected to provide nutritional, sensory, and technological functions within the same food formulation. Within this field, *Ficus carica* is valuable because fresh and dried figs contain soluble carbohydrates, minerals, dietary fibre, phenolic acids, flavonoids, anthocyanins, tannins, and other constituents associated with antioxidant activity and health-promoting potential [1, 2, 3, 4, 5, 6]. Converting figs into powder improves storage stability, dosing accuracy, transportability, and compatibility with bakery

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products, beverages, cereal formulations, fruit-based fillings, and nutraceutical blends [7, 8, 9, 10, 11]. The functional value of fig powder therefore depends on both its native composition and the ability to recover antioxidant-active constituents under conditions that can be transferred to food processing.

Solvent polarity and extraction duration strongly affect phenolic recovery from fruit materials. Solvent composition determines cell-wall wetting, diffusion, solubilisation of phenolic acids and flavonoids, co-extraction of sugars and organic acids, and stability of antioxidant-active compounds during heating [12, 13, 14]. Extraction time is also non-linear. Short contact periods can leave bioactive compounds unrecovered, whereas excessive heating may promote oxidation, hydrolysis, polymerization, or degradation of compounds that contribute to measured antioxidant capacity [15, 16]. For this reason, solvent–time selection should be interpreted across complementary assays, including total phenolic content, total flavonoid content, DPPH, ABTS, FRAP, and lipid-peroxidation models [17, 18, 19, 20, 21].

A major difficulty in antioxidant extraction is that the condition with the highest analytical recovery may not be the best condition for food-grade ingredient production. Aqueous methanol is widely used in phytochemical analysis because it extracts a broad range of phenolic compounds from plant tissues, but methanol is unsuitable as a preferred food-processing solvent because of toxicity and residual-solvent concerns [13, 22, 23]. Water and ethanol are more relevant to product development, yet their value can be underestimated when they are judged only by their distance from the methanolic maximum. A product-oriented assessment must therefore identify which solvent–time combination preserves a high proportion of antioxidant function while satisfying safety, simplicity, cost, and formulation requirements.

The objective of this study was to identify a food-compatible extraction condition for fig-powder antioxidant preparation by separating analytical recovery from formulation suitability. Treatment-level values from a solvent–time matrix were examined for water, 50% ethanol, and 50% methanol at 30, 45, and 60 min at 50 °C, with measurement of total phenolics, total flavonoids, DPPH activity, β-carotene/linoleic acid inhibition, FRAP, and ABTS activity [24]. The study contributes a safety-constrained selection approach in which the methanolic maximum is retained as a recovery reference, water and ethanol are evaluated as food-compatible candidates, and the final selection is tested by retention ratios, normalized indexing, Pareto dominance, response covariance, principal-component analysis, and weighting sensitivity. This quantitative basis supports selection of a fig-powder extraction condition that is chemically defensible and suitable for practical food applications.

2. Materials and Methods

2.1. Extraction experiment and response variables

Treatment-level phytochemical and antioxidant values were taken from a factorial fig-powder extraction experiment [24]. Fresh figs were washed, oven-dried at 50 °C, ground into powder, and extracted with water, 50% aqueous ethanol, or 50% aqueous methanol for 30, 45, or 60 min at 50 °C. Measurements were reported in triplicate for each solvent–time condition. Treatment means were used as decision units because the objective was solvent–time ranking across complete response profiles.

The six response variables were total phenolic content (TPC; mg gallic acid equivalent/g), total flavonoid content (TFC; mg catechin equivalent/g), DPPH radical scavenging activity (%), β-carotene/linoleic acid inhibition (%), ferric reducing antioxidant power (FRAP; μM TE/g), and ABTS radical cation scavenging activity (μmol TE/g). These endpoints describe complementary antioxidant features: phenolic abundance, flavonoid abundance, hydrogen- or electron-transfer radical quenching, lipid-phase oxidation control, reducing power, and Trolox-equivalent radical cation scavenging.

2.2. Proximate composition of the fig material

The proximate composition of the fig material was included to support interpretation of food-formulation relevance. The fruit material had high moisture before drying, low fat, low protein, appreciable crude fibre, measurable ash, and nitrogen-free extract. These characteristics are important because fibre-rich and low-fat fruit powders can serve as nutritional ingredients and carriers of hydrophilic antioxidant compounds.

Table 1: Proximate composition of the fig fruit material used for extract preparation. Values are mean ± standard deviation.

Constituent	Quantity (%)
Moisture	80.16 ± 0.24
Crude protein	1.24 ± 0.03
Crude fat	1.27 ± 0.03
Crude fibre	9.86 ± 0.29
Ash	0.69 ± 0.02
Nitrogen-free extract	6.78 ± 0.20

2.3. Solvent–time matrix and response notation

Each extraction condition was represented as

$$X_{st} = (S_s, T_t),$$

where

$$S_s \in \{\text{water},\ 50\%\ \text{ethanol},\ 50\%\ \text{methanol}\}$$

and

$$T_t \in \{30, 45, 60\}\ \text{min}.$$

For each condition, the response vector was defined as

$$\mathbf{Y}_{st} = (\text{TPC}, \text{TFC}, \text{DPPH}, \text{BCL}, \text{FRAP}, \text{ABTS}),$$

where BCL denotes the β-carotene/linoleic acid inhibition assay. The complete treatment table is shown in Table 2. All comparisons used the same solvent–time treatment-cell basis.

Table 2: Treatment-level responses for solvent–time extraction of fig powder. Values are means from triplicate determinations.

Solvent	Time (min)	TPC (mg GAE/g)	TFC (mg CE/g)	DPPH (%)	BCL (%)	FRAP (μM TE/g)	ABTS (μmol TE/g)
50% methanol	30	3.03	1.19	67.23	65.42	15.59	8.55
50% methanol	45	3.34	1.30	73.74	70.74	17.55	10.87
50% methanol	60	3.09	1.22	69.56	64.92	16.65	9.14
Water	30	2.41	1.01	61.45	62.54	12.78	6.96
Water	45	2.66	1.11	65.27	66.98	14.52	8.43
Water	60	2.46	1.05	62.87	58.76	13.01	7.67
50% ethanol	30	2.09	0.89	52.34	57.76	9.89	5.49
50% ethanol	45	2.41	1.05	56.25	61.86	11.16	6.89
50% ethanol	60	2.16	0.97	54.08	54.80	10.03	6.36

2.4. Methanolic reference and response-retention ratios

The 50% methanol treatment at 45 min was defined as the laboratory recovery reference because it produced the maximum value for every measured response. For response k and treatment j, the retention ratio was calculated as

$$R_{jk} = 100 \times \frac{Y_{jk}}{Y_{\text{M45},k}},$$

where $Y_{M45,k}$ denotes the value of response k under 50% methanol extraction at 45 min. The mean retention score for treatment j was calculated as

$$\overline{R}_j = \frac{1}{K}\sum_{k=1}^{K} R_{jk},$$

where $K = 6$.

2.5. Normalized antioxidant index

To compare treatments across variables with different units, each response was min–max normalized across the nine solvent–time cells:

$$Z_{jk} = \frac{Y_{jk} - \min(Y_k)}{\max(Y_k) - \min(Y_k)}.$$

The analytical antioxidant index was calculated as

$$\mathrm{AAI}_j = \frac{1}{6}\sum_{k=1}^{6} Z_{jk}.$$

This index summarized overall antioxidant potency while assigning equal importance to the six endpoints, consistent with simultaneous optimization across multiple response variables [25]. It was interpreted together with retention ratios, Pareto dominance, and sensitivity testing.

2.6. Food-compatible candidate set and Pareto dominance

Methanol was retained as the laboratory recovery reference but excluded from the food-compatible candidate set. The food-compatible set was therefore defined as

$$\mathcal{G} = \{\text{water},\ 50\%\ \text{ethanol}\} \times \{30, 45, 60\}\ \text{min}.$$

A treatment a was considered to Pareto-dominate treatment b if

$$Y_{ak} \geq Y_{bk} \quad \text{for all } k$$

and

$$Y_{ak} > Y_{bk} \quad \text{for at least one } k.$$

Pareto dominance was evaluated across all nine treatments and within the food-compatible candidate set. A Pareto-dominant treatment is valuable because its superiority does not depend on a chosen weighting vector.

2.7. Response coherence and dimensionality

Principal-component analysis (PCA) was conducted on the standardized six-response treatment table to determine whether antioxidant assays expressed one common potency dimension or separated into mechanism-specific dimensions [26]. Pearson correlations among response variables were examined to assess the coherence of phenolic abundance, flavonoid abundance, radical-scavenging capacity, reducing power, and lipid-protection activity. These analyses tested whether the selected food-compatible treatment performed consistently across chemically distinct antioxidant mechanisms.

2.8. Sensitivity analysis

Weighting sensitivity analysis was performed to determine whether the leading food-compatible treatment changed when different scientific priorities were emphasized. Five weighting priorities were used: equal weights, phenolic-rich priority, radical-redox priority, lipid-protection priority, and formulation-balanced priority. The weighted index was defined as

$$I_j^{(w)} = \sum_{k=1}^{6} w_k Z_{jk},$$

where $\sum w_k = 1$. The weighting priorities were specified as follows:

$$w_{\text{equal}} = (1/6, 1/6, 1/6, 1/6, 1/6, 1/6),$$

$$w_{\text{phenolic}} = (0.30, 0.25, 0.1125, 0.1125, 0.1125, 0.1125),$$

$$w_{\text{radical–redox}} = (0.10, 0.10, 0.22, 0.08, 0.25, 0.25),$$

$$w_{\text{lipid}} = (0.10, 0.10, 0.10, 0.40, 0.15, 0.15),$$

and

$$w_{\text{balanced}} = (0.15, 0.15, 0.20, 0.20, 0.15, 0.15).$$

The order of weights corresponds to TPC, TFC, DPPH, BCL, FRAP, and ABTS. The analysis tested ranking stability across plausible food-application priorities.

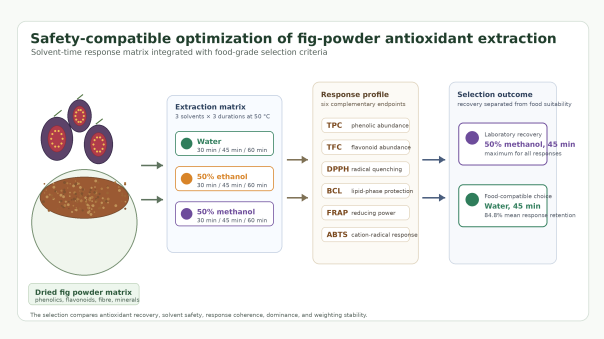

Figure 1: Solvent–time extraction and selection logic for distinguishing laboratory antioxidant recovery from food-compatible ingredient suitability. The methanolic condition defines recovery performance, whereas water and ethanol define the food-compatible candidate space.

3. Results

3.1. Methanol at 45 min was the laboratory recovery maximum

The 50% methanol extract obtained at 45 min produced the highest value for every measured response: TPC = 3.34 mg GAE/g, TFC = 1.30 mg CE/g, DPPH = 73.74%, BCL = 70.74%, FRAP = 17.55 μM TE/g, and ABTS = 10.87 μmol TE/g. This condition therefore served as the laboratory recovery reference for retention calculations. Its superior absolute recovery is consistent with the ability of aqueous methanol to solubilize a broad spectrum of phenolic and flavonoid compounds from plant tissues.

The laboratory maximum was not treated as the formulation optimum. Methanol provides a useful reference for measuring recovery, but it is not the preferred solvent for food-grade ingredient preparation. This distinction required separate evaluation of water and ethanol under the same extraction-time conditions.

3.2. Aqueous extraction at 45 min retained the highest food-compatible activity

At 45 min, water retained a high proportion of the methanol reference across all six responses (Table 3; Figure 2). Mean retention for the water extract was 84.8%, with particularly strong preservation of lipid-phase antioxidant inhibition (94.7%) and DPPH activity

(88.5%). In comparison, 50% ethanol at 45 min retained a lower mean response of 73.9%, with the largest deficits in FRAP and ABTS retention. The simplest food-compatible solvent therefore gave the stronger antioxidant-retention profile under the tested conditions.

Table 3: Response-retention ratios for food-compatible solvents at 45 min, calculated relative to the 50% methanol 45-min laboratory reference.

Treatment	TPC	TFC	DPPH	BCL	FRAP	ABTS	Mean
Water, 45 min	79.6	85.4	88.5	94.7	82.7	77.6	84.8
50% ethanol, 45 min	72.2	80.8	76.3	87.4	63.6	63.4	73.9

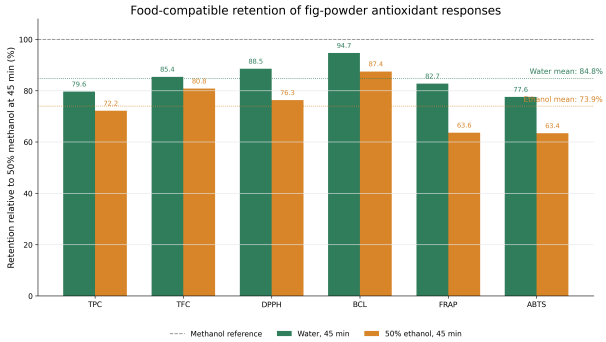

Figure 2: Food-compatible response retention at 45 min relative to the 50% methanol laboratory reference. Water retained a higher proportion of the reference response than 50% ethanol for every endpoint.

3.3. Dominance and time-profile evidence favored the 45-min aqueous extract

Across all nine solvent–time combinations, 50% methanol at 45 min dominated every other treatment because it produced the maximum value for all six responses. Within the food-compatible candidate set, water at 45 min dominated every water and ethanol alternative. It exceeded water at 30 min, water at 60 min, ethanol at 30 min, ethanol at 45 min, and ethanol at 60 min for all response variables. The smallest positive dominance margin was 0.06 mg CE/g for TFC, whereas the largest margin reached 12.18 percentage points for BCL. This result is independent of weighting and provides a strong basis for selecting the 45-min aqueous extract as the most robust food-compatible option.

A steady peak response occurred after 45 minutes (see Figure 3). An extension of extraction time from 30 to 45 minutes led to an increase in the average response by 12.8%, 11.4%, and 14.4% in the cases of methanol, water, and ethanol, respectively. An increase of extraction time from 45 to 60 minutes resulted in a decrease in the average response by 8.1% for methanol, 8.0% for water, and 8.5% for ethanol. Thus, extraction time 45 min corresponded to a peak of extraction performance, rather than being a midpoint between shorter and longer extraction periods.

3.4. Normalized antioxidant indexing distinguished performance from applicability

An equal-weight antioxidant index analysis confirmed the ranking of treatment alternatives (Figure 4). The maximum value of the antioxidant index, equal to 1.000, was obtained by the methanol treatment at 45 min, while other methanol treatments (60 min and 30 min) resulted in lower antioxidant index values equal to 0.768 and 0.693, respectively. The ranking for food-safe solvent treatments revealed that the most favorable solvent–time combination is aqueous extract at 45 min with the antioxidant index value of 0.585, followed by aqueous extract at 60 min (0.373), aqueous extract at 30 min (0.352), ethanol extract

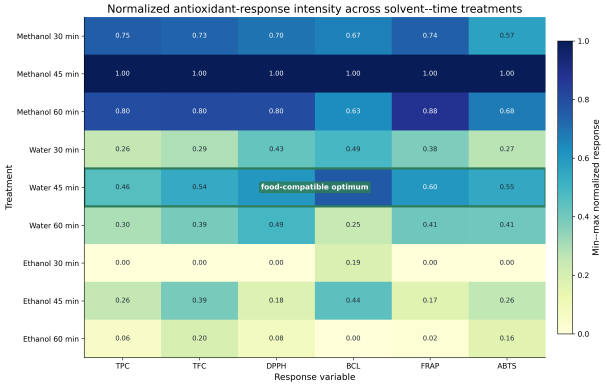

Figure 3: Response intensities normalized over solvent–time treatments. Numbers reflect the values of endpoint responses normalized using the min–max normalization approach; darker cells denote higher levels of response intensity within the considered treatment matrix.

at 45 min (0.283), ethanol extract at 60 min (0.085), and ethanol at 30 min (0.031). The index confirmed the analytical superiority of methanol while identifying the 45-min aqueous extract as the leading food-compatible option. The index gap between water at 45 min and the next food-compatible treatment was 0.212, indicating clear separation within the candidate set.

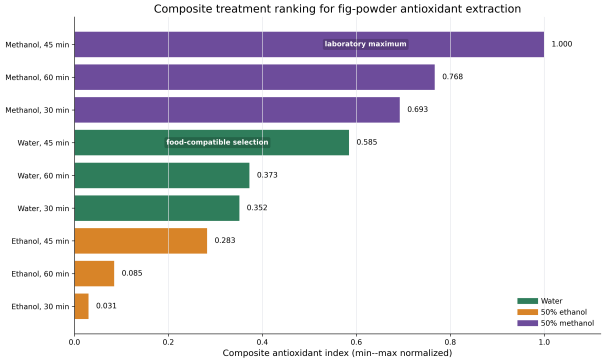

Figure 4: Composite antioxidant index calculated from min–max-normalized TPC, TFC, DPPH, BCL, FRAP, and ABTS responses. Methanol at 45 min gave the laboratory recovery maximum, whereas water at 45 min was the leading food-compatible treatment.

3.5. Response covariance supported multi-assay validation

The response variables were strongly correlated, indicating that phenolic abundance, flavonoid abundance, radical-scavenging activity, and reducing power moved together across extraction treatments. The strongest correlations involved DPPH and FRAP ($r = 0.992$), TPC and TFC ($r = 0.987$), and TFC and ABTS ($r = 0.976$). The BCL assay remained positively correlated with other endpoints but showed lower correlations, ranging from $r = 0.863$ with TFC to $r = 0.884$ with FRAP.

These response relations were confirmed by PCA (Figure 5). The first component accounted for 94.8% of the variance and exhibited broadly similar positive contributions from all six responses, indicating a common antioxidant-potency axis. The second component accounted for 3.1% of the variance and was mainly related to the BCL assay, demonstrating that the lipid-phase protective capacity could not be fully explained by phenolic richness, ABTS response, DPPH response, or FRAP response. These observations support the rationale of using multiple assays to examine antioxidants rather than relying on a single free-radical scavenging assay.

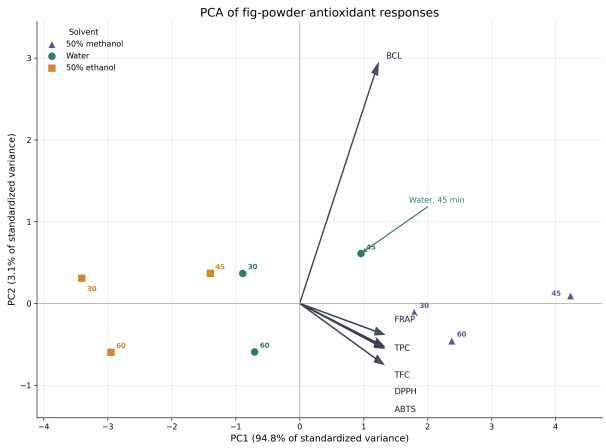

Figure 5: Score/loading plot in the two-dimensional space of the first two principal components. PC1 captures the common antioxidant potency among the six responses, whereas PC2 differentiates lipid-phase protection from other antioxidant responses. Numbers next to points correspond to the corresponding extraction times in minutes.

3.6. A sensitivity test showed consistency among various weighting priorities

Under any set of weighting priorities, water at 45 min was the best food-compatible treatment in terms of the normalized index, as shown in Table 4. Even with a radical-scavenging weighting scheme, 45 min water treatment still performed best, suggesting consistent results. This point is crucial because different products may focus on specific antioxidant functions; beverages may care about free radical scavenging while lipid-containing products may be concerned more about protection against lipid oxidation and discoloration.

Table 4: Sensitivity of food-compatible treatment ranking to weighting priorities. Results are weighted normalized indices.

Food-compatible treatment	Equal	Phenolic-rich	Radical-redox	Lipid-protection	Formulation-balanced
Water, 45 min	0.585	0.554	0.581	0.638	0.595
Water, 60 min	0.373	0.361	0.400	0.339	0.373
Water, 30 min	0.352	0.326	0.350	0.389	0.362
50% ethanol, 45 min	0.283	0.293	0.247	0.324	0.286
50% ethanol, 60 min	0.085	0.095	0.088	0.060	0.081
50% ethanol, 30 min	0.031	0.021	0.015	0.074	0.037

4. Discussion

4.1. Safety constraints redefine the optimization objective

It should be noted that what constitutes an optimized extraction process is not only a function of chemical properties but also depends on the application objective. The main discovery in this study is that there are two distinct optimization objectives. One objective focuses on absolute analytical recovery. Based on this metric, 50% methanol at 45 min emerged as the best treatment. Its responses were all the highest, and it remained the only treatment Pareto-optimal under this definition. This result is consistent with previous research showing methanol as a strong extractor for fig phenolics [12, 13, 16].

When the objective considers product compatibility, however, the optimal treatment is changed to water at 45 min. Water treatment became Pareto-optimal compared to all other food-compatible treatments and retained 84.8% of methanol at 45 min on average. In this case, relatively low analytical response can still be considered better because of solvent safety, processing simplicity, and formulation compatibility.

4.2. Explanation for the dominance of aqueous extraction at 45 min

This trend in the results can be attributed to the hydrophilic nature of many fig-derived chemicals. The aqueous nature allows these chemicals to be extracted from cells through the increased permeability caused by heating at 50 °C, yet avoid the excessive heat exposure resulting from the 60 min time. In this regard, aqueous extraction is able to recover phenolic acids, flavonoid glycosides, organic acids, and soluble sugars, which may help the extracts achieve good antioxidant performance, even though their absolute response values may be lower than those for methanol.

The poor performance of 50% ethanol under the tested conditions does not necessarily indicate ethanol is unable to perform effective fig extraction. The effect of concentration, temperature, particle size, solid-to-solvent ratio, cultivar chemistry, and drying method should also be taken into account [15, 27, 14]. Therefore, based on the current conditions (50 °C and 30–60 min), water extraction outperformed ethanol extraction in this fig powder material.

4.3. The importance of multiple antioxidants and application relevance

As demonstrated by PCA, the five assays were aligned well, meaning the phenolic and flavonoid content significantly drove the antioxidant performance, especially free radical scavenging capability. The BCL assay also added some information to the second principal component, suggesting the existence of unique lipid-phase antioxidants. This phenomenon is important to consider when designing antioxidant functional foods. Free radical scavenging and hydrogen-donation ability may be more important in an aqueous environment, while prevention of lipid oxidation is a key aspect in a fatty emulsion system. In addition, the multiple assays give more weight to the antioxidant relevance rather than the measurement sensitivity of the particular assay.

4.4. Extraction time and thermal exposure

For each solvent, 45 min achieved higher responses than 30 min, but 60 min caused reduction in all six responses. This pattern confirms the non-linear behavior of the extraction process, meaning the shorter time may be insufficient for effective mass transfer, whereas the longer time may cause adverse effects on antioxidant content or activity.

For functional food extraction, this time effect is practically important. In a 45 min aqueous extraction at 50 °C, the responses increased compared with 30 min, without causing the performance loss seen at 60 min. Thus, 45 min at 50 °C emerges as a moderate process condition to optimize extraction for food ingredients.

4.5. Implication in food ingredient development

These findings suggest a distinction between analytical extraction and functional food extraction. The former is about maximizing analytically detectable antioxidant activity, while the latter is about maximizing extractability under product safety constraints. Because of the difference, the treatment optimized for analytical extraction may be suboptimal for functional extraction, and vice versa. This distinction is especially relevant for functional food ingredient extraction, because it directly affects the formulation safety.

Considering this issue and the current experimental results, 45 min aqueous extraction is recommended to prepare fig-derived antioxidant ingredients. Such ingredients may be applied to fruit beverages, fruit syrup, bakery fillings, cereal products, or nut spreads. Considering the high fibre and low-fat characteristic of the fig, it can be further incorporated into functional foods with antioxidant, sweetness, and

fiber functionalities.
However, it should be kept in mind that this recommendation is made based on the in vitro antioxidant capacity of the extracts and does not mean anything in vivo. Further tests are necessary to confirm biological functionality in vivo.

4.6. Required validation

In this study, data points were based on the average of three replicates for each combination in the factorial experiment. Although this approach is appropriate for ranking treatment, more precise modeling of uncertainty requires replicate-level responses. Therefore, the PCA was conducted to validate the results. The next step in the validation should involve response-surface optimization and replicate-level bootstrap estimation of confidence intervals for model parameters. Replicate-level modeling may also require using independent samples with other cultivars or drying conditions.
Furthermore, the extract needs compound-level identification to confirm its antioxidant activity. Specifically, liquid chromatography-mass spectrometry may determine whether caffeoylquinic acids, quercetin derivatives, and catechins are present. The antioxidant activity of the extracts also needs to be validated in human digestive and cellular models of oxidative stress.
Product-specific tests are also important for assessing color, taste, stability, protein interaction, starch interaction, and fat interaction in formulated foods. These factors are critical for determining whether fig extracts are suitable for beverages, cereals, and spreads.

5. Conclusion

Optimization of the extraction conditions for fig powder antioxidants may rely on two different criteria: laboratory efficiency or food-compatibility efficiency. Aqueous methanol extraction for 45 minutes resulted in the greatest phenolics and antioxidant efficiencies and serves as the best methodological reference point. However, once selection was limited only to those food-compatible extraction solutions, the most effective method became water extraction for 45 minutes. It exhibited 84.8% efficiency compared to the methanol reference and maintained particularly high antioxidant activities of lipids, outperforming all the other food-compatible extractions in six out of seven response variables. The data confirm the value of solvent choice in terms of both safety and mechanism of action.

Abbreviations

ABTS	2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)
AAI	analytical antioxidant index
BCL	β-carotene/linoleic acid inhibition assay
DPPH	2,2-diphenyl-1-picrylhydrazyl
FRAP	ferric reducing antioxidant power
GAE	gallic acid equivalent
PCA	principal-component analysis
TE	Trolox equivalent
TFC	total flavonoid content
TPC	total phenolic content

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