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COMPARATIVE STUDY OF GREEN TEA AND BLACK TEA EXTRACTS (Camellia sinensis)

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Abstract

Camellia sinensis (L.) O. Kuntze is processed into green and black tea through different manufacturing steps that influence the composition of its polyphenols and other bioactive constituents. Solvent extraction is widely used to recover these compounds for analytical and applied research, while Soxhlet extraction provides repeated contact between plant material and hot solvent. This review discusses the rationale for comparing green tea and black tea extracts prepared with aqueous ethanol at 50%, 70%, 80% and 90% (v/v). Literature indicates that green tea generally retains higher concentrations of monomeric catechins, whereas enzymatic oxidation during black-tea manufacture converts a portion of catechins into theaflavins, thearubigins and related oxidation products. Ethanol–water mixtures differ in polarity and can co-extract compounds across a range of polarities; consequently, the best concentration depends on the target analytes, matrix, and extraction conditions rather than on ethanol percentage alone. Soxhlet temperature and prolonged heating may also affect thermolabile compounds and should be controlled. A comparative framework is proposed using matched sample mass, particle size, solvent-to-solid ratio, extraction duration and cycle rate, followed by extract-yield determination, total phenolic and flavonoid assays, antioxidant tests, and chromatographic profiling where available. This is a literature-based review and does not report new experimental measurements. A standardized factorial experiment is recommended to establish whether tea type, ethanol concentration and their interaction significantly affect extract yield and chemical/antioxidant properties.

Keywords: Camellia sinensis; green tea; black tea; Soxhlet extraction; aqueous ethanol; polyphenols; catechins; antioxidant activity.

Introduction



Figure 1. Green and black tea leaves and their brewed infusions

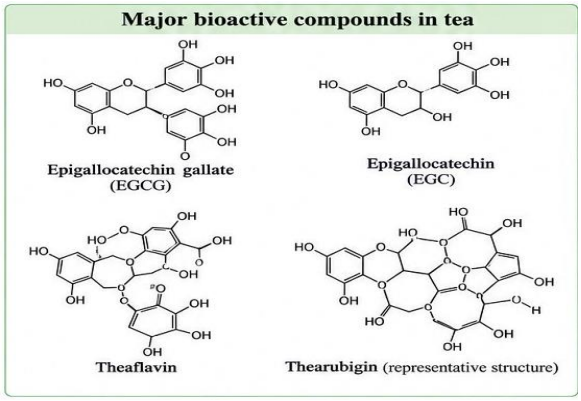
1. Tea prepared from Camellia sinensis is one of the world's most widely consumed beverages and an important source of dietary phytochemicals.
2. Green tea and black tea originate from the same plant, but their manufacturing processes produce distinct chemical profiles.
3. Green tea leaves are generally heated soon after harvest to inactivate oxidative enzymes and preserve more monomeric catechins.
4. Black tea manufacture commonly includes withering, rolling or maceration, and enzymatic oxidation before drying.
5. Major green-tea catechins include epigallocatechin gallate (EGCG), epigallocatechin (EGC), epicatechin gallate

(ECG), and epicatechin (EC).
6. During black-tea processing, some catechins are converted into theaflavins, thearubigins, and other oxidation products.
7. Tea also contains caffeine, amino acids, sugars, minerals, pigments, and volatile compounds that can be recovered to different extents during extraction.
8. The proportions of these constituents vary with cultivar, climate, leaf maturity, agronomic practice, storage, and processing conditions.
9. Comparing green and black tea extracts can therefore help explain how processing influences extract composition and measured antioxidant capacity.
10. Extraction efficiency depends on solvent polarity, temperature, extraction duration, particle size, and the ratio of solvent to plant material.
11. Mixtures of ethanol and water are frequently used for plant extraction because their composition can be adjusted to solubilize compounds with different polarities.
12. Water can hydrate and swell the plant matrix, while ethanol changes solvent polarity and may improve recovery of some phenolic constituents.
13. Soxhlet extraction repeatedly exposes a solid sample to condensed hot solvent and returns extract-containing solvent to the boiling flask by siphoning.
14. The method is useful for repeated solvent contact, but extended heating may affect thermolabile compounds and solvent use should be considered.
15. The proposed comparison considers 50%, 70%, 80%, and 90% (v/v) aqueous ethanol for both green and black tea.
16. Fair comparison requires matched tea mass, moisture basis, particle size, solvent-to-solid ratio, extraction endpoint, and solvent-removal conditions.
17. Crude extract yield alone cannot establish the recovery of target bioactive compounds because non-target substances may also be extracted.
18. Total phenolic and flavonoid assays, antioxidant tests, and chromatographic profiling can provide complementary information about the extracts.
19. Antioxidant assays are in-vitro chemical measurements and should not be interpreted as direct evidence of clinical benefit.

Review Method and Scope

A narrative literature review was prepared around research on tea processing, extraction of tea polyphenols, ethanol–water solvent systems, Soxhlet extraction and antioxidant assays. Sources include peer-reviewed studies and reviews that report tea composition or compare extraction approaches. The discussion is qualitative: reported findings from different studies are not pooled quantitatively because their sample types, analytical methods, extraction conditions and units are not directly interchangeable. The proposed experimental protocol is presented as a framework to be validated and adapted to the facilities available.

Phytochemical Composition of Green and Black Tea



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Green tea

Green tea is commonly characterized by monomeric flavan-3-ols (catechins), particularly epigallocatechin gallate (EGCG), epigallocatechin (EGC), epicatechin gallate (ECG) and epicatechin (EC). It also contains caffeine, amino acids, phenolic

acids, pigments and carbohydrates. The relative abundance of catechins varies with cultivar and processing. Green tea extraction studies report that solvent system and extraction conditions influence recovery of individual catechins and total phenolics [2,3]. Total phenolic assays, however, are nonspecific and should not be interpreted as a direct measurement of catechins alone.

Black tea

During black-tea manufacture, oxidation of catechins produces theaflavins and a heterogeneous group of higher-molecular-weight compounds often described collectively as thearubigins. Black tea still contains residual catechins, caffeine and other phenolics, but the relative profile differs from that of green tea. Comparative analytical work has found lower levels of several monomeric catechins in black tea than in green tea, consistent with their conversion during processing [1,6]. Theaflavins contribute to colour, briskness and astringency, while thearubigins contribute substantially to colour and overall phenolic complexity.

Why the comparison matters

A higher crude-extract mass does not necessarily mean a higher concentration of the desired bioactive compound. Extract mass may include sugars, amino acids, caffeine, pigments and other co-extractives. Accordingly, the green-versus-black comparison should report extract yield alongside at least one global phenolic measure and, ideally, a compound-specific profile. Antioxidant assays provide complementary functional measurements but are chemical tests in vitro and do not establish clinical benefit.

Soxhlet Extraction and Ethanol Concentration

Soxhlet extraction repeatedly washes a solid sample with condensed solvent. The solvent is heated in a flask, vapour rises and condenses, and the condensate passes through the thimble containing the tea powder. When the extraction chamber reaches the siphon level, solvent carrying soluble constituents returns to the boiling flask. Repeated cycles provide renewed solvent contact without requiring fresh solvent for each wash. The method is relatively straightforward and can provide exhaustive extraction, but it uses heat for an extended period and may consume more energy than some modern techniques.

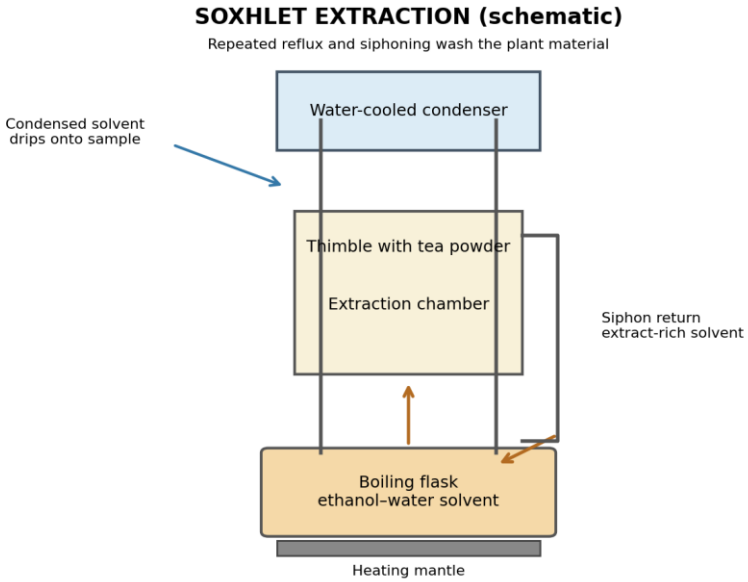


Figure 2. Schematic Soxhlet extraction apparatus and solvent-reflux cycle.



Figure 3. Soxhlet extraction apparatus used for tea extraction.

Ethanol concentration changes the polarity of the solvent mixture. A 50% ethanol solution contains more water and may promote matrix swelling and extraction of highly polar compounds. Higher ethanol fractions can favour compounds with lower polarity and may reduce extraction of some highly hydrophilic constituents. These are general solvent effects rather than guaranteed outcomes: the response depends on the chemical species, matrix, temperature and duration. Studies have reported effective recovery of tea polyphenols using aqueous ethanol, while other work shows that extraction technique and operating conditions can change catechin profiles [2–5].

Soxhlet extraction also introduces a thermal consideration. The boiling temperature of the ethanol–water mixture varies with composition, and sustained heating can affect sensitive compounds. For fair comparison, the study should document the actual solvent composition, apparatus settings, extraction time or number of cycles, and any temperature measurement. Solvent should be removed using a controlled method, preferably reduced-pressure evaporation where available, and extracts should be stored in amber containers at low temperature until analysis.

Proposed Comparative Experimental Framework



Figure 4. Working principle of Soxhlet extraction.

Study groups and controls

The proposed design contains eight primary groups: green tea extracted with 50%, 70%, 80% and 90% ethanol, and black tea extracted with the same four concentrations. Each condition should be prepared in at least triplicate independent extractions. Use a single well-mixed batch of each tea type where possible, and record brand/cultivar, origin, batch, processing details and storage history. A solvent blank should be carried through the analytical procedures. If resources permit, include a reference extraction or quality-control sample to monitor batch-to-batch assay variation.

Sample preparation and extraction

Dry the tea samples to a consistent moisture condition if moisture varies substantially, grind them to a uniform particle-size range, and mix thoroughly. Weigh an identical mass (for example, 10.0 g) into a suitable cellulose thimble. Add a fixed volume of the assigned ethanol–water solvent, keeping the solvent-to-solid ratio identical across all groups. The exact mass, volume, extraction time and apparatus scale should be selected after a small pilot test and then held constant. Run the Soxhlet apparatus at a consistent siphon-cycle rate and a pre-defined endpoint, such as a fixed duration or number of cycles. Avoid open flames; use suitable laboratory ventilation and heating equipment rated for flammable solvents.

Concentration and extract yield

After extraction, cool the apparatus and recover the solvent. Remove solvent under controlled conditions and dry the extract to constant mass where feasible. Calculate crude extract yield as: extract yield (%) = (mass of dried extract / initial dry mass of tea) × 100. Report the mean and standard deviation for each group. A high crude yield should not be described as high phenolic recovery unless supported by the chemical assays.

Suggested analytical endpoints

Total phenolic content can be estimated using the Folin–Ciocalteu method and expressed as mg gallic acid equivalents per g of dry extract or per g of starting dry tea; the denominator must be stated clearly. Total flavonoid content may be estimated using a validated aluminium-chloride-based assay, while antioxidant capacity may be assessed by DPPH, ABTS or FRAP. Include calibration curves, blanks, replicate readings and suitable controls. Folin–Ciocalteu values can be influenced by non-phenolic reducing substances, and antioxidant assays differ in reaction mechanism, so results from different assays should be interpreted together rather than treated as interchangeable.

Where instrumentation is available, HPLC-DAD or LC-MS can profile catechins (EGC, EC, EGCG, ECG), caffeine, gallic acid and selected black-tea oxidation products such as theaflavins. Use authentic standards, validated chromatographic conditions and suitable quality controls. UV absorbance alone may not reliably distinguish complex mixtures. Report concentrations using consistent units and state whether values are normalized to dry extract or original tea mass.

Comparative Interpretation of the Four Ethanol Concentrations

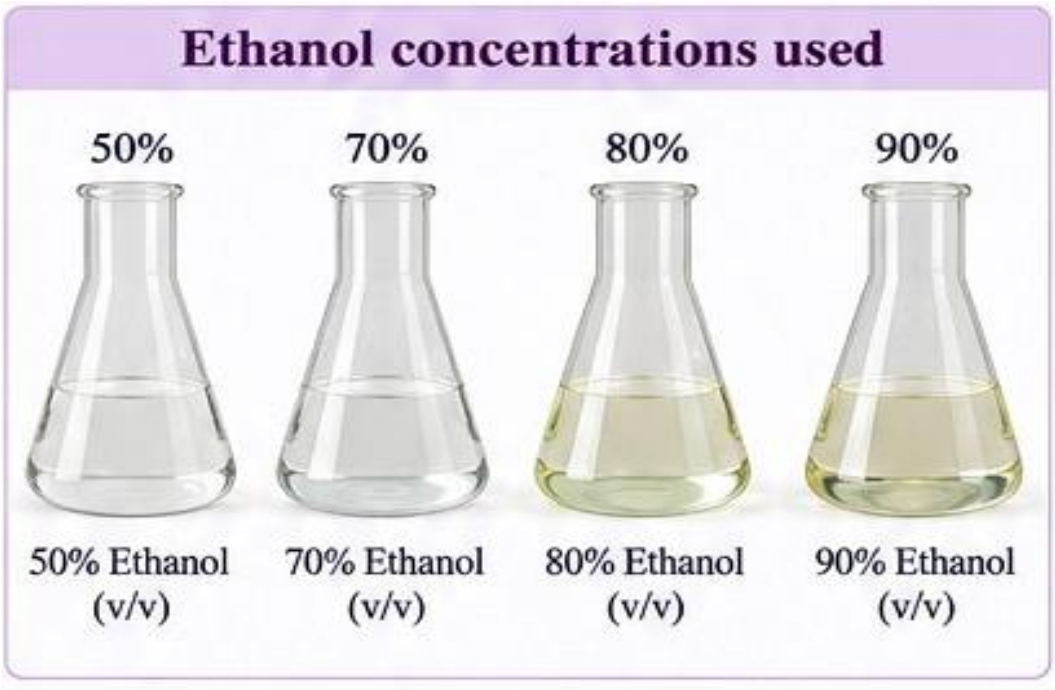


Figure 5. Aqueous ethanol concentrations considered for extraction (50%, 70%, 80%, and 90% v/v).

The four ethanol concentrations provide a useful solvent-polarity series, but a universal ranking should not be assumed. The 50% mixture may favour recovery of highly polar constituents and can support matrix hydration. The 70% and 80% mixtures provide intermediate polarity and may offer a compromise between water-soluble and ethanol-soluble components. The 90% mixture may favour some less-polar constituents, but can be less effective for compounds requiring more water for matrix swelling or dissolution. These expectations are hypotheses to test, not results for the proposed study.

The optimal solvent may differ by endpoint. One concentration could produce the greatest crude mass, another the highest total phenolics per gram of tea, and a third a more favourable catechin profile or antioxidant response. Literature on tea extraction illustrates this endpoint dependence: aqueous ethanol has been effective for polyphenol recovery, while studies using different extraction technologies report different yields and profiles [2–5]. Therefore, the article should not declare a winning concentration until replicated data and statistical comparisons are available.

Statistical Analysis and Quality Assurance



Figure 6. Proposed workflow for comparative Soxhlet extraction and analysis of green and black tea extracts.

For each endpoint, summarize independent extractions as mean ± standard deviation. A two-factor analysis of variance (ANOVA) can test the effects of tea type (green/black), ethanol concentration (50/70/80/90%) and their interaction, provided assumptions are reasonably met. Check residual normality and variance homogeneity; consider transformation or an appropriate robust/non-parametric alternative when assumptions fail. Use a suitable post-hoc test with correction for multiple comparisons, and report exact p-values, effect sizes and confidence intervals where possible. Technical repeat readings of one extract should not be counted as independent extraction replicates. Control potential confounders by matching sample mass, moisture basis, particle size, solvent-to-solid ratio, extraction endpoint, evaporation conditions and storage time. Randomize the order of extraction and assay runs where practical. Record deviations, include blanks, and present raw or supplementary data so that findings can be reproduced.

Limitations and Research Gaps

Published tea studies vary in tea source, manufacturing history, particle size, solvent composition, extraction technique and analytical endpoint. Consequently, results from maceration, ultrasound-assisted extraction, pressurized extraction and Soxhlet extraction are not directly interchangeable. Global colourimetric assays do not identify individual compounds, and antioxidant tests in chemical systems cannot directly predict biological efficacy. Soxhlet's extended heating may alter thermolabile constituents, while ethanol is flammable and requires appropriate handling and solvent recovery.

A useful next step is a fully replicated factorial experiment that combines yield, total phenolic content, antioxidant assays and chromatographic characterization. Future work could compare Soxhlet extraction with ultrasound-assisted or other lower-temperature techniques, assess energy and solvent consumption, and evaluate the stability of extracts during storage. Reporting both results per gram of dry tea and per gram of extract would distinguish extraction efficiency from extract enrichment.

Conclusion

Green and black tea differ in their polyphenol profiles because their processing histories differ: green tea generally retains more monomeric catechins, while black tea contains oxidation products such as theaflavins and thearubigins. Aqueous ethanol at 50%, 70%, 80% and 90% offers a structured way to study solvent-polarity effects in Soxhlet extraction. However, the optimum concentration cannot be established from solvent composition alone and may depend on whether the target is crude yield, total phenolics, individual catechins, black-tea pigments or antioxidant response. A controlled eight-group design with independent replicates, standardized extraction conditions, validated assays and suitable statistical analysis is recommended. The present article is a narrative review and proposed study framework, not a report of original experimental results.References

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