National Pingtung University of Science and Technology

Department of Tropical Agriculture and International Cooperation (DTAIC)

Comparative Evaluation of Antioxidant Activity and Catechin Profile of Oolong Tea from Different Geographical Origins

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Introduction

- ✓ Tea is the most popular and consumable and non-alcoholic beverages globally (Yang et al. 2021).
- ✓ It is consumed because of its aroma, taste, and health benefits.
- ✓ The vital components of tea: polyphenols and theanine (Yang et al. 2020).
- ✓ Tea quality is determined by the concentration and composition of bioactive compounds in the tea leaves, which affects the color of the tea.
- ✓ Quality of tea is mainly affected by several parameters soil, climate, plucking season, and different processing techniques.

Introduction

Taiwan produces a variety of teas due to its unique geographical and climatic conditions:

- ❖ unfermented green tea,
- ❖ fully fermented black tea, and
- ❖ semifermented **Oolong** tea.

- ✓ Tea quality and composition are influenced by cultivar, origin, environmental conditions, and processing methods.

- ✓ Such variations significantly influence the profile of volatile compounds, which are key contributors to the aroma and sensory quality of oolong tea (Lan et al., 2022).

- ✓ Additionally, antioxidants, catechins, and caffeine are important indicators of tea quality and functionality due to their strong bioactive properties.

- ✓ Owing to these distinctive qualities, oolong tea has gained increasing consumer preference (Chen et al., 2022).
- ✓ However, Taiwanese **Oolong** tea production is insufficient to meet demand and industry is influenced by neighbouring countries (Wu et al. 2020).
- ✓ In this context, fake and non-authenticated teas are being sold in the market at higher prices.

Introduction

- ✓ Traditional methods of assessing tea quality rely on sensory evaluation and physicochemical index detection (Xu et al. 2019).
- ✓ Sensory evaluation appreciate the color, smell, shape and flavor of tea (Hu et al. 2021):
  - ❑ Subjectivity, panelist variability, training requirements, and bias results
- ✓ Techniques have been used to classify tea:
  - ❑ Capillary electrophoresis (CE), high performance liquid chromatography (HPLC), spectrophotometry, and gas chromatography–mass spectrometry (GC–MS).

Introduction

- ✓ Jin Xuan, officially designated as Taiwan Tea Experiment Station No. 12 (TTES No. 12), is a well-known tea cultivar developed in Taiwan by the Tea Research and Extension Station, Ministry of Agriculture.
- ✓ It is traditionally associated with the production of high-quality of Oolong tea (Wang et al., 2025b) .
- ✓ Its cultivation has expanded beyond Taiwan to other regions due to its favourable agronomic characteristics and increasing market demand (Kuo & Boseley, 2025; Shao et al., 2023) .
- ✓ Geographical expansion increases variability in Jin Xuan oolong tea, raising mislabelling concerns and the need for reliable authentication methods.

Objectives

✓The objective of this study was to investigate origin-based differences in antioxidant activity

✓To analyze the phytochemical composition of OT samples from China, Taiwan, Indonesia, and Vietnam.

Material and methods

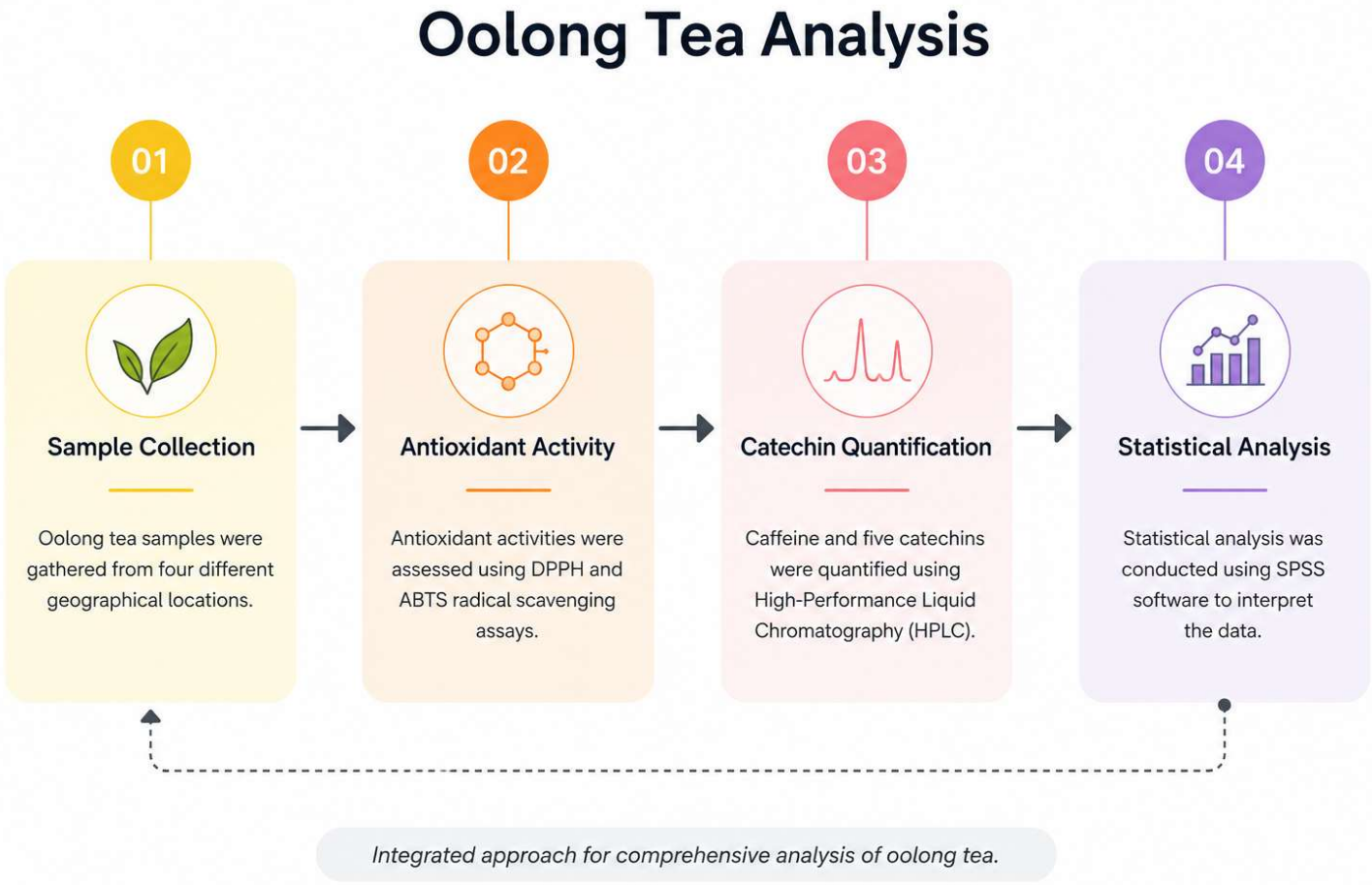


Figure 1. Experimental design of the proposed research work.

Material and methods

❑ Collection of tea samples

✓ Three different types of tea were collected from tea factory ‘Taoyuan’

Table 1. Detailed information of tea samples.

S. No.	Tea sample	Origin
1	Oolong tea	Taiwan
2	Oolong tea	China
3	Oolong tea	Vietnam
4	Oolong tea	Indonesia

Figure 2. The tea factory in Taoyuan.

Material and methods

❑ Antioxidant analysis

- ✓ ABTS and DPPH determination
- ✓ 5 catechins and Caffeine were analysed by using HPLC

❑ Chemometric methods

- ✓ The interpretation of data is accomplished by use of chemometric methods (Kiani et al. 2016)
  - ❖ **Principal Component Analysis (PCA)**
  - ❖ **Hierarchical Cluster Analysis (HCA)**

Material and methods

❑ Antioxidant activity

- ✓ **DPPH:** Sample extracts (2–20 µg/mL) were reacted with 0.2 mM DPPH for 30 min in dark conditions. Absorbance was measured at 517 nm; BHA was used as control.

- ✓ **ABTS:** Sample extracts (10–200 µg/mL) were mixed with ABTS solution for 6 min in dark conditions. Absorbance was measured at 734 nm; Trolox was used as control.

Material and methods

- **High-performance liquid chromatography**

- ✓ **HPLC:** Analysis was performed using Shimadzu LC-20AT HPLC with a Hypersil GOLD PFP column (35 °C, 1 mL/min). Caffeine and catechins were detected at 278 nm with 20 µL injection volume.

- ✓ **Quantification:** Gradient elution with acetic acid-water (A) and methanol (B) was used. Total catechins were calculated as the sum of individual catechins.

- ✓ Caffeine and five catechins (EGC, EGCG, EC, ECG, and GCG) were quantified by HPLC

Results and discussions

✓ Antioxidant activities (DPPH, ABTS) of oolong tea (OT) samples from different geographical origins.

OT Origins	Antioxidant activities	
	DPPH IC_{50} (μg/mL)	ABTS IC_{50} (μg/mL)
Taiwan	10.40 ± 0.21^{c}	98.58 ± 1.15^{d}
Vietnam	15.47 ± 0.58^{a}	105.97 ± 0.93^{c}
China	9.43 ± 0.42^{d}	116.52 ± 2.76^{b}
Indonesia	12.10 ± 0.06^{b}	128.95 ± 2.04^{a}

Table 2. Results are expressed as mean ± SD (n = 3). Different superscript letters (a-d) within a column indicate significant differences ($p < 0.05$) based on Duncan's multiple range test.

✓ **DPPH Assay:** Chinese sample showed the strongest activity (lowest IC_{50}), followed by Taiwan, Indonesia, and Vietnam.

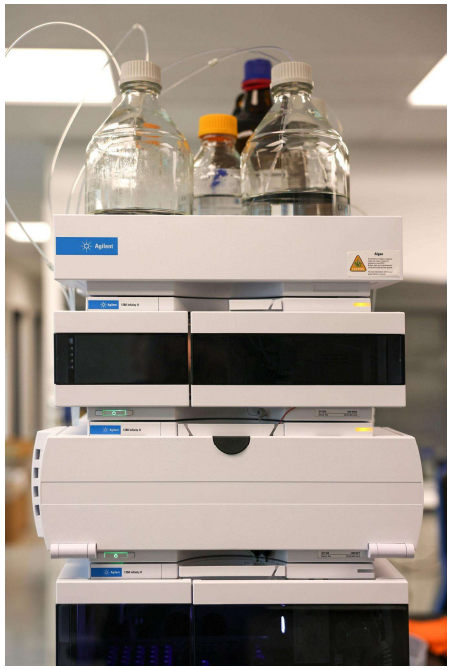
✓ **ABTS Assay:** Taiwanese sample showed the strongest activity, followed by Vietnam, China, and Indonesia.

Results and discussions

✓ Contents of caffeine and catechins in oolong tea (OT) samples from four geographical origins.

OT Origins	Caffeine (mg/g)	Catechins (mg/g)					
		EGC	EGCG	EC	ECG	GCG	TC
Taiwan	5.50 ± 0.21^{b}	22.60 ± 0.90^{d}	3.87 ± 0.04^{b}	8.10 ± 0.13^{c}	30.30 ± 0.45^{c}	39.56 ± 0.39^{b}	104.51± 14.96
Vietnam	5.75 ± 0.40^{ab}	55.33 ± 1.66^{a}	4.99 ± 0.02^{a}	6.40 ± 0.04^{d}	47.02 ± 1.27^{a}	51.63± 1.24^{a}	165.37 ± 25.17
China	6.32 ± 0.37^{a}	47.61 ± 1.27^{b}	2.10 ± 0.07^{c}	11.63 ± 0.16^{b}	44.67 ± 0.76^{b}	50.47 ± 1.48^{a}	156.48 ± 22.65
Indonesia	5.34 ± 0.18^{b}	32.19 ± 0.57^{c}	2.24 ± 0.13^{c}	12.07± 0.19^{a}	47.58 ± 0.51^{a}	40.79 ± 0.57^{b}	134.87 ± 19.21

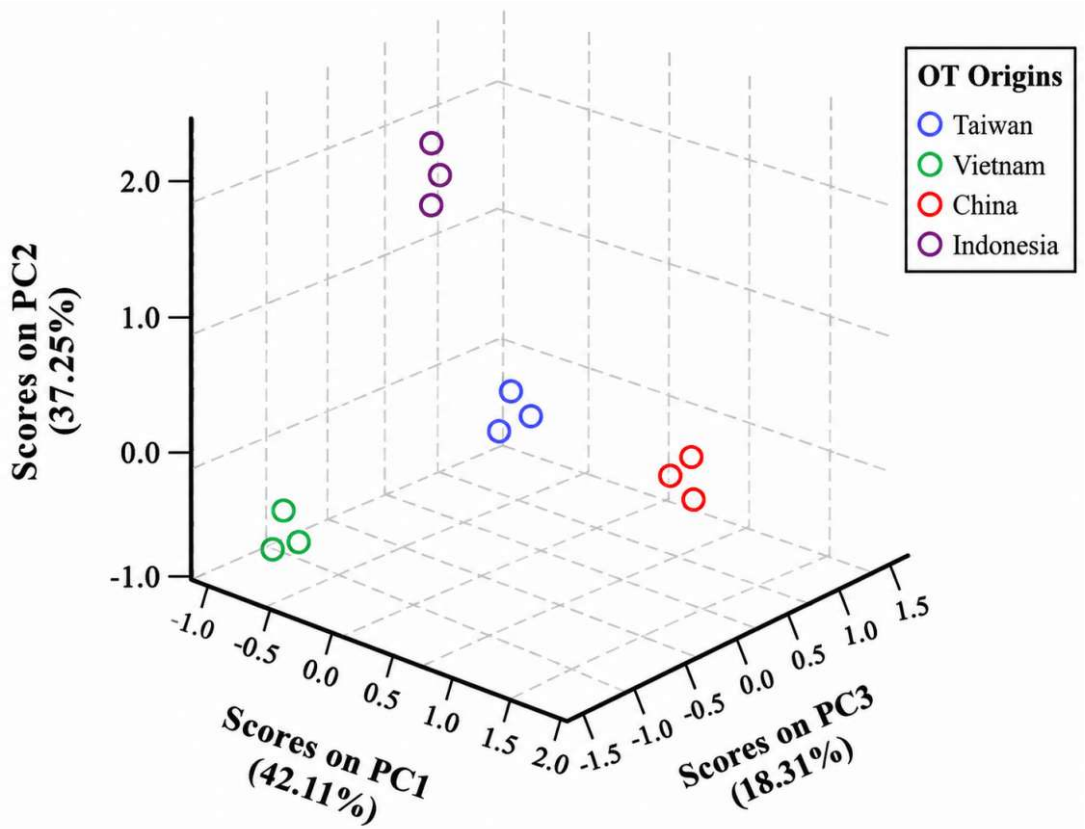
Table 3: Results are expressed as mean ± standard deviation (SD) (n=2). Different superscript letters (a-d) within a column indicate significant differences ($p < 0.05$) based on Duncan's multiple range test.



✓ Caffeine and catechin contents differed significantly among origins, with Chinese tea showing the highest caffeine level.

✓ EGC was the dominant catechin, while Vietnamese tea showed the highest EGCG and total catechin content.

Results and discussions

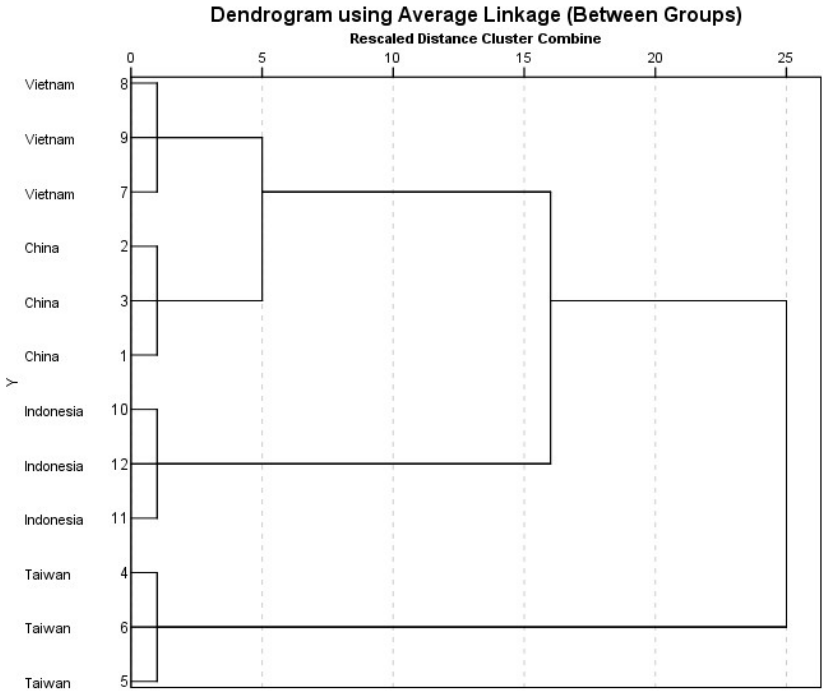


PCA- Principal Component Analysis

Figure 3: 3D-PCA score plot of oolong tea samples from Taiwan, Vietnam, China, and Indonesia showing clear discrimination based on geographical origin. PC1, PC2, and PC3 explained 42.11%, 37.25%, and 18.31% of the variance, respectively, with a cumulative variance of 97.67%.

Results and discussions

Hierarchical cluster analysis (HCA)



- ✓ Taiwan samples formed a distinct cluster, while China and Vietnam showed closer similarity, demonstrating the effectiveness

- ✓ **Figure 4**: HCA dendrogram of oolong tea samples from Taiwan, Vietnam, China, and Indonesia using average linkage (between groups), showing distinct clustering patterns according to geographical origin.

Conclusion

The study demonstrated:

- ✓ Geographical origin significantly influenced the antioxidant activity and catechin profile of oolong tea.
- ✓ PCA and HCA successfully differentiated tea samples based on origin.
- ✓ The findings support tea authentication, quality control, and prevention of mislabelling.

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Publications

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Review

Applications of Electronic Nose Coupled with Statistical and Intelligent Pattern Recognition Techniques for Monitoring Tea Quality: A Review

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Article

Geographical Origin Classification of Oolong Tea Using an Electronic Nose: Application of Machine Learning and Gray Relational Analysis

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Computer vision and deep learning-based approaches for detection of food nutrients/nutrition: New insights and advances

Sushant Kaushal [a], Dushyanth Kumar Tammineni [b], Priya Rana [a], Minaxi Sharma [c], Kandi Sridhar [d], Ho-Hsien Chen [e]

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