National Pingtung University of Science and Technology

Department of Tropical Agriculture and International Cooperation (DTAIC)

Geographical origin classification of Oolong teas using color analysis and chemometric methods

Name: Sushant Kaushal

Advisor: Dr. Ho-Hsien Chen

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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.

- ✓ 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
- ✓ Conventional analytical techniques have been used to classify tea:
  - ❑ Capillary electrophoresis (CE), high performance liquid chromatography (HPLC), spectrophotometry, and gas chromatography–mass spectrometry (GC–MS)
  - ❑ Time consuming, expensive, and require specialized workers, and pretreatment of tea samples (Xu et al. 2021).

Introduction

- ✓ Consequently, consumers often associate higher prices with higher quality due to a lack of standardized evaluation methods (Li et al. 2024).
- ✓ Therefore, it is essential to establish an accurate, efficient, and objective approach to tea quality evaluation, specifically in terms of assessing appearance.
- ✓ Implementing such standardization would provide valuable guidance to consumers in the market.

Objectives

- ✓ To develop a precise, efficient, and unbiased method for differentiating oolong teas from various geographical origins using their color characteristics.
- ✓ To apply chemometric techniques for reliable origin-based classification of oolong teas.

Material and methods

❑ Collection of tea samples

✓ Four origin-based oolong tea samples were collected from tea factory 'Taoyuan'

Table 1. Detailed information of tea samples.

S. No.	Tea sample	Origin	No. of samples
1	Oolong tea	Taiwan	24
2	Oolong tea	Vietnam	24
3	Oolong tea	China	24
4	Oolong tea	Indonesia	24

Figure 1. The tea factory in Taoyuan.

Material and methods

- **Color analysis**
  - ✓ L*, a*, and b* determination
- **Multivariate analysis of variance (MANOVA)**
- **Chemometric methods**
  - ✓ The interpretation of data is accomplished by use of chemometric methods (Kiani et al. 2016)
    - ❖ **Principal Component Analysis (PCA)**
    - ❖ **Discriminant Analysis (DA)**

Results and discussion

❑ MANOVA

Table 2. Color characteristics of Oolong tea samples from different origins.

Sample	Color characteristics		
	L*	a*	b*
Taiwan OT	19.86 ± 0.87^{c}	1.24 ± 0.37^{b}	9.47 ± 0.87^{c}
Vietnam OT	22.18 ± 1.86^{b}	2.08 ± 0.50^{a}	11.94 ± 2.49^{b}
China OT	26.91 ± 4.13^{a}	0.52 ± 0.29^{c}	11.43 ± 2.07^{b}
Indonesia OT	22.35 ± 3.56^{b}	1.99 ± 0.42^{a}	13.43 ± 2.22^{a}

- ✓ Data is represented as mean ± SD (n=72). Mean values followed by different superscripts (a-c) within the same column are significantly different ($p < 0.05$), n = replicates and OT = Oolong tea. L*: lightness/darkness; a*: redness/greenness; b*:yellowness/blueness .

- ✓ China OT is lightest, Taiwan OT is darkest, Vietnam and Indonesia OTs are red, and Indonesia OT most yellow ($p < 0.05$).

Results and discussion

❑ MANOVA

Table 3. MANOVA results of color characteristics of Oolong tea samples from different origins.

Test	Value	F-value	Hypothesis df	Error df	p-value	Partial Eta Squared
Pillai's trace	1.295	71.868	9.000	852.000	0.000	0.432
Wilks' lambda	0.107	114.982	9.000	686.465	0.000	0.526
Hotelling's trace	4.999	155.907	9.000	842.000	0.000	0.625
Roy's largest root	4.333	410.218	3.000	284.000	0.000	0.812

✓ Pillai's trace ($F(9,852) = 71.868$, $p = 0.000 < 0.05$; Pillai's trace = 1.295) and Wilks' lambda ($F(9,686.465) = 114.982$, $p = 0.000 < 0.05$; Wilks' lambda = 0.107) tests were considered.

Results and discussion

❑ Principal component analysis (PCA)

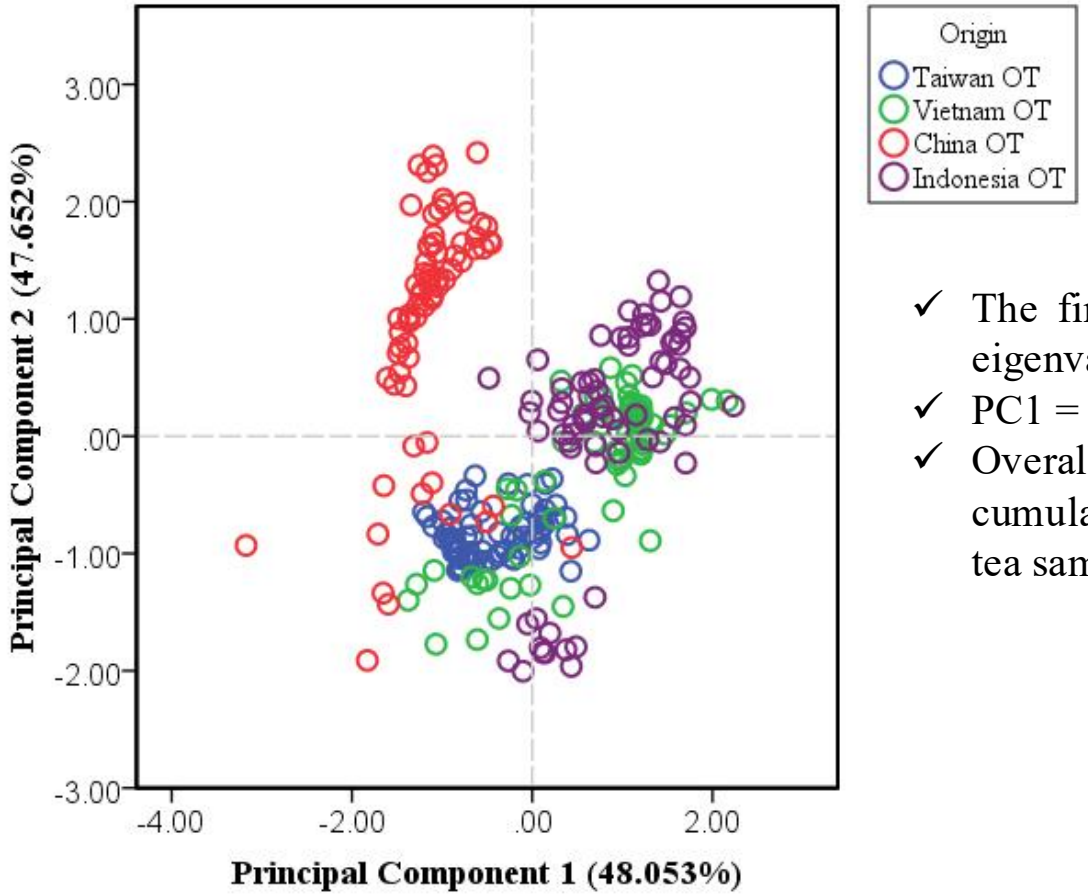
Table 4. KMO and Bartlett's Test of Sphericity.

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy		**0.270**
Bartlett's Test of Sphericity	Approx. Chi-Square	387.039
	df	3
	Sig.	0.000

- ✓ KMO value of 0.270.
- ✓ Supported the inappropriateness of the data for performing PCA.

Results and discussion

❑ Principal component analysis (PCA)



- ✓ The first two PCs extracted presented eigenvalues exceeding 1.
- ✓ PC1 = 48.053% and PC2 = 47.652%
- ✓ Overall, explained 95.704% of the cumulative variance between oolong tea samples of different origins.

Figure 2. PCA sore plot of different oolong teas based on color characteristics.

Results and discussion

❑ Principal component analysis (PCA)

Table 5. Total variance explained and principal component loading matrix.

	Principal components	
	PC1	PC2
Total variance explained		
Eigenvalue	1.442	1.430
% Variance	48.053	47.652
Cumulative %	48.053	95.704
Variable loading		
L*	-0.108	0.976
a*	0.975	-0.116
b*	0.693	0.681

Results and discussion

❑ Discriminant analysis (DA)

Table 6. Step-wise DA characteristics of different oolong tea samples.

Function	Eigen value	% Variance	Cumulative %	Canonical correlation
1	4.333	86.70	86.70	0.901
2	0.476	9.50	96.20	0.568
3	0.190	3.80	100.00	0.399

- ✓ Three significant discriminant functions (DF1 = 86.70%, DF2 = 9.50% and DF3 = 3.80%) accounted for 100% of the total variance.
- ✓ DF1 exhibited a high eigenvalue (4.333) and canonical correlation of 0.901, followed by DF2 (having an eigenvalue of 0.476 and canonical correlation of 0.568) and DF3 exhibited 0.190 eigen value with 0.399 canonical correlation.

Results and discussion

❑ Discriminant analysis (DA)

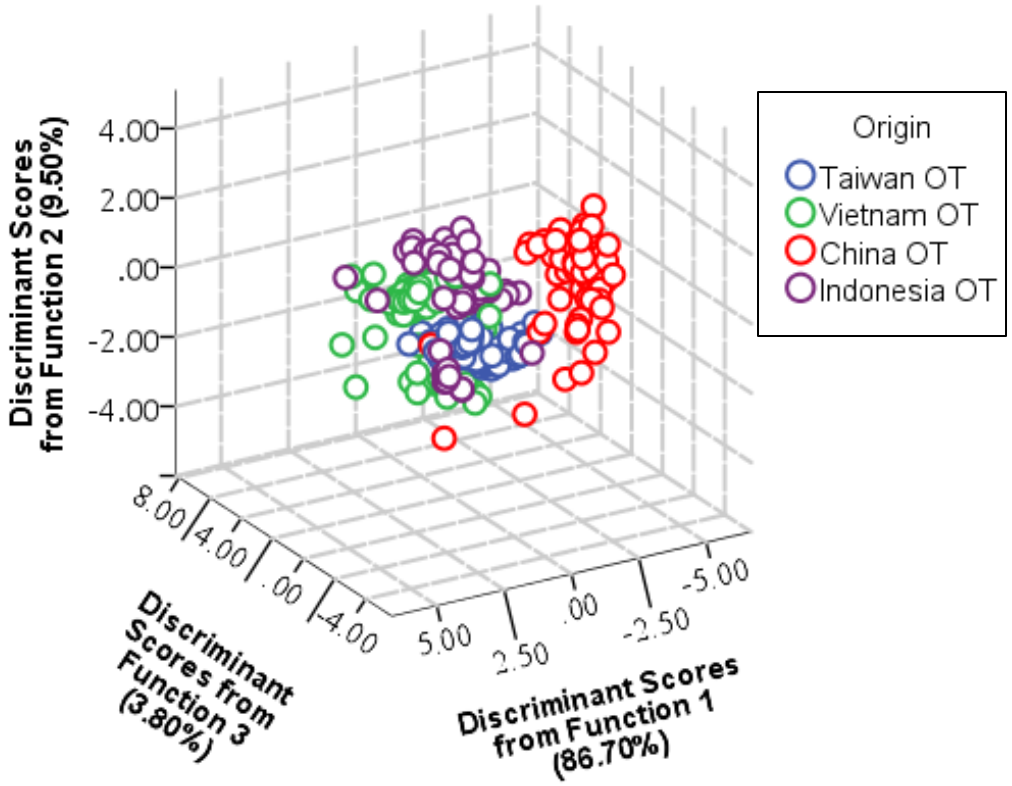


Figure 3. 3-D score plot of different Oolong tea of different origins based on three discriminant functions.

Results and discussion

❑ Discriminant analysis (DA)

Table 7. Classification results of different Oolong tea samples using discriminant analysis.

		Predicted Group membership				
	Origin	Taiwan	Vietnam	China	Indonesia	Total
Count	Taiwan	57	14	0	1	72
	Vietnam	12	44	0	16	72
	China	6	1	65	0	72
	Indonesia	10	9	1	52	72
%	Taiwan	79.2	19.4	0.0	1.4	100.0
	Vietnam	16.7	61.1	0.0	22.2	100.0
	China	8.3	1.4	90.3	0.0	100.0
	Indonesia	13.9	12.5	1.4	72.2	100.0

Conclusions

✓ The study demonstrated:

- The potential of using a color analysis coupled with chemometric methods for classification of different teas.
- DA provided the better classification among the oolong teas, providing the new insight to tea industry.

Major References

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Acknowledgements

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