frontiers | Frontiers in Agronomy

TYPE Original Research
PUBLISHED 08 May 2024
DOI 10.3389/fagro.2024.1304559

The quality difference in five oolong tea accessions under different planting management patterns in south Fujian of China

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RECEIVED 04 October 2023
ACCEPTED 12 April 2024
PUBLISHED 08 May 2024

CITATION
He H, Jiang Y, Su C, Min Q, Wu W, Xie K, Yue L, Chen Z, Lin W and Yi P-I (2024) The quality difference in five oolong tea accessions under different planting management patterns in south Fujian of China. *Front. Agron.* 6:1304559. doi: 10.3389/fagro.2024.1304559

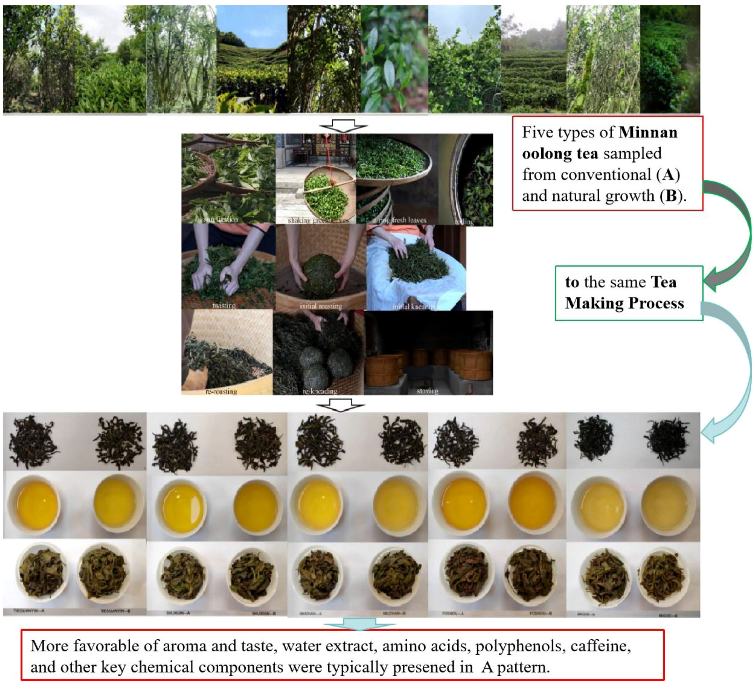
Introduction: Oolong tea, celebrated for its significance in Chinese tea culture, was the subject of investigation in this study.

Methods: Five varieties of Minnan oolong tea were sampled, each cultivated under two distinct management approaches: conventional management and natural growth methods. The study aimed to discern variations in sensory attributes, encompassing appearance and liquor color, alongside the analysis of chemical composition.

Results and discussion: The results indicated that oolong tea cultivated through conventional manual management generally exhibited qualities in terms of shape and foliage appearance, in contrast to those grown naturally. However, naturally grown oolong tea tended to exhibit more favorable aroma and taste profiles compared to conventionally managed counterparts. Furthermore, the content of water extract, amino acids, polyphenols, caffeine, and other pivotal chemical constituents were typically higher in naturally grown tea varieties compared to conventionally managed ones. Conversely, catechin content was found to be more abundant in traditionally managed bushes than in those grown naturally. These findings emphasize the significance of implementing appropriate natural growth management practices to enhance the quality of Minnan oolong tea and maintain ecological sustainability.

KEYWORDS

tea accessions, oolong tea, planting pattern, sensory evaluation, biochemical composition



GRAPHICAL ABSTRACT

1 Introduction

Oolong tea, renowned for its unique flavor, is one of the most well-known tea varieties in China and is cherished by both domestic and international consumers (Zeng et al., 2020; Lin et al., 2022). Fujian Province serves as the primary production region for oolong tea in China. In 2021, the tea gardens in Fujian covered an area of 232,066.7 hectares and yielded a total output of 488,000 tons. The entire tea industry chain generated an output value exceeding 140 billion yuan, showcasing a robust development pattern (Xu et al., 2021). As the first county to produce critical teas in China for numerous years, Anxi County stands as the birthplace of several esteemed national elite tea cultivars such as Tieguanyin, Huangdan, Maoxie, Benshan Meizhan, and Daye-oolong (Guo et al., 2022; Hu et al., 2022; Hong et al., 2023). Moreover, it boasts abundant germplasms of tea bushes. In 2022, "Anxi Tieguanyin Tea Culture System" was recognized by the Food and Agriculture Organization (FAO) of the United Nations as a "Globally Important Agricultural Cultural Heritage". The availability of local native tea germplasm resources holds significant importance in terms of agricultural and cultural heritage (Shen et al., 2021; Zheng et al., 2023). Therefore, the scientific preservation and innovative utilization of indigenous tea germplasms in Anxi, as a crucial agrarian legacy, rely on establishing the correlation between tea genetic resource growth and habitat (Chen et al., 2010; Guo et al., 2019). Presently, tea cultivation in southern Fujian Province (i.e., Minnan region) is predominantly managed conventionally; however, there are also numerous spontaneously exploited tea gardens (Li et al., 2018; Chen et al., 2022). Naturally grown tea refers to tea bushes cultivated in a natural environment without human intervention such as fertilization, pruning or pest control; hence they are referred to as wild tea bushes (Wang, 2020; Chowdhury et al., 2021). Tea bushes cultivated under conventional management by agricultural technicians are known as conventionally managed tea bushes (Zhang, 2021; Li et al., 2023). In recent years, researchers have conducted extensive studies on oolong tea quality (Zheng et al., 2022). In the existing research on tea quality under different management modes, some scholars have studied four cultivation modes: plastic greenhouse tea garden, pine tea intercropping, forest hedge intercropping, and monoculture pure tea garden. Combined with tea quality measurement, it is shown that the tea quality produced by plastic greenhouse tea garden and forest hedge tea garden mode is the highest. Secondly, the quality of tea produced by pine tea intercropping mode tea garden is the highest, the tea quality in pure mode tea gardens is the worst, second only to plastic greenhouse mode tea gardens and intercropping mode tea gardens. Scholars have also studied the comparison of tea quality in three different management methods: terrace tea gardens, native tea gardens, and ancient tree tea gardens. Through analysis, it was found that the quality relationship between native tea gardens and ancient tree tea gardens is close, while the quality relationship between terrace tea gardens and native and ancient tree tea gardens is far, providing a theoretical basis for the development of native cultivation management models. Liu Xiaohui studied the quadrate three grades of soft branch oolong tea introduced from Taiwan (Liu et al., 2022). Deng Huili researched the flavor and aroma characteristics of oolong tea at various cooking temperatures (Deng et al., 2021). Chen Rongbing investigated Taiwan's oolong tea types' quality traits (Chen, 2019). Liang Liyun et al. researched the quality of oolong tea with multiple levels of fermentation (Liang et al., 2019). Li Jinsheng analyzed the influencing factors and evaluation techniques of wool tea quality of Jian 'ou oolong tea (Li, 2019). Additionally, many researchers have studied and proved that different planting methods have a particular impact on the growth of tea bushes (Chen et al., 2021; Jiang et al., 2021). Xiao Zhengdong and Chen Guizhen et al. argued that different planting patterns also affected yield and quality (Xiao et al., 2011; Chen, 2020). Liu Guiming et al. documented that the varying cultivation patterns had impact on the quality of terrace tea in spring and summer, respectively (Liu and Liu, 2019; Liu et al., 2019).

The comprehension of oolong tea quality produced by diverse management strategies for tea cultivation is crucial (Zhang et al., 2023). Natural tea bushes are a valuable asset, providing abundant germplasm resources (Min, 2022), and the functional components in tea differ from those in conventional cultivation (Zhang et al., 2020). Tea polyphenols, catechins, free amino acids, caffeine, and water extracts significantly impact human health and serve as indicators for evaluating oolong tea quality (Huang et al., 2020; Song et al., 2021). Therefore, investigating the tea quality of different management patterns on tea bushes holds great theoretical and practical significance. Accordingly, in the study, five varieties of Minnan oolong tea were sampled from two different planting patterns managed conventionally and naturally. These samples' main biochemical component was tested along with their sensory evaluation and the quality difference in main functional components (Zeng et al., 2023). The results can be used as a reference for scientific protection of the Anxi Tieguanyin tea culture system.

2 Materials and methods

2.1 Materials

In this experiment, five Minnan oolong tea accessions, including Tieguanyin, Foshou, Maoxie, Meizhan, and Fujian Shuixian, were selected as the experimental materials. In spring 2020, a total of 10 samples of Minnan Oolong tea products were collected from fresh leaves of these five varieties grown under two planting patterns: natural growth and conventional management. Among them, two samples named Tieguanyin A (natural growth) and Tieguanyin B (conventional management) were collected from adjacent plots in Hushang Township, Anxi County. The remaining eight samples representing the other four tea bush varieties with both planting patterns - Foshou A、B, Maoxie A、B, Meizhan A、B and Shuixia A、B were all collected from adjacent plots in Baizhangyan, Penghu Town,Yongchun County.

2.2 Methods

The sensory and biochemical components of this study were evaluated and detected using the latest national standard method. Sensory evaluation was conducted in accordance with "GB/T 23776-2018 Methodology for Sensory Evaluation of Tea" (General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, SCA, 2018). The total amount and components of tea polyphenols and catechins were determined according to "GB/T 8313-2018 Determination of Total Polyphenols and Catechins in Tea" (Dalluge and Nelson, 2000). Free amino acids were detected by referencing "GB/T 8314-2013 Tea - Determination of Free Amino Acid Content" (He et al., 2009). Tea caffeine and water extract were detected following "GB/T 8312-2013 Tea - Determination of Caffeine Content" and "GB/T 8305-2013 Tea - Determination of Water Extract Content" (Wang et al., 2003; Komes et al., 2009).

2.3 Tea bush management pattern and manufacturing skills

2.3.1 Naturally growing tea garden

The selected tea garden (Figure 1) was an artificial tea garden that had been allowed to grow naturally for over 35 years without any artificial management, deep soil ploughing, pesticide use, or fertilizer application. The height of the Shuixian A bush was 6.5 m, Foshou A was 6 m, Meizhan A was 5.5 m, Maoxie A was 5 m, and Tie Guanyin A was 4 m. Shuixian A had a bush age of around 100 years, Meizhan A about 90 years, Maoxie A had grown for 75 years, Foshou A for 65 years, and Tieguanyin A for 60 years.

The tea tree fresh leaves are divided into 2-3 leaves for harvesting, and the specific initial processing process is as follows: the initial manufacturing process includes sun fixation → blue-making (shaking green leaves and airing fresh leaves) → fixation → rolling → initial roasting→ initial kneading → re-roasting→ re-kneading → stoving. The main refining process includes crude tea acceptance → bunching → screening → winnowing → picking out impurities→ blending teas together→ roasting/spicing them up→ withering them evenly→ packaging them as processed tea.

Specific parameters: sun drying time of about 30 min → making green (shaking green in four times, about 3 min, 6 min, 12 min, and 20 min respectively; drying green in four times, between 1.5 h, 2.5 h, 3 h, and 4-6 h respectively) → killing green, killing green at a temperature between 250 and 300 °C, lasting about 5 min →

FIGURE 1
Natural Growing Tea Plantation.

kneading and rolling, lasting about 5 min → initial drying, lasting about 30 min → initial packaging and kneading, temperature between 100 °C, 20-30 min → re drying, Temperature 120 °C for 5 min → Re wrap and knead for 20 min → Dry at 70 °C for 2 h.

2.3.2 Conventional management tea garden

The tea bushes have been artificially cultivated and highly favored by the people for the past 15 years (Figure 2). Traditional management such as cutting planting, artificial pruning management, conventional herbicide weeding, conventional pesticide control of diseases and insects, and standard soil deep ploughing etc, significantly differ from that in a naturally developing tea garden. The bush height of Shuixian B was 1.5 m, Foshou B was 1.35 m, Meizhan B was 1.3 m, Maoxie B was 1.2 m, and Tie Guanyin B was 1.2 m. The order of bush age is about 12 years for Shuixian B, 10 years for Meizhan B, 9 years for Foshou B, 8 years for Maoxie B, and 6 years for Tieguanyin B. The cultivation and operation processesof them were the same.

2.4 Data analysis

All data in the experiment were analyzed by Office EXCEL 2010 and SPSS 23.0.

3 Results and discussion

3.1 Sensory evaluation

The sensory evaluation of each variety of tea samples was carried out, and the results are shown in Table 1.

In terms of appearance quality, as presented in Table 1, Meizhan B and Foshou A exhibited superior visual characteristics compared to Tieguanyin A and Shuixian A. Similarly, Foshou B and Maoxie B demonstrated better appearance quality than Shuixian B. Moreover, Meizhan A and Tieguanyin B outperformed Maoxie A in terms of appearance scores. These results suggest that naturally grown varieties generally exhibit lower aesthetic appeal compared to those produced through conventional management.

FIGURE 2
Manual management of tea gardens.

Regarding the aroma quality, it displayed that Meizhan A > Tieguanyin A > Tieguanyin B > Meizhan B= Shuixian A > Foshou B > Shuixian B > Foshou A > Maoxie A > Maoxie B. The results suggested that the naturally grown species had a better aroma than the varieties managed conventionally, with Meizhan A having the highest aroma score and Maoxie B having the lowest.

In terms of appearance quality, as presented in Table 1, Meizhan B and Foshou A exhibited superior visual characteristics compared to Tieguanyin A and Shuixian A. Similarly, Foshou B and Maoxie B demonstrated better appearance quality than Shuixian B. Moreover, Meizhan A and Tieguanyin B outperformed Maoxie A in terms of appearance scores. These results suggest that naturally grown varieties generally exhibit lower aesthetic appeal compared to those produced through conventional management.

According to the findings presented in Table 1; Figure 3, Meizhan B and Foshou A displayed superior visual attributes when it comes to appearance quality as opposed to Tieguanyin A and Shuixian A. Likewise, Foshou B and Maoxie B showcased better appearance quality than Shuixian B did. Additionally, both Meizhan A and Tieguanyin B outperformed Maoxie A in terms of their respective appearance scores. These outcomes imply that naturally cultivated cultivars typically demonstrate lesser aesthetic allure when compared with those managed conventionally.

In terms of soup color, the ranking is as follows: Tieguanyin A = Shuixian A = Shuixian B = Foshou A > Meizhan A > Tieguanyin B > Foshou B > Maoxie A > Meizhan B > Maoxie B. The naturally grown varieties exhibited superior soup color compared to conventionally managed types. Among them, Tieguanyin A, Shuixian A, Shuixian B, and Foshou A scored the highest in terms of color, while Maoxie B scored the lowest. However, when it comes to foliage fundus evaluation, the ranking is as follows: Meizhan B = Foshou B = Tieguanyin B = Shuixian B = Maoxie B > Shuixian A= Foshou A> Tieguanyin A> MeizhanA> MaoxieA. This suggests that conventionally managed varieties generally have better foliage fundus than naturally grown ones.

The comprehensive analysis revealed that the two cultivation patterns with the same breed score in sensory quality evaluation exhibited the following order from highest to lowest: Meizhan, Tieguanyin, Shuixian, Foshou, Maoxie. However, tea produced by conventional management tea gardens generally displayed better appearance quality and foliage fundus compared to naturally grown bush species. On the other hand, tea from naturally grown bushes usually showcased superior aroma and taste when compared to conventional managed varieties (Figure 4); it had a more solid and lasting perfume while also possessing a heavier and mellower flavor.

3.2 Physiochemical composition analysis

The tea quality components of five varieties of tea samples were analyzed under two germplasm management patterns. The detection results, including water extract, amino acid, tea polyphenols, caffeine, total catechin (C), epigallocatechin gallate (EGCG), epicatechin (EC), and epicatechin gallate (ECG), are displayed in Figure 5. It is evident that the water extract level of organically grown and conventionally managed tea is higher than

TABLE 1 Sensory evaluation results of each tea sample.

Tea samples	Shape (20%)	Aroma (35%)	Flavor (30%)	Color (5%)	Foliage fundus (10%)	Total score
Meizhan A	Green brown, moist, twisted, little taut 88.55 ± 3.72c	The Fragrance with long and lasting aas well as apparent fruity flavor 95.11 ± 1.09a	The mellow, sweet scent of a flower is shown 95.32 ± 1.24a	Light bright yellow 93.37 ± 1.24ab	Weakly fat and thick, soft and bright, red edge slightly is showed 87.27 ± 1.33cd	92.70 ± 1.00a
TieGuanyin A	Yellow-brown, lenitive, tauter 91.57 ± 0.58ab	The fragrance with thick and mellow as well as sweet and fruity flavor 94.21 ± 1.22ab	The taste is mellow; fruity is shown, and sweet aftertaste 93.26 ± 1.07ab	Orange and bright 94.23 ± 1.15a	Lightly fat and thick, soft and bright, red edge is showed 89.11 ± 1.25bc	92.60 ± 0.52a
Meizhan B	More moist viridity, taut, heavier 92.70 ± 1.13a	More solid and lasting, have apparent fragrance 92.44 ± 1.10b	Fresh, mellow, smooth, 92.34 ± 2.15ab	Light green, slightly light 91.33 ± 1.03bc	fat and thick, soft and bright 94.22 ± 1.35a	92.15 ± 0.90ab
Shuixian A	More moist brown, cords twisted, tauter 91.58 ± 0.52ab	More solid and lasting, have an orchid fragrance 92.11 ± 2.09b	Richer flavor with fragrance 91.41 ± 2.24bc	Orange deeply, and bright 94.43 ± 1.44a	relatively fat and thick, soft and bright, red edge was showed 91.43 ± 1.02ab	91.50 ± 1.17abc
Foshou B	More Dark green moist, particles tightly rolled heavier solid 90.58 ± 0.52abc	More clear alcohol, have a little fruity sweet aroma 89.33 ± 2.22c	Alcohol slippery more umami and sweet, fruity smell 91.01 ± 0.02bc	yellow bright 92.10 ± 1.04abc	fat and thick, soft and bright 94.32 ± 3.34a	90.45 ± 0.93bcd
Tieguanyin B	More moist viridity, tauter 88.00 ± 1.00c	More solid and lasting, apparent fragrance 93.30 ± 1.20ab	Much more umami flavor with slight fragrance 86.45 ± 3.04d	Green and yellow, bright 93.02 ± 2.17ab	fat and thick, soft and bright 94.33 ± 1.88a	90.00 ± 0.59cd
Shuixian B	Moist yellow-green, rolled and heavy 89.00 ± 1.72bc	More solid and lasting, slight sweet fragrance 87.22 ± 1.32cd	richer flavor with slight fragrance 88.23 ± 3.13cd	Orange and brightness 94.24 ± 0.15a	fat and thick, soft and bright 93.68 ± 0.78a	88.75 ± 1.66
Foshou A	Brown and oleo sus, cords twisted, tauter 92.52 ± 1.57a	sweet and mellowness with slight fruity aroma 86.32 ± 3.32d	Casual taste with relatively flat 82.00 ± 0.01e	Orange and brightness 94.41 ± 2.23a	More fat and thick, soft and bright, red edge is showed 91.22 ± 1.56ab	86.9 ± 0.97e
Maoxie A	Moist green and brown, cords twisted, relatively taut 85.00 ± 0.60d	More strong and lasting 81.10 ± 1.21e	Richer flavor, have fragrance 84.87 ± 2.26de	yellow brightness 92.43 ± 2.22abc	Light fat and thick, soft and bright as well as relatively red edge 85.55 ± 2.78d	83.95 ± 0.23f
Maoxie B	Moist sand green particles tightly rolled 90.48 ± 0.58abc	strong and lasting fragrance with slight green flavor 75.44 ± 2.10f	The umami and mellow taste with slightly sweet and green flavor 75.47 ± 2.88f	pale yellow, bright 90.13 ± 0.01c	fat and thick, soft and bright 94.52 ± 1.01a	80.65 ± 1.40g

Different letters in each column indicated that there was significant differences between different teas ($P < 0.05$).

the minimum requirement of 32% set by GB/T 30357.1 (Wang et al., 2022), indicating that the selected tea samples have a rich content of substances. Moreover, naturally grown tea samples generally exhibit higher levels of amino acids, suggesting a relatively mellow freshness.

According to the results of physiochemical analysis, significant variations in the physicochemical composition were observed among tea samples of different varieties under identical planting patterns. Conversely, tea samples from the same type but grown under different planting patterns generally exhibited higher levels of

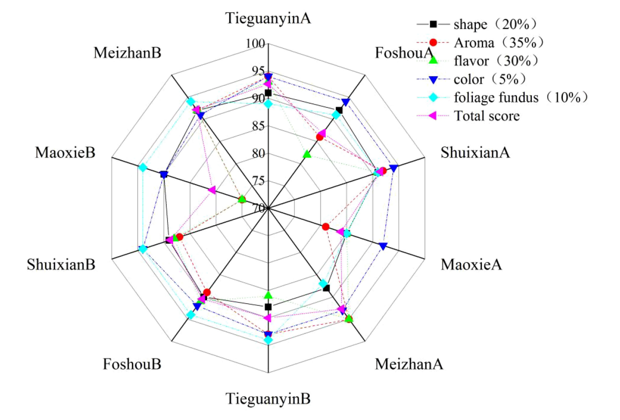


FIGURE 3
Radar chart of sensory evaluation score of each tea sample.

physicochemical composition and content compared to those managed conventionally.

3.2.1 Physiochemical analysis of different varieties under the same pattern

The Tieguanyin A variety exhibited the highest water extract and caffeine content in its natural growth pattern, measuring 44.57% and 5.09%, respectively (Figure 5). Maoxie A demonstrated the highest amino acid content at 6.89%. Foshou A had the highest tea polyphenols content at 26.72%, while also possessing a high catechin concentration of 16.69%. Conversely, Shuixian A displayed the lowest water extract percentage at 41.04%. Additionally, Foshou A had the lowest amino acid content with a concentration of 4.15%. Maoxie A exhibited the lowest tea polyphenols amount at 20.28%. Lastly, Meizhan A showcased the lowest levels of caffeine and catechins, measuring only 3.49% and 11.04%, respectively. Statistics revealed significant differences in amino acid composition between naturally grown varieties and those managed under conventional patterns of cultivation. Under conventional management practices, Shuixian B recorded maximum values for both water extract (41.62%) and amino acid content (4.86%). Tieguanyin B exhibited elevated levels of tea polyphenols (22.39%), caffeine (3.60%), and catechins (14.76%). On the other hand, Foshou B displayed lower contents for both water extract (37.82%) and amino acids (3.44%). Meizhan B presented with a reduced percentage of tea polyphenols at only16.68%. Finally, Foshou showed minimal amounts of caffeine at just 2.39%, while Shuixian B possessed lower quantities of catechins measured as 11.53%.

3.2.2 Physiohemical analysis of the same variety under different patterns

The physiochemical components of Tieguanyin A and Tieguanyin B were compared. The findings revealed that Tieguanyin A had more significant concentrations of water

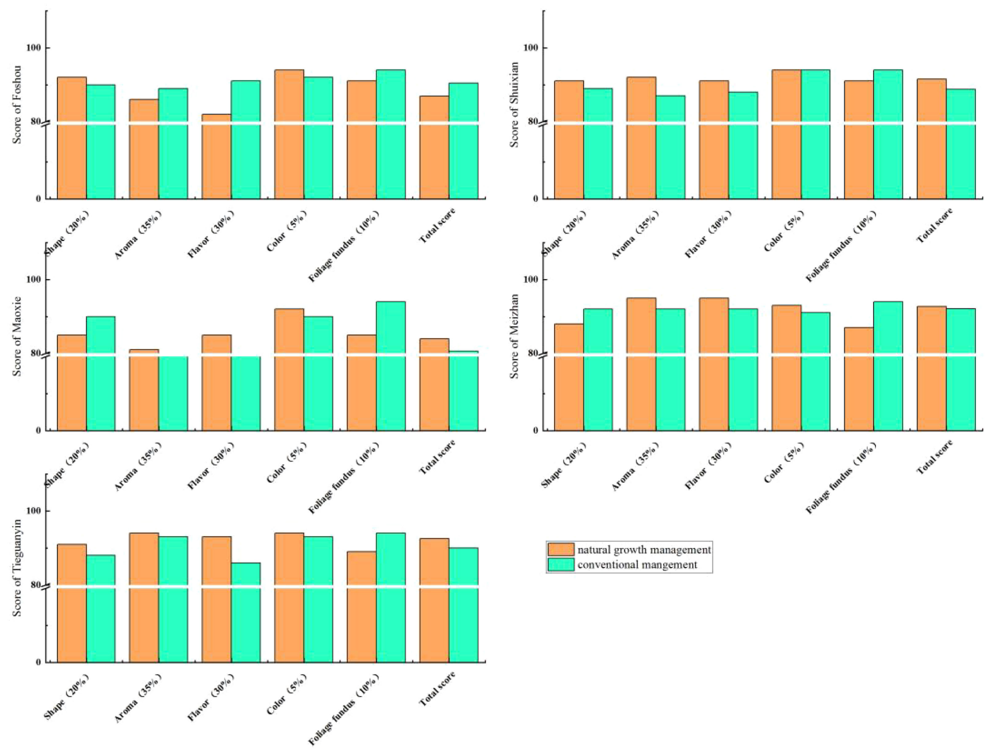


FIGURE 4
Sensory evaluation of five kinds of finished tea under two tea garden management modes. Overall, it can be seen that under natural management conditions, the overall sensory scores of the five tea varieties will be higher, and the main contribution is due to aroma (35%), flavor (30%) and color (5%).

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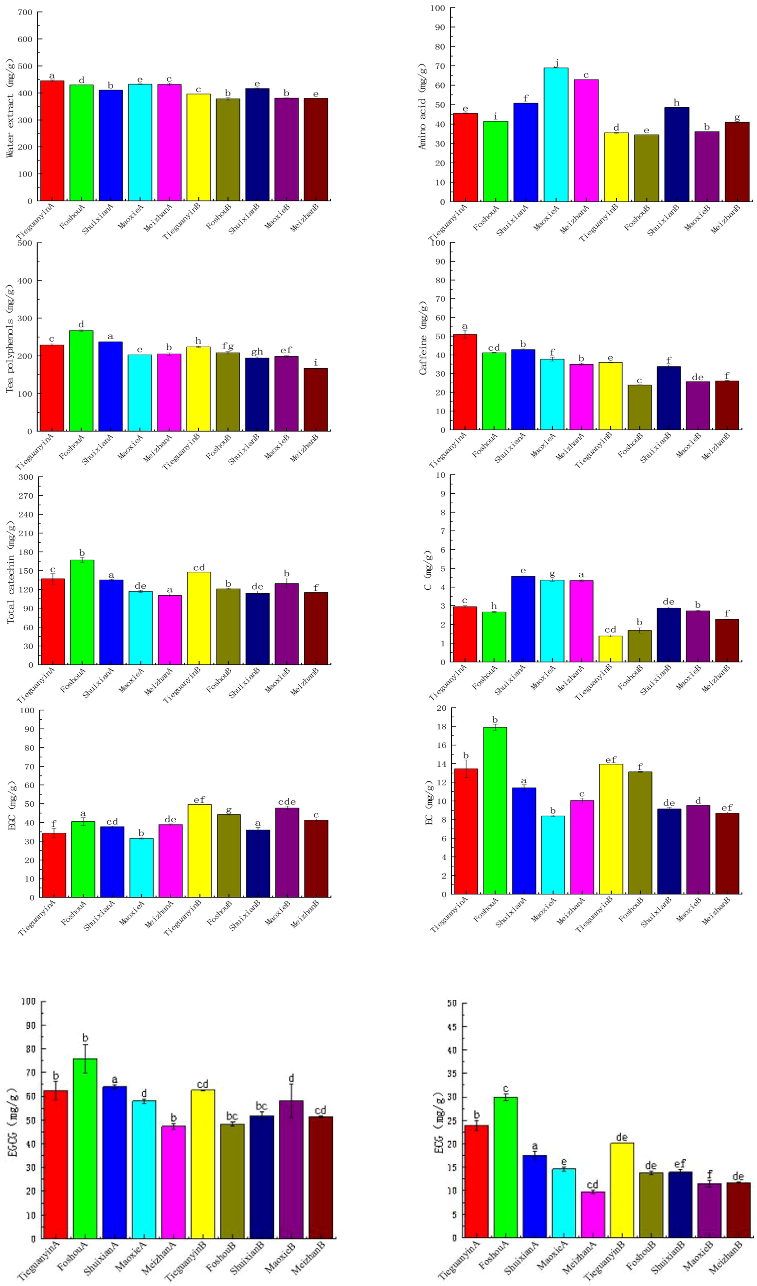

FIGURE 5
Test results of various physical and chemical components of multiple varieties (%). The lowercase letters in the same line represent significant differences at a significance level of P<0.05, and the results are presented as mean ± standard deviation.

extract, amino acids, tea polyphenols, and caffeine than Tieguanyin B, while the content of catechin was lower than that of Tieguanyin B. The significant differences in physiochemical components were found between Tieguanyin A and Tieguanyin B ($P \leq 0.05$) (Figure 6). In the comparison of Foshou A with Foshou B, the results showed that the contents of water extract, amino acid, tea polyphenol, caffeine, and catechin of Fochthole A were higher than those of Foshou B. There were also significant differences in physiochemical components between A and B ($P \leq 0.05$).

The physiochemical components of Tieguanyin A and Tieguanyin B were compared, revealing that Tieguanyin A exhibited significantly higher concentrations of water extract, amino acids, tea polyphenols, and caffeine compared to Tieguanyin B. However, the content of catechin in Tieguanyin A was lower than that in Tieguanyin B. Statistical analysis indicated significant differences in the physiochemical components between Tieguanyin A and Tieguanyin B ($P \leq 0.05$). When comparing Foshou A with Foshou B, it was observed that Foshou A had higher contents of water extract, amino acids, tea polyphenols, caffeine, and catechin than Foshou B. Significant differences in the physiochemical components were also found between Foshou A and Foshou B ($P \leq 0.05$).

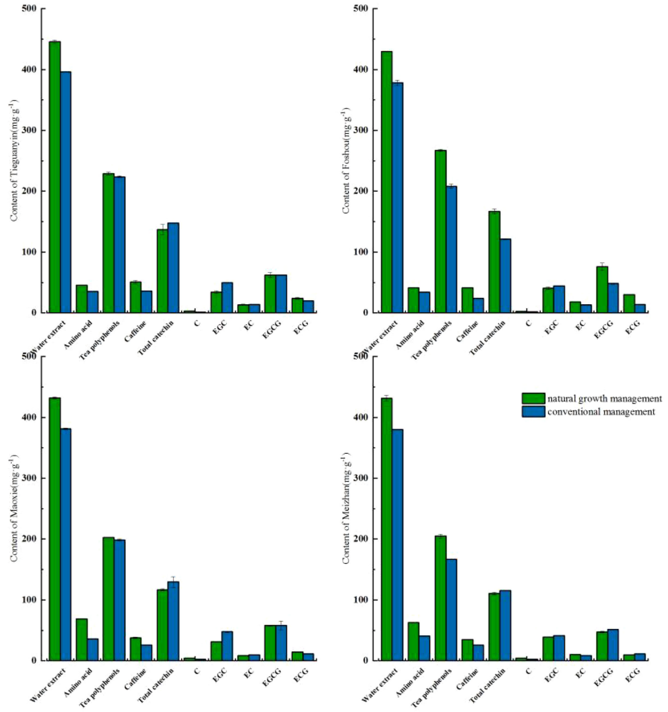

FIGURE 6
The distribution of the main quality of five kinds of finished tea under two management modes. Under natural growth management, the contents of water extracts, amino acids, tea polyphenols and caffeine in these five tea varieties were higher than those in tea gardens under conventional management, and all showed significant differences (P < 0.05).

The results revealed that Shuixian A had higher levels of amino acids, tea polyphenols, caffeine, and catechin compared to Shuixian B. Additionally, the water extract content was lower in Shuixian A than in Shuixian B. When comparing the physiochemical components of Maoxie A and Maoxie B, it was found that Maoxie A had higher levels of water extract, amino acid, tea polyphenol, and caffeine than Maoxie B. However, Maoxie B contained lower concentrations of catechin. According to Figure 4, there were significant differences between Maoxie A and Maoxie B in terms of water extract content, amino acid content, theanine content, and catechin content ($P \leq 0.05$), but no significant differences were observed in the range of tea polyphenols. Regarding the difference in physiochemical components between Meizhan A and Meizhan B, it was found that Meizhan A had higher levels of water extract, amino acids, tea polyphenols, and theanine compared to Meizhan B.

On the other hand, the catechin content was lower than that of Meizhan B. It was also found that there were significant difference the quantities of water extract amino acids theanine and tea polyphenols between Meizhan A and Meizhan B($P \leq 0.05$). In contrast, catechin content did not differ significantly between the two patterns.

3.2.3 Differences in physiochemical components of tea under different planting modes

The content ranges of various physicochemical components in tea samples from natural growth and conventional management are illustrated in Figure 7. Generally, the water extract, amino acid, tea polyphenol, caffeine, and other key quality chemical components are higher in naturally grown tea compared to conventionally managed tea bushes. Furthermore, traditional management tends to result in a greater abundance of catechins compared to naturally grown tea bushes.

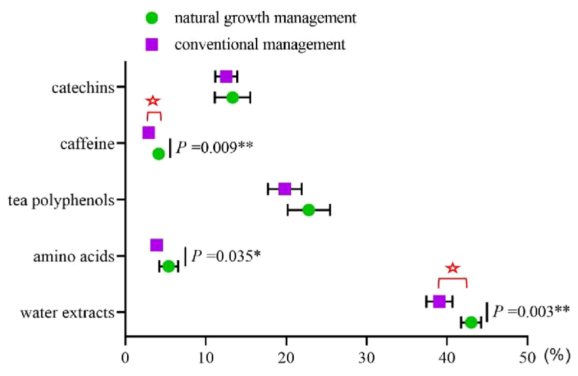

FIGURE 7
The content range of various physical and chemical components of natural growth management tea and conventional management tea. ★marked red line indicated that these types of compounds could contributed for promoting the tea quality in the two management patterns.

3.2.4 Principal component analysis of physiohemical components in tea samples from different planting patterns

SPSS 20.0 was utilized to perform principal component analysis on the aforementioned ten indexes pertaining to tea endoplasmic components in order to assess soil fertility under different planting patterns. As depicted in Figure 8, the score of naturally grown tea bush varieties within the quadrant surpassed that of conventionally managed ones, and a significant correlation existed between them, indicating superior quality of tea bushes under ecological management compared to traditional practices. Additionally, according to Table 2, PC1 and PC2 accounted for variance contribution rates of 51.00% and 36.89%, respectively. Consequently, the cumulative variance contribution rates of the first two principal components reached 87.89%, encompassing all relevant information regarding tea bush soil fertility. Notably, this includes the analytical expression of central component 1 (Table 3).

$F1 = 0.099x1-0.033x2 + 0.185x3 + 0.142x4 + 0.181x5-0.011x-0.009x7 + 0.171x8 + 0.180x9 + 0.191x10$, of which tea polyphenols, the total amount of catechin, EC, EGCG, and ECG were the main representative variables. Analytical expression formula of the principal component 2, $F2 = 0.216x1 + 0.254x2 + 0.012x3 + 0.157x4-0.09x5 + 0.240x6-0.246x7-0.094x8-0.009x9-0.015x10$. The central component scores of water extract, total free amino acid, caffeine, C and EGC were multiplied by their respective contribution rates and sorted to determine the ranking in the chemical composition score of 10 tea samples (Table 4). The results indicate that the F scores of naturally grown tea in all types of tea bush varieties are higher than those under conventional management. The growth pattern of tea trees in appropriate natural conditions is more advantageous for the accumulation and transformation of active substances.

4 Discussion

Tea is the most widely consumed beverage worldwide next to water. Tea is derived from the tender shoot plant of the tea plant, *Camellia sinensis* (L.) Kuntze. Organic tea manufacturing has been raised worldwide during recent decades as a consequence of the perceived benefits for environmental and human well-being, sustainable agriculture, consideration of food safety, and recognition of climate-smart management approaches (Piyasena and Hettiarachchi, 2023). In spite of the growing demand for naturally or organically grown tea (referred to as organic tea), most of the tea is produced using conventional management systems due to the low yield obtained in organically managed systems (Piyasena

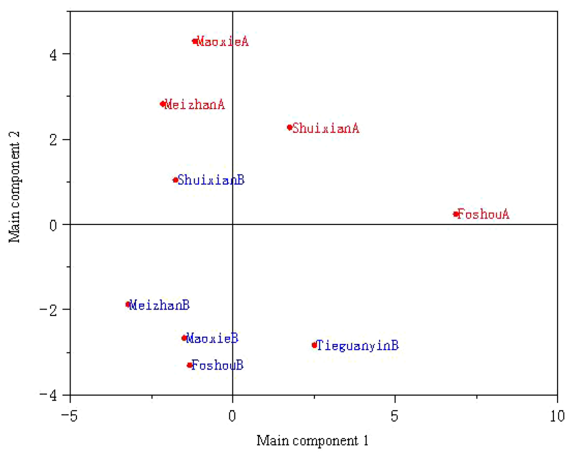

FIGURE 8
Main component score chart of each tea sample.

TABLE 2 The total variance.

Principal components	Initial eigenvalues		
	Total	Variance percentage/%	Cumulative percentage/%
1	5.10	51.00	51.00
2	3.69	36.89	87.89

TABLE 3 Eigenvector.

Variances	compound parameters	Principal components	
		1	2
X_1	water extract	0.099	0.216
X_2	amino acid	-0.033	0.254
X_3	tea polyphenols	0.185	0.012
X_4	caffeine	0.142	0.157
X_5	total catechin	0.181	-0.090
X_6	C	-0.011	0.240
X_7	EGC	-0.009	-0.246
X_8	EC	0.171	-0.094
X_9	EGCG	0.180	-0.009
X_{10}	ECG	0.191	-0.015

TABLE 4 Comprehensive evaluation of tea quality.

Planting patterns	F_1	F_2	Comprehensive scores F	Compre-hensive rankings
Tieguanyin A	2.27	1.61	2.00	1
Shuixian A	1.54	1.55	1.54	2
Foshou A	3.24	-1.10	1.42	3
Maoxie A	-1.38	2.40	0.21	4
Tieguanyin B	1.72	-2.16	0.09	5
Meizhan A	-1.95	1.97	0.04	6
Shuixian B	-1.79	1.18	-0.54	7
Maoxie B	-1.78	-1.88	-1.83	8
Foshou B	-1.74	-2.10	-1.89	9
Meizhan B	-2.43	-1.47	-2.03	10

and Hettiarachchi, 2023). Organic tea cultivation is a comprehensive approach for safe food production that takes into account environmental, animal, and social justice issues (Bathige and Moseley, 2023; Piyasena and Hettiarachchi, 2023). Furthermore, in medium and low-yielding tea gardens, there was a reduction of up to 29%. Besides yield, tea quality is a very important aspect of satisfying consumer preferences. However, there is insufficient consistent information on tea quality comparing organic and conventional agroecosystems (Piyasena and Hettiarachchi, 2023). In this studies, the authors used the selected tea garden(in fact an organic garden) that had been allowed to grow naturally for over 35 years without any artificial management, deep soil ploughing, pesticide use, or fertilizer application, and conventional management such as cutting planting, artificial pruning management, conventional herbicide weeding, conventional pesticide control of diseases and insects, and standard soil deep ploughing etc as the test materials to detect the differences of appearance traits and chemical compounds. The results showed that generally, the water extract, amino acid, tea polyphenol, caffeine, and other key quality chemical components are higher in naturally grown tea (organic tea) compared to conventionally managed tea bushes. Furthermore, traditional management tends to result in a greater abundance of catechins compared to naturally grown tea bushes. We also used the method that the central component scores of water extract, total free amino acid, caffeine, C and EGC were multiplied by their respective contribution rates and sorted to determine the ranking in the chemical composition score of 10 tea sample. The results also indicate that the F scores of naturally grown teas in all types of tea bush varieties are higher than those under conventional management, which further confirmed that the growth pattern of tea trees in appropriate natural conditions is more advantageous for the accumulation and transformation of active substances.

In naturally grown tea, the quality of the tea is usually considered to have minimum or zero chemical residues, including pesticides and heavy metals in the final product as well as higher polyphenol concentrations. In general, the quality of conventionally grown black tea is evaluated using organoleptic assessments by professional tea tasters in consideration of the appearance of the made tea (in dry condition and during liquor formation) as well as the flavor of the tea liquor. Our studies have involved the two approaches to evaluate the tea quality sampled from the two different management systems and obtained the consistent result that naturally grown tea has better quality that is counterpart. It worth mentioning that tea manufacturers define quality tea as that which earns a high income. However, consumers describe the tea as tea with overall taste and aroma (Piyasena and Hettiarachchi, 2023). The production of organic tea involves special practices and costs more than that of conventional tea productio. Organically or naturally grown food sources are favored by many consumers owing to minimum or zero pesticide residues and the better functional quality of organic foods over conventional foods (Reddy, 2013). So how to correctly price organic tea is a topic worthy of further study. In fact, value chains play an important role in transforming agricultural commodities from raw material to end products demanded by the consumers. There are a number of stakeholders involved in the agricultural commodity value chains and the partitioning of gains among the stakeholders along the chain is often debated and analyzed. There is however, little understanding about the various concepts used in value chain analysis specifically addressed to developing countries like Asia and Africa and on how smallholder farmers can participate in the value chains. Farmers, traders, wholesalers, retailers, big retail chains and consumers are major actors in the value chain. With the collective enlightenment of all stakeholders, proper enabling environment (institutions, infrastructure and policy) will be created in which various actors of value chain are functioning (Reddy, 2013).

5 Conclusion

The germplasm resources of Minnan local tea bushes constitute a vital component of both agricultural and cultural heritage. This study has confirmed that, under the prevailing natural conditions, tea bushes exhibit exceptional characteristics and possess high quality attributes. Consequently, it is imperative to enhance the exploration, collection, preservation, identification, and innovative utilization of indigenous tea germplasms in Anxi in order to provide substantial support for safeguarding these crucial agricultural and cultural heritage resources as well as promoting sustainable development within the tea industry.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding authors.

Author contributions

HH: Data curation, Investigation, Methodology, Software, Validation, Writing – original draft. YJ: Data curation, Formal analysis, Methodology, Writing – review & editing. CS: Investigation, Methodology, Project administration, Resources, Writing – original draft. QM: Conceptualization, Project administration, Supervision, Writing – review & editing. WW: Data curation, Writing – original draft. KX: Data curation, Formal analysis, Software, Writing – original draft. LY: Investigation, Resources, Writing – original draft. ZC: Conceptualization, Formal analysis, Funding acquisition, Project administration, Supervision, Writing – review & editing. WL: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing. PY: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This study was financially supported by 948 programs from the Ministry of Agriculture, China (2014-Z36) for the experiment, National Key Research and Development (R&D) China plan (2016YFD0200900), Young Teachers' programs on educational science research from the

Provincial Education Department of Fujian (JT180140), and Fujian Agriculture and Forestry University Construction Project for Technological Innovation and Service System of Tea Industry Chain (K1520005A01).

Acknowledgments

We would like to thank Professor Suk-Hwan Hong for providing guidance on the detection of tea biochemical indicators. This study was financially supported by 948 programs from the Ministry of Agriculture, China (2014-Z36) for the experiment, National Key Research and Development (R&D) China plan (2016YFD0200900), Young Teachers' programs on educational science research from the Provincial Education Department of Fujian (JT180140), and Fujian Agriculture and Forestry University Construction Project for Technological Innovation and Service System of Tea Industry Chain (K1520005A01).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer YZ declared a shared affiliation with the author(s) HH, YJ, XK, LY, WL and ZC to the handling editor at the time of review.

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