



# Chemometric assessment of the chemical profile of tea seed (*Camellia sinensis*) with different size determined by GC and ICP/OES

Erman Beyzi<sup>1</sup>

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## Abstract

This study was carried out to compare the chemical profile of tea seeds of different sizes determined by GC and ICP/OES devices with chemometric analysis. This study was carried out to determine the effects of different seed size [11.00–12.50 (SD1), 12.51–14.00 (SD2), 14.01–15.50 (SD3), 15.51–17.00 mm (SD4)] on seed internal ratio, crude oil content, fatty acid composition, mineral composition of tea seed by using different chemometric analysis methods (correlation, agglomerative hierarchical clustering, principal component analysis). In the study, fatty acid and mineral compositions were determined in GC and ICP/OES devices, respectively. Crude oil content, palmitic, stearic, oleic, linoleic, eicosenoic acids, SFA, MUFA, PUFA, Al, Fe, Mg elements were found to be significant according to different seed size. Among six different fatty acids determined, oleic acid was major component. Positive correlations were found between oleic acid and MUFA, between linoleic and  $\alpha$ -linolenic acid, between linoleic acid and PUFA, between  $\alpha$ -linolenic acid and PUFA, between Al and Na, between Ca and Pb, between Ca and Zn, between Co and K, between Cr and Cu, between Mg and Ni, between Mg and P. In PCA analysis, it was determined that the SD1 group was different from the other groups in terms of the stearic, linoleic,  $\alpha$ -linolenic, eicosenoic acids, PUFA, B mineral. In AHC analysis, seed sizes were divided into two different groups according to crude oil content, fatty acid and mineral composition, seed internal ratio. Also, different chemometric analysis methods such as correlation, agglomerative hierarchical clustering, principal component analysis were useful and decisive in determining the quality characteristics of tea seeds classified according to seed size.

**Keywords** Tea · Seed size · Fatty acids · Mineral composition · Chemometric analysis

## Introduction

Seed size is an element of the quality factors that affect the yield of the plant in field crops after harvest and is the determining factor in product development [1]. Few studies have been conducted examining the relationship between seed size and quality factors in field crops. In these studies, on different plant patterns, especially soybean [1] and canola [2], it has been reported that seed sizes have an effect on quality characteristics.

Tea (*Camellia sinensis*) is an important medicinal and aromatic plant in the Theaceae family. Tea seed has a high oil content ranging from 30 to 32%. This seed oil contains oleic acid, linoleic acid and low levels of saturated fatty

acids [3, 4]. A healthy and edible oil desired for human health should contain a suitable mixture of oleic, linoleic and linolenic acids, and tea seed also has these properties. Therefore, it has been reported that tea seed oil is beneficial against many diseases [5, 6].

Tea is an income-generating agricultural product that is considered as a beverage as a result of processing its fresh shoots and grown in marginal areas such as rough lands in Turkey [7]. The tea plant, whose leaves are used in Turkey, achieved a yield of 15.620 kg ha<sup>-1</sup> and a production of 1.3 million tons in areas of 83.200 ha in 2022 and was grown in the provinces of Artvin, Giresun, Ordu, Rize and Trabzon [8].

Different chemometric analysis methods were used in order to better see, understand and compare the results obtained for the parameters examined in recent studies. The methods used in these studies include correlation analysis [9, 10], principal component analysis [11, 12] and agglomerative hierarchical clustering analysis [13, 14] were also

✉ Erman Beyzi  
ebeyzi@erciyes.edu.tr

<sup>1</sup> Department of Field Crops, Faculty of Agriculture, Erciyes University, Kayseri, Turkey

widely used. Some studies were conducted in which the important quality parameters of the tea plant were examined by chemometric analysis such as principal component analysis and cluster analysis [15, 16].

This study was planned to determine the effects of different seed size on seed internal ratio, crude oil content, fatty acid and mineral compositions in the tea plant, which has an economic and widespread use value, by using different chemometric analysis methods (correlation analysis, agglomerative hierarchical clustering analysis and principal component analysis).

## Materials and methods

### Plant material and grouping

The seeds of the tea plant used in the study were collected in 2021 from a local producer in Artvin/Turkey. After the harvest, the seeds were divided into four different groups with the size of 11.00–12.50 mm (SD1), 12.51–14.00 mm (SD2), 14.01–15.50 mm (SD3) and 15.51–17.00 mm (SD4).

### Determination of seed internal ratio

The internal ratio of dry seeds divided into different groups was determined before the analysis. While determining the internal ratio, 10 g seeds were taken in three parallels for each group and their inner parts were separated from their shells and weighed. Afterwards, the seed kernels were ground with the help of a grinder and kept in the refrigerator at +4 °C until analysis.

### Crude oil content analysis

The ground 3 g dry seed samples were analyzed with petroleum ether in the oil analyzer and the oils obtained as a result of the analysis were kept in the refrigerator at +4 °C until the component analysis. Crude oil content analysis was performed in three parallels and the results were expressed as % [17].

### Fatty acid composition analysis

Fatty acid methyl esters (FAMES) of seed samples were obtained according to one-step extraction-transesterification method [18] and oil profile was determined by gas chromatograph (Schimadzu, GC 2010 plus) instrument equipped with FID (flame ionization detector) (Schimadzu, Kyoto, Japan) detector and capillary column (60 m, i.d. = 0.53 mm, Restek RTX-200). During the analysis, the H<sub>2</sub> was used as the carrier gas and the temperature gradient program was used to separate the FAMES [19]. While

defining the components obtained as a result of the analysis, the retention times of the peaks were compared using a standard (Sigma Supelco #37, Supelco Inc., Bellefonte, PA, USA).

### Mineral composition analysis

The mineral composition (Al, B, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, S and Zn) of tea samples was determined with ICP/OES spectrophotometer (Inductively Couple Plasma spectrophotometer) device (Agilent, 5110 Optima, ICP/OES). During the analysis, 0.2 g of the ground seed samples were treated with a nitric acid-hydrogen peroxide (2:3) mixture and analyzed in a microwave wet burning unit (Anton Paar Microwave) resistant to 40 bar pressure. The results obtained as a result of the analysis were expressed as mg kg<sup>-1</sup> [20, 21].

### Statistical analysis

Statistical analysis of the data obtained from all parameters examined after the study were performed with the SPSS package program (IBM SPSS, Version 21.0, Chicago, USA) in triplicate. In the study, one-way analysis of variance (ANOVA) and Duncan's Test were used to determine the differences between the groups ( $p < 0.05$ ). The XLSTAT program (Lumivero 2023, XLSTAT statistical and data analysis solution, <https://www.xlstat.com/en>) was used to compare the average results with correlation analysis, agglomerative hierarchical clustering analysis and principal component analysis methods.

## Results and discussion

### Seed internal ratio, crude oil content and fatty acid composition

The averages of seed internal ratio, crude oil content, fatty acid composition, SFA, MUFA and PUFA values according to different seed size are given in Table 1. According to the analysis of variance, crude oil content, palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1*n*9*c*), linoleic acid (C18:2*n*6*c*) and eicosenoic acid (C20:1*n*9), saturated fatty acid (SFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) values were statistically significant ( $p < 0.05$ ), while the  $\alpha$ -linolenic acid (C18:3*n*3) content and seed internal ratio were found to be insignificant ( $p > 0.05$ ). In the study, the seed internal ratio value changed between 65.92 and 69.40%, and although it was statistically insignificant, it had the highest value in the SD2 group. The crude oil content varied between 26.53 and 29.39%, and SD2, SD3 groups had the highest values, which were not

**Table 1** Variation of crude oil content, fatty acid composition and seed internal rate values (%) according to different seed size

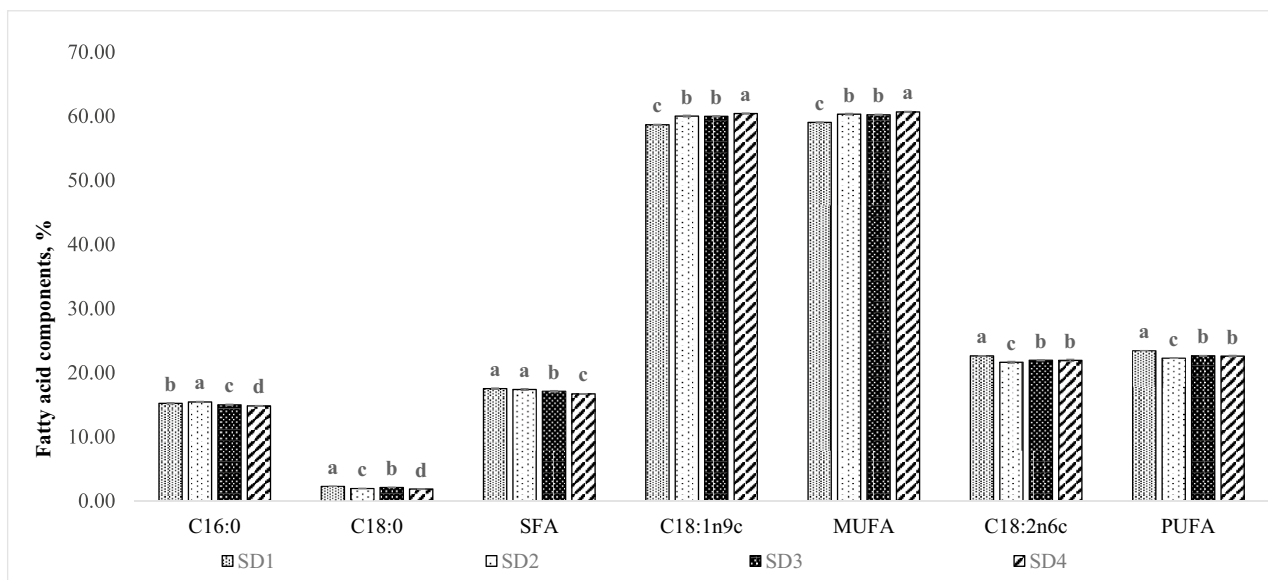
Seed Size	C16:0	C18:0	C18:1n9c	C18:2n6c	C18:3n3	C20:1n9	COC	SIR	SFA	MUFA	PUFA
SD1	15.24 b*	2.28 a	58.68 c	22.63 a	0.80	0.37 a	27.44 b	66.51	17.52 a	59.05 c	23.43 a
SD2	15.46 a	1.94 c	60.03 b	21.64 c	0.63	0.30 b	29.29 a	69.40	17.40 a	60.33 b	22.27 c
SD3	15.00 c	2.12 b	59.99 b	21.96 b	0.70	0.23 d	29.39 a	68.09	17.12 b	60.22 b	22.66 b
SD4	14.84 d	1.87 d	60.43 a	21.94 b	0.66	0.26 c	26.53 c	65.92	16.71 c	60.69 a	22.60 b
<i>p</i>	<0.05	<0.05	<0.05	<0.05	ns	<0.05	<0.05	ns	<0.05	<0.05	<0.05

\*Different letters in the same column indicate differences in  $p < 0.05$

*C16:0* palmitic acid, *C18:0* stearic acid, *C18:1n9c* oleic acid, *C18:2n6c* linoleic acid, *C18:3n3*  $\alpha$ -linolenic acid, *C20:1n9* eicosenoic acid, *COC* crude oil content, *SIR* seed internal rate, *SFA* saturated fatty acid, *MUFA* mono-unsaturated fatty acid, *PUFA* poly-unsaturated fatty acid, *ns* not significant

statistically different in terms of crude oil content. In addition, the crude oil content value (26.53%) in the SD4 group showed a significant decrease. Six different fatty acids were determined according to different seed size in fatty acid composition analysis (Table 1). Changes in the major fatty acids and SFA, MUFA and PUFA values are presented in Fig. 1. The oleic acid component was determined as the major component. This component was followed by linoleic acid, palmitic acid and stearic acid components, respectively (Fig. 1). The oleic acid component had the highest value in SD4 group (60.43%) compared to other groups. The linoleic acid component had the highest value (22.63%) in the SD1 group. In addition, palmitic acid and stearic acid components reached their highest values in SD2 (15.46%) and SD1 (2.28%) groups, respectively. The SFA values were between 16.71 and 17.52%, MUFA values were between

59.05 and 60.69% and PUFA values were between 22.27 and 23.43%. The SD1 group achieved the highest results in SFA and PUFA values, while SD4 group achieved the highest results in MUFA values (Table 1). In a study by Wang et al. (2011) [22] reported that the crude oil content of the tea seed was 25.3% as a result of Soxhlet extraction and the fatty acid compositions were oleic acid (52.9%), linoleic acid (24.2%) and palmitic acid (17.7%). In another study, Zheng-gang et al. (2021) [4] reported that *Camellia sinensis* seed oil ranged from 31.04 to 33.20% and the oleic acid content was the highest (59.21%) among all determined fatty acids. In addition, they reported the rate of SFA as 16.83%. In another study, it was reported that the crude oil content in tea seeds varied between 22.5 and 28.9% [23]. Our study results regarding crude oil content were found to be higher than the value reported by Wang et al. (2011) [22], lower than the



**Fig. 1** Change in major fatty acid compositions (components below 1% were not included in the figure) and SFA, MUFA, PUFA values according to different seed size, (Error bars represent standard deviation)

tion data, *C16:0* palmitic acid, *C18:0* stearic acid, *C18:1n9c* oleic acid, *C18:2n6c* linoleic acid, *SFA* saturated fatty acid, *MUFA* mono-unsaturated fatty acid, *PUFA* poly-unsaturated fatty acid)

value reported by Zhenggang et al. (2021) [4] and similar to the value reported by Yahaya et al. (2019) [23]. These differences in crude oil content value may vary depending on the extraction method and the solvent preferred during analysis. Additionally, our results for oleic acid in fatty acid composition were found to be higher and similar to the values reported by Wang et al. (2011) [22] and Zhenggang et al. (2021) [4], respectively.

## Mineral composition

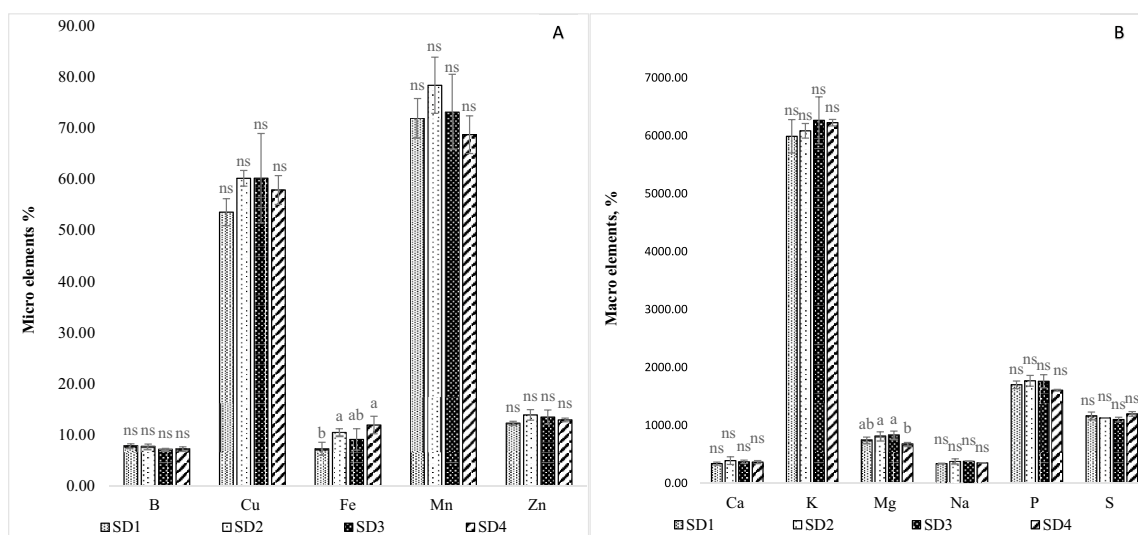
Average results of mineral composition (macro, micro elements and heavy metals) according to different seed size are given in Table 2. In analysis of variance of mineral composition values according to different seed size, Al, Fe and Mg values were found to be statistically significant ( $p < 0.05$ ), while B, Ca, Co, Cr, Cu, K, Mn, Na, Ni, P, Pb, S and Zn values were found to be insignificant ( $p > 0.05$ ) (Table 2). Changes in micro (Fig. 2A) and macro (Fig. 2B) element values according to different seed size are presented as detail

in Fig. 2. The five micro (B, Cu, Fe, Mn and Zn) and six macro (Ca, K, Mg, Na, P and S) elements were determined in this study (Fig. 2). Considering the parameters found to be important in this study, the Al content varied between 68.36 and 85.69 mg kg<sup>-1</sup> and although there was no statistical difference between the last three groups, it had the highest value in the SD3 group. The Fe content varied between 7.27 and 11.91 mg kg<sup>-1</sup> and although there was no statistical difference between the last three groups, it had the highest value in the SD4 group. The Mg content varied between 678.9 and 833.9 mg kg<sup>-1</sup> and although there was no statistically significant difference between the first three groups, it had the highest value in the SD3 group. In addition, although statistically insignificant, the B content was highest in the SD1 group, the Ca, Mn, P, Pb and Zn contents in the SD2 group, the Co, Cr, Cu, K, Na and Ni contents in the SD3 group, and the Co and S contents in the SD4 group (Table 2). In a study by Yahaya et al. (2019) [23] reported that the contents of Na, Zn, Mg, Fe, K and Ca in tea seed ranged

**Table 2** Variation of mineral composition values (mg kg<sup>-1</sup>) according to different seed size

Seed Size	Micro elements					Macro elements						Heavy metals				
	B	Cu	Fe	Mn	Zn	Ca	K	Mg	Na	P	S	Al	Co	Cr	Ni	Pb
SD1	7.87	53.56	7.27 b	71.86	12.27	338.6	5990	749.2 ab	337.9	1700	1165	68.36 b*	0.11	0.88	3.71	2.24
SD2	7.74	60.18	10.45 a	78.39	13.89	390.0	6085	814.3 a	374.4	1768	1128	83.67 a	0.13	1.08	3.93	2.40
SD3	7.17	60.20	9.09 ab	73.13	13.47	369.6	6266	833.9 a	377.8	1760	1099	85.69 a	0.15	1.11	4.08	2.32
SD4	7.28	57.89	11.91 a	68.72	12.90	364.3	6225	678.9 b	351.1	1606	1197	74.16 ab	0.15	1.08	3.57	2.33
<i>p</i>	ns	ns	<0.05	ns	ns	ns	ns	<0.05	ns	ns	ns	<0.05	ns	ns	ns	ns

\*Different letters in the same column indicate differences in  $p < 0.05$ , ns not significant



**Fig. 2** Change in micro (A) and macro (B) element values according to different seed size, (Error bars represent standard deviation data, ns: not significant)

between 2.91–3.20, 3.81–4.10, 145.9–163.1, 0.063–0.095, 21.94–23.65 and 16.16–18.41 mg 100 g<sup>-1</sup>, respectively.

### Chemometric analysis

The results of the seed internal ratio, crude oil content, fatty acid composition, mineral composition, which were made by grouping the tea seed according to different seed size, were examined using three different analysis methods (correlation analysis, agglomerative hierarchical clustering analysis and principal component analysis).

### Correlation analysis

The correlation analysis results for seed internal ratio, crude oil content, fatty acid composition and SFA, MUFA, PUFA values according to different seed size are given in Table 3 and the correlation analysis results for mineral composition values are given in Table 4. The statistically significant positive and negative correlations between these properties are presented as detail in Fig. 3. According to correlation analysis, four different positive correlations were found between fatty acid composition, MUFA and PUFA values (Fig. 3A). Accordingly, positive correlations were found between oleic acid content and MUFA, between linoleic acid and  $\alpha$ -linolenic acid, between linoleic acid and PUFA, and between  $\alpha$ -linolenic acid and PUFA ( $p < 0.05$ ) (Table 3). According to correlation analysis, seven positive and three negative correlations were found between the Al, B, Ca, Co, Cr, Cu, K, Mg, Na, Ni, P, Pb, S and Zn values (Fig. 3B). There were positive correlations between Al and Na, between Ca and Pb, between Ca and Zn, between Co and K, between Cr and Cu, between Mg and Ni, between Mg

and P. Negative correlations were found between B and K, between Mg and S, between Ni and S ( $p < 0.05$ ) (Table 4).

### Principal component analysis

The principal component analysis graph of seed internal ratio, crude oil content and fatty acid composition values according to different seed size is given in Fig. 4A, and the principal component analysis graph according to mineral composition values is given in Fig. 4B. Examining Fig. 4A, PC<sub>1</sub> (62.18%) and PC<sub>2</sub> (30.11%) explained 92.29% of the total variance. According to the graph (Fig. 4A), it was seen that the SD4 group was different from the other groups in terms of oleic acid and MUFA. Also, the SD1 group was different from the other groups in terms of stearic acid, linoleic acid,  $\alpha$ -linolenic acid, eicosenoic acid and PUFA. When Fig. 4B is examined, PC<sub>1</sub> (59.06%) and PC<sub>2</sub> (29.35%) explained 88.41% of the total variance. According to the graph (Fig. 4B), it was seen that the SD1 group was different from the other groups in terms of B content. The SD2 group was different from the other groups in terms of Mn and P contents, the SD3 group was different from the other groups in terms of Al and Na contents and the SD4 group was different from the other groups in terms of Fe and S contents.

### Agglomerative hierarchical clustering analysis

The dendrogram graph based on seed internal ratio, crude oil content and fatty acid composition values according to the different seed size is given in Fig. 5A, and the dendrogram graph based on the mineral composition values is given in Fig. 5B. When Fig. 5A is examined, two groups were formed according to seed internal ratio, crude oil content and fatty acid composition value. The SD1 was alone in the 1st group,

**Table 3** Correlation relationships of crude oil content, fatty acid composition and seed internal rate values according to different seed size

	C16:0	C18:0	C18:1n9c	C18:2n6c	C18:3n3	C20:1n9	COC	SIR	SFA	MUFA	PUFA
C16:0	<b>1</b>	–	–	–	–	–	–	–	–	–	–
C18:0	0.213	<b>1</b>	–	–	–	–	–	–	–	–	–
C18:1n9c	– 0.416	– 0.910	<b>1</b>	–	–	–	–	–	–	–	–
C18:2n6c	– 0.076	0.833	– 0.868	<b>1</b>	–	–	–	–	–	–	–
C18:3n3	0.004	0.937	– 0.907	<b>0.973</b>	<b>1</b>	–	–	–	–	–	–
C20:1n9	0.636	0.600	– 0.875	0.661	0.632	<b>1</b>	–	–	–	–	–
COC	0.520	0.103	0.087	– 0.464	– 0.251	– 0.193	<b>1</b>	–	–	–	–
SIR	0.695	– 0.138	0.185	– 0.628	– 0.466	– 0.097	0.925	<b>1</b>	–	–	–
SFA	0.863	0.678	– 0.785	0.375	0.489	0.792	0.441	0.449	<b>1</b>	–	–
MUFA	– 0.395	– 0.925	<b>0.999*</b>	– 0.875	– 0.918	– 0.856	0.077	0.189	– 0.777	<b>1</b>	–
PUFA	– 0.063	0.850	– 0.877	<b>1.000</b>	<b>0.979</b>	0.661	– 0.436	– 0.607	0.394	– 0.885	<b>1</b>

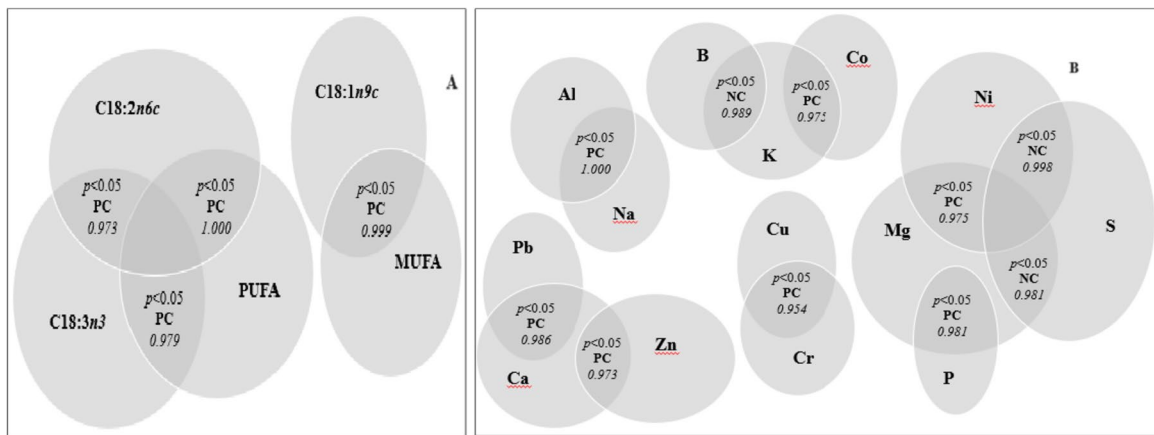
\*The numbers in bold are significant at the 5% level

C16:0 palmitic acid, C18:0 stearic acid, C18:1n9c oleic acid, C18:2n6c linoleic acid, C18:3n3  $\alpha$ -linolenic acid, C20:1n9 eicosenoic acid, COC crude oil content, SIR seed internal ratio, SFA saturated fatty acid, MUFA mono-unsaturated fatty acid, PUFA poly-unsaturated fatty acid

**Table 4** Correlation relationships of mineral composition values according to different seed size

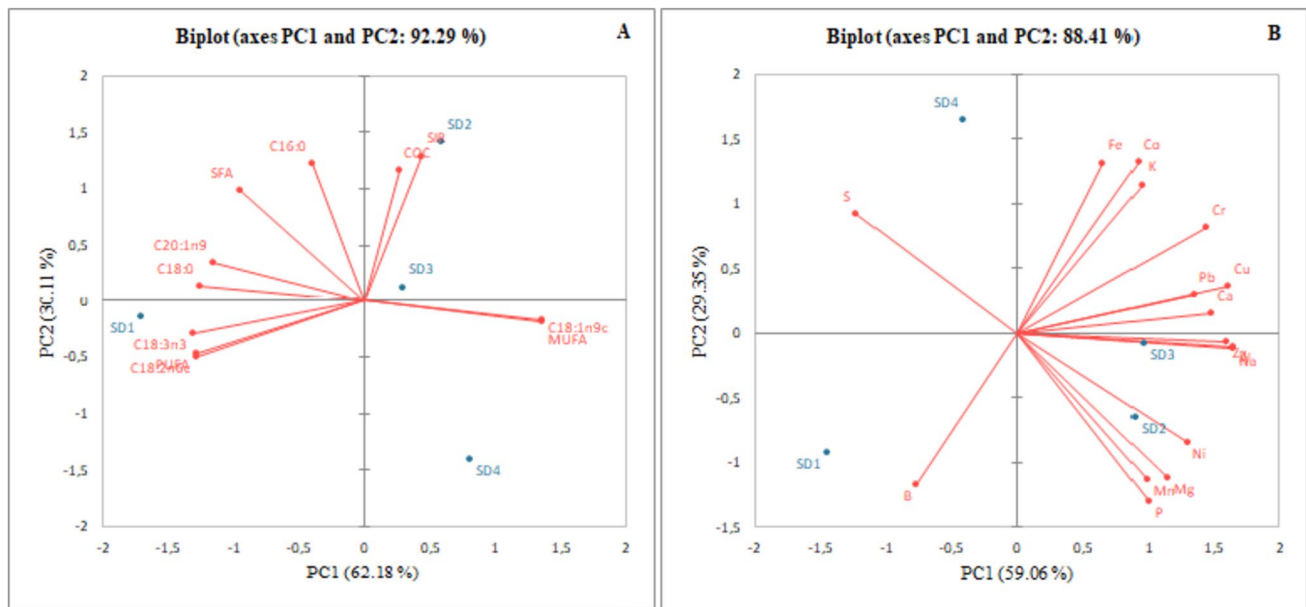
	Al	B	Ca	Co	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Zn
Al	<b>1</b>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B	-0.469	<b>1</b>	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca	0.841	-0.241	<b>1</b>	-	-	-	-	-	-	-	-	-	-	-	-	-
Co	0.526	-0.947	0.462	<b>1</b>	-	-	-	-	-	-	-	-	-	-	-	-
Cr	0.837	-0.757	0.817	0.878	<b>1</b>	-	-	-	-	-	-	-	-	-	-	-
Cu	0.949	-0.570	0.918	0.697	<b>0.954</b>	<b>1</b>	-	-	-	-	-	-	-	-	-	-
Fe	0.300	-0.496	0.626	0.743	0.729	0.585	<b>1</b>	-	-	-	-	-	-	-	-	-
K	0.569	- <b>0.989</b>	0.382	<b>0.975</b>	0.845	0.680	0.575	<b>1</b>	-	-	-	-	-	-	-	-
Mg	0.754	0.026	0.454	-0.097	0.274	0.515	-0.376	0.034	<b>1</b>	-	-	-	-	-	-	-
Mn	0.599	0.426	0.659	-0.310	0.183	0.465	-0.114	-0.310	0.779	<b>1</b>	-	-	-	-	-	-
Na	<b>1.000*</b>	-0.445	0.852	0.508	0.830	0.949	0.300	0.548	0.759	0.620	<b>1</b>	-	-	-	-	-
Ni	0.842	-0.196	0.495	0.114	0.435	0.630	-0.262	0.253	<b>0.975</b>	0.668	0.841	<b>1</b>	-	-	-	-
P	0.661	0.216	0.425	-0.265	0.143	0.415	-0.435	-0.151	<b>0.981</b>	0.858	0.671	0.914	<b>1</b>	-	-	-
Pb	0.745	-0.206	<b>0.986</b>	0.462	0.790	0.867	0.718	0.348	0.311	0.597	0.758	0.347	0.295	<b>1</b>	-	-
S	-0.803	0.157	-0.440	-0.059	-0.374	-0.575	0.328	-0.207	- <b>0.981</b>	-0.662	-0.802	- <b>0.998</b>	-0.926	-0.288	<b>1</b>	-
Zn	0.936	-0.277	<b>0.973</b>	0.438	0.815	0.947	0.466	0.409	0.636	0.718	0.945	0.683	0.592	0.921	-0.635	<b>1</b>

\*The numbers in bold are significant at the 5% level



**Fig. 3** Correlation diagrams of statistically significant parameters of fatty acids, MUFA and PUFA (A) and mineral (B) compositions according to different seed size, (PC positive correlation, NC negative

correlation, *C18:1n9c* oleic acid, *C18:2n6c* linoleic acid, *C18:3n3* α-linolenic acid, *MUFA* mono-unsaturated fatty acid, *PUFA* poly-unsaturated fatty acid,  $p < 0.05$ : significant at the 5% level)

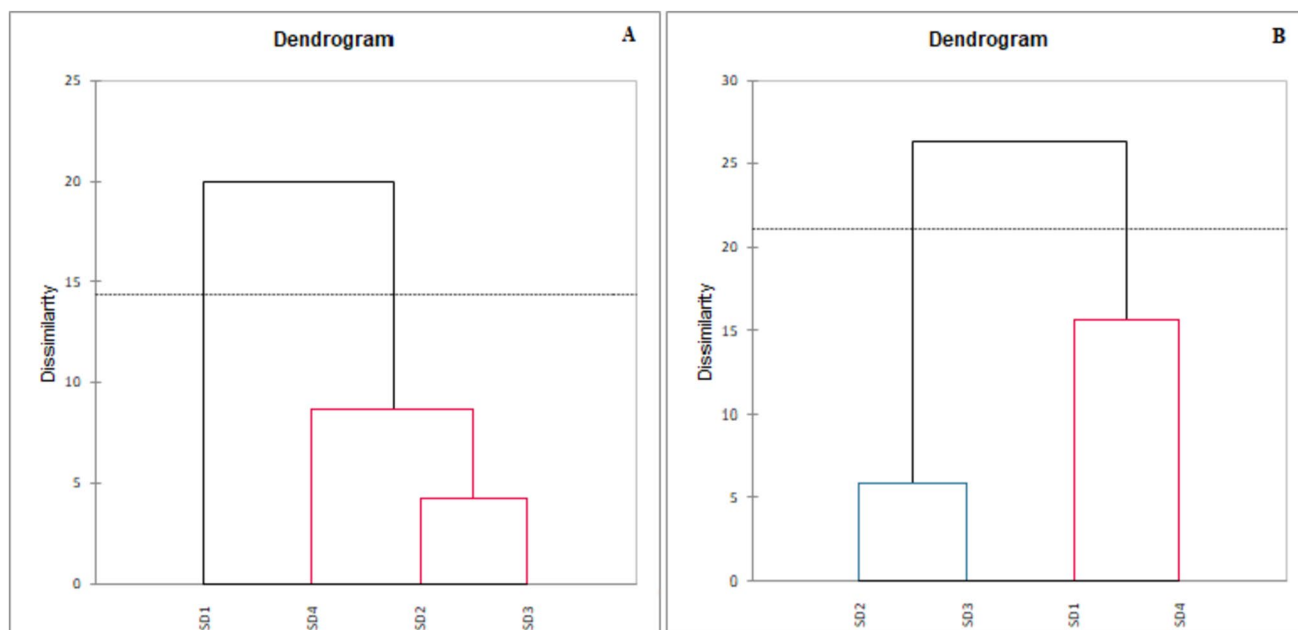


**Fig. 4** Principal component analysis graphs of crude oil content, fatty acid composition, seed internal ratio (A) and mineral composition (B) values by different seed size, (COC crude oil content, SIR seed internal ratio, *C16:0* palmitic acid, *C18:0* stearic acid, *C18:1n9c*

oleic acid, *C18:2n6c* linoleic acid, *C18:3n3* α-linolenic acid, *C20:1n9* eicosenoic acid, *SFA* saturated fatty acid, *MUFA* mono-unsaturated fatty acid, *PUFA* poly-unsaturated fatty acid)

SD2, SD3 and SD4 were in the 2nd group together (Fig. 5A). When Fig. 5B is examined, two groups were formed according to the mineral composition. SD1 and SD4 were in the 1st group together, SD2 and SD3 were in the 2nd group together (Fig. 5B). In some studies, some quality characteristics of the tea plant were examined using correlation, principal component analysis and cluster analysis [15, 16, 24–27]. In a study, Liu et al. (2022) [27] used cluster and correlation analyzes to examine the mineral composition in

tea. In a study examining the fatty acid composition of leaves of different tea species collected at different times, Anh et al. (2016) [24] demonstrated the functional use of principal component analysis to compare fatty acids in *Camellia sinensis*. In another study, Wang et al. (2017) [25] used multivariate chemometric methods such as principal component analysis and hierarchical clustering analysis to reveal relationships between fatty acid components of the tea plant. In this study, it was reported that the samples examined as



**Fig. 5** Dendrogram graphs of crude oil content, fatty acid composition, seed internal ratio (A) and mineral composition (B) by different seed size

a result of principal component analysis were divided into three groups and the variability distribution was formed by two main PCs that explained 77.4% of the total variance.

## Conclusion

At the end of the study, crude oil content, palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1*n*9*c*), linoleic acid (C18:2*n*6*c*) and eicosenoic acid (C20:1*n*9), SFA, MUFA, PUFA, Al, Fe and Mg values were found to be significant according to different seed size. In terms of crude oil content, SD2 and SD3 groups had the highest values, although they were not statistically different. In the study, six different fatty acids were determined according to different seed size in the tea seed oil, and oleic acid was the main component. According to correlation analysis, positive correlations were found between oleic acid and MUFA, between linoleic acid and  $\alpha$ -linolenic acid, between linoleic acid and PUFA, between  $\alpha$ -linolenic acid and PUFA, between Al and Na, between Ca and Pb, between Ca and Zn, between Co and K, between Cr and Cu, between Mg and Ni, between Mg and P. According to the principal component analysis, it was determined that the SD1 group was different from the other groups in terms of the ratio of stearic acid, linoleic acid,  $\alpha$ -linolenic acid, eicosenoic acid, PUFA and B. In addition, according to the agglomerative hierarchical clustering analysis, seed sizes were divided into two different groups according to seed internal ratio, crude oil content, fatty acid and mineral composition. At the end of the study,

it can be said that different chemometric analysis methods such as correlation analysis, agglomerative hierarchical clustering analysis and principal component analysis were useful and decisive in determining the quality characteristics of tea seeds classified according to seed size.

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**Data availability** The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

## Declarations

**Conflict of interest** The author declare no conflict of interest.

**Compliance with ethics requirements** This article does not contain any studies with human or animal subjects.

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## References

- Adebisi MA, Kehinde TO, Salau AW, Okesola LA, Porbeni JBO, Esuruoso AO, Oyekale KO (2013) Influence of different seed size fractions on seed germination, seedling emergence and seed yield characters in tropical soybean (*Glycine max* L. Merrill). *Int J Agric Res* 8:26–33. <https://doi.org/10.3923/ijar.2013.26.33>
- Beyzi E, Gunes A, Buyukkilic Beyzi S, Konca Y (2019) Changes in fatty acid and mineral composition of rapeseed (*Brassica napus* ssp. *oleifera* L.) oil with seed sizes. *Ind Crops Prod* 129:10–14. <https://doi.org/10.1016/j.indcrop.2018.11.064>
- Ravichandran R, Dhandapani M (1992) Composition characteristics and potential uses of south Indian tea seeds. *J Food Sci Technol* 29:394–396
- Zhenggang X, Zhiru C, Haoran Y, Chaoyang L, Zhao Y, Deyi Y, Guiyan Y (2021) The physicochemical properties and fatty acid composition of two new woody oil resources: *Camellia hainanica* seed oil and *Camellia sinensis* seed oil. *CyTA J Food* 19:208–211. <https://doi.org/10.1080/19476337.2021.1879936>
- He L, Guoying Z, Huaiyun Z, Junang L (2011) Research progress on the health function of tea oil. *J Med Plants Res* 5:485–489
- Joughi ESG, Hervan EM, Rad AS, Noormohamadi GH (2018) Fatty acid composition of oilseed rapeseed genotypes as affected by vermicompost application and different thermal regimes. *Agron Res* 16:230–242. <https://doi.org/10.15159/ar.18.002>
- Yazıcı K, Göksu Karaoğlu B, Şavşatlı Y, Akbulut M, Seyis F, Sarı H, Atay Y, Karaoğlu A, Üst E (2023) Effects of different fertilizer and kaolin applications on tea [*Camellia sinensis* (L.) O. Kuntze] plant yield. *Turkish J Agric Nat Sci* 10:29–38. <https://doi.org/10.30910/turkjans.1137413>
- TUIK (2023) Turkish Statistical Institute, Crop production statistics database. <https://www.tuik.gov.tr>. Accessed 26 April 2023.
- Suri K, Singh B, Kaur A, Yadav MP, Singh N (2020) Influence of microwave roasting on chemical composition, oxidative stability and fatty acid composition of flaxseed (*Linum usitatissimum* L.) oil. *Food Chem* 326:126974. <https://doi.org/10.1016/j.foodchem.2020.126974>
- Gao S, Wang B, Liu F, Zhao J, Yuan J, Xiao S, Masabni J, Zou F, Yuan D (2022) Variation in fruit morphology and seed oil fatty acid composition of *Camellia oleifera* collected from diverse regions in Southern China. *Horticulturae* 8:818. <https://doi.org/10.3390/horticulturae8090818>
- Shin EC, Craft BD, Pegg RB, Phillips RD, Eitenmiller RR (2010) Chemometric approach to fatty acid profiles in Runner-type peanut cultivars by principal component analysis (PCA). *Food Chem* 119:1262–1270. <https://doi.org/10.1016/j.foodchem.2009.07.058>
- Yildiz E, Pinar H, Uzun A et al (2021) Identification of genetic diversity among *Juglans regia* L. genotypes using molecular, morphological, and fatty acid data. *Genet Resour Crop Evol* 68:1425–1437. <https://doi.org/10.1007/s10722-020-01072-6>
- Bouafia M, Benarfa A, Gourine N, Yousfi M (2020) Seasonal variation of fatty acid composition, tocopherol content and antioxidant activity of lipid extracts from *Centaurea* sp. *Food Biosci* 37:100728. <https://doi.org/10.1016/j.fbio.2020.100728>
- Beyzi E (2020) Chemometric methods for fatty acid compositions of fenugreek (*Trigonella foenum-graecum* L.) and black cumin (*Nigella sativa* L.) seeds at different maturity stages. *Ind Crops Prod* 151:112488. <https://doi.org/10.1016/j.indcrop.2020.112488>
- Prayoga MK, Syahrian H, Rahadi VP, Prawira-Atmaja MI, Maulana H, Anas A (2022) Quality diversity of 35 tea clones (*Camellia sinensis* var. *sinensis*) processed for green tea. *Biodiversitas*, 23:810–816. <https://doi.org/10.13057/biodiv/d230227>
- Ariyanthini KS, Angelina E, Andina NKDP, Wijaya H, Wiratama IPRKP, Narihradnya PS, Putra IGAND, Setyawan EI (2023) Implementation of principal component analysis-cluster analysis on the extraction of green tea leaf (*Camellia sinensis* (L.) Kuntze). *Biointerface Res Appl Chem* 13:335. <https://doi.org/10.33263/BRIAC134.335>
- AOAC (1990) Official Methods of Analysis of the Association of Official Analytical Chemists, 15th edn. AOAC International, Arlington, VA, USA
- Sukhija PS, Palmquist DL (1988) Rapid method for determination of total fatty-acid content and composition of feedstuffs and feces. *J Agric Food Chem* 36:1202–1206. <https://doi.org/10.1021/jf00084a019>
- Chilliard Y, Rouel J, Guillouet P (2013) Goat alpha-s1 casein genotype interacts with the effect of extruded linseed feeding on milk fat yield, fatty acid composition and post-milking lipolysis. *Anim Feed Sci Technol* 185:140–149. <https://doi.org/10.1016/j.anifeedsci.2013.08.002>
- Mertens D (2005a) AOAC Official Method 922.02. Plants Preparation of Laboratory Sample. Official Methods of Analysis, 18th edn. Horwitz, W., and G.W. Latimer, (Eds). Chapter 3, pp1–2, AOAC-International Suite 500, 481. North Frederick Avenue, Gaithersburg, Maryland 20877–2417, USA
- Mertens D (2005b) AOAC Official Method 975.03. Metal in Plants and Pet Foods. Official Methods of Analysis, 18th edn. Horwitz, W., and G.W. Latimer, (Eds). Chapter 3, pp 3–4, AOAC-International Suite 500, 481. North Frederick Avenue, Gaithersburg, Maryland 20877–2417, USA
- Wang Y, Sun D, Chen H, Qian L, Xu P (2011) Fatty acid composition and antioxidant activity of tea (*Camellia sinensis* L.) seed oil extracted by optimized supercritical carbon dioxide. *Int J Mol Sci* 12:7708–7719. <https://doi.org/10.3390/ijms12117708>
- Yahaya LE, Jayeola CO, Ogunwolu SO, Olalekan-Adeniran A, Okunade AF (2019) Composition of seed flour of selected Nigerian tea (*Camellia sinensis*) Clones—a comparative study. *J Food Biosci Technol* 09:1–10
- Anh NTL, Tuan HQ, Tu NTM (2016) Variations in fatty acid composition of tea leaves (*Camellia sinensis*) due to plucking time and cultivars. *J Sci Technol* 54:284–290
- Wang X, Zeng Q, Verardo V, Contreras MDM (2017) Fatty acid and sterol composition of tea seed oils: their comparison by the “FancyTiles” approach. *Food Chem* 233:302–310. <https://doi.org/10.1016/j.foodchem.2017.04.110>
- Borghain A, Konwar K, Buragohain D, Varghese S, Dutta KA, Paul RK, Khare P, Karak T (2020) Temperature effect on biochar produced from tea (*Camellia sinensis* L.) pruning litters: a comprehensive treatise on physico-chemical and statistical approaches. *Bioresour Technol* 318:124023. <https://doi.org/10.1016/j.biortech.2020.124023>
- Liu Y, Tian J, Liu B, Zhuo Z, Shi C, Xu R, Xu M, Liu B, Ye J, Sun L et al (2022) Effects of pruning on mineral nutrients and untargeted metabolites in fresh leaves of *Camellia sinensis* cv. Shuixian *Front Plant Sci* 13:1016511. <https://doi.org/10.3389/fpls.2022.1016511>

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