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Study on production conditions, volatile composition, and chemical characteristics of herbal tea using Arapgir purple basil (*Ocimum basilicum* L.)

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ABSTRACT

In this work, production of purple basil (*Ocimum basilicum* L.) herbal tea was studied. Purple basil is a medicinal and aromatic herb with many health benefits; it is commonly used for seasoning foods. Semi-shade and tray drying methods were used for drying purple basil for tea production. Physical, chemical, and sensory characteristics of samples were evaluated. Total polyphenol contents of samples increased with drying processes and were between 9.55 and 14.18 mg GAE/g. Colour values decreased with drying. Volatile composition of samples was determined using the SPME/GC-MS system. 2-Propenoic acid, 1,8-cineole (eucalyptol), and eugenol were the predominant volatile compounds in all samples. In sensory evaluation, samples produced by tray drying with added citric acid had the highest general acceptance. In conclusion, purple basil was evaluated as a suitable plant for herbal tea production due to its easy preparation, pleasant flavour and colour.

KEYWORDS

medicinal and aromatic plants, drying, colour, total phenolics, sensory evaluation

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1. INTRODUCTION

Medicinal and aromatic plants are rich in antioxidant and antimicrobial compounds and are widely used for herbal tea production in the food industry. Basil grows worldwide as a subvariety of species *Ocimum basilicum* L. (Simon et al., 1999). It is purple, has a special leaf shape, flower structure, and some other properties as a result of differences in soil structure and climatic conditions (Hussain et al., 2008). Basil is used extensively in foods for its aroma and as a flavouring agent in meals and cold salads (Sonmezdag et al., 2018).

Previous studies reported many advantages of basil, such as appetising flavour, diuretic, stimulant, and spasm-resolving properties, and providing support in cases of insomnia, phlegm, and gas. Basil helps digestion, calms the stomach, and regulates the menstrual period (Akgül, 1993). Various studies were conducted on the production of herbal tea from many plants (Heck and Gonzalez de Mejia, 2009; Ravikumar, 2014); however, no study was done to produce herbal tea using purple basil. In this study, the aim was to investigate the production possibilities of purple basil herbal teas and to explore physical, chemical, and sensory characteristics.

2. MATERIALS AND METHODS

2.1. Materials

Arapgir purple basil (*O. basilicum* L.) was harvested in Arapgir (39°02′N, 38°29′E, Malatya, Turkey) during crop season (June–September, 2016). Arapgir purple basil has a different genotype from other basil species, therefore, it is geographically registered with the name of origin in Official Geographical Indication by the Turkish Patent and Trademark Office, TURKPATENT (Ankara, Turkey). *Hibiscus sabdariffa* L. (as a tasting, colouring, and flavouring agent with high anthocyanin content and bioactive properties) and citric acid (as an acidifying agent to reduce pH to enhance red colour originated from anthocyanins in purple basil) were used in dried forms for herbal tea production. Hibiscus and citric acid were supplied from local markets.

2.2. Methods

2.2.1. Drying. Fresh purple basil was harvested and cleaned. Stems and flowers were separated, then leaves were dried. Tray and semi-shade drying methods were used, and drying processes were conducted to below 5% of moisture content. Porous metal nets were used for semi-shade drying to obtain 50% of sunlight and heat. Average temperature and relative humidity were 35 °C and 22%, respectively, during 22–27 h of drying time for semi-shade drying. Tray drying was conducted with a laboratory-type tray dryer (Eksis Machine Ltd., Isparta, Turkey). Three different temperatures (40, 45, and 50 °C at 1.5 m s^{-1} airflow) were used and dried basils were evaluated by their colour values, moisture contents, and sensory scores. After evaluations of the above parameters, 45 °C temperature and 1.5 m s^{-1} air velocity were chosen for tray drying. Under these conditions, the total tray-drying time was about 7 h. Drying curves for the tray and semi-shade drying are given in Supplementary Fig. 1.

2.2.2. Production of herbal tea. After fragmenting dried basils, hibiscus and citric acid were blended according to the formulas given in Table 1. Samples were packed in tea bags (1.5 g) and kept at room temperature.

2.2.3. Determination of physicochemical properties. Moisture content was determined with an oven (Nuve, model FN 032/055/120, Ankara, Turkey) drying method (AOAC 984.25, 1984). Water extract analysis was performed according to the Turkish Standard method (TS ISO 9768, 1997). Water activity (a_w) values were determined with a water activity measuring instrument (Novasina, Lab Touch-aw, Switzerland).

2.2.4. Determination of total phenolic compounds. A 25 mL of 0.1% HCl was prepared in methanol, added to 0.5 g of dried purple basil, and kept in the freezer (−18 °C) for 24 h. Then, 40 μL of the prepared mixture was taken, mixed with 3.16 mL of distilled water and 200 μL of Folin–Ciocalteu's reagent. Each sample was vortexed (Heidolph, D-91126, Schwabach, Germany) for 1 min, then left in dark for 5 min. Then, 600 μL of 2% Na_2CO_3 was added to the mixture and kept in the dark for 120 min at ambient temperature. UV-spectrophotometer (Shimadzu, UV-1800, Kyoto, Japan) was used at 765 nm, and a calibration curve was drawn by preparing different concentrations (mg L^{-1}) of gallic acid solutions. Results were expressed as mg GAE/g (Singleton et al., 1999).

2.2.5. GC-MS volatile analysis. A 1 g of dried sample was placed into 15 mL SPME vials (Supelco, Bellefonte, PA, USA) for analysis. For the calculation of a compound, 50 ppm 2-methyl-3-heptanone was prepared in methanol as the internal standard, and 10 μL internal standard was added to each vial. A fibre containing DVB/CAR/PDMS (Divinylbenzene/Carboxen/Polydimethylsiloxane; 50/30 μm coating thickness, 2 cm length; Supelco, Bellefonte, PA, USA) was used for extraction. Vials were kept on a heater at 40 °C for 30 min and then the fibre was injected into vials for adsorption for the next 30 min. A gas chromatography-mass spectrometer system (Shimadzu GC-MS, model QP2010 plus, Kyoto, Japan) was used for the determination of volatile compounds as described in details by Korkmaz et al. (2020), and results were expressed as μg g^{-1}.

2.2.6. Colour measurement. Colour values of samples were measured using a colorimeter (Konika Minolta, CR-5, Japan). All measurements were run in 6 parallels and the average values

Table 1. Herbal tea formulations

Samples	Purple basil (g)	Hibiscus (g)	Citric acid (g)
Semi-shade dried samples			
S	1.75	–	–
SC	1.75	–	0.10
SH	1.75	0.10	–
SHC	1.50	0.25	0.05
Tray dried samples			
T	1.75	–	–
TC	1.75	–	0.10
TH	1.75	0.10	–
THC	1.50	0.25	0.05

are given. Hunter CIE (L^*, a^*, b^*) values were measured, and total colour change (ΔE), hue angle (H°), chroma value (C), and browning index (BI) were calculated.

2.2.7. Sensory analysis. Sensory analysis was conducted according to the Turkish Standard (TS 5546, 2009). A total of 8 panellists (aged between 23 and 44 years) evaluated samples for flavour, odour, colour, brightness, foreign taste, sour taste, bitter taste, basil aroma, fullness, and general acceptance characteristics on a scale of 0–5. Each sample was prepared as infusions with boiled water (100 °C) and presented to panellists after 10 min of brewing/infusion.

2.2.8. Statistical analysis. Experimental results were analysed with General Linear Model using SPSS 16.0 (SPSS Inc., USA) package program for all data, except GC-MS data. Data were evaluated using Duncan's multiple comparison test at $P < 0.05$ significance level. Effects of drying (D), formula (F), and D × F interactions on results were determined by factorial experimental design. ANOVA and principal component analysis (PCA) were applied using SPSS v.9.0 to clarify relations between samples for GC-MS data for volatiles and all volatile compounds used as variables for tests.

3. RESULTS AND DISCUSSION

3.1. Physicochemical properties

The moisture content of samples varied between 4.79 and 5.48% (Table 2) in accordance with regulation; it should not be more than 7% according to the Turkish Food Codex for Black Tea (Anonymous, 2008). Moisture contents in tray-dried herbal teas were lower than those of semi-shade dried counterparts ($P < 0.01$). This was confirmed by the values of water

Table 2. Physical and chemical properties of samples[1]

Sample	Moisture content (%)	Water extract (%)	Water activity (a_w)	Total phenolics (mg GAE/g dw)
Semi-shade dried samples				
S	5.05 ± 0.09	34.17 ± 4.20	0.312 ± 0.00	12.73 ± 0.03
SC	5.05 ± 0.03	36.25 ± 1.26	0.296 ± 0.01	12.75 ± 0.06
SH	5.48 ± 0.13	34.71 ± 4.12	0.302 ± 0.00	9.56 ± 0.05
SHC	5.12 ± 0.13	37.01 ± 3.19	0.275 ± 0.04	9.55 ± 0.15
Tray dried samples				
T	4.83 ± 0.06	39.34 ± 0.64	0.204 ± 0.03	14.18 ± 0.29
TC	4.82 ± 0.25	41.95 ± 5.22	0.209 ± 0.04	11.03 ± 0.03
TH	5.06 ± 0.24	40.32 ± 3.97	0.210 ± 0.03	10.99 ± 0.07
THC	4.79 ± 0.39	44.49 ± 1.80	0.216 ± 0.03	11.35 ± 0.10
Statistics				
Drying (D)	**	***	***	*
Formula (F)	***	***	ns	***
D × F interaction	ns	ns	**	***

ns: not significant; Significance at *: $P < 0.05$, **: $P < 0.01$ and ***: $P < 0.001$.
[1] Sample names and tea formulations are explained in Table 1.

activity (a_w) of samples. Moisture content was between 4.11–12.5% for green tea samples (Aroyeun, 2013). In another study, moisture contents of spray-dried green tea extracts varied between 4.40–4.87% (Susantikarn and Donlao, 2016).

Water extract values of samples ranged between 34.17 and 44.49% (dry basis). Water extracts of samples were significantly influenced by both drying method and formula ($P < 0.001$). The value of water extract increased with the addition of hibiscus or citric acid; and it was higher using tray drying for samples (Table 2). Water extract value should be at least 32% (on dry basis) according to the Turkish Food Codex for Black Tea (Anonymous, 2008). Almost the same values were found for water extract parameters in tea samples in various studies, e.g., values varied between 21.7–43.6% (Aroyeun, 2013).

The a_w values of samples varied between 0.204–0.312 (Table 2) in accordance with the Turkish Food Codex for tea. Higher a_w values were observed in semi-shade dried samples when compared to tray-dried samples ($P < 0.001$); however, no changes were seen in samples according to the tea formula ($P > 0.05$). Similar results were observed in several studies with values for water activity ranging from 0.21–0.29 for spray-dried green tea extracts (Susantikarn and Donlao, 2016) to 0.221–0.311 for instant sage (*Salvia fruticosa* Miller) tea samples (Nadeem et al., 2013).

3.2. Total phenolic compounds

The total phenolic content of samples ranged from 9.55 to 14.18 mg GAE/g as shown in Table 2. Total phenolic contents of tray-dried samples were higher than those of semi-shade-dried herbal teas ($P < 0.05$). Surprisingly, lower levels of total phenolic contents were observed in SH and SHC samples, which contained hibiscus. Same decrease was recorded in tray-dried samples when adding citric acid and hibiscus. In a study performed with eight different purple basils, total polyphenol contents of dried basil samples varied between 13.1–26.9 mg GAE/g (in dry matter) (Flanigan and Niemeyer, 2014). Total phenolic contents changed between 14.78–20.37% for spray-dried green tea extracts (Susantikarn and Donlao, 2016) and 13.28–29.72 g/100 g (in dry matter) for instant soluble sage (*S. fruticosa* Miller) (Nadeem et al., 2013). In a study of 110 herbal teas in China, total polyphenol contents of samples changed between 0.8–289.7 mg GAE/g (in dry matter) (Jin et al., 2016).

3.3. Volatile compounds

Volatile profiles of fresh basil, tray-dried basil, semi-shade-dried basil, and herbal teas were determined by using the GC-MS technique. A total of 61 compounds were identified in fresh basil as shown in the GC-MS chromatogram (Supplementary Fig. 2a). β-Burbonene was present only in fresh basil because drying processes caused the loss of this volatile compound. Significant differences were observed between the amounts of volatiles in herbal teas, except for 2-methylbutanal, 3-methylbutanal, hexanal, and benzyl alcohol ($P < 0.05$) as shown in Supplementary Table 1. The quantity of volatile compounds reached higher levels in herbal tea produced with tray-dried basil. Similarly, sensory scores and colour values were higher for herbal teas produced with tray-dried basil.

In total, 80 volatile compounds were identified in herbal teas produced with semi-shade-dried basil. Linalool, 1,8-cineole, 2-propenoic acid, and eugenol were the most abundant compounds in herbal teas produced from semi-shade-dried basil. Octanal, α-bulnesene, tetradecane, 3-octanol, nerolidol, α-bisabolol, geraniol, 2,3-dimethyl-pyrazine, 1-octenyl-3-acetate, benzyl alcohol, and trans-β-ionone were found only in semi-shade-dried basil. A decrease in levels of 1-octen-3-ol, dl-limonene, and α-terpinene was observed, while α-pinene, 1,8-cineole, linalool, and 2-propenoic acid levels considerably increased by semi-shade drying. There was a significant increase in some volatiles (e.g., 2-propanone, α-pinene, linalool, β-elemene, α-humulene, α-terpineol, 2-propenoic acid, and eugenol) with hibiscus addition. Also, levels of β-myrcene, benzaldehyde, α-bisabolol, and 2-propenoic acid were raised with citric acid addition. A total of 67 compounds were identified in herbal teas produced with tray-dried basil as given in the GC-MS chromatogram (Supplementary Fig. 2b). Camphor was identified only in tray-dried basil. 1,8-Cineole, linalool, and 2-propenoic acid were the most abundant compounds in herbal teas produced with tray-dried basil. 1-octen-3-ol and 3-hexen-1-ol levels decreased with tray drying, while 2-propanone, α-pinene, β-pinene, linalool, and 2-propenoic acid levels significantly increased. Hibiscus and citric acid addition caused increases in levels of some compounds (linalool, γ-cadinene, 2-propenoic acid, and eugenol).

Methyl chavicol, linalool, bergamotene, eugenol, and methyl cinnamate compounds were the most abundant compounds in five different basil species (Klimankova et al., 2008). In another study, 27 volatile compounds were found in dried basil samples; the main compounds were eugenol and linalool (Diaz-Maroto et al., 2004). Kraujalyte et al. (2016) reported that 63 compounds were identified in instant tea samples produced from black tea. Zhang et al. (2021) showed 22 aroma-active compounds determined for new herbal tea-based kombuchas. In our study, levels of volatile compounds in herbal teas using tray-dried basil were higher than those of semi-shade dried basil; however, the number of volatiles in herbal tea using semi-shade dried basil was much higher. In general, volatile profiles and predominant compounds in samples are similar to other studies mentioned above.

Principal component analysis (PCA) was performed to determine differences between samples. PC1 and PC2 accounted for 48.9% and 23.7% of the variance as shown in Fig. 1 top. The PCA graph shows volatile components of S, SC, SH, and SHC located on the positive side of PC1, while other samples were located on the negative side. Volatile components in S and SH samples were located on the positive side of PC2 but others were on the negative side. SH coded samples had a different position from other samples in the PCA graph. This was due to lower levels of volatile components in herbal teas produced with semi-shade dried basil and there was less hibiscus in this sample compared to other hibiscus added samples. In addition, sensory analysis results of SH coded samples were lower than other hibiscus and citric acid added samples (Table 4). S, SH, SC, SHC, T, TC, TH, and THC coded samples had similar volatile profiles and, therefore, they clustered together on the hierarchical cluster analysis (HCA) dendrogram (Fig. 1 bottom). HCA dendrogram was used to visualise differences in volatiles between eight herbal teas based on information in Supplementary Table 1.

3.4. Colour values

L^*, a^*, and b^* values changed between 23.27–29.89, 2.13–3.93, and 1.93–5.10, respectively (Table 3). Significant differences were observed between colour values for ΔE (2.13–5.48), C (2.13–5.48), BI (3.95–23.99), and H° (31.38–61.16) ($P < 0.001$). Generally, colour parameters increased by tray drying when compared to semi-shade drying. Addition of hibiscus and citric acid to the formula affected the colour values positively; this was confirmed by sensory scores (Table 4). Similar and different data were also obtained from some works in literature, and these

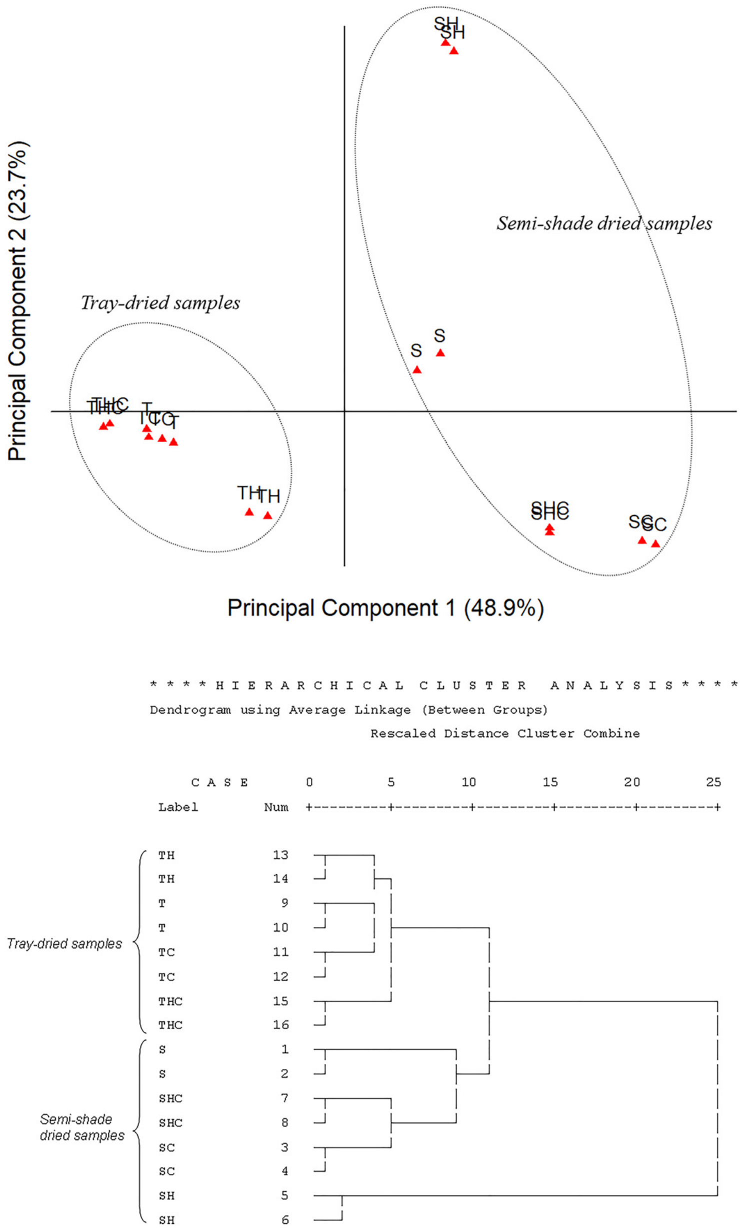

Fig. 1. Principal component analysis (PCA) plot (top) and hierarchical cluster analysis (HCA) dendrogram (bottom) of volatile compounds in tea samples. Sample names and tea formulations are explained in Table 1

Table 3. Colour values of samples[1]

Sample	L^*	a^*	b^*	ΔE	C	BI	H (°)
Semi-shade dried samples							
S	25.27 ± 2.40	2.13 ± 0.28	1.93 ± 0.02	3.90 ± 0.42	2.13 ± 0.28	6.26 ± 0.19	31.38 ± 0.25
SC	23.27 ± 2.41	3.19 ± 0.32	2.18 ± 0.01	4.24 ± 1.16	3.52 ± 0.61	3.95 ± 2.17	31.86 ± 0.10
SH	26.63 ± 3.49	3.44 ± 0.28	3.23 ± 0.01	5.76 ± 1.20	4.72 ± 0.20	21.76 ± 0.08	43.25 ± 2.31
SHC	28.77 ± 1.96	3.93 ± 0.21	3.81 ± 0.02	5.98 ± 1.58	5.48 ± 0.15	23.99 ± 2.23	44.17 ± 1.54
Tray dried samples							
T	29.89 ± 2.22	2.63 ± 0.17	5.10 ± 1.57	5.84 ± 0.04	4.31 ± 0.02	19.83 ± 0.05	61.16 ± 6.06
TC	28.35 ± 0.42	2.39 ± 0.04	2.86 ± 0.31	5.46 ± 0.04	3.74 ± 0.22	16.53 ± 0.86	49.99 ± 3.39
TH	26.96 ± 1.11	2.71 ± 0.14	2.66 ± 0.47	4.47 ± 0.46	3.82 ± 0.29	17.42 ± 1.06	44.07 ± 6.00
THC	28.13 ± 0.80	2.66 ± 0.07	2.83 ± 0.61	5.19 ± 0.37	3.90 ± 0.49	17.21 ± 2.07	46.09 ± 5.47
Statistics							
Drying (D)	*	*	*	*	*	*	*
Formula (F)	*	*	*	*	*	*	*
D × F interaction	*	*	*	*	*	*	*

* Significance at $P < 0.001$.

[1] Sample names and tea formulations are explained in Table 1.

L^*: Lightness; a^*: redness; b^*: yellowness; ΔE: Total colour change; C: chroma value; BI: browning index; H°: hue angle.

Table 4. Sensory evaluations of samples[1]

Sample	Flavour	Odour	Colour	Brightness	Foreign taste	Sour taste	Bitter taste	Basil aroma	Fullness	General acceptance
Semi-shade dried sample										
S	2.31 ± 0.44	2.62 ± 0.18	2.50 ± 0.00	2.56 ± 0.44	2.81 ± 0.26	1.69 ± 0.09	3.25 ± 0.35	3.31 ± 0.79	2.94 ± 0.26	2.31 ± 0.09
SC	3.94 ± 0.26	3.87 ± 0.35	4.44 ± 0.26	4.69 ± 0.26	4.00 ± 0.35	3.62 ± 0.35	4.25 ± 0.71	4.00 ± 0.35	4.00 ± 0.00	4.06 ± 0.09
SH	2.44 ± 0.09	2.87 ± 0.53	3.12 ± 0.00	3.19 ± 0.09	3.25 ± 0.18	2.12 ± 0.71	3.19 ± 0.26	3.06 ± 0.26	2.81 ± 0.09	2.81 ± 0.26
SHC	3.94 ± 0.09	4.12 ± 0.35	4.37 ± 0.71	4.31 ± 0.79	4.00 ± 0.71	3.69 ± 0.44	4.25 ± 0.88	4.12 ± 0.35	3.87 ± 0.53	4.12 ± 0.71
Tray dried samples										
T	2.31 ± 0.09	2.81 ± 0.62	2.56 ± 0.26	2.31 ± 0.09	3.00 ± 0.18	2.12 ± 0.00	2.50 ± 0.35	3.62 ± 0.53	3.19 ± 0.26	2.50 ± 0.00
TC	4.06 ± 0.09	4.44 ± 0.26	4.56 ± 0.44	4.31 ± 0.26	4.25 ± 0.18	3.81 ± 0.79	3.87 ± 0.35	4.06 ± 0.26	4.25 ± 0.35	4.19 ± 0.09
TH	3.00 ± 0.35	3.31 ± 0.09	2.87 ± 0.35	2.69 ± 0.26	3.12 ± 0.00	2.37 ± 0.53	2.87 ± 0.35	3.87 ± 0.18	3.12 ± 0.18	2.87 ± 0.18
THC	3.81 ± 0.09	3.87 ± 0.18	4.37 ± 0.18	4.56 ± 0.09	3.69 ± 0.09	3.31 ± 0.44	3.62 ± 0.00	3.37 ± 0.53	4.12 ± 0.35	4.06 ± 0.09
Statistics										
Drying (D)	ns	ns	ns	ns	ns	ns	**	ns	ns	ns
Formula (F)	**	**	**	**	**	**	**	ns	**	**
D × F interaction	ns	ns	ns	ns	ns	ns	ns	*	ns	ns

ns: not significant; Significance at *: $P < 0.05$ and **: $P < 0.001$.

[1] Sample names and tea formulations are explained in Table 1.

are summarized as follows: Total colour change values varied between 3.89–13.27 for microwave-dried basil samples (Demirhan and Özbek, 2009). In China, average chroma and hue angle values were 11.21 and 93.91, respectively, for 110 herbal tea samples (Jin et al., 2016). In one study, chroma and hue angle values ranged between 27.63 to 31.28 and 95.91 to 102.83, respectively, for green honeybush (*Cyclopia subternata*) herbal tea (Joubert et al., 2010).

3.5. Sensory evaluation

Sensory properties were evaluated and results are presented in Table 4. Spider plots for flavour attributes of samples are given in Fig. 2. Sample TC was the most preferred herbal tea with an

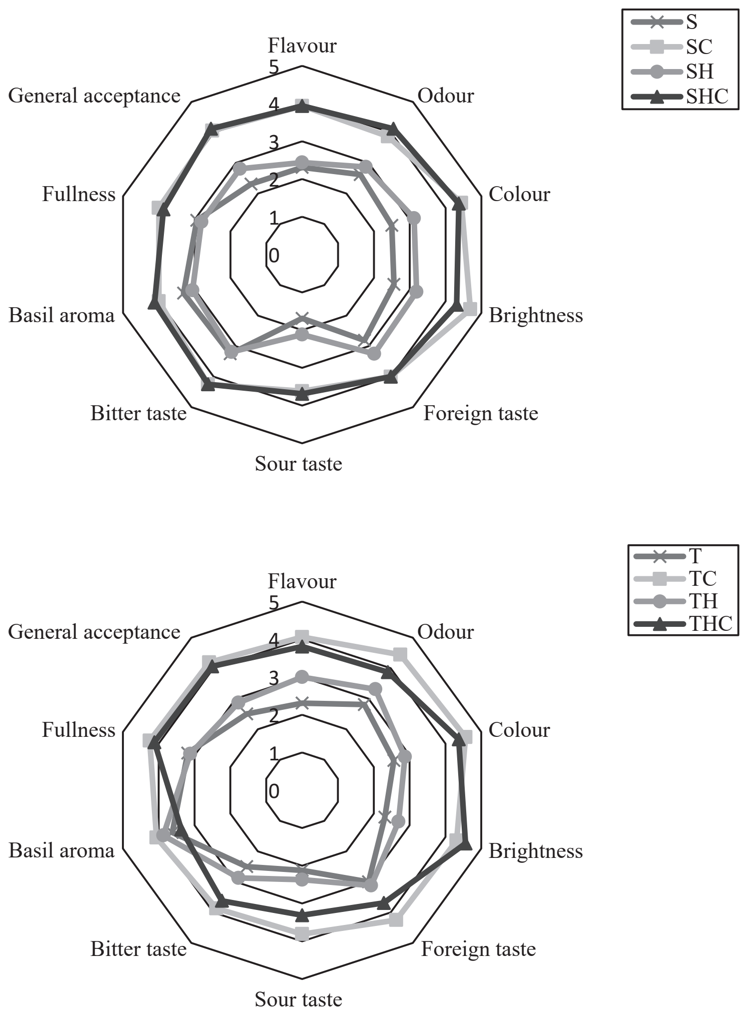

Fig. 2. Spider plot for flavour attributes of herbal tea samples produced with semi-shade dried basil (top) and tray-dried basil (bottom). Sample names and tea formulations are explained in Table 1

average rating of 4.19 points. No statistical differences were observed in sensory properties for drying processes except for bitter taste; however, the use of different formulas significantly changed the sensory scores ($P < 0.001$). Drying processes and tea formula interaction were not statistically significant for sensory properties ($P > 0.05$), except for basil aroma ($P < 0.05$). In a study with shade-dried aerial parts of Turkish basil samples, fresh, floral, and green odour descriptors had the highest scores, while minty, herbal, spicy, citrusy, sweety, and oily notes had the lowest scores (Sonmezdag et al., 2018). Wang et al. (2000) reported bitterness, sweetness, and sour taste characteristics evaluated in the range of 0–15 points for green tea samples. Average bitterness, sweetness, and sour taste values were 7.22, 4.87, and 7.43, respectively. In a study conducted with new herbal tea-based kombuchas, mint and green tea kombucha attained the highest and lowest overall sensorial acceptance ratings, respectively (Zhang et al., 2021).

4. CONCLUSIONS

Production possibilities of herbal teas from purple basil (*Ocimum basilicum* L.) were tried and some chemical and biochemical characteristics of basil and herbal teas were comparatively studied. Basil has beneficial health effects and is consumed as a spice in Turkish cuisine. Therefore, we considered the production of a new beverage may increase the use of this medicinal and aromatic plant. Beside the production of herbal tea, traditional and industrial drying methods were compared. The comparison of the drying methods showed tray drying was a better method and had some superiority in herbal tea production. Colour values of fresh basil decreased with semi-shade drying, while tray drying increased them. In volatile component analysis, volatile compounds changed qualitatively and quantitatively based on the drying method. Levels of volatile compounds for herbal teas using tray-dried basil were higher than for semi-shade-dried samples, while the number of volatile compounds was higher in herbal teas with semi-shade-dried basil. In sensory analysis, herbal teas containing citric acid had the highest points. Results indicated that Arapgir purple basil is a suitable plant for herbal tea production.

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SUPPLEMENTARY MATERIALS

Supplementary data to this article can be found online at https://doi.org/10.1556/066.2022.00165.

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