Processing of a novel powdered herbal coffee (*Pistacia Terebinthus* L. Fruits Coffee) and its sensorial properties

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Abstract In this study, the effects of roasting method, grinding and reduction in oil content on the characteristics of *Pistacia terebinthus* fruit coffee were investigated. *Pistacia terebinthus* fruit was roasted by microwave, pan and combined (microwave and convection) methods. The degree of roasting was determined by L*, a*, b* color values. The roasting times were 1,500, 1,900 and 1,620 s for microwave, pan and combined roasting methods, respectively. Cold press was used to reduce the oil content both prior to roasting and after the roasting. The oil content was reduced to around 21.5 % in all roasting methods to approach to that of coffee beans. Powdered *Pistacia terebinthus* fruit coffee brews were compared with each other and Turkish coffee in terms of aroma, flavor, acidity aftertaste, and overall acceptability. Sensorial analysis results showed that coffee brews prepared by pressing after the roasting process were better than those pressing prior to roasting.

Keywords *Pistacia terebinthus* fruit · Coffee · Roasting · Grinding · Oil removal · Sensory properties

Introduction

Coffee is consumed in high amounts around the world and differs in terms of roasting and brewing conditions with respect to different regions. However, many coffee substations known as herbal coffee have been used to reduce negative side effects, such as high caffeine content, of excessive coffee consumption. This allowed obtaining herbal products which are produced and consumed similar to coffee beans.

Pistacia Terebinthus fruit (PTF) coffee or “Menengiç” coffee is the most famous and traditional herbal coffee in Turkey. The fruits have been obtained from *Pistacia terebinthus* L. which is a member of the family *Anacardiaceae*. The PTF has been used in folk medicine for gastralgia (internally), rheumatism and cough (externally) and also as stimulant, diuretic and antitussive (Baytop 1984; Matthaus and Özcan 2006; Özcan 2004; Walheim and Stebbins 1981). In various regions of the world, different organs of this tree are exploited for several purposes because of its antioxidant effect (Topçu et al. 2007). Göğüş et al. (2011) reported that PTF contains similar flavor compounds to coffee beans, suggesting that PTF may provide an alternative for use in the coffee industry. Therefore, PTF have a high potential as an alternative to coffee beans because of its unique flavor and aroma. Çiftçi et al. (2009) reported that the PTF coffee was found to be rich in vitamins, unsaturated fatty acids and trace elements, suggesting that they may be valuable for drink uses.

Roasting is a very important process for the coffee industry due to development of aroma and flavor compounds. Buffo and Cardelli-Freire (2004) reported that roasting methods and conditions have an important effect on the formation of the roasted coffee flavors. Nebesny et al. (2007) showed that uniformly roasted coffee bean with full aroma could be obtained by using microwave roasting. Göğüş et al. (2011) reported that traditional pan roasting is the most common method for PTF coffee processing. In contrast to Arabica coffee, PTF coffee has an oily structure like sludge because of its high oil content. High oil content also results in a heavy oil flavor to drink in final brewed coffee. This needs to reduce oil content to obtain a product in powder form with a more desirable flavor.

The aim of this study was to investigate the effects of different roasting methods before or after the removal of oil by cold pressing and particle size on sensorial properties of powdered *P. terebinthus* fruit coffee brews.

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Material and methods

Materials

The ripening PTF which were collected in September, 2011 season, were purchased from a local market in Gaziantep, Turkey. The PTF were cleaned manually to remove all undesirable materials such as dust, dirt, stone and broken kernels. They were stored at 4 °C in polypropylene bag until used. Commercial roasted Turkish coffee (TC) which was ground and packed in September, 2012 was purchased from a local market.

Roasting, oil removal, grinding and fractionation

PTF were roasted by microwave, pan and combined roasting methods. 200 g samples were used for each roasting process. PTF was stirred throughout roasting to obtain homogen samples. The degree of roasting was followed by L^* , a^* , b^* color values. The roasted PTF was stored at 4 °C in polypropylene bags until used. A programmable and the coupled convection-microwave domestic oven (Arçelik MD 583, Turkey), providing both convectional (convectional power of 1,250 W) and microwave heating (maximum output of 1,300 W at 2,450 MHz) was used for microwave roasting (MWR) and combined (convection and microwave) roasting (CR). Pan roasting (PR) was carried out in a metal plate by using hot plate with a magnetic stirrer.

Oil removal was carried out by cold pressing with a laboratory scale press (Ceselsan, YP 0420, Turkey). Oil was removed both prior to roasting (Pressing-Roasting) and after roasting (Roasting-Pressing). The oil content was reduced to approximately 21.5 %.

PTF were ground using laboratory blender (Waring HGB150, USA) for 30 s. Fractionation was carried out by using the five sieves with mesh widths of 425, 450, 530, 710 and 800 μm . The particles were rotated all directions continuously to pass through the sieve opening. The sieved particles were stored at 4 °C until sensory analysis.

Determination of color and oil content

The color of samples was measured by a Hunter-Lab ColorFlex, A60-1010-615 model colorimeter (HunterLab, Reston, VA). The instrument (45°/0° geometry, D65 optical sensor, 10° observer) was standardized each time with a black and a white ($L^* = 93.76$, $a^* = -1.05$, $b^* = 0.74$) tile. The L^* , a^* , b^* color space was used to express the color changes. The L^* shows whiteness or brightness/darkness, a^* (redness/greenness) and b^* (yellowness/blueness). The experiments were carried out in triplicate.

The oil content of samples was determined by the Soxhlet extraction technique. The oil from samples was extracted

using hexane in a Soxhlet instrument (Velp Scientifica, Usmate, Italy). The oil extract was collected in an extraction cup. The extracted oil was weighed to determine the oil content. The experiments were carried out in triplicate.

Determination of pH, titratable acidity and free fatty acids

2.00 g of sample was accurately weighed into a 200 ml glass bottle, and 100 ml of deionized water was added in. The glass bottle was boiled for 10 min. Then, 50 ml of the filtered extract was cooled to room temperature and used for pH determination with a pH meter.

The titratable acidity was determined by AOAC 920.92. The results are expressed as 0.1 ml alkali required neutralizing acidity of 100 g sample. Measurements were taken in triplicate.

Free fatty acid content of extracted oil was analyzed according to official methods AOCS Ca 5a-40. Measurements were taken in triplicate.

Coffee brewing and sensory analysis

PTF coffee and TC brews were prepared according to the standard procedure used for Turkish coffee (5 g of ground coffee for each sample was gently mixed with 60 ml water for each panelist and the mixtures were cooked in a coffee maker until first boiling). The coffee brews were subjected to sensory analysis for aroma, flavor, acidity, after taste and overall acceptability. The sensory evaluation was carried out by 10 panelists (7 women and 3 men) selected from students and laboratory staff using 9 point hedonic scale. Samples for analysis were served separately in a well lit room on coded cups. The panelists washed their mouth with water before they were served the subsequent coffee brewing.

Statistical analysis

The analysis results were compared with TC as a reference sample by one-way analysis of variance (ANOVA). Means of the groups were compared using Duncan's multiple range test using a SPSS statistical packet (Version 16, 2007, Polar Engineering and Consulting, Nikiski, USA).

Result and discussion

The relationship between roasting methods and color values and oil content

Figure 1 shows the flow diagram for the production of powdered terebinthus fruit coffee from the raw terebinthus fruit by roasting and cold pressing. Roasting processes performed were pan, microwave and microwave-convection. Pressing process

Fig. 1 Flow diagram for *Pistacia Terebinthus* fruit coffee production

has been applied to reduce the oil content of terebinthus fruit prior to roasting and just after the roasting. It has been found that pressing prior to roasting resulted in poor homogeneity in roasting process because of uneven particle size distribution. Especially small particles produced during pressing burned in the first period of the roasting process. So, pressing after the roasting process has been used for further applications to obtain a homogenously roasted sample with lower oil. In addition, the removal of oil was more successful in pressing after the roasting applications. Dalgıç et al. (2011) also showed that PTF roasted at different temperatures has a high oil yield when compared with unroasted ones.

The time of roasting is a critical parameter on the characteristics of final product. The time of roasting has been decided by the color values to make it comparable for various roasting methods. The color values of the most desirable product have been decided by many trials. The oil has been removed from the roasted samples to observe the color, aroma and odor for each trial. The color values chosen as a reference have been decided by the end of their pre-sensorial analysis. The L^* , a^* , b^* values chosen as a reference were in a range of 18.00–18.05, 1.0–1.5 and 1.5–2.0, respectively. The roasting times needed to obtain those color values were 1,500, 1,900 and 1,620 s for microwave, pan and combined roasting methods, respectively. Roasting time has been kept constant in all following experiments.

Table 1 shows the oil contents of Turkish coffee, *P. terebinthus* fruit and the processed (microwave, pan and combined) terebinthus fruits after the removal of oil. It has

Table 1 The effect of roasting conditions on color characteristic and oil content of *P.terebinthus* fruits

Samples	Oil Content (%)	L^*	a^*	b^*
TC	16.05±0.13	36.68±0.53 ^a	15.44±0.22 ^a	27.44±0.33 ^a
Raw PTF	40.50±0.95	28.48±0.95 ^b	−4.79±0.11 ^b	4.42±0.17 ^b
MWR	21.50±0.72	18.37±0.63 ^c	1.16±0.08 ^c	1.84±0.13 ^c
CR	21.02±0.88	18.34±0.14 ^c	1.14±0.13 ^c	1.63±0.31 ^c
PR	20.06±0.93	18.12±0.62 ^c	1.20±0.12 ^c	1.78±0.38 ^c

Values are mean ± standard deviation ($n=3$). Different letters indicate statistically significant differences by Duncan's multiple range test at $p<0.05$. TC: Turkish coffee, PTF: *Pistacia Terebinthus* fruits, MWR: Microwave roasting, CR: Combined roasting, PR: Pan roasting

been observed that terebinthus fruits have an initial oil content of 40.05 %. However, the terebinth fruit with very high oil content was not practical to obtain a powder product after grinding. The trials showed that the critical point was 26 % to obtain a product in powder form. So, it has been reduced to almost half of its initial value after the roasting following with cold press oil extraction process. The oil contents found for processed terebinthus fruits were quite similar to that of commercial Turkish coffee. However, these values of oil content were still higher than those found by Mazzafera (1999) for Arabica coffee.

Table 1 presents the change in color values with respect to the applied process. The L^* , a^* , b^* color values of raw terebinth fruit describing brightness (L^*), greenness or redness ($\pm a^*$) and yellowness (b^*) were found to be 28.48, −4.79 and 4.42, respectively. It has been observed that L^* , a^* , b^* values found statistically different when terebinthus fruits have been processed by three different methods to obtain a powder product. L^* values have been reduced sharply in all cases to around 18.00. The roasting caused the loss of greenness and the final product in each case had a red character. Yellowness followed an irregular path during roasting process. However, it resulted in a decrease by the end of overall process. Final L^* , a^* , b^* values were almost the same for different roasting methods.

Particle size distribution

The size of coffee particles has an important affect on the final sensorial quality of coffee because of solubility of the matter. Clarke (1987) claimed that in brew coffee, when the grinding grade is finer, the extraction of soluble and volatile compounds is higher. Illy and Viani (2005) also found that particle size is one of the important factors which affects the sensory properties of coffee. Figure 2 shows the particle size distribution of ground and pressed terebinthus fruits. The highest particle size range was found to be 425–450 μm (26.67 %). The sizes in descending order with regards to the amounts were found as <425 μm (23.00 %), 450–530 μm (17.67 %), over 800 μm (17.33 %) and 530–710 μm

Fig. 2 Particle size distribution of ground powder *Pistacia Terebinthus* fruit coffee

(15.33 %). The results found for particle sizes of terebinth fruit coffee were in a good agreement with those of earlier studies (Nebesny et al. 2007; Czerny et al. 1999). Even if the whole ground product had a homogeneous distribution with a percentage over 80 % in a size range of 250–800 μm, the size range of 425–450 μm was found as the best in pre-sensorial analysis. This size range was used in the following chemical and sensorial analysis.

Titrateable acidity and pH values of terebinth fruit coffee roasted at different conditions were presented in Table 2. Titrateable acidity values were found to be 165.48, 237.05 and 220.83 ml NaOH/100 g coffee for MWR, PR and CR, respectively. Titrateable acidity for commercial TC used in this study was found to be 420.19 ml NaOH/100 g coffee. Mazzafera (1999) presented the titrateable acidity of different coffee samples in the range of 228–267 (ml/100 g). Martin et al. (1999) were also reported the titrateable acidity of coffee samples in the range of 101–114 (ml/100 g). Titrateable acidity of commercial TC is found statistically different ($p<0.05$). The different roasting methods of terebinthus fruits caused significant difference in titrateable acidity statistically ($p<0.05$). They are all found different to each other. The

Table 2 The effect of roasting conditions on titrateable acidity, pH, and free fatty acid

Sample	Titrateable Acidity (ml NaOH/100 g coffee)	pH	FFA (% Oleic)
TC	420.19±0.48 ^a	5.60±0.03 ^a	3.88±0.06 ^a
MWR	165.48±0.53 ^b	6.37±0.01 ^b	2.69±0.04 ^b
CR	220.83±0.45 ^c	6.57±0.03 ^c	2.70±0.02 ^b
PR	237.05±0.32 ^d	6.27±0.04 ^d	2.73±0.01 ^b

Values are mean ± standard deviation ($n=3$). Different letters indicate statistically significant differences by Duncan's multiple range test at $p<0.05$. TC: Turkish coffee, PTF: *Pistacia Terebinthus* fruits, MWR: Microwave roasting, CR: Combined roasting, PR: Pan roasting. FFA: Free fatty acid

differences may be due to roasting conditions, preparation of brew and age of coffee.

The pH values were found to be 6.37, 6.27 and 6.57 for MWR, PR and CR, respectively. The results found in this study are in a good agreement with those reported in literature. Somporn et al. (2011) reported that pH values of Arabica coffee were found to be 5.46, 5.49 and 5.48 for light, medium and dark roasting, respectively. Santos and Oliveira (2001) were also reported the similar pH values for different coffee samples. However, the pH value of TC was found to be statistically different ($p<0.05$) than those of pistacia terebinth coffee roasted at various conditions. It has been discussed by Brollo et al. (2008) that the titrateable acidity in coffee brews could be a more reliable indicator for correlating coffee acidity than pH values. Even if there is a good correlation between pH and titrateable acidity values in this study, especially higher pH values support the idea of more reliable values of titrateable acidity. Acidity basically is a result of the formation of formic, acetic, glycolic and lactic acids during roasting (Ginz and Bradbury 2000). These are all degradation products of oils, proteins and/or carbohydrates. Göğüş et al. (2011) identified some of these acids as volatile components in pistacia terebinth coffee in various stages of roasting. Various roasting conditions of terebinthus fruits caused significant difference on the pH value. They are all found different to each other.

Table 2 also represents the free fatty acid of oil of terebinth fruit coffee as quality parameter to show the effect of roasting on the degradation of triglycerides. It is seen that the Turkish coffee which is used as a control has highest free fatty acid content. In addition, free fatty acid content of Turkish coffee found statistically different ($p<0.05$) than those of pistacia terebinth fruit coffees. They were found to be 2.69, 2.70 and 2.73 for MWR, CR and PR, respectively. Even if there is no statistically difference among them, pan roasting has the highest value in free fatty acid content compared to those of other roasting methods of terebinth fruit coffee. This might be because of longer roasting time in pan roasting (1,900 s). Geçgel Ü and Arıcı (2008) reported that free fatty acid changes between 0.76 and 2.40 in the raw oil of PTF. Kocak et al. (2011) also found free fatty acid as 0.59 for raw pistacia terebinth fruit oil. The increased value of free fatty acids compared to earlier studies is a clear indication of high temperature roasting applications.

Evaluation of sensory properties

The average values of sensory properties, namely aroma, flavor, acidity, after taste and overall acceptability were given for brews of terebinth fruit coffee roasted by various methods and Turkish coffee in Table 3. Aroma scores were ranged from 5.6 to 6.2 points for powdered PTF coffees. It has been found that there is no difference statistically ($p<0.05$) in aroma values of studied coffee samples. The highest average aroma score was given to

Table 3 Effect of roasting conditions on sensory attributes of powdered *Pistacia terebinthus* fruits coffee brews

Sensory Attributes	Control	Roasting Conditions		
	TC	MWR	CR	PR
Aroma	5.5±2.27 ^a	5.6±0.84 ^a	6.2±1.47 ^a	5.6±1.26 ^a
Flavor	5.8±2.09 ^b	5.4±0.97 ^b	6.1±1.59 ^b	5.8±1.23 ^b
Acidity	5.2±1.75 ^c	5.3±1.33 ^c	6.0±1.63 ^c	6.3±1.33 ^c
After Taste	5.8±1.55 ^d	5.8±1.47 ^d	6.0±1.88 ^d	6.0±1.56 ^d
Overall Acceptability	5.9±2.28 ^e	5.6±1.34 ^e	6.2±1.75 ^e	6.3±1.15 ^e

Values are mean ± standard deviation ($n=10$). Different letters indicate statistically significant differences by Duncan's multiple range test at $p<0.05$. TC: Turkish coffee, PTF: *Pistacia Terebinthus* fruits, MWR: Microwave roasting, CR: Combined roasting, PR: Pan roasting

terebinth fruit coffee roasted by a combined (microwave-convective) method. Turkish coffee which is used as a reference had an aroma value of 5.5 with a very high standard deviation. These results show that the panelists are in a good agreement for powdered pistacia terebinth fruits coffee brews. Furans, furanones, benzene derivatives and pyrazines are defined as typical components of coffee volatiles. Göğüş et al. (2011) reported that the number of total volatile compounds increased with increasing roasting time up to 20 min of pan roasting then decreased slightly at 25 min. They also found that furans and furanones produced in the first 5 min of roasting and they were the dominating components by the end of the roasting of pistacia terebinth fruits. Nebesny et al. (2007) also found similar results in terms of availability of furans and furanones in Robusta coffee brews.

Flavor scores were ranged from 5.4 to 6.1 points for powdered PTF coffees. The highest flavor score was given to powdered PTF coffee which is roasted in pan. Turkish coffee flavor score was found as 5.8. This score is still lower than that of combined roasting method. However, ANOVA results showed that there is no difference ($p<0.05$) in flavor scores of studied coffee samples, statistically. Flavor is the most important criterion for coffee quality evaluation and also one of the major motivations for consumer preference in coffee industry (Clarke 1987). The chemistry of flavor development during coffee roasting is highly complex and not completely understood. Even though, roasting process appears to be simple in terms of processing conditions, it is quite complex from a chemistry point of view, since hundreds of chemical reactions take place simultaneously. In roasted coffee, a large proportion of macromolecules are composed of unidentified materials, including melanoidins which is considered as final products of Maillard reaction (Andriot et al. 2004). Göğüş et al. (2011) found that the Maillard reaction products were dominant components of volatiles of pistacia terebinthus coffee.

Acidity scores of powdered PTF coffee roasted by various methods were found in a range of 5.3 to 6.3 points. The

highest acidity score was given to the powdered PTF coffee brewed from the roasted samples by combined method. Acidity score of Turkish coffee was lower than those of powdered PTF coffees. Coffee acidity is the bright and dry taste that adds life to a coffee. Some such researchers as Pangborn (1982), Sivetz and Desrosier (1979) and Griffin and Blauch (1999) claimed that the pH of a coffee has been found to correlate with the perceived acidity in coffee. Whereas, Voilley et al. (1981) suggested that titratable acidity produces a better correlation to perceived coffee acidity. The results found for chemical acidity values and sensorial acidity scores are in a good agreement. The chemical acidity value of Turkish coffee found higher compared to those of powdered PTF coffees. Higher acidity of Turkish coffee could be correlated with its very fine particles. International Coffee Organization (1991) supported that amount of some organic acids (lactic, malic, quinic, chlorogenic) in coffee brews increased from coarse grind to extra fine. However, the panelists preferred the powdered PTF coffees with a moderate acidity. Scores given for after taste were ranged from 5.8 to 6.0 points for powdered PTF coffees. The samples brewed from powdered PTF coffees obtained from combined and pan roasting processes had the highest aftertaste score. Aftertaste is the finish of food or drink, and was defined as the sensation present in the mouth immediately following the removal of whatever food or drink was being consumed (Jackson 2011). One of the crucial factors affecting aftertaste is the ability to properly develop the flavor profile during roasting. Even if there is no difference ($p<0.05$) in flavor scores among the studied samples statistically, CR and PR caused the production of most preferable flavor profile in this study.

The overall acceptability score of PR samples was found highest as 6.3. It was lowest in samples brewed from roasted PTF by MWR. The score found for TC was 5.9. Overall acceptability includes all cupping vocabularies because of defining the overall quality and acceptability of the product. Statistical analysis showed that there is no significant difference in overall scores of samples. However, most of the panelists have chosen the PR coffee as the best in terms of its overall acceptability. This result has also been supported with the results of other sensorial and chemical analysis.

Conclusion

High oil content in the PTF was reduced from 40.5 to about 21.5 % by cold press before roasting process. PTF free from excessive oil content was roasted by microwave, combined (microwave and convective) and pan. Roasted PTF were ground and sieved through different screens to obtain powdered coffee. The sensorial analysis has been performed for the brew of powdered PTF coffee with a particle size range of

425–450 μm . The sensorial results showed that powdered *Pistacia terebinthus* fruits coffee was not found to be different ($p < 0.05$) from Turkish coffee in terms of aroma, flavor, acidity, aftertaste and overall acceptability, statistically. The results of this study showed that it is possible to produce a novel powdered caffeine-free herbal coffee. It can be used as an alternative to Turkish coffee in the coffee industry.

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