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STANDARDIZATION OF ROASTING AND GRINDING CONDITIONS OF POWDERED *PISTACIA TEREBINTHUS* FRUIT COFFEE

M.Sc. THESIS

IN

FOOD ENGINEERING

BY

Ş. SELÇUK SEÇİLMİŞ

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Standardization of Roasting and Grinding Conditions of Powdered *Pistacia Terebinthus* Fruit Coffee

M.Sc. Thesis

in

Food Engineering

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Supervisor

Prof. Dr. Fahrettin GÖĞÜŞ

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T.C
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Approval of the graduate School of Natural and Applied Science

Assoc. Prof. Dr. Metin BEDİR
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Ali Rıza TEKİN
Head of Department

This is to certify that we have read this thesis and that in our consensus it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Fahrettin GÖĞÜŞ
Supervisor

Examining Committee Members:	Signature
Prof. Dr. Cahit BAĞCI (Chairperson)	....
Prof. Dr. Sibel FADILOĞLU	....
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Ş. Selçuk SEÇİLMİŞ

ABSTRACT

STANDARDIZATION ROASTING AND GRINDING CONDITIONS OF POWDERED *PISTACIA TEREBİNTHUS* FRUIT COFFEE

SEÇİLMİŞ, Ş. Selçuk

M.Sc. in Food Eng.

Supervisor: Prof. Dr. Fahrettin GÖĞÜŞ

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In this study, the effects of roasting methods, grinding and reduction in oil content on the characteristics of powdered *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. L*, a*, b* values for various roasting methods were found in the ranges of 18.12-18.37, 1.14-1.20 and 1.63-1.84, respectively. The roasting times were 1500, 1900 and 1620 seconds 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 critical oil content was determined to be 26 % to obtain a product in powder form. However, 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 produced with variety of roasting methods was 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. As a result, roasting methods were not found significant on sensory properties of powdered *Pistacia terebinthus* coffee and powdered *Pistacia terebinthus* coffee was not found to be different compared with Turkish coffee statistically in terms of sensory properties.

Key Words: *Pistacia terebinthus* fruits coffee, microwave roasting, combined roasting, pan roasting, grinding, sensory properties, Turkish coffee.

ÖZ

TOZ PISTACIA TEREBINTHUS MEYVESİ KAHVESİNİN KAVURMA VE ÖĞÜTME KOŞULLARININ STANDARDİZASYONU

SEÇİLMİŞ, Ş. Selçuk

Yüksek Lisans Tezi, Gıda Mühendisliği Bölümü

Tez Yöneticisi: Prof. Dr. Fahrettin GÖĞÜŞ

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Bu çalışmada; kavurma metotlarının, öğütmenin ve yağ içeriğindeki azaltmanın, toz *Pistacia terebinthus* meyve kahvesi (Menengiç) karakteristiklerine etkileri araştırılmıştır. *Pistacia terebinthus* meyvesi mikrodalga, kombine (mikrodalga-konveksiyonel) ve tava kavurma metodları ile kavruldu. Kavurma derecesi L*,a*,b* renk değerleri ile belirlendi. Çeşitli kavurma metodları için L*, a*, b* değerleri sırasıyla; 18.12-18.37, 1.14-1.20 ve 1.63-1.84 aralığında bulundu. Mikrodalga, kombine ve tava kavurma için kavurma süreleri sırasıyla; 1500, 1900 and 1620 saniyedir. Soğuk pres, yağ miktarını düşürmek için hem kavurma öncesi hem de kavurma sonrası kullanıldı. Toz formda bir ürün üretebilmek için kritik yağ miktarı % 26 olarak belirlendi. Ancak, kahve çekirdeklerinin yağ miktarına yaklaşmak için tüm kavurma metotlarında yağ miktarı % 21.5 civarında düşürüldü.

Çeşitli kavurma metodları ile üretilen toz hale getirilmiş *Pistacia terebinthus* meyve kahvesi; aroma, lezzet, asitlik, tadım sonrası ve genel kabul edilebilirlik bakımından kendi aralarında ve Türk kahvesiyle kıyaslanarak istatistiksel olarak karşılaştırıldı. Duyusal analiz sonuçları; kavurma sonrası presleme ile hazırlanan kahvelerin, kavurma öncesi preslenerek hazırlananlardan daha iyi olduğunu gösterdi. Sonuç olarak; kavurma metodları, toz hale getirilmiş *Pistacia terebinthus* kahvesinin duyusal özellikleri üzerinde etkili olmadı ve üretilen kahveler, Türk kahvesi ile karşılaştırıldığında duyusal özellikler bakımından farklı bulunmadı.

Anahtar Kelimeler: *Pistacia terebinthus* meyve kahvesi, mikrodalga kavurma, kombine kavurma, tava kavurma, öğütme, ekstraksiyon, duyusal özellikler, Türk kahvesi

TO MY FAMILIY

KUBİLAY, NISA AND MY DEAR PARENTS

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NOMENCLATURE

AOAC	Association of Official Analytical Chemists
ANOVA	Analysis of variance
a*	Redness-greenness value
b*	Yellowness-blueness value
CR	Combined roasting
FFA	Free fatty acid
L*	Lightness-darkness value
MWR	Microwave roasting
µm	Micrometer
PTF	*Pistacia terebinthus* fruits
PaR	Pan roasting
PR	Pressing-Roasting
RP	Roasting- Pressing
TC	Turkish Coffee

CHAPTER I

INTRODUCTION

1.1. *Pistacia terebinthus* fruits

Pistacia terebinthus L. is a species of Pistacia and it is known terebinth or turpentine tree. It is native to the Mediterranean region from the western regions of Morocco and Portugal to Greece and western Turkey. *P. terebinthus* (Figure 1.1) is the family Anacardiaceae. The turpentine tree grows on dry rock slopes and hillsides or in pine forests, especially in the Taurus Mountains. (Baytop, 1984 and 1994). The ideal altitude for the growing of turpentine tree is 1600 m.

The leaves have odd pinnate with five to eleven opposite glossy oval leaflets which is 10–20 cm long and 1-3 cm broad. The flowers appear with the new leaves in early spring and its color is reddish-purple. *P. terebinthus* is called as “Menengiç” and “Bıttım” with respect to the nut size and tree length in Turkey. While the small size ones (5-8 mm) are called as menengiç, bıttım (8-12 mm) are the bigger ones. And also in different regions of Turkey it is referred to as “Çitlenbik”, “Çıtlık”, “Çitemik” and “Çedene” (Akan et al., 2005). The tree of bıttım is growing to approximately 10-11 m tall; however the tree of menengiç is growing to approximately 5-6 m tall. *P. terebinthus* fruits (PTF) color change from red to dark greenish with respect to ripening period. Leaves, fruits and other organs have a strong resinous smell.

The seedlings of *P. terebinthus* can grow in the stony and calcareous soil of the dry areas. For this reason, the seedlings of *P. terebinthus* growing naturally in non-agricultural areas could be grafted with pistachio cultivars and provide relevant benefits to the cultivation of the crop (Tekin et al., 1995). *P terebinthus* resists to nematodes and soil borne fungi and also cold and drought so it is used for propagation of *P. vera* (Pistachio).

P. terebinthus includes resinous materials and tannin and its aromatic and medicinal properties have been exploited through ancient times. Archaeological evidence in Turkey indicates that the nuts were being used for food as early as 7000 B.C. Especially its roots, fruits and shoots have been used commonly. Various parts of the turpentine are used for several purposes in different regions of the world. For instance, turpentine fruits and shoots are used for human nutrition. The fruits have been used as an appetizer in human nutrition in Turkey for thousand years. It is also used in Turkish alternative medicine because of the treatment of sunstroke, stomachache, gastric ailments, rheumatism, coughs and as a stimulant and diuretic (Yeşilada et al., 1995; Tuzlacı and Aymaz, 2001).

The PTF can be used as an ingredient of food in the baking of special local bread. The oil obtained from their fruits is not only used as cooking oil, but also used in soap production in some parts of Turkey as well (Tanker and Tanker, 1998). PTF are also used subsequently as a traditional coffee roasted and ground in Gaziantep and Kilis which is called as Menengiç coffee and also particularly throughout Elazığ known as Cedene coffee.

Harvesting and handling depend on request of rural people and also the growth is scattered and wild in Turkey. In other words, there is no a production policy. Harvesting and handling of the PTF are carried out by using the hand in Turkey. As a result, there is no statistical information about the amount of PTF production as annual.

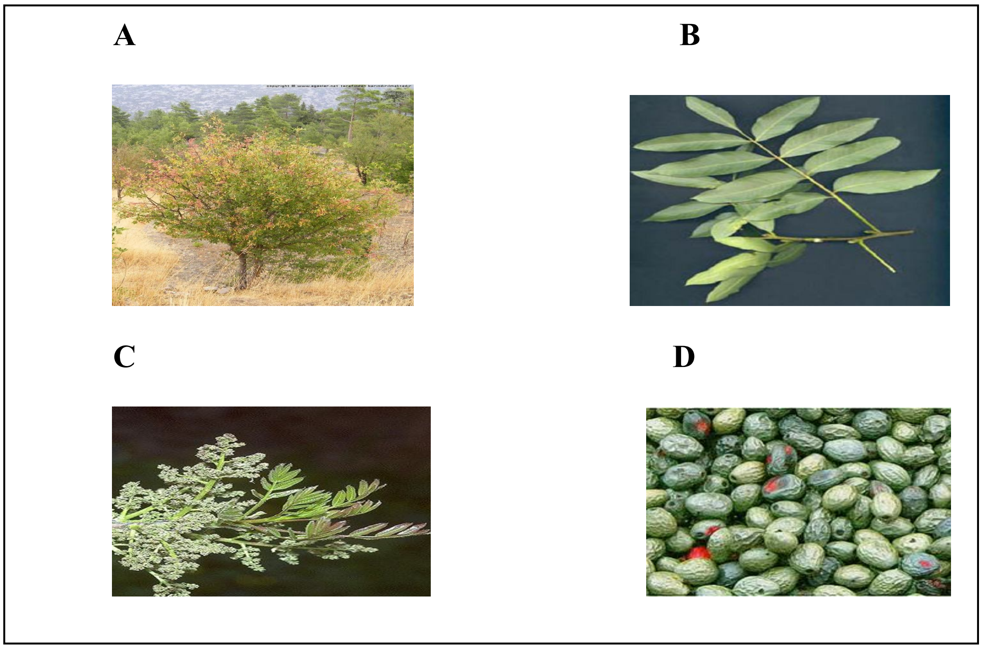


Figure 1.1. Different part of *P. terebinthus* tree, A: Typical *P. terebinthus* tree; B: Its leaf; C: Its flowers; D: *P. terebinthus* fruits (Menengiç).

1.1.1. Characteristics of *Pistacia terebinthus* fruits

The physico-mechanic properties of terebinth fruits are very important to manage some processing such as blending, storing, conveying and other processes. Aydın and Özcan, (2002) reported that the average values of sphericity and the geometric mean diameter are 89% and 5.43 mm respectively. The bulk densities of fruits (Figure 1.2a) at different moisture content are from 449 to 620 kg/m^3. The porosity depends on the bulk density similar to on the kernel densities, the magnitude of the variation in porosity depend on these factors only. Porosity (Figure 1.2b) is found to slightly decrease with increase in moisture content from 6% to 26% d.b.

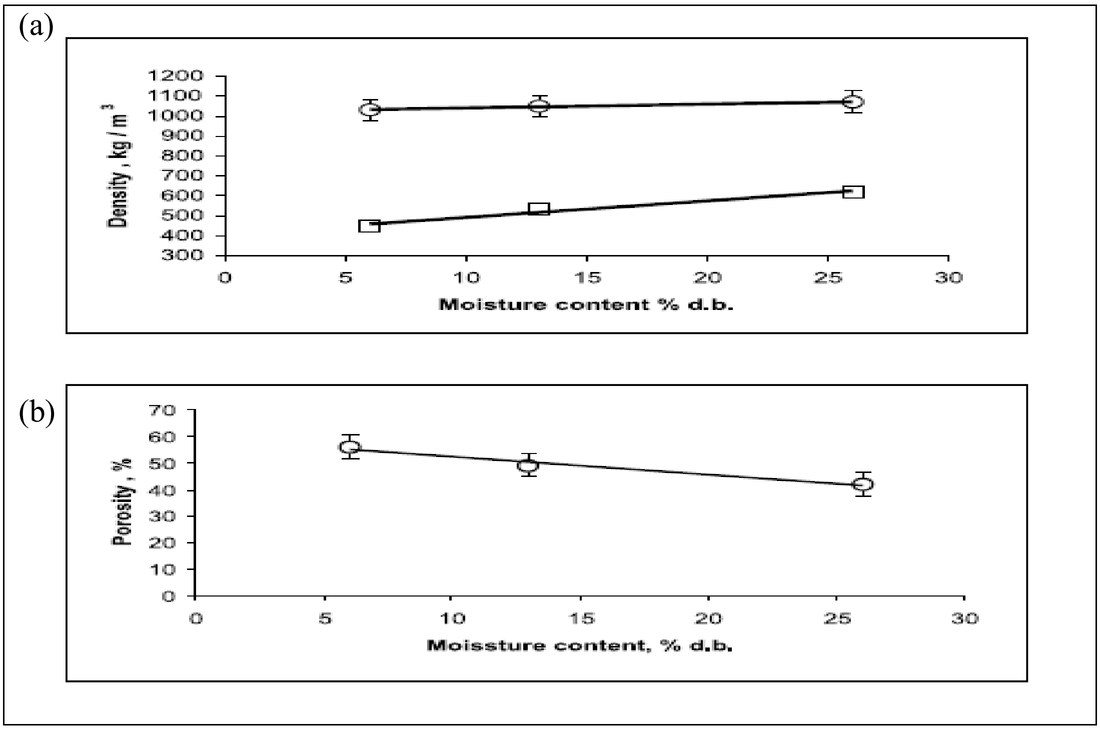


Figure 1.2. Density and porosity of *P. terebinthus* fruit, (a) Effect of moisture content on density: (O) kernel; (□) bulk; (b); Effect of moisture content on porosity (Aydın and Özcan, 2002).

According to same researchers that the terminal velocity increases linearly depending on increasing of moisture content (Figure 1.3a). They also presented that greater forces are necessary to rupture the fruits at lower moisture contents (Figure 1.3b). The small rupturing forces at higher moisture content may have resulted from the fact that the fruit tended to be very brittle at high moisture content.

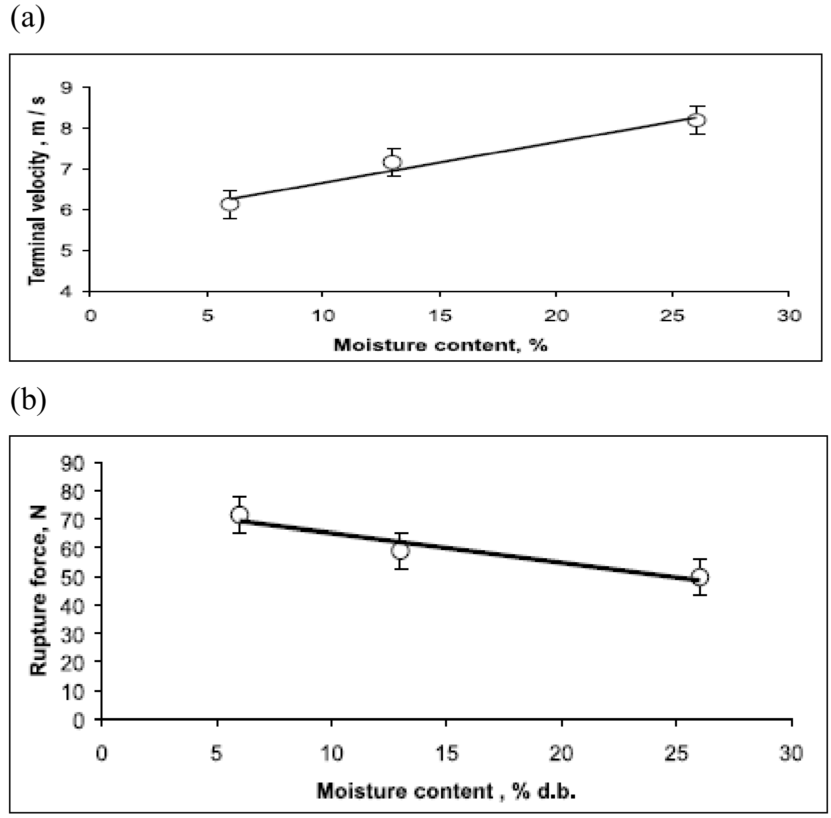


Figure 1.3. Terminal velocity and rupture force of *P. terebinthus* fruits (a) Effect of moisture content on terminal velocity; (b) Effect of moisture content on rupture force (Aydın and Özcan, 2002).

1.1.2. Chemical composition of *Pistacia terebinthus* fruits

Pistacia terebinthus is known to be rich in terms of essential oils, tannin and resinous materials. There are a lot of studies on the essential oil composition of different organs of the *terebinthus* (Couladis et al., 2003; Matthaus and Özcan, 2006). Fatty acid composition (Figure 1.4) varies in the different parts of the plant (Couladis et al., 2003). In general, PTF contain 58–60% oil and this oil is rich in fatty acids; oleic (52.3%), linoleic (19.7%) and palmitic acid (21.3%) (Özcan, 2004). Özcan, (2004) also found that some minor and trace fatty acids were such as palmitoleic, stearic, linolenic acids, lauric, myristic, eicosanoic and eicosenoic acids. Saturated fatty acids were found approximately 23.6% of total fatty acids. Oleic acids are mainly located in the sn-2 position. This composition very similar to olive oil and possible to use in the production of structured lipids as a raw material with a lower cost (Koçak et al., 2011). Due to composition of fatty acid, it can be used as desirable oil. The oil has yellowish color and specific and aromatic smell.

RI[a]	Component	Young shoots	Flowers	Unripe fruits	Ripe fruits	Identification
923	Tricyclene	tr	tr	tr	tr	a, b
936	α-Pinene	5.3	12.4	15.6	5.3	a, b
949	Camphene	2.2	2.2	4.3	0.7	a, b
980	β-Pinene	1.4	8.0	11.5	22.5	a, b
998	Myrcene	—	0.7	1.6	1.9	a, b
1005	α-Phellandrene	—	4.3	5.4	11.4	a, b
1022	*p*-Cymene	27.3	—	—	—	a, b
1028	Limonene	3.0	9.4	34.2	32.8	a, b
1048	(*E*)-β-Ocimene	—	0.2	0.7	1.8	a
1059	γ-Terpinene	tr	1.0	0.4	0.5	a, b
1086	Terpinolene	tr	0.8	6.9	7.0	a, b
1098	Linalool	—	tr	0.5	1.0	a, b
1121	α-Campholenal	4.2	—	—	—	a
1136	*trans*-Sabinol	3.8	—	—	0.3	a
1146	*trans*-Verbenol	8.8	—	—	—	a
1148	Camphor	—	tr	tr	0.2	a, b
1160	Borneol	—	tr	1.0	1.2	a, b
1172	Terpinen-4-ol	6.0	3.8	tr	0.7	a, b
1180	*p*-Methyl acetophenone	2.0	—	—	—	a
1183	*p*-Cymen-8-ol	4.6	—	—	—	a
1187	α-Terpineol	—	tr	1.4	1.6	a,b
1192	Myrtenal	1.7	—	—	—	a
1194	Myrtenol	tr	tr	tr	tr	a
1203	Verbenone	5.7	—	—	—	a
1214	*trans*-Carveol	1.0	tr	tr	tr	a
1239	Carvone	tr	tr	tr	—	a
1249	Piperitone	tr	tr	tr	tr	a
1282	Bornyl acetate	6.6	0.8	tr	tr	a
1290	*trans*-Verbenyl acetate	tr	—	—	—	a
1295	Carvacrol	tr	tr	tr	tr	a,b
1349	α-Cubebene	—	0.6	tr	tr	a
1373	α-Copaene	—	0.7	0.4	1.4	a
1382	β-Bourbonene	—	tr	tr	tr	a
1388	β-Cubebene	—	tr	tr	0.2	a
1416	(*E*)-Caryophyllene	tr	8.9	3.3	1.6	a,b
1430	β-Gurjunene	—	0.2	tr	tr	a
1436	Aromadendrene	tr	tr	tr	tr	a
1438	α-Humulene	—	2.3	1.5	0.8	a
1478	Germacrene D	tr	19.9	3.5	4.6	a
1483	β-Selinene	—	tr	tr	tr	a
1488	*cis*-β-Guaiene	—	tr	0.4	—	a
1492	α-Selinene	—	0.9	tr	tr	a
1494	Bicyclogermacrene	—	1.3	tr	tr	a
1496	α-Muurolene	—	0.9	0.5	tr	a,b
1503	α-Bulnesene	—	0.4	—	tr	a
1508	γ-Cadinene	—	0.7	0.6	tr	a,b
1522	δ-Cadinene	—	6.6	2.4	1.2	a,b
1531	Cadina-1,4-diene	—	0.6	tr	—	a
1535	α-Cadinene	tr	0.2	tr	tr	a
1546	Elemol	tr	0.4	tr	0.3	a
1552	Germacrene B	tr	tr	tr	tr	a
1559	Calacorene B	tr	tr	tr	—	a
1562	(*E*)-Nerolidol	tr	tr	tr	tr	a
1578	Caryophyllene oxide	7.1	0.6	tr	tr	a,b
1593	Guaiol	—	tr	tr	tr	a
1621	10-*epi*-γ-Eudesmol	—	1.9	tr	tr	a
1632	γ-Eudesmol	—	tr	1.0	tr	a
1643	*epi*-α-Muurolol	—	2.3	tr	tr	a
1649	β-Eudesmol	—	0.4	tr	—	a
1654	α-Eudesmol	—	tr	0.9	tr	a
1655	α-Cadinol	—	2.7	tr	tr	a
1676	Apiole	—	tr	—	—	a
Total (%)[b]		90.7	96.1	98.0	99.0	

[a] Retention indices relative to C_9–C_{24} *n*-alkanes on HP 5MS column.
[b] Relative percentage obtained from peak area.
a, Identification by RT and comparison with mass spectra.
b, Identification by RT and comparison with mass spectra; co-chromatography with authentic material.
tr, Trace (<0.1%).

Figure 1.4. The essential oil composition of different parts in the *P. terebinthus* (%) (Couladis et al., 2003).

Bakirel et al., (2003) determined that hypolipidemic effect of extract of the *P. terebinthus* is not toxic on the rabbits. *P. terebinthus* can be used as an alternative source of oil because of rich in phytochemicals including tocopherols, carotenoids and phenolic compounds. Gogus et al., (2011) reported that the dominant components of the hull of the fruits of *P. terebinthus* were α-pinene (10.37%), limonene (8.93%), β-pinene (5.53%), 2- carene (4.47%) and c-muurolene (4.29%). However, 2-carene and limonene were not detected in the PTF and β-pinene and α-pinene were found to be only in very low amounts. In another study, Orhan et al., (2012) reported that the major component was found as α-pinene. Usai et al., (2006) also supported them. However, Couladis et al., (2003) reported that the dominant component in unripe and ripe fruits was limonene. These different results are probably due to differences of locality and climate conditions in regions. All the essential oils have typical turpentine odour and a light yellow color. According to literature the essential oil yields was range of 0.06% - 0.16%. Özcan et al., (2009) were found that the fruits of Antalya origin have the highest oil yield (0.16%).

PTF are also very rich in the terms of minerals. Karacan and Çağran, (2009) reported that a total of 36 elements (As, Al , B, Ba, Ca, Bi, Cd, Co, Fe, Cr, Cu, Ge, Hg, In, K, La, Li, Mg, Mn, Na, Mo, Pb, Ni, P, Sb, Pd, Sc, Se, Si, Sn, Sr, Ti, Te, V, W and Zn) were detected from the PTF. On the other hand 26 elements were found in fruits by Özcan, (2004). *Terebinth* fruits have advantages when compared with olive, banana and fig in terms of certain minerals concentrations: potassium, magnesium and zinc contents were lower and sodium and potassium contents were higher.

The fruits are include different vitamins such as D_2 (2.50 $\mu g/g^{-1}$), D_3 (9.95), K_1 (21.00), α-tocopherol (15.35), δ-tocopherol (35.45), retinol (25.65) and α-tocopherol acetate (13.40) (Çiftçi et al., 2009).

1.1.3. Phenolic compound in the pistacia terebinthus

Pistacia spices have been attracted by researches due to their antioxidant potential. Because, they are rich in terms of flavonoids and other phenolic contents. Topçu et al., (2007) reported that its fruits have high antimicrobial antioxidant, cytotoxic and anti-inflammatory properties due to rich secondary compounds and resin. According to literature, their extract includes some phenolics such as apigenine, luteoline, 7-*O*-

glucoside, quercetin, α-tocopherol, quercetagetin, 3-methyl ether 7-*O*-glucoside, isoscutellarein and 8-*O*-glucoside. In addition, Topçu et al., (2007) invented that new flavone 6'-hydroxyhypolaetin 3'-methyl ether in antioxidant extract of PTF.

P. terebinthus is capable of antimicrobial effect on the microorganisms depending on phenolic and flavonoid concentration. According to Keles et al., (2001) that extract of *P. terebinthus* has occurred an 8 mm diameter zone against *Salmonella enteritidis.* This value was found to be 10 mm diameter for *Staphylococcus aureus* and *Salmonella gallinarum*.

Kavak et al., (2010) reported that *P. terebinthus* indicates a possible preventive role in cancer risks by eliminating the free radicals attack due to a high antioxidant capacity. It was also found that the plant extract killed gram positive *Staphylococcus aureus* but it was ineffective on gram negative *Escherichia coli*.

1.2. Coffee

Coffee is the most famous beverage around the world prepared from the roasted seeds. Although, it is usually drunk hot sometimes it can also consumed cold. Green coffee (unroasted) is one of the most traded agricultural commodities in the world (Mangal, 2007). The name of coffee derives from "kahveh" in Turkish pronunciation of the Arabian word "gahweh", signifying an infusion of the bean (Frederick, 2000).

1.2.1. History of coffee

Coffee is plant which known native to Africa (Ethiopia). The coffee plant was discovered in the 11th Century. Coffee spread quickly from Africa to the Arabian Peninsula. Coffee cultivation started in Yemen and for 300 years in the mid 14th century. Istanbul was presented to coffee in 1543 during the reign of Sultan Suleiman the Magnificent by Özdemir Pasha, the Ottoman Governor of Yemen, who had grown to love the drink while stationed in that country (http://www.turkishcoffeeworld.com/History_of_Coffee_s/60.htm).

Coffee consumption dates back 17th century as a beverage in Europe after then its consumption spread to all Europe quickly. In 1725, the first coffee plant in the Western Hemisphere was planted on Martinique in the West Indies. Its cultivation increased rapidly and its consumption soon gained the wide acceptance it enjoys today around the world.

1.2.2. Coffee fruits

The coffee is a member of *Rubiaceae* family. Depending on the species, it can grow from 3 to 12 m in height. The coffee tree or shrub is pruned at 2–2.5 m height in order to facilitate harvesting. The fruit or berry (Figure 1.5) is of a green outer longitudinal section of a coffee fruit skin. During ripening, it turns red-violet or deep red and encloses the sweet mesocarp or the pulp and the stone-fruit bean. The latter consists of two elliptical hemispheres with flattened adjacent sides. A yellowish transparent spermoderm, or silverskin, covers each hemisphere. Covering both hemispheres and separating them from each other is the strong fibrous endocarp, called the “parchment”. Occasionally, 10–15% of the fruit berries consist of only one spherical bean (“peaberry” or “caracol”), which often brings a premium price.

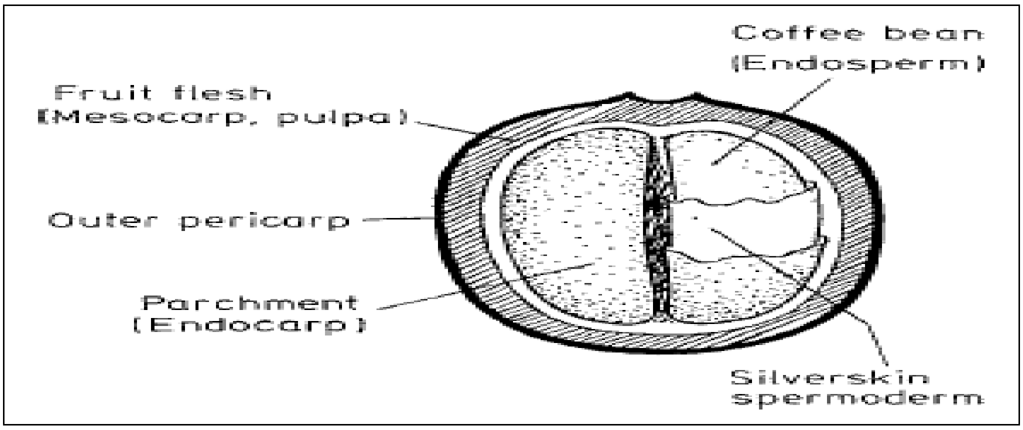


Figure 1.5. Longitudinal section of a coffee fruit (Vitzthum, 1976).

1.2.3. Cultivation of coffee

Trading coffees can be grown in subtropical and tropical climates at altitudes up to roughly 1800 m with an annual average temperature of 15–25 ˚C and mid moisture. The best yield is obtained at high elevations. The shrubs start to bloom 3–4 years after planting and they get through to a full harvest after six years of growth. The maximum yield is obtained after 10–15 years but they can bear fruit for 40 years. Fruit ripening occurs within 8–12 months after flowering.

In traditional method of planting coffee, 20 seeds are placed in each hole at the beginning of the rainy season. However, traditional method causes losing about 50%

of the seeds' potential, as about half fail to sprout. A more effective method of growing coffee, used in Brazil, is to raise seedlings in nurseries that are then planted outside at six to twelve months (http://en.wikipedia.org/wiki/Coffee.).

Many coffees from various producing areas have different characteristic flavors. Brazilian coffees as heavy body, moderately acid and aromatic and African Robusta coffees as heavy body, neutral, slightly acid and slightly aromatic. Colombian and washed Central American coffees are generally characterized as mild, winey-acid, and aromatic; higher percentages of Colombian and Central American coffees are preferred premium coffee blends.

1.2.4. World production

Brazil is usually first in green coffee production in the world and Vietnam, Colombia and Indonesia follow it (Table 1.1). Arabica coffee is grown eastern Africa, Arabia, or Asia and Latin America on the other hand Robusta coffee is cultivated in western and center Africa, throughout southeast Asia, and to some extent in Brazil (International Coffee Organization, 2010).

Coffee beans from various countries or regions can usually be difference in terms of aroma, flavor, body, and acidity (Kenneth, 2001). These differences are dependent not only on the coffee's growing region, on processing and genetic subspecies as well (Castle, 1991). Subspecies are usually known by the region in which they are grown, such as Colombian, Java and Kona.

Table 1.1. The top ten world production of coffee in 2010-2011 crop years (U.S. Department of Agriculture).

Country	Tonnes
Brazil	3270
Vietnam	1123,5
Colombia	570
Indonesia	559,5
India	306
Ethiopia	264
Honduras	240
Peru	240
Guatemala	235
Mexico	222

1.2.5. Economics of coffee

Coffee is one of the world's most important primary commodities due to which is one of the world's most popular beverages. Many studies have been showed that there is a relationship between coffee consumption and many medical conditions. According to literature, coffee was found to reduce the chances of developing cirrhosis of the liver. Similar to positive studies on the effect of coffee on the human health increase the consumer's interest in coffee. Coffee is bought and sold by roasters, investors and price speculators as a tradable commodity in commodity markets. Coffee is an example of a product that has been susceptible to significant commodity futures price variations.

1.2.6. Harvesting of coffee

Each year coffee is harvested during dry season reaching maturity, which is indicated by an intense dark red color, glossy and firm of the fruit. Although there are varieties of coffee that are yellow when mature. In general, four methods are used for harvesting. The first of these which is stripping method. Stripping method is done by hand removes all of the fruits, flowers, green fruits and deeply over ripened fruits. In the another method, a brush is used to comb the tree. This method removes all ripe fruits, the unripe fruits and green fruits, which are still connected to branches of tree. This is a time consuming process so it is preferred to obtain premium quality by the plantation owner. Mostly, it depends on being paid good prices to producers. The third method is a mechanical process. In this process used a vibrator fixed to trunk of tree. This vibrator provides shaking throughout the tree so the fruits fall down to ground. The last method is the most expensive because of high employment costs. Such this method requires hand picking.

1.2.7. Commercial coffee spices

Only three coffee species are cultivated among 70 species: *Coffea arabica*, (Figure 1.6a) which is leader with 75% of the world's production; *C. canephora* (*robusta*), (Figure 1.6b) about 25%; and *C. liberica* (Figure 1.6c) and others, less than 1%. The two main species grown, Arabica coffee (from *C. arabica*) is usually more highly considered than Robusta coffee (from *C. canephora*). Because, *C. robusta* has less flavor and bitter than *C. arabica* but better body than *arabica*. As a result, *C. arabica* are cultivated about three-quarters of coffee worldwide (International Coffee Organization, 2010).

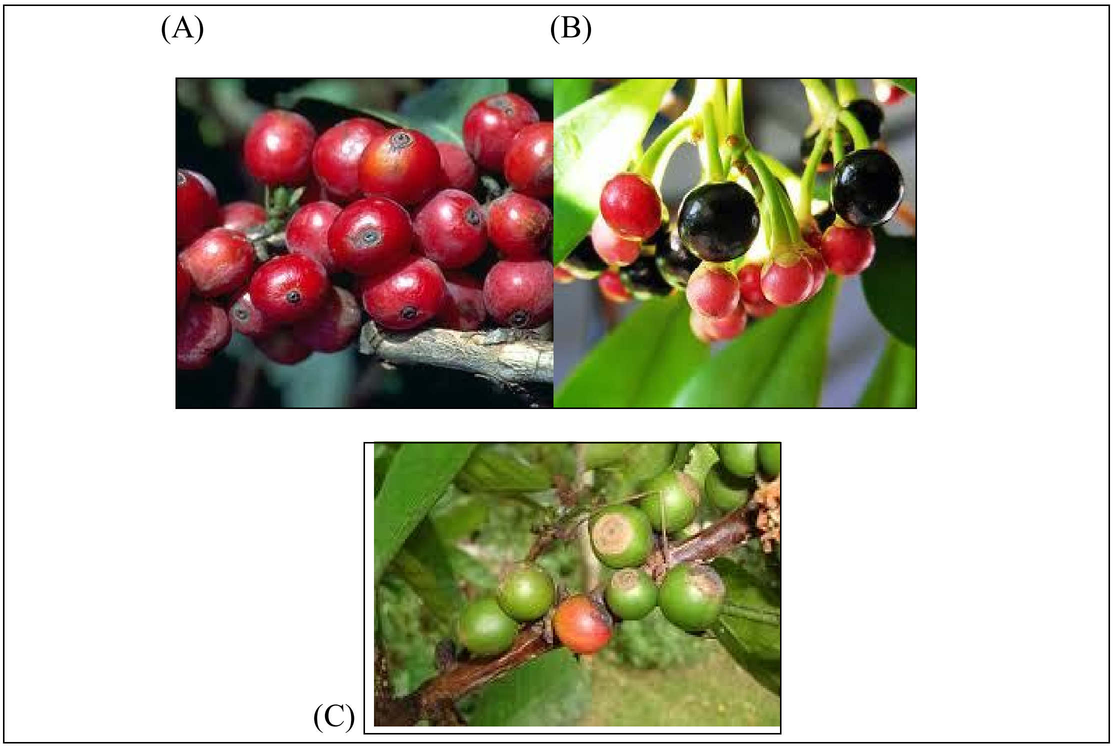


Figure 1.6. Types of coffee fruit (A) *Coffeea arabica* fruits; (B) *Coffea canephora* fruits; (C) *Coffea liberica* fruits.

1.2.7.1. Arabica coffee

C. arabica beans obtained from Brazil are characterized as the mild Santos and the hard Rio and Bahia beans. *C. arabica* coffees grown, particularly those from Kenya, Colombia and Central America, have a soft, rich, clean flavor or "fine acid" and "good body". Arabica is added to blends of Robusta to improve the quality of instant coffee so it has higher prices than others.

1.2.7.2. Robusta coffee

Robusta provides lower quality and prices are about 30 to 40 % lower than *Arabica*. Robusta coffees mostly are not washed and those are from Angola, Uganda, the Ivory Coast and Madagascar. Robusta generally is more vigorous, more productive and less vulnerable to rust. Robusta coffee has harsh and rough in aroma but is stronger.

1.2.7.3. Liberica coffee

It is cultivated mainly in low, hot climate areas. Its quality is poor and markets are limited. This coffee has a local importance in a few centuries and is not of major significance in the international coffee markets.

1.2.8. Chemical composition of coffee

Chemical composition depends on the type, region, soil, method of handling of coffee fruits and processing. And also can be added that coffee is very rich in terms of chemical components. According to literature, coffee includes hundred of different components some of which have yet been identified. Two most important commercial species Arabica and Robusta differ in terms of chemical composition (Table 1.2).

Table 1.2. Composition of green Arabica and Robusta coffee (%) (Belitz et al., 2009)

Constituent	Arabica	Robusta	Components
Soluble carbohydrates	9-12.5	6-11.5	
Monosaccharides	0.2-0.5	0.2-0.5	Fructose, glucose, galactose, arabinose (traces).
Oligosaccharides	6-9	3-7	Sucrose (>90%), raffinose (0–0.9%), stachyose (0–0.13%).
Polysaccharides	3-4	3-4	Polymers of galactose (55–65%), mannose (10–20%), arabinose (20–35%), glucose (0–2%)
Insoluble polysaccharides	46–53	34–44	
Hemicelluloses	5–10	3–4	Polymers of galactose (65–75%), arabinose (25–30%), mannose (0-10%)
Cellulose, (1–4) mannan	41–43	32–40	
Acids and phenols			
Volatile acids	0.1	0.1	
Nonvolatile aliphatic acids	2–2.9	1.3–2.2	Citric acid, malic acid, quinic acid
Chlorogenic acid	6.7–9.2	7.1–12.1	Mono-, dicaffeoyl- and feruloylquinic
Lipids	15-18	8-12	
Oil	7.7-17.7	7.7-17.7	Main fatty acids: 16:0 and 18:2 (9,12)
Free Amino acid	0.2-0.8	0.2-0.8	Main amino acids: Glu, Asp, Asp-NH2
Proteins	8.5-12	8.5-12	
Caffeine	0.8-1.4	1.7-4.0	Traces of theobromine and theophylline
Trigonelline	0.6-1.2	0.3-0.9	
Minerals	3-5.4	3-5.4	

Caffeine is well known component in the coffee. Caffeine (1, 3, 7-trimethylxanthine) (Figure 1.7) was isolated from coffee in 1820 (Arnaud, 1984). Caffeine is a white, odorless powder with a slightly bitter taste. The anhydrous form obtained by crystallization from nonaqueous solvents is a crystalline solid that melts at 235 to 237 ^{o}C. At atmospheric pressure it begins to sublime without decomposition at 120 ^{o}C and at 80 ^{o}C under high vacuum. Caffeine plays a very important role in the stimulant effect of coffee. The type of coffee and brewing method can be increased or decreased the amount of caffeine in a cup of coffee.

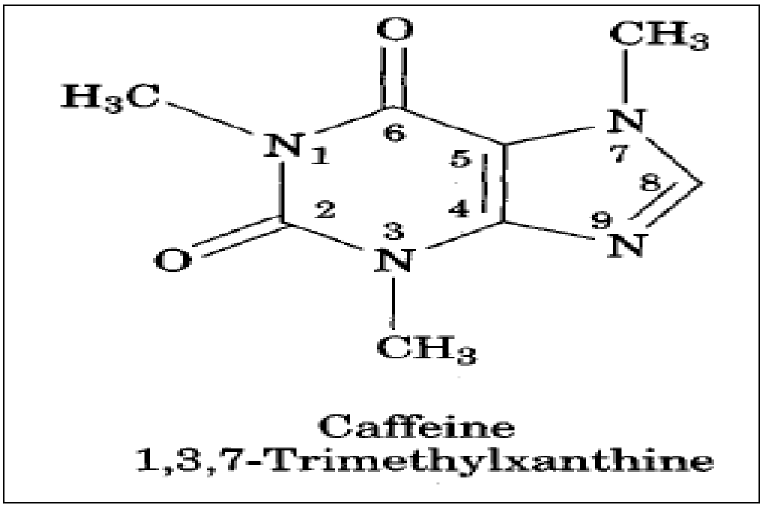


Figure 1.7. Chemical formula of caffeine.

1.2.9. Processing of coffee fruits

Processing of coffee can be described as converting the raw fruit plant into the green coffee (Figure 1.8).

Figure 1.8. Transforming from raw fruit to green coffee during processing.

It is important to understand processing of coffee that coffee bean structure must be known very well (Figure 1.9). After picking of coffee fruits, it is necessary to separate fruits from the beans. Two methods are used for separating. These are wet and dry processing. The type of coffee processing, such as the wet and the dry methods, affects the characteristic flavor and so helps to occur the typical differences in quality of the resulting green coffees.

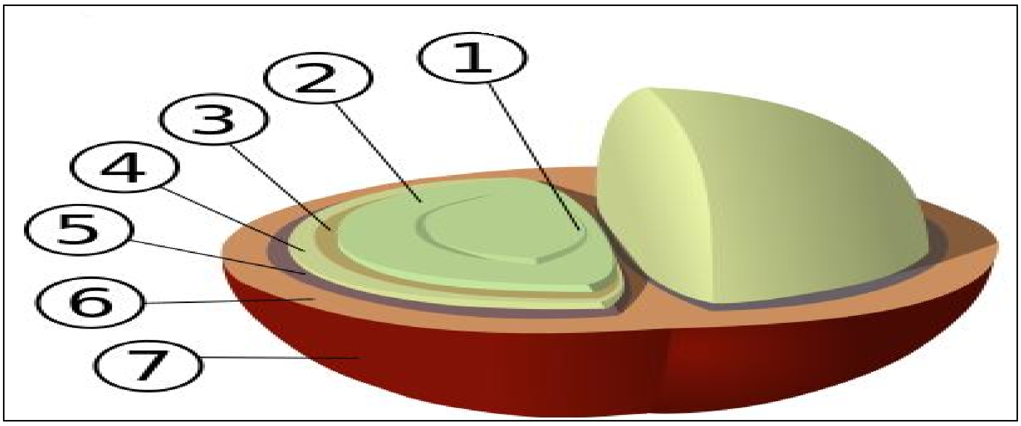


Figure 1.9. Structure of coffee berry and bean: (1): center cut; (2): bean (endosperm); (3): silver skin (testa, epidermis); (4): parchment (hull, endocarp); (5): pectin layer (6): pulp (mesocarp); (7): outer skin (pericarp, exocarp), (http://es.wikipedia.org/wiki/Archivo:Coffee_Bean_Structure.svg).

Wet process:

In this process, the seeds or beans are removed from fruits and then they are dried. Coffee produced by the wet method is known as wet processed or washed coffee. This method needs specific processing equipment and high quality water. The pericarp of fresh fruits is physically removed by pulper machine with addition of water. This process is called pulping. After removing of skin of fresh fruits that there is a mucilage layer on the bean surface. This mucilage layer coats with sugar, which is allowed to ferment over one to two days. Mucilage layer must be removed from the bean surface. This process is carried out by different methods which are natural microorganism fermentation, using of commercial pectinase preparats and varies washing process. The parchment is dried from about 53 % to until reaching 12 % moisture. After the drying, the parchment layer is ready to be removed. Parchment removing is carried out by rubbing machines. Although wet process plays a role to produce high quality coffee, but needs some requirements such as large quantities of water and very good management of fermentation and washing process to ensure the coffee flavor is not damaged during the process.

Dry processing:

Dry method is a very old and simple processing method. In this method the fruits are simply picked and put out into the sun for drying. It is spread in a thin layer and raked regularly to maintain even temperatures from top to bottom of the layer. Drying time (until 12 % moisture) changes anywhere from ten days to three weeks. Sometime on larger farms, may be speeded up by using mechanical driers. The hard, shriveled fruit husk is later stripped off the beans by machine. Coffee processed by the dry method is known as dry processed, unwashed, or natural coffee. This process has the low cost, but traditional system resulting in a low quality coffee so it is not recommended. Most Robusta coffee is currently processed this way In Lao.

Sorting and grading:

Sorting and grading are the last processing for coffee fruits. At the sorting stage, fruits are sorted with respect to bean color and defect. Electronic and very sensitive machines can be used for sorting process and also handling is widely used a method. Grading is a categorizing process for coffee beans depending on the main of different criteria such as size of the bean, where and at what altitude it was grown, how it was prepared and picked, and how good it tastes, or its cup quality. Coffees also can be graded by the number of imperfections (defective, broken beans, sticks and pebbles, etc.) per sample. For the finest coffees, origin of the beans (farm or estate, region, cooperative) is especially important. Growers of premium estate or cooperative coffees may impose a level of quality control that goes well beyond conventionally defined grading criteria, because they want their coffee to command the higher price that goes with recognition and consistent quality (http://coffeereview.com).

1.2.10. Processing of green coffee

Green coffee is processed in different stages depending on kind of the end product (Figure 1.10).

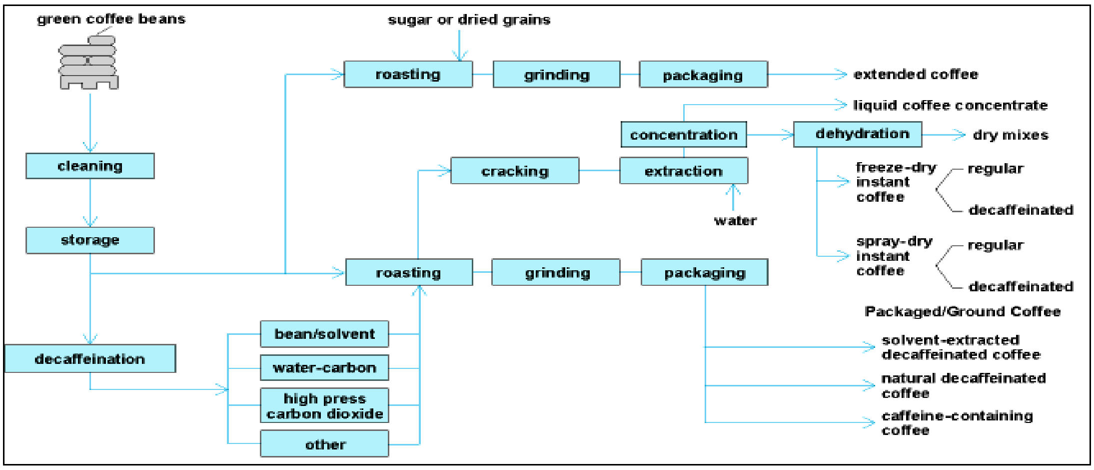


Figure 1.10. Processing of green coffee (http://www.accessscience.com).

1.2.10.1. Storage

Prolonged storage time decreases distinctively coffee quality. This is expressed by a typical flattening and slackening of the cup quality, apparently related to a reduction in the aroma potential in the green bean. As a result, the provenience-specific characteristic features, especially those of top quality coffees, gradually diminish during the course of elongated storage (Selmar et al., 2008). Drying process is very important to prevent mould growing during storage period. Sometimes the stored coffee can absorbs moisture from the atmosphere due to humid conditions. This will start formation of mouldy or musty flavors. This situation mostly takes place at inadequate ventilated warehouses and relative humidity situations over 65%. Observed other problem is oxidizing. It causes to woody taste. According to literature, storing time for coffee beans is not longer than 12 months otherwise fade and mottle problems on the beans surface can occur during storage.

1.2.10.2. Decaffeination

Decaffeinated coffee is a choice for consumers who wish to enjoy the taste and aroma of coffee without experiencing the mild stimulant effects provided by the caffeine (http://www.ico.org/decaffeination.asp). Decaffeination is carried out by different methods such as supercritical carbon dioxide, ethyl acetate, water, and methyl chloride. The methods include some basic principles. The first step, by water or stream used provides swelling coffee beans in order to make the caffeine available for extraction. After that the extraction is started from the beans. Stream stripping is used to remove all solvent residues from the beans. Finally, the beans are dried until coffee beans arrive to their ideal moisture content. Physical phase transport mechanisms play very important role in the caffeine extraction step under carefully controlled process conditions, such as time, temperature and pressure. As a result of difference of caffeine concentration in the inside and outside, the caffeine can be extracted from the beans until the concentration of caffeine is the same inside and outside the beans.

1.2.10.3. Grinding

Grinding is necessary to make coffee brewing. Coffee brewing methods depend on different grind size. For example, a medium size grinding is used for drip coffee, a fine size grinding is used for espressos and French press requires the largest grind size, while the vacuum pot also requires the largest grind size. To achieve preparing of a quality cup of coffee, freshly grinding the beans before brewing is very important. Coffee should not be ground more than 2 minutes before brewing or major staling (oxidation) begins to take place.

1.2.11. Roasting

1.2.11.1. General

Roasting which is a cooking method that uses dry heat, whether an open flame, oven, or other heat sources, is one of principal technological operations in some foods such as meat, chicken, nuts, coffee and cocoa etc. Roasting provides unique flavor and aroma for these foods. Therefore, many foods cooked in this way are attractive in appearance, tasty and healthy. This is carried out by caramelization and Maillard browning on the surface of food during roasting. These are known as non enzymatic browning reactions. Roasting does not use much grease or oil, which reduces the fat and calorie content of the food. Roasting is similar to baking, but roasting is done at higher temperatures. Roasting process not only enhancing of flavor and aroma, but also is used in order to increase oil extraction yield from oil seeds in oil industry.

1.2.11.2. Coffee roasting

Roasting is a very important step of the coffee processing where the beans are subjected to heat treatment at high temperatures of up to 200-260 °C. Because, many physical changes occur in the bean and many chemical reactions take place, producing hundreds of chemical compounds through several mechanisms (Buffo and

Cardelli-Fereire, 2004). Over 800 volatiles have been identified in the aroma of roasted coffee and most of these chemicals are induced from the roasting process (Lee and Shibamato, 2002). As a result of roasting, the formation of the characteristic coffee aroma and the dark-colored compounds occurred (These dark-colored compounds are referred to as melanoidins, and were reported which makes up to 25% of the dry matter in coffee brew by Borelli et al., 2002). Flavor compounds are formed mainly as the result of the Maillard reaction (Freidman, 1996) that takes place between carbohydrates or degraded carbohydrates and proteins (Oosterveld and Voragen, 2003). Unlike roasted coffee, hardly green coffee is flavorless and its odor can be described as grassy, earthy and haylike, and the extract made from ground green beans has no recognizable coffee flavor.

1.2.11.3. Coffee roasting methods

There are as several roasting methods based on same basic principles of heat and mass transfer, but the most common ones were described below.

<u>Rotating cylinder:</u>

This method can be described as a traditional method. Either a horizontal or vertical cylinder is used. Coffee beans are filled into this rotating cylinder (Figure1.11) and heated by gas burners that transfer heat to the beans through the cylinder walls and hot gases. This units can be batch or continuous operated with roasting times varying from eight to twenty minutes in traditional low temperature long time (LTLT) or from three to six minutes in high temperature short time (HTST) roasting systems (Mwithiga and Jindal, 2003).

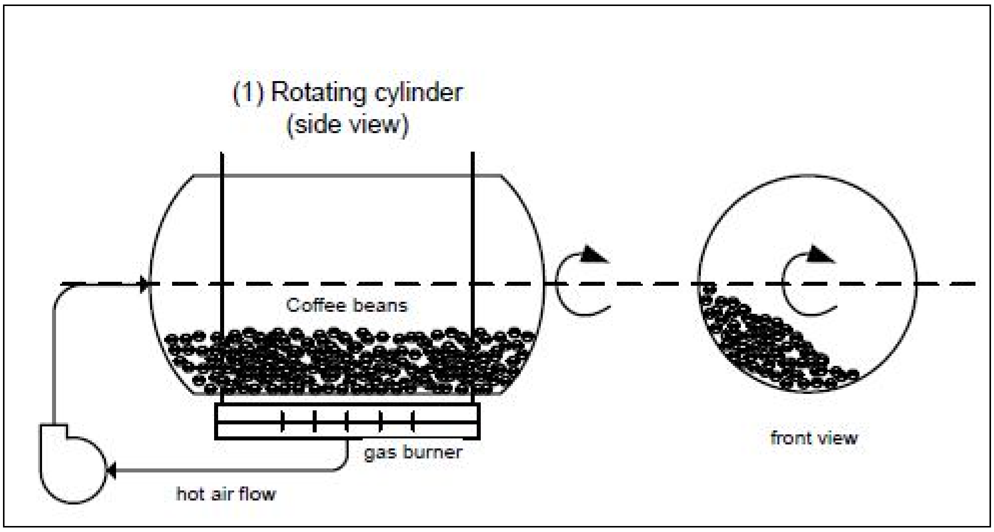


Figure 1.11. Rotating cylinder roasting (side view), (Bonnlander et al., 2005).

Drum roaster:

In this method is used direct heating by convective flow of hot gases with roasting times varying from three to six minutes (Figure 1.12). Compared to the rotating cylinder method, it has primarily the convective heating source. Also instead of a rotating drum, paddles are used to mix and homogenize the heat transfer inside the roaster. Heat is obtained from the use of electric heating elements or gas flames controlled with or without the use of a profile controller.

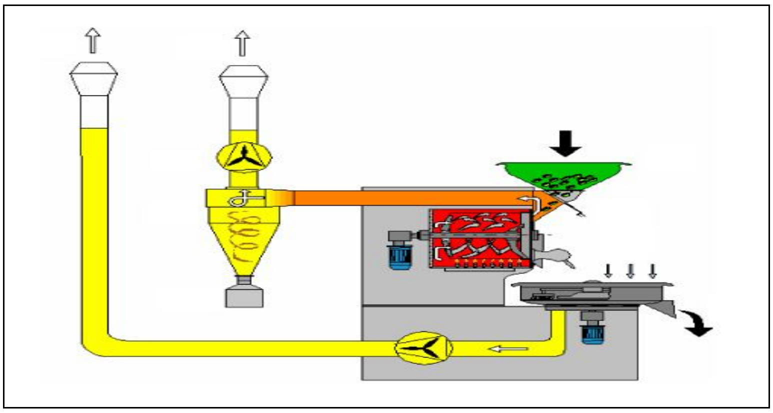


Figure 1.12. Typical drum roaster diagram, (http://www.coffeechemistry.com).

Fluized bed roasters:

These roasters depend on a completely different system for roasting. This system consists of a tall cylinder. It provides hot air to flow through a chamber providing a homogenous distribution of heat. Unlike the drum roaster, delivering of heat in this roaster is carried out by convection and also it has clear roast characteristics. Roasting times vary typically from three minutes to five minutes in fast systems.

Some variations coming from the fluidized bed system such as spouted bed (Figure 1.13) have also been described and patented for coffee roasting.

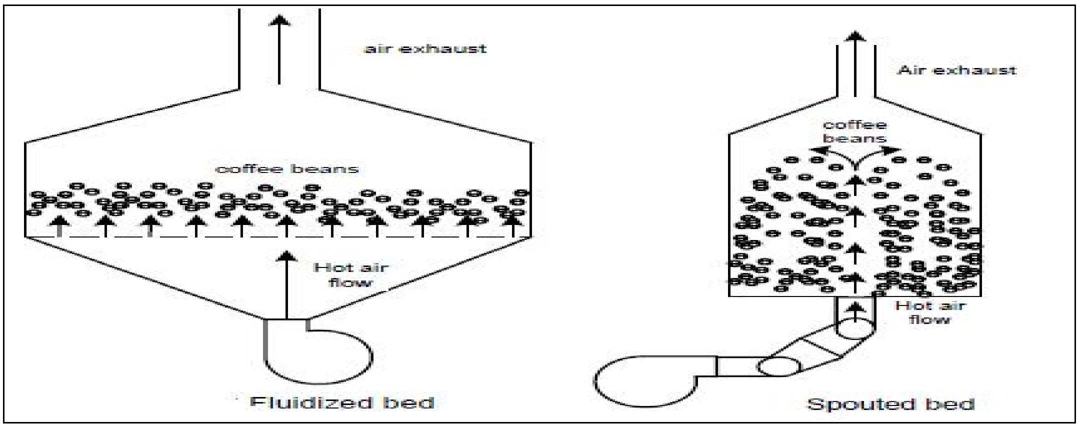


Figure 1.13. Fluized bed and spouted bed roaster diagrams, (Nagaraju et al., 1997; Nagaraju and Bhattacharya, 2010).

1.2.11.4. Changes of green coffee during roasting

The chemical compositions of green and roasted are shown in Figure 1.14.

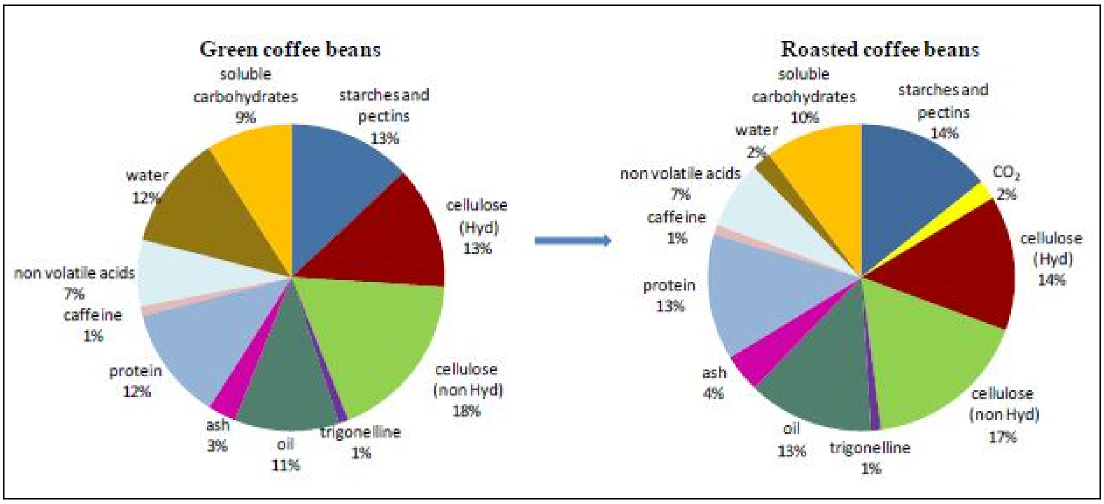


Figure 1.14. Chemical composition of green and roasted coffee, (Barter, 2004).

Roasting causes a net loss of matters in the forms of CO_2, water vapor, and volatile compounds. Resulting in the formation of caramelization and condensation products, degradation of polysaccharides, sugars, amino acids and chlorogenic acids also occurred. Overall, there is an increase in organic acids and lipids, while caffeine and trigonelline (N-methyl nicotinic acid) contents remained almost unchanged (Buffo and Cardelli-Freire, 2004).

Increasing of temperature to about 100 °C begins to lose moisture. The smell of the beans changes from herb-like green bean aroma to bread-like, the color begins to turn from green to yellowish, and the structure changes from strength and toughness to more crumbly and brittle. As long as the interval temperature of green beans approaches to 100 °C, the color turns dark slightly due to the vaporization of water. At the further temperature like 160-170 °C, Maillard and pyrolytic reactions start to take place, resulting in gradually darkening of the beans (Hernandez et al., 2007). Water pressure occurred causes the cellulose cell wall to crack which has been known as "first crack". Exceeding CO_2 pressure occurred at continuation of roasting, causes "second crack". Finally, after roasting, the fresh roasted coffee beans are quickly cooled to stop roasting (Yeretzian et al., 2002).

1.2.11.5. Degree of roast

The degree of roast greatly influences the aroma profile in coffee beans. Roasted coffee can be largely categorized as light, medium or dark roasts (Figure 1.15).

Figure 1.15. Degree of roast from light to dark.

Physical characteristics such as temperature, color, and weight-loss are often used as indicators of roast degree. However, these parameters only allow assessment of the flavor profile for coffee roasted under narrow process. Other analytical methods for quantifying the degree of roast include ratio of free amino acids alkylpyrazines, and chlorogenic acids content. As commonly, the degree of roast of coffee is measured using color of ground beans. According to literature color of coffee has been defined as lightness values from the L*, a*, and b* color space. Sometimes, instead of L*, a*, and b*, hue angle which is calculated by specific formula can be used.

1.2.11.6. Coffee aroma and flavor development during roasting

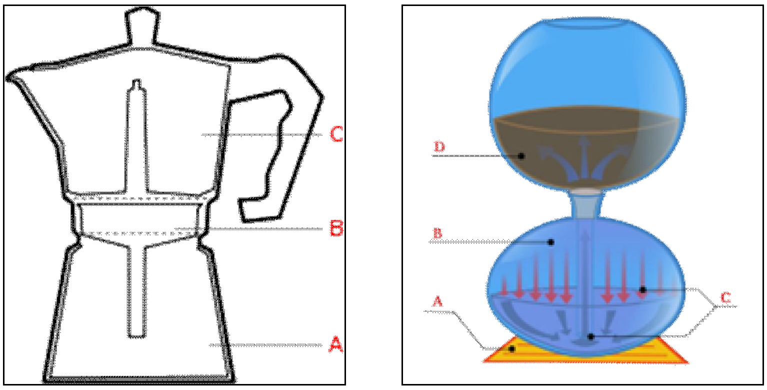
Coffee is appreciated for its pleasant aroma and flavor developed primarily during roasting, a time-temperature dependent process in which beans undergo a series of reactions leading to several changes in chemical composition. Although chemical reactions happened during coffee roasting are very complex, which have not been fully understood, these compounds present in roasted coffee can be roughly grouped into volatile and non-volatile. According to literature proteins, carbohydrates, peptides and free amino acids, polyamines and tryptamines, lipids, phenolic acids, trigonelline, and various non-volatile acids in the green coffee beans were involved in the flavor formation during roasting.

Green coffee contains high amounts of chlorogenic acids. This compound contributes to body and astringency; another compound sucrose contributes to color, aroma, bitterness, and sourness; minor protein components like free amino acids are highly reactive by interacting with reducing sugars, which make the Maillard reaction happen; triogenlline generates pyridine and may be consequently be responsible for some objectionable flavors; and caffeine can be contributed to the bitterness (Flament, 2002).

1.2.12. Coffee brewing

Coffee brewing is not only an art a science but also it mostly reflects local culture in the centuries. Therefore, coffee brewing and its equipment have been became a cultural ritual. Of the thousands of coffee machines and coffee brewing devices invented since the advent of coffee consumption, only a few have gained worldwide popularity. Coffee is a beverage which must be ground and brewed for drinking. Almost all methods of preparing coffee require to be ground and mixed with hot water long enough to extract the flavor, but without over extraction that draws out bitter compounds. The spent ground is removed and the liquid is consumed. There are many brewing variations such as the fineness of grind, the ways in which the water extracts the flavor, additional flavorings (sugar, milk, spices), and spent ground separation techniques. The ideal holding temperature is 79 to 85 °C and the ideal serving temperature is 68 to 79 °C. (http://www.coffeeresearch.org/coffee /brewing.htm).

Coffee can be prepared by such several brewing methods as boiled, pressurized or steeped. The first methods or oldest method is boiling. Turkish coffee is an example of this method (Ukers, 1922). Steeping method requires a special device such as a French press. Hot water is mixed with ground coffee in a cylindrical vessel and left to brew for a few minutes. A circular filter which fits tightly in the cylinder fixed to a plunger is then pushed down from the top to force the ground to the bottom. Because the coffee ground are in direct contact with the water, all the coffee oils remain in the beverage, making it stronger and leaving more sediment than in coffee made by an automatic coffee machine. The coffee is poured from the container; the filter retains the ground at the bottom. 95% of the caffeine is released from the coffee seeds within the first minute of brewing (Davids, 2001). Pressurized method needs high pressure (ideally between 9–10 atm). For instance, espresso which is a kind of coffee type is prepared by this method. Other pressurized water methods can include the moka pot (Figure 1.16a) and vacuum coffee maker (Figure 1.16b).



(a) (b)

Figure 1.16. Pressurized water brewing methods (a): (A) The bottom chamber (B) Basket containing ground coffee; C The collecting chamber; (b): (A) The heat source warms up the water in the bottom chamber and produces vapour and builds up pressure (because vapour takes more space than water because of the density of the molecules); (B) To handle the pressure in the bottom chamber the water is forced up the tube; (C) (going north) to the upper chamber where it is mixed with the coffee ground; (D), (http://en.wikipedia.org/wiki/File:MokaCoffeePot.svg).

1.2.13. Coffee cupping

The most important criteria of coffee quality is flavor. For that reason, coffees are assessed for taste at every stage of their journey, most importantly when the coffee is graded in the country of origin and when it is sold in the importing country. This taste action is called cupping which is to evaluate the coffee objectively and to create a flavor profile based on an established terminology. Cupping is also used to evaluate a defective coffee or to create coffee blends. The basic attributes evaluated for cupping are aroma, flavor, body (the texture or mouthfeel, such as oiliness) and acidity (a sharp and tangy feeling at the tip of the tongue, like when biting into an orange).

In a coffee cupping session, the table is usually set up with 6 to 10 cups per coffee. These are fashioned in a triangular manner. In the center of the table place a cup of room temperature water and an empty cup containing the cupping spoons. Cover both the green sample and roasted sample until the cupping session is over and the coffee aroma, fragrance, and flavor profile have been documented. After this time, the coffee samples could be uncovered and additional comments can be written based on appearance.

To prepare the coffee samples, place 2 tablespoons of freshly roasted and freshly ground coffee in a 6 oz cup. Ideally one should use 55 g of coffee per liter of water. The grind should be between a French press size and a drip coffee size. The coffee should be roasted light. In the industry the roast often is stopped about 30 seconds into the first crack long before the start of the second crack. This allows to fully evaluate the coffee for defects and for the sweetness and aroma that are burned off at darker roasts. The roast should be similar for all of the coffees evaluated. During an important coffee cupping session the roast similarity can be verified visually by grinding a portion of each sample and lining the coffee samples up next to each other on a black sheet of paper (http://www.coffeeresearch.org/coffee/cupping.htm).

1.2.14. Turkish coffee

Turkish coffee is a method of preparing coffee developed from Turkish people. Therefore it is not a kind of coffee. On the other word there is no special type of bean. Beans (frequently used Arabica coffee or its blends) for Turkish coffee are ground or pounded to the finest possible powder; finer than for any other way of preparation. The grinding is done either by pounding in a mortar (the original method) or using a burr mill. Most domestic coffee mills are unable to grind finely enough; traditional Turkish hand grinders are an exception. As with any other sort of coffee, the best Turkish coffee is made from freshly roasted beans ground just before brewing. Turkish-ground coffee can be bought and stored as any other type, although it loses flavor with time.

Roasted and then finely ground coffee beans are boiled in a pot (cezve), usually with sugar, and served in a cup where the ground is allowed to settle. While there are variations in detail, preparation of Turkish coffee consists of immersing the coffee ground in water which is usually hot, but not boiling, for long enough to dissolve the some flavor compounds. While prolonged boiling of coffee gives it an unpleasant "cooked" or "burnt" taste, very brief boiling does not and shows without guesswork that it has reached the appropriate temperature. The amount of cold water necessary can be measured in the number of demitasse cups desired (approximately 3 ounces or 90 ml) with between one and two heaped teaspoons of coffee being used per cup. The coffee and sugar are usually added to the water rather than being put into the pot first.

In Turkey, four degrees of sweetness are used. The Turkish terms and approximate amounts are as follows: “sade” (plain; no sugar), “az şekerli” (little sugar; half a level teaspoon of sugar), orta şekerli (medium sugar; one level teaspoon), and “çok şekerli” (a lot of sugar; one and a half or two level teaspoons).

A well-prepared Turkish coffee has thick foam at the top (“köpük” in Turkish), is homogeneous, and does not contain noticeable particles in the foam or the liquid. It is possible to wait an additional twenty seconds past boiling to extract a little more flavor, but the foam is completely lost. To overcome this, foam can be removed and put into cups earlier and the rest can be left to boil. In this case special attention must be paid to transfer only the foam and not the suspended particles. (http://en.wikipedia.org/wiki/Turkish_coffee).

1.2.15. Traditional menengiç coffee (*Pistacia terebinthus* fruit coffee)

PTF coffee has been using up by local people for a long time because of its health benefits. Traditionally, PTF coffee is a nut-based local herbal beverage in Turkey, especially in South-eastern Anatolia. Because of nut-based, it does not include caffeine. Coffee is made from roasted and crushed PTF. Traditionally, PTF is roasted by pan on the embers, but roasting can be with other heating equipments. Roasting is carried out slowly and efficiently. Throughout roasting, PTF color turns from green to dark. Also an attractive smell begins to release. Roasting time goes on about 25-30 minutes. It can be change amount of PTF and firepower. Degree of roast is determined and decided by previous experiences. After the roasting, PTF roasted are poured into traditional grinding mortar. Until becomes to paste, PTF is ground like crush garlic. In contrast to Turkish coffee, this coffee is a paste and an oily product. Because of high oil content, it is roasted and ground when consumed. With improving technology, PTF paste only prepared at the indoors it has been manufacturing in factories by industrial roasting and grinding machines anymore. Even packaged in glass jar and offered for sale.

Making of PTF coffee procedure is the same with Turkish coffee. Milk or water, but frequently milk preferred is used for brewing. A cup of milk or water is poured into pot as much as number of person. A spoon roasted and ground PTF coffee as much as number of person is added and mixed. Sugar can be added as much as desired. Brewing is carried out at a low heat for 15 minutes. Finally, it is served to each cup.

1.2.16. Herbal coffee

According to scientific researches, caffeine, the xanthine alkaloid that is coffee's principal active ingredient, stimulates the nervous system and can cause nervousness, irritability, anxiety, insomnia, and disturbances in heart rate and rhythm; it may also influence blood pressure, coronary circulation, and the secretion of gastric acids. These effects, coupled with coffee's high price, have spurred herbalists to seek healthful, cheaper alternatives. The most successful alternatives to coffee combine several ingredients to achieve a complex flavor. Coffee substitutes don't taste exactly like real coffee but may be mixed with it to extend it and reduce the caffeine content or they may be blended into a satisfying drink that contains no *C. arabica* at all. Herbal coffees can be classified to be root and seed. Some common herbal coffees used were discussed in below:

<u>a- Root brews:</u>

The roots of several familiar plants may be washed, sliced or chopped, and dried for use as a coffee substitute. When slow-roasted at 150-200 °C until crisp and dark brown, they are ready to be ground and infused. Common roots coffees are chicory (*Cichorium intybus*) (Figure 1.17), dandelion (*Taraxacum spp.*) (Figure 1.18), and artichoke (*Helianthus tuberosus*) (Figure 1.19). Other common roots worth trying as coffee substitutes include beet (which adds rich, dark color and a hint of caramelized sugar to herbal blends), carrot and parsnip (which add sweetness), burdock (for color), and salsify (for bitterness).

1- Chicory coffee:

Coffee blended with chicory became popular in Europe when the naval wars following the French Revolution drove up the price of pure bean brew. The taste or, perhaps more accurately, tolerance for coffee-chicory blends spread from France to the Creoles of New Orleans. New Orleans groceries have sold both coffee blended with chicory and ground chicory root on its own for as long as anyone remembers. But many natives warn that chicory is tolerable at no more than 20 percent in a blend, and then only when the coffee is drunk with milk due to the fact that chicory's acrid bite is the dominant flavor.

Figure 1.17. Chicory coffee (a) raw material; (b) sliced and (c) roasted

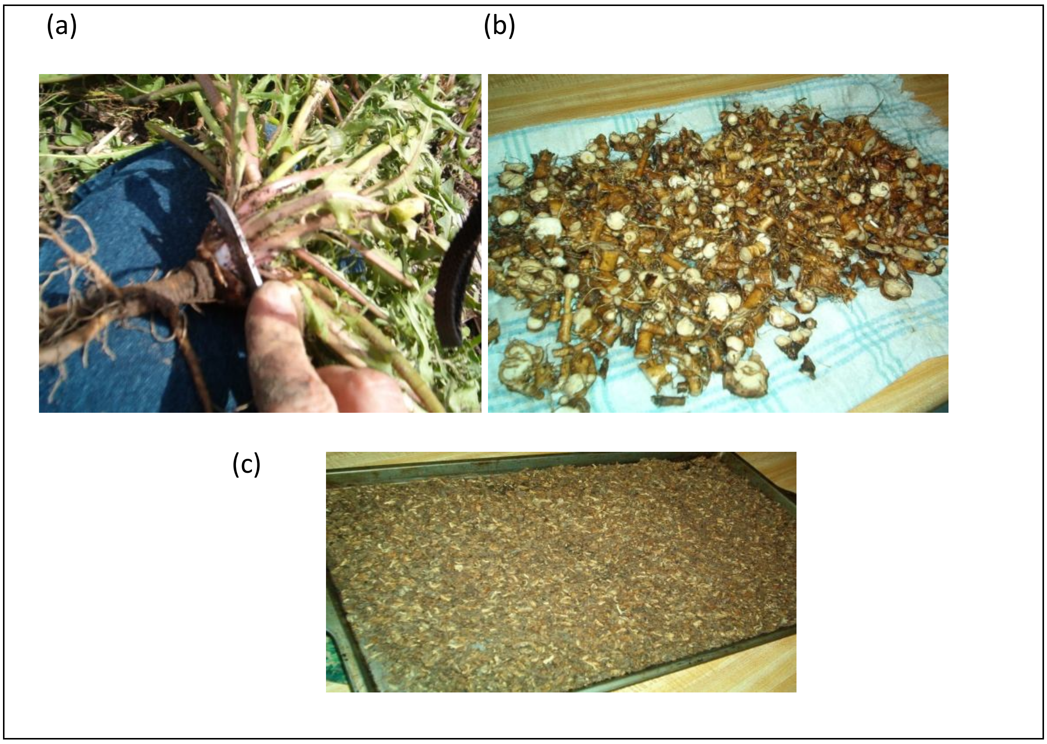


Figure 1.18. Dandelion coffee, (a) raw material; (b) chopped and roasted; (c) ground


Figure 1.19. Artichoke raw material.

<u>2- Dandelion coffee:</u>

The ubiquitous dandelion is even more widespread than chicory and just as famous as coffee stock. The rural poor traditionally stretched their supply of store-bought coffee with ground roasted dandelion taproots; some experts even consider the roots head-to-head competition for Arabica coffee. Roots gathered in late summer and fall are very bitter; those taken before the plant flowers are much milder. Dandelion coffee is said to be a good tonic for the liver. A bitter tonic made from the dandelion root is also used as a laxative.

Dandelion coffee is also currently being researched for cancer treatment (http://www.cbc.ca/news/canada/windsor/story/2012/02/16/wdr-dandelion-tea-cancer-killer.html).

<u>3-Jerusalem artichoke coffee:</u>

The tuber of a plant originally from North America. The yellow-white flesh of the Jerusalem artichoke is crunchy, juicy and sweet with a delicate flavor and covered in a thin edible skin. This is also called "sunchoke." Freshly dug tubers are washed, cut into small pieces, and roasted in a slow oven at 120 °C for 1-2 h, until they become dark brown and crisp. Because of the inulin content, the resultant coffee has a sweeter flavor than regular coffee.

<u>b-Seed brews:</u>

Seeds of some members of the pea family enjoy a high profile in traditional coffee blends. The sweet seeds of the warm-climate shrub carob (*Ceratonia siliqua*) are best known as a chocolate substitute, but when roasted and ground, they add smoothness to herbal coffees.

Other good coffee seeds include those of coffeeberry (*Rhamnus californica*), which prospectors in California milled and roasted to stretch store-bought provisions. Although it is a buckthorn, coffeeberry's roasted seeds lack the laxative effect that made the genus famous. Bitterroot (*Lewisia rediviva*), a low-growing herb that blankets Rocky Mountain grasslands with big pink or white blossoms in the spring, was one of the most important medicinal herbs to the First Nations of present-day British Columbia, Alberta, and the American West, where it was used to relieve sore throats and help heal open wounds. Early white settlers discovered that its seeds made a pleasant coffee substitute with a mild sedative effect. Seeds and plants of coffeeberry and bitterroot are available from mail-order seed houses and nurseries.
Cacao (*Theobroma cacao*) has become so intimately associated with sweets that it's easy to forget that this tree was originally cultivated to make a bitter stimulant beverage remarkably similar to coffee. The Aztecs called this brew chocolatl. Chocolatl proved too strong for Mexico's European invaders to handle. In the mid-1500s, eventually, cacao came to be used almost exclusively as the basis of the sugary substance we call chocolate today. Ground roasted cacao seeds, however, are widely available as unsweetened cocoa.

Tedious to gather owing to their small size, juniper berries and beechnuts nevertheless are outstanding in coffee blends. Roasted juniper berries have a smoky, resinous tang that blends well with the sweetish spiciness of cloves, cinnamon, and/or coriander. Beechnuts must be husked (easily accomplished by shaking the dried nuts in a paper sack), then picked over before roasting. Infusions of ground roasted beechnuts have body and mellowness that some compare to hot chocolate; they are delicious straight or mixed with regular coffee or cocoa.

1.2.17. Aim of study

Traditional *Pistacia Terebinthus* fruit (PTF) coffee or "Menengiç" coffee is the most famous and traditional herbal coffee in Turkey. 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 such as microwave, combined (microwave-convection) and pan before or after the removal of oil by cold pressing and solvent extraction and particle size on sensorial properties of powdered *P. terebinthus* fruit coffee brews.

CHAPTER II

MATERIALS AND METHODS

2.1. Materials

The ripening *Pistacia terebinthus L.* fruits 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. Chemicals were obtained from Merck (Darmstadt, Germany).

2.2. Methods

2.2.1. Processing of *Pistacia terebinthus* fruits

In this study, processing of PTF is shown below in Figure 2.1. Processing of PTF was carried out two categories such as Pressing-roasting and Roasting-pressing. The grinding and sieving processes were the same for two categories.

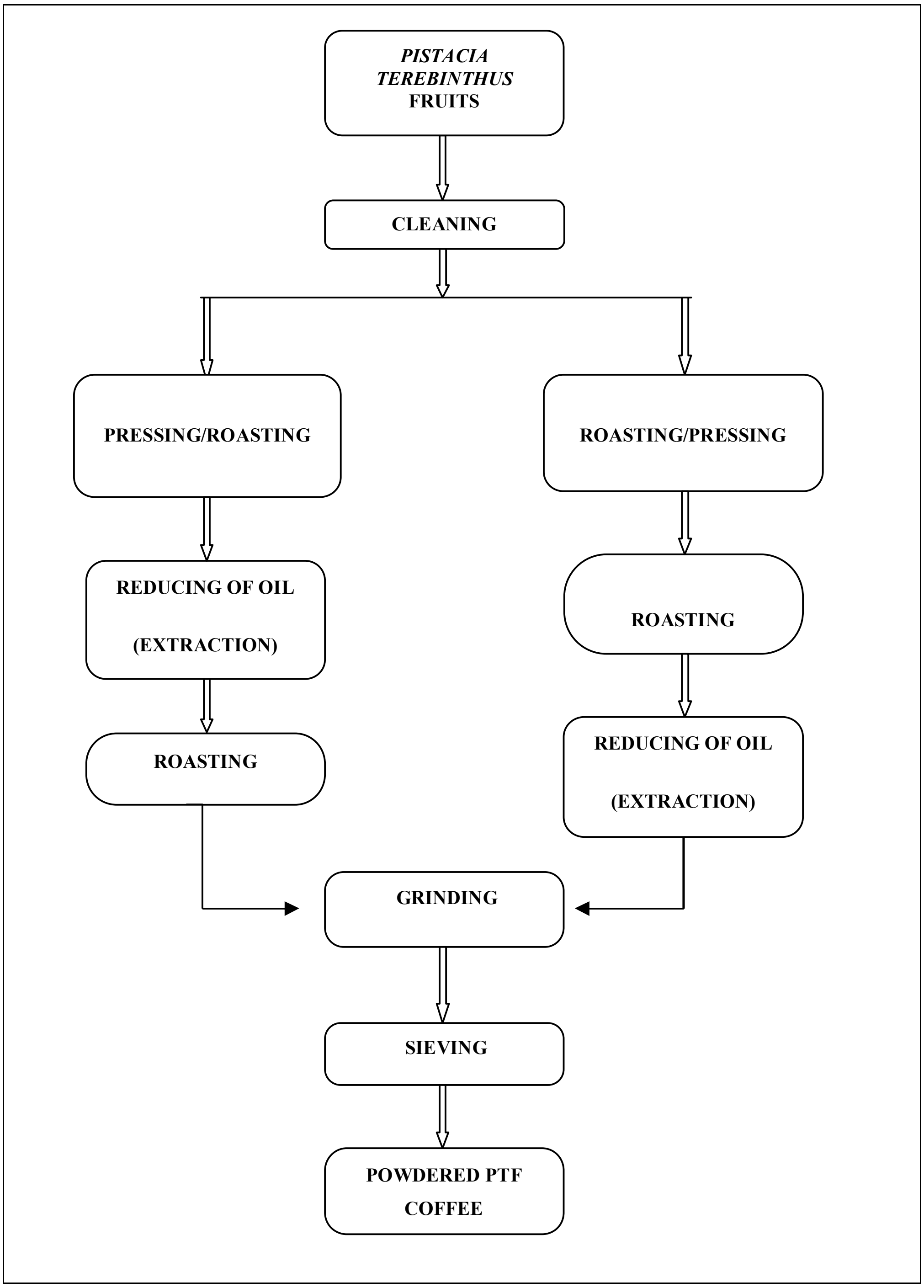


Figure 2.1. Flow diagram for powdered *P. terebinthus* fruits coffee production.

2.2.2. Determination of reducing of oil content step in the processing flow of *Pistacia terebinthus* fruits

Oil yield was defined as an efficient of reducing of oil content from PTF in this study. Therefore, determination of oil yield is important in order to obtain maximum reducing of oil content. Thus, the extraction was carried out two stages in the processing flow chart such as Pressing-roasting (PR) and Roasting- pressing (RP). PR and RP were considered comparing in terms of oil yield. The PTF roasting conditions will be described in the relevant stage, so in this part includes only extraction process step.

2.2.2.1. Pressing - roasting

The oil extraction from PTF was applied prior to roasting in this stage. 100 g of whole and unroasted PTF, which were dried at 60 °C in the incubator at the overnight, were filled in cloth bag and extracted with a laboratory type mechanic press. The oil yield (%) was calculated by weighing the extracted oil (g oil / 100 g dry sample). The extracted PTF were roasted. Finally, roasted PTF were observed in terms of roasting homogeneity.

2.2.2.2. Roasting - pressing

The oil extraction was applied after roasting in this stage. Whole PTF were roasting at different roasting methods. Roasted PTF were observed in terms of roasting homogeneity and oil yield. 100 g of roasted PTF were filled in cloth bag and extracted with a laboratory type mechanic press. The oil yield (%) was calculated by weighing the extracted oil (g oil / 100 g dry sample).

2.2.3. Reducing of oil content from *Pistacia terebinthus* fruits

Two methods such as solvent and mechanical press extraction (cold press) were used to reduce oil content from PTF.

2.2.3.1. Solvent extraction

The PTF were ground using a laboratory type blender (Waring HGB150, USA). 100 g of ground PTF were filled in the 250 ml beaker. 100 ml of n-hexane was added into the beaker. The mixture was stirred using a magnetic stirrer for 30 min. Extracted PTF were separated from hexane with a filter paper. Waited for a while under the fume cupboard until the residual hexane removed. After extraction, the solvent was removed in a rotary evaporator (Heidolph Instruments GmbH, Laborota 4000, Schwabach, Germany) to obtain extracted oil at 50 °C, under moderate vacuum, until no traces of hexane.

2.2.3.2. Mechanical pressing extraction

Mechanical pressing extraction (cold press) was used to reduce oil content from the PTF. Extractions were carried out using a laboratory type mechanic press (Ceselsan, Giresun, Turkey) (Figure 2.2). 100 g of PTF were filled in a cloth bag (Figure 2.3).

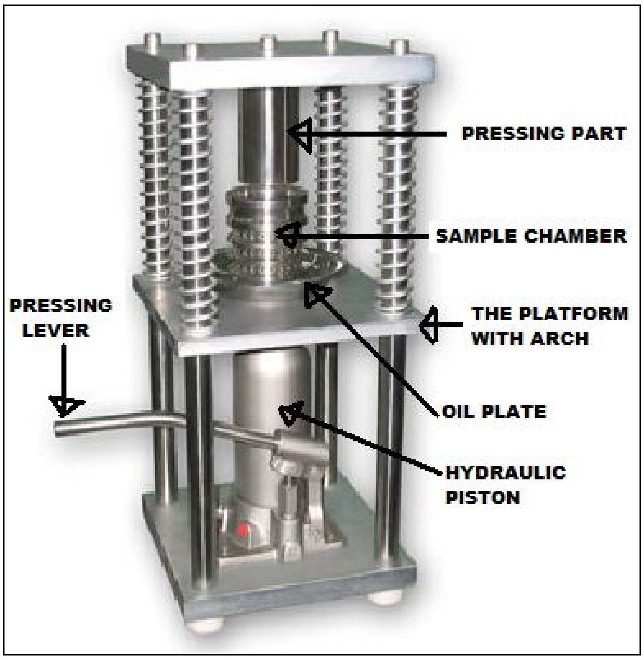


Figure 2.2. Mechanical pressing extraction system.

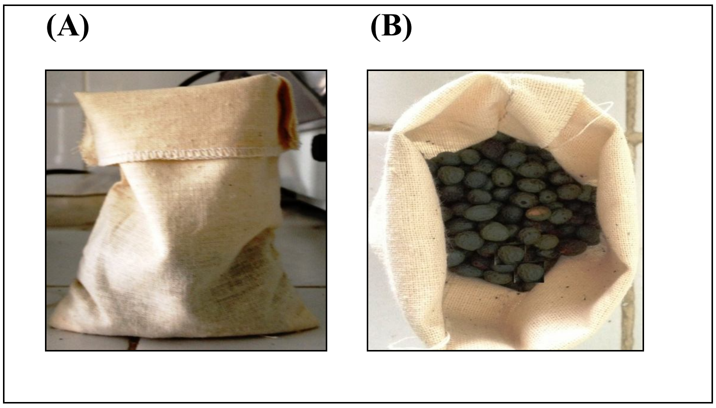


Figure 2.3. The filled cloth bag, (A) Side view; (B) Top view.

The cloth bag was put into a steel cylindrical chamber which has hollows around it to extract oil from the PTF. The pressing lever was compressed to obtain oil leak from hollows (Figure 2.4). The pressing was carried out three times for each sample.

Figure 2.4. The leak of *P. terebinthus* fruit oil from hollows.

2.2.4. Roasting

2.2.4.1. Microwave roasting

A programmable domestic microwave oven (Arçelik MD 583, Turkey) with maximum output of 1300 W at 2450 MHz was used. The oven has adjustable power and time controllers and was fitted with a turntable. Also, the oven enables grill heating.

200 g of samples were distributed in five petri dishes as 40 g of samples in each petri dishes. The oven was operated at 80 percent of maximum microwave output.

Microwave roasting (MWR) was performed according to present power and pre-determined color values. The PTF were stirred by taking out with a spoon and color change was recorded at every 50 seconds. When the samples reached pre-determined color values, the roasting was ended. All roasted PTF were poured into a plate to cool. The roasted PTF were stored in polypropylene bags at 4 °C until used.

2.2.4.2. Combined roasting

A programmable domestic microwave oven (Arçelik MD 583, Turkey) with combined cooking power output of 2500 W at 2450 MHz was used. The oven has adjustable power and time controllers and was fitted with a turntable. Also, the oven enables grill heating.

200 g of samples were distributed in five petri dishes as 40 g of samples in each petri dish. The oven was operated at 40 percent of microwave power and 60 percent grill power. The combined roasting (CR) was performed according to present power and pre-determined color values. The PTF were stirred by taking out with a spoon and color change was recorded at every 3 minutes. When the samples reach pre-determined color values the roasting was ended. All roasted PTF were poured into a plate to cool. The roasted PTF were stored at 4 °C in polypropylene bags in until used.

2.2.4.3. Pan roasting

Pan roasting (PaR) was carried out in a metal plate by using hot plate with a magnetic stirrer. 200 g of PTF were roasted in hot plate with continuous stirring and color change was recorded at every 180 seconds. When the samples reached pre-determined color values the roasting was ended. All roasted PTF were poured into a plate to cool. The roasted PTF were stored at 4 °C in polypropylene bags until used.

2.2.5. Grinding of *Pistacia terebinthus* fruits

Grinding conditions were the same both pressing-roasting and roasting-pressing. The PTF were ground using a laboratory blender type (Waring HGB150, USA) at the high grind setting for 30 seconds. End of 30 seconds, the mixture was stirred by spoon and continued grinding addition of 30 seconds. Ground PTF was stored at 4 °C before sieving.

2.2.6. Sieving of ground *Pistacia terebinthus* fruits

Sieving was carried out by hand sieve with five sieves of 425, 450, 530, 710 and 800 µm mesh width, respectively. The ground PTF was sieved from high size (800 µm) to small size (425 µm). The particles were rotated all directions continuously to pass through the sieve opening. The particles were fractionated two sizes such as 710 and 450 µm. The sieved particles were stored at 4 °C until sensory analysis.

2.2.7. Analysis

2.2.7.1. Determination of oil content

A solvent extractor (Ser 148 Velp Scientifica, Usmate, Italy) was used for determination of oil content. The device has adjustable temperature and time controllers. Hexane as solvent was used, so temperature was adjusted 180 °C according to operating manual of device. Extraction times were 50, 30 and 15 minutes for immersion, washing and recovery steps, respectively.

5 g of unroasted and roasted ground PTF and TC were weighed into 33 × 94 mm cellulose extraction thimble. Each part of sample was added hexane as a rate of 1:3 (w/v) in the extraction cup and then placed in the SER 148 Velp solvent extractor. The thimble with its contents were directly immersed in the boiling solvent for 50 min, and then suspended below the cooling condenser from which the cold refluxed condensed solvent drops and washes the sample to remove residual extractable materials for 30 min. Much of the solvent was recovered in the solvent reservoir for 15 min. The oil content (%) was determined gravimetrically. Measurements were taken in triplicate for each sample.

2.2.7.2. Determination of moisture content

The moisture content of ground unroasted and roasted PTF and TC were determined by the oven method according to AOAC (1995). Measurements were taken in triplicate for each sample.

2.2.7.3. Degree of roast as determined by color measurements

The color of the PTF was measured in the L*, a*, b* system using a Hunterlab ColorFlex EZ spectrophotometer (Hunter Associates Laboratory Inc, Virginia, USA) in the reflectance mode during roasting. Before analysis, the instrument was calibrated on both black and white standard tile, respectively. Degree of roast was based on only a* value. Other values were used to obtain additional knowledge through roasting. When a* value reached from negative levels to positive levels such as (+) 1, the roasting of PTF was ended. Measurements were taken in triplicate for each sample in determined times for every roasting condition.

2.2.7.4. Determination of particle size range

Particle size range of PTF just after the extraction and grinding process must be known in order to conceive efficient of extraction and grinding process. Measurements have been made by separating to fractions.

200 g of ground and extracted PTF were fractioned by hand sieving using different size sieves from high level to small level. These used sieves were 800, 710, 530, 450 and 425 μm. The amounts of particles obtained above and below the sieve after every sieving were weighed. It was defined as a percentage particle size range. Measurements were taken in triplicate for each sample.

2.2.7.5. Determination of pH and titratable acidity

A 2.00 g of PTF coffee and TC 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 value determination with a pH meter. Measurements were taken in triplicate both PTF coffee and TC.

A 10.00 g of PTF coffee and TC were separately weighed into a 200 ml glass bottle, and 75 ml 80% ethanol was added to wet the samples. The glass bottle was shaken for 16 h under magnetic stirring. After that, 10 ml of the filtered extract was diluted 100 ml with water and titrated against 0.1 N NaOH solution using phenolphthalein as an indicator. The results are expressed as 0.1 ml alkali required neutralizing acidity of 100 g sample. Measurements were taken in triplicate.

2.2.7.6. Determination of free fatty acid

Oil obtained from ground PTF coffee and TC was extracted which as described in 2.2.3.2 and 2.2.3.1, respectively.

5 g of extracted oil each coffee sample were weighted into 200 ml beaker. The samples were mixed with 40 ml ethanol-diethyl ether mixing (1:1, v/v) which was neutralized with 0.1 N NaOH using as an indicator 1-2 drop phenolphthalein. The solvent mixing was added to oil and titrated with 0.1 N NaOH, shaking constantly, until a pink color persists for 30 seconds. Finally, the free fatty acid value (FFA) was calculated.

2.2.7.7. Sensory analysis

PTF coffee produced and TC brews were prepared according to preparing of Turkish coffee procedure (5 g of ground coffee for each sample were gently mixed with a small coffee cup of water for each panelist and the mixtures were cooked in a coffee maker until first boiling).

The PTF brews obtained from coffee samples roasted by different methods (three PTF coffee and used only one TC sample for reference) were successively subjected to sensory analysis. The group of panelist consisted of seven women and three men. Sensitivity of ten sensory assessors selected from students and laboratory staff was tested each sample. The laboratory of sensory analysis has all the basic criteria regarding equipment and application of the suitable environmental condition. The panelists washed their mouth with water before they were served the subsequent coffee infusion. The assessors were trained to define and recognize the individual taste and aroma determinants of coffee brews according to "Basic Flavor Descriptive Language". Some of sensory properties which based on nine-point hedonic scales to describe their feelings such as aroma, flavor, acidity, after taste and overall acceptability were evaluated and pointed from 1 (dislike) to 9 (like extremely).

2.2.7.8. Statistical analysis

The PTF coffee which was prepared with three different roasting methods and TC sensory analysis results were compared by one-way analysis of variance (one-way ANOVA) to determinate for effect of roasting methods on sensory quality. 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). Differences among sample means were reported to be significant and insignificant when $p<0.05$ or $p>0.05$.

CHAPTER III

RESULTS AND DISSCUSION

3.1. General

Roasting of PTF was applied after and before reducing of oil content. These stages were compared in terms of oil extraction and roasting quality. Processing of powdered PTF coffee was produced by two production methods (PR or RP). Three roasting methods which are microwave, combined and pan were used in this study. Powdered PTF coffee produced with these roasting methods were compared with each other and TC in terms of sensory properties and statistically.

3.2. Properties of *Pistacia terebinthus* fruits and commercial Turkish coffee

Table 3.1 shows the properties of PTF used in the experiments. Properties of used commercial TC in the experiments were shown in Table 3.2.

Table 3.1. Initial properties of *Pistacia terebinthus* fruits.

Properties	Values
Moisture (%)	5.38 ± 0.44
Oil Content (%)	40,5 ± 0,95
L*	28.58 ± 0.57
a*	-4.79 ± 0.09
b*	4.34 ± 0.13

Values are mean ± standard deviation (n = 3).

Table 3.2. Properties of commercial Turkish coffee.

Properties	Values
Moisture (%)	1.67 ± 0.03
Oil Content (%)	16.05 ± 0.13
Free Fatty Acid (% Oleic)	3,88 ± 0.06

Values are mean ± standard deviation (n = 3).

Moisture content of PTF was found to be 5.38 %. This value is lower than reported by Özcan, (2004) (6.17%). Moisture content found is close to moisture of pistachio kernel reported by Razavi et al., (2007). Moisture of green coffee beans (10-13%) is higher than PTF.

According to literature, oil content of PTF changes between 38.4-45.1%. Matthaus and Özcan, (2006) reported that the average of oil content in PTF collected from around Turkey was 41.5%. Oil content of PTF used in experiments was found 40.5%. It is close to the average of Turkey. When compared with pistachio, its oil content is lower, but it has high oil content with respect to green coffee bean (11-16 %).

The color values of PTF were not found in the literature. Mostly, sources include PTF oils color values. L*, a* and b* value describing as brightness, greenness (-a*), redness (+a*) and yellowness (b*) were found to be 28.58, -4.79 and 4.34, respectively. Budryn et al., (2011) reported that L* values are 75.51 and 70.33 for Arabica and Robusta coffee, respectively. Therefore, L* value found for raw PTF is quite lower than coffee beans. The same researchers also found that a* and b* values were 1.68, 2.83 and 20.28, 21.57 for Arabica and Robusta coffee, respectively. Similar to L* values, a* and b* values were found lower than coffee beans.

Oil content and moisture were found to be 16.05 and 1.66 % for commercial TC, respectively. These results are in a good agreement with the literature.

3.3. Evaluation of Pressing-roasting and Roasting-pressing in the production flow

Traditional 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. Pressing 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 (Figure 3.1a) especially, small particles produced during pressing burned (Figure 3.1b) in the first period of the roasting process. The removal of oil was more successful in pressing after the roasting applications. So, pressing after the roasting process has been used for further applications to obtain a sample with lower oil and homogeny roasting. According to literature that temperature is very effective on the oil extraction yield. Artık, (2004) reported that the oil yield increases depending on temperature. Similarly, Dalgıc et al., (2011) showed that PTF roasted at different temperatures has a high oil yield when comparing with unroasted ones. These reports suggested results of this study.

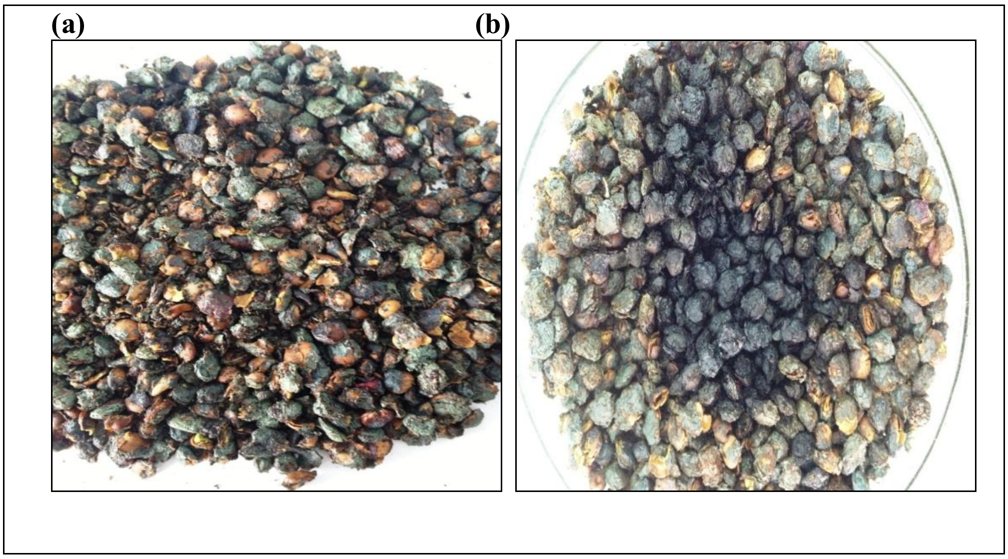


Figure 3.1. View of after the Pressing- roasting condition, (a) After the pressing with broken fruits; (b) The formation of burning while roasting.

3.4. Evaluation of reducing oil content methods

It has been found that solvent extraction resulted in poor physical, chemical and sensorial quality because of discoloration and excessive oil extraction (Figure 3.2 a/b). Therefore, solvent extraction was not used to reduce oil content in further applications. Instead of solvent extraction, the mechanical pressing extraction was only used in order to produce powdered PTF coffee in the further applications.

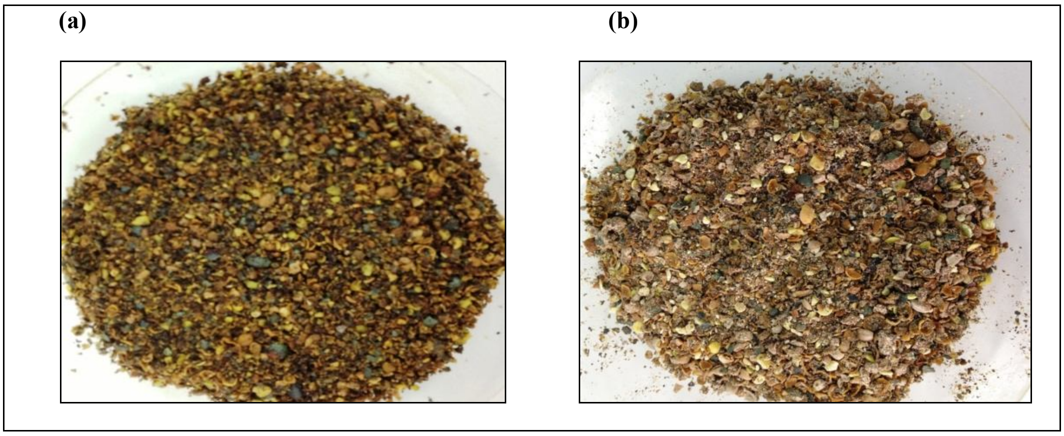


Figure 3.2. Effect of solvent extraction on the *P.terebinthus* fruits, (a) Before solvent extraction; (b) After solvent extraction.

3.5. Results of oil content after Roasting-pressing

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 for oil content were still higher than compared to those found by Mazzafera et al., (1999) for Arabica coffee. The results of oil content were summarized for each roasting method below in Table 3.3. Oil contents of after Roasting-pressing for each roasting method were not found to be different ($p < 0.05$) significantly. (Appendix A, Table A1).

Table 3.3. Oil content of *Pistacia terebinthus* fruits after Roasting-pressing.

Samples	Oil Content (%)
TC	16.05 ± 0.13^{a}
Raw PTF	40.50 ± 0.95^{b}
MWR	21.50 ± 0.72^{c}
CR	21.02 ± 0.88^{c}
PaR	20.06 ± 0.93^{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; PaR: Pan roasting.

3.6. Evaluation of physical and chemical properties during roasting

3.6.1. Color measurements as a degree of roast

Color change which is one of the most important modifications in coffee bean during roasting (Eggers and Pietsch, 2001) caused by non-enzymatic browning reactions such as Maillard reaction and caramelization (Massini et al. 1990; Parliment Thomas, 2000). The color changes in coffee beans also may be due to the destructions of pigment present in coffee beans. Brightness/Darkness (L*) is often used as a measurement of the degree of roast (e.g., light, medium, and dark). Onorio et al., (2011) reported that variations in degree of roasting were light (L* value 31), medium (L* color 24), dark (L* value 19) and very dark (L* value 17-18). 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 samples roasted and oil has been removed to observe the color, aroma and odor for each trial. The color values chosen as a reference have been decided by end of the pre-sensorial analysis. Consequently, all roasting methods were ended the range of 1-1.2 a* values. The burning of PTF were observed at 2 and over for a* value. Comparison of roasting degree for PTF was shown below in Figure 3.3a/b. In the absence of any reported data on the color of roasted PTF; it was not possible to compare the experimental values obtained in this study.

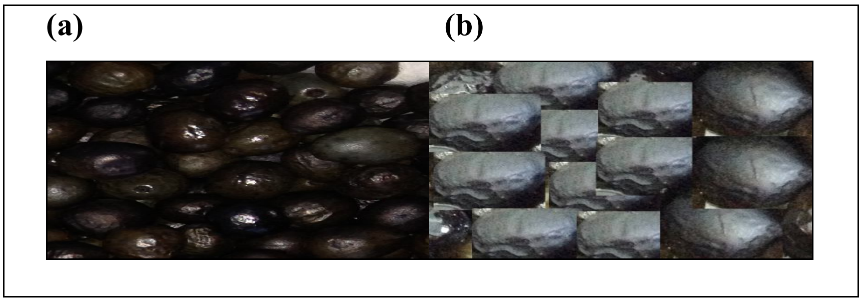


Figure 3.3. Comparison of roasting degree for *P. terebinthus fruits*, (a) Desirable roasted PTF; (b) Over roasted PTF.

3.6.1.1. Change of color during roasting conditions

The final color values for each roasting condition were presented in Table 3.4. The changes of color values during different roasting conditions were also shown below in Figure 3.4.

Initial L*, a* and b* color values were found to be 28.48, -4.79 and 4.42, respectively, before roasting in PTF. The color values of commercial TC were also presented in Table 3.3. 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. The color values of commercial TC also found statistically different from raw and roasted PTF. 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 end of overall process. All color values reached finally were not different statistically as it is presented in Table 3.4.

Table 3.4. The effect of roasting conditions on color characteristic.

Samples	L*	a*	b*
TC	36.68 ± 0.53^{a}	15.44 ± 0.22^{a}	27.44 ± 0.33^{a}
Raw PTF	28.48 ± 0.95^{b}	-4.79 ± 0.11^{b}	4.42 ± 0.17^{b}
MWR	18.37 ± 0.63^{c}	1.16 ± 0.08^{c}	1.84 ± 0.13^{c}
CR	18.34 ± 0.14^{c}	1.14 ± 0.13^{c}	1.63 ± 0.31^{c}
PaR	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; PaR: Pan roasting.

3.6.1.1. Change of color during microwave roasting

The color values have been found to decrease throughout the roasting process except a value. The L*, a* and b* values were found to be 18.37, 1.16 and 1.84 by the end of roasting, respectively. The overall roasting time for MWR was around 1500 seconds to obtain the desired color values.

3.6.1.2. Change of color during combined roasting

The color values have been found to decrease throughout the roasting process except a value. The L*, a* and b* values were found to be 18.34, 1.14 and 1.63 by the end of roasting, respectively. The overall roasting time for CR was around 1900 seconds to obtain the desired color values.

3.6.1.3. Change of color during pan roasting

The color values have been found to decrease throughout the roasting process except a value. The L*, a* and b* values were found to be 18.12, 1.20 and 1.78 by the end of roasting, respectively. The overall roasting time for PaR was around 1620 seconds to obtain the desired color values.

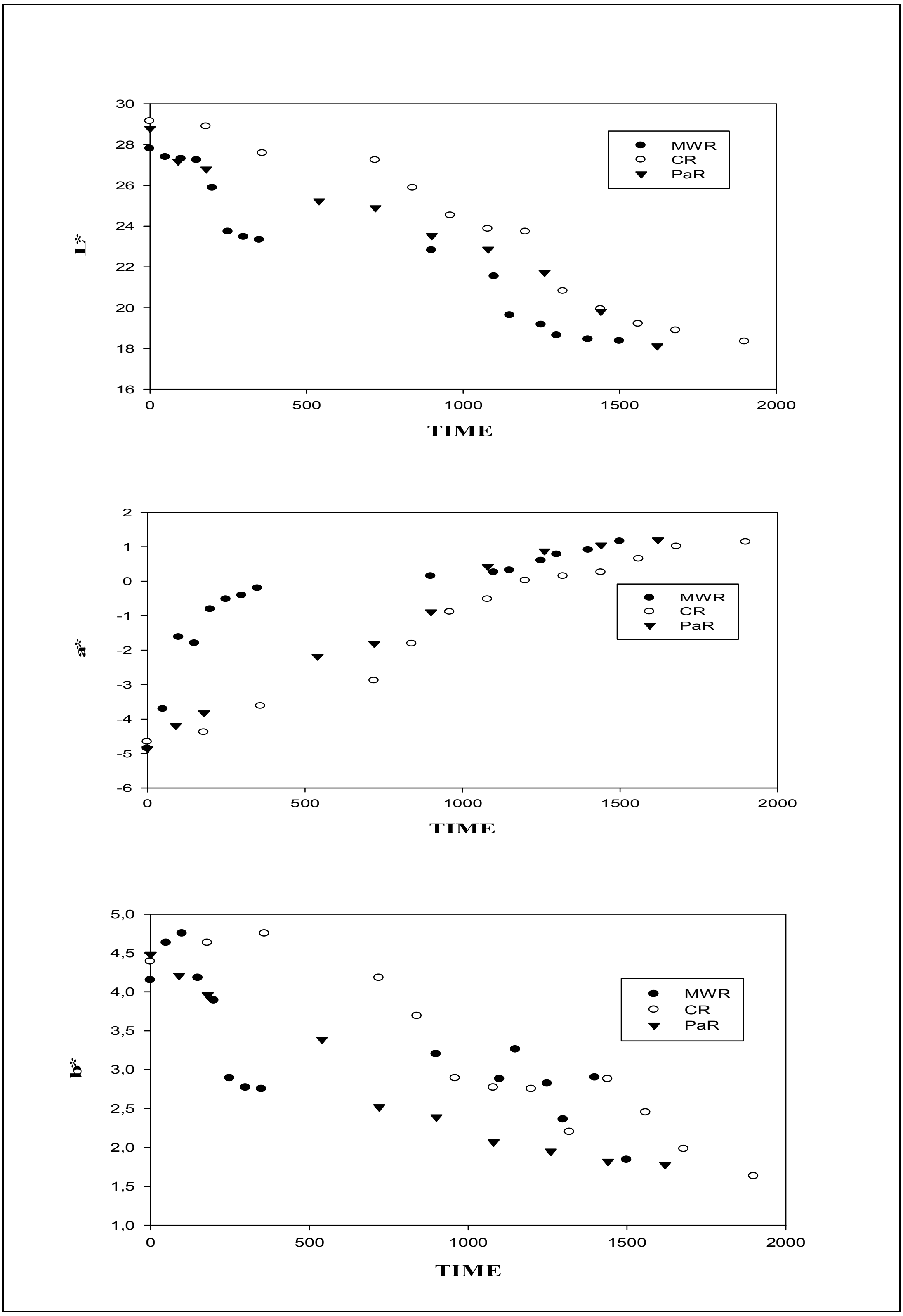


Figure 3.4. Change of L*, a* and b* values at different roasting conditions, MWR: Microwave roasting; CR: Combined roasting; PaR: Pan roasting.

3.7. Results of particle size range after grinding

Ground PTF were fractioned from high size to small size using hand sieves. Distribution of particle size range was shown below in Figure 3.5.

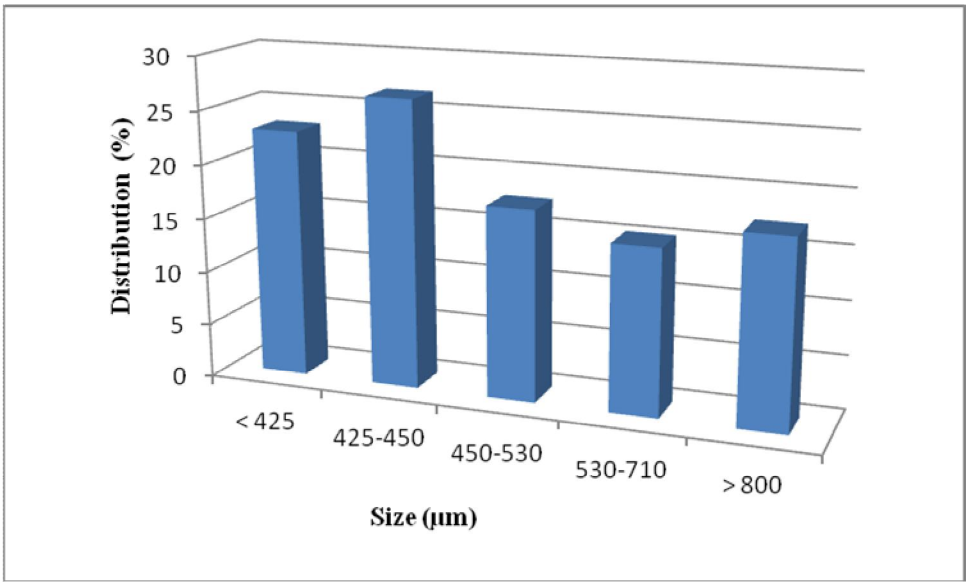


Figure 3.5. Particle size range after grinding.

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. 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 (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 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 following chemical and sensorial analysis.

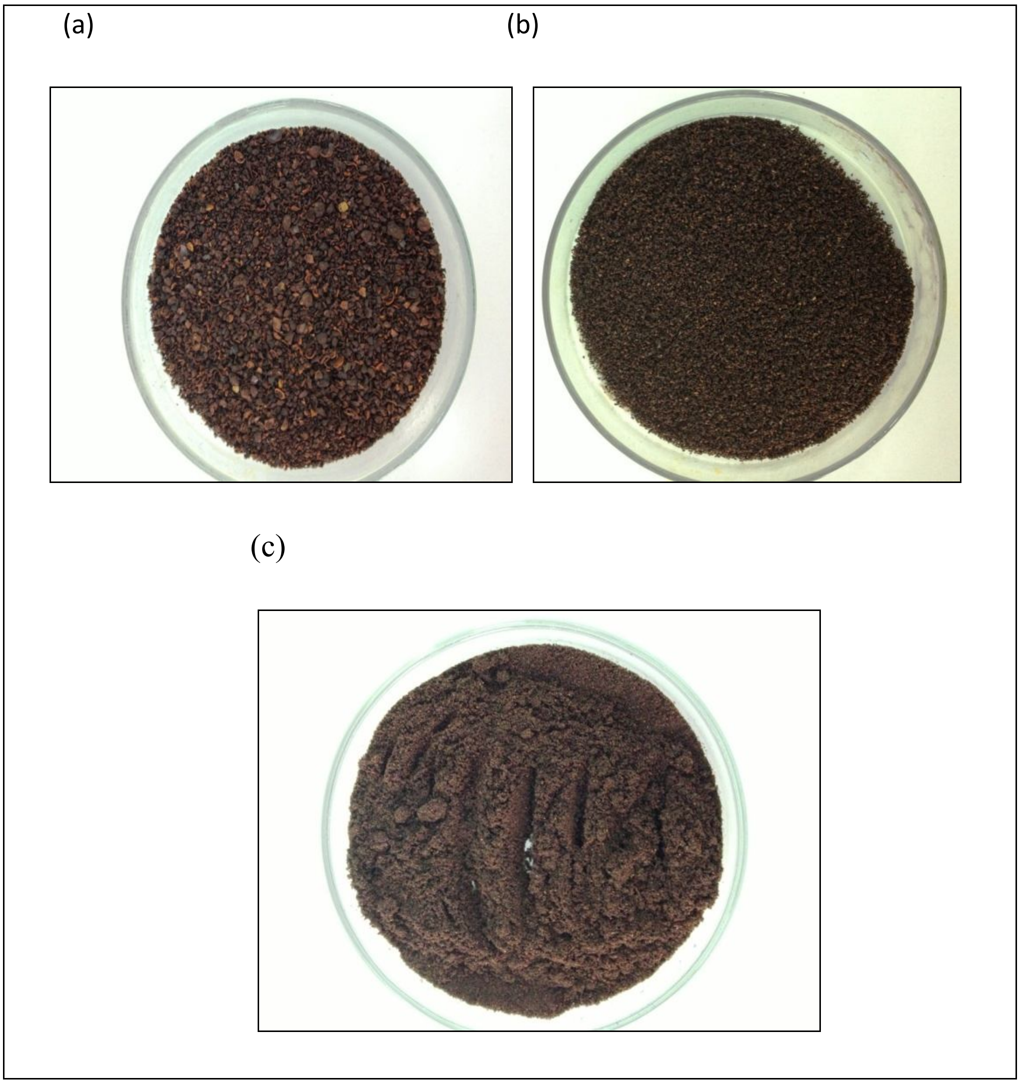


Figure 3.6. Fractioned *P. terebinthus* coffees (a) over 800 µm; (b) 530-710 µm and (c) 425-450 µm.

3.8. pH and titratable acidity

Titratable acidity and pH values of *terebinth* fruit coffee roasted of different conditions were presented in Table 3.5.

In the absence of any reported data on the pH and titratable acidity of PTF coffee; it was not possible to compare the experimental values obtained in this study. Therefore, this study will be the first time.

Table 3.5. pH and titratable acidity at different roasting conditions and commercial Turkish coffee.

Sample	Titratable Acidity (ml NaOH /100 g coffee)	pH
TC	420.19 ± 0.48[a]	5.60 ± 0.03[a]
MWR	165.48 ± 0.53[b]	6.37 ± 0.01[b]
CR	220.83 ± 0.45[c]	6.57 ± 0.03[c]
PaR	237.05 ± 0.32[d]	6.27 ± 0.04[d]

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; MWR: Microwave roasting; CR: combined roasting; PaR: Pan roasting.

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 (Appendix A, Table A2). It has been discussed by Brollo et al., (2008) that the titratable 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 titratable acidity values in this study, especially higher pH values support the idea of more reliable values of titratable acidity. Acidity basically is a result of the formation of formic, acetic, glycolic and lactic acids during roasting (Ginz and Bradbruy, 2000). These are all degradation products of oils, proteins and/or carbohydrates. Gogus et al., (2011) identified some of these acids as volatile components in *Pistacia terebinth* coffee in various stages of roasting. Various roasting conditions of powdered *terebinthus* fruit coffees caused significant difference ($p < 0.05$) on the pH value (Appendix A, Table A3). They are all found different to each other.

Titratable acidity values were found to be 165.48, 237.05 and 220.83 ml NAOH / 100 g coffee for MWR, PaR and CR, respectively. Titratable acidity for commercial TC used in this study was found to be 420.19 ml NAOH / 100 g coffee. Mazzafera, (1999) presented the titratable acidity of different coffee samples in the range of 228-

267 (ml / 100 g). Martin et al., (1999) were also reported the titratable acidity of coffee samples in the range of 101-114 (ml / 100 g). The differences may be due to roasting conditions, preparation of brew and age of coffee. Titratable acidity of commercial TC is found statistically different ($p < 0.05$) (Appendix A, Table A5). The different roasting methods of *terebinthus* fruits caused significant difference statistically on the titratable acidity ($p < 0.05$) (Appendix A, Table A4). They are all found different to each other.

3.9. Free fatty acidity

Table 3.6 represents the free fatty acid of oil powdered *terebinth* fruit coffee as quality parameter to show the effect of roasting on the degradation of triglycerides.

Table 3.6. The free fatty acid values at different roasting conditions and commercial Turkish coffee.

Samples	FFA (% Oleic)
TC	3.88 ± 0.06^a
MWR	2.69 ± 0.04^b
CR	2.70 ± 0.02^b
PaR	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 $p < 0.05$. FFA: Free fatty acid. MWR: Microwave roasting; CR: combined roasting; PaR: Pan roasting; TC: Turkish coffee.

It is seen that the Turkish coffee used as a control in this study has highest free fatty acid content. In addition, free fatty acid content of Turkish coffee found statistically different ($p < 0.05$) than those of powdered pistacia *terebinth* fruit coffees (Appendix A, Table A6). Fobe et al., (1968) reported that FFA value in coffee beans increased during roasting process. Dolezal et al., (2005) reported that FFA values in the green and roasted Arabica coffee were 2.3 and 3.5%, respectively. These results are good agreement with this study.

FFA values of powdered PTF coffee 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 ($p > 0.05$) (Appendix A, Table A7), 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 (1900 sec). Geçgel and Arıcı, (2008) reported that free fatty acid changes between 0.76-2.40% in the raw oil of PTF. Koçak et al., (2011) also found free fatty acid as 0.59 for raw *Pistacia terebinth* fruit oil. In the different a study that was found 0.86 % by Özcan, (2004). The differences in free fatty acid of PTF are probably due to environmental conditions in conjunction with the analytical methods used. In addition, PTF are affected mostly by variety and growth conditions such as soil properties etc.

The increased value of free fatty acids compared to earlier studies is a clear indication of high temperature roasting applications. Certel et al., (2007) reported that the FFA in roasted PTF was higher than unroasted. They also found that FFA was not change significantly during microwave roasting used different power and roasting times. Dalgıç et al., (2011) reported that FFA was not change significantly during roasting conditions used different temperature ranges. These results are in a good agreement with this study.

3.10. Sensory analysis

The average values of sensory properties, namely aroma, flavor, acidity, after taste and overall acceptability were given for brews of powdered *terebinth* fruit coffee roasted by various methods and Turkish coffee in Table 3.7.

Table 3.7. Effect of roasting conditions on sensory attributes of powdered *P. terebinthus* fruits coffee brews.

Sensory Attributes	**Control**	**Roasting Conditions**		
	TC	**MWR**	**CR**	**PaR**
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; MWR: Microwave roasting; CR: Combined roasting; PaR: Pan roasting.

The size range of 425-450 µm was found as the best in pre-sensorial analysis because of attractive taste and smell in brews. This size range was used in following sensorial analysis.

3.10.1. Aroma

Coffee aroma is a comprehensive term because of including a lot of such description as nutty, burnt, grassy, rancid and woody etc. These descriptions could be abstruse in terms of perception for tasters. Thus, overall aroma which is a combination of all aroma vocabularies was used in sensory analysis to provide convenience for panelists.

The scores of aroma obtained from sensorial analysis were given in the Figure 3.7. Aroma scores were ranged from 5.6 to 6.2 points for powdered PTF coffees. The relatively difference (0.6 points) in quality of brews prepared from roasted of the same provenance and roasting degree, indicates that adequate processing of powdered PTF coffee and rigorous of roasting process could improve the sensory properties of its brews. The relatively difference also may be due to variant of roasting methods. But, aroma scores of powdered PTF coffee brews obtained from different roasting methods were not difference statistically ($p > 0.05$) (Appendix B, Table B1). It has been found that there is no difference statistically ($p < 0.05$) in aroma values of studied all coffee samples (Appendix B, Table B2).

The highest average aroma score was given to *terebinth* fruit coffee roasted by a combined 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 derivates and pyrazines are defined as typical components of coffee volatiles. Gogus et al., (2011) reported that the number of total volatile compounds increased with increasing roasting time up to 20 minutes of pan roasting then decreased slightly at 25 minutes. They also found that furans and furanones produced in the first 5 minutes 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.

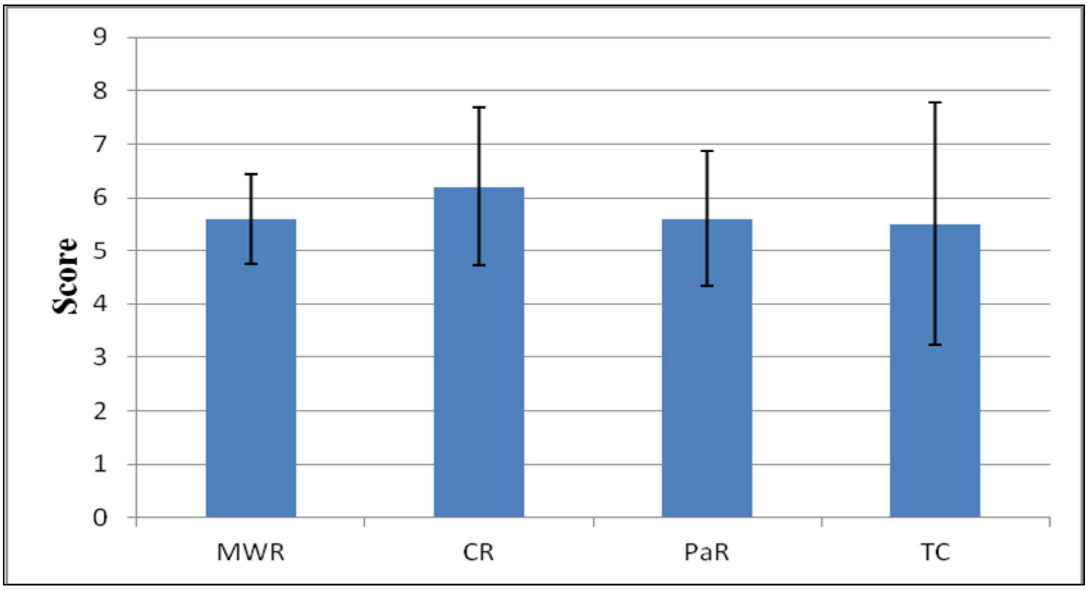


Figure 3.7. Aroma scores for powdered *P. terebinthus* coffee at different roasting conditions and commercial Turkish coffee (MWR) Microwave roasting; (CR) Combined roasting; (PaR) Pan roasting; (TC) Turkish coffee.

3.10.2. Flavor

The scores of flavor obtained from sensorial analysis were given in the Figure 3.8. 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 that of combined roasting method. However, ANOVA results showed that there is no difference in flavor scores of studied all coffee samples, statistically ($p < 0.05$) (Appendix B, Table B4). It also found that flavor scores of powdered PTF coffee brews obtained from different roasting methods were not different statistically ($p > 0.05$) (Appendix B, Table B3).

The perception of flavor compounds in a food matrix depends on the composition of this matrix. It has been shown that the macromolecules, such as proteins, are involved in the retention of flavor compounds (Guichard, 2002). Mestdagh and Collin, (1999) reported that coffee melanoidins might interact with flavor compounds, thus modifying aroma perception in coffee. Flavor is the most important criterion for coffee quality evaluation and also one the major motivations for consumer preference in coffee industry (Clark, 1987). Increasing the roasting degree of coffee affected negatively the retention capacity of coffee melanoidins was reported by Andriot et al., (2004). 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). Gogus et al., (2011) found that the Maillard reaction products were dominant components of volatiles of *Pistacia terebinthus* coffee.

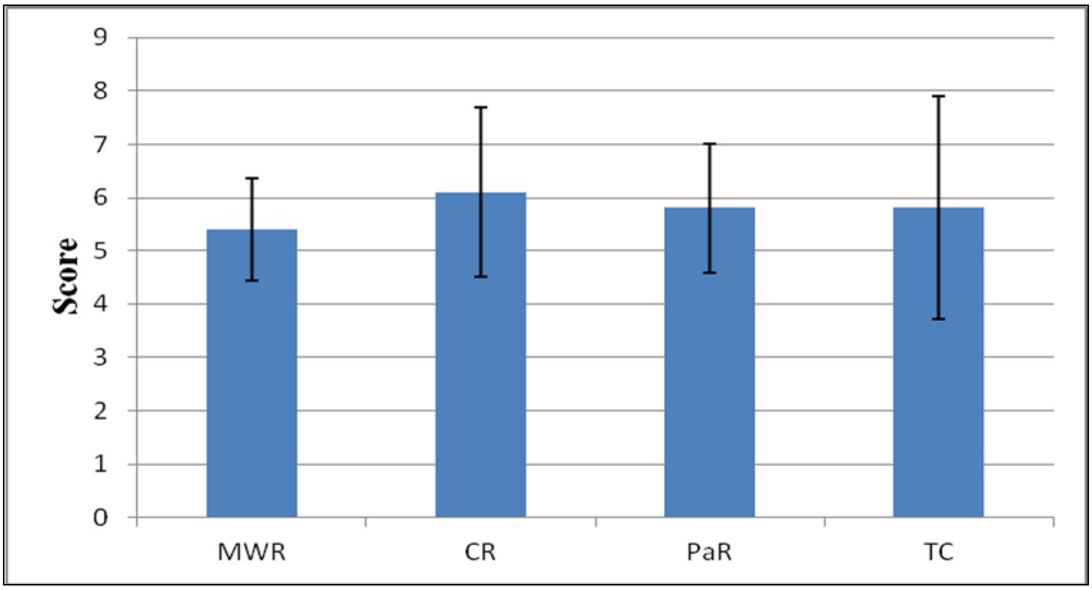


Figure 3.8. Flavor scores for powdered *P. terebinthus* fruit coffee at different roasting conditions and commercial Turkish coffee (MWR) Microwave roasting; (CR) Combined roasting; (PaR) Pan roasting; (TC) Turkish coffee.

3.10.3. Acidity

The scores of acidity obtained from sensorial analysis were given in the Figure 3.9. 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. Acidity scores of powdered PTF coffee brews obtained from different roasting methods were not different statistically ($p > 0.05$) (Appendix B, Table B5). There is also no difference in acidity scores of studied all coffee samples, statistically ($p > 0.05$) (Appendix B, Table B6).

Coffee acidity is the bright and dry taste that adds life to a coffee. Some such researchers as 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) suggests 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 course grind to extra fine. However, the panelists preferred the powdered PTF coffees with a moderate acidity.

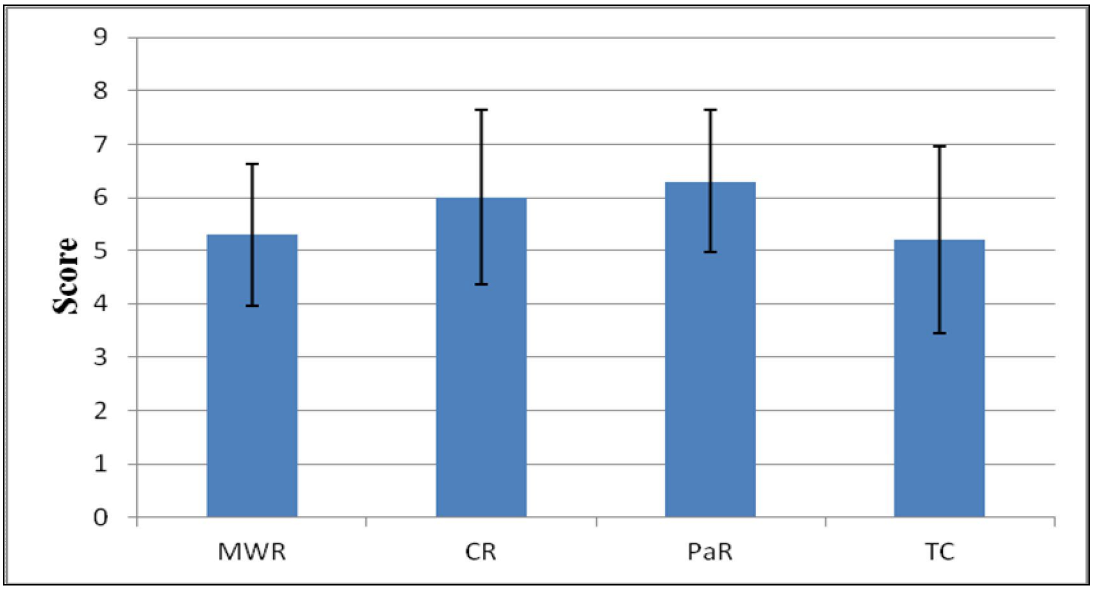


Figure 3.9. Acidity scores for *P. terebinthus* fruit coffee at different roasting conditions and commercial Turkish coffee. (MWR) Microwave roasting; (CR) Combined roasting; (PaR) Pan roasting; (TC) Turkish coffee.

3.10.4. After taste

The scores of aftertaste obtained from sensorial analysis were given in the Figure 3.10. 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 is defined as the sensation present in the mouth immediately following the removal of whatever food or drink was being consumer (http://www.stocktongraham.com/a-look-at-aftertaste). 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 in this study among the all studied samples statistically, (Appendix B, Table B7), CR and PaR caused the production of most preferable flavor profile in this study. Aftertaste scores of powdered PTF coffee brews obtained from different roasting methods were also not different statistically ($p>0.05$) (Appendix B, Table B8).

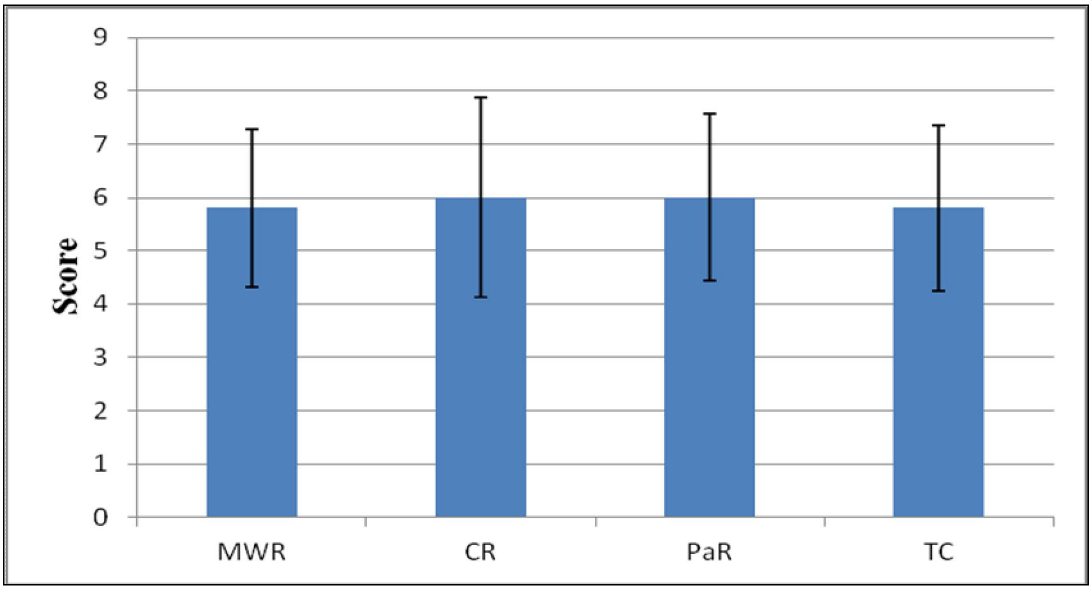


Figure 3.10. Aftertaste scores for *P. terebinthus* fruit coffee at different roasting conditions and commercial Turkish coffee (MWR) Microwave roasting; (CR) Combined roasting; (PaR) Pan roasting; (TC) Turkish coffee.

3.10.5. Overall acceptability

The scores of overall acceptability obtained from sensorial analysis were given in the Figure 3.11. The overall acceptability score of PaR samples was found highest as 6.3. It was lowest in samples brewed from roasted powdered PTF by MWR. The score was found to for TC was 5.9. Overall acceptability includes all cupping vocabularies. Because, it defines 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 PaR coffee as the best in terms of its overall acceptability. This result has also been supported with the result of other sensorial and chemical analysis. Overall acceptability scores of powdered PTF coffee brews obtained from different roasting methods were not difference statistically (p >

0.05) (Appendix B, Table B9). Similarly, aftertaste scores of all coffee types were not found different statistically ($p > 0.05$) (Appendix B, Table B10).

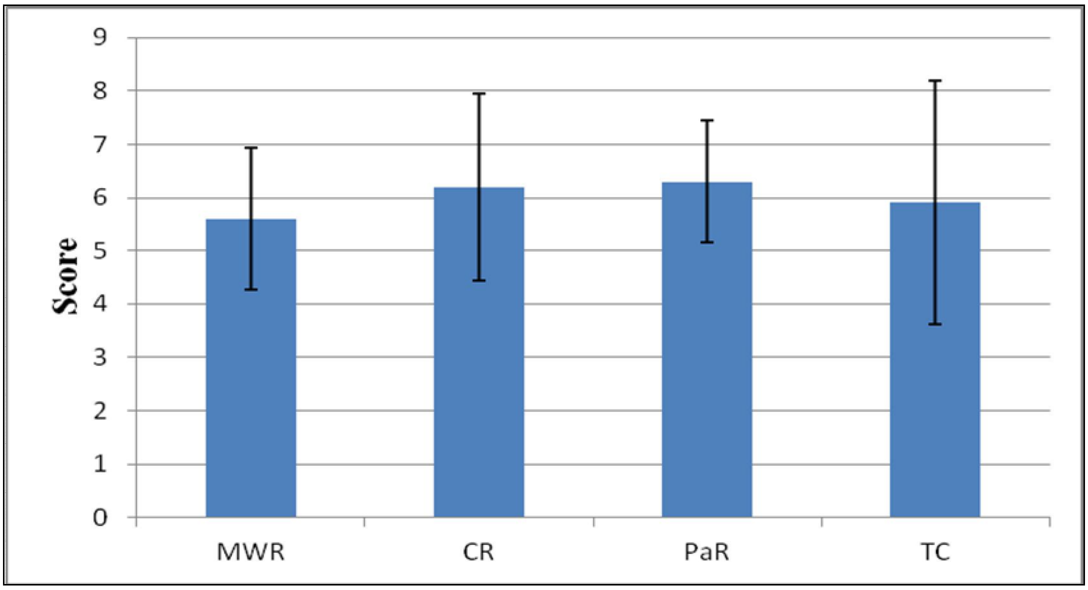


Figure 3.11. Overall acceptability scores for *P. terebinthus* coffee at different roasting conditions and commercial Turkish coffee (MWR) Microwave roasting; (CR) Combined roasting; (PaR) Pan roasting; (TC) Turkish coffee.

CHAPTER IV

CONCLUSION

The study of roasting, oil removal, grinding of *Pistacia terebinthus* fruits and sensory properties of powdered PTF coffee brews revealed the following conclusions:

1. A higher oil removal and a homogeneous roasting were observed in case of roasting-pressing method when compared with pressing-roasting.

2. L*, a*, b* values for various roasting methods were found in the ranges of 18.12-18.37, 1.14-1.20 and 1.63-1.84, respectively.

3. The roasting times determined according to the desired color values were found to be 1500, 1900 and 1620 seconds for microwave, pan and combined roasting methods, respectively.

4. Sensorial quality in powdered PTF coffee obtained by solvent extraction was poor when compared with cold extraction of oil.

5. The free flowing coffee powder was obtained at an oil content of around 21.5 % for all roasting methods.

6. The best particle size was decided to be in a range of 425-450 µm for a desirable brew of PTF coffee in terms of sensorial characteristics.

7. Sensorial quality of PTF coffee was found to be not affected by roasting methods, statistically.

8. The sensorial analysis results showed that powdered PTF coffee was not found to be different than TC statistically. Therefore, PTF coffee could be used as an alternative to Turkish coffee.

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APPENDICES

APPENDIX A

Table A1. ANOVA for oil content after Roasting-Pressing for each roasting method.

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3,226	2	1,613	2,242	,187
Within Groups	4,315	6	,719		
Total	7,541	8			

DUNCAN'S MULTIPLE RANGE TEST TABLE

ROASTING TYPES	N	Subset for alpha = 0.05
		1
PaR	3	20,0600
CR	3	21,0200
MWR	3	21,5000
Sig.		,091

Table A2. ANOVA for pH at various coffee types

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1,599	3	,533	515,750	,000
Within Groups	,008	8	,001		
Total	1,607	11			

DUNCAN'S MULTIPLE RANGE TEST TABLE

COFFEETYPE	N	Subset for alpha = 0.05			
		1	2	3	4
TC	3	5,5967			
PaR	3		6,2667		
MWR	3			6,3733	
CR	3				6,5667
Sig.		1,000	1,000	1,000	1,000

Table A3. ANOVA for pH of PTF coffee at various roasting types

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	,139	2	,069	71,770	,000
Within Groups	,006	6	,001		
Total	,145	8			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05		
COFFEETYPE	N	1	2	3
PaR	3	6,2667		
MWR	3		6,3733	
CR	3			6,5667
Sig.		1,000	1,000	1,000

Table A4. ANOVA for titratable acidity of PTF coffee at various roasting types

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	8447,544	2	4223,772	1,442E3	,000
Within Groups	17,569	6	2,928		
Total	8465,113	8			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05			
COFFEETYPE	N	1	2	3	4
MWR	3	1,6548E2			
CR	3		2,2083E2		
PaR	3			2,3705E2	
Sig.		1,000	1,000	1,000	1,000

Table A5. ANOVA for titratable acidity at various coffee types

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	228033,504	3	76011,168	1,927E4	,000
Within Groups	31,556	8	3,945		
Total	228065,060	11			

DUNCAN'S MULTIPLE RANGE TEST TABLE

COFFEETYPE	N	Subset for alpha = 0.05			
		1	2	3	4
MWR	3	1,6548E2			
CR	3		2,2083E2		
PaR	3			2,3705E2	
TC	3				5,2019E2
Sig.		1,000	1,000	1,000	1,000

Table A6. ANOVA for FFA at various coffee types

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3,093	3	1,031	719,262	,000
Within Groups	,011	8	,001		
Total	3,104	11			

DUNCAN'S MULTIPLE RANGE TEST TABLE

COFFEETYPE	N	Subset for alpha = 0.05	
		1	2
MWR	3	2,7033	
CR	3	2,7033	
PaR	3	2,7267	
TC	3		3,8833
Sig.		,489	1,000

Table A7. ANOVA for FFA of powdered PTF coffee at various roasting methods

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	,001	2	,001	1,089	,395
Within Groups	,003	6	,000		
Total	,004	8			

DUNCAN'S MULTIPLE RANGE TEST TABLE

COFFEETYPE	N	Subset for alpha = 0.05
		1
MWR	3	2,7033
CR	3	2,7033
PaR	3	2,7267
Sig.		,262

Table A8. L*,a*,b* values for roasted and raw PTF

DUNCAN'S MULTIPLE RANGE TEST TABLE

L*			
COFFEETYPE	N	Subset for alpha = 0.05	
		1	2
PAN ROASTING	3	18,2933	
COM ROASTING	3	18,3400	
MW ROASTING	3	18,3700	
Raw PTF	3		28,5800
Sig.		,865	1,000

a*			
		Subset for alpha = 0.05	
COFFEETYPE	N	1	2
Raw PTF	3	-4,7900	
COM ROASTING	3		1,1167
MW ROASTING	3		1,1333
PAN ROASTING	3		1,1467
Sig.		1,000	,736

b*			
		Subset for alpha = 0.05	
COFFEETYPE	N	1	2
COM ROASTING	3	1,7733	
MW ROASTING	3	1,8400	
PAN ROASTING	3	1,9100	
Raw PTF	3		4,3400
Sig.		,299	1,000

APPENDIX B

Table B1. ANOVA for Aroma of powdered PTF coffee at various roasting methods

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2,400	2	1,200	,802	,459
Within Groups	40,400	27	1,496		
Total	42,800	29			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
MWR	10	5,60
PaR	10	5,60
CR	10	6,20
Sig.		,310

Table B2. ANOVA for Aroma at various coffee types

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3,075	3	1,025	,425	,737
Within Groups	86,900	36	2,414		
Total	89,975	39			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
TC	10	5,5000
MWR	10	5,6000
PaR	10	5,6000
CR	10	6,2000
Sig.		,367

Table B3. ANOVA for Flavor of powdered PTF coffees at various roasting methods

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2,467	2	1,233	,742	,486
Within Groups	44,900	27	1,663		
Total	47,367	29			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
MWR	10	5,40
PaR	10	5,80
CR	10	6,10
Sig.		,262

Table B4. ANOVA for Flavor at various coffee types

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2,475	3	,825	,351	,788
Within Groups	84,500	36	2,347		
Total	86,975	39			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
MWR	10	5,4000
PaR	10	5,8000
TC	10	5,8000
CR	10	6,1000
Sig.		,360

Table B5. ANOVA for Acidity of powdered PTF coffees at various roasting methods

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5,267	2	2,633	1,265	,298
Within Groups	56,200	27	2,081		
Total	61,467	29			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
MWR	10	5,30
CR	10	6,00
PaR	10	6,30
Sig.		,154

Table B6. ANOVA for Acidity at various coffee types

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8,600	3	2,867	1,232	,312
Within Groups	83,800	36	2,328		
Total	92,400	39			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
TC	10	5,2000
MWR	10	5,3000
CR	10	6,0000
PaR	10	6,3000
Sig.		,149

Table B7. ANOVA for Aftertaste at various coffee types

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,400	3	,133	,050	,985
Within Groups	95,200	36	2,644		
Total	95,600	39			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
MWR	10	5,80
TC	10	5,80
CR	10	6,00
PaR	10	6,00
Sig.		,805

Table B8. ANOVA for Aftertaste at different roasted powdered PTF coffee

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,267	2	,133	,049	,952
Within Groups	73,600	27	2,726		
Total	73,867	29			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
MWR	10	5,80
CR	10	6,00
PaR	10	6,00
Sig.		,801

Table B9. ANOVA for Overall Acceptability of PTF coffees at various roasting conditions

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2,867	2	1,433	,690	,510
Within Groups	56,100	27	2,078		
Total	58,967	29			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
MWR	10	5,60
CR	10	6,20
PaR	10	6,30
Sig.		,315

Table B10. ANOVA for Overall Acceptability at various coffee types

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3,000	3	1,000	,350	,790
Within Groups	103,000	36	2,861		
Total	106,000	39			

DUNCAN'S MULTIPLE RANGE TEST TABLE

		Subset for alpha = 0.05
COFFEETYPE	N	1
MWR	10	5,60
TC	10	5,90
CR	10	6,20
PaR	10	6,30
Sig.		,407