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DETERMINATION OF PROCESSING PROPERTIES OF TURKISH COFFEE

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IN

FOOD ENGINEERING

BY

KEVSER TUBA ÖZKARA

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Determination of Processing Properties of Turkish Coffee

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Supervisor

Prof. Dr. Mustafa BAYRAM

by

Kevser Tuba ÖZKARA

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Kevser Tuba ÖZKARA

ABSTRACT

DETERMINATION OF PROCESSING PROPERTIES OF TURKISH COFFEE

ÖZKARA, Kevser Tuba
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In this study, a Brazil orginated *Coffee robusta* was used to obtain the optimum processing parameters and properties. Green coffee as raw material was analyzed by measuring protein content, fat content, bulk and absolute density, color, moisture content, acidity, soluble solid content, pH and ash content.

In order to determine the processing parameters and techniques; three main operations were tested namely, roasting, milling and cooking. Additionally, in order to determine the effect of the storage time for Turkish coffee quality, a storage test was made. For the roasting operations, microwave (350, 490 and 700 W), infrared (600 and 1200 W) and conventional oven (160, 180, 200 and 220^{o}C) were used. Acidity, pH, moisture content and color were measured after roasting method. The coffee was milled by using hammer and cutter type mills. According to the study, microwave roasting at 350 W for 30 min was determined as the best usable technique commercially. In cooking process, electrical and cupper pots were used as a cooking operation at various temperatures with different water softness degrees. The initial water temperature as 4^{o}C provided the best foam volume and stability for Turkish coffee. It was observed that, the foam volume of coffee which cooked with cupper pot and tap water was higher than the other methods.

The coffee was also stored at refrigeration (4^{o}C) and room (25^{o}C) temperatures for one month. After one month, pH, acidity, color, foam volume and stability were measured. The foam volume increased and foam stability decreased during the storage at refrigeration temperature.

Key words: Turkish coffee, roasting, milling, cooking, storage.

ÖZ

TÜRK KAHVESİNİN İŞLEME ÖZELLİKLERİNİN BELİRLENMESİ

ÖZKARA, Kevser Tuba
Yüksek Lisans Tezi, Gıda Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Mustafa BAYRAM
Ağustos 2012, 158 sayfa

Bu çalışmada, optimum işleme parametrelerini ve özelliklerini belirlemek için Brezilya orijinli *Coffee Robusta* kullanıldı. Hammadde olan yeşil kahvede protein miktarı, yağ miktarı, yığın ve gerçek yoğunluk, renk, nem miktarı, asitlik, çözünebilir kuru madde miktarı, pH ve kül miktarı belirlendi.

İşleme parametreleri ve tekniklerini belirlemek için kavurma, öğütme ve pişirme gibi üç temel işlem test edildi. Ayrıca, kahve kalitesine depolama süresinin etkisini belirlemek için depolama uygulandı. Kavurma işlemi için mikrodalga (350, 490 and 700 W), infrared (600 and 1200 W) ve geleneksel fırın (160, 180, 200 and 220^{o}C) kullanıldı. Kavurma metodundan sonra asitlik, pH, nem miktarı ve renk, kavrulmuş kahvelerde ölçüldü. Çekiçli ve kesici tip öğütücüyle kahve öğütüldü. Bu çalışmaya göre, mikrodalga kavurma için 350 W 30 dakika en iyi ticari kullanım teknik ve değer olarak belirlendi. Pişirme işleminde farklı yumuşaklık derecesinde ve çeşitli sıcaklıklardaki su kullanılarak, elektrikli ve bakır cezve kaynatma ekipmanları kullanıldı. Pişirme işleminde, en iyi köpük hacmi ve stabilitesi, başlangıç su sıcaklığı 4^{o}C olduğu durumda sağlandı. Bakır cezve ve şehir suyu ile pişirilen pişmiş kahvede köpük hacminin diğer metotlardan daha yüksek olduğu gözlemlendi.

Kahve, buzdolabında (4^{o}C) ve oda sıcaklığında (25^{o}C) bir ay depolandı. Bir ay sonra kavrulmuş kahvenin pH, asitlik, renk, köpük hacmi ve stabilitesi ölçüldü. Buzdolabı sıcaklığında bekleyen kahvenin depolama sırasında köpük hacmi artarken, köpük stabilitesi azalmıştır.

Anahtar kelimeler: Türk kahvesi, kavurma, öğütme, pişirme, depolama.

To My Father and Mother

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LIST of SYMBOLS/ABBREVATIONS

A	Arabica
AOAC	Association of Official Analytical Chemists
ANOVA	Analysis of variance
Brix	Soluble solids
CIE	Commission internationale de l'éclairage
IR	Infrared
NMR	Nuclear magnetic resonance
R	Robusta
SPSS	Statistical package for social sciences
TSE	Türk standartları enstitüsü
W	Watt
Min	Minute
w.b	Wet bulb
kg	Kilogram
m	Meter
mL	Milliliter

CHAPTER I

INTRODUCTION

1.1. Definition of Coffee

Coffee is one of the most popular and widely consumed beverages in the world because it has a lot of aroma compounds, which is a very significant factor in food quality (Kumazawa and Masuda, 2003; Farah, 2009). It is a brewed beverage prepared from roasted seeds, commonly called coffee beans, of the coffee plant (http://en.wikipedia.org/wiki/Coffee).

Coffee is the most important food commodity worldwide because of among all commidities the coffee is ranks second after crude oil. Coffee is produced by 60 tropical and subtropical countries extensively, being for some of them the main agricultural export product (Esquivel and Jimenez, 2003).

Recently, epidemiological and clinical studies have been attributing beneficial health effects to this drink, mainly because of its high content of phenolic compounds, which make coffee one of the highest contributors to antioxidant intake in western diets (Farah, 2009). Due to its caffeine content, coffee can have a stimulating effect in humans (http://en.wikipedia.org/wiki/Coffee).

Economic importance of coffee is mainly due to the coffee brew or beverage, an infusion prepared from the roasted and ground beans. Most coffee beverage consumed around the world is produced by the species *Coffea arabica* (Arabica) and *Coffea canephora* (Robusta). The former one is considered to be superior due to its sensory properties (Bertrand et al., 2003).

1.2. Botany of coffee

Coffee is a tropical plant which grows between the latitudes of 25 degrees North and 25 degrees South but requires very specific environmental conditions for commercial cultivation. Temperature, rainfall, sunlight, wind and soils are all important, but requirements vary according to the varieties grown (Clifford and Wilson, 1985).

Originally it grows wild in the tropical highlands on the eastern side of Africa (Bramah and Bramah, 1995). It grows up in the tropical regions. It does not grow up at the regions where the temperature declines under +5 ^{o}C. Some varieties of coffee tree typically grow over 9.144 meter. But, in cultivation, for ease of picking of the coffee berry, the coffee tree is seldom allowed over 2 meters (Baytop, 2001). The coffee crop is a native of Ethiopia and is cultivated over large areas in Brazil, Ethiopia, Kenya and India. The tropical evergreen shrub grows at elevations between 700 and 2000 m above mean sea level at a temperature of 23^{o}C and with an annual rainfall of about 1250 mm (Chandrasekar and Viswanathan, 1999).

There are a lot of species of coffee, only two are principally used (~70 % of world production) by the coffee industry: Coffee arabica and Coffee robusta (Coffee Talk , 2002). The former is more valuable because its beans produce a better tasting beverage, which is therefore more expensive than the robusta coffee (Zambonin et al., 2005; Illy and Viani, 2005).

There are other species like *Coffea excelsa* and *Coffea liberica* but they are of minor interest for the market (Valdenebro et al., 1999).

Indeed, their chemical and organoleptic properties are distinct. Arabica coffee has a finer and pronounced flavour, producing highly appreciated beverages and attaining the highest market prices (2–10 times the price of robusta, depending on the geographical origin). Robusta crops are more resistant to diseases, but the coffee flavour is not so appreciated. In fact, robusta is especially used to increase the body and foam of some coffee beverages (e.g., espresso coffee) and in instant coffee production (Alves et al., 2009)

Coffee belongs to the botanical family Rubiaceae, which has some 500 genera and over 6.000 species. Most are tropical trees and shrubs that grow in the lower storey of forests. Other members of the family include gardenias and plants that yield quinine and other useful substances (Table 1.1), but Coffea is by far the most important member of the family economically (http://www.ico.org/ecology.asp).

Table 1.1. The orijin of coffee (http://www.ico.org/ecology.asp)

Family	Genus	Species (many including:)	Varieties (examples:)
Rubiaceae	Coffea	Arabica	Typica
		Canephora	Robusta
		Liberica	

1.2.1. Arabica *(Coffea arabica)*

Coffea arabica is descended from the original coffee trees discovered in Ethiopia. These kind of coffee which is mild, aromatic and small size is produced from the the trees. On the world market, arabica coffees is sold the highest prices. Usually, the arabica coffee is grown up from 609.6 to 1828.8 meter above sea level, though optimal altitude varies with proximity to the equator. The important factor is that temperatures must remain mild, neither too hot nor too cold, ideally between 15 – 24^{o}C , with about 1524 mm of rainfall a year. The trees are hearty but a heavy frost will kill them. Arabica trees are costly to cultivate because the terrain tends to be steep and access difficult. Also, because the trees are more disease prone than robusta, they require additional care and attention. Arabica trees are self pollinating. The beans are flatter and more elongated than robusta and lower in caffeine (http://www.ncausa.org/i4a/pages/index.cfm?pageid=74)

1.2.2. Robusta *(Coffea canephora)*

Robusta is a lower quality coffee and prices are normally about 30 to 40% less than Arabica. Robusta is used mainly in instant coffee and for blending with Arabicas to add body and crema. Robusta is normally grown in warmer areas at lower elevations unsuited to Arabica, and is considered resistant/tolerant to coffee rust. Robusta is grown at higher elevations (up to nearly 1300 meters above sea level). Vietnam, Brazil and Indonesia are the largest Robusta producing countries. Compared with Arabica, Robusta is generally more vigorous, more productive and less vulnerable to rust (http://www.coffeeasean.org/details.asp?Object=16&news_ID=201281427&ID_Con =6; http://www.fao.org/docrep/008/ae939e/ae939e03.html).

1.2.3. Liberica *(Coffea liberica)* and Excelsa

Liberica and Excelsa are grown mainly in low and hot climate areas. Quality is poor and markets are limited. These coffees are of local importance in a few countries and not of major commercial significance in the international coffee market. They might have some value in breeding programs as a donor of resistance genes to certain diseases (e.g. leaf rust) (http://www.fao.org/docrep/008/ae939e/ae939e03.htm).

Some differences between Arabica and Robusta coffee are given in Table 1.2.

Table 1.2. Differences between Arabica and Robusta coffee (http://www.ico.org/ecology.asp)

	Arabica	Robusta
Date species described	1753	1895
Chromosomes (2n)	44	22
Time from flower to ripecherry	9 months	10-11 months
Yield (kg beans/ha)	1500-3000	2300-4000
Root system	Deep	Shallow
Optimum temperature(yearly average)	15-24° C	24-30° C
Optimal rainfall	1500-2000 mm	2000-3000 mm
Optimum altitude	1000-2000 m	0-700 m
Caffeine content of beans	0.8-1.4%	1.7-4.0%
Shape of bean	Flat	Oval
Typical brew characteristics	Acidity	Bitterness, full

1.2.4. Map of production

The production areas are shown in Figure 1.1.

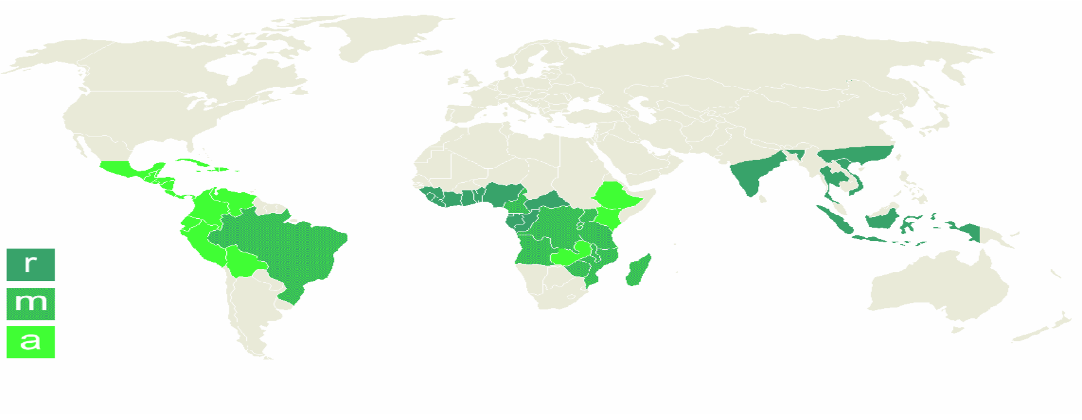

Figure 1.1. The production areas of coffee (http://en.wikipedia.org/wiki/Coffee) r: cultivation of *Coffea robusta.* m: cultivation of *Coffea robusta* and *Coffea arabica*. a: cultivation of *Coffea arabica*.

The annual yield of a medium sized coffee tree is approximately a half or a quarter kilogram of grinded coffee, and a half-kilogram of grinded coffee is obtained from 4000 green coffee beans. On the average it takes five years before a young shrub bears a full harvest and it keeps bearing for fifteen years. Nine months after the blooming its fruits become ready for harvesting. The coffee beans do not mature at the same time and because of this a coffee tree is harvested three or four times a year. On the average 45-90 kilograms of coffee fruits are picked a day. 90 kg of them is equal to 22.5 kg of green coffee beans and 17.5 kg of roasted beans (Güçlü 2002). Coffee growing regions are given in Figure 1.2.

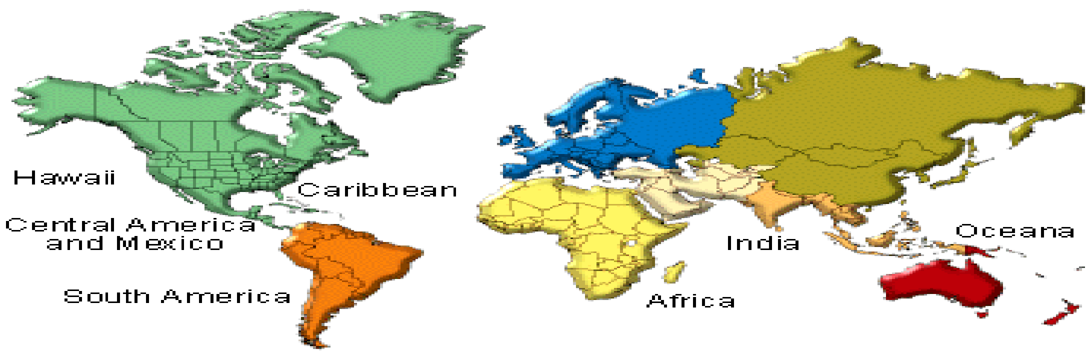

Figure 1.2. World Map of Coffee Growing Regions

(http://www.coffeeresearch.org/coffee/roast.htm)

Coffee producing countries and coffee harvesting times are given in Table 1.3.

Table 1.3. Coffee producing countries and coffee harvesting times (http://www.coffeeresearch.org/coffee/roast.htm)

Coffee Producing Country	Coffee Harvesting Time
Brazil	March-October
Colombia	October-February and April-June
Ecuador	June-October
Guatemala	October-January
Haiti	October-November and February-March
Honduras	October-March
Jamaica	August-September
Kenya	October-December (main) and June-August
Malawi	December-February
Papua New Guinea	April-September
Tanzania	October-December
Uganda	September-December
Venezuela	September-March
Zambia	October-March

The amount of robusta coffee production over the years is given in the Table 1.4.

Table 1.4. The amount of robusta coffee production (http://www.coffeeresearch.org/coffee/roast.htm)

Thousand 60-Kilogram Bags					
Robusta production	2007/08	2008/09	2009/10	2010/11	2011/12
Angola	30	30	30	25	25
Brazil	11.450	12.800	11.800	12.700	14.500
Cameroon	605	560	500	525	500
Ecuador	350	275	260	250	225
Ghana	27	19	30	35	35
Guatemala	10	10	10	10	10
Guinea	250	400	495	225	450
India	3.080	3.050	3.250	3.600	3.325
Indonesia	6.800	8.100	9.000	7.950	6.655
Laos	355	350	390	450	475
Liberia	25	7	2	1	1
Madagascar	525	500	450	500	525
Malaysia	770	975	1.000	1.000	1.100
Mexico	250	250	200	200	200
Philippines	400	300	200	400	400
Tanzania	305	340	300	275	300
Thailand	900	800	900	900	900
Togo	255	185	450	525	550
Uganda	2.100	2.800	2.300	1.900	2.100
Vietnam	17.600	16.500	18.050	18.150	19.925
Total	48.583	50.492	52.377	52.096	54.896

Exporting countries and domestic consumption of coffee is given in the Table 1.5.

Table 1.5. Exporting countries and domestic consumption of coffee (Http://www.ico.org/ecology.asp)

Crop year			2006	2007	2008	2009	2010
Total			35 086 (ton)	37 283 (ton)	38 262 (ton)	39 623 (ton)	40 782 (ton)
Angola	R	Apr-Mar	30	30	30	30	30
Bolivia	A	Apr-Mar	60	60	60	60	60
Brazil	A/R	Apr-Mar	16.331	17.125	17.660	18.390	19.130
Burundi	A	Apr-Mar	2	1	1	1	2
Cameroon	R/A	Oct-Sep	69	69	69	69	69
Congo	R	Jul-Jun	3	3	3	3	3
Costa Rica	(A)	Oct-Sep	324	274	245	229	223
Ethiopia	A	Oct-Sep	2.748	2.894	3.048	3.210	3.383
Ghana	R	Oct-Sep	1	2	2	2	2
Guatemala	A/R	Oct-Sep	300	300	335	320	340
Guinea	R	Oct-Sep	50	50	50	50	50
Haiti	A	Jul-Jun	362	359	359	351	350
Honduras	A	Oct-Sep	230	460	460	460	460
India	R/A	Oct-Sep	1417	1500	1573	1573	1573
Indonesia	R/A	Apr-Mar	2833	3333	3333	3333	3333
Kenya	A	Oct-Sep	50	50	50	50	50
Liberia	R	Oct-Sep	5	5	5	5	5

A: Arabica

R: Robusta

Coffee consumption in importing countries, and over the years are given in the Table 1.6.

Table 1.6. Importing countries and consumption of coffee (http://www.ico.org/ecology.asp)

Importing countries	2007 (60 kg bags)	2008 (60 kg bags)	2009 (60 kg bags)	2010 (60 kg bags)
European Community	40.702,972	40.267,970	39.668,648	40.740,815
Austria	846.816	907.887	885.716	902.854
Belgium	1.103,118	649.931	934.293	870.665
Denmark	794.284	688.344	678.553	862.465
Finland	1.056,903	1.114,922	1.058,406	1.080,424
France	5.627,754	5.151,567	5.676,750	5.903,499
Germany	8.626,681	9.534,508	8.896,933	9.291,959
Greece	1.014,597	978.073	973.876	993.692
Italy	5.820,949	5.892,152	5.806,025	5.781,319
Latvia	180.788	130.850	115.139	88.113
Netherlands	2.292,091	1.323,564	897.812	1.330,651
Poland	1.554,365	1.681,087	2.001,008	1.912,317
Romania	823.573	806.767	774.945	795.875
Spain	3.198,113	3.485,476	3.351,866	3.231,455
Sweden	1.244,306	1.272,455	1.132,893	1.221,449
Japan	7.282,083	7.064,685	7.130,403	7.181,261
Norway	771.422	714.556	715.239	745.699
Tunisian	253.396	317.485	288.727	188.139
Turkey	515.863	483.679	520.850	609.593
USA	21.033,273	21.652,427	21.435,967	21.784,126
Total	71.547,982	71.650,104	70.725,380	72.278,545

1.3. Ecology of coffee

What we call a coffee bean is actually the seeds of a cherry-like fruit. Coffee trees produce berries, called coffee cherries, which are composed of an outer skin, the exocarp or husk. Beneath it is the mesocarp, a thin layer of pulp, followed by a slimy layer called the parenchyma. The beans themselves are covered in an envelope named endocarp, more commonly referred to as ‘‘the parchment”. Inside the parchment, side-by-side lie two beans, each covered separately by yet another layer of thin membrane, the speroderm (Nabais et al., 2008). The layers in a coffee fruit is given in Figure 1.3.

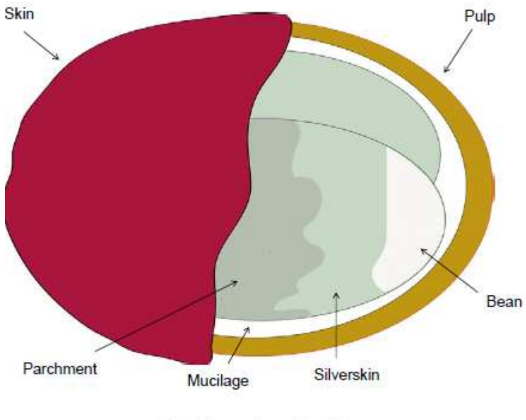

Figure 1.3. Layers in a coffee fruit (Esquivel and Jimenez, 2011)

Shelled and unshelled form the shape of coffee is given in Figure 1.4.

Figure 1.4. Shelled and unshelled form the shape of coffee (http://www.ico.org/ecology.asp; http://en.wikipedia.org/wiki/Coffee)

1.4. Harvesting of coffee

Strip Picked - the entire crop is harvested at one time. The harvest can be done by machine or by hand. In either case, all of the cherries are stripped off of the branch at one time (http://www.ico.org/ecology.asp).

Selectively Picked - only the ripe cherries are harvested and they are picked individually by hand. Pickers rotate among the trees every 8 to 10 days, choosing only the cherries which are at the peak of ripeness. Since this kind of harvest is labour intensive. Therefore, it is more costly and it used primarily to harvest the finer arabica beans. At the end of the day, each worker's harvest is carefully weighed and each picker is paid on the merit of his or her work. The day's harvest is then combined and transported to the processing plant (http://www.ico.org/ecology.asp).

Today the mechanical harvesting machines are not developed enough to substitute for the people, consequently the coffee cherries are picked by hand as they were in the past. To pick only the ripe fruits means to harvest the same tree more than once a year, and this causes some difficulties in the big plantations. To be considered as high quality beans and sold with high prices, the producers bear these difficulties of the handpicked coffee beans. Instead of being picked one by one, by hand, in Brazil the coffee beans are scraped from the branches of the tree. The disadvantage of this method is that the ripe and the unripe beans are processed altogether, and this causes a decline in the quality and the price of the coffee (Heise 2001). Coffee harvesting is shown in Figure 1.5.

Figure 1.5. Coffee harvesting (http://www.coffeeresearch.org/coffee/roast.htm)

1.5. Drying of coffee

Coffee beans must be removed from the fruit and dried before they can be roasted; this can be done in two ways, known as the dry and the wet methods. When the process is completed the unroasted coffee beans are known as green coffee (http://www.ico.org/ecology.asp).

Production of green tradable coffee beans renders thus several byproducts depending on the processing method followed. The main byproduct of the dry processing is composed by the skin, pulp, mucilage and parchment, all together in a single fraction (coffee husks) (Prata and Oliveira, 2007).

The coffee fruit comprises the pulp which houses the parchments, surrounded by a layer of mucilage. The fruits of the arabica variety undergo green or wet processing, in which the pulp is removed from the ripe fruit by a pulping process, the mucilage is removed by demucilaging and washing processes and the parchments are dried on the estate where they are grown. The robusta fruits are processed dry by firrst drying the ripe fruits into cherry on the estate. The dried parchments and cherry are further processed at the curing centres by hulling, sorting and grading (Chandrasekar and Viswanathan, 1999). Cross-section of a coffee berry is given in Figure 1.6.

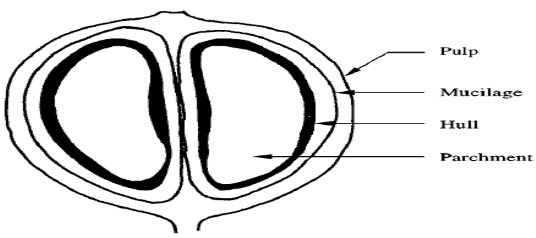

Figure 1.6. Cross-section of a coffee berry (Chandrasekar and Viswanathan, 1999)

Coffee is dried to enable storage and transport. Due to the following roasting process the humidity of the dried coffee is required to be around 11%. This work focusses on the drying of wet processed coffee. In many countries coffee is dried in rotary dryers due to the two main advantages compared to sun drying: higher plant capacities and independency of climatic conditions. For the optimization of the drying process a better understanding of the process is essential. Therefore, drying curves and temperature evolution as well as coffee properties and transport coefficients need to be investigated (Burmester and Eggers, 2010).

As the cherries dry, they are raked or turned by hand to ensure even drying. It may take up to 4 weeks before the cherries are dried to the 12.5% maximum moisture content, depending on the weather conditions. On larger plantations, machine-drying is sometimes used to speed up the process after the coffee has been pre-dried in the sun for a few days (http://www.ico.org/ecology.asp).

Coffee that has been overdried will become brittle and produce too many broken beans during hulling (broken beans are considered defective beans). Coffee that has not been dried sufficiently will be too moist and prone to rapid deterioration caused by the attack of fungi and bacteria (http://www.ico.org/ecology.asp). Drying of the coffee is as shown in Figure 1.7.

Figure 1.7. Drying of coffee (http://www.ico.org/ecology.asp)

1.5.1. Wet processing

The coffee cherry are wet processed after harvesting process. The wet method is used with handpicked, fully ripe beans. These are the washed beans carried by specialty stores (Perry, 2001). The pulp rip out from the coffee bean. After that, the beans are seperated each other with floating process for quality degree of coffee (Ghosh and Gacanja, 1970). Wet method of coffee processing is shown in Figure 1.8.

Figure 1.8. Wet method of coffee processing
(http://www.ncausa.org/i4a/pages/index.cfm?pageid=74)

After separation, the beans are transported to large and water-filled fermentation tanks. The purpose of this process is to remove the slick layer of mucilage (called the parenchyma) that is still attached to the parchment; while resting in the tanks, naturally occurring enzymes will cause this layer to dissolve.

When fermentation is complete the beans will feel rough, rather than slick, to the touch. At that precise moment, the beans are rinsed by being sent through additional water channels. They are then ready for drying. beans must now be dried to approximately 11 percent moisture to properly prepare them for storage. It can be sun dried by spreading them on drying tables or floors, where they are turned regularly is shown in Figure 1.9., or they can be machine dried in large tumblers (http://www.ncausa.org/i4a/pages/index.cfm?pageid=74).

Figure 1.9. Drying tables of coffee (http://www.ico.org/ecology.asp)

Wet processing, in contrast, potentially allows recovery of the skin and pulp in one fraction (43.2% w/w from the whole fruit), mucilage and soluble sugars in a second fraction when fermentation is not used (11.8% w/w) and, finally, the parchment (6.1% w/w) (Bressani, 1978).

As a result of processing of 250 kg fresh cherry which is processed with dry and wet method is obtained from 45 kg dry coffee.

Roasting causes on average a 16 percent loss in weight and an increase in bean volume of 50 to 80 percent. The moisture content of fresh cherry is 50 percent. The moisture content of green coffee is 12.5 percent and after roasting, the moisture content is below 7 percent, depending on humidity (http://www.ico.org/ecology.asp). After drying, they are patiently graded by size, shape, and quality by men and women, and are shipped to roasters around the world (Perry, 2001).

1.6. Roasting of coffee

The quality of coffee used for beverages is strictly related to the chemical composition of the roasted beans, which is affected by the composition of the green beans and post-harvesting processing conditions (drying, storage, roasting and grinding). The criteria commonly used to evaluate the quality of coffee beans include bean size, colour, shape, roast potential, processing method, crop year, flavour or cup quality and presence of defects (Banks et al., 1999).

Coffee roasting is an unitary operation of considerable importance to developing the specific organoleptic properties (flavor, aroma and color) which underlie the quality of coffee and guarantee a satisfactory beverage (Hernandez et al., 2008). During this process, coffee beans are subjected to high temperatures (in the case of an Italian-style roasting it ranges between 200 and 240^{o}C bean temperature) for different times depending on the desired characteristics of the fınal product (Pittia et al., 2001).

Coffee beans are roasted using hot combustion gases or air at temperatures above 200 ^{o}C to develop the characteristic flavors, colors, and aromas (Clarke and Macrae, 1987). Carbon dioxide is the major gas produced during roasting. According to Clarke and Macrae (1985), 87% of gases released from roasted coffee are carbon dioxide.

The process can be divided into two phases. The first phase corresponds to the drying (bean's temperature below 160 ^{o}C) and the second phase is the roasting (bean's temperature between 160 and 260 ^{o}C). In this last phase, pyrolytic reactions start at 190 ^{o}C causing oxidation, reduction, hydrolysis, polymerisation, decarboxilation and many other chemical changes, leading to the formation of substances essential to give among other, the sensory qualities of the coffee. These moisture loss and chemical reactions are accompanied by important changes (color, volume, mass, form, bean pop, pH, density, volatile components) and generate CO^2, of which a part escapes and other part is retained in the cells of the beans. After this second phase, the beans must be rapidly cooled to stop the reactions (using water or air as cooling agent) and to prevent an excessive roast which alter the quality of the product (Hernandez et al., 2007; Sıevetz and Desrosier, 1979).

The roasting conditions also give rise to significant changes in the textural properties of the coffee bean. In fact, during this process, beans lose their strength and toughness and become progressively more crumbly and brittle, which are typical characteristics of the roasted product. On the other hand the reaching of a certain degree of brittleness is very important for the grinding to which coffee beans have to be subjected to before brewing. The uniformity of the product of the grinding process depends on various factors including the brittleness of the roasted coffee bean and it affects the extraction of soluble solids to obtain the coffee brew (Pittia et al., 2001).

The first stage is endothermic. The green beans are slowly dried to become a yellow color and the beans begin to smell like toast or popcorn. The second step, often called the first crack, occurs at approximately 205 °C (400 °F) in which the bean doubles in size, becomes a light brown color, and experiences a weight loss of approximately 5%. In the next step the temperature rises from 205 °C to approximately 220 °C, the color changes from light brown to medium brown , and a weight loss of approximately 13% occurs. The second step is followed by a short endothermic period which is followed by another exothermic step called the second crack. This second pyrolysis occurs between 225-230°C, and the roast color is defined as medium-dark brown. The second pop is much quicker sounding and the beans take on an oily sheen (http://www.coffeeresearch.org/coffee/roast.html).

From 170-200°C the sugars in coffee begin to caramelize. From tasting pure sugar versus its caramelized component it is evident that uncaramelized sugar is much sweeter. The dark color of coffee is directly related to the caramelization of the sucrose in coffee. Therefore, to maximize sweetness you want to minimize the caramelization of sucrose, yet you do not want to roast too lightly or bitter tasting compounds will not thermally degrade (http://www.coffeeresearch.org/coffee/roast.html).

Too much heat and the beans are roasted too dark and too much *caffeol* is burnt; not enough and the *caffeol* is not precipitated. In industrial quantities, the process is carefully controlled, but in smaller quantities, it is down to individual judgement. The higher the roast, the more uniform the resulting flavour. (http://www.ico.org/ecology.asp)

During the roasting process, the beans volume increase of up to 100% because of it is depending on the set values for roasting conditions namely, roasting temperature and time. Lower temperatures coupled to longer times of roasting will lead to smaller increases in the beans volume. (Mellmann, 2001).

1.6.1. Roasting method of coffee

When the coffee is starting to roasting, heat transfer occurs and then achieved by a number of mechanisms. But generally, hot combustion gases is used in industrial. Degree of roasting can be determined with time and temperature. For light roast coffee, 195 ^{o}C and for dark roasted coffee 220^{o}C is used. The time of the roasting change from 2 min. to more than 25 min. After that, the coffee which is finished the roasting,is cooled quickly with not only water but also air (Goodman et al., 2011).

Applications of commercial coffee roasting is a good example for such operations, since initial drying phase of the coffee beans occurs in roasting, then the pyrolytic reactions of the coffee beans while being during mixed. Traditional roaster has a horizontal revolving cylindir, with bars mounted in the inner wall for the mixing of the beans. heat is applied to the turning bed of beans which means hot airflow. Dehydration will takes place during heating of beans and its temperature will increase until onset of exothermic pyrolysis reactions that characterizes roasting (Clarke, 1987a).

It was demonstrated that, during roasting of coffee in a conventional roaster, due to the increase in beans volume (and consequently in the filling degree) and changes in their physical properties, the flow regime of the coffee beans in the transversal section will be affected. Thus, the intensity of the mixing of beans and the heat transfer to the beans will be also affected. The recommended flow regimes for conventional roasting of coffee are those presenting the best performance in the transversal mixing of the beans, i.e., rolling and cascading-type of motion. (Cristo et al., 2006)

The Conventional roasting is conducted in a rotating cylinder with internal paddles for mixing and tumbling beans, hot air blast assisted by centrifugal force carries the beans to the periphery; they then fall back to the center. Other coffee roasters currently used for largescale roasting consist of fluidized bed and spouted bed roasters. Spouting bed technology increases the heat transfer but roasting can be inhomogeneous (Eggers and Pietsch, 2001).

Rotating drum roasters are the most commonly employed equipments by the roasting industry for batch or continuous processes Among the others kind of roasters fluidised bed and spouting bed roasting facilitate roasting for short time 62 periods with low gas temperatures. The higher gas velocities in the roasting processes fluidized bed and spouted bed lead to a better heat transfer. The spouted bed needs less gas (energy consumption), 64 but may lead to less homogeneous roasting result than fluidized bed roasting. (Eggers and Pietsch, 2001).

The traditional, convective roasting is more commonly applied than microwaving of coffee. Microwave heating differs from conventional treatment because it is accomplished by means of electromagnetic waves, which penetrate deeply and heat rapidly (Schlegel, 1992). These waves have lengths between radio and infrared waves on the electromagnetic spectrum (Giese, 1992).

These methods differ fundamentally in the direction of heat transfer within the bean. Thus, in microwaving, the temperature 160 of the core of the bean is higher than that of its surface, whereas the opposite occurs in convective (Budryn and Nebesny, 2006).

Infrared (IR) heating offers several advantages over conventional heating in terms of heat transfer efficiency, compactness of equipment, and quality of the products (Kumar et al., 2009). Infrared (IR) radiation is an energy in the form of electromagnetic wave and is more rapid in heat transfer than convection and conduction mechanisms. IR heating has been found to be more effective compared to conventional heating (Yang et al., 2010). Besides shortening the duration of roasting, infrared roasted products have been reported to have superior sensory and chemical qualities compared to conventional roasting.

1.6.2. Coffee roast and characteristics

The degree of roasting is usually monitored through ground coffee color value from light to dark (Strezov and Evans, 2005). During the roasting process of the green coffee beans, the aroma compounds are formed by a number of complex pyrolytic reactions, while different degrees of roasting (light, medium, dark) produce various aroma profiles (Mondello et al., 2005). Average values per roasting degree were 13%, 15% and 17%, corresponding to light, medium and dark roasts, respectively (Vasconcelos et al., 2007).

As the beans roast, distinct stages of appearance and flavor occur. Due to their longer roasting times and greater loss of soluble oils, darker roasts have less caffeine than the lighter varieties. The roasting stages can be referred to as 'light or pale roast', 'medium, city, or American roast', 'full, high, or Viennese roast' and 'espresso or Italian roast'. Light roast is the roast, which is typically used for canned or institutional coffee. It is also used for delicately flavoured beans. The beans have a dry, cinnamon coloured surface and often brewed as a morning coffee and served with milk. Medium roast is the all-purpose roast. The beans have a medium-brown coloured dry surface. Full roast is the roast with the taste, which strikes an even balance between sweetness and sharpness. The beans are chestnut brown coloured and show patches of oil. Espresso roast is the darkest roast. The beans are almost black in colour and have a shiny, oily surface. Its pungent flavour is a favourite of espresso lovers (Perry, 2001). Degrees of roasting and properties are given in Table 1.7.

When the temperature of roasting is increased, the coffee beans is darker. For the darker roasting coffee, roasting time change from 90s to 40 min. The roasting time not only affect the reactions but also affect the aroma compounds. When the coffee roasting time decreased, bitterness taste occurs and aroma compounds of coffee not occurs because of all pyrolytic reactions can not be completed (Buffo and Cardelli-Freire, 2004).

Table 1.7. Degrees of roasting and properties (http://www.ncausa.org/i4a/pages/index.cfm?pageid=74;http://www.coffeeresearch.org/coffee/roast.htm)

Roast Degree	Characteristics
Light	Light brown to cinnamon color Low body and light acidity. The beans are dry. There will be no oil on the surface of these beans, This roast is too light and does not allow the coffee to develop to its full potential.
Medium – Light	Medium light brown color. The acidity brightens and body increases slightly. The bean is still dry.
Medium	Medium brown color. The acidity continues to increase and the body becomes more potent. The bean is mostly dry. a stronger flavor, and a non-oily surface.
Medium – Dark	Rich, dark color with some oil on the surface and with a slight bittersweet aftertaste. Very small droplets of oil appear on surface. The acidity is slowly diminished and body is most potent. This is the ideal roast for a well blended espresso.
Dark	Deep brownish/black color. The darker the roast, the less acidity will be found in the coffee beverage. The bean has spots of oil or is completely oily. Subtle nuances are diminished. Flavor decreases, while body dominates.
Very Dark	Black surface covered with oil. All subtle nuances are gone, aroma is minor, and body is thin. This roast is characteristic of American espresso.

1.7. Grinding of coffee beans

Nowadays, coffee can be bought roasted and ground to suit the method of brewing, but there will always be people who prefer to grind their own (Bramah, 1995).

There are basically three types of grinders, ‘the mortar and pestle’, ‘the hand mill’, and ‘the electric grinder’. The beans are grinded by feeding into the top of the box. A funnel or slotted screw drops the beans between two corrugated steel discs, one stationary, one rotated by a crank. When the crank is turned the beans are crushed between these discs and fall into a drawer at the bottom of the grinder. The fineness of the grind is determined by adjusting the space between the discs (Perry, 2001).

Electric grinders are used with the ease of handling. They work much like kitchen blenders. With a central stainless steel blade rotating at high speed, they chop the beans into little pieces. The length of time the blade is run determines the grind's fineness. There is one disadvantage that is the grinder's tendency to overheat the beans, so that the flavour is lavished on the air (Başarır, 2005).

1.8. Turkish Coffee

Yahya Kemal who was the Turkish poet of 20th century claimed that coffee has gained its special culture in Turkey. A few occasional visits to Turkey would be sufficient to realize that case. Not just a drink of coffee for the Turks, but it has own history, associations, and rituals. Moerover, it has special rules of when and how to drink it and an interesting tradition: reading of the coffee grinds remained at the bottom of the traditional coffee cup by the fortune teller (http://www.turkish-coffee.org/make_turkish_coffee.htm).

1.9. History of Turkish coffee

Coffee was introduced by Turkish people about 16th century. After a short time, beans of Coffee Arabica was introduced to the Ottoman capital city, Istanbul by a governor of Yemen leading to teeming of the city with coffeehouses. Through the medium of Ottomans, Venice, London and Paris met the coffee as "Turkish coffee" respectively in a century. However some western countries know the Turkish coffee as Greek coffee via the Greeks.

In a very short time coffee had been so popular that coffeehouses and small special shops were opened. In Istanbul there is a street, where the Egyptian spice bazaar is located, named as 'Tahmis' which is the name of coffee roasting at the same time. This name has been come from the so many coffee shops in this street many years ago (http://www.turkish-coffee.org/turkish_coffee.htm).

1.10. Equipment to make Turkish coffee

Generally, Turkish coffee is prepared by using a small pot with narrow neck which is called ‘cezve’ in Turkish, a teaspoon and a heating instrument. The raw materials for Turkish coffee are consist of very finely ground coffee, cold water and sugar it is desired. The cooked hot coffee is served in a demitasse. Traditional cups have no handles whereas some modern cups have. Coffee is generally drunk by handling cup with fingertips.

The pot is commonly made of copper, although several metals such as aluminium with a non-stick cover can be also used. It also has an applicable handling. The size of the pot is chosen to be close to the total volume of the cups to be prepared, since using too large a pot causes much of the foam to stick to the inside of it. The teaspoon is used for adding sugar and coffee and stirring the coffee. The size of teaspoons in some countries are generally larger than the teaspoons in countries where Turkish coffee is common: The dipping side of these teaspoons are nearly about 1 cm (0.4 inches) long and 0.5 cm (0.2 inches) wide.

1.11. Preperation of Turkish coffee

Turkish coffee is a method of preparation, not a kind of coffee. Therefore, there is no special type of bean. Beans for Turkish coffee are ground or pounded to the finest possible powder; finer than for any other way of preparation. 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 flavour with time (http://en.wikipedia.org/wiki/Coffee).

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;), *orta şekerli* (medium sugar; one level teaspoon), and *çok şekerli* (a lot of sugar; one and a half or two level teaspoons) (http://en.wikipedia.org/wiki/Coffee).

The water which used in to make coffee is very important to the quality of cooked coffee. Filtered or bottled water should be use because ıf tap water is used the taste of coffee is not good or imparts a strong odor or taste, such as chlorine. If tap water is used, it is let run a few seconds before filling the coffee pot. Distilled or softened water is not used. Cold water should be used in order to maxsimize foam volume (http://www.ncausa.org/i4a/pages/index.cfm?pageid=74).

1.11.1. Cooking of coffee with pot

Cold water is poured into coffee pot (Figure 1.10). One cup cold water should be used for each cup of cooked coffee and an extra half of water is added ‘for the pot’.After then a teaspoonful of the ground Turkish coffee is added per cup of water in the pot while the water is cold and the water and coffee are stirred.The pot should not be filled too much .If adding sugar is needed ,this is time to do it. The pot is heated slowly as it is possible. The slower the heat the better it is. Make sure it is watched to prevent overflowing when the coffee is boiled. When the it boils,some (not all) of the coffee is poured equally between the cups filling each cup about a quarter to a third of the way in order to get a fair share of the foam forming on the top of the pot, without which coffee loses much of its taste.The heating of the rest coffee is continued until coffee boils again (it should be very short now that it has already boiled).Then the rest of the coffee is distributed between the cups.

Since there is no filtering of coffee at any time during this process, you should wait for a few minutes before drinking your delicious Turkish coffee while the coffee grounds settle at the bottom of the cup (http://www.turkish-coffee.org/make_turkish_coffee.htm).

Figure 1.10. Coffee pot (Başarır, 2005)

A well-prepared Turkish coffee has a 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 flavour, 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/Coffee).

1.11.2. Cooking of coffee with electrical pot

In 2002, the same manufacturer launched a new product brewing Turkish coffee. The product was ‘electric ibrik’ (Figure 1.11). It consists of a monoblock water reservoir with the spout having a capacity up to four cups that is 0.4 litres, maximum water level mark inside the reservoir, a concealed heating element, a handle with on/off switch, a hanging ring and an electric cord. It also has a security thermostat avoiding operating without water. Coffee, sugar and the water are put in the reservoir and the switch is turned on. When the water starts boiling, the switch is turned off to stop boiling, and the coffee is ready. The maximum brewing time is two minutes. The coffee brewing process of ‘electric ibrik’ is similar to the traditional Turkish coffee brewing method. The product is also similar with ibrik in shape. The only difference is the source of energy to heat the water. The heating element is hidden therefore it is safe to use, and its advertisement attributing to the plastic Turkish coffee makers mentions that metal spoons can be used without the risk of electric shock (Başarır, 2005).

Figure 1.11. Electrical pot (Başarır, 2005).

1.13. The aim of the study

In the literature, there is no reseach on its properties and processing parameters. Therefore, technologically there is a big gap on this food product. The purpose of this thesis was to determine the properties and processing parameters of Turkish coffee.

This thesis is important for culture, technology, science and economy.

CHAPTER II

MATERIALS AND METHODS

2.1. Materials

In this study, a Brazil originated *Coffee robusta* was used which was obtained from a local coffee producer.

2.2. Experimental Set-up

In this study, physical and chemical characteristics of green coffee such as moisture content, color, protein, bulk density, absolute density, fat content, ash content, pH, soluble solid and acidity were determined (Figure 2.1).

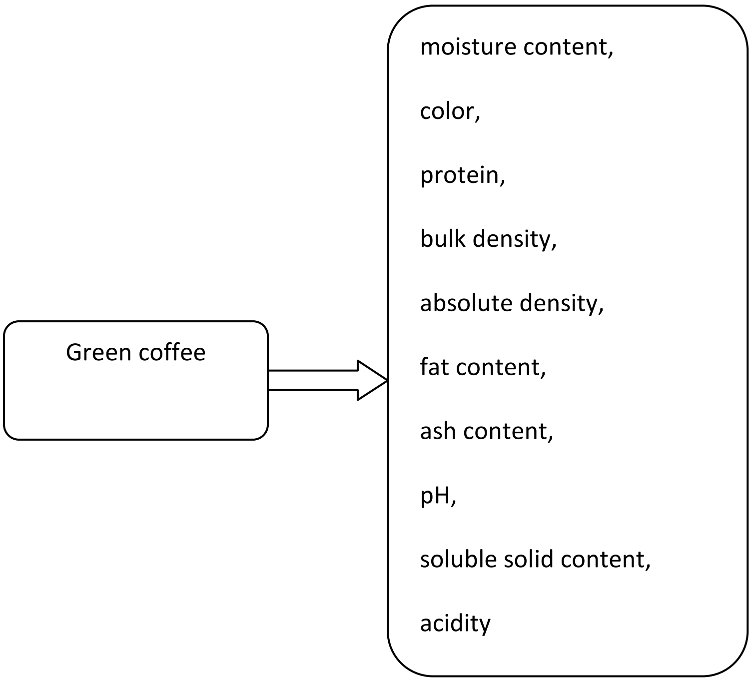

Figure 2.1. The parameters of green coffee

Green coffee was roasted with the infrared, microwave and conventional oven roasting at different powers, temperatures and time. After each roasting process, soluble solid content, pH, color, acidity and moisture content were determined. Roasted coffees were grinded with the hammer and cutter type mills. For each type of grinded coffees angle of repose, bulk density, ash content and color were measured. The most suitable grinding and roasting methods for coffee were determined. Also, the properties of water for to determine proper cooking properties were determined by measuring foam stability, soluble solid content and foam volume. In cooking process, different hardness having water and different water temperatures (4, 25, 40 and 97^{o}C) were used. Electrical pot and cupper pot was used for cooking the coffee which initial water temperature different. After these steps, the selected coffee was kept in refrigerator (4^{o}C) and room temperature (25^{o}C) to determine storage stabilty by measuring pH, acidity, foam stability, foam volume and color. The experimental set up was shown in Figure 2.2.

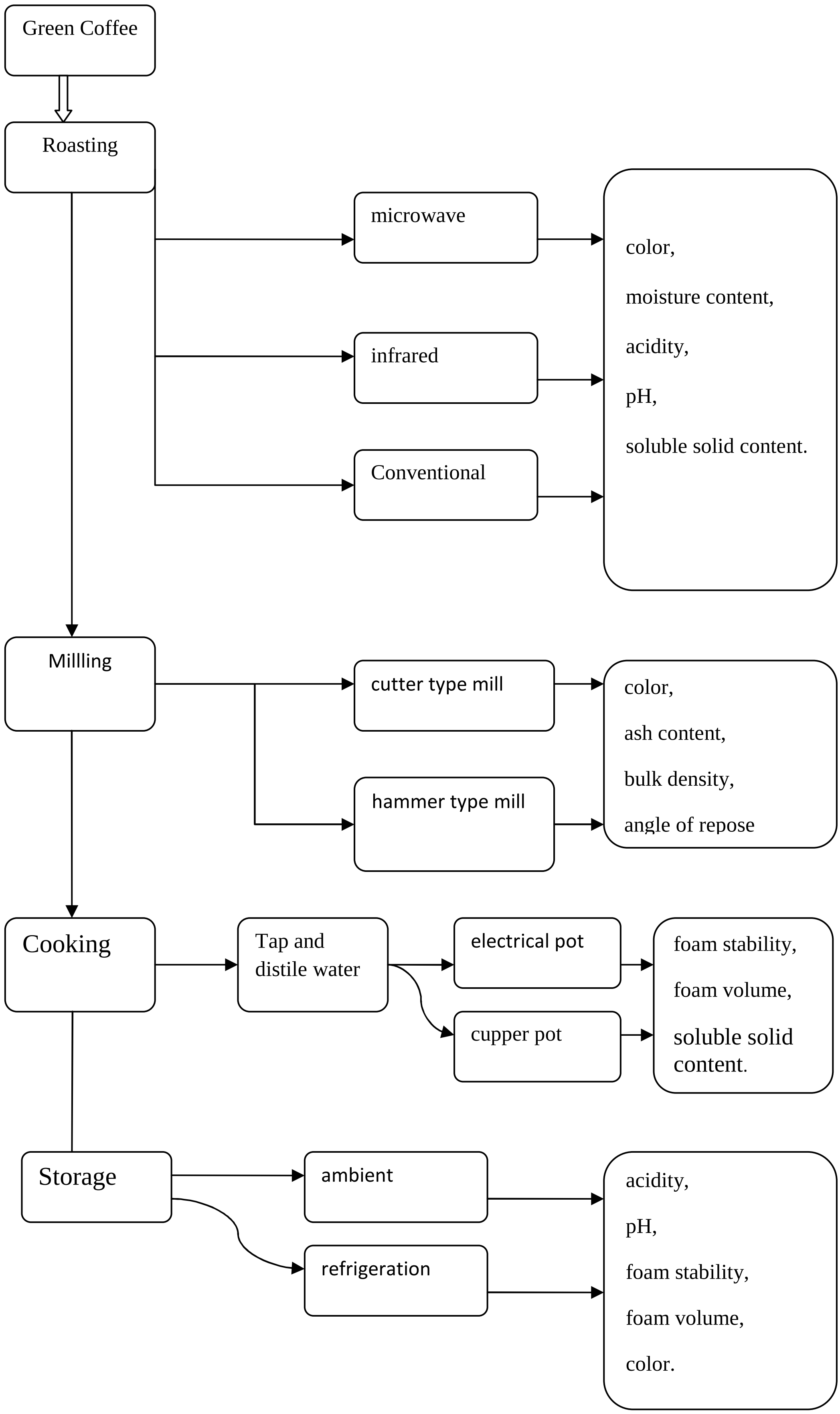

Figure 2.2. Experimental set-up

2.3. Methods

2.3.1. Determination of color of coffee

The color of the coffee samples were measured at D65 and C10^o with Hunter Lab Colorimeter (Colorflex, USA). Before each of the color measurement, white standard tile was used to calibrate colorimeter (L= 93.01, a=-1.11, b=1.30). In the Hunter scale, CIE L* measures lightness and various from 100 for perfect white to 0 black, approximately as the eye could evaluate it. The chromatically (CIE a* and CIE b* values) gives understable designation of color as follows; “CIE a*” measures redness when positive, gray when zero and greenness when negative. “CIE b*” measures yellowness when positive, gray when zero and blueness when negative. CIE YI (yellowness index) visually; yellowness associated with scorching, soiling, and general product degradation by light chemical exposure, and processing. Yellowness indices are used chiefly to measure these types of degradation.

2.3.2. Determination of protein content

Kjeldahl method was used to determine the protein contents of coffee samples (Nagao et al., 2007). A sample between 0.8-1g was weighed and put in Kjeldahl tube. Seven grams potassium sulfate and 12 ml (95%) sulfuric acid was added into the tube. After copper sulfate was added to catalyze, a pre-burning operation was conducted in fume hood at 400^{o}C for 40 min. After the liquid in tube turned green, distillation was made with Kjeldahl protein device (FOSS, Kjeltec TM 2200 mode, Sweden). After these steps, the titration of sample was conducted by using 0.1N of HCl.

2.3.3. Determination of pH

The pH was measured at 20^{o}C using a pH-meter (Hana pH 211, Microprocessor pH meter, Portugal). To determine the pH of coffee, 3 g coffee powder was stirred with 50 mL hot water and the mixture was left to cool till 20^{o}C. The pH of the coffee sample was measured by using pH meter (Manonmani and Murthy, 2009) .

2.3.4. Determination of moisture content of coffee

The moisture content of coffee was measured at 105±2°C using oven method (TS ISO 11294) (TS 2314). After the coffee was ground, 2-3 g was placed in a sample pot. It was kept in 105°C oven until constant weigh, and then it was taken to desiccators to cool it to room temperature for the weighting.

2.3.5. Determination of ash content

The ash content of roasted coffee was measured at 800 °C using AOAC method (AOAC, 1990). 2-3 g of grounded coffee sample was put in a crucible and it was burned at 800 °C until constant weigh. The crucibles taken out of the oven was cooled in desiccators to room temperature for the weighting.

2.3.6. Determination of absolute density

The absolute density of green coffee beans was measured using modified picnometer method. 500 ml graduated cylinder was taken and water which volume was known was put. Then the sample which weight was known was put to cylinder. The increase of volume was observed and the increase of volume was noted. After that, the coffees' weight was divided to the coffee's volume to find the absolute density.

Absolute density (g/mL) = weight (g) / unit volume (mL) (2. 1)

2.3.7. Determination of acidity

The acidity of roasted coffee was measured using AOAC method (AOAC, 1990). Fistly, 10 g sample was prepared in an erlenmeyer flask and 75 mL of 80% ethyl alcohol was added. The erlenmeyer flask was closed, then let stand 16 hr by shaking occasionally. After that the sample was filtered and transferred into 10 ml of beaker. Then it was diluted to 100 mL with H_2O and then titration was made with 0.1N alkali (NaOH), using phenolphthalein. The result was expressed as mL of 0.1N alkali required to neutralize acidity of 100 g sample (Ramalakshmi et al., 2007).

2.3.8. Determination of soluble solid content

The soluble solid content of roasted coffee was measured using a refractometer (PTR 46X, Index Instrument Ltd., England). Soluble solid content of the powdered coffee samples was measured by refluxing coffee powder (2 g) with hot water (200 mL) for

1 h and made up to 500 mL. Fifty millimeter(50mL) of the sample was used for soluble solid content by using the refractometer.

The soluble solid of cooked coffee was also determined with same procedure.

2.3.9. Determination of bulk density

Bulk density is defined as the weight per unit volume of material. Graduated cylinder was used for measure the bulk density. The result was found by using Eq. 2. 2.

$$\text{Bulk density (g/mL)} = \text{weight (g)} / \text{unit volume (mL)} \qquad (2.\ 2)$$

2.3.10. Determination of fat content

The fat content of green coffee beans was determined by extracting the coffee sample by using soxhlet apparatus using hexane as solvent (Manonmani and Murthy, 2009). The sample was put in a cartridge and the glass was weighed. Hexane was added till it reaches to the half of glass and it was placed in the solvent extract device (VELP, Scientific, SER148, Europe). After 30 minutes of immersion, 20 min of washing and 15 min recover processes was completed, the glass was taken out of the machine and it was placed in desiccators to cool. The cooled glass was weighed.

2.3.11. Determination of angle of repose

The angle of repose is the minimum angle at which any piled-up bulky or loose material will stand without falling downhill. A special instrument is used for obtain angle of repose of coffee. For determination of this property, a box with open sides at the top and bottom is placed on a surface. The angle of repose is determined by filling the box with sample and lifting up the box gradually. Instrument was translated to the left for the determined first fallen angle (Bayram and Göğüş, 2008).

2.3.12. Determination of foam volume

Foam volumes were measured immediately after the cooking using a 100 mL graduated cylinder (Cid et al., 2007). The coffee which has been cooked was poured into the graduated cylinder and the first foam volume was noted by reading from the cylinder.

2.3.13. Determination of foam stability

The foam stability (FS) was defined as the time (in seconds) that the liquid phase below the cream layer took to appear during cooling at room temperature, using a 50 mL beaker (Numes and Coimbra, 1998). The coffee which has been prepared was poured into a beaker and kept till it cools to the room temperature.

2.3.14. Roasting of coffee samples

Microwave, infrared heating and conventional oven were used to the roast the coffee beans at different temperatures and/or powers.

In roasting with microwave, 700, 490 and 350W powers and 10, 20 and 30 minutes of roasting times were applied for each power. This process was carried out in a programmable 2450 MHz microwave oven with maximum household type microwave oven (Arçelik, ARMD580, Turkey). In each batch, 100 g sample was used

In roasting with infrared method, 600 and 1200 W of the powers were applied . This process was carried out in an infrared heater with maximum 1200 W output power, household type (ISIMATİK 507, Turkey).

In the process of roasting with conventional oven, 160, 180, 200 and 220°C temperatures were applied and time was determined at each time. This process was carried out in a programmable oven with maximum 1400W output power, household type oven (Arçelik, ARMD580, Turkey).

After each treatment, color, moisture content, acidity, pH and soluble solid content were measured.

2.3.15. Milling of coffee samples

The powder size of roasted coffee is very important for Turkish coffee quality and acceptibility. Therefore, firstly commercial coffee powder size obtained from the local markets was determined. Then, two alternative mills were used namely cutter type (Sinbo, SCM-2914, Turkey) and hammer type (Brook Crompton, 2000 series, England).

2.3.16. Cooking of coffee samples

In this step, a constant traditional Turkish preparation way (The amount of water necessary can be measured using the cups. For each cup, between one and two heaped teaspoons of coffee and no sugar was used.) and methods (electrical and traditional cupper pot) were studied. In order to determine the effect of water temperature, water, at the different initial temperature was used such as chilled (4°C), 25°C, warm (40°C) and boiling water (97°C). Additionally,tap and distilled water were used to determine the effect of hardness of water on the foam stability and volume. In order to determine the effect of the commercially used electrical heater (Sinbo, SCM-2908, Turkey) and cupper pot, the both were tested based on the soluble solid content, foam stability and volume.

2.3.17. Storage stability

The powder coffee was stored in open and closed form at ambient (25°C) and refrigeration (4°C) conditions. Acidity, pH, foam stability and foam volume, color were determined.

2.4. Statistical analysis

ANOVA was performed for data to determine significant differences (P=0.05). Duncan Post Hoc test was carried out. The measurements were duplicated.

CHAPTER III

RESULT AND DISCUSSION

3.1. Properties of Raw Material

In this study, *Coffee robusta* was used. The Brazilian origin green coffee was obtained from Gaziantep. Table 3.1 shows the measured properties of green coffee as intack and ground kernels used in the experiments.

Table 3.1. The properties of green coffee used in the experiments

	Properties	Values
Grain (Intack form)	CIE L*	0.18
	CIE a*	3.54
	CIE b*	21.52
	CIE YI	60.62
	Absolute density (g/mL)	0.29
Powder (Ground form)	CIE L*	4.74
	CIE a*	1.91
	CIE b*	9.31
	CIE YI	5.27
	Moisture content (%, w.b.)	7.16
	Ph	5.82
	Protein (%, d.b.)	14.26
	Bulk density (g/mL)	0.54
	Soluble solid content (^{o}Brix)	0.05
	Acidity (quinic acid)	3.95
	Fat content (%, d.b.)	8.97
	Ash (%, d.b.)	2.75

The moisture content was also observed to change between 5.52 % and 7.38 % in coffee beans (Mazzafera, 1999). In the study of Murthy and Manonmani, (2008) it has been notified that the moisture content amount was 13-14 % in monsooned coffee and 10-12 % in normal coffee. They found that, it was found that high moisture caused the flavor components come off.

In the present study, the fat content of green coffee was found as 8.97 %. According to an earlier report, the fat content of green coffee beans is in the range of 9-16 % (Speer and Kölling-speer, 2001). It has been clarified that during the roasting process, there is a little change in the lipid acid concentration (Vitzthum, 1976; Casal et al., 1997; Speer and Kölling-Speer, 2006). It has been observed by Casal et al. (2005) that the amount of lipid in Arabica coffee is 13.8 and 13.6 % in Robusta, protein value is 12.8 % in Arabica and 8.3 % in Robusta. Respectively, moisture content value is 8.5 % in Arabica and 8.3 % in Robusta (Trugo, 1985; Pittia et al, 2001).

The coffee which used in the experiment has higher protein content (14.26 %) compared to the other studies 11 % (Clarke, 1987) and 8.3 % (Casal et al, 2005). The protein content is directly related to the quality of coffee. It has been found by Ramalakshmi et al., (2008) that in low-grade coffee beans the protein content was 49.71 mg/m. In Clarke's (1987) study, the protein content, lipid content and acidity were 11, 16 and 6.5 %, respectively.

3.2. Roasting of coffee

In the present study, microwave, infrared and conventional oven were used for roasting of the coffee. 700, 490 and 350 W of power were applied for microwave roasting. 10, 20 and 30 minutes were used for 700 and 490W power. But, only 30 minute was used for 350W because of 10 and 20 minutes were not enough for the coffee roasting.

600 and 1200 W power was applied to the process of roasting with infrared. With conventional oven roasting process 160, 180, 200 and 220^{o}C were used. 10, 20 and 30 minutes were used for roasted coffee for both infrared and conventional oven roasting. Roasting time was determined by the color of roasted coffee for both

infrared and conventional oven roasting. Hammer type and cutter type milling were used to grind microwave, infrared and conventional oven roasted coffees .

3.2.1. The moisture content of microwave, infrared and conventional oven roasted coffee

3.2.1.1. Microwave roasting

The moisture content of the coffee was measured after the microwave roasting operation at different powers i.e. 700, 490 and 350 W for 10, 20 and 30 minutes. After the roasting, the grounded samples were used for the moisture content analysis.

It was found that the increases in time and power for the microwave roasting decreased the moisture content as expected (Figure 3.1). However, the changes in time and temperature were significantly (P ≤0.05) effective.

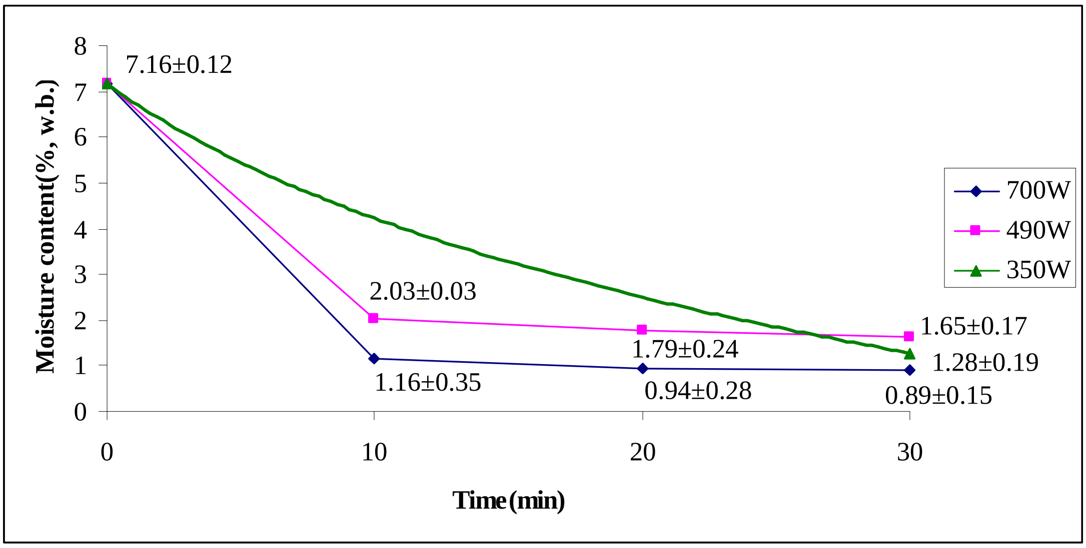

Figure 3.1. Moisture content of microwave roasted coffee

3.2.1.2. Infrared roasting

Moisture content was measured at 600 and 1200W powers of infrared roasting. The roasting time was determined by the color of coffee which were 1 hr : 55 min and 55 min for 600W and 1200W respectively.

The increase in the power for infrared roasting operation, caused to increase in the moisture content (Figure 3.2.). This change was not significantly (P≥0.05) important. This small difference can be explained by the rapid color change at 1200 W of infrared power. In order to prevent the burning at high power, the roasting operation was stopped. This result showed that roasting rate was higher than moisture evaporation from the coffee bean, therefore the moisture change was low.

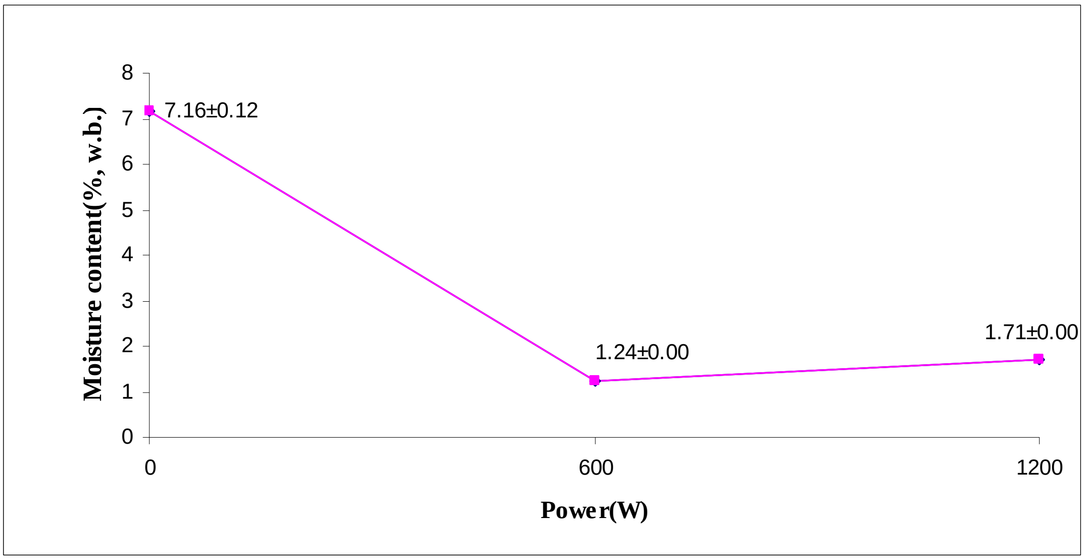

Figure 3.2. Moisture content of infrared roasted coffee

3.2.1.3. Conventional oven roasting

The moisture content of coffee which was roasted at 160, 180, 200 and 220^{o}C was measured. Roasting with the oven, the roasting time was determined by the color of coffee (1hr : 47 min., 1hr : 30 min., 55 min. and 27 min. at 160, 180, 200 and 220 ^{o}C, respectively).

The lowest moisture content was obtained at 160 ^{o}C. The moisture content at 180 ^{o}C had higher moisture content than the others (Figure 3.3). The change in the moisture content at different roasting temperature was significantly ($P \leq 0.05$) important. This change was due to gelling, case hardening and shrinkage effect at high temperatures.

Especially, in industrial scale roasting operations, the roasting operation starts with low temperature to supply the water diffusion from center to surface for evaporation (to prevent shrinkage and case hardening), then continues with high temperatures. As a note, this temperature profile is opposite of the normal drying operation (e.g. co-current type).

To prevent the surface case hardening and shrinkage, low temperature can be preferred (~160 ^{o}C) to supply the water diffusion from center to surface. At high temperature (> 180 ^oC), this diffusion stops. At high temperatures, (for example 200 and 220 ^oC in the present study), caused partically breakdown/disturbance on the surface film to generate a new capillaries for water diffusion and evaporation. Therefore, the moisture contents were between 160 and 180 ^oC.

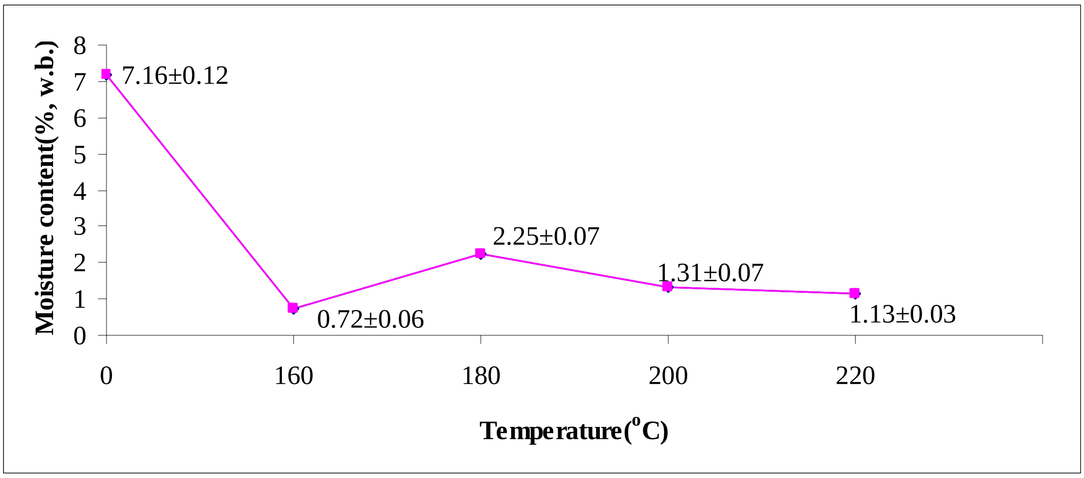

Figure 3.3. Moisture content of conventional oven roasted coffee

In the study of Nicoli et al., (1997) and Pittia et al., (2006), it was determined that moisture content decreased when the time of roasting increased. It was mentioned that different roasting degrees were important for moisture content. Also moisture content in less roasted coffee beans it decreased from 11.67 % to 1.6 % while in more roasted coffee beans, it decreased to 0.76 %.(Sivetz, 1963; Varnam and Sutherland, 1994).

In the study of Shimoni and Labuza, (2000), it was seen that the moisture content decreased while the time of roasting and heat increased. It was observed that the porosity was greater for the darker roast as compared to medium or light.

In the literature, Arabica and Robusta coffees were roasted in two different temperatures. After that, moisture content was measured. It was seen that moisture content decreased with the increase of heat. The moisture content in Robusta coffee was less than Arabica coffee. Regardless of the different heating conditions, the trend of the strength of the samples as a function of the correspondent dry matter is almost similar showing a progressive and significant decrease as the moisture content of the coffee becomes lower (Pittia et al., 2001).

It was observed that at the roasting with microwave and traditional techniques, the time depends on the degree of the moisture before roasting, but after roasting process the moisture content depends on roasting technique, and also at roasting with microwave, moisture content was more than other techniques (Nebesny and Budryn, 2002).

Besides, when the green coffee, which had the same roasting degree, was roasted with traditional or microwave techniques, it was observed that the time in microwave was much longer than the other one (Nebesny E. & Budryn G., 2006).

In the study of Tang et al., (2002) it was observed that more moist food absorbed much more microwave energy while being dried with microwave and moisture tended to disperse irregularly. It was mentioned in the situation of being under critical degree of moisture, the effect moisture content was less significant as the reduction of loss factor with reducing moisture content was not as significant. It was observed that in far infrared roasted coffee beans the amount of moisture reduced fast compared with the coffee beans which was roasted by hot air. Analysis by NMR indicated that far infrared roasted coffee beans showed more uniform distribution of moisture content and higher rate of bonded water than hot air roasted ones, thus suggesting that the samples suffered from uniform decrease in moisture.

3.2.2. Acidity

The acidity of microwave, infrared and conventional oven roasted coffee was measured.

3.2.2.1. Microwave roasting

The acidity of powder coffee by roasted with microwave at 700, 490 and 350 W powers was measured.

The acidity decreased during roasting with microwave when power increased. At 490W, the acidity firstly increased and then decreased. It was found that acidity was significantly ($P \leq 0.05$) affected from the roasting operation. The acidity increased while the power decreased (Figure 3.4).

Similar results have been observed by Varnam and Sutherland, (1994) who reported that formic, citric and malic acid increased in concentration in the early stages of roasting, but were subsequently degraded. With the effect of roasting heat, power and time, acidity which is volatile in coffee, removed and it was seen that while the time of roasting increased, the acidity value decreased.

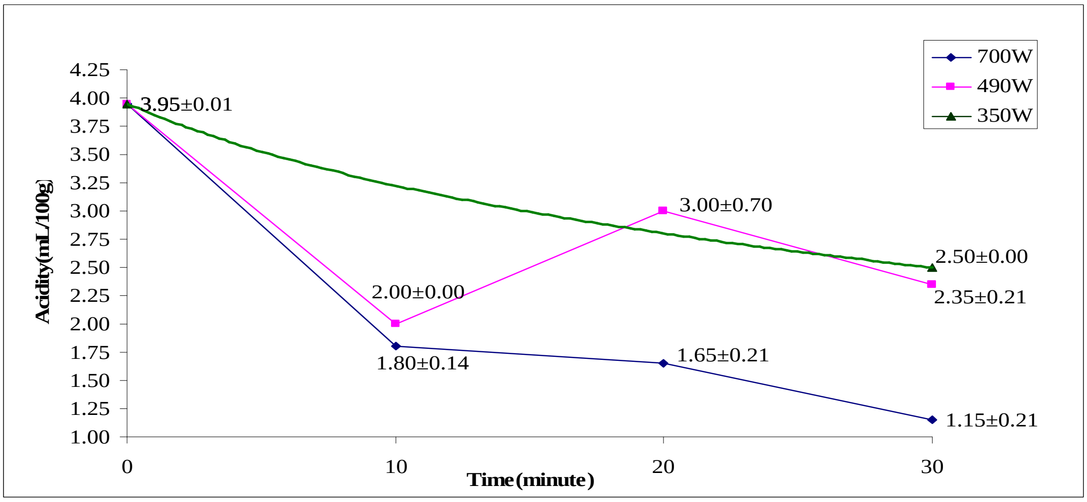

Figure 3.4. Acidity of microwave roasted coffee

3.2.2.2. Infrared roasting

It was seen that when the power increased, the acidity decreased similar to microwave roasting (Figure 3.5). With the effect of roasting power and time, acid which is volatile in coffee removed. However, It was found that acidity was not significantly ($P \geq 0.05$) affected from the infrared roasting operation.

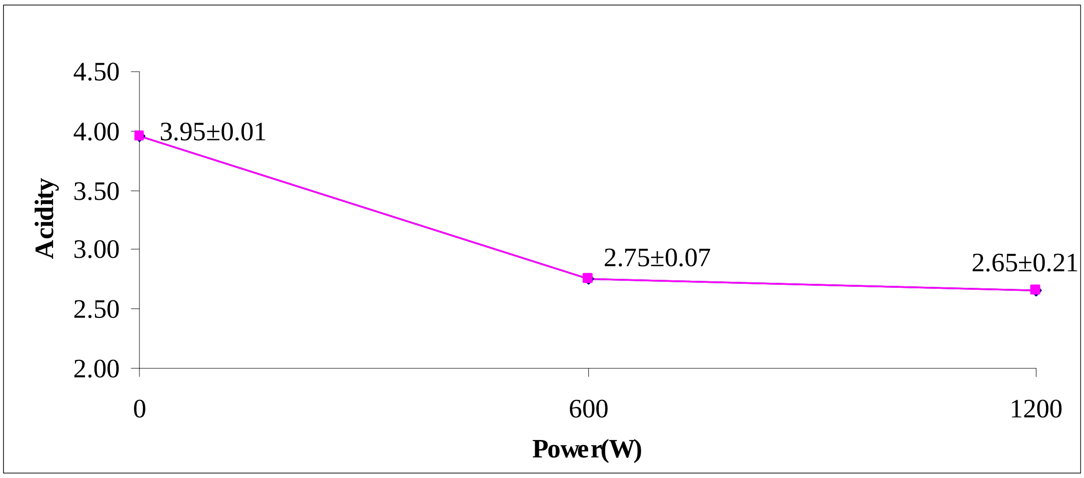

Figure 3.5. Acidity of infrared roasted coffee

3.2.2.3. Conventional oven roasting

The acidity of coffee, which was roasted with conventional oven using 160, 180, 200 and 220^{o}C temperatures, was measured. Also it was observed that as a result of roasting with oven when the heat increased, the acidity decreased (Figure 3.6). It was also found that acidity was not significantly (P≥0.05) affected from the oven type roasting operation.

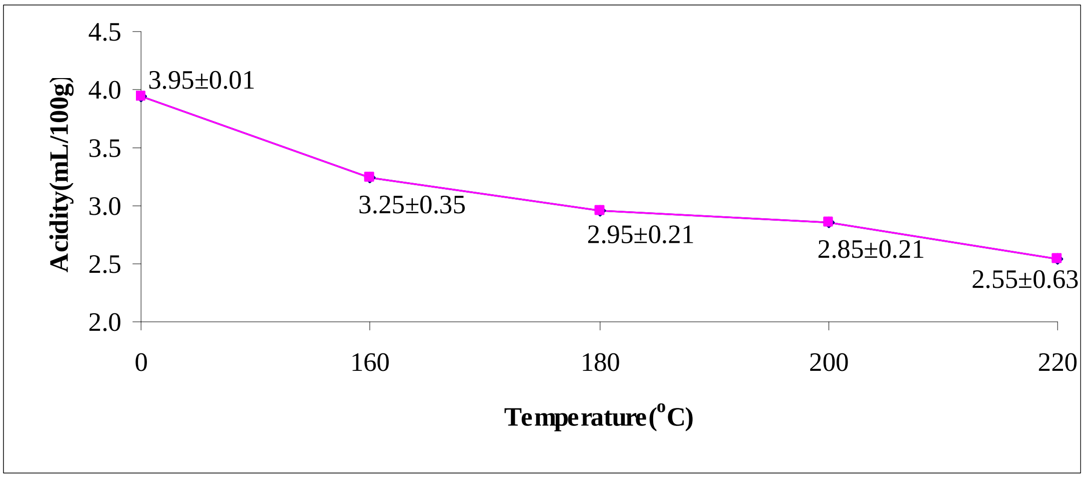

Figure 3.6. Acidity of conventional oven roasted coffee

It was mentioned that total chlorogenic acid decreased while the degree of roasting increased (Trugo and Macrae, 1984a). In roasted samples, it was seen that the acidity decreased and it was stated that its reason is conversion of chlorogenic lactones (Murthy and Manonmani, 2008). The similar results were observed in the present study. There was a relationship between temperature/power and acidity.

3.2.3. pH

The pH was used to understand the hydrolized hydrogen ion content in the coffee. Therefore, It was measured additional to titratable acidity. pH of the coffee was measured for microwave, infrared and conventional oven roasting operation.

3.2.3.1. Microwave roasting

In the coffees which was roasted with microwave, it was seen that the pH increased while the roasting time and power increased. In case of different powers but same time (30th minute) it was seen that pH of coffee samples decreased (Figure 3.7). It was found that pH was significantly (P≤0.05) affected from the microwave type roasting operation.

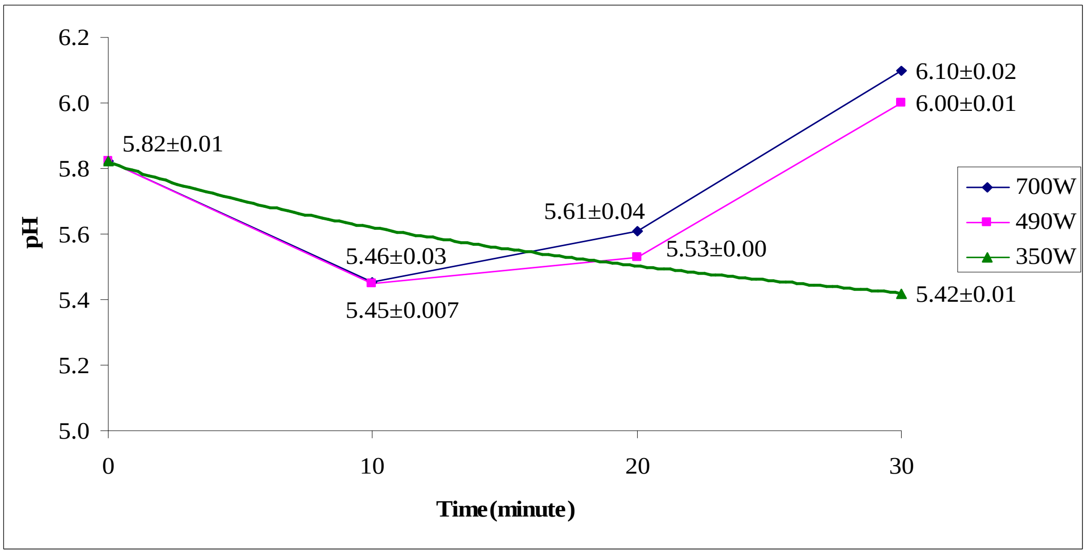

Figure 3.7. pH of microwave roasted coffee

3.2.3.2. Infrared roasting

In the coffee which was roasted with infrared techniques it was observed that while the power increased the pH also increased (Figure 3.8). There was relationship between pH and acidity. When the time and power increased, the acidity decreased or pH increased. So, the pH increased with increased of time and power. It was found that pH was not significantly (P≥0.05) affected from the infrared type roasting operation.

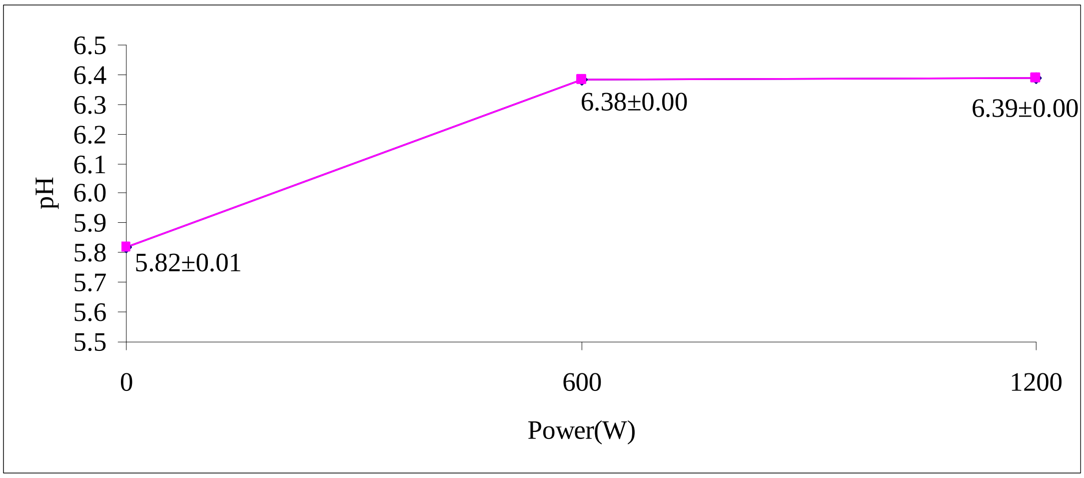

Figure 3.8. pH of infrared roasted coffee

3.2.3.3. Conventional oven roasting

The pH of coffee which was roasted conventional oven using 160, 180, 200 and 220 ^{o}C, was measured. In the process of roasting with oven, it was found that there was fluctuations in pH. The pH which was 5.67 at 160°C then increased at 180°C and decreased again at 200°C but it increased again at 220°C (Figure 3.9). Additionally, It was found that pH was significantly (P≤0.05) affected from the conventional type oven roasting operation.

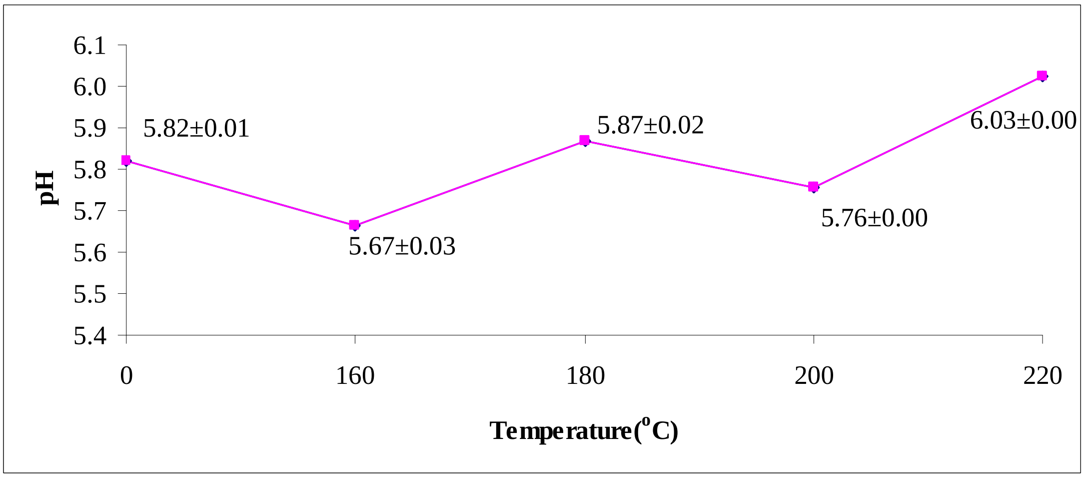

Figure 3.9. pH of conventional oven roasted coffee

Also it was seen that there is a correlation between acidity and pH. When it was looked different proportion of Arabica and Robusta coffees pH values, it was observed that while added Robusta to Arabica coffee the pH level increased. Liete da Silveira et al., (2007) observed that there was a correlation between pH and tyramine and agmatine contents and it was observed while pH value increased the others decreased.

It was determined that while the heat increased, the pH decreased. pH of Robusta coffee was higher than Arabica coffee. Besides, it was stated that titratable acidity decreased while the heat increased (Albonese et al., 2009).

3.2.4. Color of coffee

Color broadly is a parameter that is used for classification of coffee as light, medium and dark (Illy and Viana, 1995; Eggers and Pietsch, 2001).

3.2.4.1. Microwave roasting

For microwave roasted coffee it was seen that when the power and time increased the CIE a*, CIE b*, CIE L* and CIE YI values decreased (Table 3.2). The CIE L* decreased because of the roasting. While it was found that color was significantly ($P \leq 0.05$) changed during the microwave roasting.

Table 3.2 Color values of microwave roasted coffee (bean)

Power (W)	Time(min)	CIE L*	CIE a *	CIE b*	CIE YI
0	0	0.18±0.35	3.54±0.22	21.52±0.58	60.62±0.93
	10	28.04±0.73	7.39±0.34	11.56±0.61	63.86±2.22
700	20	23.80±0.52	5.85±0.16	7.09±0.20	48.82±0.81
	30	20.36±0.48	4.42±0.22	4.37±0.24	36.27±1.34
	10	36.04±1.90	9.24±0.16	18.36±1.45	76.82±1.37
490	20	23.83±1.58	6.78±0.57	8.90±1.03	58.22±3.48
	30	23.78±0.30	6.42±0.20	7.84±0.41	53.33±2.14
350	30	33.26±1.28	9.48±0.12	17.04±0.63	77.59±0.52

3.2.4.2. Infrared roasting

For infrared roasted coffee, it was seen that when power increased the CIE a*, CIE b*, CIE L* and CIE YI decreased (Table 3.3). CIE a*, CIE b*, CIE L* and CIE YI were significantly ($P \leq 0.05$) changed. The color of coffee was getting darker and CIE L* values decreased because of non-enzymatic browning and caramelization.

Table 3.3 Color values of infrared roasted coffee (bean)

Power (W)	Time(min)	CIE L*	CIE a *	CIE b*	CIE YI
0	0	0.18±0.35	3.54±0.22	21.52±0.58	60.62±0.93
600	55	29.19±2.00	7.89±0.25	14.35±1.44	72.00±1.02
1200	115	22.76±1.60	6.66±0.13	9.17±0.02	60.53±1.99

3.2.4.3. Conventional oven roasting

In the process of roasting with oven, the CIE a*, CIE b*, CIE L* and CIE YI values decreased (Table 3.4). It was found that CIE a*, CIE b*, CIE L* and CIE YI were significantly ($P \leq 0.05$) changed. It was observed that browning degrees increased with increasing roasting temperature for coffee samples, in agreement with result reported by Da porto et al., (1991).

Table 3.4 Color values of conventional oven roasted coffee (bean)

Temperature(^{o}C)	Time(min)	CIE L*	CIE a *	CIE b*	CIE YI
0	0	0.18±0.35	3.54±0.22	21.52±0.58	60.62±0.93
160	107	28.80±0.66	8.52±0.29	15.62±0.51	77.75±1.40
180	90	29.18±0.81	8.68±0.10	16.12±0.24	78.97±1.25
200	55	27.97±0.58	7.89±0.13	13.98±0.49	72.69±0.58
220	27	24.72±0.28	7.00±0.04	11.11±0.40	65.69±1.03

In the literature, CIE a*, CIE b*, CIE L* and CIE YI* also decreases with increase in roasting time (Da Porto et al., 1991; Anese et al., 2000; Romani et al.,2003; Pittia et al.,2006; Sacchetti et at.,2008; Lopez- Galileo et al.,2008). When the degree of roasting increased, there is a changing in coffees' color and its reason is non-enzymatic browning (Nicoli et al., 1997). The color changing of Robusta coffee is more restricted because of lower sugar involvement (Trugo, 1985). During roasting process the color of coffees changes because of non-enzymatic browning and pyrolysis reactions (Pittia et al., 2000).

3.2.5. Soluble solid content

3.2.5.1. Microwave roasting

In microwave roasting, the soluble solid content decreased with respect to time and also power (expect 350 W) (Figure 3.10). The soluble solid content was not significantly ($P \geq 0.05$) changed during the microwave roasting operation. A small decrease in the soluble solid content during the microwave roasting might be due to gelling and hardening of coffee. For 350 W, with increased the time and power, soluble solid content increased. It was expected result because of roasting.

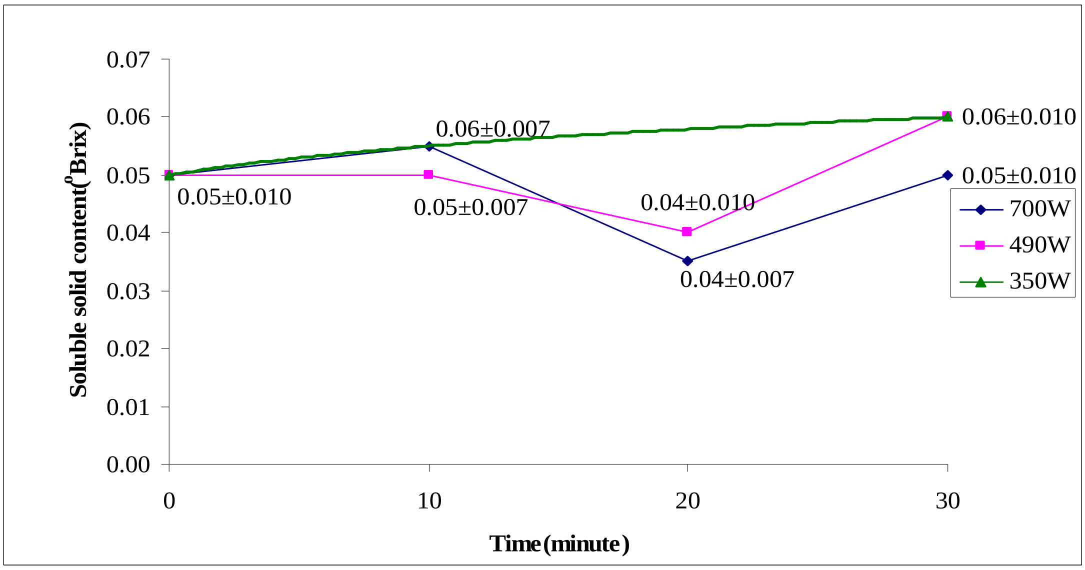

Figure 3.10. Soluble solid content of microwave roasted coffee

3.2.5.2. Infrared roasting

In the process of infrared roasting it was seen that as power increased, the soluble solid content of coffee increased (Figure 3.13). However, soluble solid content was not significantly (P≥0.05) changed. Because, in roasting process, when the power increased the coffee became crispier and better ground, therefore, solubility increased sligtly.

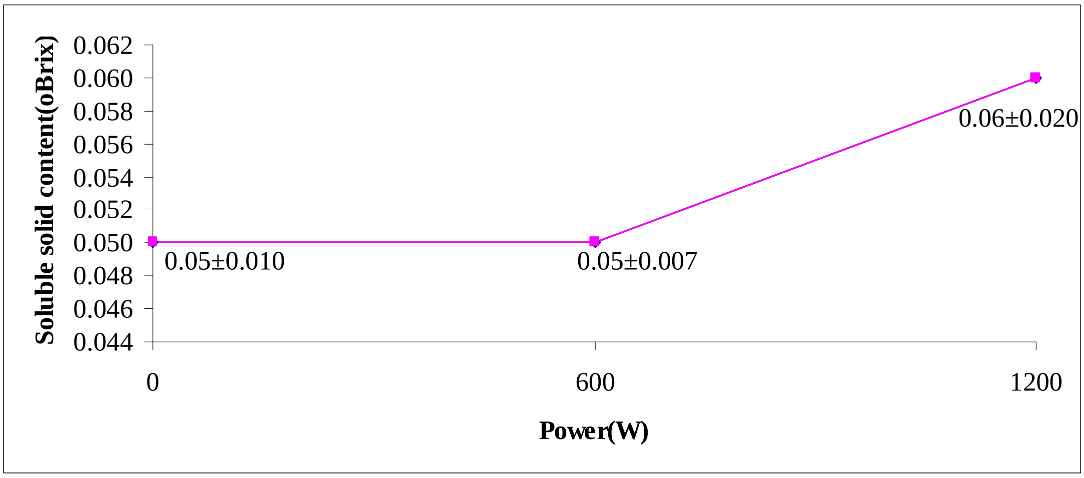

Figure 3.11. Soluble solid content of infrared roasted coffee

3.2.5.3. Conventional oven roasting

In oven roasting, the soluble solid content of coffee powder which were found as 0.04 (160^{o}C), 0.03 (180^{o}C), 0.03 (200^{o}C) and 0.04 Brix (220^{o}C) (Figure 3.12). There was fluctuations at 180^{o}C of roasting, similar to the moisture content. The trends were also similar with the moisture content when compared with the other temperatures. As a note, the soluble solid content was not significantly ($P \geq 0.05$) changed.

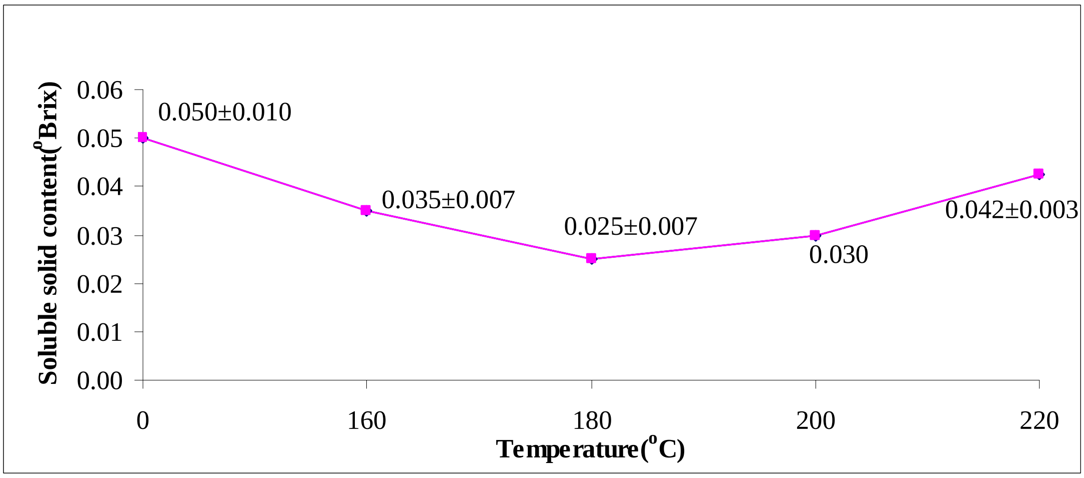

Figure 3.12. Soluble solid content of conventional oven roasted coffee

3.3. Grinding of coffee

Microwave, infrared and oven roasted coffee were milled with using both hammer type and cutter type mills. After the milling operations, angle of repose, color, bulk density and ash content of ground coffees were determined to determine the better milling technique.

3.3.1. Angle of repose

The angle of repose is the minimum angle at which any piled-up bulky or loose material stands without falling downhill.

3.3.1.1. Microwave roasted coffee

Microwave roasted coffee was ground by using cutter and hammer type mills. There was a small increase in the angle of repose of the coffee with increasing the microwave power and roasting time which was milled with cutter type mill. This increase was significantly (P≤0.05) important (Figure 3.13). This result was expected result, because; angle of repose generally related to particle size, stickness, shape and moisture content.

Theoritically, the decrease in particle size causes to increase the angle of repose due to increase in surface area. The increase in stickness and moisture content cause increase in the angle of repose due to adheniveness. Sharp shape/edge also increase the angle of repose, theoritically.

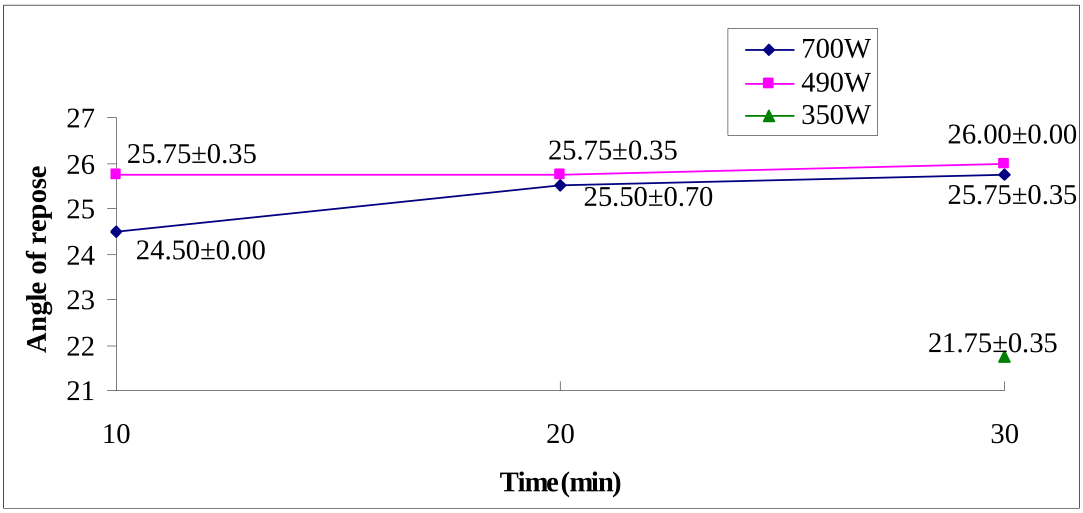

Figure 3.13. Angle of repose of microwave roasted and cutter type millled coffee

This similar result were also obtained for the hammer type mill (Figure 3.14). The increase in the roasting time and power was significantly (P≤0.05) effective on the angle of repose.

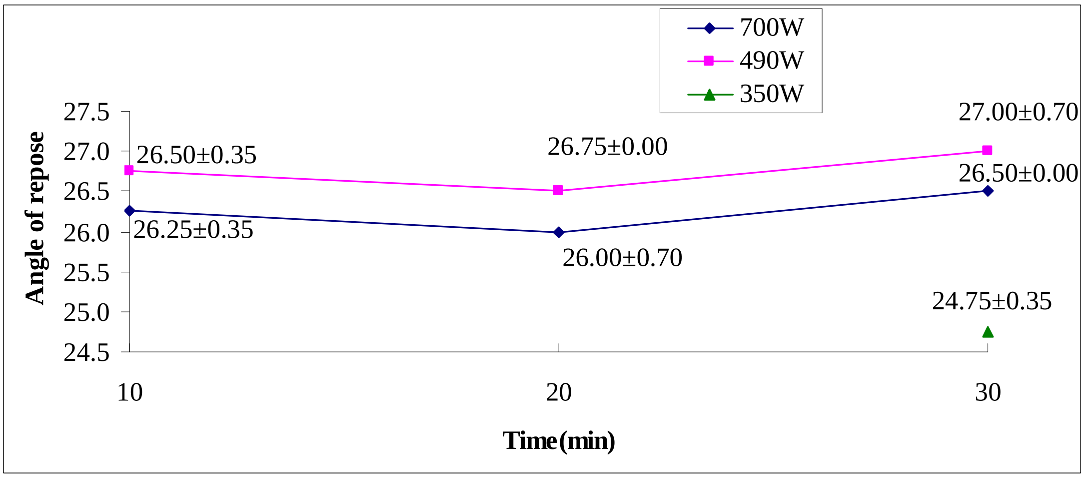

Figure 3.14. Angle of repose of microwave roasted and hammer type millled coffee

3.3.1.2. Infrared roasted coffee

In infrared roasted coffee, angle of reposes for 600W and 1200W were found as 25.25 and 25.75, respectively for cutter type mill (Figure 3.15). While the power increased, the angle of repose increased. However, the angle of repose was not significantly (P≥0.05) changed for cutter type mill. The increase in the power increased the crispiness of coffee particles, therefore, it flowed easily, and angle of repose increased, slightly.

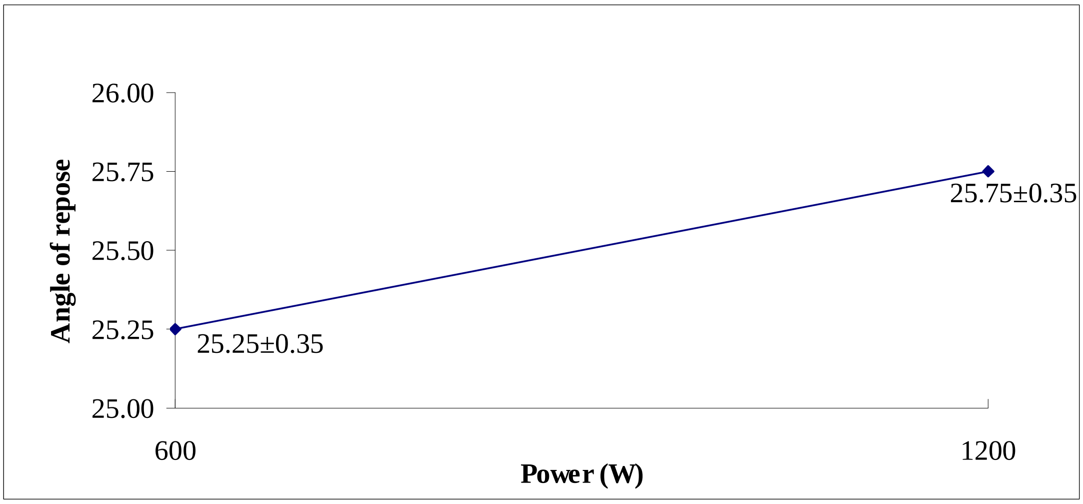

Figure 3.15 Angle of repose of infrared roasted and cutter type millled coffee

In hammer type of milling, it was not change for 600W and 1200W. It had constant value which was 26.75 (Figure 3.16). It was found that angle of repose was not significantly (P≥0.05) changed. Whereas in Hammer type of milling p value was 1.000, it was 0.293 in cutter type of milling. This difference in both mills might be due to the working principle of the mills. Hammer mill generally breaks the kernel randomly, however under the hammers, there is a screen, therefore ground particles have a uniform size and shape, therefore; roasting power was not important for hammer mill. Additionally, the same unsignificant effect was observed for microwave and conventional oven roasting operations.

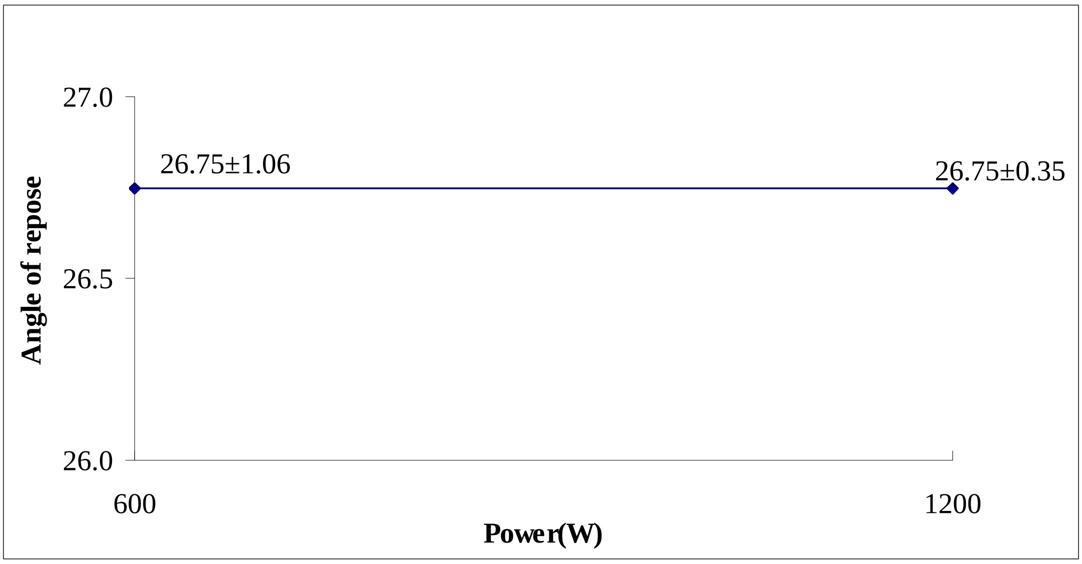

Figure 3.16. Angle of repose of infrared roasted and hammer type millled coffee

3.3.1.3. Conventional oven roasted coffee

The angle of repose of the coffee powder which was milled by using cutter type miller as seen there was fluctuations (Figure 3.17), however, it was not significantly (P≥0.05) effective for the cutter type milling.

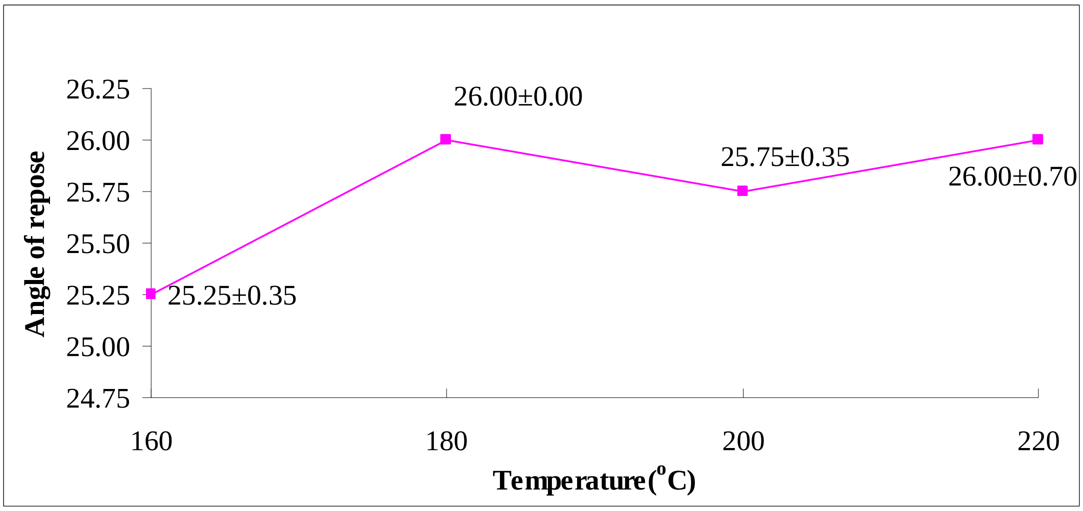

Figure 3.17. Angle of repose of oven roasted and cutter type millled coffee

In the same way, in the coffee powder which is milled by using the hammer type mill there was fluctuations in the the angle of repose like the cutter type mill (Figure 3.18), however it was not significantly (P≥0.05) effective.

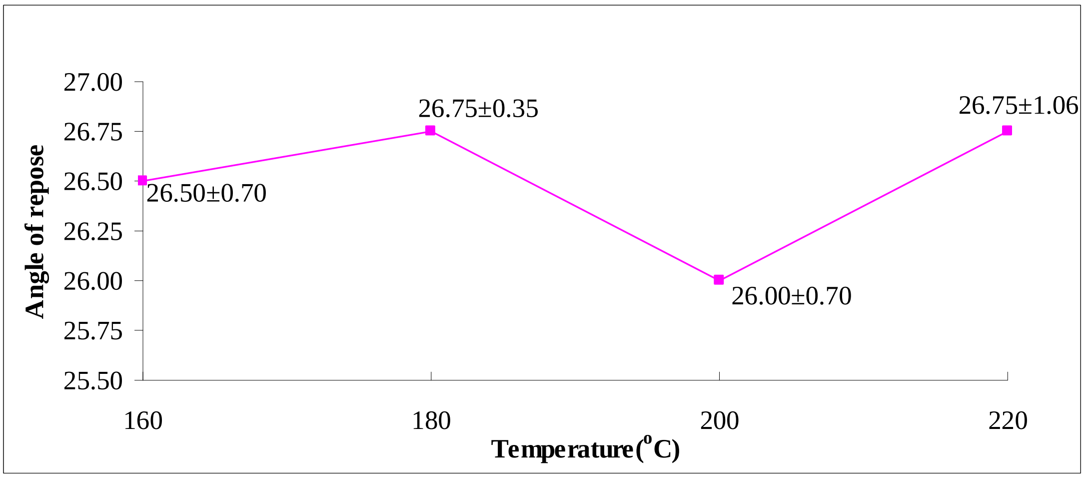

Figure 3.18. Angle of repose of oven roasted and hammer type millled coffee

3.3.2. Color

The color of coffee was measured after the roasting operation, as explained previously. The kernel size of the coffee is big, therefore it is difficult to obtain the uniform color to compare the outside and inside color changes. Therefore, the color was measured after the milling operations.

3.3.2.1. Microwave roasted coffee

CIE L*, a* and b* values of coffee powder which was roasted with microwave and then milled by the cutter type mill, decrease significantly ($P \leq 0.05$) at 700 W during the roasting (Table 3.5).

At 490 W, there was fluctuations after 20 and 30 minutes. It might be due to unhomogeneous roasting of the coffee beans at this power level in microwave. This is well known property of microwave. Due to different emission of microwaves, the obtaining uniform temperature is difficult for microwave ovens.

Table 3.5 Color values of microwave roasted and cutter type milled coffee

Power (W)	Time(min)	CIE L*	CIE a *	CIE b*	CIE YI
0	0	4.74±0.23	1.91±0.18	9.31±1.24	5.27±0.89
700	10	25.52±0.35	11.08±0.10	13.48±0.21	82.80±1.04
	20	22.05±0.26	9.16±0.06	9.30±0.10	68.84±0.10
	30	20.66±0.16	8.02±0.10	7.01±0.25	58.45±0.25
490	10	34.44±0.02	12.66±0.02	21.86±0.99	94.20±0.87
	20	23.18±1.27	9.03±0.06	8.86±0.04	66.67±0.12
	30	23.28±0.82	10.21±0.19	10.64±0.16	74.77±2.53
350	30	32.23±0.01	13.38±0.09	21.04±0.19	90.11±0.09

For microwave roasted and hammer type milled coffee, the color values were given in Table 3.6. Similar to the cutter type mill, the same trend was obtained at 700 W, which CIE L*, a* and b* decreased significantly ($P \leq 0.05$). However there was fluctuations at 490 W after 20 minutes.

Table 3.6 Color values of microwave roasted and hammer type milled coffee

Power (W)	Time(min)	CIE L*	CIE a *	CIE b*
0	0	4.74±0.23	1.91±0.18	9.31±1.24
700	10	23.79±0.25	8.63±0.05	11.51±0.21
	20	20.69±0.04	7.62±0.06	9.03±0.29
	30	18.82±0.05	6.88±0.17	6.96±0.12
490	10	30.91±0.31	10.86±0.02	18.34±0.12
	20	18.57±0.00	7.48±0.04	8.46±0.01
	30	19.70±0.03	8.35±0.04	9.68±0.01
350	30	26.89±0.02	11.15±0.01	17.09±0.04

3.3.2.2. Infrared roasted coffee

After the roasting operation, by using infrared roaster, it was found that CIE a*, b*and YI values changed significantly ($P \leq 0.05$). After the milling operations by using cutter and hammer type mills, the color values was also measured to determine the inside color of the coffee beans and the effect of the roasting operation through the kernel. The result were given in Table 3.7 and 3.8. for the cutter and hammer type mills, respectively. It was found that CIE L* values decreased significantly ($P \leq 0.05$) for cutter type milled coffee powder. CIE a* and b* decreased, however this decrease was insignificant ($P \geq 0.05$). The increase in CIE YI was also insignificant ($P \geq 0.05$). The difference in the color of whole coffee beans and powder was due to more dark brown color of outer surface of the coffee beans. However, after the milling, the inner color of the coffee was nearly homogeneous, therefore the change in the color values was mostly insignificant.

Table 3.7 Color values of infrared roasted and cutter type milled coffee

Power (W)	CIE L*	CIE a *	CIE b*	CIE YI
0	4.74±0.23	1.91±0.18	9.31±1.24	5.27±0.89
600	28.46±0.06	12.54±0.23	16.98±0.48	91.50±1.94
1200	24.49±1.26	12.50±0.53	15.86±1.29	95.58±7.60

For hammer type milling, CIE L*, CIE b*, CIE a* and CIE YI decreased significantly ($P \leq 0.05$) when the power increased (Table 3.8).

Table 3.8 Color values of infrared roasted and hammer type milled coffee

Power (W)	CIE L*	CIE a *	CIE b*	CIE YI
0	4.74±0.23	1.91±0.18	9.31±1.24	5.27±0.89
600	29.58±0.50	12.45±0.32	17.78±0.85	91.42±2.25
1200	25.36±0.38	10.95±0.34	13.22±0.91	81.74±3.83

3.3.2.3. Conventional oven roasted coffee

In the coffee which was roasted by using oven, after the coffee beans milled by cutter type; CIE L*, a* and b* decreased by increasing temperature and time, however CIE YI increased when the temperature reached to 180^{o}C and then, lowered by increasing temperature over 180^{o}C (Table 3.9). It was found that in cutter type of milling, CIE L*, a*, b* and YI changed significantly ($P \leq 0.05$).

Table 3.9 Color values of oven roasted and cutter type milled coffee

Temperature(^{o}C)	Time(min)	CIE L*	CIE a *	CIE b*	CIE YI
0	0	4.74±0.23	1.91±0.18	9.31±1.24	5.27±0.89
160	107	33.87±0.05	14.20±0.04	22.67±0.12	99.75±0.26
180	90	31.57±0.35	14.17±0.07	21.37±0.14	100.65±0.19
200	55	29.38±0.35	13.21±0.02	18.05±0.06	94.29±0.53
220	27	23.18±0.80	11.60±0.42	14.09±0.92	90.48±5.54

In hammer type milling, CIE L* decreased with increasing time and temperature, however CIE a*, b* and YI increased when the temperature was 180^{o}C and then above this temperature, these values decreased with increasing temperature (Table 3.10). It was found that CIE L*, a*, b*, and YI changed significantly ($P \leq 0.05$). The similar result was also observed in the study of Mendanca et al., (2009).

Table 3.10 Color values of oven roasted and hammer type milled coffee

Temperature(^{o}C)	Time(min)	CIE L*	CIE a *	CIE b*	CIE YI
0	0	4.74±0.23	1.91±0.18	9.31±1.24	5.27±0.89
160	107	32.39±0.20	13.49±0.07	21.73±0.43	98.55±0.74
180	90	31.45±0.34	14.29±0.23	23.44±1.02	105.54±3.10
200	55	28.28±0.30	13.02±0.21	18.39±0.53	96.61±1.36
220	27	23.15±0.45	10.40±0.31	12.28±0.22	81.35±0.85

3.3.3. Bulk Density

Bulk density was expressed as weight of powder (g) per unit volume (mL). The decline of density was concerned to roasting degree. There was an overrun and a loss of weight because of the water and volatile ingredients. It was observed that the bulk density was changed being dependent on different milling types.

3.3.3.1. Microwave roasted coffee

The bean coffee which was roasted with microwave, when the time and power were increased, the bulk density of coffee which was milled by using cutter type mill decreased (Figure 3.19). However, some fluctuations occured because of non-homogeneous roasting. Roasting with microwave requires a uniform blending of coffee. If not, some of part is more roasted however, the other part is little roasted.

The coffee which was roasted more, when the water and volatile substances decreased, the bulk density also decreased. According to the statistical analysis, bulk density was significantly (P≤0.05) changed.

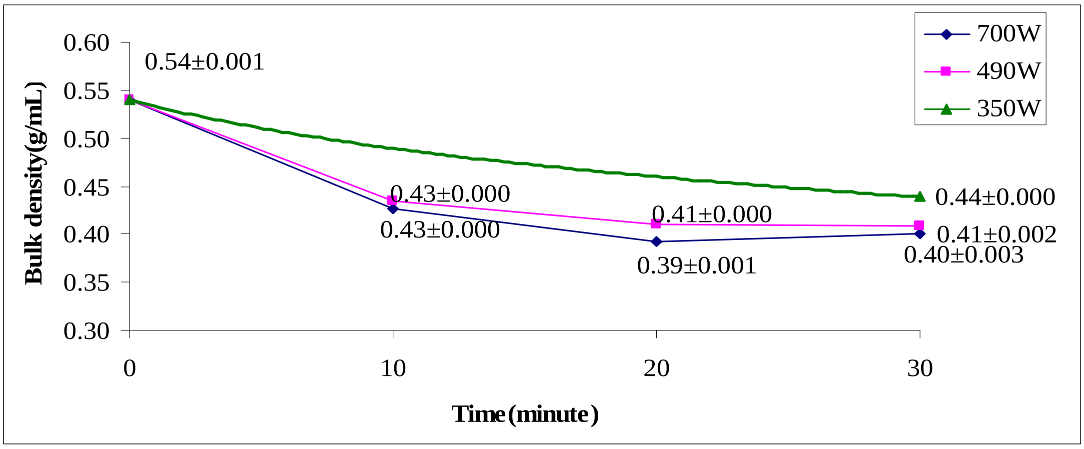

Figure 3.19. Bulk density of coffee milled with cutter type mill

It was seen that in the coffee which was milled with hammer type mill, the bulk density decreased when the time and power increased (Figure 3.20). Bulk density was significantly (P≤0.05) changed.

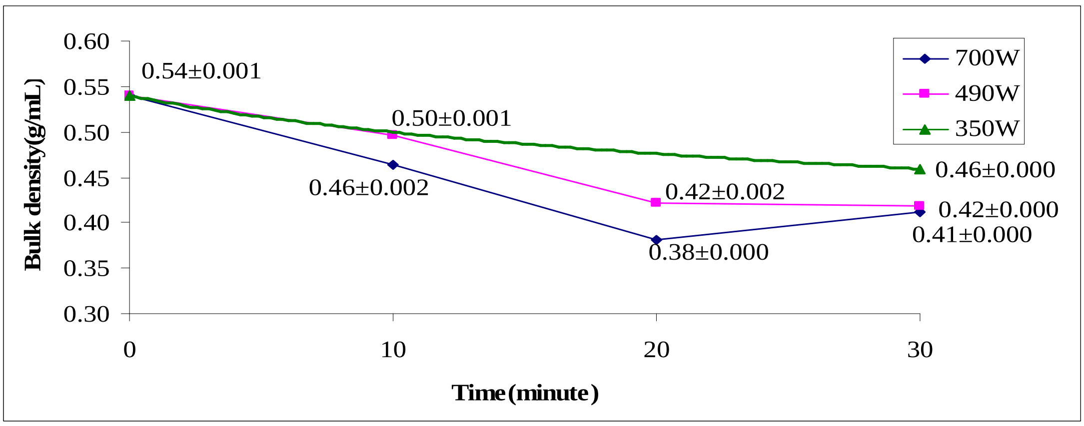

Figure 3.20. Bulk density of coffee milled with hammer type mill

3.3.3.2. Infrared roasted coffee

The coffee which was milled by using cutter type milling when the power was increased, the bulk density firstly increased and then decreased (Figure 3.21). Bulk density was significantly ($P \leq 0.05$) changed.

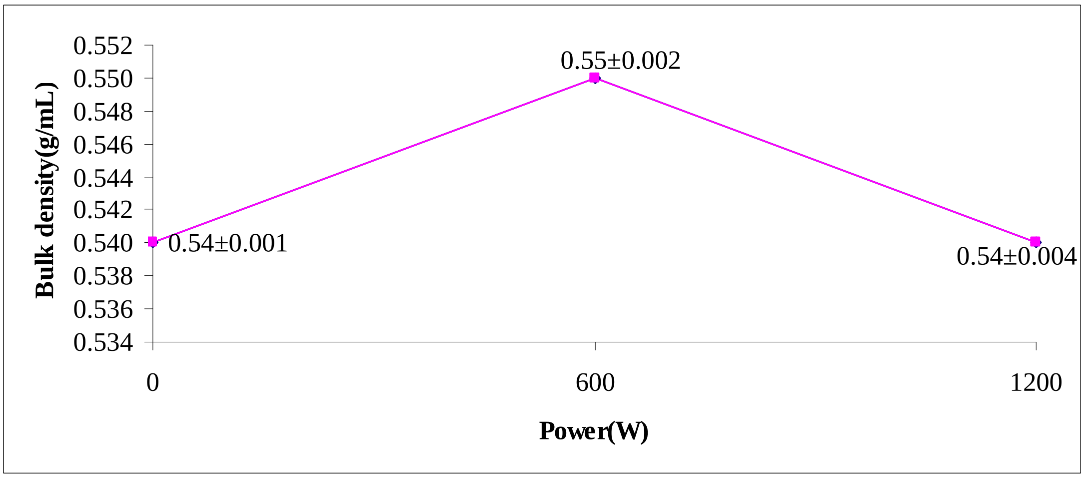

Figure 3.21. Bulk density of coffee milled with cutter type mill

When the power was increased, the bulk density decreased (Figure 3.22). Bulk density was not significantly ($P \geq 0.05$) changed.

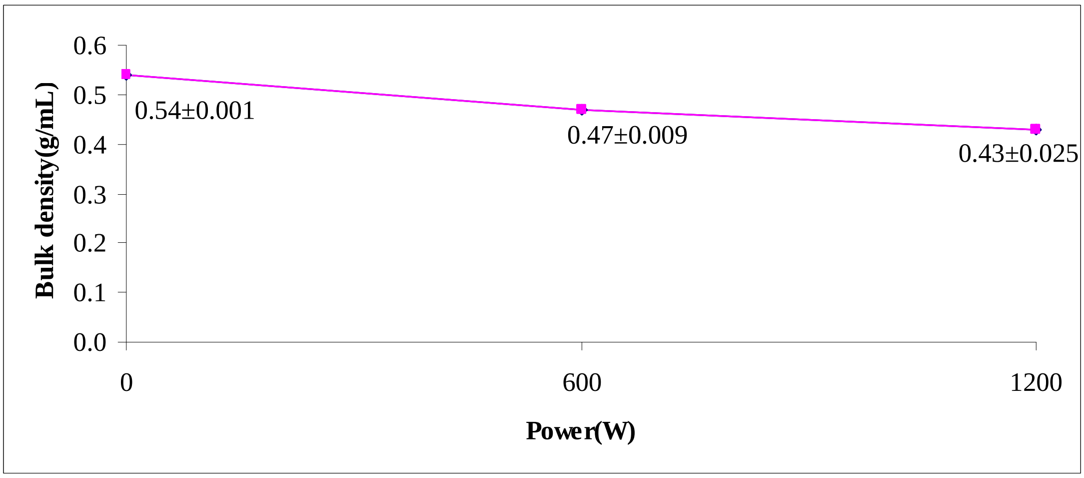

Figure 3.22. Bulk density of coffee milled with hammer type mill

3.3.3.3. Conventional oven roasted coffee

In cutter type milling of coffee beans which was roasted conventional oven, when the temperature and time were increased, the bulk density decreased (Figure 3.23). It concerned with the roasted coffee. Because of lost of the water and volatile ingredients when roasting. Therefore, bulk density decreased. Bulk density was significantly (P≤0.05) changed.

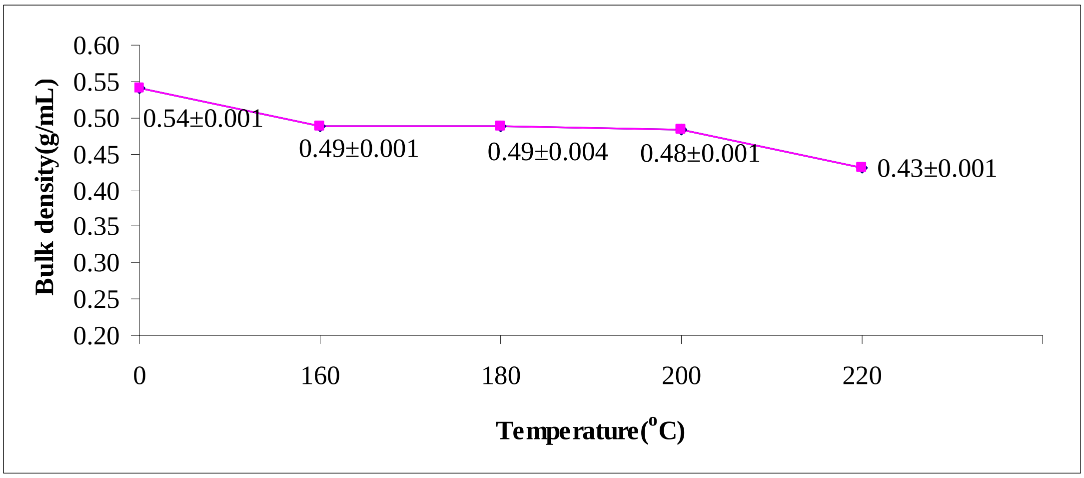

Figure 3.23. Bulk density of coffee milled with cutter type mill

In hammer type mill, the coffee which was roasted oven when the temperature and time were increased, the bulk density was decreased (Figure 3.24). Bulk density was significantly (P≤0.05) changed.

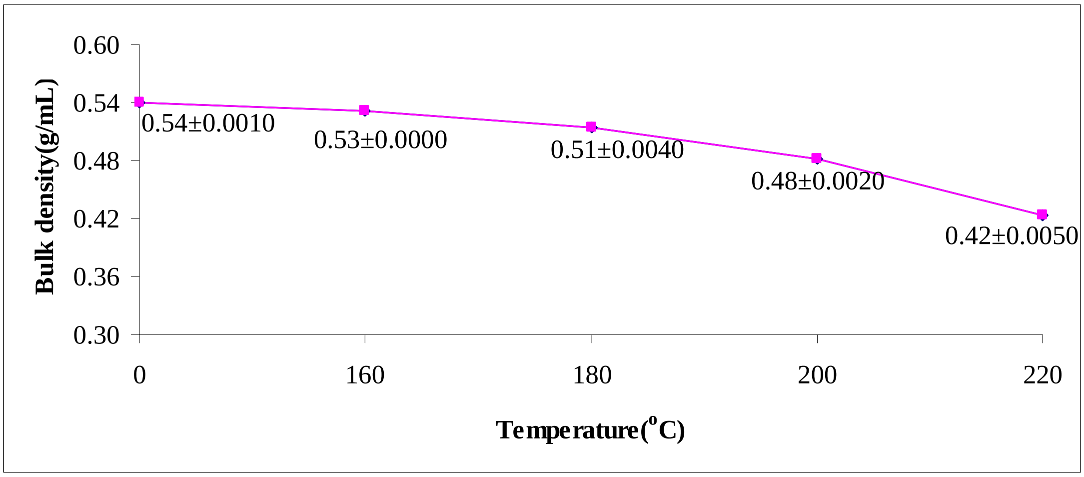

Figure 3.24. Bulk density of coffee milled with hammer type mill

3.3.4. Ash Content

3.3.4.1. Microwave roasted coffee

While power and time were increased, the ash content firstly increased and then decreased at 490W for the cutter type mill (Figure 3.25). But for 700W, firstly ash content increased and then decreased. While ash content in the coffee which was roasted during 30 minutes at 490 W, was 3.59, ash content in roasted coffee 30 minutes at 700 W was 3.64. At 300 W, it was 3.57 . Ash content of coffee was significantly (P≤0.05) changed.

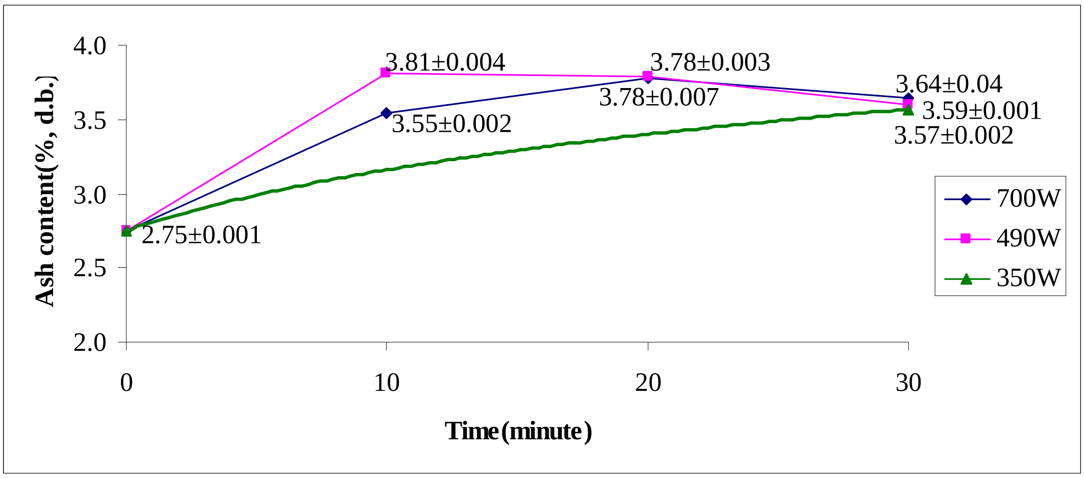

Figure 3.25. Ash content of coffee milled with cutter type mill

In the same way, the coffee which was milled with the hammer type mill, a change was observed in the ash content. However, there was fluctuations. Ash content increased and then decreased (Figure 3.26). The reason of this could be the non-homogenous roasting process. Ash content was significantly (P≤0, 05) changed.

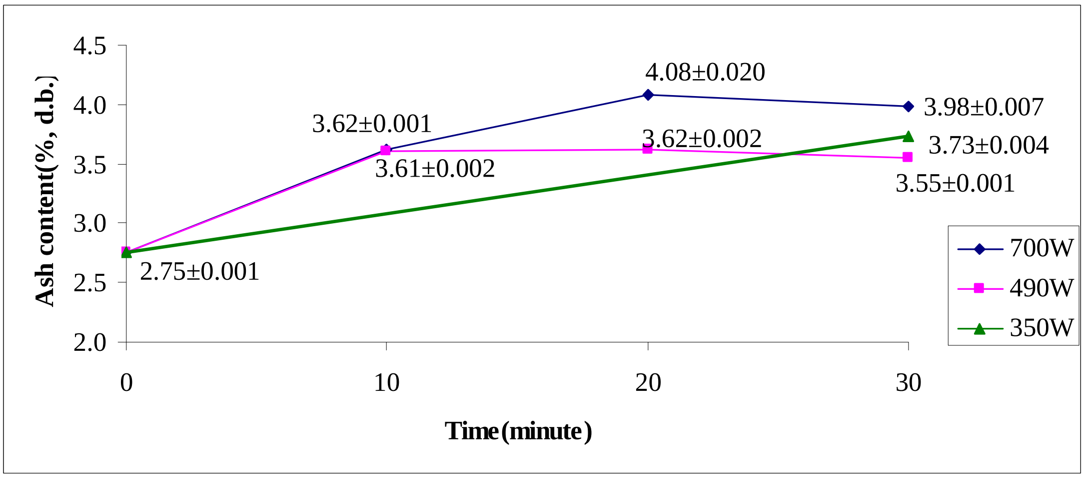

Figure 3.26. Ash content of coffee milled with hammer type mill

3.3.4.2. Infrared roasted coffee

In general, increase in temperature, time and power, the surface of coffee starts to peeling. The husk of coffee beans contains inorganic acids. Therefore, peeling process causes the decrease of ash content.

It was observed that roasting with infrared as the power was increased, ash content of coffee powder which milled using cutter type milling was decreased (Figure 3.27). But these result was higher than green coffee. Therefore, roasting method was affect the result significantly. It was observed that the amount of change in ash content depends on the type of mill. According to the stastistical analysis, ash content was significantly (P≤0.05) changed.

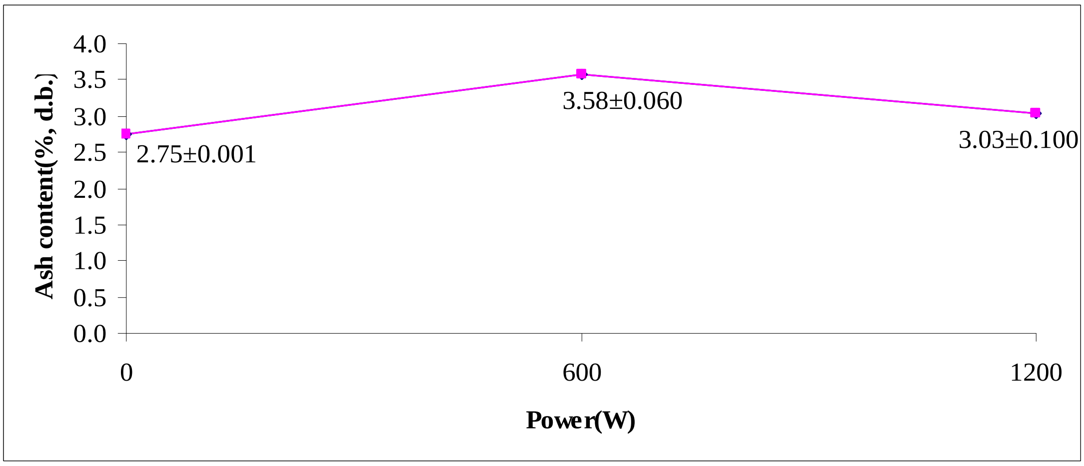

Figure 3.27. Ash content of coffee milled with cutter type mill

It was observed that whereas the power increased, ash content of coffee powder which milled using the hammer type mill decreased (Figure 3.28). Ash content was not significantly (P≥0.05) changed by the hammer type mill.

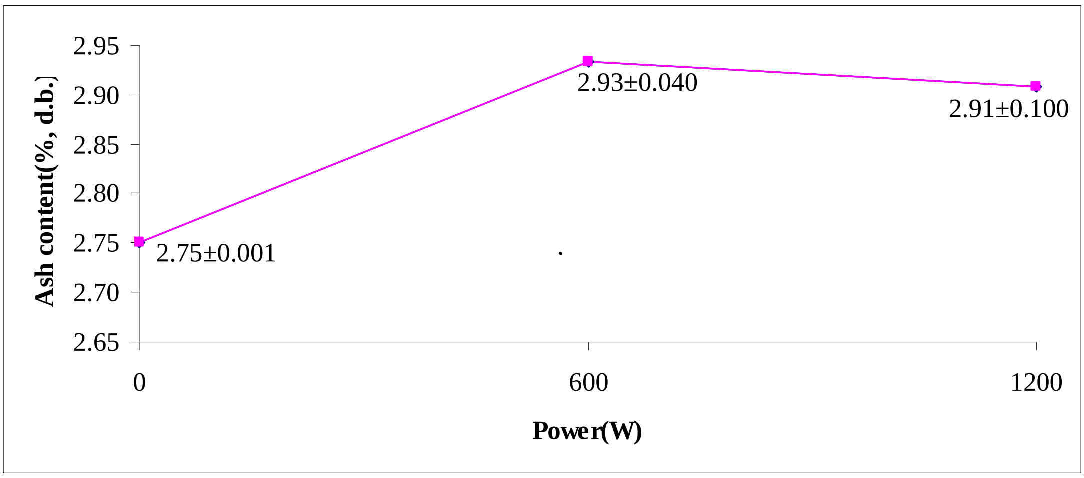

Figure 3.28. Ash of coffee milled with hammer type mill

3.3.4.3. Conventional oven roasted coffee

The coffee which was milled using the cutter type mill, when the temperature was increased, the ash content increased (Figure 3.29). However, ash content was significantly ($P \leq 0.05$) changed.

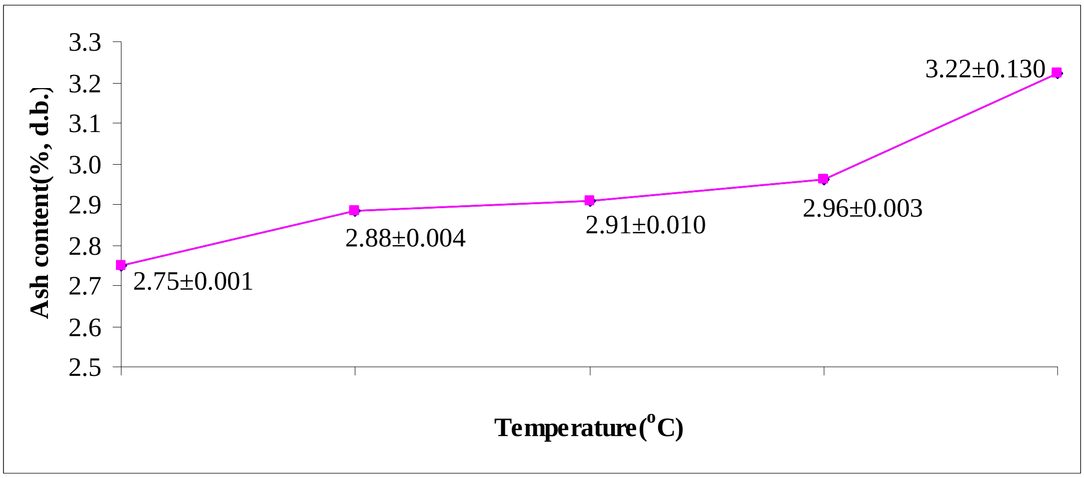

Figure 3.29. Ash content of coffee milled with cutter type mill

The similar result were observed for the hammer type mill, however, there was significant ($P \leq 0,05$) changed in the ash content.

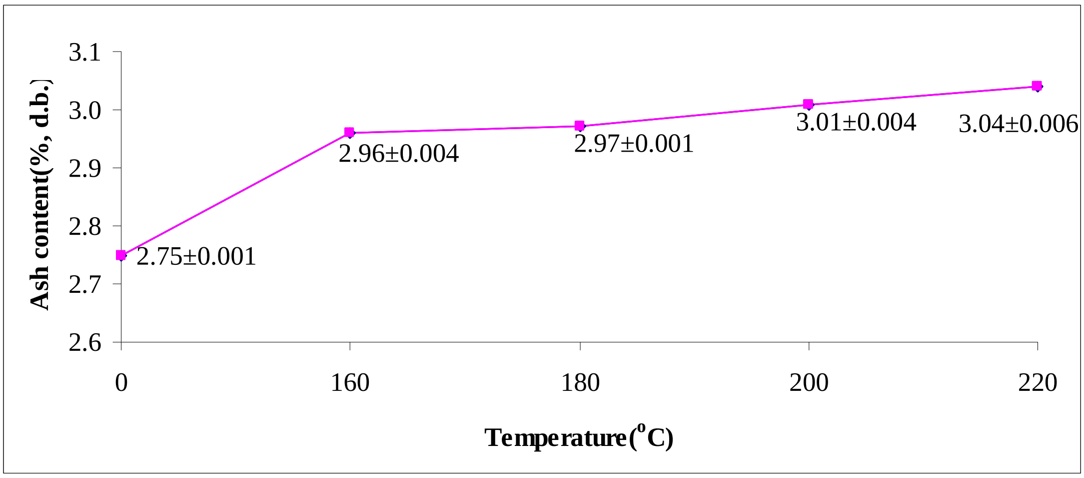

Figure 3.30. Ash content of coffee milled with hammer type mill

The coffee which was roasted with the microwave and infrared, the ash content decreased with time and power but the coffee which was roasted with oven, it increased. The reason of this may be with the integration of the membrane of beans to the endosperm and high lose of water during the roasting. The biggest amount in ash content were obtained for infrared and oven roasted coffee,which was less than for microwave roasting.

According to study of El-Badrawy et al. (2007), the ash content of microwave roasted peanut decreased. In ordinary roasting operation, the ash content decreased, in the microwave roasting operation, it increased. The reason was detected as low moisture content.

3.4. The effect of different water and cooking methods on the quality of the coffee

Traditionally, Turkish people believes that soft water and cupper pot give a good taste and high foam volume to Turkish coffee. Additionally, they believe that the initial temperature to the cooking operation after adding the coffee powder to water affects the foam volume and stability. Therefore; in this part of the study, this consumer opinions were tested. The ground coffee was used for the next operation, e.g. cooking.

The coffee powder which was roasted using microwave (at 350W 30 minute) and was milled with cutter type mill was used for the cooking of coffee for the next operations. The water was used for the cooking of the coffee at different temperatures (4, 25, 40 and 97°C). Cupper pot and electrical pot were used for cooking the coffee.

To prepare Turkish coffee, distilled (soft water) (4-8 dH) and tap water (8-12 dH) at different temperatures were used by using cupper and electrical pots. To determine quality of Turkish coffee, soluble solid content, foam volume and stability were measured. All should be high for a good quality Turkish coffee. All results were given in Table 3.11.

Table 3.11 Overall result of the cooking of Turkish coffee

Water type	Quality parameter	Cupper pot				Electrical pot			
		4°C	25 °C	40 °C	97°C	4°C	25 °C	40 °C	97 °C
Distilled water	Soluble solid content (Brix)	0.98	1.00	1.02	1.20	0.88	0.92	0.98	1.02
	Foam volume (mL)	4.40	3.00	1.40	1.00	4.00	3.00	2.12	1.10
	Foam stability (sec.)	2466.0	2105.5	1979.0	1482.0	2889.5	2479.0	1928.0	1792.0
Tap water	Soluble solid content (Brix)	0.81	0.83	0.87	1.14	0.91	0.98	1.03	1.06
	Foam volume (mL)	4.40	3.35	2.50	1.45	4.10	3.40	3.00	1.55
	Foam stability (sec.)	2528.0	2060.0	1773.5	1643.0	2714.0	2435.5	1968.0	1591.0

3.4.1. Distilled water and cupper pot

In order to prepare the Turkish coffee by using distilled water and cupper pot, water was used at 4, 25, 40 and 97 °C as initial water temperatures for cooking. Soluble solid content, foam volume and stability were measured under these conditions after the coffee preparation. According to the statistical analysis, soluble solid content was not significantly ($P \geq 0.05$) changed different initial water temperatures. However, foam volume and stability were changed significantly ($P \leq 0.05$).

When the initial water temperature was increased; soluble solid content increased slightly ($P \geq 0.05$). However; foam volume and stability decreased with respect to increase in the initial water temperature ($P \leq 0.05$) (Figures 3.31-33).

With this results, the most important results were obtained about the cooking of Turkish coffee. According to the results, if distilled water is used to prepare Turkish coffee, initial to cooking with cold water supplies high foam voume and stability.

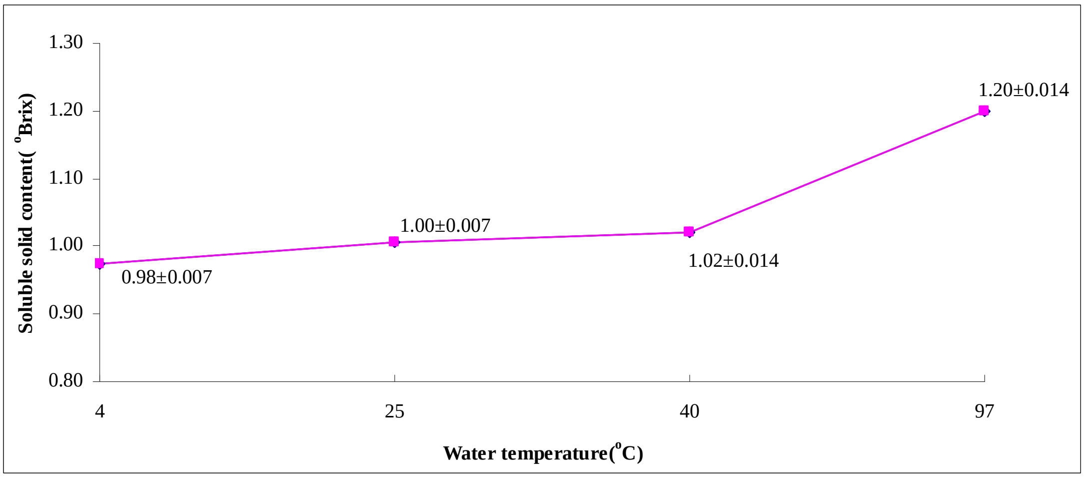

Figure 3.31. Soluble solid content of coffee cooked with cupper pot and distilled water

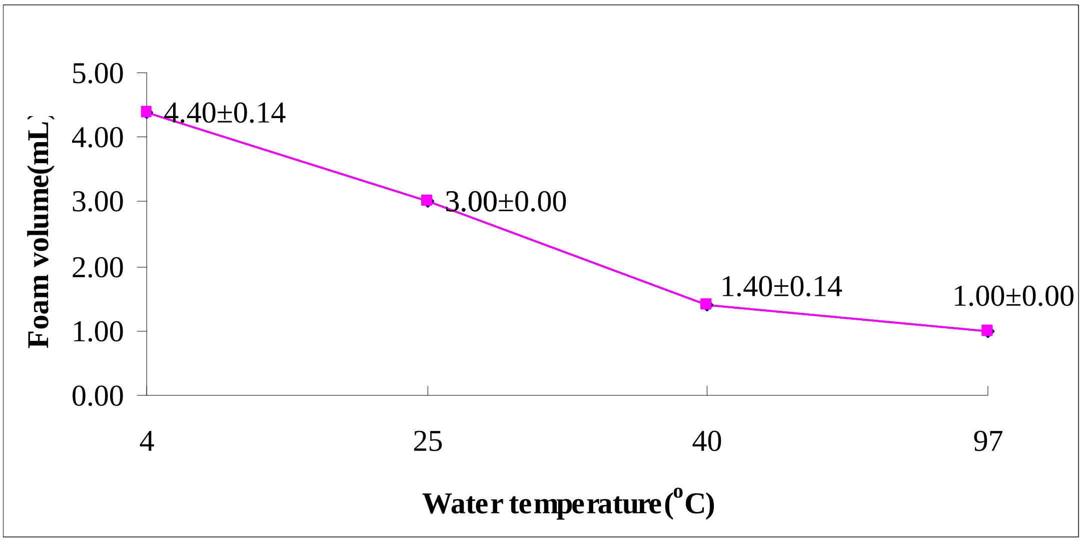

Figure 3.32. Foam volume of coffee cooked with cupper pot and distilled water

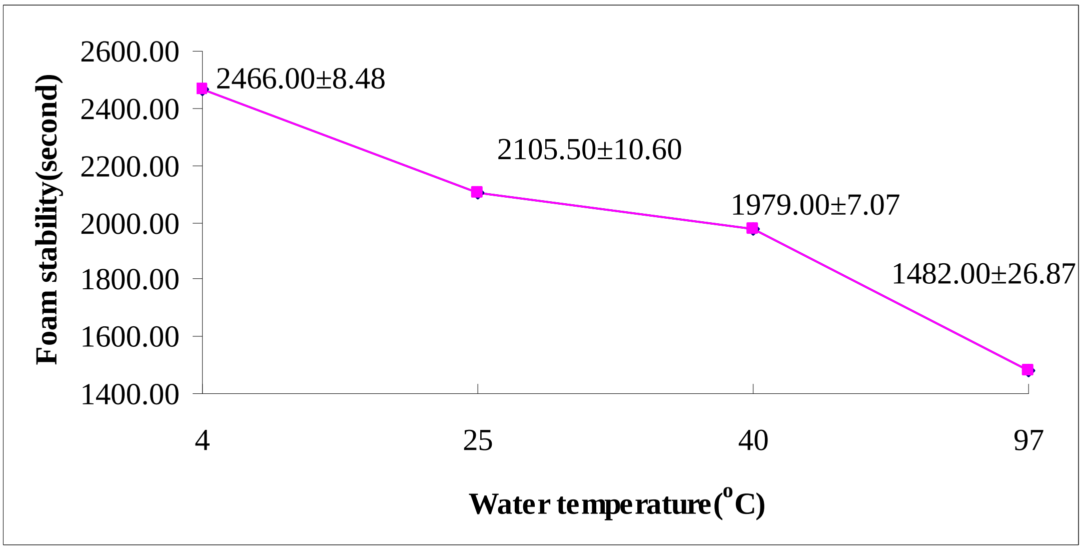

Figure 3.33. Foam stability of coffee cooked with cupper pot and distilled water

According to the study of Navarini & Rivetti (2010), there may be an important relationship between quality of water and foam volume, permanence (stability) and texture of coffee. Additionally, bicarbonate ion is important not only for foam volume, but also important for foam stability. If water is poor in terms of bicarbonate ions, the foam surface constitutes desired structure. If water is rich in terms of ions, undesired big bubbles occur.

Piazza et al., (2006), expressed that in the espresso coffee, the stability of foam, which consists of emulsion fat, depends on the size and the composition of the dispersed fat parts.

3.4.2. Tap water and cupper pot

When the initial temperature of water was increased, the soluble solid content of coffee also increased (Figure 3.34). Soluble solid content changed significantly ($P \leq 0.05$) with increased water temperature.

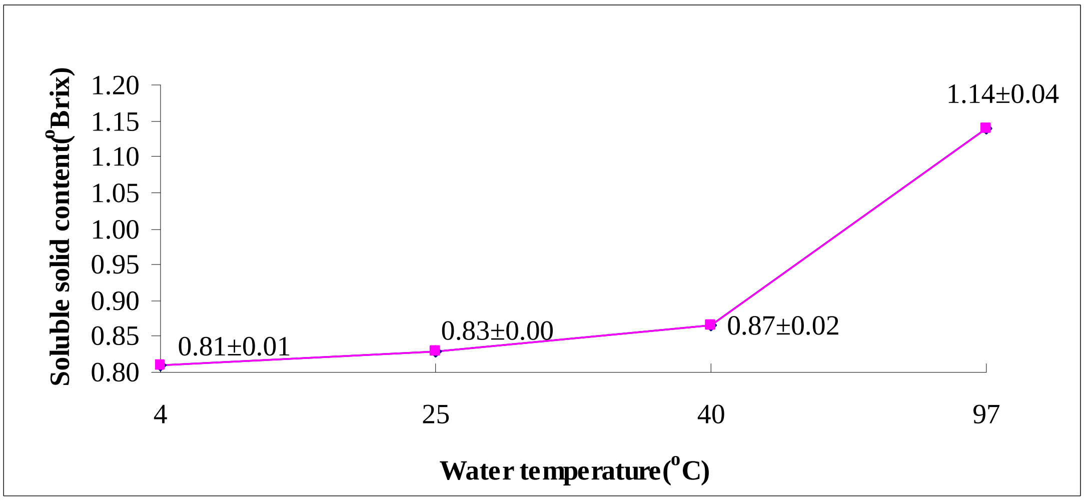

Figure 3.34. Soluble solid content of coffee cooked with cupper pot and tap water

In the coffee which was made with tap water and cupper pot, the foam volume decreased whereas the initial tempeature of water was increased (Figure 3.35). Foam volume was significantly (P≤0, 05) changed.

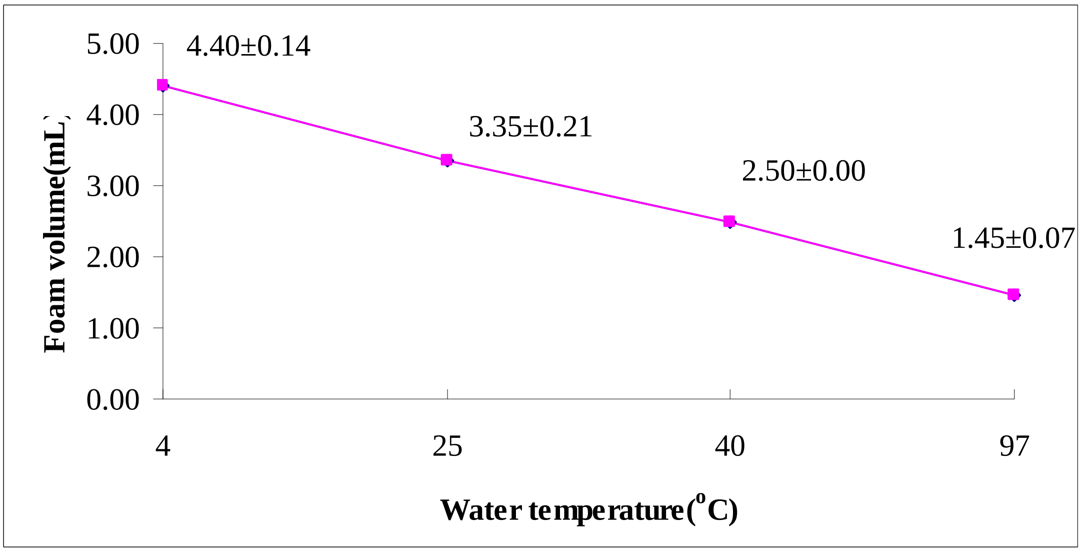

Figure 3.34. Foam volume of coffee cooked with cupper pot and tap water

Stability of foam decreased when the temperature of water was increased significantly (P≤0, 05) (Figure 3.36).

It was supported that in the mixture of protein and surfactant interface, the poor protein interaction and restricted diffusion degree cause the decline of the foam stability and sometimes even the split of the foam; in addition, polysaccharides are known to stabilize the foam by increasing the viscosity of the liquid phase (Coke et al., 1995; Heerje et al., 1998; Piazza et al., 2008).

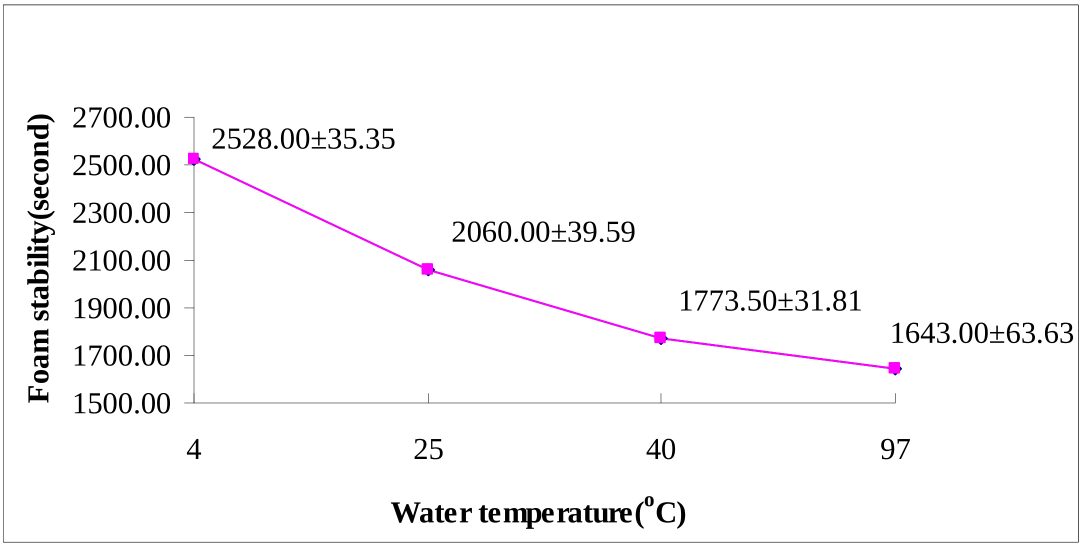

Figure 3.36. Foam stability of coffee cooked with cupper pot and tap water

3.4.3. Distilled water and electrical pot

Recently, electrical pots are used by Turkish people due to practical purpose. Therefore, instead of cupper pot, electrical pot was tested by using two different water e.g. distilled and tap water, in order to determine its effect on the quality of Turkish coffee.

Soluble solid content increased when the temperature of water which was used for cooking coffee was increased (Figure 3.37). The coffee at high temperature solved better than lower temperature. The effect of water temperature on soluble solid content was significantly ($P \leq 0.05$) important.

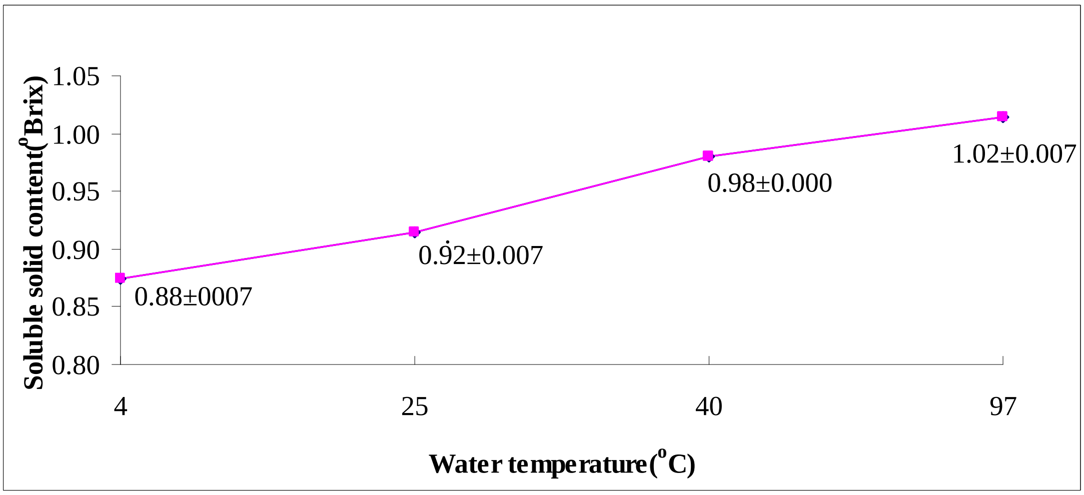

Figure 3.37. Soluble solid content of coffee cooked with electrical pot and distilled water

The coffee which was made with distilled water and electrical pot, volume of foam decreased when the temperature of the water was increased significantly (P≤0, 05) (Figure 3.38). It can be expressed that temperature of water was increased, protein denatures. Therefore, the foam volume decreases.

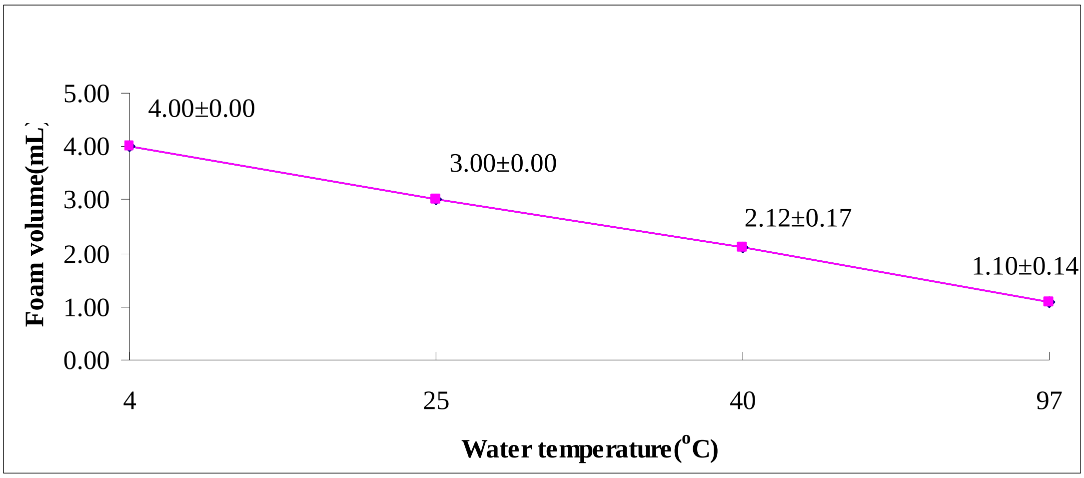

Figure 3.38. Foam volume of coffee cooked with electrical pot and distilled water

Foam stability decreased when the temperature of the water was increased (Figure 3.39). Foam stability was significantly P≤0.05) changed.

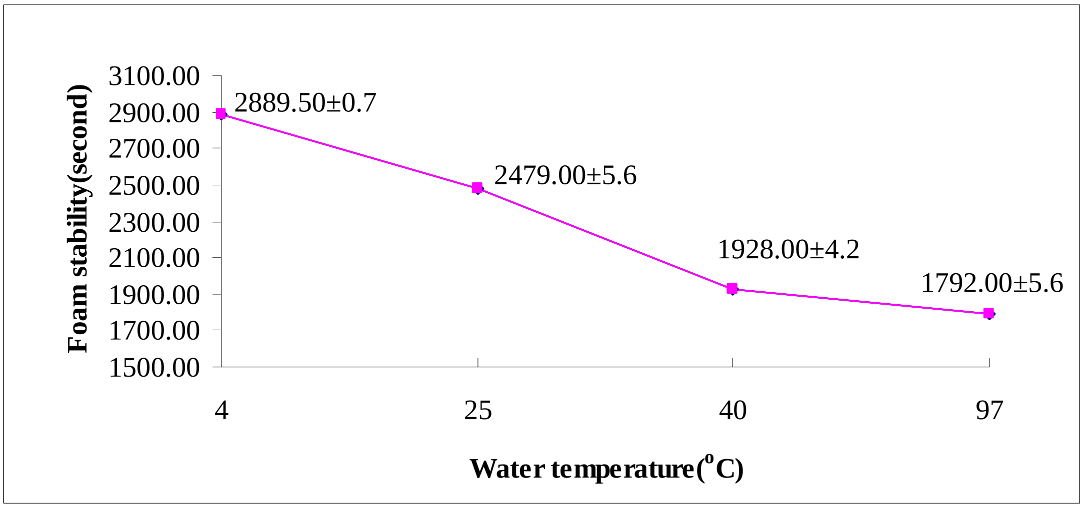

Figure 3.39. Foam stability of coffee cooked with electrical pot and distilled water

3.4.4. Tap Water and Electrical Pot

Similar to other soluble solid content result, soluble solid content was also increased when the temperature of water, which was used for cooking coffee was increased (Figure 3.40). The water temperature on soluble solid content was significantly ($P \leq 0.05$) effective and each temperature of water was different effect on the soluble solids content. It was observed that, when distiled and tap water were compared for electrical pot, the soluble solid content was higher for tap water than distilled water.

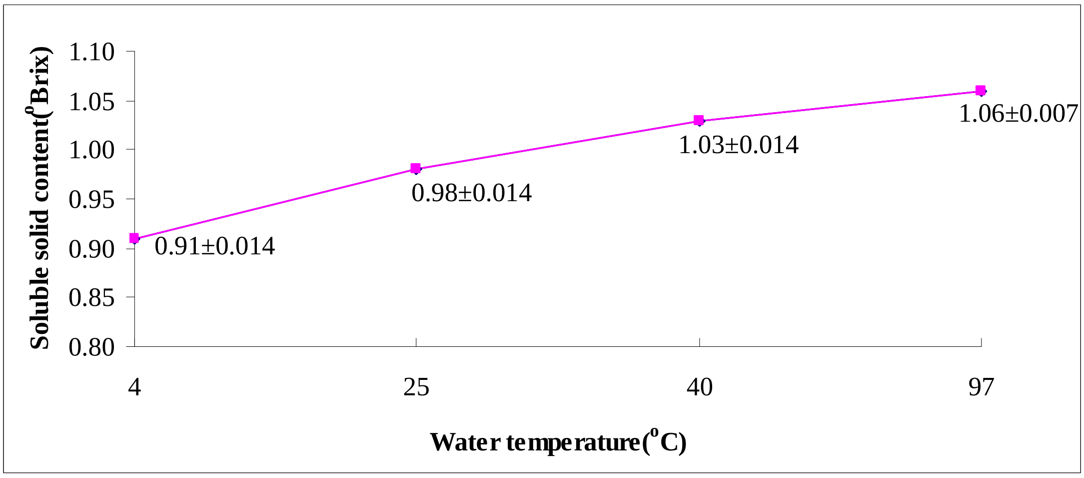

Figure 3.40. Soluble solid content of coffee cooked with electrical pot and tap water

Foam volume was decreased when the temperature of the water was increased (Figure 3.41). Foam volume was significantly ($P \leq 0, 05$) effective. The temperature of water was increased, the protein denatures. Therefore, the foam volume was decreased.

It was also reported that protein, polysaccharides, and lipids are major varieties of ingredients consisting foam mechanism (Nunes and Coimbra, 1998, 2001; D'Agostino et al., 2004).

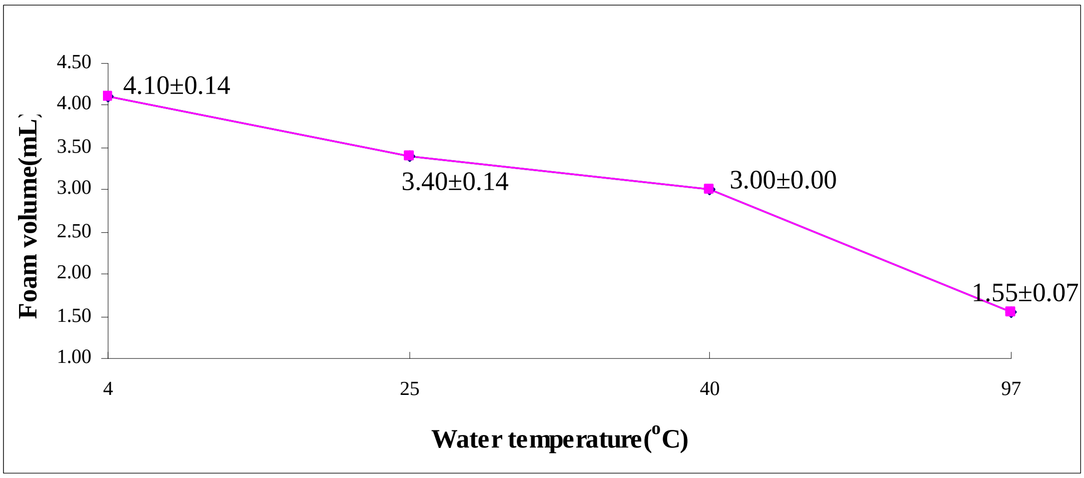

Figure 3.41. Foam volume of coffee cooked with electrical pot and tap water

Foam stability was decreased when the temperature of the water was increased (Figure 3.42). Foam stability was significantly ($P \leq 0.05$) changed. Reason of this, the temperature of the water used was increased, the bubbles disturbed rapidly.

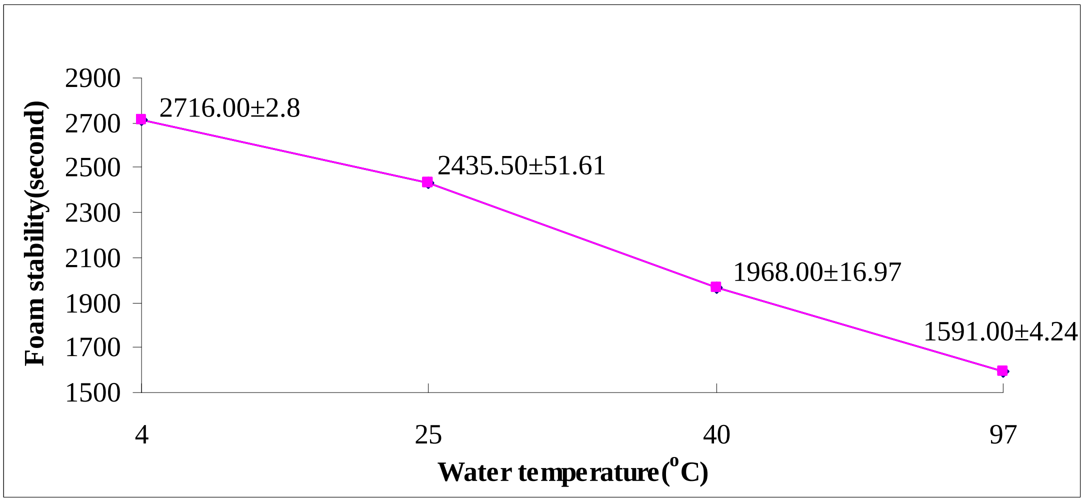

Figure 3.42. Foam stability of coffee cooked with electrical pot and tap water

As understood from the results, it was observed that in the coffee which was made of distilled water, the stability of foam was higher; while in the coffee which was made of tap water, the volume of foam was higher. It was emphasized that even the water espresso coffee contains can totally affect the character of foam by Navarini et al., (2006).

The coffee which was made of distilled water and cupper pot, it was observed that soluble solid content was higher. It was also observed that in both kinds of water in the coffee, which was made by using pot, the volume of foam was higher when compared to electric pot. While the temperature of water, which was used in coffee-making was decreased the volume and stability of foam higher.

Piazza et al., (2008) was observed that while making foam in espresso coffee is more consistent if fat breaks apart their biopolymer (protein and polysaccharides), the stability of foam increases in system which does not consist of fat. Oils are necessary to supply the stability of foam. Polysaccharide, protein and phenolic which are brought along ultrahigh molecular weight roasting process, can be as a result of the complexes between the compounds (Nunes et al., 1997). Ultrahigh molecular weight ingredients could give a good relationship for foam stability (Hattari et al., 2007).

3.5. The impact on the quality of coffee storage

In this stage, in order to test Turkish coffee quality based on the storage conditions, microwave roasted coffee at 30 mins/350W, and 25^{o}C of cooking initial water temperature (due to traditionally used temperature) were used with tap water (traditional usage) and cupper pot (traditional usage)

According to Turkish cooffee tradition, the consumers store their coffee in the refrigerator. They believe that the storage in the refrigerator increases the foam volume of the coffee.

3.5.1. Acidity

It was observed that coffee powder staled during storing. The acidity raised during storing process. However, storing in refrigerator was caused acidity to rise from 2.5 to 3.25 while the level was risen from 2.5 to 3.75 in normal conditions (Figure 3.46). That is to say, the acidity value of coffee in normal conditions raised more. However, this change in the acidity was not significantly ($P \geq 0.05$) important.

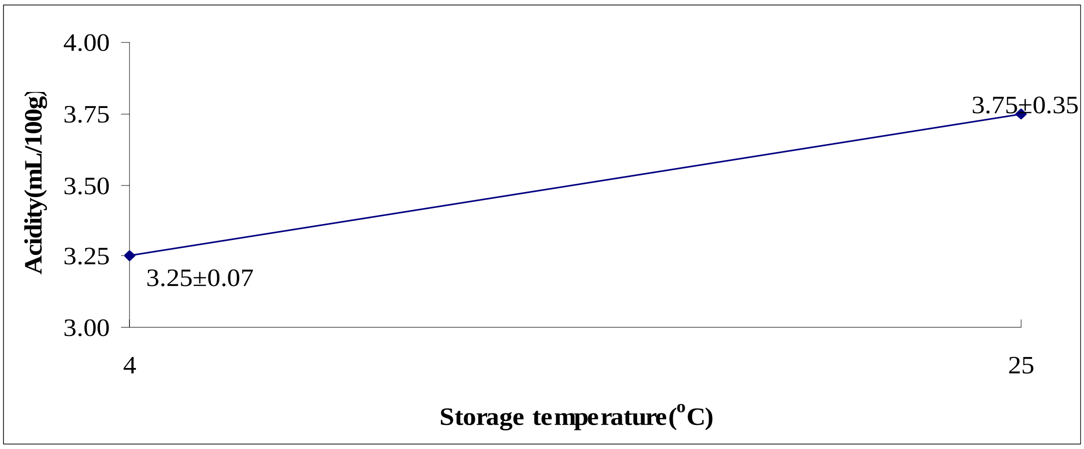

Figure 3.43. Acidity of coffee stored at different temperatures

It was observed by Bolzer, (2001), there was a big rise in the acidity. This result was approved that sensorial perceptible acid composition is a common incident during coffee getting stale. It was expressed by Perez-Martinez and Sopelono (2008), the acidity had the tendency to decrease during storing while it was high first. However, in this study, indicated that a wrong as initially it had been interpreted as the disappearance of the typical acidity of Arabica coffee that was replaced by a sour taste.

3.5.2. pH

It was seen that there was an increase in both coffees' pH as a result of staying at 25 and 4°C (Figure 3.44). This increase was more in coffee that had been kept in refrigerator temperature than the one that had been kept in room. pH was not significantly ($P \geq 0.05$) changed parallel to the acidity.

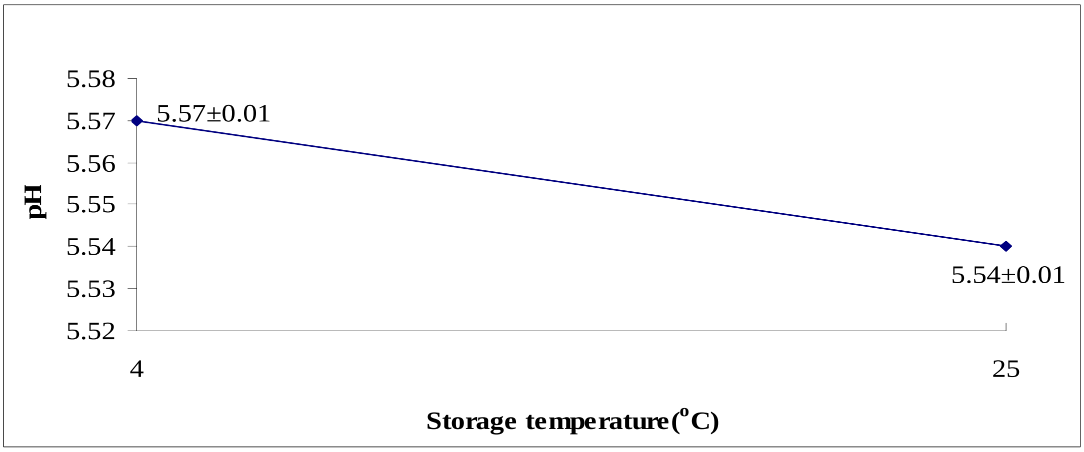

Figure 3.44. pH of coffee stored at different temperature

It was reported by Nicoli et al. (1991) that pH was decreased in both temperature degrees and the existence of oxygen had an effect in that situation but with the usage of nitrogen. pH was change slightly. The increase in pH might result in dissatisfaction of consumer and the more the storage time gets longer, the more pH decrease. In a study, it was observed that there was an important decrease in the pH with respect to the frame of hydrogen ions, during the deterioration of coffee in the storage process (Manzocco & Lagazio, 2009).

3.5.3. Color

After one month storage, it was observed that CIE L*, a*, b*, and YI was decreased gradually compared to coffee powder which was roasted 30 minutes at 350 W power and milled hammer type mill. However, it had been seen that this decrease in the sample that was kept in room temperature was more than the other sample. The reason for this could be the fact that light beams outside the room could be affect the color of coffee. CIE a*, b*, and YI were not significantly (P≥0.05) changed, but CIE L* was significantly P≤0.05) changed (Table 3.12).

Table 3.12 Color parameters of coffee powder stored at different temperatures

Temperature(^{o}C)	CIE L*	CIE a *	CIE b*	CIE YI
4	26.00±0.11	11.23±0.03	15.19±0.04	87.57±0.08
25	25.34±0.20	11.10±0.21	14.88±0.39	87.44±1.54

3.5.4. Foam Volume

Foam volume increased in both samples which was stored for one month compared to cooked coffee which was used tap water and cupper pot. This increase was observed as the rise from 3.35 to 3.5 stored sample in room temperature and 3.35 to 4.2 for refrigerator stored sample(Figure 3.45). Foam volume was significantly (P≤0.05) changed.

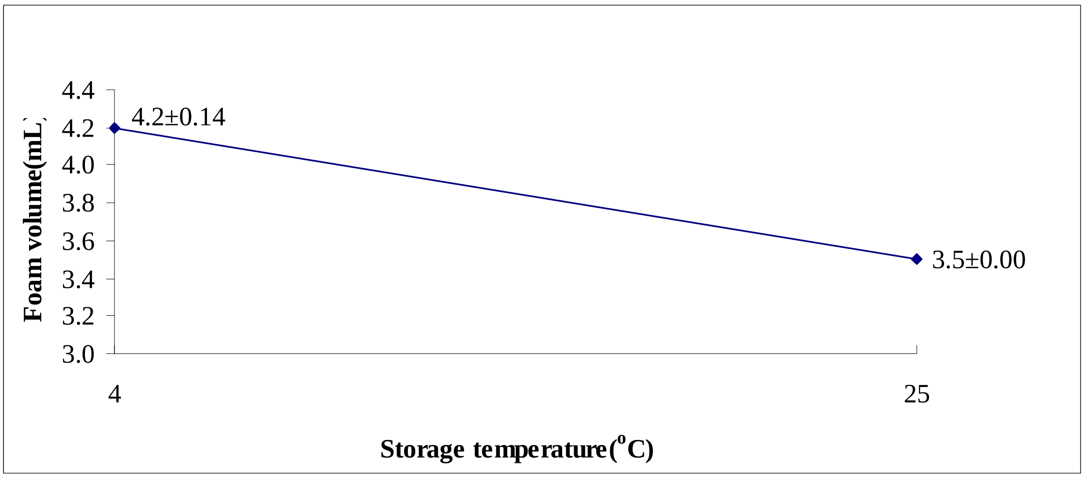

Figure 3.45. Foam volume of coffee stored at different temperatures

3.5.5. Foam Stability

The foam stability of coffee,which made in cupper pot was kept at 4°C and 25°C for one month, was decreased as a result of the storage. However, when the refrigeration and room temperatures were compared, it was noticed that the foam stability of the coffee was kept in refrigerator higher than the other one (Figure 3.46). Foam stability was significantly ($P \leq 0.05$) changed.

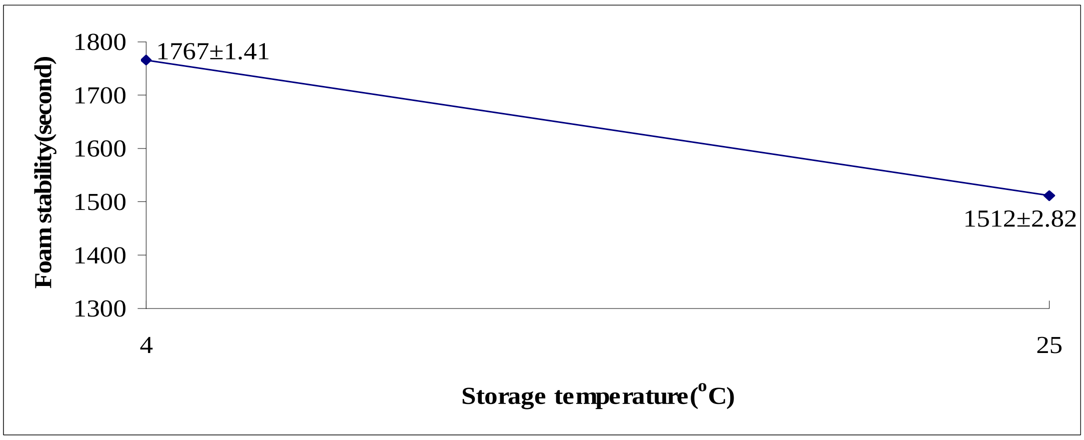

Figure 3.46. Foam stability of coffee stored at different temperature

CHAPTER IV

CONCLUSION

1. The moisture content of green coffee was measured as 7.16 %
2. In the roasting operation, microwave roasted coffee showed that at 350 W for 10 and 20 min was not enough and roasting process failed.
3. It was found that the coffee which roasted with microwave and conventional oven method affected moisture content significantly. When temperature and power increased, the moisture content of roasted coffee decreased, but roasting process with infrared method by increasing temperature and power was not significantly changed the moisture content.
4. The acidity was significantly affected by microwave roasting method but infrared and conventional oven methods did not affect the acidity of coffee.
5. In all roasting methods, when temperature and power were increased, the acidity of coffee decreased.
6. It was found that the coffee which was roasted with microwave and conventional oven methods affected the pH, significantly. When temperature and power increased, the pH of roasted coffee decreased, but roasting process with infrared method by increasing the power, pH did not significantly change.
7. In all roasting processes, the increasing the temperature and power caused darkening of coffee, therefore the color changed.
8. The soluble solid content of roasted coffee did not significantly change.
9. The coffee which was roasted with microwave roasting and then hammer and cutter type milled, the change of angle of repose was significantly affected, but the coffee which was roasted with infrared and conventional oven roasting and milled with hammer and cutter type mills, the change of angle of repose was not significantly affected. This result showed that increasing temperature and power of roasting methods have little effect on angle of repose.
10. The coffee which was roasted with microwave roasting and milled with hammer type and cutter type mills, the change of color was significantly affected.

11. The coffee which was roasted with infrared roasting and cutter type mill, CIE L*, a*, b* and YI decreased. For hammer type mill, the increasing power and time of roasting process affected the color change, significantly.

12. The coffee which was roasted with conventional oven roasting method and milled hammer type and cutter type mills, the increasing the temperature, CIE L* was affected significantly, but CIE a*,b* and YI were not affected significantly.

13. After infrared and conventional oven roasting method, coffee milled with hammer and cutter type mills, it was observed that increasing power and time of roasting caused the decreasing of bulk density.

14. According to analysis, the best roasting method was found as microwave 350 W for 30 min and the best milling process was found for cutter type mill.

15. Cupper pot cooking coffee with distilled water: When the initial distilled water temperature was increased, the soluble solid content increased but it was insignificantly.

16. When the initial distilled water temperature was increased, the foam volume and stability decreased significantly.

17. Cupper pot cooking coffee with tap water: When the initial tap water temperature was increased, the soluble solid content increased but, foam volume and stability decreased. This change observed as significantly.

18. Electrical pot cooking coffee with distilled water: When the initial distilled water temperature was increased, the soluble solid content increased but, foam volume and stability decreased. According to the statistical result, it was found that soluble solid content, foam volume and stability was significantly changed.

19. Electrical pot cooking coffee with tap water: When the initial tap water temperature was increased, the soluble solid content increased but, foam volume and stability decreased.

20. According to the analysis, the used 4^{o}C of initial water in this process provided the best foam volume and stability. In both type of water, foam stability was higher in cupper pot than electrical pot.

21. In cooking process, when the temperature of initial water was 4^{o}C, the foam stability was maximum for distilled water and electrical pot.

22. The acidity of roasted coffee increased by room and refrigeration temperature but this increasing acidity in room temperature was higher than refrigeration storage.

23. The change in the pH of roasted coffee was increased by both room and refrigeration temperature, but this change was not significantly.

24. In both storage conditions, CIE L*, a*, b* and YI decreased.

25. Foam stability and volume significantly changed in both storage conditions but the coffee which was stored at refrigeration temperature has higher foam volume and stability.

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APPENDIX A

1. DATA OF MICROWAVE ROASTING

a) Color

POWER(W)	TIME (min)	RUN 1 CIE L*	RUN 2 CIE L*	RUN 3 CIE L*	RUN 4 CIE L*	AVERAGE	STANDART DEVIATION
700	10	28.89	27.94	27.11	28.20	28.0350	0.735504
700	20	23.66	24.36	24.05	23.14	23.8025	0.526395
700	30	20.04	20.03	20.31	21.07	20.3625	0.489174
490	10	33.22	36.62	36.91	37.39	36.0350	1.903339
490	20	22.39	25.51	24.86	22.57	23.8325	1.585820
490	30	23.98	23.71	23.37	24.05	23.7775	0.308693
350	30	32.54	34.06	34.58	31.84	33.2550	1.280247

POWER(W)	TIME (min)	RUN 1 CIE a*	RUN 2 CIE a*	RUN 3 CIE a*	RUN 4 CIE a*	AVERAGE	STANDART DEVIATION
700	10	7.66	6.89	7.44	7.55	7.3850	0.342004
700	20	5.89	5.70	6.07	5.75	5.8525	0.165806
700	30	4.21	4.39	4.33	4.73	4.4150	0.222935
490	10	9.43	9.02	9.24	9.28	9.2425	0.169386
490	20	6.17	7.31	7.23	6.40	6.7775	0.577314
490	30	6.65	6.49	6.35	6.17	6.4150	0.204206
350	30	9.39	9.65	9.51	9.38	9.4825	0.126326

POWER(W)	TIME (min)	RUN 1 CIE b*	RUN 2 CIE b*	RUN 3 CIE b*	RUN 4 CIE b*	AVERAGE	STANDART DEVIATION
700	10	12.19	10.89	11.21	11.98	11.5675	0.617650
700	20	6.95	7.18	7.33	6.90	7.0900	0.201163
700	30	4.29	4.17	4.28	4.73	4.3675	0.247706
490	10	16.37	18.46	18.72	19.87	18.355	1.458275
490	20	7.82	9.79	9.77	8.20	8.8950	1.033650
490	30	8.42	7.68	7.79	7.45	7.8350	0.414930
350	30	16.45	17.43	17.73	16.55	17.040	0.636763

POWER(W)	TIME (min)	RUN 1 CIE YI	RUN 2 CIE YI	RUN 3 CIE YI	RUN 4 CIE YI	AVERAGE	STANDART DEVIATION
700	10	65.35	60.66	64.04	65.40	63.8625	2.225914
700	20	48.52	48.21	50.03	48.52	48.8200	0.819797
700	30	35.62	35.55	35.61	38.28	36.2650	1.343689
490	10	75.85	75.92	76.71	78.79	76.8175	1.371602
490	20	54.34	60.85	61.46	56.24	58.2225	3.482780
490	30	56.06	53.00	53.43	50.84	53.3325	2.142574
350	30	76.81	77.88	77.72	77.95	77.5900	0.528835

b)Moisture Content(grain)

POWER (W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	0.60	0.57	0.585	0.021213
700	20	0.35	0.42	0.385	0.049497
700	30	0.42	0.49	0.455	0.049497
490	10	1.45	1.88	1.665	0.304056
490	20	1.41	1.12	1.265	0.205061
490	30	1.13	1.24	1.185	0.077782
350	30	0.46	0.57	0.515	0.077782

c)Moisture Content(powder)

POWER(W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	0.91	1.41	1.160	0.353553
700	20	1.14	0.74	0.940	0.282843
700	30	1.00	0.78	0.890	0.155563
490	10	2.05	2.00	2.025	0.035355
490	20	1.96	1.62	1.790	0.240416
490	30	1.52	1.77	1.645	0.176777
350	30	1.14	1.42	1.280	0.197990

d)Acidity

POWER(W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	1.7	1.9	1.80	0.141421
700	20	1.5	1.8	1.65	0.212132
700	30	1.0	1.3	1.15	0.212132
490	10	2.0	2.0	2.00	0.000000
490	20	2.5	3.5	3.00	0.707107
490	30	2.5	2.2	2.35	0.212132
350	30	2.5	2.5	2.50	0.000000

e)pH

POWER (W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	5.48	6.11	5.455	0.021213
700	20	5.64	5.58	5.610	0.042426
700	30	6.14	5.43	6.125	0.035355
490	10	5.45	6.01	5.445	0.014142
490	20	5.53	5.53	5.530	0.000000
490	30	5.99	5.44	6.000	0.007071
350	30	5.43	5.41	5.420	0.014142

f) Soluble Solid Content

POWER (W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	0.05	0.06	0.055	0.007071
700	20	0.03	0.04	0.035	0.007071
700	30	0.06	0.04	0.050	0.014142
490	10	0.04	0.05	0.045	0.007071
490	20	0.03	0.05	0.040	0.014142
490	30	0.04	0.08	0.060	0.028284
350	30	0.05	0.07	0.060	0.014142

2) ANOVA for coffee roasted microwave
a) Color

	COLOR	S. of Squ.	Df	M. Squ	F value	Significant
L*	Between Groups	786.096	6	131.016	102.709	.000
	Within Groups	26.788	21	1.276		
	Total	812.884	27			
a*	Between Groups	78.737	6	13.123	149.657	.000
	Within Groups	1.841	21	.088		
	Total	80.578	27			
YI	Between Groups	5357.647	6	892.941	237.542	.000
	Within Groups	78.941	21	3.759		
	Total	5436.588	27			
b*	Between Groups	656.549	6	109.425	179.977	.000
	Within Groups	12.768	21	.608		
	Total	669.316	27			

L* Duncan

COLOR	N	Subset for alpha = 0.05				
		1	2	3	4	5
3	4	20.3625				
6	4		23.7775			
2	4		23.8025			
5	4		23.8325			
1	4			28.0350		
7	4				33.2550	
4	4					36.0350
Sig.		1.000	.949	1.000	1.000	1.000

a* Duncan

COLOR	N	Subset for alpha = 0.05				
		1	2	3	4	5
3	4	4.4150				
2	4		5.8525			
6	4			6.4150		
5	4			6.7775		
1	4				7.3850	
4	4					9.2425
7	4					9.4825
Sig.		1.000	1.000	.098	1.000	.265

YI Duncan

COLOR	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
3	4	36.2650					
2	4		48.8200				
6	4			53.3325			
5	4				58.2225		
1	4					63.8625	
4	4						76.8175
7	4						77.5900
Sig.		1.000	1.000	1.000	1.000	1.000	.579

b* Duncan							
COLOR	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
3	4	4.3675					
2	4		7.0900				
6	4		7.8350	7.8350			
5	4			8.8950			
1	4				11.5675		
7	4					17.0400	
4	4						18.3550
Sig.		1.000	.191	.068	1.000	1.000	1.000

b) Moisture content (grain)

Moisture content (grain)	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	3.004	6	.501	23.062	.000
Within Groups	.152	7	.022		
Total	3.156	13			

m.c.grain Duncan

POWER (W)	N	Subset for alpha = 0.05		
		1	2	3
2	2	.3850		
3	2	.4550		
7	2	.5150		
1	2	.5850		
6	2		1.1850	
5	2		1.2650	
4	2			1.6650
Sig.		.239	.604	1.000

c) Moisture content (powder)

Moisture content (powder)	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	2.292	6	.382	7.453	.009
Within Groups	.359	7	.051		
Total	2.650	13			

m.c.powder Duncan

power	N	Subset for alpha = 0.05			
		1	2	3	4
3	2	.8900			
2	2	.9400			
1	2	1.1600	1.1600		
7	2	1.2800	1.2800	1.2800	
6	2		1.6450	1.6450	1.6450
5	2			1.7900	1.7900
4	2				2.0250
Sig.		.147	.078	.067	.150

d) Acidity

Acidity	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	4.089	6	.681	7.282	.010
Within Groups	.655	7	.094		
Total	4.744	13			

Acidity Duncan

POWER (W)	N	Subset for alpha = 0.05		
		1	2	3
3	2	1.1500		
2	2	1.6500	1.6500	
1	2	1.8000	1.8000	
4	2		2.0000	
7	2		2.2000	
6	2		2.3500	2.3500
5	2			3.0000
Sig.		.080	.070	.071

e) pH

pH	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.994	6	.166	293.527	.000
Within Groups	.004	7	.001		
Total	.998	13			

pH Duncan

POWER (W)	N	Subset for alpha = 0.05				
		1	2	3	4	5
7	2	5.4200				
6	2	5.4450				
3	2	5.4550				
5	2		5.5300			
2	2			5.6100		
4	2				6.0000	
1	2					6.1250
Sig.		.199	1.000	1.000	1.000	1.000

f) Soluble solid content

Solublesolid	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.001	6	.000	.860	.565
Within Groups	.002	7	.000		
Total	.003	13			

Solublesolid Duncan

POWER (W)	N	Subset for alpha = 0.05
		1
2	2	.0350
5	2	.0400
4	2	.0450
3	2	.0500
1	2	.0550
6	2	.0600
7	2	.0600
Sig.		.159

3) DATA of coffee roasted microwave and milled cutter type milling

a)Color

POWER (W)	TIME (min)	RUN 1 CIE b*	RUN 2 CIE b*	RUN 1 CIE YI	RUN 2 CIE YI	AVERAGE CIE b*	AVERAGE CIE YI	STANDART DEVIATION CIE b*	STANDART DEVIATION CIE YI
700	10	13.63	13.32	83.54	82.06	13.475	82.800	0.219203	1.046518
700	20	9.22	9.37	68.97	68.71	9.295	68.840	0.106066	0.183848
700	30	7.19	6.83	59.16	57.74	7.010	58.450	0.254558	1.004092
490	10	22.56	21.15	94.82	93.58	21.855	94.200	0.997021	0.876812
490	20	8.83	8.89	66.76	66.58	8.860	66.670	0.042426	0.127279
490	30	10.75	10.53	76.56	72.97	10.640	74.765	0.155563	2.538513
350	30	20.90	21.17	90.04	90.17	21.035	90.105	0.190919	0.091924

POWER (W)	TIME (min)	RUN 1 CIE L*	RUN 2 CIE L*	RUN 1 CIE a*	RUN 2 CIE a*	AVERAGE CIE L*	AVERAGE CIE a*	STANDART DEVIATION CIE L*	STANDART DEVIATION CIE a*
700	10	25.27	25.77	11.00	11.15	25.520	11.075	0.353553	0.106066
700	20	21.86	22.23	9.20	9.11	22.045	9.155	0.26163	0.06364
700	30	20.54	20.78	7.94	8.09	20.660	8.015	0.169706	0.106066
490	10	34.42	34.46	12.82	12.5	34.440	12.660	0.028284	0.226274
490	20	24.08	22.28	9.07	8.98	23.180	9.025	1.272792	0.06364
490	30	22.69	23.86	10.34	10.07	23.275	10.205	0.827315	0.190919
350	30	32.24	32.22	13.44	13.31	32.230	13.375	0.014142	0.091924

b)Ash content

POWER (W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	3.544	3.548	3.5460	0.002828427
700	20	3.787	3.776	3.7815	0.007778175
700	30	3.647	3.640	3.6435	0.004949747
490	10	3.803	3.810	3.8065	0.004949747
490	20	3.786	3.781	3.7835	0.003535534
490	30	3.592	3.594	3.5930	0.001414214
350	30	3.571	3.567	3.5690	0.002828427

c)Bulk Density

POWER(W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	0.425900	0.42610	0.426000	0.000141
700	20	0.391407	0.39284	0.392124	0.001013
700	30	0.402870	0.39850	0.400685	0.003090
490	10	0.434880	0.43366	0.434270	0.000863
490	20	0.410261	0.41102	0.410641	0.000537
490	30	0.407200	0.41030	0.408750	0.002192
350	30	0.439000	0.43860	0.438800	0.000283

d)Angle of repose

POWER (W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	24.5	24.5	24.50	0.000000000
700	20	25.0	26.0	25.50	0.707106781
700	30	25.5	26.0	25.75	0.353553391
490	10	25.5	26.0	25.75	0.353553391
490	20	26.0	25.5	25.75	0.353553391
490	30	26.0	26.0	26.00	0.000000000
350	30	21.5	22.0	21.75	0.353553391

4) ANOVA for coffee roasted microwave and milled cutter type milling

a) Color

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
L*	Between Groups	500.928	6	83.488	328.348	.000
	Within Groups	3.560	14	.254		
	Total	504.488	20			
a*	Between Groups	71.959	6	11.993	272.751	.000
	Within Groups	.616	14	.044		
	Total	72.575	20			
YI	Between Groups	3050.625	6	508.437	610.928	.000
	Within Groups	11.651	14	.832		
	Total	3062.276	20			
b*	Between Groups	611.559	6	101.927	413.791	.000
	Within Groups	3.449	14	.246		
	Total	615.008	20			

L* Duncan

POWER (W)	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
3	3	20.7100					
2	3		22.0400				
5	3		22.8600	22.8600			
6	3			23.4233			
1	3				25.6000		
7	3					32.2300	
4	3						34.2433
Sig.		1.000	.066	.193	1.000	1.000	1.000

a* Duncan

POWER (W)	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
3	3	7.9867					
5	3		8.9667				
2	3		9.1367				
6	3			10.2267			
1	3				11.3433		
4	3					12.5933	
7	3						13.3800
Sig.		1.000	.338	1.000	1.000	1.000	1.000

YI Duncan

POWER (W)	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
3	3	58.5933					
5	3		67.0000				
2	3		68.4433				
6	3			74.9267			
1	3				82.7100		
7	3					90.3167	
4	3						94.0833
Sig.		1.000	.073	1.000	1.000	1.000	1.000

b* Duncan

POWER (W)	N	Subset for alpha = 0.05				
		1	2	3	4	5
3	3	7.0767				
5	3		8.9867			
2	3		9.1967			
6	3			10.7267		
1	3				13.5500	
7	3					21.0200
4	3					21.2767
Sig.		1.000	.612	1.000	1.000	.537

b) Ash content

Ashcontent	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.156	6	.026	4.9163	.000
Within Groups	.000	7	.000		
Total	.156	13			

Ashcontent Duncan

POWER (W)	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
1	2	3.5460					
7	2		3.5695				
6	2			3.5910			
3	2				3.6485		
5	2					3.7870	
2	2					3.7890	
4	2						3.8050
Sig.		1.000	1.000	1.000	1.000	.413	1.000

c) Bulk density

Bulkdensity	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.004	6	.001	258.783	.000
Within Groups	.000	7	.000		
Total	.004	13			

Bulkdensity Duncan

POWER (W)	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
2	2	.3921000					
3	2		.4006850				
6	2			.4087500			
5	2			.4106100			
1	2				.4260000		
4	2					.4342400	
7	2						.4388000
Sig.		1.000	1.000	.266	1.000	1.000	1.000

d) Angle of repose

Angleofrepose	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	27.500	6	4.583	32.083	.000
Within Groups	1.000	7	.143		
Total	28.500	13			

Angleofrepose Duncan

POWER (W)	N	Subset for alpha = 0.05		
		1	2	3
7	2	21.750		
1	2		24.500	
2	2			25.500
3	2			25.750
4	2			25.750
5	2			25.750
6	2			26.000
Sig.		1.000	1.000	.252

5) DATA of coffee roasted microwave and milled hammer type milling

a) Ash content

POWER(W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	3.621	3.619	3.6200	0.001414
700	20	4.094	4.065	4.0795	0.020506
700	30	3.978	3.988	3.9830	0.007071
490	10	3.614	3.610	3.6120	0.002828
490	20	3.626	3.622	3.6240	0.002828
490	30	3.546	3.548	3.5470	0.001414
350	30	3.723	3.729	3.7260	0.004243

b) Bulk density

POWER (W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	0.461788	0.46510	0.463444	0.002342
700	20	0.381389	0.38200	0.381695	0.000432
700	30	0.411520	0.41183	0.411675	0.000219
490	10	0.496014	0.49783	0.496922	0.001284
490	20	0.420354	0.42380	0.422077	0.002437
490	30	0.418920	0.41783	0.418375	0.000771
350	30	0.459600	0.45897	0.459285	0.000445

c) Angle of repose

POWER (W)	TIME (min)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
700	10	26.50	26.00	26.25	0.353553
700	20	26.50	25.50	26.00	0.707107
700	30	26.50	26.50	26.50	0.000000
490	10	26.00	27.00	26.50	0.707107
490	20	26.50	26.75	26.75	0.000000
490	30	26.50	27.50	27.00	0.707107
350	30	25.00	24.50	24.75	0.353553

d)Color

POWER (W)	TIME (min)	RUN 1 CIE L*	RUN 2 CIE L*	RUN 1 CIE a*	RUN 2 CIE a*	Av. CIE L*	Av. CIE a*	STANDART DEVIATION CIE L*	STANDART DEVIATION CIE a*
700	10	23.97	23.61	8.59	8.67	23.790	8.630	0.254558	0.056569
700	20	20.72	20.65	7.57	7.66	20.685	7.615	0.049497	0.063640
700	30	18.86	18.78	6.75	7.00	18.820	6.875	0.056569	0.176777
490	10	30.69	31.13	10.84	10.87	30.910	10.855	0.311127	0.021213
490	20	18.56	18.57	7.45	7.51	18.565	7.480	0.007071	0.042426
490	30	19.72	19.67	8.31	8.38	19.695	8.345	0.035355	0.049497
350	30	26.91	26.87	11.16	11.14	26.890	11.150	0.028284	0.014142

POWER (W)	TIME (min)	RUN 1 CIE b*	RUN 2 CIE b*	AVERAGE	STANDART DEVIATION
700	10	11.66	11.35	11.505	0.219203
700	20	8.82	9.24	9.030	0.296985
700	30	7.05	6.87	6.960	0.127279
490	10	18.43	18.25	18.340	0.127279
490	20	8.47	8.45	8.460	0.014142
490	30	9.69	9.67	9.680	0.014142
350	30	17.06	17.12	17.090	0.042426

6. ANOVA for coffee roasted microwave and milled hammer type milling

a) Ash content

Ashcontent	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.512	6	.085	1.1753	.000
Within Groups	.001	7	.000		
Total	.512	13			

Ashcontent Duncan

POWER (W)	N	Subset for alpha = 0.05				
		1	2	3	4	5
6	2	3.54700				
4	2		3.61200			
1	2		3.62000			
5	2		3.62400			
7	2			3.72600		
3	2				3.98300	
2	2					4.07950
Sig.		1.000	.217	1.000	1.000	1.000

b) Bulk density

Bulkdensity	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.018	6	.003	1.4983	.000
Within Groups	.000	7	.000		
Total	.018	13			

Bulkdensity Duncan

POWER (W)	N	Subset for alpha = 0.05						
		1	2	3	4	5	6	7
2	2	.38169450						
3	2		.41167500					
6	2			.41837500				
5	2				.42207700			
7	2					.45928500		
1	2						.46344400	
4	2							.49692200
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000

c) Angle of repose

Angleofrepose	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	9.929	6	1.655	8.424	.006
Within Groups	1.375	7	.196		
Total	11.304	13			

Angleofrepose Duncan

POWER (W)	N	Subset for alpha = 0.05	
		1	2
7	2	24.250	
2	2		26.000
1	2		26.250
3	2		26.500
5	2		26.500
4	2		26.750
6	2		27.000
Sig.		1.000	.074

d) Color

	Color	S. of Squ.	Df	M. Squ	F value	Significant
L*	Between Groups	262.723	6	43.787	1.8103	.000
	Within Groups	.169	7	.024		
	Total	262.893	13			
a*	Between Groups	33.547	6	5.591	923.069	.000
	Within Groups	.042	7	.006		
	Total	33.589	13			
b*	Between Groups	242.695	6	40.449	1.3863	.000
	Within Groups	.204	7	.029		
	Total	242.900	13			

L* Duncan

POWER (W)	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
5	2	18.5650					
3	2	18.8200					
6	2		19.6950				
2	2			20.6850			
1	2				23.7900		
7	2					26.8900	
4	2						30.9100
Sig.		.145	1.000	1.000	1.000	1.000	1.000

a* Duncan

POWER (W)	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
3	2	6.8750					
5	2		7.5000				
2	2		7.6150				
6	2			8.3450			
1	2				8.6300		
4	2					10.8550	
7	2						11.1600
Sig.		1.000	.183	1.000	1.000	1.000	1.000

b* Duncan

POWER (W)	N	Subset for alpha = 0.05						
		1	2	3	4	5	6	7
3	2	6.9600						
5	2		8.4600					
2	2			9.0300				
6	2				9.6800			
1	2					11.5050		
7	2						17.1500	
4	2							18.5900
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000

APPENDIX B

1. DATA of coffee roasted infrared

a) Color

POWER (W)	COLOR	RUN 1 CIE L*	RUN 2 CIE L*	RUN 3 CIE L*	AVERAGE	STANDART DEVIATION
600	CIE L*	27.96	28.11	31.50	29.19000	2.001924
600	CIE a*	8.15	7.87	7.64	7.886667	0.255408
600	CIE b*	13.46	13.57	16.01	14.34667	1.441539
600	CIE YI	71.69	71.18	73.15	72.00667	1.022464
1200	CIE L*	21.97	21.71	24.61	22.76333	1.604535
1200	CIE a*	6.78	6.52	6.67	6.656667	0.130512
1200	CIE b*	9.16	9.15	9.20	9.170000	0.026458
1200	CIE YI	61.8	61.55	58.23	60.52667	1.992896

b)Moisture content (powder)

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	1.24	1.245	1.24	0.007071
1200	1.71	1.710	1.71	0.000000

c) Moisture content (grain)

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	0.628	0.592	0.61	0.025456
1200	0.500	0.560	0.53	0.042426

d) Acidity

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	2.8	2.7	2.75	0.070711
1200	2.8	2.5	2.65	0.212132

e) pH

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	6.39	6.38	6.385	0.007071
1200	6.39	6.39	6.390	0.000000

f) Soluble solid content

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	0.05	0.04	0.045	0.007071
1200	0.04	0.07	0.055	0.021213

2. ANOVA for coffee roasted infrared

a) Color

	Color	S. of Squ.	Df	M. Squ	F value	Significant
L*	Between Groups	61.953	1	61.953	18.824	.012
	Within Groups	13.164	4	3.291		
	Total	75.118	5			
a*	Between Groups	2.269	1	2.269	55.171	.002
	Within Groups	.165	4	.041		
	Total	2.434	5			
b*	Between Groups	40.197	1	40.197	38.674	.003
	Within Groups	4.157	4	1.039		
	Total	44.354	5			
YI	Between Groups	197.686	1	197.686	78.805	.001
	Within Groups	10.034	4	2.509		
	Total	207.720	5			

c) m.c. powder

m.c.powder	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.223	1	.223	.493	.555
Within Groups	.906	2	.453		
Total	1.129	3			

c) Moisture content (grain)

m.c.grain	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.006	1	.006	5.229	.150
Within Groups	.002	2	.001		
Total	.009	3			

d) Acidity

Acidity	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.010	1	.010	.400	.592
Within Groups	.050	2	.025		
Total	.060	3			

e) pH

Ph	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.000	1	.000	1.000	.423
Within Groups	.000	2	.000		
Total	.000	3			

f) Soluble solid content

Solublesolid	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.000	1	.000	.400	.592
Within Groups	.001	2	.000		
Total	.001	3			

3. DATA of coffee roasted infrared and milled cutter type milling
a)Color

POWER (W)	COLOR	RUN 1 CIE L*	RUN 2 CIE L*	RUN 3 CIE L*	AVERAGE	STANDART DEVIATION
600	CIE L*	28.40	28.46	28.53	28.46333	0.065064
600	CIE a*	12.80	12.46	12.35	12.53667	0.234592
600	CIE b*	17.52	16.84	16.59	16.98333	0.481283
600	CIE YI	93.67	90.91	89.91	91.49667	1.947443
1200	CIE L*	23.12	24.72	25.62	24.48667	1.266228
1200	CIE a*	13.08	12.39	12.03	12.50000	0.533573
1200	CIE b*	17.35	15.24	14.99	15.86000	1.296418
1200	CIE YI	104.14	92.99	89.61	95.58000	7.603374

b) Angle of repose

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	25.0	25.5	25.25	0.353553
1200	25.5	26.0	25.75	0.353553

c) Bulk density

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	0.551	0.5480	0.54950	0.002121
1200	0.532	0.5379	0.53495	0.004172

d) Ash content

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	3.629	3.534	3.5815	0.067175
1200	2.959	3.103	3.0310	0.101823

4. ANOVA for coffee roasted infrared and milled cutter type milling
a) Color

	Color	S. of Squ.	Df	M. Squ	F value	Significant
L*	Between Groups	23.721	1	23.721	29.511	.006
	Within Groups	3.215	4	.804		
	Total	26.936	5			
a*	Between Groups	.002	1	.002	.012	.918
	Within Groups	.679	4	.170		
	Total	.681	5			
b*	Between Groups	1.893	1	1.893	1.980	.232
	Within Groups	3.825	4	.956		
	Total	5.717	5			
YI	Between Groups	25.010	1	25.010	.812	.418
	Within Groups	123.208	4	30.802		
	Total	148.218	5			

b) Angle of repose

Angleofrepose	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.250	1	.250	2.000	.293
Within Groups	.250	2	.125		
Total	.500	3			

c) Bulk density

Bulkdensity	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.000	1	.000	19.329	.048
Within Groups	.000	2	.000		
Total	.000	3			

d) Ash content

Ashcontent	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.303	1	.303	40.731	.024
Within Groups	.015	2	.007		
Total	.318	3			

5. DATA of coffee roasted infrared and milled hammer type milling

a) Color

POWER (W)	COLOR	RUN 1 CIE L*	RUN 2 CIE L*	RUN 3 CIE L*	AVERAGE	STANDART DEVIATION
600	CIE L*	29.79	29.94	29.00	29.57667	0.505008
600	CIE a*	12.79	12.40	12.15	12.44667	0.322542
600	CIE b*	18.52	17.98	16.85	17.78333	0.852193
600	CIE YI	93.74	91.27	89.25	91.42000	2.248755
1200	CIE L*	25.28	25.78	25.02	25.36000	0.386264
1200	CIE a*	11.33	10.89	10.64	10.95333	0.349333
1200	CIE b*	14.14	13.20	12.31	13.21667	0.915114
1200	CIE YI	85.86	81.10	78.27	81.74333	3.835679

b)Ash content

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	2.899	2.966	2.9325	0.047376
1200	2.833	2.982	2.9075	0.105359

c)Angle of repose

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	26	27.5	26.75	1.060660
1200	27	26.5	26.75	0.353553

d) Bulk density

POWER (W)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
600	0.4724	0.4590	0.46570	0.009475
1200	0.4460	0.4103	0.42815	0.025244

6. ANOVA for coffee roasted infrared and milled hammer type milling
a) Color

	COLOR	S. of Squ.	Df	M. Squ	F value	Significant
L*	Between Groups	26.670	1	26.670	131.956	.000
	Within Groups	.808	4	.202		
	Total	27.479	5			
a*	Between Groups	3.650	1	3.650	24.169	.008
	Within Groups	.604	4	.151		
	Total	4.255	5			
b*	Between Groups	31.282	1	31.282	40.011	.003
	Within Groups	3.127	4	.782		
	Total	34.409	5			
YI	Between Groups	140.457	1	140.457	14.210	.020
	Within Groups	39.539	4	9.885		
	Total	179.995	5			

b) Angle of repose

Angleofrepose	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.000	1	.000	.000	1.000
Within Groups	1.250	2	.625		
Total	1.250	3			

c) Bulk density

Bulkdensity	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.001	1	.001	3.879	.188
Within Groups	.001	2	.000		
Total	.002	3			

d) Ash content

Ashcontent	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.001	1	.001	.094	.788
Within Groups	.013	2	.007		
Total	.014	3			

APPENDIX C

1. DATA of coffee roasted oven

a) Color

TEMPERATURE (°C)	COLOR	RUN 1	RUN 2	RUN 3	AVERAGE	STANDART DEVIATION
160	CIE L*	28.51	28.32	29.56	28.79667	0.667857
160	CIE a*	8.28	8.43	8.84	8.516667	0.289885
160	CIE b*	15.14	15.57	16.16	15.62333	0.512087
160	CIE YI	76.21	78.06	78.97	77.74667	1.406426
180	CIE L*	28.29	29.35	29.89	29.17667	0.813962
180	CIE a*	8.77	8.70	8.56	8.676667	0.106927
180	CIE b*	16.10	15.89	16.38	16.12333	0.245832
180	CIE YI	80.41	78.09	78.40	78.96667	1.259537
200	CIE L*	27.75	27.53	28.64	27.97333	0.587736
200	CIE a*	8.05	7.80	7.82	7.890000	0.138924
200	CIE b*	13.63	13.76	14.55	13.98000	0.497896
200	CIE YI	72.33	72.39	73.36	72.69333	0.578129
220	CIE L*	24.49	25.03	24.64	24.72000	0.278747
220	CIE a*	6.95	7.00	7.04	6.996667	0.045092
220	CIE b*	10.79	11.56	10.97	11.10667	0.402782
220	CIE YI	64.80	66.82	65.45	65.69000	1.031164

b)Moisture Content(grain)

TEMPERATURE (°C)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	0.2620	0.2770	0.26950	0.010607
180	0.3266	1.0794	0.70300	0.532310
200	0.3894	0.6051	0.49725	0.152523
220	0.4536	0.4958	0.47470	0.029840

c)Moisture Content(powder)

TEMPERATURE (°C)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	0.6738	0.7650	0.71940	0.064488
180	2.3073	2.1980	2.25265	0.077287
200	1.3660	1.2543	1.31015	0.078984
220	1.1515	1.1090	1.13025	0.030052

d)Acidity

TEMPERATURE (°C)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	3.0	3.5	3.25	0.353553
180	2.8	3.1	2.95	0.212132
200	3.0	2.7	2.85	0.212132
220	3.0	2.1	2.55	0.636396

e)pH

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	5.64	5.69	5.665	0.035355
180	5.89	5.85	5.870	0.028284
200	5.75	5.76	5.755	0.007071
220	6.02	6.03	6.025	0.007071

f)Soluble Solid content

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	0.03	0.040	0.0350	0.007071
180	0.02	0.030	0.0250	0.007071
200	0.03	0.030	0.0300	0.000000
220	0.04	0.045	0.0425	0.003536

2. ANOVA for coffee roasted oven
a) Color

	Color	S. of Squ.	df	M. Squ	F value	Significant
L*	Between Groups	37.002	3	12.334	32.210	.000
	Within Groups	3.063	8	.383		
	Total	40.065	11			
b*	Between Groups	46.026	3	15.342	83.744	.000
	Within Groups	1.466	8	.183		
	Total	47.491	11			
YI	Between Groups	327.794	3	109.265	88.081	.000
	Within Groups	9.924	8	1.241		
	Total	337.718	11			
a*	Between Groups	5.226	3	1.742	59.658	.000
	Within Groups	.234	8	.029		
	Total	5.460	11			

L* Duncan

temperature	N	Subset for alpha = 0.05	
		1	2
4	3	24.7200	
3	3		27.9733
1	3		28.7967
2	3		29.1767
Sig.		1.000	.052

b* Duncan

temperature	N	Subset for alpha = 0.05		
		1	2	3
4	3	11.1067		
3	3		13.9800	
1	3			15.6233
2	3			16.1233
Sig.		1.000	1.000	.190

temperature	N	Subset for alpha = 0.05		
		1	2	3
4	3	65.6900		
3	3		72.6933	
1	3			77.7467
2	3			78.9667
Sig.		1.000	1.000	.217

a* Duncan

temperature	N	Subset for alpha = 0.05		
		1	2	3
4	3	6.9967		
3	3		7.8900	
1	3			8.5167
2	3			8.6767
Sig.		1.000	1.000	.285

b) m.c. grain

m.c.grain	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.188	3	.063	.817	.548
Within Groups	.308	4	.077		
Total	.496	7			

c) m.c. powder

m.c.powder	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	2.525	3	.842	194.868	.000
Within Groups	.017	4	.004		
Total	2.542	7			

m.c.powder Duncan

		Subset for alpha = 0.05		
		1	2	3
1	2	.719400		
4	2		1.1302500	
3	2		1.3101500	
2	2			2.2526500
Sig.		1.000	.052	1.000

m.c.grain Duncan

Temperature	N	Subset for alpha = 0.05
		1
1	2	.269500
4	2	.474700
3	2	.497250
2	2	.703000
Sig.		.198

d) Acidity

Acidity	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.500	3	.167	1.075	.454
Within Groups	.620	4	.155		
Total	1.120	7			

Acidity Duncan

Temperature	N	Subset for alpha = 0.05
		1
4	2	2.550
3	2	2.850
2	2	2.950
1	2	3.250
Sig.		.156

e) Soluble solid

Solublesolid	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.000	3	.000	3.963	.108
Within Groups	.000	4	.000		
Total	.000	7			

Solublesolid Duncan

temperature	N	Subset for alpha = 0.05	
		1	2
2	2	.02500	
3	2	.03000	.03000
1	2	.03500	.03500
4	2		.04250
Sig.		.138	.082

f) pH

pH	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.145	3	.048	89.884	.000
Within Groups	.002	4	.001		
Total	.147	7			

pH Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
1	2	5.6650			
3	2		5.7550		
2	2			5.8700	
4	2				6.0250
Sig.		1.000	1.000	1.000	1.000

3. Data of coffee roasted oven and milled cutter type milling

a) Color

TEMPERATURE (°C)	COLOR	RUN 1	RUN 2	RUN 3	AVERAGE	STANDART DEVIATION
160	CIE L*	33.92	33.86	33.82	33.86667	0.050332
160	CIE a*	14.26	14.17	14.18	14.20333	0.049329
160	CIE b*	22.76	22.71	22.53	22.66667	0.120968
160	CIE YI	99.97	99.83	99.45	99.75000	0.269072
180	CIE L*	31.64	31.88	31.19	31.57000	0.350286
180	CIE a*	14.20	14.23	14.09	14.17333	0.073711
180	CIE b*	21.48	21.42	21.21	21.37000	0.141774
180	CIE YI	100.8	100.43	100.71	100.6467	0.192959
200	CIE L*	28.97	29.56	29.61	29.38000	0.355949
200	CIE a*	13.23	13.21	13.19	13.21000	0.020000
200	CIE b*	17.98	18.09	18.09	18.05333	0.063509
200	CIE YI	94.89	94.10	93.87	94.28667	0.535008
220	CIE L*	22.26	23.51	23.77	23.18000	0.807279
220	CIE a*	12.07	11.47	11.25	11.59667	0.424421
220	CIE b*	15.14	13.77	13.37	14.09333	0.928242
220	CIE YI	96.74	88.52	86.18	90.48000	5.546134

b)Ash content

TEMPERATURE (°C)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	2.887	2.881	2.8840	0.004243
180	2.900	2.920	2.9100	0.014142
200	2.960	2.965	2.9625	0.003536
220	3.316	3.129	3.2225	0.132229

c)Bulk density

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	0.4900	0.4880	0.48900	0.001414
180	0.4846	0.4910	0.48780	0.004525
200	0.4815	0.4840	0.48275	0.001768
220	0.4328	0.4312	0.43200	0.001131

d)Angle of repose

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	25.5	25.0	25.25	0.353553
180	26.0	26.0	26.00	0.000000
200	26.0	25.5	25.75	0.353553
220	25.5	26.5	26.00	0.707107

4. Anova of coffee roasted oven and milled cutter type milling
a) Color

	Color	S. of Squ.	Df	M. Squ	F value	Significant
L*	Between Groups	189.928	3	63.309	280.244	.000
	Within Groups	1.807	8	.226		
	Total	191.736	11			
b*	Between Groups	132.073	3	44.024	195.578	.000
	Within Groups	1.801	8	.225		
	Total	133.874	11			
YI	Between Groups	206.165	3	68.722	8.823	.006
	Within Groups	62.311	8	7.789		
	Total	268.476	11			
a*	Between Groups	13.464	3	4.488	95.289	.000
	Within Groups	.377	8	.047		
	Total	13.841	11			

L* Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	3	23.1800			
3	3		29.3800		
2	3			31.5700	
1	3				33.8667
Sig.		1.000	1.000	1.000	1.000

b* Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	3	14.0933			
3	3		18.0533		
2	3			21.3700	
1	3				22.6667
Sig.		1.000	1.000	1.000	1.000

YI Duncan

temperature	N	Subset for alpha = 0.05	
		1	2
4	3	90.4800	
3	3	94.2867	
1	3		99.7500
2	3		100.6467
Sig.		.133	.704

a* Duncan

temperature	N	Subset for alpha = 0.05		
		1	2	3
4	3	11.5967		
3	3		13.2100	
2	3			14.1733
1	3			14.2033
Sig.		1.000	1.000	.870

b) Angle of repose

Angleofrepose	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.750	3	.250	1.333	.381
Within Groups	.750	4	.188		
Total	1.500	7			

Angleofrepose Duncan

Temperature	N	Subset for alpha = 0.05
		1
1	2	25.250
3	2	25.750
2	2	26.000
4	2	26.000
Sig.		.164

c) Bulk density

Bulkdensity	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.005	3	.002	223.277	.000
Within Groups	.000	4	.000		
Total	.005	7			

Bulkdensity Duncan

Temperature	N	Subset for alpha = 0.05	
		1	2
4	2	.43200	
3	2		.48275
2	2		.48780
1	2		.48900
Sig.		1.000	.077

d) Ash content

Ashcontent	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.145	3	.048	10.892	.021
Within Groups	.018	4	.004		
Total	.162	7			

Ashcontent Duncan

temperarure	N	Subset for alpha = 0.05	
		1	2
1	2	2.88400	
2	2	2.91000	
3	2	2.96250	
4	2		3.22250
Sig.		.310	1.000

5. Data of coffee roasted oven and milled hammer type milling
a)Angle of repose

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	27.0	26.0	26.50	0.707107
180	27.0	26.5	26.75	0.353553
200	25.5	26.5	26.00	0.707107
220	27.5	26.0	26.75	1.060660

b)Bulk density

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	0.532	0.531	0.5315	0.000707
180	0.518	0.511	0.5145	0.004950
200	0.483	0.479	0.4810	0.002828
220	0.428	0.420	0.4240	0.005657

c)Ash content

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
160	2.967	2.961	2.9640	0.004243
180	2.972	2.970	2.9710	0.001414
200	3.014	3.020	3.0170	0.004243
220	3.036	3.045	3.0405	0.006364

d)Color

TEMPERATURE (°C)	COLOR	RUN 1	RUN 2	RUN 3	AVERAGE	STANDART DEVIATION
160	CIE L*	32.55	32.15	32.46	32.38667	0.209841
160	CIE a*	13.52	13.41	13.54	13.49000	0.070000
160	CIE b*	21.93	21.23	22.02	21.72667	0.432474
160	CIE YI	98.81	97.71	99.14	98.55333	0.748755
180	CIE L*	31.05	31.58	31.71	31.44667	0.349619
180	CIE a*	14.53	14.28	14.07	14.29333	0.230290
180	CIE b*	24.39	23.59	22.35	23.44333	1.027878
180	CIE YI	108.61	105.61	102.40	105.5400	3.105592
200	CIE L*	28.56	27.96	28.31	28.27667	0.301386
200	CIE a*	13.27	12.89	12.90	13.02000	0.216564
200	CIE b*	18.99	17.96	18.23	18.39333	0.534072
200	CIE YI	98.18	95.72	95.92	96.60667	1.366211
220	CIE L*	23.30	22.64	23.50	23.14667	0.450037
220	CIE a*	10.35	10.12	10.74	10.40333	0.313422
220	CIE b*	12.37	12.02	12.45	12.28000	0.228692
220	CIE YI	81.26	80.54	82.25	81.35000	0.858545

6. ANOVA for coffee roasted oven and milled hammer type milling
a) Angle of repose

Angleofrepose	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.250	3	.083	.148	.926
Within Groups	2.250	4	.562		
Total	2.500	7			

Angleofrepose Duncan

Temperature	N	Subset for alpha = 0.05
		1
1	2	26.500
2	2	26.750
4	2	26.750
3	2	27.000
Sig.		.543

b) Bulk density

Bulkdensity	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.013	3	.004	276.482	.000
Within Groups	.000	4	.000		
Total	.014	7			

Bulkdensity Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	2	.42400			
3	2		.48100		
2	2			.51450	
1	2				.53150
Sig.		1.000	1.000	1.000	1.000

c) Ash content

Ashcontent	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.008	3	.003	137.654	.000
Within Groups	.000	4	.000		
Total	.008	7			

Ashcontent Duncan

temperature	N	Subset for alpha = 0.05		
		1	2	3
1	2	2.96400		
2	2	2.97100		
3	2		3.01700	
4	2			3.04050
Sig.		.189	1.000	1.000

d) Color

	Color	S. of Squ.	Df	M. Squ	F value	Significant
L*	Between Groups	156.307	3	52.102	453.425	.000
	Within Groups	.919	8	.115		
	Total	157.226	11			
a*	Between Groups	25.496	3	8.499	167.404	.000
	Within Groups	.406	8	.051		
	Total	25.902	11			
b*	Between Groups	218.095	3	72.698	183.918	.000
	Within Groups	3.162	8	.395		
	Total	221.257	11			
YI	Between Groups	934.713	3	311.571	97.298	.000
	Within Groups	25.618	8	3.202		
	Total	960.331	11			

L* Duncan

Temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	3	23.1467			
3	3		28.2767		
2	3			31.4467	
1	3				32.3867
Sig.		1.000	1.000	1.000	1.000

a* Duncan

Temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	3	10.4033			
3	3		13.0200		
1	3			13.4900	
2	3				14.2933
Sig.		1.000	1.000	1.000	1.000

b* Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	3	12.2800			
3	3		18.3933		
1	3			21.7267	
2	3				23.4433
Sig.		1.000	1.000	1.000	1.000

YI Duncan

temperature	N	Subset for alpha = 0.05		
		1	2	3
4	3	81.3500		
3	3		96.6067	
1	3		98.5533	
2	3			1.05542
Sig.		1.000	.219	1.000

APPENDIX D

1. Data of coffee cooked with electrical pot and distilled water
a)Foam stability

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	2890	2889	2889.5	0.707107
25	2483	2475	2479.0	5.656854
40	1931	1925	1928.0	4.242641
97	1796	1788	1792.0	5.656854

b)Foam volume

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	4.00	4.0	4.000	0.000000
25	3.00	3.0	3.000	0.000000
40	2.25	2.0	2.125	0.176777
97	1.00	1.2	1.100	0.141421

c)Soluble solid content

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	0.88	0.87	0.875	0.007071
25	0.92	0.91	0.915	0.007071
40	0.98	0.98	0.980	0.000000
97	1.01	1.02	1.015	0.007071

2. ANOVA for coffee cooked with electrical pot and distilled water

a) Foam stability

foamstability	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	1545782.375	3	515260.792	2.4984	.000
Within Groups	82.500	4	20.625		
Total	1545864.875	7			

Foamstability Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	2	1792.00			
3	2		1928.00		
2	2			2479.00	
1	2				2889.50
Sig.		1.000	1.000	1.000	1.000

b) Foam volume

ANOVA

Foamvolume

	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	9.176	3	3.059	238.724	.000
Within Groups	.051	4	.013		
Total	9.227	7			

Foamvolume Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	2	1.100			
3	2		2.125		
2	2			3.000	
1	2				4.000
Sig.		1.000	1.000	1.000	1.000

c) Soluble solid content

Soluble solid content	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.024	3	.008	211.889	.000
Within Groups	.000	4	.000		
Total	.024	7			

Soluble solid content Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
1	2	.8750			
2	2		.9150		
3	2			.9800	
4	2				1.0150
Sig.		1.000	1.000	1.000	1.000

3. Data of coffee cooked with electrical pot and fresh water
a)Foam stability

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	2718	2714	2716.0	2.828427
25	2472	2399	2435.5	51.61880
40	1980	1956	1968.0	16.97056
97	1594	1588	1591.0	4.242641

b)Foam volume

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	4.2	4.0	4.10	0.141421
25	3.5	3.3	3.40	0.141421
40	3.0	3.0	3.00	0.000000
97	1.5	1.6	1.55	0.070711

c)Soluble solid content

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	0.92	0.90	0.910	0.014142
25	0.99	0.97	0.980	0.014142
40	1.02	1.04	1.030	0.014142
97	1.07	1.06	1.065	0.007071

4. ANOVA for coffee which cooked electrical pot and fresh water
a) Foam stability

Foamstability	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	1488837.375	3	496279.125	666.482	.000
Within Groups	2978.500	4	744.625		
Total	1491815.875	7			

Foamstability Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	2	1591.00			
3	2		1968.00		
2	2			2435.50	
1	2				2716.00
Sig.		1.000	1.000	1.000	1.000

b) Foam volume

Foamvolume	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	6.944	3	2.315	205.741	.000
Within Groups	.045	4	.011		
Total	6.989	7			

Foamvolume Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	2	1.550			
3	2		3.000		
2	2			3.400	
1	2				4.100
Sig.		1.000	1.000	1.000	1.000

c) Soluble solid content

Soluble solid content	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.027	3	.009	55.667	.001
Within Groups	.001	4	.000		
Total	.028	7			

soluble solid content Duncan

temperature	N	Subset for alpha = 0.05		
		1	2	3
1	2	.9100		
2	2		.9800	
3	2			1.0300
4	2			1.0650
Sig.		1.000	1.000	.052

5. Data of coffee cooked with pot and distilled water
a)Foam stability

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	2472	2460	2466.0	8.485281
25	2113	2098	2105.5	10.60660
40	1974	1984	1979.0	7.071068
97	1463	1501	1482.0	26.87006

b)Foam volume

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	4.5	4.3	4.4	0.141421
25	3.0	3.0	3.0	0.000000
40	1.5	1.3	1.4	0.141421
97	1.0	1.0	1.0	0.000000

c)Soluble solid content

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	0.98	0.97	0.975	0.007071
25	1.01	1.00	1.005	0.007071
40	1.03	1.01	1.020	0.014142
97	1.10	1.30	1.200	0.141421

6. ANOVA for coffee cooked with pot and distilled water
a) Foam stability

Foamstability	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	993574.375	3	331191.458	1.3853	.000
Within Groups	956.500	4	239.125		
Total	994530.875	7			

Foamstability Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	2	1482.00			
3	2		1979.00		
2	2			2105.50	
1	2				2466.00
Sig.		1.000	1.000	1.000	1.000

b) Foam volume

Foamvolume	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	14.620	3	4.873	487.333	.000
Within Groups	.040	4	.010		
Total	14.660	7			

Foamvolume Duncan

temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	2	1.000			
3	2		1.400		
2	2			3.000	
1	2				4.400
Sig.		1.000	1.000	1.000	1.000

c) Soluble solid content

Soluble solid content	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.062	3	.021	4.079	.104
Within Groups	.020	4	.005		
Total	.082	7			

Soluble solid content Duncan

temperature	N	Subset for alpha = 0.05	
		1	2
1	2	.9750	
2	2	1.0050	1.0050
3	2	1.0200	1.0200
4	2		1.2000
Sig.		.566	.055

7. Data of coffee cooked with pot and fresh water
a)Foam stability

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	2553	2503	2528.0	35.35534
25	2032	2088	2060.0	39.59798
40	1751	1796	1773.5	31.81981
97	1598	1688	1643.0	63.63961

b)Foam volume

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	4.5	4.3	4.40	0.141421
25	3.5	3.2	3.35	0.212132
40	2.5	2.5	2.50	0.000000
97	1.5	1.4	1.45	0.070711

c)Soluble solid content

TEMPERATURE (^oC)	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
4	0.80	0.82	0.810	0.014142
25	0.83	0.83	0.830	0.000000
40	0.85	0.88	0.865	0.021213
97	1.17	1.11	1.140	0.042426

7. ANOVA for coffee cooked with pot and fresh water
a) Foam stability

Foamstability	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	922260.375	3	307420.125	156.041	.000
Within Groups	7880.500	4	1970.125		
Total	930140.875	7			

Foamstability Duncan

Temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	2	1643.00			
3	2		1773.50		
2	2			2060.00	
1	2				2528.00
Sig.		1.000	1.000	1.000	1.000

b) Foam volume

Foamvolume	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	9.425	3	3.142	179.524	.000
Within Groups	.070	4	.017		
Total	9.495	7			

Foamvolume Duncan

Temperature	N	Subset for alpha = 0.05			
		1	2	3	4
4	2	1.450			
3	2		2.500		
2	2			3.350	
1	2				4.400
Sig.		1.000	1.000	1.000	1.000

c) Soluble solid content

Soluble solid content	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.143	3	.048	77.626	.001
Within Groups	.002	4	.001		
Total	.145	7			

soluble solid content Duncan

Temperature	N	Subset for alpha = 0.05	
		1	2
1	2	.8100	
2	2	.8300	
3	2	.8650	
4	2		1.1400
Sig.		.095	1.000

APPENDIX E

1. Data of coffee stored at refrigeration (4^{o}C)

PROPERTIES	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
ACIDITY	3.30	3.20	3.25	0.070711
Ph	5.56	5.58	5.57	0.014142
FOAM VOLUME	4.10	4.30	4.20	0.141421
FOAM STABILITY	1766	1768	1767	1.414214

PROPERTIES	RUN 1	RUN 2	RUN 3	AVERAGE	STANDART DEVIATION
CIE L*	25.93	25.94	26.14	26.00333	0.118462
CIE a*	11.19	11.26	11.24	11.23000	0.036056
CIE b*	15.20	15.14	15.23	15.19000	0.045826
CIE YI	87.63	87.62	87.47	87.57333	0.089629

2. Data of coffee stored at room temperature (25^{o}C)

PROPERTIES	RUN 1	RUN 2	AVERAGE	STANDART DEVIATION
ACIDITY	3.50	4.00	3.75	0.353553
Ph	5.55	5.53	5.54	0.014142
FOAM VOLUME	3.50	3.50	3.50	0.000000
FOAM STABILITY	1510	1514	1512	2.828427

PROPERTIES	RUN 1	RUN 2	RUN 3	AVERAGE	STANDART DEVIATION
CIE L*	25.44	25.10	25.47	25.33667	0.205508
CIE a*	11.34	10.94	11.02	11.10000	0.211660
CIE b*	15.34	14.64	14.66	14.88000	0.398497
CIE YI	89.21	86.80	86.32	87.44333	1.548688

3. ANOVA for coffee which stored at refrigeration (4^{o}C) and room temperature (25^{o}C)

Ph	S. of Squ.	df	M. Squ	F value	Significant
Between Groups	.001	1	.001	4.500	.168
Within Groups	.000	2	.000		
Total	.001	3			

Acidity	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.250	1	.250	3.846	.189
Within Groups	.130	2	.065		
Total	.380	3			

color		S. of Squ.	Df	M. Squ	F value	Significant
L*	Between Groups	.667	1	.667	23.697	.008
	Within Groups	.113	4	.028		
	Total	.779	5			
b*	Between Groups	.144	1	.144	1.792	.252
	Within Groups	.322	4	.080		
	Total	.466	5			
YI	Between Groups	.025	1	.025	.021	.892
	Within Groups	4.813	4	1.203		
	Total	4.838	5			
a*	Between Groups	.025	1	.025	1.100	.353
	Within Groups	.092	4	.023		
	Total	.118	5			

Foamvolume	S. of Squ.	Df	M. Squ	F value	Significant
Between Groups	.490	1	.490	49.000	.020
Within Groups	.020	2	.010		
Total	.510	3			

foamstability

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	65025.000	1	65025.000	1.3004	.000
Within Groups	10.000	2	5.000		
Total	65035.000	3			

APPENDIX F

a) Green coffee

b) Microwave roasted coffee

c) Infrared roasted coffee

d) Oven roasted coffee

e) Microwave roasted and cutter type milled coffee

f) Microwave roasted and hammer type milled coffee

g) Infrared roasted and cutter type milled coffee

h) Infrared roasted and hammer type milled coffee

ı) Conventional oven roasted and cutter type milled coffee

k) Conventional oven roasted and hammer type milled coffee