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Full Length Research Paper

Processing method, variety and roasting duration effect on physical quality attributes of roasted Arabica coffee beans

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Coffee quality is affected by pre and post harvest practices. Among these practices, processing method and roasting are the main ones. Dry, washed and recently introduced semi-washed processing methods are common green coffee preparations in Ethiopia. Regardless of the processing method used, roasting is required to obtain typical coffee aroma from green coffee beans. However, comprehensive information on the effect of processing method, variety, roast duration and their interaction on final quality is not available. Hence, this study was conducted at Jimma Agricultural Research Centre to evaluate the impact of processing method, variety and roasting duration on physical quality attributes of roasted Arabica coffee during the 2011/2012 cropping season. It was designed in a factorial combination of three released coffee berry disease resistant coffee varieties, three processing methods and four roasting durations in completely randomized design with three replications. The physical quality attributes of roast weight loss, volume change, and bulk density of roasted coffee were recorded and the analysis was computed using general linear model procedures of SAS version 9.2. The result indicated that interaction of variety by roasting duration was highly significant (P<0.01) for roast volume change and bulk density of roasted coffee. The highest roast volume change (116.27%) was recorded for variety 744 roasted for 10 min and the minimum roast volume change (14.29%) was for variety 74110 roasted for six minutes. Variation on roast physical properties of Arabica coffee during roasting was profound for coffee quality. The result can be used to enhance cup quality of Arabica coffee aiming at roasting for different processing methods.

Key words: Arabica coffee, processing method, variety, weight loss, volume change, and bulk density.

INTRODUCTION

Arabica coffee has originated in Ethiopia where wild coffee trees are still the primary source of harvested coffee. As a matter of fact, Ethiopia is the only center of origin and diversity of Arabica coffee (Anthony et al., 2001). In addition, coffee is a truly global commodity and a major foreign exchange earner for many developing countries (Tadesse and Feyera, 2008). The vast majority of coffee is exported as green beans for roasting in consuming countries. Ethiopia plays an important role in the 'global value chain' because of the fine quality of its coffees (Solomon et al., 2008) but the total share of its coffee export in the world trade is small.

Coffee quality is generally affected by pre-harvest and post-harvest practices. Among these practices, processing method and roasting duration are the main ones. It is widely agreed that traditional hand picking, as opposed to mechanical harvest, produces the best quality green coffee due to the decreased percentage of defects in coffee batches. Beginning at the time of harvest, moisture is also a key factor in determining the final quality of coffee with its continuing influence on subsequent processing stages. It determines the amount of drying needed to stand the rigors of shipping and it is a principal economic factor due to weight loss of the green beans during storage and roasting (Robin, 2009).

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Moisture content can also influence the way coffee is roasted and the loss of weight during roasting.

Physical changes in coffee during roasting include reduction in mass due to loss of moisture and decomposition of carbohydrates, increase in volume of coffee beans, lowering of density due to puffing and increase in brittleness (Mwithiga and Jindal, 2003). The density of coffee continues to decrease rather slowly and appear to level off at the end of the roasting period (Illy and Viani, 1995). It is well known that during roasting, coffee beans lose their strength and toughness and become brittle and fragile (Pittia et al., 2007). Roasting is a decisive operation influencing coffee final quality. It is dependent on variables as coffee type, temperature and time. Though genetics, environmental management practices and soil type can affect coffee quality, there had not been much work on the effect of roasting duration on quality characteristics of Arabica coffee. Taking this fact into account, this research was designed to evaluate the impact of processing method and roasting duration on roast physical quality in selected Arabica coffee varieties.

METHODOLOGY

Sampling and processing method

The experiment was conducted at Jimma Agricultural Research Center (JARC), in the 2011/2012 cropping season, which is the National Coffee Research Coordinating Center in Ethiopia. Red fully mature cherry of three coffee berry disease (CBD) resistant varieties (744, 7440 and 74110) selected from the Centre's well established seed orchard of uniformly grown coffee trees having similar agronomic management was selectively harvested. Then each variety's red cherry was processed in three different methods (dry, wet and semi washed) as follows:

Dry processing

After removing foreign materials and unripe green berries by sorting, samples (6 kg per sample) were sun dried on raised compartmented mesh wire drying tables (about 0.8 m above the ground) and regularly turned to maintain uniform drying to moisture level of 11%. During drying, the moisture content of the bean was measured using Electronic Rapid Moisture Tester (HE 50, Germany) to know and maintain the moisture level of all samples at similar level. Finally, fully dried coffee cherries were collected and packed separately. Dried cherries were hulled using manual/hand hulling machine. The skin part of the husk with parchment was removed.

Wet processing

Six kilogram of fully ripe red cherries (per sample) were pulped using single disc manual pulper (IRIMA-67, England) which squeezes the cherries between fixed and moving surface. Subsequently wet parchment coffees were put in fermentation tank for 40 h to facilitate breakdown of mucilage. After complete fermentation, the parchment coffee was properly washed and soaked for a further 24 h (Woelore, 1993). This was followed by washing, using clean water to remove all traces of decomposed products of mucilage. Then, wet parchment coffee was sun dried on mesh wire raised bed. All defective coffee beans were manually removed. Drying was continuously monitored till the needed moisture content was achieved. The moisture content of the beans was uniformly maintained at 11% for all samples. Finally, the samples were hulled and hand polished to remove the parchment and silver skins from green coffee beans.

Semi washed processing

Similar to wet processing method, fully ripe red coffee cherries (six kg per sample) from each variety was pulped using single disc motorized pulper. Without fermentation, samples were washed using clean water to remove all traces of decomposed products of the mucilage and dried to 11% moisture content. The dried parchment was hulled using manual huller and subsequent cleaning was followed.

Roasting

A six cylinder roaster machine (Probat BRZ6, Welke, Von Gimborn Gmbhan Co. KG) was first heated to 200°C and then 100 g of green coffee beans per sample were put into the roasting cylinder. Samples were roasted for six, eight, ten and twelve minutes. During roasting, the roaster temperature was controlled at 200°C by adjusting the gas source for the heater. Immediately, the roasted coffee samples were put into a cooling tray to cool down rapidly by blowing cool air through a cooling plate. The loose silver skin of each cool roasted sample was removed by manual blowing.

The weight and volume of coffee beans were measured separately for each sample unit just before and after roasting in grams and volume in milliliter using 1000 ml graduated cylinder (Merck, Germany). Then, the recorded results were converted into percent of weight loss during roasting, percent of volume change after roasting and density of roasted coffee using the following equations:

Roast weight loss: This was determined by taking the weight of the green and roasted coffee beans before and after roasting respectively:

$$RWL = \frac{(WGC - WRC)}{WGC} \times 100. \quad 1$$

Table 1. Weight loss percentage of coffee affected by processing method, variety and roasting duration.

Factors	Level	Weight loss (%)
Processing method	Dry	15.64^{b}
	Semi-washed	16.97^{a}
	Washed	16.66^{a}
CV (%)		12.49
LSD (5%)		0.96
Variety	744	17.02a
	7440	15.52b
	74110	16.73a
CV (%)		12.49
LSD (5%)		0.96
Roasting duration	Six	8.48^{d}
	Eight	13.41^{c}
	Ten	19.06^{b}
	Twelve	24.74^{a}
CV (%)		12.49
LSD (5%)		1.11

Mean values followed by the same letter(s) within a column for a factor are not significantly different at P < 0.05.

Where: RWL = Roast weight loss, WGC = Weight of green coffee (gram), and WRC = Weight of roasted coffee (gram).

Roast volume change: This was determined by taking the volume of the green and roasted beans before and after roasting respectively using graduating cylinder:

$$RVC = \frac{(VRC - VGC) \times 100..}{VGC} \qquad 2$$

Where: RVC = Roast volume change, VRC = Volume of roasted coffee (milliliters), and VGC = Volume of green coffee (milliliters).

Bulk density of roasted coffee: To determine the density of roasted beans, first the weight of roasted beans was taken in grams and then divided by the volume of roasted coffee beans in milliliters. Its unit was gram per milliliters:

$$BDRC = \frac{WRC}{VRC} \ldots.. \qquad 3$$

Where: BDRC = Bulk density of roasted coffee, WRC = Weight of roasted coffee (gram) and VRC = Volume of roasted coffee (milliliters).

Analysis of variance (ANOVA) was carried out for each quality parameter in order to identify the variability among the factors based on the procedures described by Gomez and Gomez (1984). SAS statistical software Version 9.2 (SAS, 2008) was employed for ANOVA, in CRD with three replications. The factors were factorially combined and tested in completely randomized design (CRD) with three replications. Significant differences of the treatments were compared using Fisher's Least Significance Difference (LSD) at P<5% probability levels.

RESULTS AND DISCUSSION

Roast weight loss

The change in roast weight loss due to processing method, variety and roasting duration is shown in Table 1. The effect of preparation method was found to be highly significant (P<0.01) on roast weight loss. The maximum roast weight loss (16.97%) was recorded for coffee processed under semi washed followed by wet processed coffee (16.66%), and the minimum loss was recorded for dry processed coffee with a loss of 15.64%. The weight loss ranged from 15.64 to 16.97%. A report by Abera (2006) indicated that loss of weight due to evaporation of water and loss of volatile substances in coffee beans was in the range of 14 - 23%, which is in full agreement with the results obtained in this study.

Similarly, highly significant (P<0.01) roast weight loss was recorded among coffee varieties. The maximum roast weight loss (17.02%) was recorded for variety 744 followed by variety 74110 and 7440 with roast weight loss of 16.73% and 15.52% respectively. This indicates presence of varietal difference for the character studied. The result agrees with data presented by Mekonen (2009) indicating high variation in roast weight loss among coffee varieties during roasting. Thermally treated coffee had several physical changes including colour,

Table 2. Interaction effect of variety and roasting duration on roast volume change.

Variety	Roasting duration (minutes)	Roast volume change (%)
744	Six	18.70[f]
	Eight	80.93[d]
	Ten	116.27[a]
	Twelve	113.42[ab]
7440	Six	26.62[e]
	Eight	78.66[d]
	Ten	98.46[c]
	Twelve	106.90[b]
74110	Six	14.29[f]
	Eight	82.06[d]
	Ten	109.40[ab]
	Twelve	109.74[ab]
CV (%)		12.17
LSD (5%)		7.89

Mean values followed by the same letter(s) in the column are not significantly different at P < 0.05.

weight loss, volume, density and texture (Frisullo et al., 2010). In addition, reduction in mass due to loss of moisture and decomposition of carbohydrates occurs in coffee during roasting (Mwithiga and Jindal, 2003).

Moreover, the results revealed highly significant differences (P<0.01) in roast weight loss due to roasting duration. The minimum roast weight loss (8.48%) was recorded for six minutes and the maximum loss (24.74%) was recorded when coffee was roasted for 12 min (Table 1). The weight loss during the first six to eight minutes is due to the slow release of water and volatile components. The increase in weight loss after that time can be attributed to an intensive release of organic compounds and CO_2. In general, weight loss increased as the roasting duration increased. Coffee roasted for eight and ten minutes showed respective weight loss of 13.41% and 19.06%. This could be due to moisture and dry matter loss which leads to total weight loss of roasted coffee. Similar studies conducted elsewhere indicated total roasting loss of 10% and 25% dry matter and water respectively (Clifford, 1985). During roasting, the physical and chemical changes in coffee beans cause roast weight losses (Schenker et al., 2002; Oosterveld et al., 2003), and the extent of weight loss during roasting greatly depends on the roast duration.

Roast volume change

The variation in roast volume change is presented in Table 2. The interaction effect of variety by roasting duration on roast volume change was highly significant (P<0.01). The highest roast volume changes (116.27 and 109.40%) were recorded for roasting duration of 10 min for varieties 744 and 7410 respectively. In addition, with 12 min of roasting duration, 113.42 and 109.74% change in roast volume were observed for varieties 744 and 74110 respectively. However, the difference was not statistically significant (P>0.05). On the other hand, variety 74110 showed minimum percentage volume change (14.29%) at roasting duration for six minutes (Table 5). Except variety 744, all coffee varieties used in this study showed increasing roast volume change with increasing roasting duration. This finding indicated that as roasting duration increases beyond six minutes, roast volume change also increases to the maximum level and decreases after 10 min of roasting. There was no significant increment of volume after ten minutes of roasting. Moisture and dry matter loss during roasting creates creaked coffee bean and volume increment (Mekonen, 2009). Physical change in coffee beans during roasting leads to considerable expansion of beans (Clarke, 1985). In general, roast volume change may be due to chemical and physical changes in the coffee bean caused by heat energy. Physical changes in coffee during roasting include increase in volume of coffee beans (Mwithiga and Jindal, 2003; Abera, 2006).

Processing method also had a highly significant (P<0.01) effect on roast volume change. The highest roast volume change (83.83%) was observed for dry processed coffee, followed by semi washed coffee (79.46%) (Table 3). The minimum value was achieved for wet processed coffee (77.66%). Previous reports also indicate presence of variations in roast volume change in response to coffee processing methods (Mekonen, 2009).

Varietal difference for roast volume change was also highly significant. Varieties 744 and 74110 showed roast volume changes of 82.33 and 78.87% respectively. The minimum value (77.66%) was achieved for variety 7440. The increase in coffee bean volume results from the softening of the cellulose bean structure coupled with the increase in pressure from the release of pyrolysis

Table 3. Effect of processing method, variety and roasting duration on roast volume change.

Factors	Level	RVC	(%)
	Dry	83.83a	
Processing method	Semi-washed	79.46ab	
	Washed	75.57b	
CV (%)		12.17	
LSD (5%)		4.56	
	744	82.33a	
Variety	7440	77.66b	
	74110	78.87ab	
CV (%)		12.17	
LSD (5%)		4.56	
	Six	19.87c	
Roasting duration	Eight	80.55b	
	Ten	108.04a	
	Twelve	110.02a	
CV (%)		12.17	
LSD (5%)			5.26

Mean values followed by the same letter(s) in the column are not significantly different at P < 0.05.

Table 4. Effect of processing method, variety and roasting duration on bulk density roast coffee.

Factors	Level	Bulk density roasted coffee (gm/cm^3)
	Dry	0.35
Processing method	Semi-washed	0.35
	Washed	0.35
CV (%)		8.71
LSD (5%)		ns
	744	0.35
Variety	7440	0.35
	74110	0.35
CV (%)		8.71
LSD (5%)		Ns
	Six	0.53a
Roasting duration	Eight	0.34b
	Ten	0.27c
	Twelve	0.25d
CV (%)		8.71
LSD (5%)		0.016

Mean values followed by the same letter(s) in the column are not significantly different at P < 0.05.

products (Sivetz and Desrosier, 1979). Coffee beans lose their strength and toughness and become brittle and fragile during roasting, and expansion of coffee beans during roasting leads to considerable volume change (Pittia et al., 2007).

The data also revealed highly significant differences in roast volume change with roasting duration. Roast volume change was minimum in the first six minutes of roasting duration. The least volume change was 19.87% which was recorded at six minutes and the maximum value of 110.02% was recorded at 12 min of roasting duration (Table 3). The roast volume change increases as time of roasting duration increases. Similarly, Clarke (1985) and Frisullo et al. (2010) have reported the occurrence of volume change during coffee roasting due to gas expansion, as roasting creates a major change on physical properties of roasted coffee beans (Schenker et al., 2002; Oosterveld et al., 2003).

Bulk density of roasted coffee

The interaction of coffee variety and roasting duration on bulk density of roasted coffee was highly significant (P<0.01) (Table 4). The highest mean value of bulk density of roasted coffee (0.56 gm/cm^3) was recorded for

Table 5. Interaction effect of variety and roasting duration on bulk density roast coffee.

Variety	Roasting duration (minutes)	Bulk density roasted coffee (gm/cm^3)
	Six	0.53^b
744	Eight	0.36 ^{c}
	Ten	0.26^{de}
	Twelve	0.24 ^{e}
	Six	0.51^{ab}
7440	Eight	0.34 ^{c}
	Ten	0.29^d
	Twelve	0.26^{de}
	Six	0.56^a
74110	Eight	0.33^c
	Ten	0.27^{de}
	Twelve	0.25^e
CV (%)		8.71
LSD (5%)		0.03

Mean values followed by the same letter(s) in the column are not significantly different at $P < 0.05$.

vareity 74110 roasted for six minutes, folowed by variety 7440 (0.53 gm/cm^3) and 744 (0.51 gm/cm^3) for the same roast duration (Table 4). The lowest value recorded was 0.24 gm/cm^3 for vareity 744 roasted for 12 minutes. Bulk density of roasted coffee decreased as roasting duration increased. During roasting, firmness of the coffee beans decreases; weight loss and volume increases and, as a result, bulk density of roasted coffee decreases. During roasting, several physical changes, like weight loss and volume increments take place in coffee beans, as a result density is reduced (Frisullo et al., 2010). In addition, Mwithiga and Jindal (2003) reported that lowering of density was due to puffing and increase in brittleness. The density of coffee continued to decrease rather slowly and appeared to level off at the end of the roasting period (Illy and Viani, 1995). Clarke (1985) also observed that physical changes in the coffee beans during roasting may lead to considerably decreased density due to weight loss and expansion of the beans.

CONCLUSIONS

The variation on roast physical properties of Arabica coffee during roasting was profound. The evaluated characteristics (volume, weight loss and bulk densities) were all significantly affected by roasting. As a result, both volume and weight loss increased during roasting, and there was a significant decrease in bulk density due to the continuous increase in roast volume change and roast weight loss. The result can be used to enhance cup quality of Arabica coffee aiming at roasting for different processing methods. Further studies will be conducted aiming to evaluate the response of more varieties and landraces of Arabica coffee to roasting conditions.

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