

# Raw coffee processing yield affected more by cultivar than by harvest date<sup>1,2</sup>

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## ABSTRACT

Conversion of cherry and parchment coffee (*Coffea arabica* L.) to green coffee was determined during two consecutive years of harvest for eight different coffee cultivars grown in Mexico. 'Mass balance' was useful to adjust the fruit humidity to 0.12 g/g for coffee bean raw processing. Univariate and multivariate analyses showed significant differences ( $P \leq 0.05$ ) among the cultivars. A linear discriminant function based on twelve variables measured on several dates in two consecutive harvest years showed that 'Typica' and 'Mundo Novo' had high efficiencies in conversions from cherry to green coffee on three harvest dates in 1999 and one in 2000. In contrast, 'Bourbon' and 'Yellow Caturra' required greater amount of fresh fruit to obtain 46 kg (1 quintal) of green coffee. The cultivar effects on the parchment to green coffee bean yield were not clearly identified. Harvest dates studied did not significantly influence the conversion of cherry or parchment to green coffee bean yields in the two years evaluated.

**Key words:** *Coffea arabica*, coffee beans, raw coffee processing, parchment coffee, green coffee

## RESUMEN

**Influencia del cultivar y de la fecha de cosecha en el beneficiado industrial de granos de café**

Se estudiaron conversiones de café cereza y café pergamino a granos de café verde o pilado (*Coffea arabica* L.) en ocho cultivares de cafeto, durante dos años consecutivos de cosecha en México. Un 'balance de masas' fue útil en ajustar la humedad del fruto a 0.12 g/g para granos de café a procesar. Análisis univariados y multivariados mostraron diferencias significativas ( $P \leq 0.05$ ) entre los cultivares. Una función lineal discriminante basada

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en doce variables medidas en varias fechas durante dos años consecutivos de cosecha mostró que 'Typica' y 'Mundo Novo' tuvieron una alta eficiencia en conversiones de café cereza a granos de café verde en tres épocas de cosecha en 1999 y una en el 2000. En contraste, 'Bourbon' y 'Caturra Amarillo' requirieron una mayor cantidad de fruto fresco o café cereza para obtener 46 kg (1 Qq) de granos de café verde. La influencia de los cultivares en el rendimiento industrial de café pergamino a granos de café verde no se identificó claramente. Las fechas de corte estudiadas no influyeron significativamente en la conversión de café cereza o café pergamino a granos de café verde en dos años de estudio.

**Palabras clave:** *Coffea arabica*, granos de café, procesamiento industrial de café, café pergamino, café verde, café pilado

## INTRODUCTION

Coffee is the most important tropical crop consumed worldwide. According to van der Stegen (2003), the world production of coffee amounts to ~110 million 60-kg bags per year (6.6 million tons/year), with about 90 million bags in the exportation market. The adequate moisture content for storage of green coffee beans is near 0.12 g/g (Atmawinata, 1995); consequently, the reference for trade operations is based on this moisture value. The international coffee market recognizes factors that influence coffee quality: species, plantation altitude, latitude, cultivars, raw coffee processing type, physical quality of green coffee and sensory properties of coffee beverage (Villa, 1990; Puerta-Quintero, 2000a; Figueroa-Solares et al., 2000; Njoroge, 1998; Reyna, 1989; González-Arcos, 1996). Coffee beverages are made from roasted green coffee beans of two species with economic importance, *Coffea arabica* and *C. canephora* (P.), known in the trade market as arabica and robusta, respectively (Martín et al., 2001). *Coffea arabica* presents high standards in aroma and flavor whereas *C. canephora* contains higher caffeine and soluble solid levels (Cléves-Serrano, 1998; Ky et al., 2001).

The transformation from coffee fruit cherries to green coffee beans, known as raw coffee processing, plays an important role in the final quality of the beverage. In fact, coffee quality is obtained in the field and it is preserved during raw coffee processing. Wet and dry processes are the two main methods used for green coffee production. Wet processing differs from dry processing basically in the production of parchment coffee as an intermediate product, whereas dry processing has dried cherries as an in-between product (Figure 1). Previous to trade, parchment coffee can be stored for almost one year without any loss because of the isolation provided by the endocarp. Mexican green coffee beans are mainly obtained from *C. arabica* and produced by wet processing. The beverages produced through this process have a high acidity and distinctive aroma.

Fruit yield, tolerance to pathogens, and environmental adaptation have been key criteria for coffee breeding (Villaseñor, 1987). However,

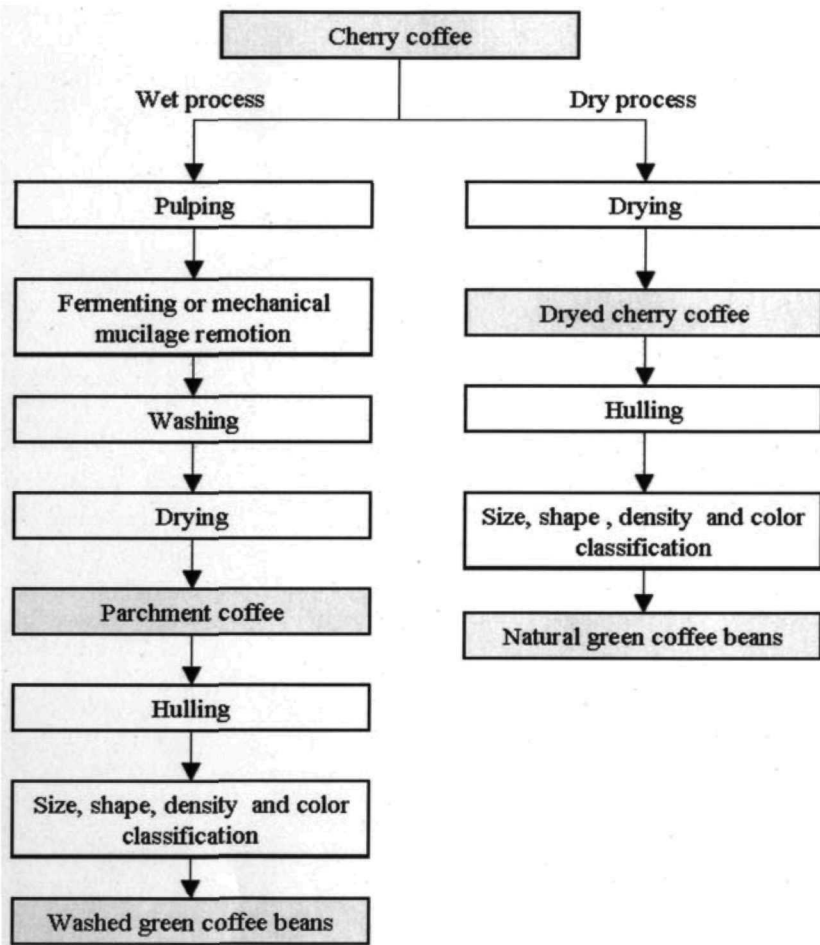


FIGURE 1. Wet and dry cherry coffee processing.

since green coffee is the final product, it is important to consider wet processing yields in breeding programs. Specifically, it is valuable to study the conversion from cherry to parchment and from parchment to green coffee beans. In commercial coffee trade agreements, 57.5 kg of parchment coffee is considered as one 'Quintal' (Qq), which corresponds to 46 kg of green coffee at 0.12 g/g of humidity. Some authors have demonstrated that raw coffee processing yield is affected by cultivar, plant age, location and fruit ripeness grade (Castillo, 1981; Guyot et al., 1996; Montagnon et al., 2000; Soto-Pinto et al., 2000). Coffee growers assume that

processing yield increases as harvest date advances. In Africa, there is information on this assumption (Haarer, 1980). However, the influence of harvest date on raw coffee processing has not been carefully studied in Mexico. In fact, there are only a few local reports concerning this issue.

Puerta-Quintero (2000b) reported the negative influence of immature beans on wet processing. Parchment coffee yield of immature beans was reduced by 7% as compared to that of ripe beans. This author also showed that immature beans affect physical and sensory properties; thus, the higher percentage of ripe coffee in a sample, the higher number of good quality cups is obtained.

Reyna (1989) found that cultivar influenced processing yield. In that study, 'Typica' required 230.4 kg of ripe cherry fruit to produce 1 Qq of green coffee, followed by 'Villa Sarchi' (241.5 kg), 'Catuaí' (246.5 kg), 'Pacas' (250.2 kg), and 'Caturra' (256.2 kg). Guadarrama and Trujillo (2001) showed that the conversion from cherry to parchment in 'Mundo Novo' was influenced by the environmental conditions of the plantation.

The present work was conducted to determine the influence of harvest dates on green coffee yields for several coffee cultivars in a Mexican tropical upland environment producing high quality green coffee beans. Mass balance, univariate and multivariate analysis of variance, and canonical discriminant analysis were used to evaluate conversion changes from cherry to green coffee and parchment to green coffee obtained by wet processing in two consecutive years of harvest.

## MATERIALS AND METHODS

**Plantation and harvest.** An 18-year-old coffee (*C. arabica*) plantation established on an Andosol soil, located at 1,344 m above sea level at the Centro Regional Universitario Oriente of the Universidad Autónoma Chapingo in Huatusco, Veracruz, Mexico (19°09' N and 96°57' W), was used in the experiment. The study area had a mean annual rainfall of 1,700 mm, and an annual temperature average of 17.2°C. Eight cultivars widely grown on local plantations were selected: Garnica, Typica, Pluma Hidalgo, Catuaí, Red Caturra, Yellow Caturra, Mundo Novo, and Bourbon. According to the classification of type of canopy (Gobbi, 2000), the production system had a 'technified' shade, with predominancy of *Inga* sp. trees. Fruit harvested in 1999 and 2000 was considered in the study. Three hand harvests were performed each year. The first two harvests were in January and February in both years, and the last in March of 1999, and May of 2000. The criterion adopted in defining the harvest date was the red color of the fruit skin as indicator of ripening. Yellow Caturra was harvested when the fruit attained a yellow color.

**Raw coffee processing.** Three replicates of 2-kg samples of cherry coffee were randomly harvested and processed by the wet method for each cultivar and harvest date. Only ripe fruits were used throughout all the experiments. The fruit processing included pulping, fermenting, washing, and drying. The product obtained was parchment coffee at a humidity of about 0.12 g/g. Afterwards, parchment was hulled to obtain green coffee beans.

**Mass balance and conversion factors.** Mass balances were used to standardize the samples to 0.12 g/g of humidity (Himmelblau, 1997). Cherry to green coffee ( $CF_{Ch-G}$ ) and parchment to green coffee ( $CF_{P-G}$ ) conversion factors were used for comparing the raw coffee processing yield. Both conversion factors were defined by using the mass of the samples of each treatment and defined by equations 1 and 2. These equations define, respectively, the amount of cherry and parchment needed to obtain 46 kg (1 Qq) of green coffee beans.

$$CF_{Ch-G} = \frac{46 \text{ kg}}{\frac{\text{mass of green coffee}}{\text{mass of cherry}}} \quad (1)$$

$$CF_{P-G} = \frac{46 \text{ kg}}{\frac{\text{mass of green coffee}}{\text{mass of parchment}}} \quad (2)$$

**Statistical analysis.** Univariate (Steel and Torrie, 1980) and multivariate analysis of variance (Krzanowski, 1988) and canonical discriminant analysis (Cruz-Castillo et al., 1994) were performed to compare the influence of harvest date and cultivar on raw coffee processing yield, considering the cherry to green coffee and parchment to green coffee conversion factors over two-year harvests. The SAS (1989) ANOVA and CANDISC procedures were used to perform these statistical techniques.

## RESULTS AND DISCUSSION

Mass balance was useful in obtaining the equivalent amount of parchment and green coffee beans at the typical commercial humidity (0.12 g/g). Cherry to green coffee yields were significantly ( $P \leq 0.05$ ) affected by the cultivars on most of the different harvest dates (Table 1). The Typica cultivar achieved the highest cherry to green coffee conversion, to complete 45.45 kg of green coffee (1 Qq) in March 1999 and in May 2000 with 241.9 and 231.3 kg, respectively. Coffee growers in Huatusco, Mexico, claim that the best yield conversions from cherry to

TABLE 1.—Harvest dates in January (J), February (F), March (M), May (My) and factor conversion means (kg) of cherry to green (CF<sub>Ch-G</sub>) and parchment to green coffee (CF<sub>P-G</sub>) for eight different coffee cultivars in the harvest seasons of 1999 and 2000.

Cultivars	1998-1999 Season						1999-2000 Season					
	J. CF <sub>Ch-G</sub>	J. CF <sub>P-G</sub>	F. CF <sub>Ch-G</sub>	F. CF <sub>P-G</sub>	M. CF <sub>Ch-G</sub>	M. CF <sub>P-G</sub>	J. CF <sub>Ch-G</sub>	J. CF <sub>P-G</sub>	F. CF <sub>Ch-G</sub>	F. CF <sub>P-G</sub>	My. CF <sub>Ch-G</sub>	My. CF <sub>P-G</sub>
Bourbon	272.9 a	58.0 a	236.5 ab	56.1 a	281.9 a	56.3 ab	267.9 a	55.7 a	252.6 a	56.1 a	274.2 a	54.6 a
Catuai	257.4 ab	56.4 bc	227.4 ab	56.4 a	260.2 abc	55.8 ab	245.3 ab	54.6 a	255.4 a	55.3 a	259.1 ab	54.0 a
Garnica	279.4 a	57.7 ab	226.2 ab	56.8 a	270.8 ab	55.9 ab	239.4 ab	54.7 a	246.6 a	56.2 a	258.8 ab	54.6 a
Mundo Novo	255.1 ab	56.5 bc	222.3 b	56.2 a	249.1 bc	56.0 ab	230.6 ab	55.0 a	254.2 a	56.0 a	254.5 b	54.2 a
Pluma												
Hidalgo	274.1 a	57.5 abc	221.8 b	57.6 a	264.0 abc	56.3 ab	235.8 ab	53.9 a	257.3 a	57.5 a	269.4 ab	54.2 a
Typica	236.0 b	56.2 c	219.3 b	55.9 a	241.9 c	55.5 b	199.5 b	53.0 a	243.9 a	57.8 a	231.3 c	53.4 a
Red Caturra	280.2 a	57.7 ab	251.3 a	57.3 a	269.5 ab	56.1 ab	234.9 ab	54.3 a	260.0 a	58.9 a	264.8 ab	55.9 a
Yellow												
Caturra	268.4 a	57.6 ab	242.3 ab	56.1 a	271.4 ab	56.9 a	235.3 ab	53.5 a	258.0 a	56.4 a	267.3 ab	54.6 a
Means and SE per harvest date	265.4 ± 3.4	57.2 ± 0.1	230.9 ± 2.7	56.5 ± 0.1	263.6 ± 2.9	56.1 ± 0.1	236.1 ± 5.0	54.3 ± 0.2	253.5 ± 2.0	56.8 ± 0.3	259.9 ± 2.7	54.4 ± 0.2

Mean separation in each column by Tukey at 5%.

green coffee occurred at the end of the harvest period. In the present work, there was not any late high harvest industrial yield trend when all cultivars were considered. For example, the first harvest in January 2000 achieved a high cherry to green coffee yield conversion across all the cultivars (236.1 kg). Likewise, this conversion was high in February during the first harvest season (230.9 kg). Particular cultivar effects influenced by harvest date in this regard were shown by Bourbon, Catuaí, Mundo Novo, Typica, and Yellow Caturra with high cherry to green conversions in January for each season (Table 1). In contrast, Red Caturra, Pluma Hidalgo, and Garnica did not follow any harvest trend in the cherry to green coffee conversion in either season (Table 1). Thus, pre-harvest factors such as management of the plantation shade (Muschler, 2000) may be more important in some cultivars for achieving adequate yield conversion values irrespective of the time of harvest. In a study in Costa Rica, cultivars with longer periods of fruit growth on the plant produce the heaviest green coffee beans (Alpizar, 2000), but there are no similar reports for Mexico. Typica was significantly different from the other cultivars in May 2000, achieving 231.2 kg of cherry for 46 kg of green coffee (Table 1). The parchment to green yield conversion in the first season was significantly different among the cultivars in January and March for Catuaí, Mundo Novo, Pluma Hidalgo, and Typica, requiring less parchment coffee to attain 46 kg of green coffee (Table 1). In the second season, all cultivars had similar parchment to green coffee conversions (Table 1).

The multivariate analysis of variance showed significant differences ( $P \leq 0.05$ ) among the eight different cultivars, where cherry to green and parchment to green coffee yield conversion factors were measured on different harvest dates, in two consecutive harvest seasons. The canonical discriminant analysis showed that the first two canonical functions were significantly different ( $P \leq 0.05$ ) from the other four canonical functions, thus indicating that the eight different cultivars differed most in these two linear functions, which accounted for 91.2% of the variation (Table 2). The first canonical discriminant ( $CDF_1$ ) function explained 83.2% of the variability, and it was highly associated with the cherry to green coffee conversions in March 1999 and May 2000, according to the correlation coefficients between the  $CDF_1$  and all the conversion values. The standardized canonical coefficients in the  $CDF_1$  showed large absolute values for the conversion of cherry to green coffee in May 2000, and January, February, and March 1999. Absolute values were also high for the parchment to green coffee conversions in May 2000 and February 1999. Typica, with the highest absolute score (Table 3), was distinctly different from the other cultivars. With Typica, less harvest yield was needed to obtain 46 kg of

TABLE 2.—Standardized canonical coefficients (SCC) and correlation coefficients between canonical discriminant functions ( $CDF_1$ ,  $CDF_2$ ), and factor conversions of cherry to green ( $CF_{Ch-G}$ ), and parchment to green coffee ( $CF_{P-G}$ ) for eight different coffee cultivars in the harvest seasons of 1999 and 2000.

Variables	Notation in Equation 3	$CDF_1$		$CDF_2$	
		SCC	$r^2$	SCC	$r^2$
1998-1999 Season					
January. $CF_{Ch-G}$	$X_1$	1.29	0.63	-0.35	0.07
January. $CF_{P-G}$	$X_2$	-0.36	0.64	0.89	0.14
February. $CF_{Ch-G}$	$X_3$	3.55	0.50	0.17	0.15
February. $CF_{P-G}$	$X_4$	-2.39	0.11	-0.60	-0.21
March. $CF_{Ch-G}$	$X_5$	1.24	0.80	2.92	0.22
March. $CF_{P-G}$	$X_6$	-0.64	0.55	-1.67	-0.31
1999-2000 Season					
January. $CF_{Ch-G}$	$X_7$	1.85	0.66	1.38	0.14
January. $CF_{P-G}$	$X_8$	-0.48	0.38	0.81	0.30
February. $CF_{Ch-G}$	$X_9$	0.52	0.33	-0.41	-0.30
February. $CF_{P-G}$	$X_{10}$	-0.09	-0.15	-0.30	-0.01
May. $CF_{Ch-G}$	$X_{11}$	6.96	0.88	-3.98	-0.16
May. $CF_{P-G}$	$X_{12}$	-3.59	0.31	1.92	0.12
Variance explained (%)		83.2		8.0	

green coffee in 1999 [219 kg (Feb); 236 kg (Jan); and 242 (Mar)]; and in 2000 [200 kg (Jan); 231 kg (May)] (Table 1). Reyna (1989) also demonstrated that Typica fruit was highly efficient at producing green coffee. Regarding parchment to green coffee conversion for Typica, the low correlation coefficient values (Table 2), and non significant ( $P \leq 0.05$ ) mean values (Table 1) in February 1999 and May 2000 indicated no distinct

TABLE 3.—Means of standardized canonical scores of the first two canonical discriminant functions (CDFs) for eight different coffee cultivars in the harvest coffee seasons of 1999 and 2000.

Coffee Cultivars	$CDF_1$	$CDF_2$
Bourbon	13.3 a	3.1 a
Yellow Caturra	7.8 b	-2.7 cd
Red Caturra	2.7 c	1.4 ab
Catuai	1.1 c	-0.1 bc
Pluma Hidalgo	0.7 cd	-4.8 d
Garnica	-1.7 d	3.5 a
Mundo Novo	-5.5 e	-1.6 c
Typica	-18.5 f	1.2 ab

Mean separation in each column by Tukey at 5%.



advantages with respect to the other cultivars in completing 46 kg of green coffee. These findings could be attributed to the dependence of this conversion on the endosperm-endocarp ratio, which varies with the natural differences among fruits (Puerta-Quintero, 2000 b). Although Mundo Novo was significantly different from Typica (Table 3), it also scored high in this linear function and showed efficiency in attaining 1 Qq on the above mentioned dates. Typica presented higher fruit weight and larger seeds but lower total yield on the coffee plantations in comparison with the other cultivars studied (Villaseñor, 1987). In addition to cultivar effects on coffee conversion ratios (Temesgen and Michael, 1995), cultural practices to increase coffee bean weight in other coffee cultivars may enhance cherry to green coffee conversion yields. For example, mulching (Kamau, 1976), optimal balance of nutrients (Njoroge, 1998) or shade (Muschler, 2000) may benefit coffee industrial yield conversions. In contrast, Bourbon and Yellow Caturra following with high absolute scores (Table 3) required more cherry fruit to completing 46 kg (1 Qq) of green coffee those dates (Table 1). As with Typica, no clear advantages were observed for these cultivars with respect to complete 46 kg (1 Qq) of green coffee from parchment (Table 1). The  $CDF_2$  accounted for only 8.0% of the variation among the coffee cultivars; therefore, this function was not used for interpretation.

A plot of the canonical coefficient scores (Figure 2) of the coffee cultivars illustrates the high discriminant capacity of  $CDF_1$  in separating Typica and Bourbon from the other cultivars, mainly on the basis of their cherry to green coffee conversions in January, February, March 1999, and May 2000. Thus on the basis of the linear combination presented in Equation 3, the complexity of the data was summarized. This model was useful to understand coffee conversion yields on several harvest dates carried out with eight different coffee cultivars.

$$CDF_1 = 1.29x_1 - 0.36x_2 + 3.55x_3 - 2.39x_4 + 1.24x_5 - 0.64x_6 + 1.85x_7 - 0.48x_8 + 0.52x_9 - 0.09x_{10} + 6.96x_{11} - 3.59x_{12} \quad (3)$$

Where  $x_1, x_2, \dots, x_{12}$  represent the cherry and parchment to green coffee conversion factors described in Table 2.

In general, Bourbon and Yellow Caturra yield more fruit than Typica and Mundo Novo (Villaseñor, 1987). However, in the present work Typica showed higher cherry to green coffee conversions because the size of the beans was larger. Therefore, local cherry producer growers would receive premium prices from the coffee processor industry for Typica and Mundo Novo fruit because of the high conversion rate of cherry to green coffee, and less reward for cherries harvested from

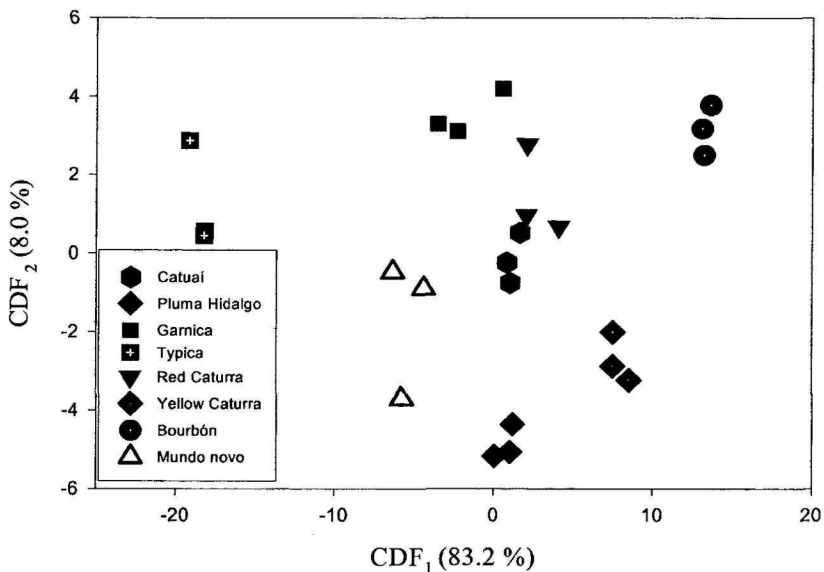


FIGURE 2. Plot of the canonical scores of the first two canonical discriminant functions for cherry to green, and parchment to green coffee conversions harvested on different dates in 1999 and 2000 for eight different coffee cultivars.

Bourbon and Yellow Caturra. The decision on planting cultivars will depend on the grower market strategy commercializing cherry, parchment or green coffee.

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