Rev. Fac. Agron. (LUZ). 2005, 22: 388-398

Effect of the Post harvest Treatments on the Temperature and Index of Fermentation in the Quality of the Cocoa Criollo Porcelana (*Theobroma cacao* L.) in the South of Maracaibo's Lake.

E. Portillo[1], L. Graziani de Farinas [2] y E. Betancourt[3]

[1]Universidad del Zulia (LUZ). Departamento de Agronomía. Facultad de Agronomía.
[2]Universidad Central de venezuela (UCV). Departamento de Química. Facultad de Agronomía.
[3]Ingeniero agrónomo Asistente de Investigación egresado de la Facultad de Agronomía de LUZ.

Abstract

In order to establish the adequate fermentation conditions it is necessary to know the factors that have an influence in this, in this sense, it is very important to define the physical parameters that would reveal with more accuracy the particularities associated to the quality of Porcelana cacao. Therefore, the following post-crop factors that influence the fermentation of the porcelana criollo cacao: Type of fermentator (TF), removal frequency (FR), ear tolerance (AM) and the time of fermentation (TPF). The methodology consisted on a totally randomized design with a split plot arrangement where four factors were studied (TF, FR, AM, TPF). The studied variables were: temperature of the cacao mass and index of fermentation. Results show highly significant differences ($P<0.01$) for all the factors and for the two analyzed variables in relation to the interactions, these reflect that the maximum temperature values (45.4ºC) were obtained in the square drawer and endurance zero. Removal treatments every 24 hours also registered the highest proves of fermentation at 72 hours (46.5ºC) and (46ºC) in both cases. The highest fermentation index was obtained in square fermentators (65.4%) and for the interaction (AmxFR) the best combination resulted is endurance five with removals every 24 hours passed 96 hours of initiated the process. Results allow to conclude that both variables have their maximum values in squared fermentators, endurance zero, removals every 24 hours and 72 hours of

Received February 24, 2003 ● Accepted May 24, 2005
[1]Author's email: elvisportillo@hotmail.com; eportillo@luz.edu.ve; ticoet@net.uno.net; elebetafe@hotmail.com

fermentation for temperature and 96 for the fermentation index.
Key words: Theobroma cocoa, quality, temperature, index of fermentation.

Introduction

The development of the commercial cocoa activity (colonial time), contributed that Venezuela was characterized as one of the main producer countries of cocoa in relation to quality and quantity. Nowadays, Venezuela has the second place as a supplier country of cocoa of great quality, but this condition reduces everyday due to some factors that have caused its fall. Even though, Venezuela is inside the producer countries of fine and smelly cocoa, where varieties as Chuao and Porcelana are considered of excellent quality (11).

The taste of chocolate develops through three main processes: fermentation and dry, which is done by the producers and the toast done by the industry, that is why they are important in the elaboration of chocolate. The type of cacao, the fermentation method used, along to the time of fermentation, removal frequency, drying and the environmental conditions of the area determine the quality of the cocoa and at the same time conditions the price to pay for it (9). It is important to mention that the investigations done in this area indicate that the fermentation constitutes the main and decisive moment in order to obtain a good quality of the seed that would allow a better commercialization in the national and international market (12).

One of the parameters to consider in the classification of cocoa are the laws of the Foundation for the Normalization and Certification of Quality (FONDONORMA), based on the exigencies of the international markets of cocoa, the following classification of seed in function of some parameters has been considered (8). For this is established: extra-fine cocoa, fine smell, fine taste (F1), fine cocoa finding fine AAA, fine AA and fine A; fine cocoa of second, current cocoa or F2, natural cocoa, in the law is also established the defects in each of the categories cocoa pasilla, musty grains, slaty grains, germinated grains and multiple grains.

Another aspect is that the fermentation processes come along to a temperature increment of the cocoa mass. This phenomenon is mainly by the microbial activity that is developed in the pulp (13), due to a fermentation process where the existent sugars in the pulp of the fruit are transformed into alcohol which at the same time oxidize becoming acetic acid by effect of the glycolysis that is generated into energy. The rising of temperature might also be due to the heat produced by respiration of seeds, then the temperature falls rapidly (7). Therefore, due to all things mentioned before, the aim of this research is to evaluate the effect of factors on the quality of cacao criollo porcelana (*Theobroma cacao* L.) during fermentation with the study of physical variables.

Materials and methods

The essay was carried out at the experimental station Chama of Corpozulia, located at the 41 Km of Santa Bárbara road, El Vigía, Colón municipality, Zulia state. There is a plantation surface of approximately 6 ha, which altitude is of 10 msnm, classify as tropical dry forest. The cocoa used in this essay belongs to «criollo» porcelana type of the collection of the experimental station. It was a totally randomized design with 2^3 x 5 split plot design, evaluating four factors with three replications: Type of fermentator (TF), removal frequency (FR), hold of the fruit (AM) and time of fermentation (TPF), the three firsts factors were evaluated at two levels each one, and the fourth at five levels, for a total of 80 treatments. The experimental unit was formed by 400 g of sample. Type of fermentator (TF): the fermentation system used was the box type under two designs, square and rectangle, the squared box dimension (TF_1): 50cmx50cmx50cm and rectangle box (TF_2): 83cmx30cmx50cm. Two removal frequencies of the cocoa mass were evaluated, this was done every 12 and 24 hours for 20 minutes. The hold of the fruit was considered to be a common practice in the region, for this essay two holds were considered: hold of the fruit = 0 (AM_1); the fermentation is done just after the crop, and hold of the fruit = 5 days (AM_2), the fermentation initiates five days after had done the first crop. This factor was evaluated at five levels: Time of fermentation of 0 hours (TPF_1), (without fermentation), time of fermentation of 24 hours (TPF_2), time of fermentation of 48 hours (TPF_3), time of fermentation of 72 hours (TPF_4) and time of fermentation of 96 hours (TPF_5). The temperature of cacao mass was daily measured in three points and at three depths 10 cm of the superior border of the mass, in the center of the fermentator and at the bottom of it, using for it a calibrated thermometer from 0 to 100°C and appreciation of ± 0.1°C. For the fermentation index the Venezuelan law Nº 442-98 (COVENIN, 1998) and results were expressed in percentage, the criteria used for this test was the brownish-gray color of seeds, these laws are applied for fermented and dried cocoa; measuring them at 24, 48, 72 and 96 hours after initiated the fermentation (8). For all variables the corresponding variance analysis and Duncan mean test were done, using the statistical software SAS (15).

Results and discussion

Temperature of the cacao mass

The variance analysis for this variable has highly significant differences ($P<0.01$) for factors: type of fermentator (TF) just at the bottom of the cocoa mass, removal frequency (FR), hold of the fruit (AM) and type of fermentation (TPF) for all the fermentator points where the

temperature was measured. Double interactions TFxAM, FRxTPF, AMxTPF, TFxTPF and FrxAM were highly significant for all measured temperatures excepting FrxAM interaction which was not significant for temperature measured at the bottom of the fermentator. For the interpretation of the information, only double interactions are considered.

According to the TfxAM interaction, mean test detected differences in the temperature of the cacao mass in the three fermentator points, considering the factors type of fermentator (TF) and hold of the fruit (AM) (table 1). These results show that the maximum temperatures reached in the fermented cocoa mass were obtained when the process was done in squared box and with opening of the fruit five days after the crop in all points of the fermentator where this variable was measured, with values of 45.4ºC, 44.3ºC and 41.7ºC at the surface, medium and bottom respectively, different to 44.2ºC, 43.5ºC and 39.7ºC for those three levels with rectangle box. In the case of treatments, which fruits were opened immediately after the crop, showed inferior temperature values in both fermentators.

The optimum combination that allows a higher temperature happened when the cocoa is fermented in a square box and fruits are retained for five days. These results are superior and corroborate the mentioned by other investigators (13, 17), who say that the delay in the thresh favors the increment of the temperature during the process and increment of 2ºC in the temperature when fruits were hold for two days or more without opened.

Mean test for the interaction of the type of fermentator and the time of fermentation (TFxTPF) shows that temperatures of the cocoa mass increment with the time of fermentation, being 72 hours the critical point where the maximum temperature is reached, 46.5ºC at 10 cm depth (top), 45.7ºC in the center of the fermentator and 43.1ºC at the bottom of the square box. In the rectangle box the tendency is the same but with inferior values to the previous, that is, 46ºC, 45.1ºC and 41.8ºC respectively, for each of the mentioned aspects (table 2).

Another aspect important to mention is that passed 72 hours of initiated the fermentation, a reduction in the temperature was observed in each of the stratum considered in this research, and for both fermentators, being this effect more evident in the rectangle fermentator and in the central stratum where differences between the third and fourth day were minimum. It has been theoretically said that at the beginning of the fermentation the microbial activity provokes an increment in the temperature until reaching a maximum (40 – 45ºC) and later reduces as a consequence of the inactivation of acetic bacterium and the death of the embryo, caused by the penetration of the acetic acid toward it (7). Similar results (1, 5) to the ones of this investigation show and increase in the temperature during

Table 1. Average temperature of the cocoa mass for the interaction type of fermentator by hold of the fruit (TfxAM)

Tipe of fermentator	Hold of the fruit (days)	Temperature (ºC)		
		10 cm (Top)	Center	Bottom
Square box	Aguante 0	42.8^{d}	41.4^{d}	40.1^{bc}
Square box	Aguante 5	45.4^{a}	44.3^{a}	41.7^{a}
Rectangle box	Aguante 0	43.4^{c}	42.1^{c}	39.6^{cd}
Rectangle box	Aguante 5	44.2^{b}	43.5^{b}	39.7^{cd}

^{a,b,c,d}and d. Means followed by different letters indicate significant differences (P<0.01).

the fermentation process and the maximum was reached the second day of initiated the process, which value was of 39.43ºC for cocoa criollo Ocumare-61.

In relation to the interaction of the removal frequency (FR) and the hold of the fruit (AM), the mean test corroborated the results of the statistical analysis, that is, there were also significant differences for the superior stratum and the center except at the bottom of the fermentator. This mean test also shows that maximum temperatures were reached when the cocoa mass was removed every 24 hours and fruits were restrained for five days, with values of 45.5ºC at 10 cm and 44.7ºC in the center of the

Table 2. Average temperature of the cocoa mass for the interaction type of fermentator by time of fermentation (TFxTPF)

Time of fermentactor	Time of fermentactor (hours)	Temperature (ºC)		
		10 cm (Top)	Center	Bottom
Square box	24	39.4^{d}	37.9^{d}	36.4^{d}
Square box	48	44.4^{c}	43.1^{c}	41.3^{b}
Square box	72	46.5^{a}	45.7^{a}	43.1^{a}
Square box	96	44.2^{b}	45.1^{a}	42.9^{a}
Rectangle box	24	38.5^{c}	37.7^{d}	35.7^{d}
Rectangle box	48	45.3^{b}	44.2^{a}	40.8^{c}
Rectangle box	72	46.0^{a}	45.1^{a}	41.8^{b}
Rectangle box	96	44.9^{bc}	43.6^{bc}	40.2^{c}

^{a,b,c,d}and d. Means followed by different letters indicate significant differences (P<0.01).

fermentator, additionally, it is observed that the contain of 5 days favored the increment of temperature with two employed removal frequencies (table 3). This allow to reiterate that both factors (FrxAM) are determinant in the increment of the temperature variable. Other investigators found that the temperature of the upper stratum was higher, which rank was between 40 and 46ºC and was reached when the mass was removed at intervals of 12 hours (16, 17).

Mean test for the interaction of removal frequency (FR) by the time of fermentation (TPF) showed as a result an increased of the mass temperature during the fermentation process, being 72 hours the time where the highest quantity of this temperature is registered in the three points, for the removal of 12 hours as well for those of 24 hours, nevertheless, when the mass is removed every 24 hours the mass temperature at 72 hours is statistically the same at 96 (table 4). Another important aspect is that even though there is the same behavior in both treatments the reduction in the temperature of 72 hours after fermentation is stronger in removals of 12 hours in three points of the mass, registering superior variations at 1ºC. On the contrary, when the mass is removed every 24 hours temperature between the third and fourth days of initiated the process is similar, this allows to say that when cocoa mass is removed with a 24 hours frequency the temperature is maintained in all the fermented.

There are investigators who mention the importance of the removal on the quality of chocolate and they suggest that this must be done in intervals of 24 hours (7), (10), (14).

In relation to the mean test of the hold of the fruit (AM) interaction by the time of fermentation (TPF), this showed results that corroborate the statistical analysis, indicating that the maximum temperature of cocoa mass was reached 48 hours of initiated the process, when fruits were

Table 3. Average temperature of the cocoa mass for the interaction removal frequency by hold of the fruit (FRxAM)

Removal frequency (hours)	Hold of the fruit (days)	Temperature (ºC)		
		10 cm (Top)	Center	Bottom
Every 12	Hold 0	42,9^{d}	41,6^{d}	39,7^{a}
Every 12	Hold 5	44,1^{b}	43,1^{b}	40,4^{a}
Every 24	Hold 0	43,3^{cd}	41,9^{cd}	40,0^{a}
Every 24	Hold 5	45,5^{a}	44,7^{a}	41,0^{a}

^{a,b,c,d}and d. Means followed by different letters indicate significant differences (P<0.01).

Table 4. Average temperature of the cocoa mass for the interaction removal frequency by fermentation time (FRxTPF).

Removal frequencies (hours)	Time of fermentation (hours)	Temperature (ºC)		
		10 cm (Top)	Center	Bottom
Every 12	24	38.2[d]	36.9[d]	35.1[d]
Every 12	48	44.6[b]	43.6[b]	40.6[b]
Every 12	72	46.3[a]	45.1[a]	42.5[a]
Every 12	96	44.9[b]	43.5[b]	41.2[b]
Every 24	24	39.7[c]	38.7[c]	36.9[c]
Every 24	48	45.1[b]	43.7[b]	41.4[b]
Every 24	72	46.5[a]	45.7[a]	42.5[a]
Every 24	96	46.1[a]	45.2[a]	41.9[a]

[a,b,c,d]and d. Means followed by different letters indicate significant differences (P<0.01).

kept for five days (table 5), which values were of 46.6ºC in the top, 45.4ºC in the center and 42.3ºC.

In the temperature measured at the bottom, the maximum was reached at 72 hours. It is important to mention that the behavior of the variable temperature in the three fermentator levels is very similar, that is, at the same time that happens the fermentation process the temperature increases for each of the stratums until reaching the maximum point which was reached in 72 hours, these results allow to say that the hold of the fruit accelerated the fermentation process (table 5). The delay in the thresh and opening of the cocoa seeds causes an abrupt increment of the temperature during fermentation (7), (13).

Fermentation index (Cut-test)

The variance analysis for this variable shows highly significant differences (P<0.01) for factors: type of fermentator (TF), removal frequency (FR), hold of the fruit (AM), time of fermentation (TPF) and the FrxAM interaction and significant (P<0.05) for TFxTPF interaction. Once analyzed the interactions and simple effects, were considered for the analysis: TF, TPF and the FrxAM interaction by being the most relevant.

In relation to the type of fermentator, the mean Duncan test (table 6) shows differences in the percentage of fermented seeds according to the cut test in function of the evaluated fermentator types, seeing that the highest value of this variable was reached in square box (65.41%) compare to the rectangle which was of 54.47%. This might be related to the fact that mean temperature measured at the bottom of the fermentator was a little higher in the square box, which is an

Table 5. Average temperature of the cacao mass for the interaction hold of the fruit by time of fermentation (AMxTPF)

Removal frequency (hours)	Fermentation time (hours)	Temperature (ºC)		
		10 cm (Top)	Center	Bottom
Hold 0	24 hours	36.0[d]	35.0[d]	33.0[c]
Hold 0	48 hours	43.7[c]	41.9[c]	39.8[d]
Hold 0	72 hours	46.0[a]	45.2[a]	40.9[a]
Hold 0	96 hours	44.8[b]	43.5[b]	39.6[d]
Hold 5	24 hours	42.0[b]	41.5[c]	39.9[d]
Hold 5	48 hours	46.6[a]	45.4[a]	42.3[b]
Hold 5	72 hours	46.3[a]	45.6[a]	43.9[a]
Hold 5	96 hours	46.0[a]	45.3[a]	43.6[a]

[a,b,c,d]and d. Means followed by different letters indicate significant differences (P<0.01).

indicator of a better fermentation (13), agreeing to the reported by Madriz J (9), who said that the fermentation index depends on the fermentation system and not on the quantity. In this matter, other investigations indicate that the use of wood box causes a better fermentation of cocoa grains (4).

The mean Duncan test for the time of fermentation evidences that the fermentation index increased at the same time that happens the fermentation process, going from 30.94% to 68.56% (table 7). Similar results were reported by other investigators who found that the percentage of fermented seeds increases with the fermentation (1, 2). In this matter, was also found in Cocoa Ocumare-61 the fifth day of the process an index of 87.67%, superior to the one found in the investigation the fourth days of fermentation (68.56%). This results is contrary to what is reported in the literature, since porcelana is a cacao that ferments more rapidly than other crio-

Table 6. Indexes of fermentation in grains of porcelana cocoa fermented in tow types of fermentators.

Type of fermentator	Fermented almonds (%)
Square box	65.41[a]
Rectangle box	54.47[b]

[a,b]and d. Means followed by different letters indicate significant differences (P<0.01).

Table 7. Fermentation index in grains of porcelana cacao during fermentation

Time of fermentation (hours)	Fermented seeds (%)
24	30.94[d]
48	49.50[c]
72	65.75[b]
96	68.56[a]

[a,b,c,d]and d. Means followed by different letters indicate significant differences (P<0.01).

llo, therefore it is normally let in the fermentator for two or three days (4).

Theoretically, the fermentation duration is related to the quantity of purple pigments present in fresh grains, hence the more intense the purple is the longer must be its fermentation, that is why the criollo grains (not too pigmented), ferments faster than the other with purple color (13). Considering the criteria where some people establish as an optimum fermentation index a value higher than 60% (2) and other consider a maximum limit of 65% (1) in the fermented mass, the adequate time of fermentation in the porcelana cacao of the South of Maracaibo's Lake was of three days (65.75%).

The hold of the fruit interaction (AM) by removal frequency (FR) can be seen in table 8, that when the removal frequency is of 12 hours, the fermentation index was not affected by the hold of the fruit, different when the removal time was of 24 hours observing that this index was higher when the restrain was of 5 days (56.2% at five days vs. 52.2% at 0 days). This higher fermentation index might be related to the fact that higher temperatures were reached when the removal was done every 24 hours, favoring the fermentation process and the number of brownish-gray almonds similar to the found by other authors (3, 6). Some investigations where were evaluated

Table 8. Fermentation indexes averaged for the interaction hold of the fruit and removal frequency (AmxFR).

Hold of the fruit (days)	Removal frequency (hours)	Fermentation index (%)
Hold 0	Every 12	50.6[c]
Hold 5	Every 12	50.7[c]
Hold 0	Every 24	52.3[b]
Hold 5	Every 24	56.2[a]

[a,b,c,d]and d. Means followed by different letters indicate significant differences (P<0.01).

three varieties of cacao, three localities and three removal frequencies found that the highest percentages of fermented almonds (84-94%) were obtained with removals done every 12 hours, disagreeing to what was found in this research (16).

Conclusions

The analysis of physical variables shows that the maximum values for temperature in the mass of cocoa were reached when the fermentation was done in square boxes with removal time every 24 hours, hold of the fruit of five days and a fermentation time of 72 hours measured at 10 cm depth. With regard to the interactions it was defined that for this variable those that had the best results were: type of fermentator x hold of the fruit (TfxAM), type of fermentator x time of fermentation (TFxTPF), removal frequency x hold of the fruit (FRxAM), removal frequency x time of fermentation (FRxTPF).

With the used methodology the highest values for the variable index of fermentation were reached when the fermentation was done in square boxes, removals every 24 hours, delay in the thresh of five days and of 96 hours of initiated the fermentation in the same box for this variable. Likewise, the interaction time of removal x hold of the fruit (FRxAM) corroborated the results of the individual factors, and the optimum combination of these two elements happened when the fruit was restrained for five days and the cocoa mass was removed every 24 hours.

Recommendations

In base of these results it is suggested as the ideal interaction the one that guarantees a higher temperature, represented in this case by treatments that were submitted at 24 hours of removal for three days.

Acknowledgment

Authors want to express their acknowledgment to the National Foundation of Science, Technology and Innovation. By the co-financing of projects Nº 96001510 and 96001547 of Cacao.

Literature cited

1. Álvarez, Y. 1997. Efecto del tiempo transcurrido entre la cosecha y el desgrane sobre algunas características del cacao criollo (*Theobroma cacao* L.) selección Ocumare 61, durante el proceso de fermentación, utilizando el sistema trinitario. Trabajo de grado. Universidad Central de Venezuela. Facultad de Agronomía. Maracay, Septiembre 149pp.

2. Barel, M., D. Leon and J.C. Vicent. 1985. Influence du temps de fermentation du cacao sur la production des pyrazines du chocalat. Café, Cacao, The (París) 29(4):277-286.

3. Bornette, F. 1977. Peroxidase an its relationship to food flavour and quality. review Food science and technology. 42 p.

4. Chirinos, J., C. Viloria, E. Portillo and D. Esparza. 1997. Evaluación de los diferentes métodos de fermentación en cacao (*Theobroma cacao* L.) en la Zona Sur del Lago de Maracaibo. Tesis Ing. Agr. LUZ – Maracaibo. Venezuela. 86 p.

5. Contreras, A. 1999. Efecto del uso de diferentes fermentadores sobre algunas características físicas y químicas durante la fermentación del cacao forastero (*Theobroma cacao* L.). Tesis de grado. Facultad de Agronomía, Universidad Central de Venezuela. Maracay. 84 p

6. Cros, E., 1997. Factores condicionantes de la calidad del cacao. Memorias del 1er Congreso Venezolano del Cacao y su Industria. Noviembre. Maracay, Estado Aragua. Venezuela.

7. Enriquez, G. 1985. Curso sobre el cultivo del cacao. Centro Agronómico Tropical de Investigación y Enseñanza, CATIE. Costa Rica. 239p.

8. Fondo para la normalización y certificación de la calidad (FONDONORMA). COVENIN 1998. Normas venezolanas que deben cumplir los granos de cacao. Caracas-Venezuela. 12 p.

9. Madriz, J., 1987. Estudio de la fermentación del cacao en Gavetes Rohan en tres fincas de la zona Atláctica de Costa Rica. Informe Técnico 79p.

10. Montero, G. 1989. Tiempo óptimo de fermentación de cacao en cajones grandes. Memoria, Seminario regional sobre tecnología postcosecha y calidad mejorada del cacao. 20-21 julio. Turrialba. Costa Rica. 120 p.

11. Organización internacional del cacao (ICCO). 2.000 Producción Mundial de Cacao. Boletin Informativo SPIS/MAG/SICA. Enero. 1p.

12. Portillo, E., E. Martínez, F. Araujo, R. Parra, and D. Esparza. 1995. Diagnóstico técnico agronómico para el cultivo cacao (*Theobroma cacao* L.) en el Sur del Lago de Maracaibo. Rev. Fac. Agron. (LUZ). 12:151 –166.

13. Rohan, T. 1964. El beneficiado del cacao bruto destinado al mercado. Roma. FAO. 79p.

14. Schawn, R. 1990. Microbiología de la fermentación del cacao: Estudio para mejorar la calidad CEPLAC/ CEPEC/SETEA. Cp 07, 45600-000, Itabuna, Bahia, Brasil. Agrotrópica. 2(1): 22-31.

15. STATISTICAL ANÁLISIS SYSTEMS INSTITUTE. 1985. SAS. User's guide: statistics, version 5 edition. SAS. Institute cary, N.C.

16. Senanayake, M., E. Jansz and K. Buckle. 1997. Effect of different mixing intervals on the fermentation of cocoa beans. J. Scie. Food Agr. 74. 42-48.

17. Torres, O. 2001. Efecto del tiempo transcurrido entre la cosecha y el desgrane sobre algunas características físicas y químicas del cacao (*Theobroma cacao* L.) durante la fermentación. Tesis de grado. Facultad de Agronomía. Universidad Central de Venezuela. Maracay. 96 p.