Rev. Fac. Agron. (LUZ). 2006, 23: 339-351

Post-harvest and storage practices of cacao (*Theobroma cacao*) in Miranda state, Venezuela

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Abstract

A survey with 150 farmers (that belong to all production sectors) of Miranda, Venezuela, located in three municipalities of Barlovento was carried out, during the main crops from 1998 to 2000, in order to evaluate variations in post-harvest practices (post-harvest storage of the ears, the place where they ferment, fermentation method, stirring frequency and dryness), time of the exploitations, production levels of dry cacao, related activities to the post-harvest practices and storage conditions. Statistical differences were observed with the ji-squared analysis (χ^2), among the different municipalities at two significant levels ($P<0.05$ and $P<0.01$), these differences show the variability in the post-harvest practices (excepting the stirring frequency), antiquity of the production unit, storage conditions and production levels of dry cacao. The factorial analysis of multiple correspondence revealed that the six classify variables: age of the exploitation unit, fermentation method, and characteristics of the place where they ferment, time of the dryness during the rainy periods, conditions of the place where they stored the cacao and the production of dry cacao explained more than 45% of total variability. The ascendant hierarchical classification analysis allowed grouping the producers in ten types with defined profiles.
Key words: *Theobroma cacao*, cacao, post-harvest, fermentation, dryness, storage.

Introduction

Venezuela has been considered as a country with a great cocoa tradition, especially in the production of fine and superfine cocoa. However, the International Organization of Cocoa, decided to change the production classification of the country, from a pure producer of fine cocoa to a 50% producer of this type (12). This decision was taken because of the number of crossbreeding with amazonic and trinitarian cocoa, the

Received October 29, 2004 ● Accepted september 30, 2005
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poor management of agronomic actrivities and the post-harvest lack of treatment (4).

Miranda and Sucre are the most important traditional areas because of their high level of production (14). In Miranda, which is located in the central-north-coastal region of Venezuela, cocoa is cultivated in a surface of aprox. 28.753 ha, conformed by big, medium and small exploitations with a production of 7.936t $^{-1}$ (14). In Barlovento, the zone production in the state, a lot of small producers are exploited with mono-cultivation with low rates of production and low economic profits by surface unit. Trinitarian cocoa is mainly produced in the zone, typically fermented and the «Carenero Superior» has the best reputation internationally. Cultivations in this zone are pretty heterogeneous, as a consequence of the crossbreeding of Foreign and Trinitarian cocoa with local native types (4). Trinitarian cocoa, which is more resistant than native cocoa and less rustic than the foreign type, was introduced in Venezuela among the years 1820 and 1830, from Trinidad and Tobago Islands. Having an inferior quality than native cocoa, trinitarian cocoa displaced it from the most important zones of production and had a huge influence in the post-harvest process of Venezuelan cocoa (11, 16, 18). However, it did not have any success in Mérida and Táchira states, where native cocoa is still used in exclusive zones (15).

The parts of cocoa tree that are used are the seeds and the cotyledons, which suffer important changes during the process of benefit (fermentation and drying) and manufacture, originating a flavor and an aroma truly appreciated by the consumers of chocolate around the world. In contrast to cocoa without fermentation, extremely bitter and astringent, totally lack of flavor and aroma (10, 20, 24). It is been proved that genetic material, post-harvest treatment and environmental conditions influence the quality of flavor and aroma of cocoa (5, 6, 7). Especially, fermentation and drying are essential to develop the components of flavor and aroma of cocoa (23).

The objective of this research was to determine variations in the post-harvest practices and storage of cocoa in three municipalities with different types of producers, environmental conditions and geographic characteristics.

Materials and methods

In Barlovento, during the main harvests of the years 1998 to 2000, some cultivators were interviewed and asked to complete a survey in three productive municipalities: Acevedo (municipality 1), Páez (municipality 2) and Andrés Bello (municipality 3).

Cocoa plantations samples.

The samples were chosen at

random. To obtain the accuracy of the answers from the survey, the owners of the exploitations were interviewed; it was not allowed to accept information from delegates or from any other family member. The questions for the quantitative variables were: time of fermentation (DF), stirring frequency of the fermented mass (NV), time of drying (DS) and time of drying on rainy days (DSLL). The questions for the qualitative variables were: post-harvest storage of the cocoa (APM), antiquity of the exploitation unit (AUE), characteristics of the place where they ferment (LF), fermentation method (MF), conditions where the beneficiated cocoa is stored (CA), volume of dry cocoa produced in a year (PCS), continuous or discontinuous dry of cocoa (SCD), storage of incomplete dry cocoa (MSINC), sow distance (DSI) and cleaning labors, classification and polish of cocoa (LCP). All variables have 4 categories but variable CA which has 5 categories. The final number of tabulated, analyzed and interpreted surveys after depurating, analyzing information and validation of information were obtained from 150 producers.

Statistical analysis.

The statistical analysis used to determine the most discriminative variables of the group of producers was the monovaried. Ji-square test (χ^2) was used to analyze quantitative and qualitative data, classified according to a unique criterion to obtain a 5% of accuracy. Once determined the most discriminative variables, these were used to classify the 150 producers. The first phase was to apply the Factorial Analysis of Multiple Correspondences (AFCM), specific for qualitative multistage variables, to estimate the variables with the highest contribution in the classification of the 150 cocoa producers (17). To follow the parameters of the AFCM, the variables were codified in 4 and 5 categories, to generate a rectangular matrix of 150 rows (producers) and 14 columns (variables). This table was the base to create a similarity matrix of 14 variables having as fundament Burt table (1,8). Factors and factorial coordinates were generated thanks to the similarity matrix. Based on this method, were chosen the variables that offered the biggest contributions to the final variance. The variables were: 1) The generated factors should be one bigger than the previous one: $\lambda_1+\lambda_2+\lambda_3+\ldots+\lambda_n = \lambda_{total}$ (total variance). 2) Then a) $\lambda_1>\lambda_2>\lambda_3>\ldots>\lambda_n$ and b) $\lambda_1+\lambda_2+\lambda_3 \geq 35\%$ of the total variance (8). Once determined the group of variables, the second phase began with the analysis of hierarchical ascendant classification (ACJA). The distance of χ^2 was assumed to obtain the dissimilitude matrix (8). The aggregation criterion that was applied was the second order moment. The one that was verified by the ACJA was the coefficient of cophenetic correlation, based on Mantel test (8). Statistics models used for the monovaried analysis were the package SPSS Inc. 1999 version 10.0.1 and for the multivaried the WinStat-IC version 1.0 from ITCF/CIRAD.

Results and discussion

The averages values of the quantitative variables based on the results of the survey applied in Barlovento are the following: DF = 6.6 ±1.4 days; NV = 2.6 ± 1.0 stirring frequency, DS = 3.7 ± 0.8 days and DSLL = 8.4 ± 1.8 days. The variables among the municipalities showed a significant difference ($P<0.01$): The statistic test did not reveal any significant difference for the variable NV.

Time of fermentation.

Figure 1 shows the results of the variable DF for Barlovento and its municipalities. In the region, 93.2% of producers fermented from five to eight days. Reyes *et al* (19) found a smaller proportion of producers (54%) who fermented from five to eight days and 33% did it in a changeable way. Producers in Barlovento tend to ferment for six days followed by those who ferment for eight days. In the Municipality 1, the fermentation follows the same pattern, different as in the Municipality 2, that do it for seven days and others who do it for eight days. In the Municipality 3, the preference is to do it for eight days and then others who reduce it for six days. A small percentage of producers ferment from four to five days. Time of fermentation depends on the type of cocoa (20, 24). The heterogeneous mix of cocoa in Barlovento has produced changes in fermentation activities, especially in the duration of the process established by the producers, based on their own experiences with cocoa exploitations. Senanayake (21) said that in Sri Lanka the heterogeneous mix of native and foreign cocoa leads to variations on fermentation requirement.

Drying.

The last step of fermentation is the drying of cocoa, that reduces the

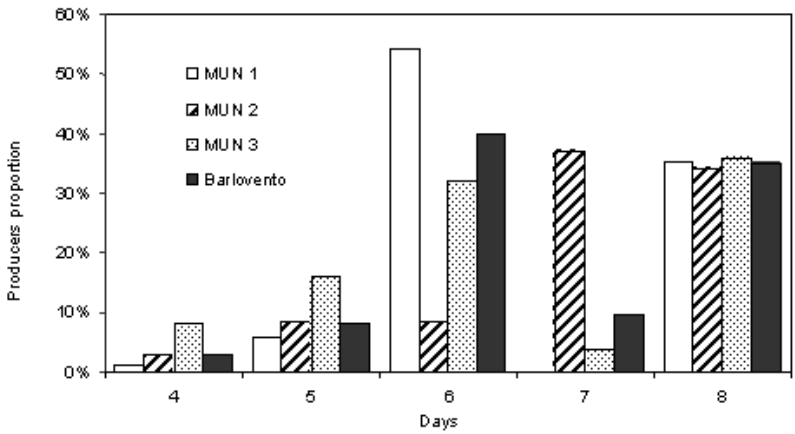

Figure 1. Variation on fermentation time of cocoa in Barlovento and its municipalities.

humidity to levels where is safe its storage and improves its appearance (3). In the region predominates drying in a natural way (drying by solar exposure), even though it is inefficient under adverse climatic conditions (3). Most of producers dried cocoa from three to four days (figure 2). Reyes *et al.* (19) showed a different situation, where producers dried cocoa from four to six days. Figure 2 reveals the preference in Municipality 1 and 3 to dry for three days and others for four days. In Municipality 2 people dry for four days and few of them for five days. Figure 3 illustrates the highest number for DSLL is eight days. In the Municipalities, the highest number was 9 days in Municipality 1, in the other two municipalities was eight days. However, an important number of producers in Municipality 3 extend days to ten. The variations in DS and DSLL are influenced by local climate conditions, according to studies about precipitations and respective temperatures; 2.101,1 mm and 26.3ºC in Municipality 1; 1.838,9 mm and 28.7ºC in Municipality 2 and 1.470,1 mm and 29.4ºC in Municipality 3.

Qualitative variables AUP, LF, CA and PCS among municipalities, revealed highly significant differences ($P<0.01$), but MF that turns out to be just a little significant ($P<0.05$) and APM did not show any significant statistic.

Antiquity of the exploitation unit.

Table 1 reveals the results of the variable AUP at the beginning of the survey. In the region, the most important AUP are from 21 to 40 years old and from 41 to 60 years old. In Municipalities 1 and 3, most of the AUP are from 21 to 40 years old, but in Municipality 2 are from 41 to 60 years old. According to the results, the presence of old plantations is evident. Perpetuity of cocoa is relative; as it gets old its productive energy is reduced.

Fermentation place.

Table 2 shows the results of this

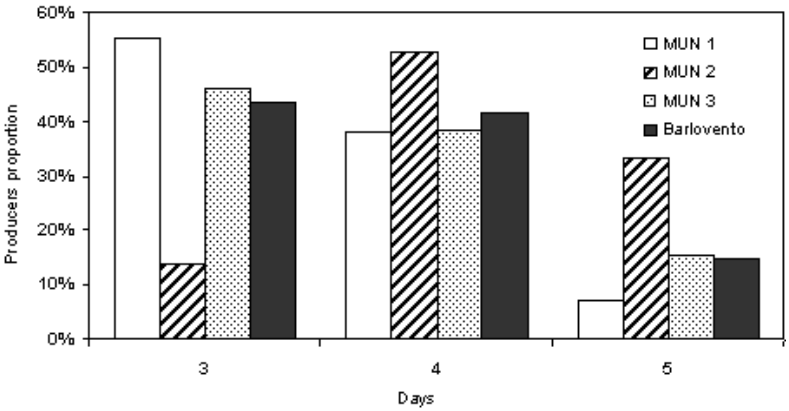

Figure 2. Variation on drying time if cocoa in Barlovento and its municipalities

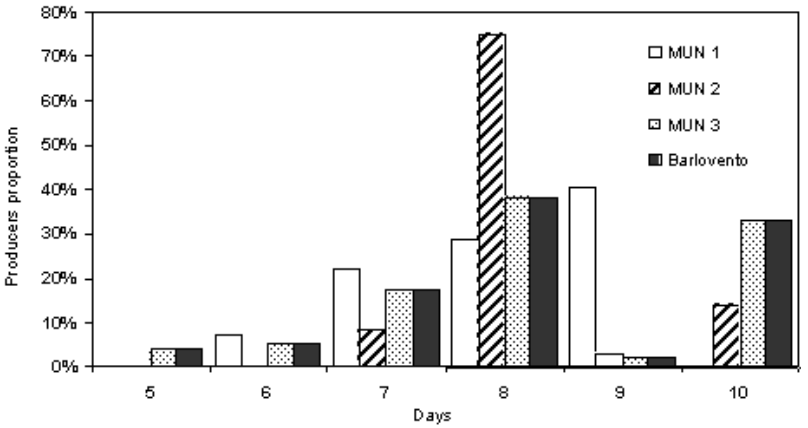

Figure 3. Variation on drying rainy days in Barlovento and its municipalities.

variable. It illustrates that the 86.7% of region producers carry out fermentation in places with roofs, the difference is the type of soils. Most producers said that soils where made of cement, there are others who put cocoa on sandy soils over a blanket, plastic or vegetal origin leaves; this could also happen under no roof. To finish, there were some producers who put cocoa under cover with wooden soils. In Municipality 1, cement soils under a roof are predominant, followed by sandy soils with a blanket, plastic or tree leaves under no roof and at last, few people ferment under cover with wooden soils. In Municipality 2, almost half of producers use cement soils under cover. The rest of the people ferment on sandy and wooden soils under a roof and few of them use sandy soils with no roof. In Municipality 3 the preference is for cement soils under cover, after this, following a priority, sandy soils with no roof and wooden

Table 1. Frequencies analysis among municipalities for the variable "antiquity variable".

MUN	Yearsold			
	4-20	21-40	41-60	61-80
1	20.7%	49.4%	16.1%	13.8%
2	10.2%	13.5%	65.2%	11.1%
3	19.2%	41.4%	23.1%	16.3%
Barlovento	16.8%	38.3%	33.6%	11.3%

Significant to this level $P = 0{,}0000$ according to test χ^2.

Table 2. Analysis of frequencies among municipalities for variable "fermentation place"

MUN	Fermentation place			
	C1	C2	C3	C4
1	79.3%	9.2%	nr	11.5%
2	55.6%	22.2%	13.9%	8.3%
3	61.5%	11.6%	nr	26.9%
Barlovento	70.5%	12.8%	3.4%	13.4%

Significant to this P level = 0,0000 according to test χ^2.
nr = No answer.
C1 = Under cover over cement soils; C2 = Under cover over sand soils with tree leaves on; C3 = Under cover over wooden soils; C4 = Under no roof over sand soils with a blanket or plastic, etc.

soils under cover. The variations of LF may be economical issues and/or traditions and customs.

Conditions of storage.

Table 3 exemplifies the results about variable CA. Most of producers put bags on clay bricks and less people put them on wooden logs, both under roof. The regular activity is to put cocoa in a place with roof. The biggest variation is over what materials are going to be located the cocoa bags. In Municipality 1, clay bricks were mostly used, then the wooden soil. There are a small percentage of people who have great conditions for a good cocoa storage. In Municipality 2, is more common to use clay bricks, then wooden soils, sand soils and the rest of them just sell immediately. Putting

Table 3. Analysis of frequencies between municipalities for the variable "storage conditions".

MUN	Storage characteristics				
	C1	C2	C3	C4	C5
1	3.5%	30.2%	2.3%	47.7%	16.3%
2	11.1%	27.8%	22.2%	38.9%	nr
3	19.2%	46.2%	3.8%	26.9%	3.8%
Barlovento	8.1%	32.4%	8.1%	51.4%	10.1%

Significant to this P level = 0,0000 according to test χ^2.
nr = No answer.
C1 = Do not storage; C2 = Under cover storage where bags are put on wooden soils; C3 = Under cover storage where bags are out on sand soils; C4 = Under cover storage where bags are put on clay bricks; C5 = Good technical conditions for a proper storage.

the cocoa bags over sandy soils brings out humidity because the dry grain is hygroscopic and may be contaminated with bad smells and microorganisms that decrease quality (20, 24). In Municipality 3, producers prefer to use wooden soils less over clay bricks. There is a big difference between this municipality and the other two: there are a big number of producers who tend to sell immediately, maybe, because of the lack of knowledge about appropriate techniques of storage and/or the small economic possibility to begin to practice them.

Volume of dry cocoa produced in a year.

Results of this variable are on table 4. It reveals that an important number of producers have a small quantity of dry cocoa (200 to 500 kg a year^{-1}) then in a row, the ones who produces from 801 to 1.200 kg a year^{-1}, 2.401 to 3.400 kg a year^{-1} and 4.001 to 6000 kg a year^{-1}. It was observed that Municipality 1, had the producers with the lowest PCS (200 to 500kg a year $^{-1}$). In Municipality 2 were more important producers with a PCS of 801 to 1.200kg a year $^{-1}$ and then the ones with 2.401 to 3.400 kg a year^{-1} and 4.001 to 6000 kg a year^{-1}. In Municipality 3 the levels of dry cocoa are low. In this municipalities plantations of cocoa are very old (table 1), maybe there has not been a renewal or the responsible is the lack of knowledge about the appropriate agronomic activities.

Fermentation Methods.

Table 5 shows results about variable MF. It can be observed that producers have similar preferences for the following methods: piling method and put cocoa in a basket to ferment. These baskets are made of rustic materials. Also, they use wooden boxes individually or in a row (Trinitarian method to ferment), wooden trays and Rohan method to ferment (20, 24). The most important MF were: in Municipality 1 the use of baskets, in Municipality 2 the piling method and in Municipality 3, producers use the wooden boxes. In countries where cocoa is produced, the methods to ferment it are varied, because it depends on the volume of the cocoa

Table 4. Analysis of frequencies between municipalities for the variable volume of dry cocoa produced per year.

MUN	Volume of dry cocoa (kg p/year $^{-1}$)			
	200-500	801-1.200	2.001-3.400	4.001-6.000
1	74.7%	24.1%	1.2%	nr
2	8.3%	47.2%	25.0%	19.5%
3	57.7%	31.5%	8.1%	4.7%
Barlovento	55.7%	31.5%	8.1%	4.7%

Significant to this P level = 0,0000 according to test χ^2.
nr = No answer.

Table 5. Analysis of frequencies between municipalities for the variable "Fermentation methods"

MUN	Fermentation methods			
	C1	C2	C3	C4
1	35.3%	41.2%	22.4%	1.1%
2	47.2%	25.0%	13.9%	13.9%
3	26.9%	30.8%	42.3%	Nr
Barlovento	36.7%	35.4%	23.8%	4.1%

Significant to this P level = 0.0228 according to test χ^2.
nr = No answer.
C1 = Piling method; C2 = Baskets; C3 = Wooden boxes; C4 = Other fermentation methods (refrigerator disposable boxes, jute bags y cement tank).

production, culture and traditions in every country, region or town (20, 24). It was reveled that in the three object municipalities the combination of methods is popular (72.0%, 57.7% and 77.4%): they combine the piling method with the baskets. Small producers prefer easy and low costs methods to ferment. Baskets made of vegetal fiber or plastic are also used to transfer fresh cocoa and to storage beneficiated cocoa. Reyes *et al.* (19) show a different picture where 44% of producers from Barlovento and the East of the country prefer to ferment with wooden boxes, Trinitarian style, and 33% used a bunch of baskets. Medium and big producers, usually use wooden boxes to ferment great volume of cocoa because it makes easier the management of cocoa for an only man while turning it (20). In Municipality it was observed the use of unusual containers to ferment, such as, boxes with cement walls, refrigerators' disposable boxes, jute bags, etc.

The 87.4% of producers in Barlovento did not make the APM, because they harvest a good amount of cocoa pods that shell and beneficiate the same day. Baker *et al.* did not notice any significant difference about the APM in Ghana. Reyes *et al.* found out that 66% of producers beneficiated the pods with a APM of different days. The practice to mix different cocoa of different ages of harvested, produces changes in fermentation and damages its quality (20). The preference of the NV was three stirring frequencies (49.0%) and for the rest was variable. It was observed that similar preferences for one or two stirrings, 18.8% and 19.5% respectively. The stirring of the cocoa mass requires special skills to obtain the appropriate ventilation to regulate production of heat and bitterness so the process is homogeneous. Senanayake (22) experimenting with different stirring frequencies, found out that increasing the number of stirrings also increased ventilation and that was good for the temperature and the level of

fermentation. It is possible that most of producers get good results with three stirrings, in spite of the different characteristics. About the variables MSINC, SCD and LCP, there were not significant statistics differences between municipalities (P<0.05). The variable MSINC revealed that 50.9% of producers store cocoa during the drying process in baskets and the other used option by 44.8% is to pile it up on cement soils under cover. Most people (95.4%) dry in a continuous way. About LCP variable, 99.3% eliminate stones, rests of pods, etc. This is very important for buyers and when producers do not carry it out they have to sell for less money or simply, customers reject the product. Only 0.7% have machines that clean, classify and polish the cocoa almond. The survey reveled that for DSI 97.3% of producers that had founded, acquired, inherited or received by the government said that the distance of the sown field was 3X3m.

Analysis of classification.

The AFCM provided this research with three coordinates that explain 45% of the variability. Considering all the factorial coordinates, there were chosen the ones that supply a superior variability to the inferior limit of the average. The selected variables were: EUP, MF, LF, DSLL, CA and PCS. With the help of ACJA 150 producers were grouped in 10 categories, depending on the chosen variable (figure 4). The cophenetic correlation coefficient with a value of 0.735 was significant (P<0.05). Indicating enough consistences between the generated dendrogram and the distance matrix. The first group has the following characteristics: Ferments in a pile over sand soils covered with a blanket or plastic under no roof. The production of dry cocoa is from 200 to 500 kg a year^{-1}. The second group is younger (4 to 20 years old) dedicating life to cocoa. Its level of production is from 801 to 1.200 kg a year^{-1}. Its fermentation method is to pile up cocoa over cement soils under a roof. Bags are stored in roof places over clay bricks. The third group reduces the time of fermentation for three or four days. The fourth group has been dedicated to cocoa exploitation from 21 to 40 years. The place where they ferment is under cover with cement soils and to ferment they use wooden boxes. Beneficiated cocoa is put on wood under roof. The volume of dry cocoa is from 4.001 to 6000 kg a year^{-1}. The fifth group put baskets on cement soils under cover. The volume of cocoa dry is from 801 to 1.200 kg a year^{-1}. The sixth group ferment cocoa on cement soils under a roof. They storage cocoa in a covered place with wooden soils. The seventh group prefers to ferment cocoa in baskets over cement soils with a roof. The volume of dry cocoa is from 200 to 500 kg a year^{-1}. The eighth group has from 41 to 60 years working with cocoa. They ferment just like group seven. The levels of dry cocoa are from 801 to 1.200 kg a year^{-1}. Bags with beneficiated cocoa are storage in covered places over clay bricks. The ninth group is constituted by producers with recent units of production (4-20 years). Just like the eighth group they ferment in a covered place on cement. Drying on rainy days lasts from four to seven days. The production of dry cocoa is from 200 to 500 kg a year^{-1}. They storage the bags

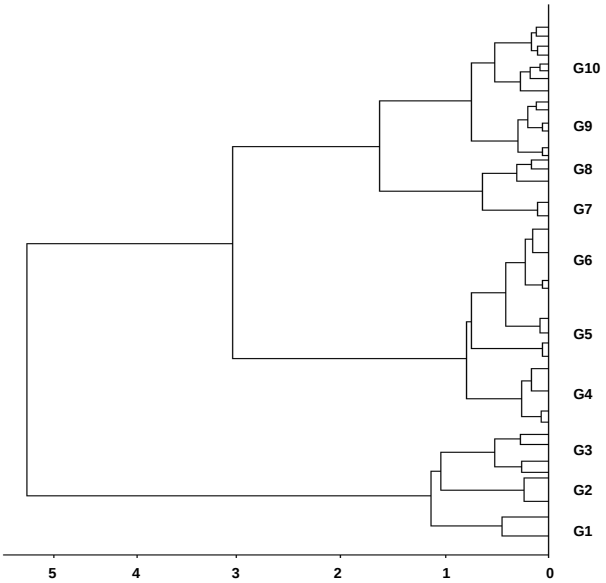

Figure 4. Dendrogram of 150 producers in 10 groups according to AHAC

of cocoa over clay bricks and under roof. The tenth group ferment in baskets, on cement and under cover. Its annual dry cocoa production is from 200 to 500 kg a year^{-1}. They store as the other groups.

Conclusions

The survey reveled that the beneficial practices related to places where they ferment, fermentation methods, time of fermentation and dryness are variable. Conditions of storage and dry cocoa production were also variables among municipalities. Small producers, who are the majority, employ the pile and use baskets, considering these, low cost methods. There are high number of old cocoa exploitations and because of this antiquity and climate factors the productivity is low. The preponderant volume of dry cocoa production is from 200 to 501 kg a year^{-1}. Most of producers store beneficiated cocoa on clay bricks. The mix of heterogeneous types of cocoa, customs and traditions, besides, the lack of techniques to manage the harvest, the low economical resources of producers to develop agriculture, guide to a great variability in activities post-harvest and cocoa storage in the studied municipalities. The variables LF, MF, DSLL, EUP, PCS and CA provide a lot of information to classify producers. The ACJA, using these variables grouped in ten categories producers with defined profiles.

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