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Extraction of Palm Kernel Oil in Cameroon: Effects of Kernels Drying on the Oil Quality

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Abstract: The kernels of the *Elaeis guinensis* palm fruits grow in the littoral region of Cameroon were collected, analysed and the composition of oil extracted were investigated. The effect of time and drying temperature (in sun and in electric ovens) of palm kernel on the quality of palm kernel oil obtained were studied. The lipid content of the kernels was 52.76%. The major fatty acids in kernel oil were about 54.51% lauric acid, 15.49% myristic acid and 9.53% oleic acid. Palm kernel oil was about 88.58% saturated and 11.37% unsaturated. Hexane extracted oil from the collected kernels give 9.58% as oleic acid, 3.59 as peroxide value. The research of optimal conditions during sun drying of different kernels sizes at different times showed that oil extracted from flours have much free fatty acids after 10 days drying as compared to other samples dried in the same conditions. In addition, the peroxide number of this oil sample from flours is very high (127.45 meq kg^{-1}). Finally, for oil with acceptable qualities, kernels destined for extraction have to be dried in the whole state and deprived from flour smash during 6 days. In electrical air dryer, the regression model have shown that it is suitable to dry at <120°C for >100 min, so as to have perfect dehydration without loss of fats. Less acidic oils (percent oleic acid ≤1.5) are obtained when working at temperature >60°C for >100 min. High peroxide value (>30 meq) are obtained from drying kernel at very high temperature (>120°C) or from drying kernel for <300 min. While, acceptable value, propose by Codex Alimentarius (IP<10 meq kg^{-1}) are obtained from drying kernels between 60-100°C for >300 min. Finally, in an electrical air dryer, kernels have to be dried between 60 and 100°C during 300-400 min to limit the fat losses and to obtain oil with poor free fatty acids and less oxidized.

Key words: *Elaeis guinensis*, Palm kernels oil, sun drying, electrical air drying, oil quality

INTRODUCTION

The palm oil tree (*Elaeis guinensis*) is a monoique plant similar to the coconut palm. It grows straight and being able to reach 30 m in the nature or 15 m in culture. It has no branches, but a trunk and sheets (Vandenput, 1981). Fruits form prematurely on young palm trees of hardly 3 years. They are more or less fleshy, similar to small plums, length from 2-3 cm, elongated egg-shaped, of reddish colors, gathered in big clusters of 3-15 kg called regimes. Its fruits are constituted of a pericarpe, the pulp containing 40.5% of palm oil and 20% of fibers. The walnut has a hard hull or shell, which surrounds a kernel. It is from these kernels that palm kernel oil is extracted, also known as lauric oil because of its high content in lauric acid (Detheux, 2004).

The extraction of the palm kernel oil is made by various techniques and the obtained oil is used as well in the food domain as non-food domains. In the food domain, it is used in the preparation of certain traditional dishes and enter also in the constitution of food fats (Dosumno and Ochu, 1995; Alonso *et al*., 2000). In the non-food domain, its higher proportion in lauric acid gives to this oil an important characteristic used in the industries of beauty care and soap factory. This property also, characterizes its strong use in traditional pharmacopoeia (Salmiah *et al*., 1998). In Cameroon, the transformation is much more made in the producing regions of palm oil. After the ended harvest of fruits, palm oil is extracted from the pulp by hot pressure and it is after drying of walnuts, crushing, sorting and mechanical grinding that we obtain the yellowish or whitish palm kernel oil.

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Concerning the black color oil, it is obtained only after wire netting. The sun exposure of kernels obtained after crushing of walnuts, or their drying in electric ovens was identified as treatments responsible for the variability of the quality of oil (Tiencheu, 2006; Tenyang, 2006). The natural drying in the sun is made under radiations of weak temperatures, varying daily, creating an environment favourable to the chemical and enzymatic reactions of hydrolysis and oxidation (Tenyang, 2006). The temperature and the time applied during the drying in electric ovens vary from a producer to another. Kernels are dried between 70-120°C till the beginning of the exudation of oil. So, by proceeding, there is not only loss of oil, but also the variation of the temperature and of time entail biochemical modifications of fat, which are explained by the variation of the acidity and the degree of oxidation (Tiencheu, 2006). The aims of the present research are to determine the conditions of the drying to the sun and in electric ovens susceptible to alter the quality of the oil and afterward to determine the levels of these factors, which minimize the production of free fatty acids and the oxidation of the fat.

MATERIALS AND METHODS

Samples: The samples of fresh walnuts were collected in Bonaberi (littoral region of Cameroon) and transported to the laboratory of Biochemistry (University of Dschang) for chemical characterization of kernels and treatment (drying in the sun and in the steam room).

Drying of palm kernels: The exposure of the kernels to sun was realized by varying the sizes of kernels (flour, crushed kernels and whole kernels) and the time of the exposure (0, 1, 3, 6 and 10 days). Kernels were dried in the sun according to a Split plot design (3×5), three sizes of kernels and five exposure times.

The drying in the steam room, notably aimed at completing the effect of the size of kernels to estimate during the exposure to the sun, by the effect of the electric temperature variation of ovens on the quality of the oil. This was realized by using the temperatures noted in industrial process (70-120°C) as center and to see what will happen on both sides of this zone. To the temperature variation, we associated the variation of drying time.

For this fact, the whole kernels stayed during 0-720 min in the steam room with temperatures varying between 35-135°C. The programming of the temperatures and time of drying in the steam room was made according to a central composite experimental design, with two points in the center. The real values and coded one of these variables of command are given in the Table 1. This

Table 1: Coded and real levels of the independent variables used in the design to estimate effect of temperature and time of electrical drying

	Real levels		Coded levels	
Row	Temperature (°C) x_1	Time (min) x_2	Temperature (°C) x_1	Time (min) x_2
1	120	620	1	-1
2	120	100	1	-1
3	50	100	-1	1
4	50	620	-1	1
5	85	360	0	0
6	85	360	0	0
7	135	360	α	0
8	35	360	-α	0
9	85	720	α	0
10	85	0	-α	0

plan allows to calculate the measured parameters following a model of mathematical equation which, of two factors corresponds to:

$$y = 1 + ax_1 + bx_2 + cx_1x_2 + dx_1^2 + ex_2^2$$

with a-e being the coefficients of the equation.

The losses of masses of the dried kernels were determined by difference and the percentage of mass loss calculated.

Oil extraction: Kernels dried in the sun and in the steam room were weighed then crushed in a mechanical machine, which was cleaned during the passage from a sample to another. Seventy gram of flour of kernels were soaked in 300 mL of hexane during 48 h with shaking from time to time. The mixture was filtered on Wathman paper and the hexane separated from the oil at 70°C in rotary evaporator.

Chemical analysis: The moisture content and the volatile matters were determined using the UIPAC method (1979). While, proteins, carbohydrates and ashes contents were determined by the method AOAC (1980). Acid and peroxide values were determined by the methods of AFNOR (1993).

The fatty acid compositions of oil were investigated after conversion to their Fatty Acid Methyl Esters (FAME) by using boron trifluoride-methanol method. About 50 mg of oil was heated under a nitrogen atmosphere at 100°C in 1.5 mL hexane and 1.5 mL boron trifluoridein methanol (8% solution) for 1 h in screw capped (teflon-lined) glass centrifuge tubes. Water was added and the FAME were extracted with hexane (3 mL), dried over anhydrous sodium sulfate and the solvent was evaporated under a nitrogen stream. One micro liter of 2 mg mL^{-1} hexane FAME was injected into the gas chromatograph. Analytical Gas Chromatography (GC) of FAME was carried out in a Perichrom 2000 system

(Saulx-les-Chartreux, France), equipped with a Flame Ionization Detector (FID) and a fused silica capillary column (30 m×0.22 mm, 0.25 μm film thickness), BPX70 SGE Australia Pty, Ltd (Victoria, Australia).

Statistical analysis: The assays were carried out in duplicate. ANOVA with Tukey post test was performed using GraphPad InStat version 3.05 for Windows 95, GraphPad Software, San Diego California USA, 2000. Central composite experimental design results were analyzed by STATGRAPHICS Plus program and different equations of regression established. Countor plots and Surface plots were constructed by using STATISTICA 6.0 program. Significance was defined at $p<0.05$.

RESULTS AND DISCUSSION

Chemical composition of kernels and oil: The chemical composition of the palm kernels used for drying is represented in the Table 2. It emerges from the Table 2 that the kernels are rich in lipids (53%), contain 35% of carbohydrates, 10% of proteins and 2% of inorganic compounds. The lipids content is close to 54% found by Onyeike and Acheru (2002) with the palm kernels in Nigeria. This content remains superior to the value found by Puhskar *et al.* (2003) in Brazil. The carbohydrates content is superior to that found by Tano-Debrah and Yoshiyuki (1996) in Ghana (28%). As for the proteins content, it remains superior to that found by Onyeike and Acheru (2002) in Nigeria (<7%). The differences observed would be due, to the climatic and pedological variations of the harvest zone and the state of maturity of fruits, among others (AFNOR, 1993). We can also think of the variation of the genetic background of these palm trees (Huang, 1990).

The fatty acids composition of the kernels oil is shown in the Table 3. We note that the palm kernels oil contains approximately 89% of saturated fatty acid against 11% of unsaturated fatty acids. Among these saturated fatty acids, fatty acids with short chains (C8-C14) are most strongly represented, the lauric acid (C12) occupy approximately, 55% with regards to the total fatty acids.

Table 2: Proximate chemical composition of palm kernels

Constituants	Dry mater (%)
Water	9.44 ±0.50
Ash	2.19±0.66
Proteins	10.24±0.52
Total fat	52.7±0.15
Carbohydrates (by difference)	34.82±0.62

Table 3: Fatty acid composition of palm kernel oil

Fatty acids	Symbol	Percentage
Caprilic acid	C8:0	5.17±1.13
Capric acid	C10:0	4.70±0.51
Lauric acid	C12:0	54.51±1.00
Myristic acid	C14:0	15.49±0.79
Palmitic acid	C16:0	6,39±0.59
Stearic acid	C18:0	2.33±0,21
Oleic acid	C18 1n9	9.53±0.81
Linoleic acid	C18 2n6	1.84±0.15
NI		0.06
Saturated fatty acids		88.58±1.05
Unsaturared fatty acids		11.37±0.95

NI: Not Identified

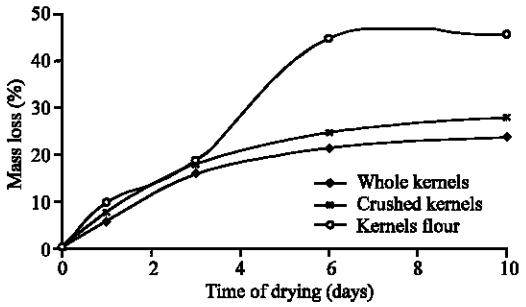

Fig. 1: Mass loss of palm kernels during solar drying

Impact of sun drying on the loss of mass of kernels and on the chemical indices of oil

Loss of mass of palm kernels: The variation of the percentage of loss of mass of kernel dried in the sun is shown by Fig. 1. At all size of kernel, the loss of mass is accelerated during the first 3 days. Then it is slowed down beyond for whole and crushed kernel. Whereas, with the flour, it is only after 6 days of drying that we note a decrease of loss of mass. The increase in the percentage of loss of mass during the first 3 days of drying would be due to the accentuated evaporation of interstitial water present in these kernels samples. In the case of kernels reduced to flour, the rise in the percentage of loss of mass after the 3 first days of drying would be not only be related to the loss of interstitial water and the volatiles products, but also with the oil loss, this is because of the disorganization of the kernels walls during crushing. Grinding breake down the walls containing oil and give smaller particle sizes. This allows not only easier diffusion of matter soluble components but also disintegration the original structure and facilitating oil release (Rosenthal *et al.*, 1996).

Unsaturated fatty acids contents: It is illustrated according to the exposure time in Fig. 2. We can note that unsaturated fatty acid content drops with the time then is stabilized from the second day. This fall is felt much in the case of the flour. It would be due to the fact that when kernels are exposed to the sun and in the free air, their unsaturated fatty acids fix oxygen and oxidize

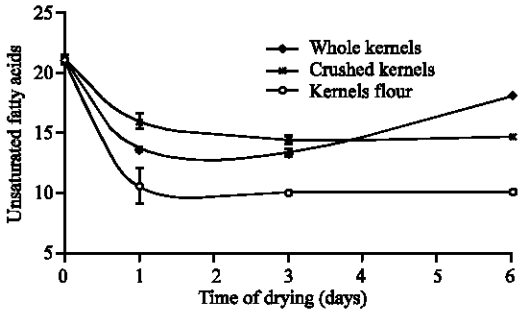

Fig. 2: Content of unsaturated fatty acids of oils as a function of drying time of palm kernels exposed in sun

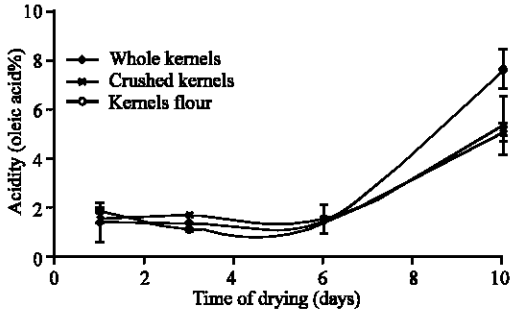

Fig. 3: Acidity of oils as function of drying time of palm kernels exposed in sun

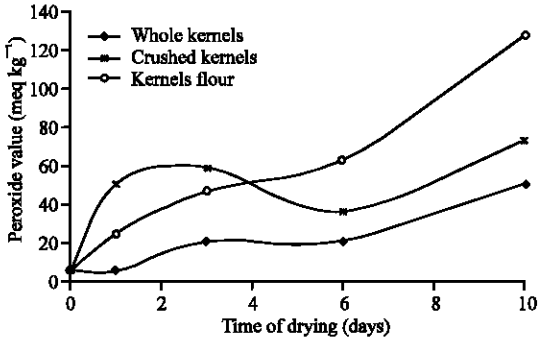

Fig. 4: Peroxide value of oils as function of drying time of palm kernels exposed in sun

(Blumenthal and Stier, 1991). The contents of unsaturated fatty acid remain higher in the oils extracted from whole and crushed kernels because these fatty acids remain imprisoned in cells that contain discrete cellular organelles called lipid bodies also known as spherosomes and oleosomes, consequently are not exposed to oxygen and the enzymes likely to attack double bonds. The destruction of the walls during crushing producing the flour where double bonds are directly exposes to the attacks (Ory *et al*., 1985).

Acidity of oils: The percentage of oleic acid of the oils extracted from palm kernel according to the duration of drying in the sun is presented on Fig. 3. This result shows that the acid values remain constant with time during the first 6 days of sun exposure, then increase significantly after 6 days of drying. This increase is much significant in the case of oil resulting from kernels dried in the form of flour. The constant evolution of the acidity of the various kernels samples during the first 6 days of exposure would be due to inactivation of the enzyme (lipase) responsible for the hydrolysis by external factors. After 6 days, the increase in the acid value would be a consequence of the activation of exogenous lipase. The significant increase in the cases of the flours would be always related to the destruction of the walls of the kernels, which would facilitate the contact between the triacylglycerols and lipases. The exposure to the sun does not allow the inactivation of endogenous lipases. The extension of the exposure time is favourable to the development of moulds, which produce exogenic lipases contributing to release free fatty acids and glycerol.

Peroxide values of oils: The peroxide values of the oils extracted from kernels is shown in Fig. 4. This result show that peroxide value increase with the exposure time of the kernel to the sun. After 1 day of drying, the oils extracted from crushed kernels and flour, have peroxide values higher than the 10 meq kg^{-1}, highest value recommended according to OMS/FAO (Codex, 1992). In the study of oil extracted from whole kernels it is after 3 days of exposure that peroxide values exceed the value of 10 meq kg^{-1}. Before the 10th day of drying, these values remain around 20 meq kg^{-1}, highest limit recommended by Wolff (1991). At the end of this exposure time, the peroxide value is highest in the oils extracted from the flour. The increase of the peroxide content during the exposure to the sun would be explained by the fact that the samples being exposed to free air, the conditions of the medium would be favourable to the activation of peroxidase, enzyme responsible for the peroxidation of the fatty acids. This peroxidation being higher in the case of the flours would be due to the broken of the cellular membranes, putting in contact the enzyme and the substrates of peroxidation (Ory *et al*., 1985). Oil with a peroxide value <15 meq kg^{-1} would be obtained in kernel dried with the sun in a whole state between 3-6 days.

Impact of the electrical drying on the loss of mass of kernels and on the chemical values of oil

Loss of mass of kernels: The percentages of mass loss were analyzed and had generated an equation whose

Table 4 : Regression Coefficients (RC), p-values and r^2 for chemical values following central composite experimental design

	Mass loss (%)		Acidity		Peroxide value	
Variables	RC	p-value	RC	p-value	RC	p-value
x_1	0.0397	0.0002*	-0.0044	0,0352*	-2.4112	0.0011*
x_2	0.0164	0.0025*	0.0005	0.7438	-0.09964	0.6826
x_1^2	0.0004	0.2425	0.0000	0.9408	0.0130775	0.0001*
x_1x_2	0.000019	0.6990	0.0000	0.2070	0.00132268	0.0016*
x_2^2	-0.000009	0.2395	0.0000	0.4517	0.0000244782	0.6340
Constant	-1.0454	-	1.9298	-	111.369	-
r^2	98.7594	-	75.6023	-	87.5912	-

*$p<0.05$, x_1 = Temperature, x_2 = Time, RC = Regression Coefficients

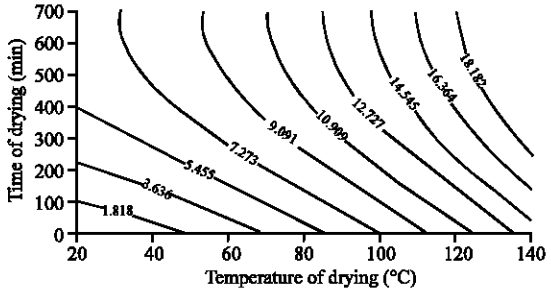

Fig. 5: Contour plots for mass loss of kernels (% of initial mass) as function of drying temperature and time in drying oven

coefficients of regression are given in Table 4. These losses vary from 2-18%. The analysis of the model shows that the variation of the water content depends at 98.75% on the effects of the variables time and temperature ($p<0.05$). It is noted that the loss of mass increases with increase in temperature and time of drying (Fig. 5). These losses should be explained by the fact that during the drying of a wet body like kernels, it would be established spontaneously between this body and the hot draught, an exchange of temperature as described by Gauthier and Bimbenet (1977). It could also be established a variation of partial pressure of water so that it results from a transfer of heat from the air towards the product under the effect of the variation in temperature and a transfer of water in opposite direction because of the difference of water concentration with the air. The speed of evaporation increases with increase in temperature. Indeed, the kernel has on the surface an unspecified temperature and a vapour pressure and once put in the drier, it occurs with the hot air, the matter and heat transfers. The water carried in the form of vapour requires the corresponding contribution of energy of vaporization. The excess of heat brought by the air thus, overheats the product what leads to the assessment of energy balance. However, the interior of the product is less hot than its surface and the internal transfer will be done gradually. Bimbenet (1978) mentioned that heat diffuses in a medium when the temperature is not the same everywhere, in the same way, the matter is transferred when in a medium there is a gradient of concentration for a substance it is likely to diffuse. Investigations carried out on similar processes of drying made by Mittelman *et al.* (1982), Reddy and Dash (1993) had already revealed that the temperature and the time of drying of the products are the principal variables of control in which the mass transfer depends.

Beyond 80°C and with >400 min of stay in the drying oven, the losses of masse is higher than the water content of the kernels (9.44%), which would correspond to the period of loss of non aqueous matter in occurrence, the fat content. This loss increases with the rise in temperature until 18% beyond 120°C.

Acidity of oils: The analysis of the model of equation generated by the values of the acidity of the oils extracted from kernel dried in the electric drying oven shows that the variations depend at 75.60% on the effects of the variables temperature and time (Table 4). The significant effect being that of the temperature ($p<0.05$). Figure 6 presents, the contour plots showing the variation of the acidity of these oils. These contour plots present two phases. The first corresponding to temperatures >60°C where, acidity is <1.5% of oleic acid. This low percentage of acid would be due to the progressive inactivation of the hydrolysis enzymes (lipases) at high temperature, then the use of the temperatures >60°C would reduce the degradation of the triacylglycerols. These observations are in agreement with those found by Womeni *et al.* (2003) on the shea butter extracts from kernels dried with the drying oven.

The second phase corresponds to the zone of temperature <60°C with acid values at 1.5%. With <60°C, the acid value increases with a fall in temperature and the extension of the duration of drying. The increase in the acid value would be due to the fact that one is still in the zone of temperatures favourable to the lipasic activity and high water content. These temperatures would be low to allow a fast dehydration of kernel and to make water unavailable for the reactions of degradation, which leads to oils of high acidity. These results let appear that to

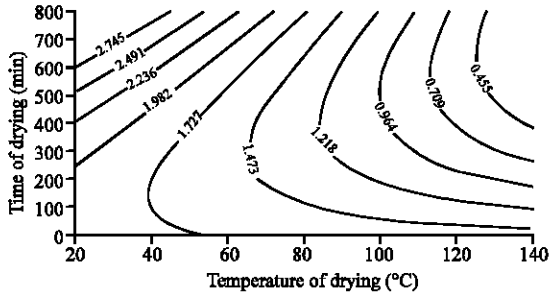

Fig. 6: Contour plots for acidity (percenr oleic acid) of oil as function of drying temperature and time in drying oven

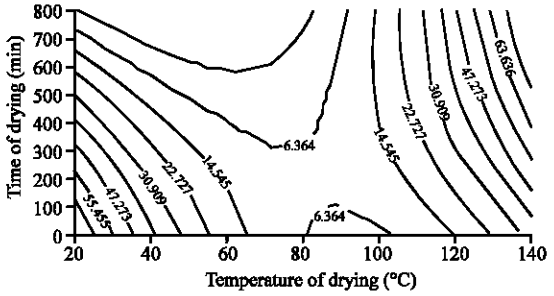

Fig. 7: Contour plots for peroxide value (meq kg^{-1}) of oil as function of drying temperature and time in drying oven

have oils having acidity included in standard (0-1.5% of oleic acid, Codex, 1992), we must research at >60°C, for >100 min.

Peroxide value: The results obtained for the determination of the peroxide value of the oils extracted for palm kernels dried with the drying oven have generated a model of expression of this variable according to the temperature and the time of drying. The coefficients of regression and the equation of the model are given in Table 4. According to this model, the variations of the time and the temperature of drying explain at 87.59% of the variations of the peroxide values. The terms of first and second order of the temperature and the interaction time temperature of drying have significant effects. Figure 7 presents, the contour plots showing this variation of the peroxide value. It is noted that the high peroxide values (Ip >30 meq kg^{-1}) are obtained with the oils extracted from kernel dried for <300 min (little dehydrated kernel) between 20-80°C or beyond 120°C for >300 min. These values remain <30 meq kg^{-1} when the kernels are dried between 60-120°C for >300 min.

Above 120°C, the peroxide value increases with the time of drying. At this temperature, the saturated fatty acids and even the unsaturated would be more likely to undergo non-enzymatic oxidation, in addition to thermal hydrolysis of the triacylglycerols releasing peroxides and free fatty acids. The latter are themselves responsible for the appearance of a rancid smell very unpleasant as well as a reduction of the nutritional value of the lipids by loss of essential fatty acids and liposoluble vitamin activity. In addition to the volatile products with rancid smell, this oxidation would produce epoxyde polymers and even hydrocarbons of which some were revealed toxic and carcinogenic. The low indices obtained by drying kernels at the intermediate temperatures (60-120°C) would be explained by the fact that at these temperatures oxidative thermolysis is slow. Moreover, during the period of cooking of the fruits for palm oil extraction, heat would inactivate the enzymes responsible for the reactions of degradation. This would stop fermentation and the development of the moulds and especially would create the dilation of the kernels cells by softening, causing the exhaust of air and gas (O_2) from interstitial spaces and then reduce oxidation reactions. It is known that this oxygen contributes to the formation of radical peroxides only from the unsaturated fatty acids since at this temperature the saturated acids cannot yet be oxidized quickly, even if the lipasic hydrolysis is intensive.

The very high values obtained for the oils extracted from kernel dried at low temperature (20 with 80°C) and for short time (<300 min) would be related to the facts that at these temperatures the dehydration of kernels is weak and the high moisture content would support the hydrolysis and even the oxidation of oil.

CONCLUSION

To obtain, less degraded oil, when drying kernels in the sun, we must reduce as much as possible the presence of cracks and flour of kernels. Pre-cooked whole kernels must be exposed to the sun during 3-6 days. In the case of electrical air dryer, less acid oils (% of acid oleic <1.5%) are obtained with kernels dried at temperatures >60°C for >100 min. The low peroxide values are obtained with oils extracted from kernels dried for >300 min between 60 and 100°C. Finally, in an electrical air dryer, kernels have to be dried between 60 and 100°C during 300-400 min to limit the fat loss and to obtain oil poor in free fatty acids and less oxidized.

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