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Setting up a Process for Drying Cocoa Beans

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Abstract In Cameroon, despite the use of various drying devices (natural solar drying, improved solar drying and artificial drying), cocoa is mostly sold as grade II or lower. This lack of sales is mainly due to the poor water content of dried cocoa beans (TE<8%) and their high acidity (pH<5.5). The objectives of this study were to evaluate the influence of these drying devices on moisture content and acidity; to increase the knowledge in the field of cocoa bean drying; and to identify a drying process that would result in good quality dried cocoa beans. To carry out this work, the drying kinetics of cocoa beans in five (05) drying devices were observed during an experimental study. The results showed that the drying process has an influence on the water content and acidity of the dried cocoa beans and that the drying process that gives a good triplet, drying time/water content/pH, is the mixed solar-improved/Artificial drying at 50°C.

Keywords: *drying device, moisture content, pH and cocoa*

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1. Introduction

The coffee and cocoa sectors are vital to the economies of tropical countries. They account for more than 46% of export earnings and employ more than 2/3 of the population [1]. In Cameroon, cocoa production has been booming. Cameroon is the 4th largest cocoa producing country in the world and the 3rd largest in Africa, with 290,000 tonnes of cocoa produced in the last 2021-2022. The country's ambition is to increase production to 640,000 tonnes per year by 2030 [2]. Cocoa plays a critical role in the country's economy as it is the second largest export product, with an average of US$2 billion in export sales per year according to Cameroon's Ministry of Trade. However, over the past two decades, the quality of Cameroonian cocoa has declined, with almost 95% of the production sold as grade II cocoa, resulting in a significant loss of earnings for farmers of about 152 billion CFA francs. This poor quality of Cameroonian cocoa is due to post-harvest treatments whose primary objective is to transform the harvested products into marketable or directly consumable products. To this end, the simplest succession of treatments is: picking or harvesting, shelling, fermentation [3] and drying [4]. All these operations affect the characteristics of the product and are highly dependent on each other. They contribute to the quality of the final product [5]. It is possible to intervene in any of the links of this chain and adapt the whole according to the product that one wishes to obtain.

Studies have shown that drying is a very important step as it has an influence on the quality of marketable cocoa beans [6]. Indeed, drying aims to reduce the water content of the beans from 55% to about 7% [7] and to reduce the acids produced during fermentation to an acceptable level (pH>5.5) [8] and [9]. Several authors have contributed on the drying of cocoa beans, including [10] and [11] and [12] on drying in an improved solar dryer; [13] and [14] on artificial drying in a wood dryer. It can be seen that despite these various works, which focus on the drying device, African cocoa is still underpriced on the international market. A survey to identify and characterise local cocoa drying practices in southern Cameroon was conducted [15]. The survey revealed that the main problems encountered by producers were related to post-harvest treatments, particularly the drying process. It is therefore in the wake of all this that this work will focus on the establishment of an innovative process for drying cocoa in the humid tropics.

The aim is to study the drying kinetics of cocoa beans by using five (05) processes, in order to determine the drying process best suited to our context. This experimental part is carried out at the Laboratory of Energetics and Applied Thermics (LETA) of the National School of Agro-Industrial Sciences of the University of Ngaoundéré.

2. Materials and Methods

2.1. Materials

Vegetable material

The vegetable material used consists of fresh cocoa beans (Theobroma cacao) harvested in the department of Mbam and Inoubou (Bafia) and fermented for six (06) days before being packaged in banana leaves and stored at 5°C. These beans are of the Forastero variety. Their average moisture content in wet basis is 59.72 ± 1% for a pH of 5.14 ± 0.1.

Experimental equipment

- Natural solar dryer

It is a 50×50cm tray placed on a concrete slab.

- Improved solar dryer

The device used is a direct solar dryer with forced convection, which consists of a single room that acts as both a drying chamber and a solar collector. The interior of the dryer is completely covered with polished aluminium sheets to act as a collector/reflector of solar radiation. [16]

- Stropikade dryer

The dryer used in this section is the STROPIKADE electric dryer, which is located at the Laboratory of Energetics and Applied Thermics (LETA) of the National School of Agro-Industrial Sciences of the University of Ngaoundéré. [17]

Measuring instruments

- Digital display scale, brand ADAM, type Nymbus Max = 2600 g with an accuracy of 0.01g;
- Solarimeter, brand AMR, type FLA613-GS with a measurement range of 0 to 1800 w/m2 and an accuracy of 0.01 w/m2;
- Almemo data acquisition unit, series 2590, equipped with k-type temperature probes, an FH A646 humidity sensor and a hot wire anemometer.

2.2. Methods

On arrival at the laboratory, a sample of beans is taken for analysis of moisture content and pH. For each experiment, a 1000g sample is used. Each experiment has to be carried out three times in order to guarantee the reliability of the results. Figure 1 shows the overview of the experimental procedure. We will start with an open air drying, then drying in a direct solar dryer with forced convection, then drying in an electric dryer and finally we will do two couplings.

The tests were carried out with an ambient temperature varying from 27 to 35°C during the drying period. The initial moisture content of the cocoa beans is 51.79%, with an initial pH of 5.14.

2.2.1. Experimental Protocol

During the tests, the drying parameters are continuously varied over time. Weather parameters, mass and product temperature are measured during this operation. These parameters are measured every 60 minutes, from the beginning to the end of the drying process. The beans are left for 30 minutes in the open air in order to equalise their temperature to that of the laboratory before the start of drying.

In order to ensure a better stability of the drying conditions and a homogenisation of the temperature inside the dryer, all the equipment must be running at least half an hour before the loaded trays are introduced into the drying chamber. The weighing of the trays is carried out outside the dryer. The duration of a weighing is 30 to 40 seconds and is deducted from the total drying time. The measurement at time t gives us the wet mass of the product M(t). The drying experiment is stopped when the moisture content is 8% or less.

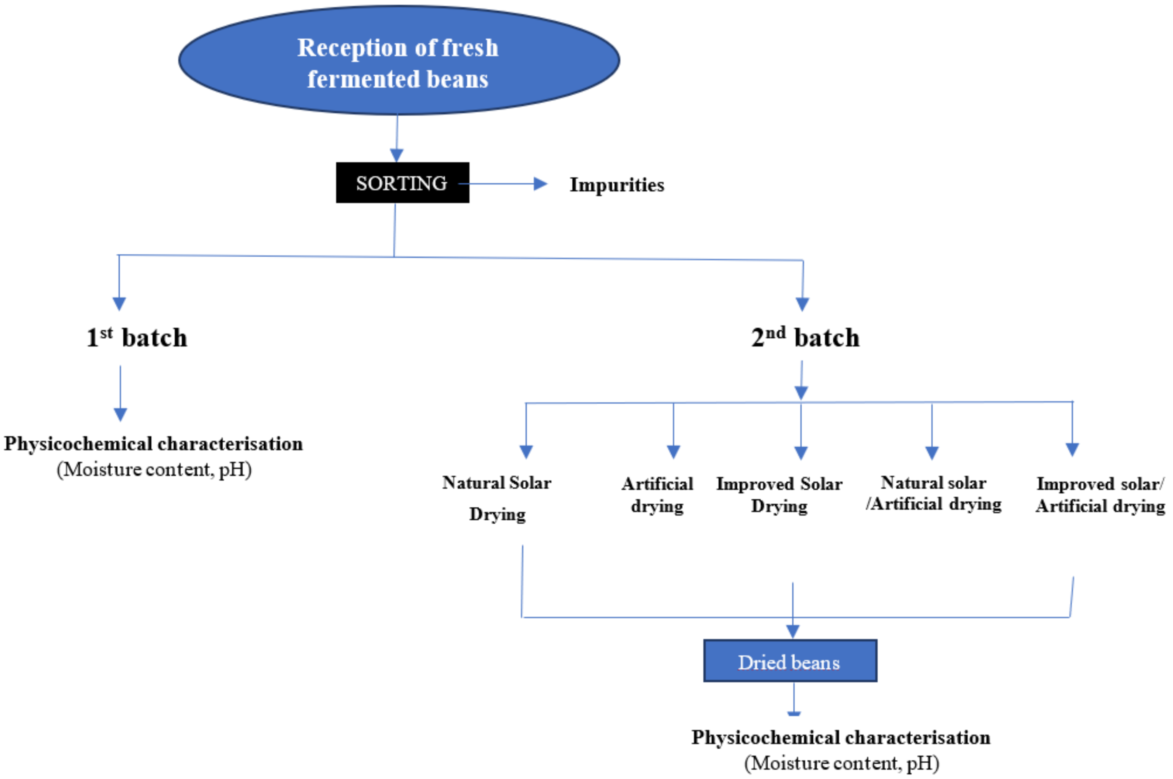

Figure 1. Overview of the experimental study

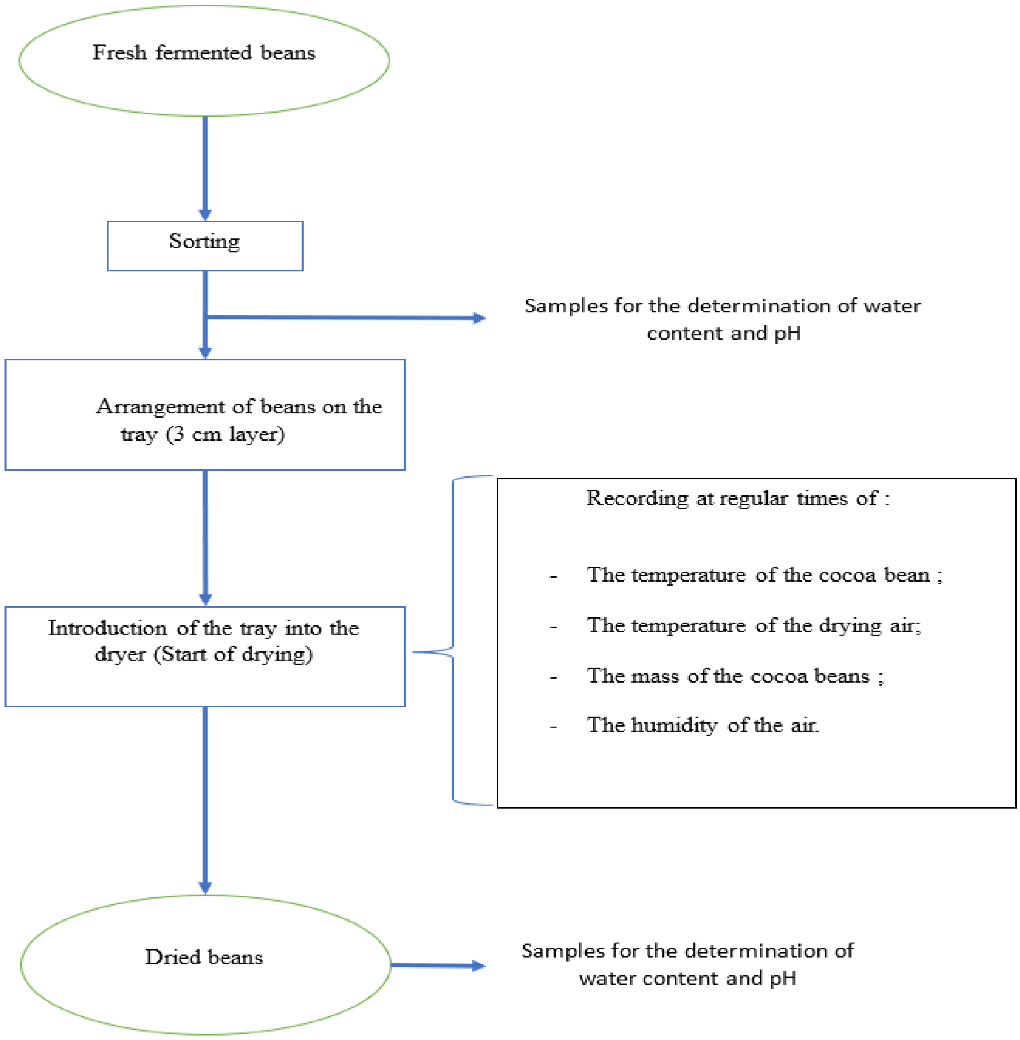

Figure 2. Experimental protocol

2.3. Analysis of the Samples

2.3.1. Moisture Content of Cocoa Beans

The moisture content was determined using AOAC method 981.12. Three empty crucibles were oven dried for 35 min at 105 ± 2 °C and then tared after cooling in a desiccator. 2.000 ± 0.001g of cocoa powder were weighed into each of the crucibles and then placed in the oven at 105°C for 24 hours until the sample was constant weight. The crucibles were removed from the oven and weighed after cooling in a desiccator. The analysis was done in triplicate, the initial and final water contents of the samples are calculated according to equation 1:

$$TE = \frac{M_1 - M_2}{M_2 - M_0} * 100 \quad (1)$$

With:
TE: Moisture content (% kgwater/kMS)
M1: Mass of the crucible containing the fresh sample before steaming (g)
M2: Mass of crucible containing dry sample after steaming (g)
M0: Mass of crucible in empty condition (g)

2.3.2. Determination of pH

The pH was measured according to the method described in AOAC 981.12. A 5g sample of cocoa powder dry matter was taken and mixed with 20 ml of distilled water in a beaker. The resulting suspension was stirred with a magnetic stirrer for 5 min and then left to stand for 10 min. The pH of the aqueous phase was measured using a pH meter calibrated at pH 4 and 7, at a temperature of 25.03± 0.22 °C.

3. Results and Discussion

3.1. Drying Kinetics of Cocoa Beans

3.1.1. Natural Solar Drying

Figure 3a and Figure 3b show the evolution of water content and pH as a function of time for natural solar drying with and without intermittence.

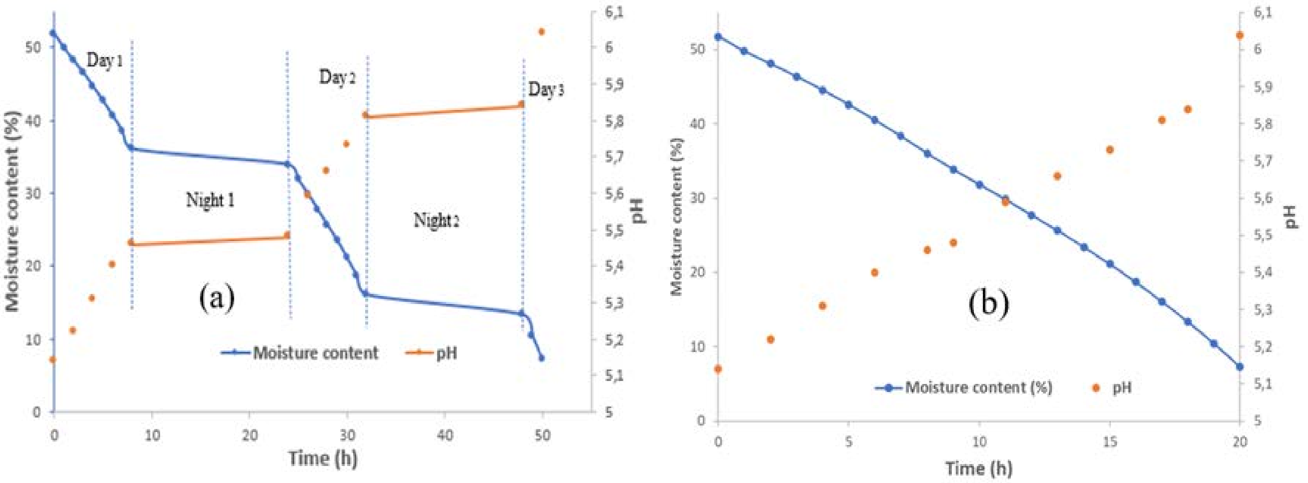

Figure 3. Evolution of moisture content and pH as a function of time with and without dwell time, Tm= 32°C

We note that during the day the moisture content decreases significantly with time, whereas during the night it decreases very slightly and that the drying time is 50h for an average drying temperature of 32°C. We also note that the decrease in moisture content is greater on day 2 (-17.84%), than on day 1 (-15.75%). This could be explained by the fact that during the night moisture migrates to the periphery of the bean and thus facilitates its extraction on day 2. This finding is in agreement with the work of [18], on mango. Finally, a comparison between figures 3a and 3b shows us that the 30h intermittence period is greater than the 20h actual drying period. The pH of the beans increases with time during the day, and decreases very slightly during the night, to reach a final pH of 6.04. However we can see in Figure 3a that its increase is greater on day 2 (+0.33) than on day 1 (+0.32), this could be due to the temperature change period. The results obtained show that the drying rate decreases with time.

3.1.2. Improved Solar Drying

Figure 4a and Figure 4b show the evolution of moisture content and pH as a function of time for improved solar drying, with and without intermittence.

We note that the drying time in this case is shorter (27h) than in the natural dryer. The moisture content decreases very significantly on day 1 since the average drying temperature is 41°C. During the day the moisture content decreases significantly with time, while at night it decreases very slightly. Finally, a comparison between figures 4a and b shows that the 15 hour intermittent period is longer than the 12 hour real drying period. The pH of the beans increases with time during the day, and decreases very slightly during the night. However, we can see that at the end of the drying process it is 5.89, which is lower than the natural solar drying process. The maximum drying speed is 132.10-3 kgwater/kgMS.h, which is more than three times the drying speed of the natural solar dryer.

3.1.3. Artificial Drying

Figure 5a and Figure 5b show the evolution of moisture content and pH as a function of time for artificial drying at 50 and 60°C.

These figures show us that the moisture content decreases rapidly to reach the desired moisture content in 8 hours for drying at 50°C and in 7 hours for drying at 60°C. We note that the pH at the end of drying is 5.64 for drying at 50°C and 5.60 for drying at 60°C, which is approximately equal. However, this pH is lower than the pH of the previous devices (6.04 and 5.89 respectively). The drying speed is higher than the drying speed of the previous devices.

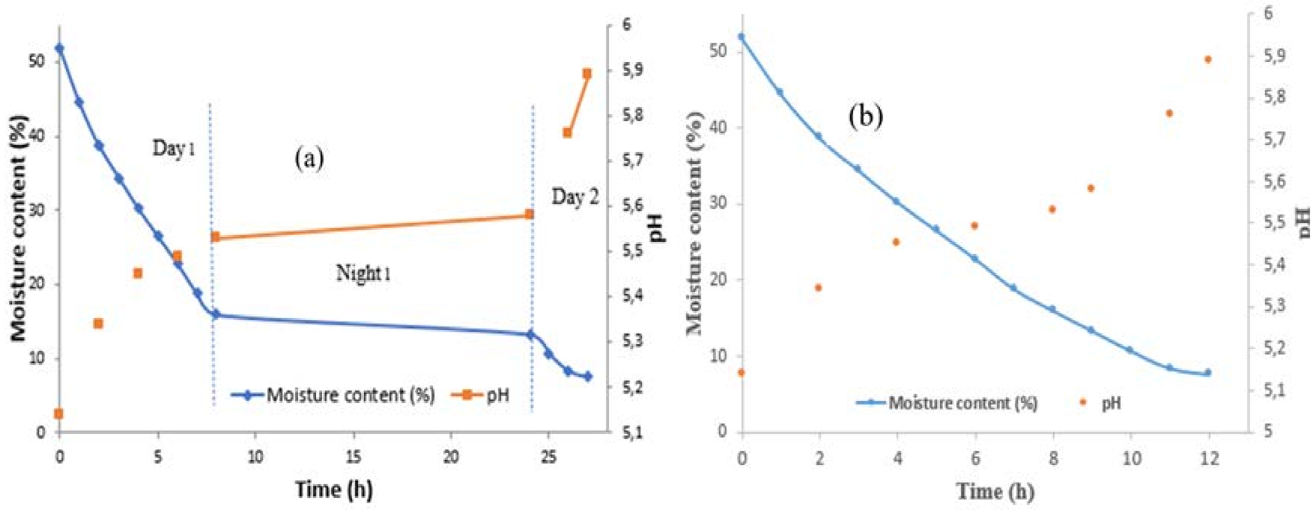

Figure 4. Evolution of moisture content and pH as a function of time, with and without intermittence, Tm= 41°C

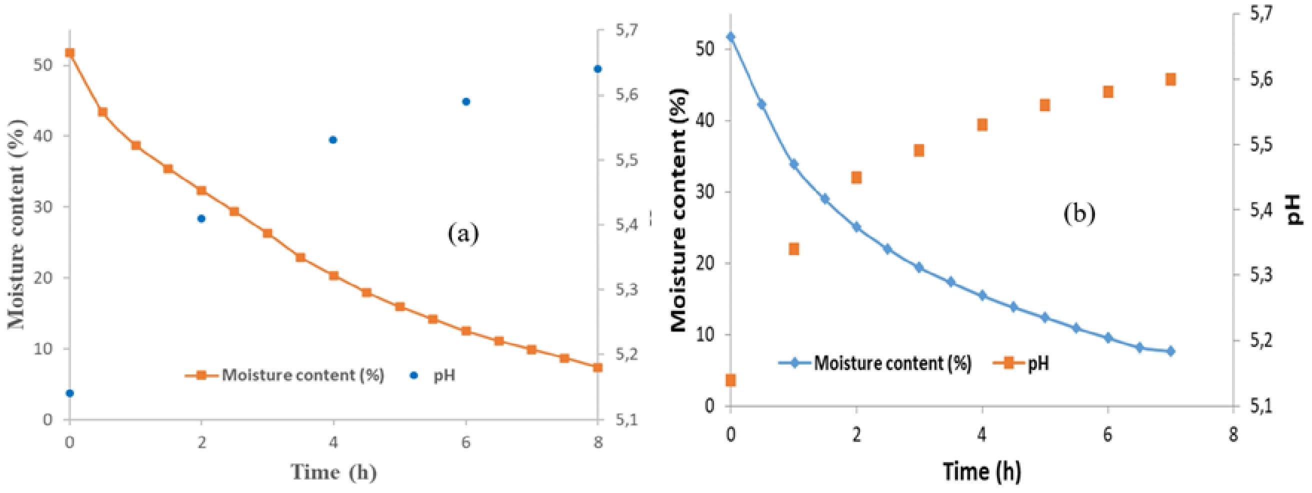

Figure 5. Evolution of moisture content and pH as a function of time; Vair= 0.5 m/s

3.1.4. Natural Solar /Artificial Drying 50

Figure 6 shows the evolution of moisture content and pH as a function of time for natural drying coupled with artificial drying at 50°C.

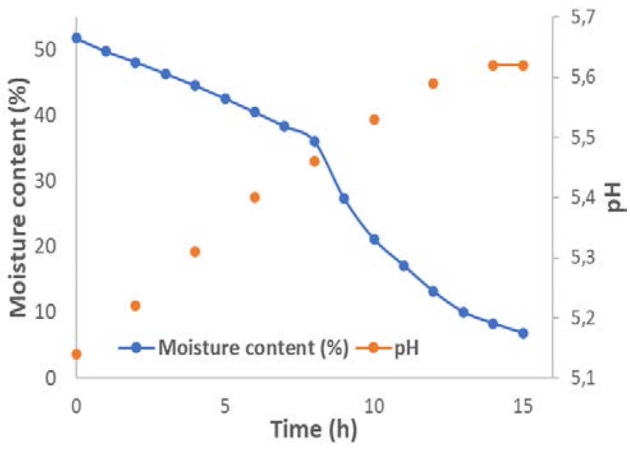

Figure 6. Evolution of moisture content and pH as a function of time

The drying time for this experiment is 15 hours, with a final pH of 5.62. It can be seen that the moisture content decreases faster during the artificial drying, which is normal because the drying temperature increases from about 32°C to 50°C. The maximum drying rate is 90.3*10-3 kgwater/kgMS.h.

3.1.5. Natural Solar /Artificial Drying 60

Figure 7 shows the evolution of moisture content and pH as a function of time for natural solar drying coupled with artificial drying at 60°C. Vair= 0.5 m/s.

The drying time for this experiment is 12 hours, with a final pH of 5.56. It can be seen that the moisture content decreases more rapidly during artificial drying, which is normal because the drying temperature increases from approximately 32°C to 60°C. The maximum drying rate is 106.4.10-3 kgeau/kgMS.h.

3.1.6. Improved Solar /Artificial Drying 50

Figure 8 shows the evolution of moisture content and pH as a function of time for improved solar drying coupled with artificial drying at 50°C.

The drying time for this experiment is 11 hours, with a final pH of 5.71. It can be seen that the moisture content decreases almost constantly, which can be explained by the fact that the average drying temperature remains approximately the same during the drying process, about 50 ± 2°C. The maximum drying rate of 130.10-3 kgeau/kgMS.h.

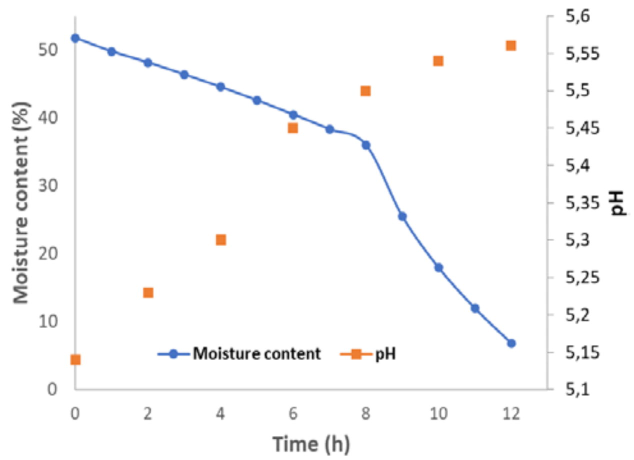

Figure 7. Evolution of moisture content and pH as a function of time; Vair= 0.5 m/s

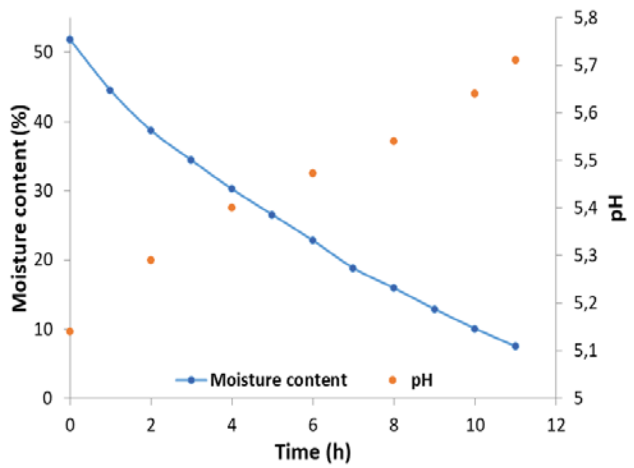

Figure 8. Evolution of moisture content and pH as a function of time, Vair = 0.5 m/s

3.2. Comparative Study

Table 1. Comparative study of final moisture content and pH content

Drying solar	Drying time	Final moisture	Final pH
Natural solar drying	50h	7.25%	6.04
Artificial drying at 50°C	15h	6.82%	5.62
Natural + Artificial drying at 50°C	15h	6.82%	5.62
Improved+Artioficial at 50°C	11h	7.46%	5.71

The curves are marked by an ever decreasing moisture content of the product until the end of the drying process. They highlight the drying phase with decreasing speed, which reflects the evaporation of moisture linked to a greater or lesser extent to the dry matter of the product. In the case of organic products, several authors reveal that it is difficult to locate the first drying phase.

It can be seen that as the air temperature increases, the drying speed increases. This is the result of the increase in the heat flux brought by the air to the product on the one hand, and the acceleration of the internal migration of moisture on the other. The increase in product temperature not only modifies the activity of moisture but also influences the diffusion coefficient and to a lesser extent the enthalpy of vaporisation. On the other hand, it can be observed that the pH decreases when the drying temperature increases. This is due to the fact that when the drying temperature is high the moisture, being less bound to the structure than the acids, leaves the beans more quickly, leaving a medium with concentrated acidity. Therefore, in order to remove the acidity from the cocoa beans, the drying should be done in a way that allows a balanced extraction of moisture and acids.

4. Conclusion

This paper reported on the comparative study of five hot air drying processes (artisanal solar drying, improved solar drying, electric drying, mixed artisanal solar+electric drying, mixed improved solar + electric drying). The results obtained showed that the drying process that allows to obtain the best triplet of drying time/ moisture content/PH, is the mixed solar/electric drying at 50°C, which allowed for 1000g of fresh beans, to obtain a drying time of 11h for a moisture content of 7.46% and a pH of 5.71. For the first time in a scientific study, the evolution of pH as a function of moisture content and/or time during the drying of cocoa beans was demonstrated. These results are very important for the design of a dryer adapted to cocoa drying in the context of producers in the humid tropics.

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